Appendix to the History of the UC Berkeley Microlab
Technical Report No. UCB/EECS-2013-158
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Year End Reports
1987-2012

by

Katalin Voros
Operations Manager
(1987-2011)

Abstract

The UC Berkeley Microfabrication Laboratory (Microlab) in Cory Hall had its opening dedication ceremony on 23 March 1983. It was officially closed on 31 December 2010. Technical Report No. UCB/EECS-213-158 is the documentation, in wide swathes, of 28 years of operation, including management of resources: facilities, staff, finances, and related activities of control, communications and planning.

This report is the Appendix to Technical Report No. UCB/EECS-213-158. It is a collection of the year-end reports Katalin Voros submitted to the Microlab’s Faculty Director, from 1987 through 2012. Starting 1990, the professional staff of the Microlab also submitted year-end reports. These can be seen on the Microfabrication Laboratory Archive Portal, Microlab Staff and Reports, http://microlab.berkeley.edu/people/staffpage.html.

2013
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1987 Year End Report
Katalin Voros
Microlab Manager

To: Prof. Ping K. Ko, Faculty-in-Charge
From: Katalin Voros, Microlab Manager
Subject: Performance Appraisal
Date: March 2, 1988.
Cc: W. G. Oldham, E. Wong, W. Zeilinger

Following is a description of what has been done in the Microlab during the past year, to assist you in writing my A&PS Employee Performance Appraisal. I started working for the Microlab as an Associate Development Engineer, Process Engineering Supervisor, on 14 January 1995 and was named Microlab Manager on 1 Dec. 1986.

SUPERVISION OF STAFF

Management Style

1. During the past year I put in a concentrated effort to develop awareness of several basic principles which, I believe, are essential for the wellbeing of the Microlab and its staff. Some of these ideas are very simple; such as: The Microlab provides a service for the students; we are here because of them and not the other way around. We have to do our best to keep the lab open and machinery working so that users can come in at any time and do their work successfully. They, in turn, are the basis of our support. They provide the lab's income through the recharge system, and provide us our jobs.

2. I believe in us fully maintaining the machinery, with an absolute minimum of outside service. We have the talent and skills needed in all areas of semiconductor processing equipment maintenance and we can learn what we do not yet know. This, however, requires that everyone pull their own weight and cooperate with the others.

3. I believe that a certain amount of discipline is indispensable in a smoothly working unit. This must come from within the members of the group rather than from enforcement by supervisors. If everyone behaves responsibly, starting with arriving to work on time and keeping breaks to proper lengths, doing their work conscientiously, and caring for the wellbeing of the unit, life will be much more pleasant for everyone.

4. Everyone's job is equally important in the Microlab, and everyone's work reflects on the performance of the whole group. I expect respect for each other and a positive attitude towards the group effort. This also means that everyone represents the whole unit in dealing with students, professors or outside groups, and what kind of report card we are getting depends on all of us.
5. I believe in keeping the communication lines open and in taking care of personnel problems immediately. I am available to the staff at any time if they ask for a private discussion and I do not hesitate to state my request/comments in clear and unambiguous terms.

**Communications with Staff**

1. The above ideas were developed and discussed during the regular monthly staff meetings; weekly meetings with individual staff members, private discussions and annual performance evaluations. Communication often occurs through computer messages or distributing/circulating relevant information in hard copy. I make a point to immediately distribute good news items, positive comments from within EECS/ERL or outside.

2. Performance reviews are being given on time, and after careful preparation. I believe that the evaluation has to be extended to both the strong and the weak points in an employee's performance. It is always harder to write a negative evaluation which has to be well substantiated to be fair and effective; thus, I find myself spending considerable amount of time writing reviews. With the introduction of the new Administrative and Professional Staff program, this managerial responsibility has increased.

**Employee Development**

I am working with Bob Hamilton, the supervisor of our maintenance technicians to develop his supervisory skills. While excellent in most technical areas, his talents in organization, prioritization, employee development, need to be enhanced. We are making progress, I am happy to say. Comparing his actions now to those of a year ago, there is great improvement.

**Analysis of Staff Allocation and Action**

After taking over the management of the Microlab a little more than a year ago I analyzed all areas of the operation to find the weak points and to identify needed improvements. Besides the budget mess (see below), I spent a great deal of time on examining staff allocation. It was obvious that with employee salaries and benefits comprising more than half of the budget, this expenditure had to be cut if we were going to make a dent in the deficit. First, the process development engineering position I vacated was not filled; then, one of the two overlapping Principal Electronics Technician positions was eliminated. The person with the lower seniority was laid off as of Sept. 1987. We took up the slack by redistributing the work load and increasing the efficiency of the operation by cross training; however, it must be understood that we are at the minimum staffing level necessary for required services in the lab.

**Results of Staff Reduction**

At this point, we have a balanced budget at the expense of cutting out process development work. Whatever little of it there is, is carried out by the processing staff under my direct supervision. They also provide needed service to the students who require help with the
introduction of more and more sophisticated machinery. Process characterization and operational maintenance is also the process staff's responsibility along with performing special services for researchers from other departments.

Administrative Staff

Office administration, accounting, purchasing, and inventory is taken care of by Rosemary Spivey in an AAI position. Clearly the servicing of this unit encompasses at least AAII responsibility; unfortunately, I have been unable in two attempts to have the position reclassified. It is of paramount importance for our successful operation to have a higher level off ice manager and I will try all avenues to secure an AAII position for the Microlab.

Steady State Operation

After a year of hard work we have progressed to an acceptable level of steady state operation and I am satisfied with staff performance in general.

- Everyone puts in an honest day's work, at the level expected of them. They care about their job and show dedication to the Microlab.
- Productivity and efficiency increased noticeably; but, there is still room for improvement.
- Staff members are pleasant to the students and often go out of their way to help them.
- Celebration of special occasions such as employment anniversaries, are helpful in fostering group spirit. Last year we celebrated Bob Hamilton's 20th and James Parrish's 10th year anniversary at the University. We organize holiday staff luncheons; maintain a coffee club; and celebrate birthdays once a month. I encourage staff to take part in Departmental/College/University events like Breakfast with the Dean and UC Staff Picnic.

We have a good group and I am glad to be part of it.

ADVISING OF STUDENTS

Advising in General

The most pleasant aspect of my job is advising of students. I hold daily office hours to discuss long term projects or to answer simple "how can I do this" questions for a large number of students. Out of the 130 or so registered users I usually see and talk to 30-40 a week, either in my office, or, when I am in the lab, in the hallway, in seminars, or on my way out, sometimes even at home. Reducing student advising strictly to office hours does not work for me; I simply cannot turn them away if I can help.

Students from other departments such as Material Science, Geology, Biology, and Chemistry come in to discuss the possibility of applying microfabrication techniques to their projects. They require more guidance and help than EE's; but their presence is beneficial from the point of view of widening the scope of research in the lab.
CIM

With the expansion of Prof. Hodges' Computer Integrated Manufacturing (CIM) projects, I became very much involved with providing the users' point of view in developing silicon processing software.

- Improvement and extension of the WAND and STAFF programs have been ongoing tasks for the past two years and provided the staff with excellent lab management tools.
- FLIP (Facilities Layout Information Program) is currently being developed to give us ready access to accurate lab equipment layout and facilities connection information.
- BLIMP (Berkeley Lab Infrastructure Monitoring Program) will provide capability of monitoring important facilities such as DI water level, gas line pressures, etc.
- PARTSINVEN is a much needed spare parts inventory program.
- I am advising a student in developing structures to test the statistical process simulator FABRICS on our CMOS process.
- BIPS (Berkeley Intelligent Processing System) will help in optimizing the poly-silicon deposition process in both the current tube (tylan11) and in the new tube (tylan16) being built by staff.

Lab Orientation

We are holding lab orientation courses regularly every other month to allow new students to become members. This way the places of graduating students will be filled with new students and our job of training them can start all over again. The hardest part of this procedure is to make students accept lab safety rules and behave in a responsible manner; to respect the rights of others and to keep their work area clean and in order. We are doing everything possible to accommodate all 130 researchers with sometimes clashing interests. I had to learn to be a patient mediator and to provide balanced support to all groups involved. It is not easy.

INTERACTION WITH FACULTY AND RESEARCH GROUPS

There are several major research groups working in the lab whose space and equipment requirements are only partially overlapping. When one group's activities expand or take on a new direction we have to be aware of what is needed to support them. We had several meetings with professors and students this past year to discuss equipment and space problems.

Sensors

Increased activity in the sensors group necessitated the installation of a second poly-Si deposition system (see FACILITIES DEVELOPMENT section) and modification of the silicon-nitride tube. We discussed equipment use policies and eliminated some restrictions.
Cryo

The cryoelectronics group's activities in the field of the new high-temperature superconductors placed new demands on our sputtering systems and furnaces. The crowding problem has been resolved to some extent by strict adherence to scheduling and by assigning a technician to change targets. Also, some of the activities were moved to the Physics department and LBL. The group was assigned a dedicated furnace tube (tylan4) for their critical annealing procedures.

Deep UV

The Deep UV project required the complete rearrangement of room GL4 and adjoining service chases.

Compound

A new plasma etcher, on loan from Lockheed Research Laboratory, was installed for the exclusive use of the compound semiconductor group.

SAFETY

The question of safety from both the occupational and environmental points of view is constantly being addressed and being kept in the forefront in the Microlab. The following programs illustrate our commitment to safety, submitted by Bob Hamilton:

1. All students, staff and visiting scientists who work in the lab are required to take a lab orientation course, a major part of which concerns safety education. During this course the newcomers are instructed by staff on the safety procedures to be used in the lab, the equipment that is available to exercise safety, and further information they can obtain both on procedures to be used in the lab, the equipment that is available to exercise safety, and further information they can obtain both on procedures and chemicals. Currently, it is required that all users wear safety glasses at all times in the lab, and in addition, that they wear a face shield, acid resistant gloves and apron when handling chemicals. This is being enforced by the staff of the Microlab.

2. We are in contact with the office of EH&S and OH&S. They have inspected the Microlab on several occasions after which we reviewed their observations and took corrective actions. I personally contacted the new director of EH&S, Elaine Bild, and invited her, and her staff to visit our facility. They were here on March 5, 1987.

3. Dr. James P. Seward, Occupation Health Physician of the OH&S, visited our facility several times with other occupational and environmental health professionals as part of his efforts to educate his peers through seminars and continuing education courses. He uses the lab to demonstrate semiconductor industry safety practices.

We have a firm policy on areas of service that have a high risk associated with them. It forbids lab users from doing electrical wiring, changing gas cylinders and making modifications to equipment without permission from the lab management. Summary of following safe practices:
1. Electrical wiring is done only by staff and it is done to California Electrical Code standards. "Wigglers" are provided to staff members and have been purchased for use by machine personnel so that a reliable method of testing line voltage is always available.

2. Gas cylinders are changed by staff members trained in cylinder safety. We have had seminars on this subject from Ed Sawicki, former Safety Director at Intel and also from our gas vendor, Liquid Carbonic. Cylinders are always chained and toxic and corrosive cylinders are operated in vented steel cabinets. The Microlab has also purchased two SCUBA units and has 3 staff members certified by the Lawrence Berkeley Lab to use them for rescue. SCUBA is used by certified staff members when changing toxic gases.

3. The lab has developed its own "low center of gravity" transportation carts for chemicals, and maintains a stringent policy for the transportation of chemicals. Mandatory safety glasses are now required in the lab.

4. Bulletins provided by vendors and bulletins from Environmental Health and Safety are routed with a sign off sheet to staff members. We also keep up-to-date MSDS (Material Safety Data Sheets) on all chemicals used in the lab. They are available to the lab users and a duplicate set is kept in the office.

We are actively pursuing safety in the lab. We are responding rapidly to any safety problems that we become aware of. Many of the steps we have implemented are new to the University and we are considered a model by the offices of Environmental Health and Safety and Occupational Health.

**STAFF PROJECTS**

Staff projects are carried out by the process staff (Tom Booth/SRAI, Kim Chan/SRAII, Marilyn Kushner/LAII, Jules Nagy/LAI, Robin Rudell/SRAII) under my direct guidance. These projects involve wafer processing for students using our silicon base line processes. The technology installed in the Microlab the past two years, during which most of the training of the processing staff also took place, was summarized in a 102 page ERL report, *MOS Processes in the Microfabrication Laboratory*, by Katalin Voros and Ping K. Ko. (Memorandum No UCB/ERL M87/12, 10 March 1987.)

**Processing**

1. We have processed this past year several CMOS lots for students of Professors Gray and Hodges; NMOS lots for BSAC (Berkeley Sensors and Actuators Center) students. Partial processing was done for students of Professors Hu, Ko, VanDuzer, Clarke, Oldham and Neureuther.

2. Simple layouts and photo masks are routinely made by staff for students. Tom Booth operates the electron microscope as a service; Jules Nagy operates the ion implanter.
3. Students are instructed to discuss special processing requests with me; this results in an ETR, (Engineering Test Request) a step-by-step description of what has to be done. While carrying out the work, the staff is in direct contact with the students; I am called in to help solve problems or to resolve ambiguities.

4. We completed masks and a simple two level process for bio-electronic researchers at the University of Utah. We are also doing some processing for Dr. Chi-Yung Fu at the Lawrence Livermore Laboratory. Cmos/sensors wafers were processed for Prof. Dennis Polla at the University of Minnesota.

CIM

1. The staff is also very much involved with the CIM projects. Dick Chan JE, has been working on installation of sensors and data collection hardware for BLIMP. A student engineering aide, James Hopkin, is maintaining and expanding the WAND and STAFF programs; however, the majority of his time is spent on making measurements in the lab and inputting data for FLIP, under my supervision. A systems analyst, David Mudie, wrote RESERVE and is in the process of writing the PARTSINVEN using our input.

2. Besides allotting staff time to support these projects, the CIM work must be coordinated with the other researchers in the lab to avoid disasters. This is no small feat. When the computer controlling the furnaces was modified for BIPS to allow for SECS communication with the lab computers, the whole system had to be shut down placing everyone on hold. When it came up all old programs had to be modified to run with the new software. We are still finding bugs and the whole project is just beginning.

3. Expanding the CIM program required upgrading of the main computer (a VAX 750) and changing to a distributed system, comprised of several SUN work stations. The SUNs are connected through the ETHERNET with the file server (a SUN 3/280, called 'argon') maintaining a common data base. The changeover is still in progress and, in spite of all precautions, the process is rather disruptive, with either the old or the new machines dying on us; bugs cropping up everywhere. I believe, however, that we have to do it to keep Berkeley at the forefront of CIM research; I just wish we were past this part.

PUBLIC RELATIONS

Policy

I believe that participation in public relations activities are an important part of the Microlab manager's job; thus, during this past year I have been working on developing a systematic approach to the issues. First of all, we had to realize that the Microlab cannot be an open house for anyone who comes to Berkeley, (to the San Francisco area, to the Silicon Valley, to Disneyland, to the U.S. or to the American Continent!) Handling visitors not only takes a lot of time, it is disruptive for the staff and students and introduces unnecessary contamination in the ultra-clean area.
After discussing the subject with Prof. Ping K. Ko, Faculty-in-Charge, and Prof. Oldham, ERL Director, we agreed that we shall accept only selected visitors. These are our supporters in industry, visiting professors and scientists in our field. We are also cooperating with the EECS Graduate Admissions Office by giving tours to the most desirable graduate prospects and affirmative action candidates.

Slide Show

We have worked out several presentations containing different levels of information for groups ranging from bright high school students to medical doctors doing work in EH&S. Robin Rudell is my main help in this effort. A 10 minute slide show with tape recorded explanation is utilized whenever possible for small groups in the lab lobby. Larger groups are accommodated in the Hughes room. We also have an extra set of slides for professors to borrow for their own presentations.

Booklet

In cooperation with the ILP office we have published a new informational booklet, called Microfabrication at Berkeley. Prof. Ko and I worked closely with the editors on the text and factual data, and staff contributed the pictures. The end result is an attractive publication which presents accurate information about the Microlab. We had 4500 copies printed; ILP mailed out about 1000 and the Microlab sent out about 200 to our industry contacts. Visitors are being given a copy when they come in.

Display Cases

This past year the Department decided to update the second floor display cases and the Microlab was given a section to fill. We supplied all the technical information, text, pictures and other items to be included and worked with the summer employee, an anthropology major, who was hired by EECS to assemble the presentation. The display is up now and will last a good 5 years.

Conferences

Whenever I am attending technical conferences or even during private travels, I try to include visits to other university or industrial research laboratories. Last year I had a chance to visit the Submicron Facility at Cornell and Philips Research Laboratories at Eindhoven. These occasions help me in keeping myself up to date on which way the industry is going, where we are in the picture, and it gives me a chance to talk about our work. Invariably, people are very interested in what is happening at Berkeley.

Other Labs

Often we receive telephone calls, computer mail or visitors from other university laboratories inquiring about our facility, how we built it, information about equipment vendors, etc. Bob Hamilton and I are trying to help them as much as we can and often encourage the caller to spend a day or two with us, and see the operations in action. The lab manager from the Pennsylvania State University liked the lab information system so much that he requested a copy of the WAND and STAFF and is trying to install it in his own lab. We are spreading the Berkeley gospel.
FISCAL CONTROL

When I took over the management of the Microlab last December (1986) we were half way through the fiscal year and $19K in the red. In addition, there was and still is the looming $400K+ debt which was accumulated during the building and startup of the new lab. While I made it very clear to the Director that I cannot accept the responsibility for recovering such a huge deficit in the projected time of 6 years, I said I will try to break even in fiscal year 86/87. After that, I will see about possible recovery when I make up the new budget. This will require that current BMA/ERL/EECS support is maintained.

Reduction of Expenses

Expenditures for lab operation were reduced watching every penny. We reduced inventory of slowly moving items and looked for alternate vendors to get better prices. We bought nothing that was not absolutely necessary for maintaining lab activities. We made sure that all recharges were properly recorded and collected, and that we were not overcharged for services from other units, especially the Machine Shop. As it was, the Microlab paid out $40K for Machine Shop work. We closed fiscal year 86/87 with only $2,190.00 on the minus side.

The new budget (FY 87/88) contains an 8% cut in S/E, 21% reduction in salaries, and is based on $205K BMA support and that two FTE's are paid by EECS and one by ERL (maintaining the previous level). With this arrangement we predicted a $50K debt reduction. The Supplies/Expenses budget was made lean. To facilitate the reduction of salary expenditures a principal electronics technician's position was eliminated. In addition, we had to maintain or increase income to reach our goal.

Increase of Income

The most straightforward way to increase income was to have more users in the lab. Our number one priority became to provide students with working machinery and processes and to reduce down time as much as possible. This went a long way in maintaining and increasing income. There is no doubt about it: our basic group of clientele, students who cannot do their research anywhere else, will come in and support the lab if it supports them. The number of users from other departments, outside of EECS, also increased as a result of people learning about the technology and about the lab; however, this did not represent a significant increase in income. Although 30% of registered users are non-EE, they provide only 10% of the income.

Balanced Budget

Seven months into the current fiscal year we are maintaining our budget. The enclosed charts show that we are ahead by $57K, effectively fulfilling the projected deficit reduction. If our income remains at this level we will be able to make some much needed, expensive equipment repair and upgrading during the rest of the fiscal year.
SUPPORT OF EE 143

The IC laboratory in 218 Cory is a small independent facility where undergraduate students build NMOS devices as part of the course EE 143. Phil Guillory has been assigned and trained to provide maintenance and service support. The course is given each semester with at least 6 lab sessions per week; thus, the lab must be in running condition at all times. To assure proper instruction I am recruiting TAs from among those graduate students who do their research in the Microlab. They report problems for EE143 on the computer just like any other machine problem; those are then taken care of by a Microlab technician. Supplies and gases are bought through the Microlab and recharged to the Department.

New Process

Last summer as a staff project we redesigned the EE143 chip to bring it more up to date with current industrial processes. Robin Rudell did the layout; the technology is now a poly-silicon gate NMOS process and we wrote, with Professor Ko, an extended characterization procedure. Each lab group comes to the Microlab to deposit poly-silicon (for which there is no provision in 218) and has a chance to see an advanced semiconductor facility in operation. The new process was successfully introduced in the Fall of 1987; some students had even 2 μm devices working.

PROCESS DEVELOPMENT

Process Development at a Halt

Development of new processes in the Microlab dropped to a minimum level when I took over management. There are simply not enough hours in the day to take care of everything and to do development work at the same time. This makes me sad, but I cannot help it. We are maintaining whatever processes we have and will adopt any new ones from students; unfortunately, this does not occur too often. We had one successful new project when Kim Chan worked with graduate student, Pei-lin Pai on the double metal process. This was then incorporated into the existing p-well CMOS process.

Associated Researchers

The cryoelectronics group takes care of their development work by supporting an Associate Development Engineer. While he is considered Microlab staff from the administrative point of view, Dave Hebert reports to Prof. VanDuzer for assignments and projects. Professors Oldham and Neureuther have opened a position for a similar arrangement in conjunction with their Deep UV project.

FACILITIES DEVELOPMENT

Equipment Budget

The funds available for replacing/upgrading equipment in the Microlab are rather limited. We were given a BMA donation of $120K for the past and current fiscal year to buy new equipment. Anyone vaguely familiar with the semiconductor industry knows that prices start
at $100K even for simple machinery. On occasion professors buy equipment for their own research but, even though the unwritten rule has been that equipment maintained by staff is available for everyone, it cannot be used by all members because of cross-contamination caused by different processes.

**Equipment Donations**

To supplement our own resources we are actively recruiting equipment donations from companies. We have to be careful, however, of what we accept, to avoid the trap of collecting irrelevant machinery and junk, as I have seen at some other university laboratories.

**“New” Equipment**

All in all we managed to obtain and install seven new pieces of instruments, (login names: cpa, lam2, microstrip, as200, semi, hld, rga) and retrofitted two Tylan furnaces (tylan10 and tylan16). We also took on the installation and maintenance of the new cold probe in the Device Characterization Lab (407 Cory).

**Equipment-Use Analysis**

During this past year I had reviewed the facilities status from several points of view.

1. What do we need to complete the equipment requirements for a standard silicon CMOS process?
2. What can we do to alleviate users crowding on certain apparatus?
3. How much maintenance is needed to keep a machine up?
4. What is the number of users a machine serves, to determine servicing priorities?
5. What type of modifications are feasible considering our resources?

**Action: Equipment Requirements for a Complete CMOS Process**

1. The donation of a 3-target sputtering machine by CPA greatly enhanced our standard metallization capabilities in the VLSI area. Installation was completed last February and the cpa has been up, except for minor repairs, continuously. Prof. Hu bought a titanium target and Prof. Howe a tungsten target for their groups' research.
2. The acquisition of a SiO2 plasma etcher, at a reduced price, enabled us to increase the reliability and reproducibility of several processes, by restricting chlorinated gas processes to lam1 and fluorinated gases to the new machine, lam2.
3. We bought a Microstrip plasma etcher to facilitate photoresist removal with O2 gas and save on acetone expenses.
4. A very much needed helium leak detector was bought for servicing the vacuum systems. We also paid for half of a residual gas analyzer for Prof. Oldham's Si epitaxial growth project (tylan10). This instrument will be turned over to general use after the project is completed.

**Action: Avoiding Conflicts**

1. Prof. VanDuzer bought a Semigroup reactive ion etching system, which is restricted to the use of cryoelectronics researchers.
2. The expansion of sensors research increased the demand and toll on the poly-silicon deposition tube (tylan11) to such an extent that obtaining a second system was
unavoidable. The decision to build one in-house was most unfortunate (see discussion below); however, we are now close to completion and to making both the BSAC and the Device and Process Technology groups happy.

3. One of the analytical instruments which is used by all lab users, the Alphastep profilometer, needed upgrading and more flexibility to accommodate measuring samples of varying sizes. We were able to buy, at a reduced price, an automated instrument; thus, diminishing aggravation caused by having to change settings between the Si and GaAs samples.

Action: Old Machines Retired

We have some old machines in the Microlab which are simply worn out. Maintaining these is an unending job and at one point we have to decide that we cannot afford to do so any longer. One prime example is the MRC zinc oxide sputterer which serves a rather limited clientele. Our discussions with the BSAC professors resulted in them including a request for a new sputterer in one of their research proposals. These type of requests have been and will be communicated to the professors, many of whom seem to be oblivious to the fact that equipment has a limited lifetime and patch-up jobs will not resurrect them from the junk pile.

Action: Service Priorities

Establishing priorities in servicing equipment used by different groups turned out to be quite a balancing act. We were made aware on several occasions that a professor was unhappy with the service his group was getting, or that the service is not in proportion to the support his student are providing for the lab. Well, what can we do? Bob Hamilton and I are trying to do our best to satisfy every need; but, sometimes certain jobs have to take lower priority. There is no partiality here, only limited resources. We asked Dave Mudie to write us the TECHJOB program which lists the projects for each technician in order of priority. Every morning we review the list together and discuss what is the most efficient way we can handle the problems. Inevitably, some jobs will not get done right away. It is not for lack of trying.

Action: In-House Modifications

One of the nice things about our lab, visitors often say, is the freedom students have in accessing equipment, in requesting changes to accommodate some special need. Flexibility is a key word here and we are really trying to do everything to help researchers. Some equipment modification, upgrade, is going on all the time. Major ones we completed last year were:

- Modification of the ion implanter (rewiring for automation of vacuum system and control panel);
- Upgrading of the Plasmatherm RIE to accept 4” wafers and to handle corrosive gases, such as HI and HBr;
- Retrofitting of one of the Lindberg furnaces for atmospheric silicon nitride deposition for the compound semiconductor group;
- Conversion of three vacuum systems (nrc, ionmill, dw) to cryo-pumps;
- Modification of the Eaton Wafer Track to spin on contrast enhancement material;
- Remodeling of sinks 2 and 9 according to special requests;
- Installation of special gas lines, Ar, NH3, into tylan6.
With the rapidly advancing sophistication and availability of semiconductor processing equipment, the long standing philosophy of building our own machinery must be put to rest. While we may have the design capability to build certain systems we certainly do not have the manpower to execute it without a great burden to the rest of the operations. The new poly-silicon deposition system turned out to be just that. We are near completion now but a list of other jobs, including preventive maintenance, had to be put on hold and all we were able to do these past four months was to keep our head above water. When I took over the management I made the statement to the staff that we are not in the equipment-building business and I will not accept such jobs. After a year we are still not completely done with winding down what I inherited. We certainly did not save any money. The cost of retrofitting tylan16 cost $25K in parts only.

**New Liquid Nitrogen Vessel**

We took an active part in helping the Department to build the new MBE lab (155 Cory). Bob Hamilton and Dick Chan served as consultants to the Department Engineer and the Development Engineer in the new lab, John Benasso. We had to arrange for a larger LN tank (3000 gal) to also service the new lab. Chemical and other supplies are obtained by them through the Microlab.

**COMMENTS**

I have spent a considerable amount of thought and time on formalizing the requisites of the manager's job in this unit. I was given the charter of "running the lab", which, as I learned during this past year, meant that I am to "operate it without creating problems for EECS/ERL; make it transparent to professors; do everything to further research projects; do it within a budget which includes partial repayment of inherited deficit; and smile!" I translated this into the job description, which in turn served as the outline for these notes. In the subsections I presented some of my thoughts on each subject and what we have done in that area. This process gave me an opportunity, in fact made me do it, to place everything in perspective and to formulate a workable system for "running the lab", the way I know how.
Year to Date Income and Expenditures
Fiscal Year 87/88

Monthly Income and Expenditures
Fiscal year 87/88
1988 Year End Report

MEMORANDUM

TO: Prof. Ping K. Ko, Faculty-in-Charge
FROM: Katalin Voros, Microlab Manager
SUBJECT: Microlab Status Report
Information for Performance Appraisal (1988)
DATE: January 17, 1989
cc: N. Cheung
    D. Hodges
    W.G. Oldham
    E. Wong

Yet another year passed in the life of the Microlab, and mine, and it is time for another performance evaluation. Actually, this is a good occasion to summarize what happened during 1988 and to put it in perspective to see if any trends or possible predictions developed. To assist you in writing my A&PS Performance Appraisal, I will be following, same as last year, the sequence of entries in my job description, which covers fairly exhaustively the work involved in managing the lab.

SUPERVISION OF STAFF

This area of responsibility continues to take up quite a large chunk of my time and efforts. As can be seen in the attached staff chart we have 20 staff members (8 A&PS) directly involved with the Microlab (although not all of them are paid by the lab), all of whom have to be supervised/managed, reviewed, and have their problems taken care of.

1. Maintenance Staff

Under the supervision of Robert Hamilton we now have a high level technicians’ staff who are expected to and are capable of maintaining equipment from a simple bake oven to a sophisticated exposure tool or ion implanter. Their area of responsibility also includes facilities such as the DI water plant, gas supplies, air handling, etc. The equipment list contains 135 machines with mechanical and/or electronic subassemblies and controls, and a total of 82 vacuum pumps (a mixture of both low and high vacuum pumps).

We found that the job classification best suited to the lab’s needs is the Development Technician’s series, which requires having a wide range of skills encompassing mechanical/electrical/electronical repair and design capability. Thus, when Dick Chan, Junior Dev. Eng. resigned, we retired his classification and hired a Dev. Tech. V. After the reclassification of Robert Norman from level IV to V, we now have three Dev. Tech. V’s, Phillip Guillory, Robert Norman, and new hire Evan Stateler.

With the two other, more specialized technicians, Steve Hoagland, Principal Electronics Technician, who takes care of complex electronics subassemblies; and James Parrish, Principal Laboratory Mechanic, who services, rebuilds all the vacuum pumps, we now have good maintenance coverage and only rarely need to call outside services. From the first, this was my goal and we have come as close to it as possible with available resources.
Bob Hamilton developed into a very capable, hands-on supervisor. He now deploys efforts efficiently with recognition of priorities. He works where help is needed and acts in cases when a technician is out and when an emergency arises. He initiates and coordinates development projects and sees them through completion. We have daily discussions and status updates and I am careful to appraise him of budget constraints, of near and long term process development goals, and other items concerning the lab. We can fill in for each other at times when one of us is out.

2. Process Staff

One of the main components of successful operation of the Microlab is the service provided by the process staff: Tom Booth, Staff Research Associate I; Kim Chan, Staff Research Associate II; Marilyn Kushner, Laboratory Assistant III; Robin R. Rudell, Staff Research Associate II. Not only do they carry out so-called staff projects, such as complete integrated circuit processes, they also characterize equipment after repair; execute operational maintenance, such as chemical changes in sinks, lamps changes in exposure tools, calibration of analytical instruments, etc.; they help out and collaborate with students on joint projects. The process staff gives lab orientation classes; maintains operating manuals and provides continuity of information for the ever changing student body.

This group was organized and trained by me in 1985-86, after I was employed as a development engineer in the Microlab, to establish a baseline cmos process. After I became lab manager (Dec. 85) the process staff continued to report to me directly. However, due to growing demands of my duties as manager, this arrangement is untenable and I have been reexamining the situation pertaining to the supervision of this group. It seemed that Robin Rudell after advancement to the level of SRA III could be made Process Supervisor. Unfortunately, she will be leaving at the end of August, 1989. This will be a great loss to the Microlab and I have very little hope of finding someone with the combination of her talents, excellent processing ability and a great affinity to computer utilization.

If and when Robin leaves, I would like to post the open position as a Staff Research Associate III, Process Supervisor, to seek someone with semiconductor process engineering and/or supervisory experience, and to keep it open until such a person is found. It is essential to the dynamic development of Microlab activities that the process group be strengthened, that we hire a person who can contribute to our efforts and through whom I can manage processing activities more effectively.

Unfortunately, this plan depends very much on what the budget will look like at the end of the fiscal year, and on what kind of BMA contribution will be made available for the next FY (89/90). It would look simple to reduce expenses by not hiring anyone for Robin's position when it is vacated; however, I would take such a step with the greatest reluctance. Not maintaining an effective process staff would compromise future developments and present operations in general. A lab of this size simply does not run by itself.

3. Administrative Staff

During this past year we were successful in obtaining an Administrative Assistant II position for the servicing of our unit. Rosemary Spiwy, with the help of a Lab Assistant I, does an excellent job of administering over 130 recharge accounts, managing accounting, purchasing of all materials and chemicals, maintaining inventory of supplies and does a million other things running the office requires.

As a result of increased lab usage, (i.e increased duties in stocking of supplies, material/chemical inventory maintenance, buying/selling supplies to students), the LA I position in which we used to have part-time students, had to be extended into a FTE position, now filled by Mario Santiesteban. To ensure smooth lab administration, the current level of employment in the office will be maintained.
4. Associated Research Staff

Under this heading we are grouping those researchers who for administrative reasons are considered Microlab staff yet they are under the direct supervision of PI's and are paid by them. This arrangement was established to satisfy the sensible ERL practice or rule that all staff people should report to staff supervisors and not to professors. This is to avoid additional administrative burden of PI's and at the same time, to protect employees' interests, such as delivering timely performance evaluations and relaying of information concerning UC staff policy/benefits changes. In case of the Microlab also the questions of research space and equipment repair priorities had to be resolved every time a dedicated researcher was hired.

Looking at it strictly from the "What is in it for the lab" point of view I have to say: not much. Associated researchers are paying for the use of the lab same as other users when they are working on project/process development. (They are exempt from paying when repairing/rebuilding machines). The equipment they are building/buying are restricted to their own group's use due to process compatibility, yet these are maintained by the lab staff. The positive aspect of the work of dedicated researchers are reaped by the research group itself, which is of course why they were hired in the first place. The Microlab gets the extra work in administration and in conflict resolution.

We make the system work, however, and we are glad when promising results show that it was worth the effort. Three of our main research groups employ dedicated staff. They are Dave Hebert, Associate Development Engineer in cryoelectronics (PI: TVD); Richard Hsu, Associate Development Engineer in the Deep UV Project (PI: WGO); and Jongnam Kim, Staff Research Associate II in Sensors research (BSAC-PI: R. Muller).

5. Computer Support Staff

Members of this group, who are paid entirely by Prof. Hodges, are not under my management administratively; however, their work assignment is in the Microlab and they receive a good deal of instructions from us. As part of the larger CIM project (PI: DAH) Dave Modic, Systems Programmer/Analyst II, and two students, Adhi Gaduh and James Hopkin, part-time Engineering Aides, work on all aspects of lab maintenance and management software. This works out well, because we usually get help in what we need, such as programs for inventory, facilities monitoring, etc; in return we, the staff and students, immediately use or abuse, and help to debug them. As a result of this cooperation, BLIS (the Berkeley Laboratory Information System) software is developing nicely and a host of further applications are planned. We have good rapport with the "hackers" and they are considered part of the Microlab staff.

6. Comments on My Management Style

It has been mentioned to me that my management style is too straightforward, or abrupt on occasion, or that it is sometimes undiplomatic. I thought about this a lot and went about analyzing it using engineering methods: I read some books, compared their examples with mine; took a one day course (as was suggested on my last year’s performance evaluation) titled, "How to Handle People with Tact and Skill". What I learned is that while there are some techniques one can acquire, basically, you work with what you have. What I have is a honest straightforward style and high standards. This combination is often called demanding. I see absolutely nothing wrong with this; as long as it is fair. I am doing my best to be fair; I am stating my requests in clear, unambiguous terms and I expect delivery. At the same time I will defend my employees' rights to the utmost and give them the best possible evaluation and compensation I can. I will also say if something is amiss. The bottom line is that the Microlab Staff is a rather steady group and during my tenure we have only had one departure, Dick Chan, who left for a better career opportunity.
ADVISING OF STUDENTS

This continues to be the most pleasant aspect of my job and both Bob and I did quite a lot of it last year. Sometimes we find that we get more involved with a project than we would like to or would be wise, but there are always students who take the easy way and pick our brains before they do any homework. When I notice this I let them know my opinion and tell them to come back when they have a better concept of what they want to do. All in all, our cooperation is successful.

1. New CMOS Test Chip
I have spent a considerable amount of time working with a CIM student in developing a new (p-well) CMOS test chip which contains all the desirable structures for parametric extraction and has a pad layout which allows automatic probe testing. Paul Kruger did a thorough and excellent job and I am very happy with the result.

ERL Memo

We now have a p-well CMOS test chip which is completely documented and can be used to tune FABRICS, a statistical process simulator. We have converted it into n-well and will be using it shortly.

2. Lab Orientation Seminars
We had five lab orientation sessions last year with a total of 71 attendees, almost all of whom subsequently became lab users. This number has been reached gradually, from 56 in 1985.

In the morning the staff presents lectures on general procedures, safety, administration, computer use, equipment and process capabilities, and lab etiquette. In the afternoon the attendees are given a lab tour in which safety features are emphasized. After the safety quiz they may register to become lab users; however, the course does not qualify them to use any equipment except the computer. New users have to learn to operate each machine they need from a fellow student and become qualified separately. We are giving them as much help as we can to get started.

INTERACTION WITH FACULTY AND RESEARCH GROUPS

This past year we have added a new entry in the lab user information data base. All members are assigned a research group and one can send mail directly to the group. They are: sensor, compound, device, cryo, process, physics, chem, cheme, cim, mascei, ic, lnl, others.

Membership has been steady around 130 this past year, with lab usage fluctuating according to the academic calendar, the summer months being the busiest. Besides our regular daily interactions with the users concerning their work, the following items were discussed with our three largest groups:

1. Sensors
The Berkeley Sensors and Actuators Center's (BSAC) lab membership increased to 20 students and a visiting scientist whose activities imposed a disproportionately large burden on some equipment, such as the furnaces. We had several meetings to discuss maintenance, service priorities, improvements, etc.; problems, some of which we did not anticipate. We are working hard on giving this group satisfactory service and on keeping the communication lines open.

After some trepidation we also agreed that the best way for BSAC to enhance progress on certain special projects would be to hire a dedicated researcher who would spend full-time on the these projects. As a result Jongnam Kim, an SRA II was hired to work on the miniature pressure sensor (microphone) project.
2. Cryoelectronics

Prof. VanDuzer’s group employs, since 1986, Dave Hebert, an Associate Development Engineer, in the development of various Josephson Junction devices. The arrangement seems to work very well for the group; however, there were complaints that we did not live up to expectations in repair and maintenance service. During part of the year we had monthly meetings to resolve priority problems, with the end result of us agreeing to give every cryo problem reported top priority if/when a repair time estimate is submitted with the request.

Another subject of contention was assigning space in the lab for a donated 3-target sputterer (TOP-GUN). Considering the fact that the cryo group occupies one dedicated room, GL3, and has another restricted machine in GL1, I could not agree to bringing in the new lab another large machine. Prof. VanDuzer minced no words in expressing his displeasure at this and accepted space in the old lab only after some negotiations with the Faculty-in-charge. The final note on this subject is that the machine is being completely overhauled and rebuilt with active participation of staff technicians (at no extra charge). Progress is rather slow, partly because of special requirements by the cryo engineer, partly because I will not compromise general lab service by pulling off technicians to rebuild the TOPGUN. Since we have no proper place for this type of work, the machine has been sitting in the lab, broken down into components, cluttering up space, for the past six months. We are now in the assembly mode and when it is done, the TOPGUN will be an excellent machine. The understanding is that it will be available to all users - as long as their process is compatible with cryo requirements. We shall see.

3. Deep UV Project

In many respects this group caused the least amount of disturbance as their activities have grown. Working with the students are, Post Doc. Chris Spence and Richard Hsu, Associate Development Engineer. In addition, Prof. Neureuther pays the salary of a half-time employee, Kim Chan, SRA II, to help out with their routine tasks. The agreement is that we can have Kim back for emergency work.

The project occupies a dedicated room, GL4, in which equipment is being rebuilt/modified by members of the group with the help of staff when requested. Cooperation has been smooth in executing the following jobs: installation of gas cabinet and excimer laser in CG4; exchanging of wall panels to red to eliminate unwanted light during experiments; removal of sink and addition of work surfaces and storage space; installation of spinner2 and the syilization system; and completion of various minor requests.

STAFF PROJECTS

Staff projects are carried out under my direct supervision and involve both process and maintenance people. The main thrust of process staff activities are wafer processing, layout and mask making. Maintenance and computer support staff, besides their routine work, take an active part in facilities development (detailed later) and in CIM projects, described below.

1. Wafer Processing and Mask Making

Using our base line processes we have completed several CMOS and NMOS lots and did partial processing for our students, as requested. We did non-standard processing for users from other departments, (chemistry, chem. eng., mat. sci., physics, geophysics). We took on various jobs for scientists and professors from LBL, SSL, LEL, UCD, UCSD, UCLA, U of Minnesota; these jobs involved some wafer processing but most of them were layout and mask preparation. Robin Rudell has become quite an expert at laying out simple, non-standard structures; thus, we can fill these type of requests with relative ease. We have also been successful in making masks from CIF files which we received over the arpanet. I need to be careful, however, that we do not become a mask shop for other labs and place undue burden on the pattern generator; thus, I have been discussing each project with outside researchers and made clear what our conditions were.
2. CIM Projects

2.1 Operational Maintenance

Visitors to the Microlab are impressed with our Laboratory Information System, a good part of which cannot even be appreciated looking at just the WAND. When they ask me how I manage all the students and the staff I always emphasize that I could not do it without the computer. This is absolutely true. After reworking and improving them several times both the WAND and STAFF programs are indispensable and up-to-date tools for daily lab operations, administration, account maintenance and communication. On the WAND we recently extended user information (research groups listing, students by professors, current lab charges to student); STAFF additions were: gases, pumps and parts inventory. Menus have been reviewed and unused options eliminated. James Hopkin wrote the new PURCHASE program which prints out purchase orders using vendor information in the database. LABGRAPH by Dave Mudie (using a UNIX utility) helps me to analyze lab usage and income patterns.

2.2 Development Projects

FLIP

The Facilities Layout Information Program (written by A. West, data entry by J. Hopkin) is completed as far as data entry is concerned. This program shows the map of the lab, with equipment and facilities lines in it. It can calculate areas, show dependency lists (what machine needs what facilities), and it is connected to the WAND to allow turning machines on and off by pointing with the cursor. Unfortunately, FLIP, as well as the other programs discussed in this section, require graphics terminals; thus, their use is rather limited in the lab. I am planning some in depth discussions with the CIM people on how to proceed with these projects.

BLIMP

The Berkeley Laboratory Infrastructure Monitoring Program written by Anit Sharma (master's project) and made user friendly by Aditi Gadud (using VEM) is designed to monitor sensors placed at strategic locations in the lab and on delivery systems (DI water, air, N2 pressure, etc.). Dick Chan worked on the installation of sensors and data recording instrument (Accurex), which sends the information to the computer. Although the information currently collected is not very meaningful from lab operations' point of view, the project served as a good vehicle for a master's report.

Now that we have the software, to which Dave Mudie added the capability of reading just numbers on a regular terminal (instead of looking at charts on a graphics terminal), I have every intention of making it fully functional. Bob Hamilton and I had several discussions with two of our techs, Phil Guillory and Evan Staterle, who will submit a design proposal for placing sensors at critical points. My goal is to put together a system which monitors all important facilities (specifically: DI resistivity, air, N2, O2 pressure, recirc. water pressure and temperature, lab temperature and humidity) and sends warning mail when something falls below a critical level. Not all of this will happen next year but I would certainly like to make some progress toward this goal.

BIPS

The Berkeley Intelligent Processing System is the PhD project of Norman Chen and it involves controlling and monitoring of processes by sending instructions to and taking data directly from the machine's computer. This is not as simple as it sounds. Every piece of equipment we have has some sort of computer or microprocessor in it; however, none of them talk to Argon (or to any other computer), a situation which is not unique in the industry.

After a nice start and Norman's writing of many lines of code the project reached a screeching halt because of hardware problems. We had to upgrade the eeproms in the furnace controllers to allow for SECSII communication ($10k, paid by DAH). Unfortunately, the new edition communicates only in one direction, down, and does not allow uploading of instructions. When we complained to Tylan,
they could not help us; in the meantime they sold the furnace division. Tystar, who bought it, was willing to pick up the pieces and help us, but they do not have what it takes. We asked for the source code for the sprooms so that we could program them ourselves; they sent whatever they had, which is not what we need. At this point Steve Hoagland is spending considerable time, some of it his own, trying to decipher the source code and to modify it to our needs. Since December is usually a slow month in the lab I agreed to allow some time for this but soon we shall be ready to review the whole project.

In the meantime, boards in the two Lam etchers were upgraded for SECSII communication. It looks like this attempt will be more successful, especially with the help of Dr. Peter Byrne, of Brookside Software, who wrote the software (LAMLINK) while working at Lam.

PUBLIC RELATIONS

1. Visitors

In spite of our efforts to reduce the number of visitors in the lab to those who are directly involved with a project, we had 796 names logged in on the computer last year. This was an increase of 200 over 1987, mostly due to the flurry of activities in BASC. While I believe that publicity is necessary to advance a good idea there is a point beyond which it can become untenable. Well, we reached that point and I had to ask the BASC professors cooperation in not bringing in any more camera crews.

2. Informational Material

One way to avoid unnecessary traffic and to ease the burden of visitors taking up staff time is to show, on video, what the lab looks like inside. We are currently in the process of producing a 15-20 minute video tape, with the help of the campus TV Office. Robin Rudell is carrying the project which is now in the post production stage, i.e. editing. We are planning to set up the video monitor such that it can be viewed from the hallway through the glass doors.

FISCAL CONTROL

The Microlab met its budgetary goals for FY 87/88; in addition a $50K deficit recovery was achieved. This accomplishment was made possible by:

- A 16% increase in income from the use of the facility by the leading research groups;
- Strictly adhering to the cuts laid out in the 87/88 budget;
- Receiving the projected BMA/ERL/EECS support on which the budget was based.

The new budget for FY 88/89 is balanced; however, no deficit recovery is shown. With increased lab usage our expenses also increased and no further cuts could be made; at the same time BMA subsidy allotment was reduced by 25% (to $150K). Even with these setbacks and counting on income level remaining the same as last year the budget is balanced without increasing rates. I estimate that if income increases we will be able to show some deficit recovery.

Well, this is not happening. Half way into the current FY income is slightly off from last year and we are just about breaking even, (see attached income and expenditure graphs). Unfortunately, this is not good enough for the campus Recharge Committee, who would like to see us chipping away at our debt to the University. Thus, when Joan Barulich prepared the new proposal I agreed to raising the access fee and the staff services fee. This way the burden is more evenly distributed and our major users are not disproportionately penalized.

In spite the fact that the lab's fiscal condition seems to be in good order now, I do not feel comfortable about the future. Even if I ignore the debt, which according to the latest statement is at $389K, I cannot discount the fact that our equipment is aging and sooner or later machines will have to be overhauled or replaced. Some examples: this past year we had to have the stage rebuilt in each of
the exposure tools. The cost for the Canon was $6364.00, for the GCA wafer stepper $5702.00, and for the GCA pattern generator $3840.00. The last two were squeezed out of the S&E budget and the Canon rebuild was paid from the $50K BMA equipment allotment for the year.

SUPPORT OF EECS143

With Phil Guillory being in charge of the processing equipment, maintenance of the undergraduate teaching lab is under control. The new process we introduced in the Fall of 1987 is working well and I have seen some very nice reports. To aid the teaching assistants we summarized the contents of the laboratory material in an ERL report titled, "EECS143, Processing and Design of Integrated Circuits Laboratory Project", by Ping K. Ko, Robin R. Rudell, and Katalin Voros (Memorandum No. UCB/ERL M88/50, August 1988).

FACILITIES DEVELOPMENT

The funds available for replacing/upgrading equipment in the Microlab are rather limited. We were given, out of BMA funds, $74K in FY 87/88, and $50K in FY 88/89. We bought new equipment jointly with several professors, the rest of the money went to rebuild/upgrade old machines. Following is the list of major projects completed this past year.

1. Tylan16
   This furnace tube was retrofitted to a LPCVD system for poly-silicon. We completed it early in 1988 and the BSAC group has since been using it intensively. Total cost in parts was $43,770.00 and we spent over two years an estimated 800 man-hours building it.

2. Ptherm2
   The Plasmatherm dual chamber RIE machine, on loan from Lockheed Laboratories to Prof. S. Wang's group, was installed during January 1988. Associated costs paid by us, was $3760.00 for shipping and parts, and we spent 66 man-hours to set it up...

3. Static Eliminators
   Ion Systems Inc. was looking for a test site and after we agreed to it, they installed 4 static eliminators, free of charge, in the VLSI photo rooms, (Y2, Y3). They asked only that we allow them to come in once a month to check them.

4. Cold Probe
   We installed a cold probe system for Prof. Ko's group in the Device Characterization Lab (407 Cory) and are continuously supplying high pressure, high purity N2 cylinders to operate it.

5. New ZnO Sputterer
   We have spent considerable effort and time selecting and specifying the requirements in detail on the new ZnO sputterer bought jointly by BSAC and the Microlab (the lab paid about $20K) from the Briggs Gallo Group Inc. We also made a deal with Advanced Energy, the maker of the power supply, to donate a DS-20 process controller to go with the machine. This adds the capability of system management by BIPS. In return we will write processing and regeneration programs which they can have after we test them. Aditi Gadde, under Bob Hamilton's guidance, wrote the program which can be run on an IBM PC or directly on Argon. We are waiting for the machine to be delivered (after many postponements, scheduled for middle of Feb.).
6. Reichert Microscope

Two groups bought jointly with us a high quality inspection microscope with Nomarski interference capability (Microlab paid $12.5K). This instrument is partially restricted, i.e. users must be qualified to operate it. Unfortunately, University Purchasing made us buy it from the lowest bidder, McBain, a contracted vendor, the result of which was that many parts were not as specified in our PO. After pursuing the matter with Reichert, Cambridge Inst., the parent company, agreed that we did not receive a perfect instrument and replaced improper parts. To arrange all this took some effort on Bob Hamilton's part.

7. Heatpulse2

A used rapid thermal annealer, identical to our heatpulse was donated by Analog Devices. Although it needed extensive repair and cleaning (we spent about $1.5K on parts) we were glad to receive it because having a dedicated machine for Si and another one for GaAs eliminated changing chambers (which often broke in the process due to poor design) and scheduling conflicts.

8. Modification of HF Sink

One of the sinks in the old lab (in 432D) was extensively modified for electrolytic formation of porous silicon. Since this process is carried out in concentrated HF, safety had to be the number one priority. It was rebuilt; all teflon and exhaust velocity was increased to provide appropriate protection to the users.

9. Exposure Tool Stage Rebuild

I presented this expense as an example earlier in the Fiscal Control section. The work simply had to be done because of wear and tear over the years. Stage movement accuracy slowly degraded with use; we were lucky to stretch it out this long. Because of the complex and specialized nature of the wafer steppers and pattern generator, all three jobs had to be done by outside services.

10. Replumbing of the Recirculating Cooling Water System

When the 5th floor of Cory Hall was built the Microlab's recirculation water system was redesigned and moved to the roof of the new floor. The design as implemented was not successful in supporting Microlab equipment. Modifications as specified by DOFM made the recirc. system marginally usable; however, we continued to encounter problems with insufficient working pressure.

The recirc. system supplies all vacuum systems in the lab with cooling water for the cryo pump compressors and for target/electrode cooling. Loss of cooling water not only causes temporary shut-downs of essential equipment but it reduces the effective life time of the pumps and the equipment. Low recirc. water pressure causes us to resort to fresh water cooling, which means that a valuable resource, water, is being wasted where it could be conserved.

We have complained to DOFM on several occasions and requested that the recirc. system be replumbed. Finally, as a result of Wil Zeilinger's good rapport with DOFM, they hired Gayner Engineers to redesign, and Berkeley Plumbing to rework the system. Replumbing was completed in July, paid for by DOFM and the system has been working reliably since.

11. Water Conservation

Responding to the request of the campus Energy Conservation Office, we did a study of the lab's water usage and submitted a memo concerning same to the Department Engineer. The Microlab has three interdependent water loops which were examined for efficient operation and for possible reduction of water usage. These are 1) the sinks, 2) the recirculating cooling water, and 3) the DI water system.

For several months we have put additional effort into locating wasteful usage, changing procedures and/or plumbing wherever possible. Improvements resulted in reduction of usage by 40% over the past year.
We have achieved, and in fact surpassed the goal of 17% reduction in water consumption the Energy Conservation Office asked for. More could be done by addressing the problem of conserving the rejected water at deionization. With that we need help. We asked the ECO to advise us of any further steps we can take.

12. Feasibility Study for a New Telephone System

Several students using the lab commented that the paging system in the lab is way behind in technology compared to the rest of the equipment. The main concern was that a person inside has no way of paging others when the office is closed. I asked Phil Guillory, who previously worked for Pacific Bell, to submit a proposal for a new telephone system with paging capability. He looked at several options and came up with a cost of about $7500.00 just for equipment. Installation by him would take about 80 man hours. Because of the price tag, this project is on hold.

COMMENTS

By the end of the second year under my management, Microlab operations reached steady state, as much as a research lab is ever in a steady state. I am proud of our accomplishments which could not have happened without the dedicated support of Bob Hamilton and the Microlab staff. Also, Wil Zeilinger's help in dealing with DOFM was invaluable. Last year's goals, listed in my 1987 EPA, were met, as discussed in the appropriate sections above.

PERFORMANCE PLANNING FOR 1989

Performance objectives for the next appraisal period are:

1. Maintain laboratory at the current level of service.
2. Develop in-kind donations.
3. Reorganize processing staff.
4. Further develop CIM projects.
5. Make BLIMP useful.
6. Prevail in obtaining a vacuum service room.

YEAR TO DATE INCOME AND EXP.
FISCAL YEAR 88/89

![Graph showing income and expenditures](image)

26
1989 Year End Report

MEMORANDUM

TO: Professor Ping K. Ko, Faculty-in-Charge
FROM: Katalin Voros, Microlab Manager
SUBJECT: Microlab Activities Report - 1989
DATE: January 30, 1990
cc: D. Hodges, R. Howe, W.G. Oldham, W. Zeilinger

This report summarizes Microlab activities during 1989. It is the third such year-end review since I assumed management of the lab; and again, it follows the sequence of areas of responsibilities listed in my job description.

SUPERVISION OF STAFF

The major event concerning the staff occurred when we were assigned badly needed additional space to establish a mechanical service room for rebuilding of pumps and miscellaneous machinery. In addition, we obtained another room for office expansion, to relieve overcrowding and to consolidate staff offices into one common area. Remodeling took 3 months, during which staff was without an office, scattered all over the lab and hallways. Our spirits lifted however, when we moved, in November, first into the new "pump room", then into the new office for 20 people. The fact that we are together in the same room has some unexpected advantages. A lot of running around trying to talk to people has been eliminated, communications improved. At the same time, staff members are not getting on each other's nerves by being crowded together; there is room for discussions with students, without disturbing others. The new service room, storeroom and new office improved staff morale remarkably.

Other developments during the year occurred in the area of staff allocation. To provide the staff structure with a stable framework, responsibility for supervision has been distributed by assigning individual supervisors to the processing and administrative groups. Figure 1. shows the new assignments and staff listing, as of January 1990. Further classification and payroll allocation can be seen in Table 1.

1. Maintenance Staff

Settling of the pump room question improved working conditions for the whole maintenance staff considerably. The new mechanical service room (located next to the office), is actually a small machine shop which is handy for a variety of minor jobs and eliminates lot of tracking down to the first floor. James Parrish took active part in designing the layout and installation of equipment, including a wet sink with an exhaust hood. Phillip Guillory did an excellent job in rewiring the whole reconstructed section, including rooms 406 (office), 413 (mech. service), and 421 (storeroom). He designed and installed all the power, telecommunications and computer lines. A special memo was attached to his performance evaluation in support of a "superior" rating.

During the year we have made sufficient progress in cross training of technicians, that we now have back-up coverage for critical equipment. In addition, we have established and developed cost efficient and reliable outside service contacts. Reaching a consensus with concerned PI's, the old, maintenance intensive ion implanter was decommissioned, freeing up some technician's time. After
careful consideration of all factors and with the knowledge that equipment design and development activity will be cut back, we have decided that if we have to reduce the number of staff, in order to meet the budget, we can do it with the least amount of disturbance in this area. By November it was clear that we were lagging in meeting our budget and, as a cost saving measure, our principal electronics technician has been laid off indefinitely, effective January 3, 1990. So far, we are managing well enough with a reduced staff; however, the big test will come during the Summer, the peak period of Microlab use. We are working on some contingency plans.

2. Process Staff

Reorganization of the processing group went fairly smoothly, according to the plans outlined in my last year’s Status Report. Robin Rudell’s position has been reclassified to a Staff Research Associate III, a supervisory position, effective July 1. (At the same time, Tom Booth advanced to an SRAII position and Marilyn Kushner to SRAI.) When Robin resigned, effective at the end of the year, we hired Debra Hebert into the supervisory position. Debra has a BS degree in Materials Engineering and brought with her three years of industrial process engineering experience. We allowed two months of overlap for her to be trained by Robin, during which she also completed the short course given by the campus Personnel Office for the orientation of new supervisors. As a result, the transition went very smoothly and Debra is handling her responsibilities exceeding expectations.

3. Administrative Staff

Rosemary Spivey has been assigned the position of Administrative Supervisor, effectively given the assignment of "running the office", which she does extremely well. At her proposal, we reorganized the office staff into a more manageable and responsible unit. Instead of student workers, we hired a half-time career employee, Susan Kellogg-Smith, as a Purchasing Assistant I / Receptionist in the afternoons, who also maintains inventory, and assists Rosemary in clerical duties. We retained one student lab assistant for stocking chemicals and miscellaneous items inside the lab.

As part of the remodeling, a new storage room was constructed immediately next to the office. All lab material inventory has now been consolidated, from several hall closets and cabinets, into 421; again, eliminating a lot of time wasted in storing and distributing from scattered areas. In addition, expensive plumbing parts and fittings, which had a habit of disappearing from their drawers inside the lab, will be stored here and inventory will be maintained by office staff.

4. Associated Research Staff

Four of the main research groups working in the Microlab continue to employ dedicated staff. After almost three years of this type of cooperation, most of the possible conflicts have been worked out and we support each other successfully.

The question of how far should we go in allowing associated researchers work in the Microlab has been explored to considerable depth this past year. Specifically, should we allow outside researchers come in to work on their own projects, with their own staff, in return for a fee? At the time this option was proposed by several PI’s, the Faculty-in-Charge of the Microlab surveyed the faculty’s opinion and called a meeting of major PI’s to discuss the subject. (Nov. 88) At the meeting all PI’s agreed that the activities of associated research endeavors shall remain at the same level as they are now; i.e. PI’s may employ associate researchers as long as they are involved with graduate students’ research projects. A recent resurfacing of this question prompted me to reiterate the accepted policy. Unless I am advised otherwise by the Faculty-in-charge and/or ERL Director, I will adhere to the above policy.
INTERACTION WITH FACULTY AND RESEARCH GROUPS

Microlab membership increased to around 150 this past year. The major research groups continue to be: sensors (31), device (21), compound (19), process/DUV (16), sundry (off campus) (16), physics (14), matsci (12), cryo (8), cheme (8), cim (6). Important items discussed with individual groups were the following:

1. Sensors

1.1 We have accepted the fact that low stress silicon nitride films, which have been applied successfully in several research projects, are here to stay and will continue to require intensive furnace maintenance. We have researched the subject of pumping corrosive gas mixtures, and after some unsuccessful experiments arrived at the conclusion that the best way to handle the problem is by rote maintenance. This means that pump oil and filters are changed and throughput is checked after every 10 hrs. of deposition (often this means only one run); exhaust manifold and valves are taken apart for cleaning of deposits after 20 hrs. The furnace tube, quartz-ware, pressure gauge and DCS MFC have a lifetime of about 6 months at the rate the tube is currently being used.

1.2 As a follow up to my memo to the BSAC professors (Feb. 1989), we had several meetings on how to ease the burden on LPCVD systems and on how to resolve the question of allowing metallized wafers in the LTO tube. We have agreed that any replacement parts required for the maintenance of the low stress nitride process will be paid by BSAC. The PI's also promised, more or less, that they will propose a yearly $100K equipment fund in the BSAC budget. To start, we received the go-ahead to obtain a second LTO system, in which sensors researchers can experiment with whatever films they like. Tystar, the company that took over Tylan's furnace division, offered us a good deal on a 4-stacker. We have ordered only one tube for now, an LTO system. The plan is that further systems will be added as BSAC budget permits.

1.3 We have encountered severe, unforeseen problems with the delivery of the new ZnO sputterer, which we ordered from the Briggs Gallo Group in 1988 and partially paid for in 1989. After many postponements and promises of delivery, the company defaulted and went bankrupt. At this point, University Purchasing is trying to secure the partially built machine, which is not much more than the frame, as equity.

1.4 We were recently informed that Prof. Howe has assumed the responsibility of handling Microlab related issues within BSAC. We were certainly glad to hear of this arrangement as it will ease communications and will help in maintaining cooperative efforts with our largest research group, and will expedite resolution of problems that require decisions by PI's.

1.5 Another helpful move in a cooperative spirit on the part of BSAC professors was the decision that all student researchers in their group will be required to serve as teaching assistants for the undergraduate IC processing lab, EE143. I expressed my gratitude for establishing this new policy, through which we shall have a steady supply of TA's with lab experience.
2. **Device**

2.1 One of the subjects we discussed extensively with one of Prof. Hu’s students was the retrofitting of the randex with high temperature (>550°C) sputtering capability to enable the deposition of good quality ferro-electric materials such as PZT. (Sensor researchers are also interested in these.) We decided that it can be done, if we carefully prepare and coordinate with the other users the shut down of the randex for about a week. The project has not been started yet, awaiting initiation by Prof. Hu.

2.2 The Device Characterization Lab (407) went through a partial face lift and expansion (into 409), in conjunction with the recent remodeling of our service areas. We are currently in the process of connecting additional utilities to equipment (for example water cooling for a hot chuck) and reinstalling equipment after the expansion. Maintenance of services for this lab is assigned to one of our technicians. Problems are reported by the standard method on the WAND, under equipment name: dcl.

3. **Compound**

3.1 In March, 1989 we have been asked by Prof. Wang to prepare lab space for the installation of a new LPE system. The request led to discussions on efficient space utilization in the LPE room (432A) and to an agreement that one of the current, old systems will be decommissioned. Unfortunately, all equipment (lpe1, lpe2, breah, hummer) has to be dismantled and/or moved to allow for the positioning of the new machine. Although this will require some detailed planning in time and deployment of technicians, it will give us a chance for a long overdue reorganization and clean-up of the area.

3.2 Our initial difficulties in agreeing on the rate of liquid nitrogen use by the Microlab and by the new MBE lab in room 155 have been resolved. Problems arose from the fact that we cannot meter MBE use in the liquid form, because of the expensive instrumentation it requires. Thus, we are left with metering Microlab use in gas form, the volume of which is converted back into the liquid amount; specifically, into height in inches in the bulk container. Evan Stater and Bob Hamilton spent considerable time and effort in reviewing recording procedures and in examining the gas line for leaks, before it enters the totalizing meter. MBE researchers report their use in inches every time they run the machine. The height of LN in the storage tank can be checked on the computer through BLIMP, the utilities monitoring program, which sends warning mail to the appropriate people. Now, the total amount reported by MBE users and our numbers agree within 5% and each group is billed accordingly. In addition, 1/3 of the tank rental fee, which as of this year is a buy-out fee over 6 years, is paid by the MBE lab. Depending on the activities in the MBE lab we request LN deliveries every 1-2 weeks.

4. **Process/UV**

We currently have only one group actively engaged in process technology development, the Deep UV Lithography group. Their dedicated development engineer, Richard Hsu has been assigned his own cubicle in the new staff office (406). We have been trying to obtain a donated wafer track for their special needs, so far unsuccessfully. The available machines were too large or did not have the required features, such as post exposure bake. This effort is continuing.
5. **Sundry**

Under this heading we list those researchers who come from other UC campuses or from other universities. Here we also include those accounts for whom Microlab staff performs work, such as standard processing or mask making. Because those accounts cannot be charged directly through the campus recharge system, instead they have to be billed through UC Sundry Debtors, the group has been named "sundry".

6. **Physics**

Last Spring Prof. Clarke made an inquiry about our possible interest in installing an e-beam system for deep sub-micron photolithography for his research in SQUIDS. His proposal was that he would obtain the machine and we would install and maintain it. We felt obliged to examine such a proposal in more detail; but, it became obvious very soon that maintaining an expensive machine, which requires a dedicated technician to operate it, was way beyond our means. By May, this idea was laid to rest.

7. **Matsci**

Researchers from the Department of Materials Science and Mineral Engineering have been steady lab users over the years. Their requirements are relatively easy to satisfy but last year some researchers had a conflict of interest with our compound people. Bob Hamilton skillfully resolved the crisis over one of the LPE systems at that time; however, since Prof. Wang bought the new machine his requests prevail in the long run. We believe that those who invest in the future of the Microlab should get preferential service.

8. **Cryo**

We have completed installation and overhauling of the donated sputtering system "topgun" (for having the e-guns on top). It was a long job, but at the end we were all happy with the results. The Microlab supplied a large part of the manpower (Robert Norman) and paid or arranged for most of the additional parts needed. This effort was summarized in a memo to Prof. VanDuzer in May 1989.

9. **Cheme**

We have embarked on a joint project with one of Prof. Hess' student to characterize thin (50-100 angstrom) nitride films, because he was interested in them for his chemfet device. Since we have the sensors people collecting data on thick nitride films (1-2mu m) we thought it might be valuable to look at thin nitrides. Both types of film are grown interchangeably in the same tube, with sufficient repeatability.

10. **CIM**

Last but not least, our CIM researchers have been quite active this past year. All of their projects involve the lab in one way or another; however, I will discuss only those which had a direct impact on operations.

10.1 Although the utilities monitoring software (BLIMP) was completed in 1988 and I commented on it in my last year-end report, we began to implement it successfully only this year. It became a staff project, during which sensors were installed to monitor the following utilities: DI water level in holding tank; DI water resistivity entering lab; Dichlorosilane use rate (when running tytan 9,10); LN tank level; nitrogen pressure; oxygen pressure; house vacuum status; air conditioner status.
Current status of all sensors can be seen by typing "sensorstat" on any terminal connected to argon or going through the WAND. Being able to check critical sensor status, by logging in from home, makes a pleasant improvement in our life.

10.2 We have started a new category on the WAND: Equipment Communications, under which are: Tylan furnace interface (tytalk), Flatgauge data interface, Nanospec data interface, and Sensor monitoring. Through these programs equipment or sensors' status can be monitored and data downloaded into personal files. They are all being used, especially the Tylan and sensors' status monitors.

10.3 Communications in the lab have been enhanced by the installation of DECTALK, a speech synthesizer, which announces typed-in messages on the intercom system. It is an option on the WAND, under Mail and Messages. Students can call each other without having to go through the office pager. Although the system has been in use since November, we are still working on the volume problem.

10.4 When Dave Mudie, the systems analyst working with us on CIM projects, resigned to become a graduate student, the position had been added to the Microlab staff in "associated research" category. Lauren Massa has taken over the responsibility of system maintenance and development, since September, and is currently preparing another upgrade, both hardware and software.

STAFF PROJECTS

Besides their routine assignments, Microlab staff members take part or work independently on special projects, assigned by me through their supervisors. Staff projects may be initiated by PI's request, by students, supervisors or staff members. We always discuss their relative merits and give careful consideration to their impact on resources. Most projects, certainly the major ones, are discussed with the Faculty-in-Charge. Listing of the most important activities in 1989 follows:

1. Maintenance Staff

   Phill Guillory: Design and installation of power and communications lines in the remodeled area (406, 407, 409, 413, 421, 422, lab lobby); DECTALK, BLIMP.

   Steve Hoagland: Tylan communications.

   Robert Norman: Topgun rebuild, LAMTALK, safety enhancements.

   James Parrish: Layout design and installation of equipment in the mechanical service room (413); decommissioning of the ion implanter.

   Evan Stateler: Design and deployment of sensors for BLIMP; LN metering procedures; DI system improvement; various utility improvements; DECTALK.
2. Process Staff

Tom Booth: Silicon diode radiation detector (S. Holland); ZnO strain sensors (D. Polia); plasma development of inorganic photoresist (J. Carl).

Debra Hebert: I-line photoresist process; eddy-current sensor probe (BSAC).

Robin Rudell: Microlab video tape.

PUBLIC RELATIONS

Most of the public relations activities are handled by the process staff.

1. According to names registered on the computer, the Microlab had 452 visitors in 1989.

2. Visitors from several institutions which are in the process of designing/building a lab asked for extensive information on how we have built and how we manage our lab. These also followed up with requests for further details: UCD, UCLA, UCR, UCSD, Caltech, Princeton, Rochester Inst. of Techn., SF State, UT, Yale, Chalmers U., Julich Res. Ctr, Seoul Nat. U., Technion.

3. We wrote with Prof. Ko an ERL memo which answers many of the questions posed by interested visitors. (Evolution of the Microfabrication Facility at Berkeley, Memorandum No. UCB/ERL M89/109, September 1989).

4. ILP arranged for reprinting (2000 copies) of our informational booklet Microfabrication at Berkeley. The first 4500 copies, printed in August 1987, lasted two years.

5. We have assembled a display of framed historical chip photos on the walls of the hallway leading to the Microlab. Prof. Muller donated the photos and BSAC paid for the frames of the series titled 20 years of integrated circuit history: chronicle by Fairchild. Prof. Neureuther donated funds and pictures were collected from PI's for the series Microlab History, Superconductors, SAMPLE, and Sensors History.

6. For the past three summers, we have participated in the UC Academic Development Program for bright junior high school students. Several other groups concerned with secondary education also received tours or informational material and presentations.

7. Our 18 minute video tape, Microfabrication at Berkeley, turned out excellently and we received many compliments. Robin Rudell carried much of the responsibility for the project and worked with the campus Educational Television Office producing it. We have already distributed about 200 copies by request. We also use it extensively showing it to visitors, instead of taking them into the lab; and during lab orientation sessions for new students.
FISCAL CONTROL

Fiscal Year 1988/89

The Microlab met its budgetary goals for FY 88/89. With help from ERL, we exceeded the projected debt recovery by about $14K. Total debt owed to the University at the end of FY 88/89 is $336,816.

Comparing projected and actual figures for FY 88/89, we were:

- 0.6% over S&E target;
- 14% below S&B expenses budgeted by the recharge proposal, and
- 3.9% below estimated income.

- Adhering within 0.6% to the S&E budget can be considered excellent.

- Salaries & Benefits expenditures were considerably below the targeted figure because at the end of the FY, ERL contributed about $27K out of miscellaneous funds which had to be spent. Without the ERL contribution S&B would have been still under budget by about 6%, because of gaps between resignations and new hires.

- We have noticed early in the FY that actual income was lagging behind estimated figures. A closer look at the numbers showed that we were loosing on staff recharge fees. These were indeed low, compared to staff fees charged by other units in the Department; thus, when the new recharge rates were submitted we increased staff rates. Unfortunately, the adjustment came at halfway through the fiscal year and we could not recoup our earlier losses. (Income from general lab use was actually about 2% higher than target.) At the end we still came out ahead, because lower income was offset by having to spend less on S&B, which is approximately half of the total budget.

Fiscal Year 1989/90

Six months into the new fiscal year we are running about 4% below our income target and about 1% over the S&E target (see Figure 2.) At this rate we will not be able to meet the required deficit recovery of $50K; although we may be able to break even. What can we do?

- We cannot raise the rates again; they are high enough as they are. We have to remember that this is the first FY when PI's do not receive BMA subsidies and they are carrying the total load. Thus, the new recharge proposal was submitted showing only minor rate adjustments. (Oct. 1989)

- The S&E budget is as tight as it can be; no reduction can be effected there.

- This leaves cutting the S&B budget as the only possibility for closing the gap. In January 1990, one technician has been laid off, as a cost saving measure. (See pp. 1-2.)

At the end of 1989, the Microlab recharge account/fund (67505) was audited by the University. We came through with flying colors. The auditor was very impressed with our organization and management system, especially with the fact that all requested information was at our finger tips. Rosemary Spivey handled the two-week auditing procedure with great aplomb.
FACILITIES DEVELOPMENT

Since our BMA equipment allotment for FY 88/89 ($100K) was not sufficient to purchase new processing equipment, we spent only $48K on various replacement items and upgrades, such as a new mechanical pump and throttle valve controller; a welding unit (cost shared with the Machine Shop); sink for new mechanical service room; laminar flow hood (topgun); equipment transport cart; LN pressure transmitter. Following is the list of major projects completed in 1989:

1. **Service Area Construction**

   The total budget for this project was $40K. Four research groups, BSAC, device, compound, DUV, donated $5K each for construction. We received $10K from BMA and the rest was paid by EECS. Total expenses, with only minor items outstanding, came to $36K. In addition, we spent about $10K from our operating budget, mostly on wiring and on special work orders for the departmental machine shop. Construction was handled by PFM, with Wil Zeilinger supervising the project. Demolition started on August 30 and we were moved in by the end of November.

2. **Wafer Stepper I-line Retrofit**

   We received a donation from HP (Santa Clara) of a GCA wafer stepper, an identical machine to ours but with an I-line lens. Since ours was in better condition we decided after discussing it with concerned PI’s, that we will keep our system, only the lens will be replaced with the I-line lens. We made a deal with SVA, that they will do the retrofitting, in exchange for the rest of the machine and the old G-line lens. The work took just a week; we had scheduled it to take place in December, our slowest month, to minimize revenue loss. Debra Hebert developed a photoresist process with the standard KTI 820 resist. Currently, we are evaluating new I-line resists for faster exposures.

3. **Topgun Installation**

   The 3-target sputterer donated by HP (Deer Creek) to the cryo group has been installed and overhauled as specified by Dave Hebert. (See page 5.)

4. **Utility Upgrade**

   To further distance the Microlab from Cory Hall utility failures, we have installed an automatic switch to enable $N_2$ gas to flow when compressed air pressure, supplied by two compressors in the basement and maintained by PFM, falls below the required level. Compressed air is used to operate solenoids in many equipment, and when the pressure fails operations in the lab come to a screeching halt. Auto-switching works well, we don’t even notice it. (This will be the next sensor to be added to BLIMP.) In addition, we avoid overheating the lab when air pressure fails and the steam valves in Cory Hall open (and the atmosphere becomes stifling on the fifth floor.) Compressor failure came up often enough in the past for us to be concerned about it. PFM usually handles it as an emergency job, but we cannot afford to be down for any length of time.
5. **Lam2 Communications**

   CIM efforts were considerably enhanced when upgraded circuit boards were donated by Lam Corp. and LAMLINK by Brookside Software.

6. **New Nanospec**

   Three groups, BSAC, DUV and CIM bought jointly with us (we paid $7K) a new Nanospec thin film measuring system, to facilitate faster measurements and equipment communication. Data can be directly downloaded into the user’s computer files. We have arranged for the donation of the old instrument, which we were supposed to trade in, to the EE143 lab. It has been installed in 218.

7. **Nanoduv**

   The DUV group received a donation from Nanometrics of a thin film measuring instrument which utilizes wavelengths in the UV range. This machine has been installed in the No 3 analytical area (AN3) of the lab.

8. **SEM Upgrade**

   Prof. Oldham arranged for the donation of the digital image enhancement software and hardware by Nanometrics. While we have seen excellent improvement in contrast, resolution is still not satisfactory for some projects. Part of the problem may be attributed to electromagnetic interference and to vibration.

9. **Other Proposals**

   We were invited to submit proposals to HP to request the donation of a SPECTRUM CVD system. There were two machines available, one at Fort Collins, the other at Corvallis. The first went to MIT and the second to Stanford, where we were offered access to it by Prof. S. Wong.

10. **Decommissioning of the Ion Implanter**

    Performance of our 14 year old ion implanter, modified several times over its lifetime, was never up to the level required by modern devices. As it became more and more of a maintenance headache, it was decided that the implanter should be decommissioned. Since it has no resale value it will be removed by Excess Salvage and Surplus. We are sending wafers for ion implantation to outside services. This is more cost effective than maintaining our own machine.

11. **New Ion Implanter**

    Through Prof. Hodges’ contacts at Varian we initiated a donation request for an advanced ion implanter, possibly a Model 220. After we realized that even if we received the machine free, associated costs of facility preparation on the first floor and prospective maintenance expenditures would be prohibitive and we have withdrawn the request.
12. Safety Issues

The Microlab's safety officer, Bob Hamilton, submitted the following list of safety improvements, which occurred during the past year:

- Upgrading of hazardous material disposal (glass, razor blades, needles, chemicals);
- Survey of ionizing and non-ionizing radiation in the lab;
- Improved spill clean-up equipment and procedures;
- Improved earthquake safety;
- Upgrading of safety lectures to new users;
- Submission of chemical inventory listing to EH&S;
- Improved communication capability for emergency situations.

COMMENTS ON THE PERFORMANCE OBJECTIVES FOR 1989

1. Maintain laboratory at the current level of service.

This has been done as attested to by the increased number of users; by the satisfactory fiscal performance; and by PI's and graduate students who expressed their appreciation. We will continue to strive for excellent service; however, I will not list it as a separate performance objective for next year. It is understood that the primary goal of this unit and its manager is to maintain the best service possible with available resources.

2. Develop in-kind donations.

This goal has been met. We have received several machines and subassemblies as donations; we have applied for others, but were turned down. This is another ongoing goal and both Bob Hamilton and I are looking out for, and trying to recruit, usable equipment and material (chemicals, wafers, etc.) donations.

3. Reorganize processing staff.

This goal has been met exceeding expectations. With the creation of the process supervisory position, the activities of this group have been focused and became more efficient. (See pp. 2,7).

4. Further develop CIM projects.

Again, this is an open-ended goal and related staff activities will continue as long as there is a CIM group. The objective, in general, has been met. (See discussion on pp. 5-6.) I will list only specific programs as future goals.

5. Make BLIMP useful.

This is the utilities monitoring project which has been, along with some of the equipment communications programs, a resounding success. (See pp. 5-6.)

6. Prevail in obtaining a vacuum service room.

This goal has been met exceeding expectations. (See pp.1,9.)
SUMMARY

During the past three years under my management the Microlab has acquired considerable stability and developed into a respected university facility. The framework for effective and efficient technical support and for financial control is in place. The immediate future of the lab looks secured. Larger questions concerning long term goals and financial security, which need to be addressed, are beyond the scope of this report.

PERFORMANCE PLANNING FOR 1990

Performance objectives for the next appraisal period are:

1. Install and use FAULTS for recording equipment problems and repairs.
2. Write overview, in form of an ERL memorandum, of CIM projects currently in use.
3. Develop test engineering position.
4. Develop plans for possible new standard processes, such as BiCmos,
5. Work with BSAC on enhancing thin film deposition capabilities.

Microlab Employee Classification and Payroll Allocation

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<th>Employee Group</th>
<th>No. of Persons</th>
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<td>Administrative &amp; Professional (A&amp;PS)</td>
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<tr>
<td>General Staff</td>
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<td>Student Employees</td>
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<td>Paid by other account/funds (EECS,EPL,SRC)</td>
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*Full Time Equivalents

Table 1.
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<tr>
<td>Kim Chan (0.5)</td>
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<td>Richard Hsu</td>
<td>A. R. Neureuther</td>
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<td>David Hebert</td>
<td>W. G. Oldham</td>
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<td>Jongnam Kim</td>
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<td>Lauren Massa</td>
<td>T. VanDuzer</td>
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<tr>
<td>Thomas Booth</td>
<td>Berkeley Sensors and Actuators Center</td>
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<tr>
<td>Marilyn Kushner</td>
<td>R. Howe, R. Muller, R. White</td>
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<tr>
<td>Christine Saunders (0.5)</td>
<td>Computer Integrated Manufacturing</td>
</tr>
<tr>
<td>Debra Hebert</td>
<td>D.A. Hodges, L. Rowe, C.J. Spanos</td>
</tr>
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Figure 1.
Figure 2.
Microlab Monthly Operating Income and Expenditures
First Half of Fiscal Year 89/90
EVOLUTION OF THE MICROFABRICATION FACILITY AT BERKELEY

by

Katalin Voros and Ping K. Ko

Memorandum No. UCB/ERL M89/109

22 September 1989

ELECTRONICS RESEARCH LABORATORY
College of Engineering
University of California, Berkeley, CA 94720
Evolution of the Microfabrication Facility at Berkeley

Katalin Voros, Microlab Manager
Ping K. Ko, Faculty-in-Charge

ABSTRACT

The Berkeley Microfabrication Facility has been in operation since 1962. It is a shared facility that supports a wide variety of experimental research in microelectronics and other fields. Currently, 46 faculty investigators and 153 graduate students use the facility. The Microlab is used principally to fabricate devices and structures that cannot be obtained through commercial sources. Principal operators are graduate students. A professional and technical staff of 13 full-time equivalents supports the processes, equipment and facility.

Policies and operating procedures have developed over the years to provide economical support for diverse technical procedures. This report describes our important policies and procedures, including those relating to training, safety, maintenance, budgeting, technology upgrades, and sharing of sophisticated research equipment. Faculty and students consider the Microlab to be an excellent and indispensable tool in their research.

September 22, 1989
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I. Introduction

The Microlab frequently receives visitors from representatives of U.S. and foreign universities who are planning or building new microfabrication facilities. While most of them are aware of the high cost of building a laboratory, few express much concern about finding the money to operate and maintain it once it has been built. After running our lab for over 25 years, we feel that the issue of operating costs is far more important than most people think. For us, the battle to balance the operating budget has been long and hard. At present, we are still far from winning it, although we have had some successes after various cost control and revenue expansion measures were put in place. While the financial support structure, scale of operation, and missions of other labs may differ from ours, we believe that many of the problems we have been struggling with are fundamental, and that every lab's management will eventually have to deal with them. In this report, we shall review our experiences in physical development, operation and financing of our lab. We hope that those embarking upon similar endeavors will find them useful.

Before going into details, however, we would like to say that the type and scale of a university laboratory should be in line with the existing and planned research activities and with the realistic support likely to come from them. Grants obtained for lab construction and startup are quickly expended, leaving the organization to its own resources. Without a strong supporting base, maintaining a working IC lab is infeasible.

Throughout this paper we will use the terminology "working" lab and "capability to build chips" as suggested by J.D. Plummer in his report, Building Chips in a University Environment - The Stanford BICMOS Project, October 1988. Plummer defines "the capability to build chips as being able to fabricate an IC containing several thousand transistors in a reasonably advanced technology such as 2 micron CMOS"; and a "working" lab as one "in which the equipment is operational most of the time; one in which the equipment is characterized; one in which processes (oxidations, implants, CVD, etc.) are run often enough that they are understood and reproducible; and one in which technical assistance is available to students to run complex pieces of equipment (implanters, for example)." These terms apply to the Berkeley Microlab.
II. Development of the Berkeley Microfabrication Facility

History

Microelectronics research and instruction began at Berkeley soon after the invention of the chip. A 1200-square-foot laboratory was constructed and the first working circuits on 3/4-inch-diameter silicon wafers emerged in 1962. A major goal of this effort was to demonstrate the feasibility of IC research in a university environment.

During the 60's laboratory activities expanded to include complete bipolar processing along with the development of novel IC design techniques and the widely accepted SPICE circuit analysis program. In the 70's, analog MOS research led the way, and successful ideas developed at Berkeley became widely used in industry. The second half of the 70's also brought about the emergence of MOS device and technology research, and the development of process CAD tools, such as SAMPLE. Research in circuit design continued to be a strong program, in both bipolar and in MOS technologies, resulting in new concepts such as switched capacitor filters and A/D, D/A converter circuits.

Most of the IC's designed and published up to 1983 by Berkeley researchers were fabricated in-house, in what we now call the "old lab". By the end of the 70's however, it was obvious that to keep up with the pace of developments in the industry and to enable fabrication of more complex, higher density chips, a new, modern facility was needed.

Specific planning for renovation and expansion began in 1979. A state appropriation of $2.4 million was obtained and defended against a series of statewide budget cutbacks and freezes. Additional funding for research equipment was obtained from industry ($1.1 million), federal agencies ($570,000), and the Regents of the University of California ($500,000), for a total amount of $4.57 million. Construction costs, to build a new lab inside an existing building, were $1.1 million. The rest of the funds, $3.47 million were spent on new equipment.

During construction, which started in 1981, work in the old lab proceeded more-or-less undisturbed until the new lab opened in the Fall of 1983. At that time, the two sections were joined. Access to the old lab was provided through a door from the main hallway of the new lab. At present, the total area of the Microlab is approximately 10,000 square feet; about half that area is maintained under Class-100 clean room conditions.
Looking back after four years of successful operation (1985-89), we have to conclude that the original plans were well conceived. Most of the decisions which were made because of space and financial constraints were good compromises. Even major concessions which carried the potential of adverse impact on the lab did not prove detrimental.

Some examples of successful decisions:

- One decision, which turned out to be extremely judicious, was equipping the mask shop with an optical pattern generator. Readily available masks made by students, or by staff as a service, provide tremendous flexibility to any project. The GCA 3600 pattern generator has been the most heavily used equipment in the past 3 years.

- A laboratory design comprised of some small separated rooms, general areas, and a more-or-less isolated VLSI area at one end, turned out to be advantageous. This advantage manifested itself to a great extent when research emphasis changed from the planned silicon chip fabrication to more heterogeneous, all-encompassing activity. The layout of the lab made it possible to dedicate rooms to special work and to minimize interference between processes.

- Another decision, to fully computerize the new lab, — to render it "paperless" as the initiating researchers called it, — had unforeseen ramifications in managing the lab. Besides their research value, the programs resulting from the CIM project are extremely useful tools in both facility and fiscal control. This concept will be discussed later in more detail.

Some examples of unsuccessful decisions:

- Lack of funds necessitated keeping the 10 year old ion implanter and rebuilding it in-house to accommodate 4" wafers. This machine became a maintenance nightmare and was never able to deliver implants with the accuracy we need.

- Some equipment we bought was of unproven new design; thus, we had to invest a tremendous amount of time characterizing, operating and maintaining these machines. Start up time was long and no revenue was coming in because users were not satisfied with the results produced.

- We have embarked on too many in-house equipment rebuilding/upgrading projects, with the intention of cost savings. Most of these turned out to be costly both in time and money.

- The hardest problem to deal with, however, was the limited service and storage area provided. With 108 operative systems to maintain — there is not one piece of equipment in the lab which is not
being used — logistics quickly become a major concern. The lack of a *dirty* repair shop, where pumps and machines can be repaired and rebuilt, places an undue burden on the maintenance staff.

This problem is currently being remedied by the assignment of an additional room adjacent to the lab.

The original design team did an excellent job given the constraints of space, money and time. This emphasizes the fact that it is very important to have people with strong technical competence and extensive hands-on experience involved from the very beginning in the design and construction process. All in all, the facility serves its researchers well, although the current needs are quite different from those for which the laboratory was planned.

**Changing Policy**

The new facility was planned with chip fabrication as the major activity in mind. It was to provide:

1. a working laboratory for students who wished to build their own circuits;
2. a foundry service for the systems group.

In return, we expected the circuits and systems people to be the main financial supporters of the lab. This was, of course, before the inception of MOSIS — the highly successful DARPA/NSF program, to provide university researchers with chip foundry services for industry-standard MOS LSI processes at little or no cost.

It took us two years (1983-85) to render the lab fully operational; to have a 2 µm CMOS process in place supported by fully trained personnel. Unfortunately, by the Fall of 1985, when we were ready, IC business had all but vanished from the lab due to the success of the MOSIS service. At that point we had an accumulated debt to the University of about $400K. The deficit resulted from construction overruns and operating expenses during construction and start-up. While there was no revenue, staff had to be retained because they were essential to the expansion, renovation and start-up. With this burden on the lab, we were forced to do some careful planning. The primary goals of the lab, support of research and teaching, did not change, but it was clear that adjustments were needed if the users were to fully support the lab.

With the IC and systems business gone, we looked to our other groups for increased activity. Fortunately, we always had a very diverse program, from which device and technology development emerged in 1986 and continue to date as main groups supporting the lab. In addition, after some quiet years doing preparatory work, the sensors people burst upon the scene in full force in 1987. Sensors research involves both
standard MOS and esoteric processes, the latter often detrimental to the former. While maintaining our standard process, we rendered some procedural changes to accommodate the non-standard needs. We had to give up some of our "MOS mentality" and protectionism. It is a balancing act every step of the way, but it is worth the effort. This approach paid off handsomely. With the establishment of the Berkeley Sensor & Actuator Center, an NSF/Industry/University Cooperative Research Center, in the Fall of 1986, sensors research has become a major source of support.

From early on, the Berkeley Microlab had the tradition of encouraging researchers to join from all other areas of microelectronics as new fields emerged, such as compound and low temperature semiconductors. Thus, non-silicon people were not compelled to establish their own separate labs; instead, they helped to maintain one common facility. By necessity, some equipment was always reserved for dedicated tasks, but other equipment, such as photolithography tools and analytical instruments, were shared. This tradition, carried over to the new lab, has helped us bridge low income times during construction and ramping up operations. Non-silicon researchers continue to be strong lab supporters.

Finally, the lab has always had a group of members from other departments, such as Physics, Materials Science, Chemistry and Chemical Engineering. These users are involved in applying microfabrication techniques to build structures to examine phenomena in their field. We looked at extending this user base by advising them of IC technology, by making minor adjustments to accommodate them, and by extending BMA subsidies. These efforts resulted in increasing the number of non-EE members to 25-30% of the total. As the activity of these people is usually low and/or intermittent, income received from them constitutes only about 10-15% of the total. (See Figures 1 and 2.) They are also more problematic, having no technical support from their own research group. We think, however, that their presence is beneficial and plays an important role in teaching students to embrace a cooperative spirit.

Currently the Microlab has 153 active users. The numbers vary monthly as senior students graduate and new ones join. The total number has been slowly increasing during the past three years and along with it the utilization of and traffic in the lab. We estimate that at around 200 users we will reach capacity, although this will depend greatly on the rate at which each research group grows and the particular demands placed on equipment.

Representative research publications, based on work done in the Microlab, are listed in Table 6.
Some Guidelines

In the previous discussion we described our efforts to halt the down-spiraling financial situation of the lab by finding *modus vivendi* with a changed user base. Slowly, a set of guidelines emerged, which has helped us achieve our goal of providing students with a working lab, and keeps the lab on course with a balanced budget.

Our guidelines are as follows:

1. The lab maintains, with staff, a baseline 2 μm CMOS process to calibrate and exercise equipment and provides standard process modules and foundry service for device and IC people.

2. The philosophy of the lab management is to accommodate the needs of all users, as far as possible without detriment to the work of others. This especially applies to sensors research, which involves both standard MOS and esoteric processes.

3. The lab continues to provide strong support for compound semiconductor research, by maintaining dedicated equipment and addressing special needs.

4. The lab maintains a dedicated room and equipment for superconductor research. Staff cooperate with their research engineer to provide optimum support.

5. The lab maintains a dedicated room and equipment for deep UV photolithography research. Staff cooperates with their research engineers to provide optimum support.

6. Management strongly encourages and helps interested researchers from other departments and from other UC campuses to use our facility.

7. In general, the facility is used to carry out non-standard processes, which are not available commercially.
Implementation of Fiscal Control

In addition to establishing philosophical guidelines for lab operations, we also implemented very strict budgetary control procedures. These involved the following:

1. Yearly budget itemized in detail;
2. Monthly monitoring of expenditures;
3. Manager signing off all non-standard expenditures of greater than $100.00;
4. Careful review of standard and large expenditures;
5. Periodic review of staff allocation;
6. Full computerization of charging procedures;
7. Establishing an efficient structure for revenue collection;
8. Establishing an independent recharge account number for the Microlab.

The lab came under new management in December 1986 and by June 1987, the end of FY 1986/87, we broke even. This requires some explanation.

When the new lab opened for general use, a new recharge structure was initiated, based on estimated expenses and income. Recharge rates were much higher than those in the old lab. Even at the new rates, income fell far short of expenses. Membership was below old levels and many expenditures associated with startup had to be absorbed. This was not unexpected and plans were made early to partially finance the lab from donations during this critical period. The Berkeley Microelectronics Affiliates (BMA) was established in 1984 to provide ongoing support for research and instruction in microelectronics and CAD/CAM. Each BMA company pledged an annual cash grant for a period of five years. The Microlab received from these gifts an annual support which has been gradually reduced as lab income increased. Thus, when we say that in FY 86/87 we broke even, the budget still included a $194K BMA grant, which did not come from users (see Figure 3).

In 1987, the Campus Recharge Committee required that we start paying back some of our debt to the University. In compliance, the last two budgets included a proposed $50K debt recovery, which we met; but again, only with BMA support. At this rate, it will take 8 years to pay back our obligations, if we do not incur new ones. The University does not charge interest on such arrears.
By 1987, income showed a slow but steady increase and we knew who our main supporters were. We restructured our accounting system: instead of the lab receiving a fixed sum from BMA, enabling us to charge lower rates to all users across the board, each PI received an individual grant toward his share of lab expenses. The amount was calculated such that heavy users were subsidized at a higher percentage than light users. Over the last two years, as BMA contribution was slowly reduced, the subsidies to PI’s were also reduced and they paid for an increasingly larger portion of lab expenses. This procedure helped PI’s to adjust gradually to higher rates.

At the end of FY 88/89, five years of BMA commitments expired. Subsidies to PI’s were discontinued on July 1, 1989. Now comes the real test: can the users fully support the Microlab? The word fully is applied loosely here; there are expenditures for which the Microlab does not have to pay.

- The University provides, from research contracts’ overhead, in kind support in the form of electricity, air conditioning, compressed air, industrial water, recirculating cooling water; building maintenance (outside walls of the lab) and custodial service (floor cleaning inside the lab); and removal of hazardous waste. This list is complete.

- The Department of Electrical Engineering and Computer Sciences pays the salaries of 1.75 FTE’s. (Total number of Microlab FTE’s is 13.) This is in lieu of the service Microlab staff provides to maintain two undergraduate teaching labs (EECS 143, Processing and Design of Integrated Circuits, in room 218 Cory; and EECS 135, Microwave, Optics and Plasma Laboratory, 391 Cory) both of which are small independent facilities, located on the second and third floors of Cory Hall. (The Microlab is on the fourth floor.) In addition, we do not charge for graduate classes held in the Microlab.

- The Electronics Research Laboratory pays the salary of one Microlab FTE from ERL overhead, as contribution from all member PI’s. (Total ERL membership is 75 PI’s.)

- The salary of one Microlab FTE is paid by SRC support. (26 PI’s are involved in SRC projects.)

- Computer system hardware and software support is provided by the CIM research project.

After everything is tallied, of the 46 PI’s who had students in the lab in FY 88/89, one third paid anywhere between $13K and $75K, one third between $1K and $8K and the last third below $1K. (See Table 1.) Total amounts do not include extra supplies, which were bought by students through the Microlab.
Current Budget

The Financial Summary for Fiscal Year 88/89 (July 1, 1988 - June 30, 1989) is shown in Table 2. Supplies and expenses, shown in Table 3, were within 1% of target; salaries and benefits within 3%. Income increased by 17.5% over that of last year. The additional income was due partially to a rate increase in January 1989 in staff service charges and partially to increased lab use, resulting in the desired debt recovery. Figure 4 shows the breakdown of lab expenditures in FY 88/89.

Charges to each researcher using the lab are grouped in five categories. These are:

1. **Access fee** is a fixed sum, charged monthly, as long as an account is active, regardless of lab use. Each user has an individual account and PI’s pay an access fee for each account, i.e., for each student, even if the student was not in the lab during the month. This is shown in the Access column of the monthly statement that PI’s and their grant administrators receive. (A sample page from a monthly statement is shown in Table 4.)

   An account may be suspended if it is to be reactivated within 6 months. This is important for those students, mostly outside of our department, who, after fabricating a device, need a longer time to test and characterize it. If they stay away for a longer period, they will have to attend the lab orientation seminar and take the safety test again.

2. **Lab use** fees are charged at an hourly rate, computed by the minute from login to logout, for the time users spend in the lab. (The maximum lab fee charged to any student is $1000/month.) This fee covers access to Class-100 clean rooms, and to all processing and analytical equipment except those listed in section 4 below. They receive disposable clean room attire, safety equipment, chemicals, and gases used in semiconductor processing. The lab fee does not cover wafers and photolithography masks.

3. **Staff service** fees are charged at an hourly rate, computed by the minute, for special services provided directly to a student or a project. This service may include certain standard process steps, such as thin-film deposition or mask-making. The scanning electron microscope is operated by staff only; thus, staff service fee is charged for the time spent on a job. There is no charge for consultation time spent discussing projects or providing information.

4. **Special equipment** use fees are charged at an hourly rate, computed by the minute, for using maintenance-intensive equipment in the lab. (The maximum equipment fee charged to any student is $1000/month.) These are the Tygan automated furnaces (11 atmospheric and 5 LPCVD tubes), three plasma etchers (lam1, lam2, ptherm), the Cwickscan scanning electron microscope, GCA 10X
wafer stepper, and the GCA optical pattern generator. With the exception of the wafer stepper and pattern generator, these machines use specialty gases, the cost of which is included in the fee.

5. The Microlab provides a service to its users by handling special orders. If students need special materials, chemicals or gases for their work, they can order it through the lab office and have the cost, without extra charge, applied to their account. These charges, along with those for items obtained from lab inventory, such as silicon wafers and masks, are listed in the Supplies column for each account.

Current recharge rates are as follows:

<table>
<thead>
<tr>
<th>Access Fee</th>
<th>$73.86/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Use</td>
<td>$21.90/hour</td>
</tr>
<tr>
<td>Staff Service</td>
<td>$53.77/hour</td>
</tr>
<tr>
<td>Special Equipment</td>
<td>$21.60/hour</td>
</tr>
</tbody>
</table>

The new budget is based on these rates. We are counting on increased income to offset salary and S&E increases and a $50K debt recovery. If by the end of this calendar year, it does not look like these plans can be realized, we shall have to raise rates.

**New Equipment**

Under current policies for the Microlab as a recharge unit, new equipment purchases are not included in the budget. Some funds for replacing/upgrading equipment come from BMA allotments, which were, for the last three fiscal years, as follows:

<table>
<thead>
<tr>
<th>1986/87</th>
<th>87/88</th>
<th>88/89</th>
</tr>
</thead>
<tbody>
<tr>
<td>$117.3K</td>
<td>$74K</td>
<td>$48K</td>
</tr>
</tbody>
</table>

On occasion, professors buy equipment related to their own research. Even though the unwritten rule has been that equipment maintained by staff is available for everyone, this may not be possible because of cross-contamination caused by different processes. To supplement our own resources, we actively solicit equipment donations from companies. We have to be careful, however, of what we accept, to avoid the trap of collecting irrelevant machinery which only takes up space.
III. Current Operations

Maintaining a working university laboratory with capability to build chips is a major effort and commitment on the part of the faculty. The only way we can manage is by taking the following steps:

- pooling all efforts in a common facility;
- keeping expenses under control;
- having a dedicated, professional staff to maintain equipment and processes;
- efficient equipment utilization;
- computerization;
- providing student training and support;
- keeping safety issues in the forefront.

We have dealt with the first two aspects; discussion of the rest follows.

Staff

At present, the Microlab has 13 FTE positions, filled by 15 people, who are directly involved in maintaining operations. This is the absolute minimum number necessary to keep equipment and processes running without unreasonably long down times. Just as there is a critical mass in equipment and utilities necessary to build chips, there is a critical mass in staffing necessary to maintain a working lab. We believe that we are at the lower limit, with nothing to spare.

Figure 5 shows staff allocation and payroll titles, which are indicative of the staff’s technical level. Our hands-on supervisors are actually doing a good part of the work for which their group is responsible. In addition, they prioritize jobs, help where necessary, substitute when someone is out, conduct performance evaluations and take care of their subordinates’ personal problems. Part-time undergraduate students, one under each supervisor, help out in operating/repairing machinery, stocking supplies inside the lab, maintaining cleanliness, attending to computer problems; and in general, lend a hand wherever they can. After some time-wasting experiences, we established the policy to hire only engineering or natural science majors.

The lab manager is under the administrative supervision of the EECS Department Engineer, who coordinates the work of all technical staff in the building and whose office is the connecting link to Campus Planning and Facilities Management. The Faculty-in-Charge, a professor assigned by the Director of ERL, is the technical advisor to the lab management. (He also evaluates the manager’s performance.) Together they develop short-term and long-term goals and policies affecting facilities and process development. He has an active role in overseeing the budget, in purchasing new equipment, and acts as liaison between the PI’s and the lab.
1. **Maintenance Staff**

Under the Maintenance Supervisor we have a highly competent technician staff who maintain a wide variety of equipment, from simple bake ovens to sophisticated exposure tools and vacuum systems. The equipment list contains 108 machines with mechanical and/or electronic subassemblies and controls, and a total of 82 vacuum pumps (a mixture of both low and high vacuum pumps).

We found that the job classification best suited to the lab’s needs is the Development Technician series (in UCB’s technical staff structure), which requires a wide range of skills encompassing mechanical/electrical/electronic repair and design capability. With two other more specialized technicians, a Principal Electronics Technician who takes care of complex electronics subassemblies, and a Principal Laboratory Mechanic, who services and rebuilds all the vacuum pumps, we have sufficient maintenance coverage and rarely need to call outside services. From the beginning, this was our goal and we have come as close to it as possible with available resources.

The Microlab maintains its own utilities, which include deionized water, clean air, N₂, O₂, and specialty gases. To provide uninterrupted service, the maintenance staff must also keep constant vigilance over services supplied by the Campus, such as electricity, industrial water, recirculating cooling water, compressed air, and air conditioning. Problems with these have to be reported to Planning and Facilities Management through the Office of the Department Engineer, and repairs must be followed up with them, to avoid disasters in the lab. The computer program BLIMP, as part of our in-house CIM package, provides help in utilities monitoring and TECHJOB with assignments and prioritizing of jobs.

2. **Administrative Staff**

The Microlab is an independent recharge unit within ERL and as such, we take care of all of our purchasing, inventory and accounting. Our Administrative Supervisor, with the help of a half-time purchasing assistant, does an excellent job of overseeing over 160 recharge accounts; managing accounting; purchasing all materiel, including chemicals and specialty gases; maintaining inventory of supplies; and taking care of the innumerable details involved in servicing a unit of 20 employees. This is possible only with complete computerization of administrative tasks. An example: When entering the lab, students must log in on Argon, the lab computer, prior to use of any equipment. From that time on, lab use charges are compiled by the minute (including special machine charges,
if any) and summarized in a monthly statement (itemized by student, PI, charge number, etc.) All income and expenses are entered in BEARS, the University's accounting program, then reconciled against the UCB general ledger. The purchasing assistant also acts as an office receptionist, and fills students' requests for material from inventory or through special orders.

3. Process Staff

One of the main components of successful operation of the Microlab is the services provided by the process Staff Research Associates under our Process Supervisor. This job classification series requires graduation from college (B.S.) with a major in an applicable science plus some years of experience, depending on the level within the series, in the kind of work to be performed; or an equivalent combination of education and experience.

Process Staff carry out so-called staff projects, which can be:

- complete integrated circuit processes;
- collaboration with students on joint projects;
- providing continuity of information for the ever-changing user base.

They also carry out operational maintenance. This includes:

- characterization of equipment after repair;
- calibration of analytical instruments;
- maintaining of user manuals;
- changing chemicals in sinks;
- changing lamps in exposure tools;
- operating restricted equipment, such as the SEM.

The process staff, along with the supervisors,

- give lab orientation seminars;
- are active in public relations;
- take care of visitors;
- give limited lab tours;
- conduct informational presentations.

An effective process staff is the key to future developments.
New process development activity decreased greatly when staff organization was restructured and the process engineer became the lab's manager. To ease the financial burden on the lab, the process engineering position was not filled and new process development effectively halted. The process staff's activity was redirected to process maintenance and service to students, coordinated by the process supervisor.

4. Associated Research Staff

Under this heading we are grouping those researchers who, for administrative reasons, are considered Microlab staff, yet are under the direct supervision of PI's and are paid by them. This arrangement was established according to the ERL practice that all staff people should report to staff supervisors and not to professors. This is to avoid an additional administrative burden on PI's and at the same time, to protect employees' interests, such as delivering timely performance evaluations, (done jointly by the PI and the Microlab manager), and relaying of information concerning UC staff policy/benefits changes. Also, the questions of research space and equipment repair priorities can be resolved more easily among staff.

The Development Engineering series defines a professional employee with a B.S. or M.S. degree in engineering and some years of experience, depending on the level within the series, including responsible design work; or an equivalent combination of education and experience. There are no Ph.D.'s on the staff of the Microlab.

Our associated researchers are not independent PI's and are not involved in obtaining grants on their own; they are working with their groups to enhance the progress of specific projects. They have no maintenance responsibility in the lab; their dedicated equipment is maintained by the maintenance staff. On the other hand, PI's pay lab fees for associated researchers, same as for any student user. (They are exempt from paying when the engineers are repairing/rebuilding their own machines.) Our four main research groups employ associated researchers. They are listed in Figure 5.
Processing Equipment

Table 5 contains the list of equipment available in the Microlab. These can be grouped into three categories:

1. New (in 1983) equipment for mask making and 4" silicon processing; (60 pieces of equipment fall in this group)
2. Old rebuilt/retrofitted/remodeled equipment to accommodate 4" wafers; (11)
3. Dedicated equipment, both old and new, for non-silicon processing.(37)

During the past years we have reviewed the facilities status from several points of view.

1. What is needed to complete the equipment requirements for a standard CMOS process?
2. What can we do to alleviate user crowding on certain apparatus?
3. How much maintenance is needed to keep a machine up?
4. What is the number of users a machines serves, to determine servicing priorities?
5. What type of modifications are feasible considering need and resources?

1. Equipment for Standard CMOS Process

After the start up of the new lab, we have slowly acquired all necessary equipment for CMOS processing and retired "make-do" and old systems. We are still in need of an essential aluminum plasma etcher, the lack of which limits research in sub-micron devices.

2. Reducing Crowding and Avoiding Conflicts

The expansion of sensors research placed heavy demand and toll on the LPCVD furnaces. We have retrofitted a second tube for poly-silicon deposition to relieve crowding, and modified the nitride tube for low-stress film deposition. These low stress films are in great demand. Their popularity, coupled with the method used to deposit them, place a heavy burden on the furnace. Not only are the runs quite long (it takes about 5 hours of deposition time to grow a 1 μm thick low-stress film), but after that, the tube must be taken down for pump and exhaust manifold maintenance. We are in the process of looking at viable alternatives to accommodate the BSAC group.
3. Retiring Old Machinery

We have several old machines in the Microlab which are simply worn out. Maintaining these is an unending and demanding job and at some point we have to decide whether we can afford to do so any longer. If it is dedicated equipment, we ask the concerned PI's to replace it out of their own funds. If it is a generally used machine, the decision will be made by consensus of the users. The most recent example of this was the retiring of our 14 year old ion implanter. It was decided that using readily available and reliable outside services is more cost-effective than maintaining or replacing the old machine.

4. Servicing Priorities

Establishing priorities in servicing equipment used by different groups turned out to be a delicate balancing act. We were made aware on several occasions that a PI was unhappy with the service his group was getting; or, that the service is not in proportion to the support he is providing through his students in the lab. We are doing our best to satisfy every need; but sometimes certain jobs have to take lower priority. Every morning the list of problems reported on the computer is reviewed, and followed by a discussion of the most efficient way to deal with them. Inevitably, some jobs will not get done right away. It is not for lack of trying, but for lack of manpower.

5. In-House Modifications

One of the nice things about our lab, visitors often say, is the freedom students have in accessing equipment and in requesting changes to accommodate some special need. Flexibility is a key word here, and we are trying to do everything possible to help researchers. Equipment modification or upgrade is going on all the time. We have to be careful, however, that we are not drawn into complicated, long term jobs. While we may have the design capability to build systems, we certainly do not have the manpower to execute it without a great burden to the rest of the operation.
Computers

Computers in the Microlab are not only part of the facility, but also part of research projects. Computerization of the new lab started at the planning stage and communication lines and terminals were installed along with other equipment at the outset. Lab information and management software was developed and improved with constant use, and today they are indispensable, up-to-date tools for daily operation, administration, facilities maintenance and communication. The WAND program used by students includes on line processing and operating manuals, equipment on/off functions and reservation, equipment problem reporting, emergency procedures, available materials and chemicals and a visitors list. STAFF includes accounting, user information, technician’s manuals, equipment logs, technician’s job list, qualified user’s list, inventory, vendors and purchasing.

Student projects within the Computer Integrated Manufacturing (CIM) program include designing of expert systems for processing; process modeling, characterization and diagnosis; equipment monitoring, diagnosis and control; facilities layout and utilities monitoring programs; speech input and synthesis. The staff is very much involved with CIM projects, starting with suggesting areas to explore, installing sensors, modifying hardware to allow for computer communication/control, testing of software and reporting results.

Besides allotting staff time to support these projects, CIM work must be coordinated with the other researchers in the lab to avoid disasters. For example, when the computer controlling the furnaces was modified to allow for SECS communication with the lab computers, the whole system had to be shut down placing everyone on hold. When it came up, all old programs had to be modified to run with the new hardware. All changes, no matter how well planned, are disruptive, but students and staff regard these as part of another research project.

Expanding the CIM program required upgrading of the main computer (a VAX 750) and changing to a distributed system comprised of several SUN workstations. The SUNs are connected through ETHERNET with the file server (a SUN 4/280, called 'Argon') maintaining a common data base (INGRES). We have 20 terminals and 4 workstations inside the lab, and 4 terminals and two workstations in the office.
User Training

The Microlab is a complete facility in which semiconductor devices and circuits are fabricated, beginning with layout, all the way through testing. The student study area is equipped with graphics terminals and a workstation for those who do not have layout capability in their own department. All lab users receive an account on the Microlab’s computer, Argon, which is connected to the department and campus Ethernet. Equipment is shared by all users, except for those items that, by necessity, are dedicated to specific processes in three major categories - silicon, III-V compounds and superconductors. There are about 150 registered users; up to 30 usually work in the lab at any given time.

The facility is accessible with a key card 24 hours a day, 365 days a year, the only rule being that no one can work alone. Anyone wishing to work in the lab must take a one-day orientation course, presented by Microlab staff, which focuses on laboratory safety procedures. They must then pass a safety test before being granted admission to the lab. Students learn to operate equipment and to run processes from their fellow students. They become qualified users on a given machine after demonstrating to a superuser that they are sufficiently familiar with the operation of the instrument. Usually, two superusers are designated to a machine. They are senior graduate students whose research depends on the well being of that equipment. The qualified and superuser lists are updated immediately, and the new student is allowed to operate the machine independently.

We believe in allowing students as much freedom as possible, even at the expense of equipment breakdowns. They are encouraged to try out new ideas and are welcome to draw upon the experience of the staff, both in equipment and process technology.

Safety

The question of safety, from both occupational and environmental points of view, is constantly being addressed and kept in the forefront in the Microlab. The following programs illustrate our commitment to safety:

1. All students, staff and visiting scientists who work in the lab are required to take a lab orientation course, a major part of which concerns safety education. During this course the newcomers are instructed by staff on the safety procedures to be used in the lab, the equipment that is available to exercise safety, and where further information can be obtained. Currently, it is required that all users wear safety glasses at all times in the lab, and in addition, that they wear a face shield, acid
resistant gloves and apron when handling chemicals. This is being enforced by the staff of the Microlab.

2. We are in contact with the offices of Environmental Health and Safety and Occupational Health and Safety. They have inspected the Microlab on several occasions, after which we reviewed their observations and took corrective actions. Removal of hazardous waste is provided by the office of EH&S.

3. The Occupational Health Physician from the Occupational Health Service, visited our facility several times with other occupational and environmental health professionals as part of his efforts to educate his peers through seminars and continuing education courses. He uses the lab to demonstrate semiconductor industry safety practices.

We have a firm policy on areas of service that have a high risk associated with them. It forbids lab users from doing electrical wiring, changing gas cylinders and making modifications to equipment without permission from lab management.

1. Electrical wiring is done only by staff and it is done to California Electrical Code standards.

2. Gas cylinders are changed by staff trained in cylinder safety. Cylinders are always chained and toxic and corrosive cylinders are operated in vented steel cabinets. The Microlab has two SCBA (self-contained breathing apparatus) units and three staff members are certified to use them for rescue.

3. The lab has developed its own "low center of gravity" transportation carts for chemicals, and maintains a stringent policy for the transportation of chemicals.

4. Bulletins provided by vendors and bulletins from Environmental Health and Safety are routed with a sign off sheet to staff members. We also keep up-to-date MSDS (Material Safety Data Sheets) on all chemicals used in the lab. They are available to the lab users and a duplicate set is kept in the office.

We actively pursue safety in the lab and respond rapidly to any safety problems that we become aware of. Many of the steps we have implemented are new to the University and we are considered a model by the offices of Environmental Health and Safety and Occupational Health.
IV. Looking into the Future

In the few years since the new facility was constructed, Microlab users have produced numerous publications and research results that testify to the effectiveness of our cooperative approach. At the moment, our financial footing, although precarious, seems to be established. However, if we hope to continue to support teaching and research of the highest quality, we must seriously examine our position and identify its weak points. Those immediately obvious are the following:

1. We have no new development activity to speak of on the part of the staff. This means that we are falling behind industry standards and soon we will be unable to support our students’ efforts in a meaningful way.

2. We have no program in place to provide new equipment and staff help for advanced projects.

3. We have very limited funds to upgrade/overhaul/replace current equipment as these become worn out and obsolete. Within 3-4 years, we estimate, the lab will be obsolete.

4. Although we now have a balanced budget, we will not be able to maintain it for long. We are counting on increased revenue to offset cost increases, but, with current utilization of about 75%, there is not much space to grow. Increasing recharge rates would be another option; however, this would be counter-productive. Our cautious estimate says that available research grants will not grow at the same rate as expenses, and increased rates would simply exhaust those funds faster. We can expect running into deficit again, within 2-3 years, merely maintaining our current mode, which is not satisfactory.

V. Conclusions

It has been our experience that maintaining a working university laboratory, where integrated circuits can be fabricated, requires substantial commitment on the part of the faculty. There must be a group of PI’s whose research depends on a working lab, who will serve as its major supporters. There must be a critical mass of technical staff who maintain the lab and provide continuity for the changing student body. An advanced lab, such as ours, cannot be financed fully from recharge rates; even when the user base is as wide as ours (153 lab users from 46 PI’s). If we are to maintain excellence and remain up-to-date with current technologies, other sources of support must be found.
Biographies

Ping-Keung Ko received the Ph.D. degree in electrical engineering in 1982 from the University of California at Berkeley.

He spent 1982 and 1983 at Bell Laboratories, Holmdel, NJ, working on high-speed MOS technologies. In 1984 he joined the University of California at Berkeley where he is an Associate Professor of Electrical Engineering and Computer Sciences. He has been the Faculty-in-Charge of the Microfabrication Facility since 1984. His current research areas include high-speed VLSI technologies and devices, and MOS device modeling for circuit simulation. He has authored or co-authored one book and over 90 research journal articles.

Katalin Voros graduated from the Drexel Institute of Technology (Philadelphia) in 1966 with a B.S. degree in physics. She gained extensive experience while working as a process engineer for Philco-Ford Microelectronics (bipolar ICs), Solid State Scientific, Inc. (RF transistors, CMOS circuits), and Microwave Semiconductor Corporation (high frequency power transistors). Her primary assignments were in process support and development, material and equipment evaluation, device testing, failure-mode analysis, yield enhancement and product engineering. She joined RCA’s David Samoff Research Center in Princeton, New Jersey in 1980, working as an associate member of technical staff in the high-density bulk CMOS (SRAM) development group.

In 1983, Ms. Voros came to the EECS Department at UC Berkeley as a master’s student working with Professor W. G. Oldham. After receiving her Master of Science degree, she was hired in January 1985 as a process development engineer assigned to establish a baseline CMOS process in the Microlab. She organized and trained a process group of four who are well versed in all aspects of semiconductor processing. She became manager of the Microlab in December of 1986.
Figure 1. Number of Microlab Users from Each Research Group, September 1989

Figure 2. Distribution of Operating Income from Research Groups, FY 88/89
Figure 3. Microlab Operating Income and Expenditures
Figure 4. Breakdown of Expenditures for Supplies, FY 88/89
(Salaries not included, only cost of materials and replacement parts;
direct expenses paid by Microlab)
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<td>Lauren Massa</td>
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Figure 5. Microlab Staff
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| Net Cost | 537679.81 | 106176.85 | 300432.84 | 29312.89 | 101757.30 | 91290.55 |

Table 1
Microlab Financial Summary
Fiscal Year 88/89

Expenditures

Supplies & Expenses $351,459.66
Sal. & Ben. (9 FTE) $292,362.19

Total $643,821.85

Income

ML Income $614,141.32
BMA Cont. $94,051.28

Total $708,192.60

Total Expenditures, FY 88/89 $643,821.85
Total Income, FY 88/89 $708,192.60

Debt Recovery, FY 88/89 $64,370.75
Total Debt at the End of FY 88/89 $336,816.73

Table 2
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</table>

| Total Supplies & Expenses           | $351,459.66 | $98,483.60 | $252,976.06 |

Table 3
74


Mask Making
- GCA 3600 Pattern Generator
- APT Chrome Mask Developer
- APT Emulsion Mask Developer
- 10:1 Mask Reduction Camera
- Ultratech Mask Duplicator

Photolithography
- Ultratech 900 Wafer Stepper (modified)
- GCA 6200 10X (4") Wafer Stepper
  with Excimer laser light source
- Canon 4X Wafer Stepper
- Kasper Contact Aligner
- 2 Headway Spinners
- Eaton 4" Wafer Trak
- MTI 4" Developer/Stripper
- Silylation System
- 2 Bake Ovens

Wafer Cleaning
- 12 Semifab Wet Process Stations
- 2 Dexon Wet Process Stations
- 2 Fluorocarbon 4" Spin Dryers
- DI Water: Continental Water RO System

Thermal Processing and CVD
- Tylan/Tyfan-II Furnaces
  - 11 general purpose tubes
  - 5 LPCVD tubes
- Lindberg Diffusion Furnaces
  - 9 tubes for 2" wafers
- 2 AG Heatpulse RTA Systems
- 2 Liquid Phase Epitaxy Furnaces

Thin-Film Systems
- CPA 3-target Sputtering System
- MRC Sputterer for zinc oxide
- Varian NRC WE-04 Evaporator
- Varian 936 Leak Detector
- Veeco 401 Evaporator
- Vecco 775 Evaporator
- Vecco Microtech Ion Milling System
- Perkin-Elmer Randex 3-Target Sputterer
- Davis and Wilder Evaporator
- Gartek 3-Target Sputterer with ESCA
- S-Gun (3) Sputtering System
- 2 Hummers for metal coating SEM samples

Plasma Systems
- 2 Lam Autoetch Systems (4")
- Technics Plasma Etching System
- 2 Technics Plasma Deposition Systems
- Technics Microstripper
- PlasmaTherm RIE System
- Semi-Group Plasma/RIE System
- Barrel Etcher for 2" wafers

Packaging
- Tempress Wafer Saw
- Westbond Ultrasonic Bonder

Analytical Equipment
- 6 High-Power Microscopes
  - 1 with color TV monitor, 1 with 35 mm
  - Olympus auto-exposure camera
- Reichert Polylite with Nomarski
- Vickers Image-Shearing Microscope
- Nanometrics Nanolime IV
- Nanometrics Nanospec AFT
- Nanometrics Cwikscan II SEM
- Nanometrics Deep UV Microspectrophotometer
- Hitachi S-310A SEM
- Gaertner Ellipsometer with HP compcon
- Tencor Alpha-Step Profilometer
- Tencor Alpha-Step 200 Auto. Profilometer
- Tencor Sonogage rt2 Resistivity Meter
- Tencor Flatgage
- Prometrix Resistivity Mapping System
- Signatone Manual 4-Point Probe with HP inst.
- Signatone C-V Probe Station with HP compcon
- Signatone I-V Probe Station with HP compcon
- Scientech Electronic Balance
- Perkin-Elmer PR Dev. Rate Monitor
- VG Instruments Residual Gas Analyzer

Table 5. Microlab Equipment


Table 6. Representative List of Publications
1990 Year End Report

MEMORANDUM

TO: Ping K. Ko, Faculty-in-Charge
FROM: Katalin Voros, Microlab Manager
SUBJECT: Microlab Year End Report - 1990
DATE: January 17, 1991

This report summarizes Microlab activities during 1990. It is the fourth year-end review I am submitting, along with the reports of the lab's professional employees (A&PS) for the first time. I believe the review of their work helps to form a more accurate picture of Microlab operations.

SUPERVISION OF STAFF

The staff structure as finalized last year is shown in Figure 1. and Table 1. Supervisors are now taking turns in attending Wil Zeilinger's monthly supervisors' meeting, where departmental policy and building matters are discussed.

1. Maintenance Staff

Because of the budget constraints outlined in my 1989 report, we operated with one less technician during part of the year. For the busy summer months we hired low level (Dev. Tech, ID) temporary help. However, by Fall it was obvious that to support the current level of activities in the lab we must have full staffing, i.e. five technicians and some student help, under the guidance of Bob Hamilton, a working supervisor. Otherwise, job lists become unfeasibly long and preventive maintenance is delayed. Thus, a Dev. Tech. IV position was included in the 90/91 budget and the position filled in November by Mike Linan. Activities of this group are described in detail in Bob Hamilton's report.

2. Process Staff

The success of the Microlab depends on the process staff as much as on the maintenance staff. Tariq Haniff's and Debra Hebert's reports describe their work well. Besides maintaining current and developing new processes, and assisting graduate students, the process staff is fully responsible for supporting sundry researchers; the latter supplied about 9% of our total income in Fiscal Year 89/90.

This past year we started regular process monitoring in the lab, to insure expected process performance at critical steps. Results are recorded on the computer, in the equipment comment logs, where the information is available to all users. We plan to utilize the CIM group's in-line supervisory control programs to track this data.

There was one major change in process personnel this past year. Our long time staff research associate, Tom Booth, resigned, effective August 1. A talented and experienced process person, Tom knew many of the intricacies of processes and equipment in the lab. He gave sufficient notice in time to allow the training of the new SRA, Tariq Haniff. Tariq graduated in EECS from UC Davis in 1990 and started working with us in June. We also made a concentrated effort to record all relevant details of processes and equipment operation, which Tom knew but habitually neglected to record. Debra updated several chapters in the operating manual and started a manual on the WAND for technicians.

3. Administrative Staff

The recent computer upgrade placed a disproportionately large burden on the administrative staff. All charges, such as students' time spent in the lab, inventory, purchasing, etc. had to be compiled manually and entered item-by-item when the system came up. We hired a student helper just for data processing. Rosemary Spivey kept matters well in hand and with the extra effort she expended, we avoided missing the monthly billing and posting dates. After the upgrade the software was slowly debugged and pieces of the administration programs came up one by one. We have a few more to go.
4. **Associated Research Staff**

I have worked with the BSAC professors to develop an engineering position for their group. Prof. Spanos was also interested in joining with either BSAC or the device group in partially supporting a base line process with a development engineer. As everything, this depends on funding and it is uncertain at this time what can be afforded. In the mean time, the two researchers working with BSAC the past two years resigned and the group is now under own process support personnel.

The Deep UV Photolithography group and Prof. T. Van Duzer (cryo) continue to maintain their development engineering positions.

**INTERACTION WITH FACULTY AND RESEARCH GROUPS**

Beginning March we started to hold regular monthly members' meetings, to enhance communications between lab users and management. These meetings give us an opportunity to inform members of planned changes and to let them express their concerns and suggestions for improvements.

- One important activity which resulted from these discussions was the introduction of standard process monitoring on VLSI equipment at regular intervals. We now monitor 15 pieces of equipment (see Debra Hebert's report.) Although this requires considerable staff time and we had to hire a student worker to assist with it, the effort is worthwhile because it increases the users' trust in equipment reliability.

- It was suggested that we ask new members to restrict their work hours in the lab to 8am-5pm during their first three months. We agreed most wholeheartedly, as this practice will enable us to assist inexperienced students to work more efficiently.

- We repeatedly address safety issues during these meetings and reiterate emergency procedures. We also asked members to conserve energy by turning lights out when they leave after working late in the lab.

Although attendance has been less than overwhelming (10-15 students at a meeting) we have heard and implemented many good ideas and we will continue to hold these meetings.

Other items discussed with individual groups:

1. **Sensors**

   We have worked closely with BSAC on the specification of the new low temperature oxide deposition tube bought by them. Microlab staff handled sight preparation and installation and Tystar turned on the furnace. Now that the new LTO tube, tylan20, is running, the question of contamination by ZnO and W will be investigated. Specifically: if a wafer with ZnO or W has LTO deposited on it in tylan20, in which furnaces can it go afterwards? As a result of several meetings, we agreed on a qualification procedure for W, which is being carried out jointly by staff and BSAC students.

   In addition, we are actively pursuing a plasma etcher donation or a used machine at an affordable cost, to each thick, 1-2 μm silicon nitride films extensively used by this group.

2. **Device**

   We have spent considerable time looking for an RF sputterer on the used equipment market for Prof. Hu's group. We found a 3-target machine in good condition, at a reasonable price. It needs cleaning, parts and retrofitting for sputtering PZT at elevated temperatures. Staff is doing the work and Prof. Hu is covering additional expenses.
3. Compound

With the hook-up of the old RIBER MBE machine to the LN tank and the increase of activity on the new, Varian MBE system, LN use increased dramatically to the point where we have to examine all available options to handle the demand. I am preparing a separate memorandum to Professors Lau, Smith and Wang on this subject.

4. Cryo

Josephson junction device research is moving to smaller and smaller critical dimensions and is stretching our photolithography capabilities. This group, along with researchers in Physics, is interested in e-beam direct writing lithography. Last year I reported on our discussions with Prof. Clarke and subsequent investigations of the possibility of obtaining an e-beam system. It was decided then and it is still the case that it is beyond our means. There is, however, an excellent e-beam facility at UC San Diego’s Department of Electrical and Computer Engineering. When I visited the department I talked with the development engineer responsible for the operation. He is accepting jobs (in CIF file form) from both industry and academia, for an hourly fee. (It takes about $250K to maintain the facility.) This information has been relayed to interested parties.

5. CIM

The activities of the Computer Integrated Manufacturing group required major involvement on our part. A new piece of software, FAULTS was installed and the whole computer system was upgraded.

FAULTS - This program has been in preparation for a year. First, we worked with Dave Mudie on the specifications and design of the program, i.e. how equipment problems are/should be reported; how updates, repairs are entered and information disseminated. The program also had to be friendly to technicians and lab members and had to be able to run on both ascii and graphics terminals.

While the software was being written our technicians had to assemble a list of the most commonly occurring problems (=symptoms) for each of the 142 machines and the faults which were responsible for the problems. Bob Hamilton and I then reviewed all symptoms and faults. When the framework was done, Dave Mudie and Norman Chang installed the data and tested it with each technician individually.

At this point the system went down for the upgrade and FAULTS had to be tested again when it came up. Surprisingly, this piece of software had very few bugs in it and most of our comments were directed to improvements or to making it more friendly.

Finally, FAULTS was installed in November, replacing equipment comments. Although it was a lot of work, I must say we really like it. It is so much more efficient in storing, sorting, and extracting service information that there is no comparison with the simple text files used previously.

UPGRADE - Lauren Massa’s report describes what was involved. From the users’ point of view it looked like this:

Computers went down on August 21.
Office terminals came up August 31.
Lab terminals started coming up intermittently September 20.
Equipment control (taurus) came up in January.

There remain a few more problems to be taken care of.
We have come to rely so much on computers in managing the lab that this shutdown was a very painful experience. What have we learned?

- Upgrades, both hardware and software, must be installed on a regular basis, otherwise the system becomes outdated and cannot be maintained.
- The Microlab's CIM software must be reviewed/reorganized for easy portability and to allow for partial upgrades. Design and implementation guidelines must be specified.
- We must have documentation. We have always known this; however, never allocated time for it. There were always more urgent things to do.
- Computers are machines. Both hardware and software need maintenance and they have life spans, just like all the other equipment in the lab. We now have several computer related names on the equipment list, such as: bimp, delta, equipcom, faults, printers, software, suns, taurus, terminals, wand and computers, as a catch all, where problems and service can be reported.
- The Microlab's CIM system, because it was developed as a research project, is unique. It is a complex, dynamic machine and it is intertwined with all areas of lab operation in a way no other equipment is. Its management and maintenance requires dedicated staff.

PUBLIC RELATIONS

According to names recorded on the computer, the Microlab had 263 visitors in 1990. This drop to almost half since last year is the result of using the video tape Microfabrication at Berkeley, to show the lab to visitors, instead of taking them in. This was the primary purpose for making the video.

The Microlab has been featured in two recent departmental publications, in ILP's EECS/ERL News, Fall 1990 issue, with the title Putting It Together in the Microlab (p.10) and Meeting the Challenge, in the October 1990 issue of the ERL Newsletter. Both articles included a photo of the staff.

We continue our participation in programs for selected groups, such as Vintage Alumni Association, Hispanic Engineers; Academic Development Programs, and special recruiting efforts for both faculty and graduate students.

FISCAL CONTROL

At the end of FY 89/90, I submitted a detailed financial report to the Faculty-in-Charge (Microlab Financial Report, Fiscal Year 89/90, September 28, 1990.) In it I reported on:

- Attainment of budgetary goals during the past fiscal year;
- New budget and proposed recharge rates for the next fiscal year;
- Financial analysis comparing four years' data;
- Microlab utilization analysis.

Half way into FY 90/91 fiscal status is as follows:

- Microlab operating income and expenditures are in tandem. (see Figure 2)
- Budgetary goals are being met. (See Table II.)
FACILITIES DEVELOPMENT

1. Utilities

POWER - In a memorandum submitted to the Department Engineer, (Microlab Power Survey, December 27, 1990), as a response to energy conservation requests, I discussed:

- Power Distribution,
- Power Consumption,
- Conservation Measures.

Results of the survey showed that the Microlab needs additional 408V, 3φ, 5 wire power and that we use approximately 12% of the total power consumed in Cory Hall.

ICW - Evaluation of the existing industrial cold water system in Cory Hall indicates that the lines are undersized for the supply of sufficient volume of water to the Microlab. The problem appears during high demand periods, and when the recirculating system is down for repair or maintenance. To remedy low and fluctuating water pressure problems, modification of the ICW system to the building is required; thus, a Project Proposal for Minor Capital Improvement, for 1992-93, has been submitted to the Department Engineer.

STEAM - During the current unusually cold winter we have encountered severe temperature control problems inside the lab. This was the first time since the construction of the new lab that heating problems occurred. Usually the heat generated by equipment is sufficient to keep a balanced climate. As the Stationary Engineer's report and request was insufficient to have this problem remedied by the office of Physical Resources, we will have to initiate action.

LN - With the hook up of two molecular beam epitaxy systems to the liquid nitrogen supply we are experiencing increased and variable demand. Protecting the Microlab against diminished LN levels is an additional burden on the maintenance staff. This problem is under evaluation and a proposal to resolve it will be submitted to the concerned parties.

2. Equipment

The Microlab's space is fully utilized and, for all practical purposes, we cannot add new equipment without removing some of the old. We are also limited by the availability of power and cooling water. Thus, our only option is to gradually upgrade instead of expanding. At the same time, allocation of our limited storage space has to be periodically reviewed and old, unused equipment and parts discarded. For some reason, this is an unending job and it seems like after we clean up everything we could start all over again.

Bob Hamilton and I spend considerable time looking for equipment donations and at the used market for affordable deals. We have also worked with AMD's Asset Reclaim Group, handling used equipment sales and donations. Unfortunately, it takes time to develop these contacts, which require numerous follow ups before they result in something usable. We just have to keep working at it.

3. Computers

When the new lab was built eight years ago it was decided that it should become computerized to provide a test site for CIM projects. At the same time, software developed by researchers could be utilized to manage the lab. This plan worked out very well, with motivation for new software and expansion going from CIM groups' ideas to requests by lab management, and back. The result is an excellent, versatile and working lab management system.
It is time however, to reexamine CIM research/Microlab interrelations and to chart out a parallel path for the future. There are several reasons for doing this:

1. Lab software (and hardware) have grown to such size and complexity that it now requires considerable time to manage and maintain it. As it is, 60% of the CIM researcher’s (P/A II) time is allocated to this task, which could really take up full-time, including documentation and periodic improvements.

2. Computer maintenance costs are currently met by the CIM research group and are not included in the Microlab budget. Thus, Microlab maintenance costs appear lower than they really are.

3. CIM research has expanded into several new areas and staff support could be utilized more effectively working towards research goals. This is the mode in which other groups, who maintain their own support staff, operate. Cryo, DUV and BSAC engineers work directly on research projects and have very little to do with lab maintenance.

Separation of CIM research from other lab operations has already started to happen. After the upgrade, accounts were arranged such that Radon became purely a research machine and Argon remained as the server for lab operations. This was an excellent decision, because it protected Radon users from experiencing our start-up problems.

To take care of lab computer maintenance I have undertaken to develop a career part-time PA II position, to be paid by the Microlab. That is all we can afford now, since we are more than half way through the current fiscal year. A full-time position will be included in the next budget. Over the past years we have been gradually absorbing computer related expenses, such as 15% of Kirk Thege’s and Kevin Zimmerman’s salaries; network access fees, tape drive (formerly on cad) maintenance contract (shared with ILP), and hardware repair expenses. Additional work stations and related hardware are still furnished by the CIM group.

**SUMMARY**

This report provides an overview of Microlab activities during 1990. Major issues discussed are supervision, interaction with faculty and research groups, public relations, fiscal control, and facilities development. The Microlab continues to operate smoothly and within budget.

rs 1/29/91
FIGURE 1.
Microlab Employee Classification and Payroll Allocation
January, 1991

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<td>Paid by other acct/funds (EECS, ERL, SRC)</td>
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*Full Time Equivalents

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<td>Guillory, Phill</td>
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**TABLE I.**

84
Microlab Monthly Operating Income and Expenditures
First Half of Fiscal Year 90/91

FIGURE 2.
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<th>% +/-</th>
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</tr>
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<td>8056</td>
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<td>0.00</td>
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<td><strong>Sub 3&amp;4 Subtotal</strong></td>
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<td><strong>278,117.93</strong></td>
<td><strong>210,900.00</strong></td>
<td><strong>32%+</strong></td>
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<tr>
<td><strong>(Supplies &amp; Expenses)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td><strong>Sub 2&amp;6 Subtotal</strong></td>
<td></td>
<td><strong>179,927.75</strong></td>
<td><strong>192,000.00</strong></td>
<td><strong>7%</strong></td>
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<tr>
<td><strong>(Salaries &amp; Benefits)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Expenditures</strong></td>
<td></td>
<td><strong>458,045.68</strong></td>
<td><strong>402,900.00</strong></td>
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<td><strong>481,819.43</strong></td>
<td><strong>427,500.00</strong></td>
<td><strong>13%+</strong></td>
</tr>
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</table>

TABLE II.
1991 Year End Report

MEMORANDUM

To: Ping K. Ko, Faculty-in-Charge
From: Katalin Voros, Microlab Manager
Subject: 1991 Year-End Report
Date: January 16, 1992
cc: P. R. Gray, M. Lieberman

This is the fifth year-end report I am submitting as manager of the Microfabrication Laboratory. As can be seen from the details discussed, the lab operated smoothly, safely and within budget.

SUPERVISION OF STAFF

With the addition of two development engineers as Associated Researchers, and the hiring of our own computer system manager, the staff of the Microlab grew to 25 people by the end of 1991. (See Figure 1.) Out of these, 10 report to me directly: the three lab supervisors and seven associated researchers. Thus, personnel aspects of the manager's job demand an increased portion of my time. Also, with overall budget reductions and no merit raises, employee motivation is an area requiring greater attention. Fortunately, the staff of the Microlab is a group of dedicated people who care greatly about their work. This is manifested in our low personnel turnover rate, and in that absenteeism (3.7%) is no problem.

This past year smooth interaction between the three support groups assured the most efficient use of personnel and fast response to problems. Process and maintenance people worked together on equipment characterization and repair, had joint discussions and submitted proposals together for required expenditures. The administrative staff took on all possible paper-work-type jobs to allow technical support personnel to attend more effectively to equipment and process problems. Computer reliability increased and more emphasis was given to users' problems as we began to take over responsibility for our own machines.

Employee development received greater attention. Staff was given an opportunity to attend trade shows, workshops, training courses and technical meetings, to enhance their skills. (See supervisors' reports.) We applied greater scrutiny to the selection of our undergraduate student employees. They each work 15-20 hrs/week; time spent on training and supervising them is not a negligible task. Their total hours worked, with full-time employment during semester breaks and Summer, add up to more than 2 FTE-s. We now require engineering or science background (except for the administrative help), look for long-term commitment (i.e. hire freshmen or sophomores), train them well so they can work on their own and carry their weight, and encourage them to bring in promising candidates when we have an opening. We consider them full members of the group.

Personnel highlights of 1991:

- Bob Hamilton was reclassified to Senior Development Engineer.
- Dave Hebert was reclassified to Senior Development Engineer.
- Debra Hebert received an A&PS Professional Development Award.
- Phill Guillory received a Special Performance Award.
- Lauren Massa received an A&PS Professional Development Award.
- Evan Stateler obtained his BS degree in Physical Science at Hayward State.
- Katalin Voros received an A&PS Distinguished Achievement Award.
1. Maintenance Staff

This group was fully staffed throughout 1991 and handled its responsibilities well. Bob Hamilton, Maintenance Supervisor's report describes their activities in the areas of equipment and utilities maintenance, and development. Also, safety issues were addressed, practices reexamined and improvements made. Bob and I signed a document requested by the Chairman and Director, stating that we accept the responsibility for safe operations in our laboratory. In addition, I submitted a report to the Department's Safety Officer, of the corrective actions taken, suggested after the lab inspection at the end of last year by E,H,&S representatives. (Safety Inspection Follow-Up, May 3, 1991)

Because of the growth of lab operations and their expansion in scope and complexity, Bob Hamilton's position was reclassified to Senior Development Engineer, effective July 1, 1991.

2. Process Staff

Under Debra Hebert, Process Supervisor, the process staff again contributed greatly to the effective operation of the Microlab. (See reports by Tariq Haniff, Debra Hebert, and Maria Perez.) Through supporting sundry researchers with a wide range of processing problems, and through her process development and characterization work, Debra demonstrated that her position is commensurate with an engineering classification. Accordingly, a reclassification request to Assistant Development Engineer has been submitted.

By the middle of last year a large portion of Tariq Haniff's work involved research with the Device group; thus, Prof. Ko suggested that Tariq be employed by them. We agreed that Tariq will train his replacement, after which he will become one of the Associated Researchers. Maria Perez started working in August and Tariq joined the Device group in December. His reclassification to Assistant Development Engineer has been submitted.

The process group is greatly aided by a succession of carefully chosen undergraduates. As I mentioned above, critical selection really paid off here. After one and a half years, Jennifer Dockter transferred in May to a lab assistant's position in the Molecular Biology Department. Vadim Gutnik, EE jr. and Robert O'Donnell, Chem E sr. are still with us, hopefully until they graduate.

3. Administrative Staff

Rosemary Spivey, Administrative Supervisor, submitted a report describing what is involved in administering our unit. From the beginning, management requested that all administrative actions be computerized. The STAFF software, which contains most of the administrative programs to handle the data stored in Ingres, was developed nicely over the years, along with the rest of the lab management software. Unfortunately, we cannot transfer data directly into the campus accounting system, and all our expenditures and income have to be entered manually into BEARS. This is a critical operation and Rosemary supervises it very closely.

Servicing a technical unit, like the Microlab, differs from other administrative positions in the Department in that this person must be completely knowledgeable and self-sufficient in accounting and administrative matters. The technical manager is relying fully on the administrative assistant's knowledge and integrity when it comes to the business of fiscal monitoring, procurement and inventory. Following University administrative procedures, rules, and guidelines is a prerequisite for the successful operation of the unit.
4. Computer Support Staff

The growth and stabilization of Microlab operations these past five years required that computer activities become independent and self-sufficient. The demands placed on our real-time system are quite different from those required for research. Thus, separation of lab and computer integrated manufacturing (CIM) research started last year, as it was laid out in my 1990 year-end report, and has been successfully completed this year. The Microlab is now fully responsible for maintaining and upgrading both hardware and software necessary to run the lab.

Mark Kraitchman, Programmer/Analyst I, started working for the lab in February, first part time, then slowly built up to full-time employment by July. He was trained by Lauren Massa, CIM PA II, who requested reduced work hours to allow her to take classes. Also, Lauren asked to work on research problems instead of application software maintenance. In September Mark took on full responsibility for maintaining Microlab software, with Lauren remaining an advisor when called upon.

System management has been provided by Kirk Thege, whose major assignment is to support Prof. Brodersen's research group's activities. In August Kirk requested that he be relieved of Argon/Radon responsibility; thus, we began the search for a new system manager. Christopher Hyldans started working as a PA II on December 17, 1991, and is now in the process of taking over Argon/Radon system management.

INTERACTION WITH FACULTY AND RESEARCH GROUPS

Our monthly lab membership meetings continue to be successful in communicating, albeit low in attendance (10-15 students). The minutes, listing all matters discussed, are sent to all members. These included:

- equipment changes, upgrades, acquisition, major shut-downs;
- coordination of alternate use;
- process problems, improvements, correction efforts;
- computer status;
- chemical use and waste disposal;
- safety;
- members requests and suggestions.

We had a Microlab T-shirt logo contest, which resulted in a nice clean design, featured on the cover page.

The number of groups employing associated researchers increased to six by the end of 1991. Now all of our major research groups have at least one dedicated engineer working for them. These associated researchers are members the Microlab staff, directly under my supervision. We have weekly meetings on individual basis and I call in other staff when coordination and/or increased need for support is justified.

Major issues worked on with individual research groups:

1. Sensors

After long and careful consideration of their budget, BSAC professors hired a development engineer. This was a long overdue step, which I encouraged and assisted all the way. The group's demands definitely warranted professional support, way beyond what the Microlab's staff could provide. Jim Bustillo, Senior Development Engineer, started working in July and found himself very quickly in the middle of the activities.
BSAC made progress also on the equipment front. First, we bought a used sputterer (from Microlab BMA and Prof. Hu/Ko funds); then, BSAC financed the redesign and upgrade of the machine to produce high quality PZT films. Microlab contributed technician-time in excess of 300 hours.

We were also successful in obtaining a donated plasma etcher, to facilitate the etching of tungsten and thick nitride films. The lab took care of installation and provision of a recipe for standard (1000 Å) nitride films. Jim Bustillo developed a process for etching thick (~1.5µm) silicon-rich nitride films.

Finally, it looks like we will be able to construct a second nitride deposition tube, dedicated to low stress (Si-rich) nitride films. We purchased the furnace element and power module for tylan19, and obtained a donated pump package. The rest: gas control system, boat loader, tube control computer (total ~$60K), is up to BSAC. We will do the assembly, whenever given the go-ahead.

2. Compound

Organizational changes in the Department and ERL resulted in the transfer of John Benasso, Associate Development Engineer, to be supervised by the Microlab Manager. (See memo Organizational Changes, October 4, 1992 by Paul R. Gray, Chairman, EECS Department and Mike Lieberman, Director, ERL.) John assists equally in the activities of the Plasma Lab and MBE Labs on the first floor of Cory Hall.

The problem of delivering high pressure N₂ to the Microlab and supplying the MBE labs with low pressure LN has been resolved by installing a second vessel. See details in the Facilities Development section.

3. CIM

No new software resulting from research projects was added to the Wand. Our joint activities concentrated on eliminating the involvement of research people in routine maintenance and assistance to lab members. We did have another upgrade, which will be discussed in the Facilities Development section.

PUBLIC RELATIONS

According to names registered on the computer, the Microlab had 203 visitors inside the lab in 1991. We had many others, of course, who had the window tour, i.e. lobby visit and/or video presentation of Microfabrication at Berkeley. We had given away many copies of this tape, including copies in the PAL format for our European and Asian visitors. Since its introduction, we have received many compliments on this tape.

Our regular public relations activities continue to be the yearly ILP program in March and presentations to selected groups, such as minority engineers, academic development programs, and outstanding graduate candidates.

We participated in an open house organized by the BSAC professors this past year. The Transducers '91 conference, General Chairman Prof. R. Muller, was held in San Francisco, in June. The last day's program was a visit to Berkeley. Part of the activities were held on the 4th floor of Cory Hall, where the Hughes room, BSAC offices, and the hallways were jammed with people. The sensor video in the Hughes room and the Microlab video, in front of the lab door, were shown continuously. BSAC posters were placed in the hallway, and along with our historical pictures, kept the milling throngs busy reading, or talking to students and staff. The event was a great success.
FISCAL CONTROL

The Microlab’s budgetary goals have been met for the fifth year in a row. (See my Financial Report, Fiscal Year 90/91, October 22, 1991.) The new budget included a 5% increase in access, general lab, and staff fees, and a 3% increase in special equipment fee. The policy of maximum charge of $1000/month for general lab use, and maximum charge of $1000/month for special equipment use remained in effect.

Lab-use analysis indicated that lab-hours increased by 9% from the previous year, to ~26K hours in FY 90/91; however, the rate of increase slowed down and the various research groups grew more-or-less evenly.

At the midpoint of FY 91/92, status is as follows:

- Operating income and expenditures are in balance. (See Figure 2.)
- Budgetary goals are being met. (see Table II.)
- Computer maintenance expenses have been fully included in the budget. (See discussion below.)

Computer Expenses

The CIM research group (Hodges/Rowe/Spanos) subsidized ML computer activities since the construction of the new lab in 1982. Five years ago we started to absorb some of the costs; however, CIM continued to fully fund a PA II position and a student programmer for lab software maintenance and upgrade. In addition, CIM paid 17% and the ML 13% of Kirk Thege’s and his assistant’s salaries and benefits, plus ~2% for administrative expenses, for system management.

This year the Microlab was requested to take on the responsibility of maintaining its own computer operations; thus, the following arrangements were made:

- A Programmer/Analyst II position has been opened and filled in December, 1991, to manage Argon (ML) and Radon (CIM); it is 70% supported by the Microlab and 30% by CIM.
- A PA I position, since Feb., 1991, for lab software maintenance, is fully funded by the ML.
- Effective Jan. 2, 1992, Kirk works only for the Brodersen/Rabaey, Lee, Messerschmitt groups.
- CIM purchased the Ingres database license and made it available for the Microlab.

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Table I below shows computer expenditures for the past five years. The projected figures for FY 91/92 include all ML responsibilities except as stated above. (No upgrades are planned.) The percentage of total expenditures resembles numbers quoted in the industry more closely than those shown in previous years.

<table>
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<tr>
<th>Fiscal Year</th>
<th>Computer S&amp;E</th>
<th>Computer S&amp;B</th>
<th>Total Yearly Computer</th>
<th>Total Yearly ML Expenditures</th>
<th>Computer % of Total ML Expenditures</th>
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</thead>
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</tr>
</tbody>
</table>

S&E = Supplies and Expenses; S&B = Salaries and Benefits

Table I.
FACILITIES DEVELOPMENT

1. Utilities

POWER—We continued our energy saving efforts throughout the year. Cory Hall has been consistently below targeted reduction figures, as can be seen on the graphs published by the Utilities & Conservation Unit of the Office of Physical Resources. (Posted in the elevators.) The Microlab consumes about 12% of the total power in Cory Hall.

As part of the campuswide Electrical Distribution Upgrade project, we had a planned, four hour long power interruption in August. This gave us the opportunity to perform needed maintenance on the lab’s electrical panels and transformers. It was an additional bonus that the Office of Physical Resources coordinated their maintenance of Cory Hall transformers with the shutdown. (They needed to change the oil in the transformers to meet the State limit of 5 ppm PCBs; the Federal limit is 8 ppm, which was met.) Thus, we avoided another interruption. Every time power goes down we lose a quartz furnace-tube (or two) and, inevitably, some equipment will fail. Non-refunded expenses are usually over a thousand dollars just for parts.

LN—After examining demand from the Microlab and the MBE labs we developed and submitted a proposal to install a second, low pressure liquid nitrogen holding vessel outside Cory Hall. (See my report *Liquid Nitrogen, March 6, 1991.*) This has been approved by the Chairman, and BMA funds were made available for the project. John Benasso took over expediting installation. The newly installed 1500 gal vessel is operated at a pressure of 50 psi to meet the MBE Labs’ requirement. The Microlab’s 3000 gal. vessel remains at 110 psi for N₂ gas delivery at 90 psi pressure on the 4th floor, coming into the lab.

2. Equipment

Bob Hamilton’s report lists equipment installation and upgrades in 1991. No major equipment purchases were made. We utilized our allotment of BMA funds to obtain a used sputterer for deposition of PZT; a furnace element and power module for the tylan19 LPCVD nitride system; minor test and computer equipment; totaling $45K. Successful equipment solicitations included a Tegal plasma etcher, an IPC plasma barrel etcher and a brand new back-up pump module. One of the Heatpulse RTP systems had major damage and is out of commission. Our efforts to obtain a donation of another RTP have been so far unsuccessful.

3. Computers

Argon went through another upgrade, to SunOS 4.1.1, in September. This was a much less painful experience than the major upgrade we had last year, from Sun 3 to 4. The Ingres database was upgraded to 6.3.

In addition, to further reduce reliability problems, some of which were attributed to long connection lines, we moved two Sun 3 machines inside the lab. Bell and Copper, each with an ALM II board, have sufficient number of ports to handle all equipment and dumb terminals less than 50 feet away. Xterms and client work stations are connected to the system by ethernet.

The new OS, reduced line lengths, better distribution of ports, and improved software maintenance resulted in a much improved system and higher reliability. Also, the daemon program Pluto is running again, logging members into lab whenever they use a terminal inside, — a much desired feature. We are missing only one piece of the complete lab management system, the utilities monitoring program, BLIMP, which has been down since the first upgrade a year ago. Repairing the Aureau data collecting computer and the BLIMP program will receive high priority in 1992.
Two new pieces of peripheral equipment were added.

- We bought a new cassette tape drive for Argon to facilitate dumps. Previously, Argon and Radon shared one.

- We inherited from Prof. Brodersen a Sun 3 tape drive, for making tapes for photolithography masks. We have upgraded the tape drive on the pattern generator to accept both 800 bpi and 1600 bpi density tapes. This allows us to still use our old mask tapes and also the higher density tapes that the Sun 3 drive produces. The Sun 3 tape drive is located in the lab lobby, running on Zirconium, a Sun 3 client of Argon. This arrangement, which has just been completed, will greatly simplify turning layouts into masks. At the same time, we do not have to maintain the old, problematic Aviv tape drive, which we shared with ILP. (ILP is already in the process of obtaining a new one for their own use.)

The Microlab has completed the long and arduous process of separating lab maintenance and CIM research activities. This does not mean, however, that we can relax. As I pointed out in my report last year, both hardware and software have finite life spans, just like any other equipment in the lab. If we do not keep up with new developments, they will become obsolete fast, even faster than the rest of the machinery. I can already see another upgrade looming on the horizon.

**SUMMARY**

This report, along with the others submitted by the Microlab’s professional staff, provides an overview of Microlab activities in 1991. Major issues discussed are staff supervision, equipment maintenance and development, interaction with faculty and research groups and fiscal management. Microlab operations are under control and within budget.
Figure 1.
Microlab Monthly Recharge Income and Expenditures
Fiscal Year 1991/92

Figure 2.
## Second Quarter Budget vs. Actual Expenditures
(7/91 - 12/91)

<table>
<thead>
<tr>
<th>Item</th>
<th>OC</th>
<th>Expenditure</th>
<th>6 Mo. Budget</th>
<th>% +/-</th>
</tr>
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<tbody>
<tr>
<td>Misc. Equipment</td>
<td>8026</td>
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<td>Wafers</td>
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<td>18603.25</td>
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<td>LN/O2</td>
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<td>Masks</td>
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<td>Lam Etchers</td>
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<tr>
<td>Machine Shop</td>
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<tr>
<td>Computers</td>
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<tr>
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<tr>
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<td>Electrical Supplies</td>
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<td>Disco Saw</td>
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<td>Copier</td>
<td>5305</td>
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<td>Books</td>
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<td>Misc./Tax</td>
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<td>1500.00</td>
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<td>Travel/Courses</td>
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<td>365.00</td>
<td>720.00</td>
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<tr>
<td>Tools</td>
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<td>600.00</td>
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</tr>
<tr>
<td>Phtherm</td>
<td>8052</td>
<td>290.85</td>
<td>300.00</td>
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<td>CSSEM</td>
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<td>157.63</td>
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<td>Drafting</td>
<td>7214</td>
<td>0.00</td>
<td>600.00</td>
<td>-100%</td>
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</tbody>
</table>

Sub 3&4 subtotal      | $254,899.04 | $240,450.00 | +6%    |
(Supplies & Expenses)

Sub 2&6 subtotal      | $216,726.13 | $222,300.00 | -3%    |
(Salaries & Benefits)

Total Expenditures    | $471,625.17 | $462,750.00 | +2%    |
Total Income          | $482,998.43 | $487,740.00 | -1%    |

rs 1/92

Table II.
1992 Year End Report

MEMORANDUM

To: Ping K. Ko, Faculty Director
From: Katalin Voros, Microlab Manager
Subject: 1992 Year-End Report
Date: January 11, 1993
cc: P. R. Gray, M. Lieberman, C. Spanos

From my year-end summaries of Microlab activities and goals a picture emerges which shows pragmatic progress over the years. The year 1992 fits the pattern, as can be seen in this sixth report.

SUPERVISION OF STAFF

The number of the Microlab's direct support staff remained the same for the last three years, 15 FTE's. With the initiation of the baseline process in April 1992, the number of associated researchers grew to 8 FTE's. (See Figure 1.)

Personnel highlights of 1992:

- We celebrated the following employment anniversaries:
  
<table>
<thead>
<tr>
<th>Name</th>
<th>Years of Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bob Hamilton</td>
<td>25</td>
</tr>
<tr>
<td>James Parrish</td>
<td>15</td>
</tr>
<tr>
<td>Evan Stateler</td>
<td>10</td>
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</table>

- Tariq Haniff was reclassified to Assistant Development Engineer.
- Debra Hebert received an A&PS Professional Development Award.
- Debra Hebert was reclassified to Assistant Development Engineer.
- Mark Kraitchman was reclassified to Programmer/Analyst II.
- Marilyn Kushner received her Associate Arts Degree in Liberal Arts at Diablo Valley College.
- Rosemary Spivey was reclassified to Administrative Assistant III, Supervisor.
- Katalin Voros was reclassified to Principal Development Engineer.

Employee development continued to be an important factor in keeping staff motivated. Last year's College of Engineering Training Days Program was very successful with every Microlab staff member attending at least one workshop. (See my memo to Dean Hodges, January 28, 1992.) During our regular monthly staff meetings we had two seminars, one by an outside speaker on technical writing and one by Debra Hebert on methods of statistical process control. We are taking advantage of the computer classes offered by TCS, departmental seminars, workshops, extension and outside courses offered throughout the year. One of our goals as Microlab supervisors is to encourage and help staff to continue developing professionally.

Following the Chancellor's emergency budget meeting with MAP members in May, I have discussed the discouraging UC budget news with Microlab staff. Subsequently, I sent a memo to the ERL Director with our concerns about budget cuts and proposed staff reductions measures. (UC Budget Problems, dated May 26, 1992.)
Year-end reports of the Microlab’s supervisors are attached. For further details on each group’s activities see the following reports:

Maintenance Staff: Bob Hamilton, Supervisor, Safety Officer,

Process Staff: Debra Hebert, Supervisor,

Administrative Staff: Rosemary Spivey, Supervisor,

Computer Support Staff: Christopher Hylands and Mark Kraitchman.

The Microlab’s computers are supported by Mark Kraitchman, Programmer/Analyst II, full-time and by Christopher Hylands, Programmer/Analyst II, half-time. The other half of Christopher's time is taken up by supporting CIM research. Because Microlab and CIM activities are interrelated, the areas of responsibility are somewhat overlapping. The common goal is, however, to keep the systems up and reliable. Basically, Mark handles all "production" (i.e., those used in running the Microlab) software, application programs and database. Christopher takes care of both the Argon and Radon systems' hardware (servers, clients, peripherals), and systems administration. The two P/As work well together, act as back-up for each other, and complement each other’s work. Because of this, we made great improvements in system uptime and reliability.

A major accomplishment this past year was the release of our lab management software, BCIMS (Berkeley Computer Integrated Manufacturing System) to the Industrial Liaison Program. (See my memo BCIMS Software Release, October 1, 1992.) BCIMS was included in the Fall 1992 ILP catalog. We sent copies to over 120 institutions which indicated an interest through their visitors here over the years. We have received some inquiries already about obtaining BCIMS.

Associated Researchers: See individual reports.

Although these development engineers are directed by their PI's, I have bi-weekly meetings with them to discuss projects. This is necessary because the associated researcher’s work has an impact on the whole lab and must be coordinated among the various groups. I will discuss specific projects in the next section.

INTERACTION WITH FACULTY AND RESEARCH GROUPS

Baseline

Last year Prof. Spanos proposed to initiate a baseline process in the Microlab, and by February 1992 several groups and the Microlab joined in funding a development engineer's position. (Budget: $90K/year.) The purpose of the baseline process is to maintain standard process steps used by all groups and to produce cmos circuits for the supporting groups. The operation of the baseline provides immediate feedback on equipment performance and maintains processes in calibration.

At the beginning of April, Shengqing Fang joined the staff as an associate development engineer to run the baseline. A recent graduate of the University of Hawaii (MS in EE), Fang came on board quickly and started to characterize, modify and stabilize the Microlab’s cmos processes. (See S. Fang’s status reports and year-end summary.) We are using the test chip designed by P. Kraeger (ERL Memorandum M88/82) which has a pad layout allowing automated testing. Vadim Guninik, undergraduate laboratory assistant, is working on auto-test procedures, and upgrading computer data acquisition.

The baseline is supporting 2µm p-well and n-well, double poly technology, and has started to produce wafers for two contributing groups.
BSAC

The Berkeley Sensor and Actuator Center includes ~22% of the Microlab’s membership and provides ~32% of the lab’s income. Their wide-spread research activities involve the use of both the clean VLSI line and other, potentially contaminating processes. They are interested in building cmos circuits, but while they are fabricating the sensor and actuator elements they are placing conflicting demands on equipment. From the beginning, the most often occurring requests were to place metallized wafers into the LPCVD tubes. The simplest solution would have been to set up a second set of furnaces for sensors applications. Lack of funds precluded this action and we had to implement shared use as well as prohibit some processes. At the same time, we were looking to alleviate restrictions, at least partially, by building a new LPCVD system in-house, using purchased components. This placed a tremendous burden on our resources but by 1988 we constructed a second poly-si tube (tylan16) for the use of the sensors group. The project was financed completely by the Microlab.

In 1989 BSAC PIs at our request, proposed to include in the BSAC budget $100K yearly for equipment. This resulted in the installation of bank5, with one tube (tylan20) retrofitted for low temperature oxide deposition, completed in August, 1990. A third LPCVD tube, a low-stress Si nitride deposition system, was completed in December 1992. The total cost of ~$160K was equally shared between BSAC and the Microlab. Thus, we now have a full complement of LPCVD systems dedicated to sensors applications, and conflict of interest issues should be eliminated.

Cryoelectronics

Dave Hebert submitted a request to bring additional equipment into the Microlab for dedicated use by the Cryo group. We had many discussions about the feasibility of the addition of several major pieces of equipment and after careful consideration of all possible ramifications we came up with a plan to accommodate them. At the same time, I reiterated our request that the Cryo group hire a technician to maintain their own equipment, to which they agreed. (See my memo dated 2/12/92, and D. Hebert’s memo of 2/13/92.)

The first piece of equipment brought in was a refurbished wafer stepper (geaps2), identical to the lab’s existing stepper. The installation required the move of several instruments and the expansion and reconstruction of the stepper environmental chamber. All acquisitions and moves are financed by Cryo; however, these cannot be done without the assistance of Microlab staff. Also, we have to plan carefully to minimize the impact of the moves on the rest of the lab. Cryo expansion is continuing.

Competitive Semiconductor Manufacturing (Sloan)

This past year I have been participating in a joint project with researchers from engineering, business, and economics. The Competitive Semiconductor Manufacturing research survey is a 3-5 year study co-directed by Professors D. Hodges and R. Leachman, supported by the Sloan Foundation.

The project’s charter is to "measure manufacturing performance and identify underlying determinants of performance in the semiconductor industry." We have completed the pilot phase (visits to three manufacturing plants to establish and test our methodology) and are well into the main phase of the study, with visits to seven additional plants. I cooperated in developing the site visit interview guide, and participated in five visits. The first working paper in the main phase is currently being written; I am co-author on the New Process Introduction and Process Control chapters. My purpose in joining this research project was to update myself of current industrial practices and develop a feel for which way manufacturing processes are heading — information essential in managing the Microlab.
Laboratory Operations and Safety Committee (LOSC)

I have been appointed by the Provost for Research to serve as a member of the newly established Laboratory Operations and Safety Committee, for the 1992-93 academic year. Professor R. Bergman of Chemistry is chairing this campus-wide committee, which has the assignment "to bring good safety practices to campus laboratories and to oversee their implementation." Issues currently under discussion with the assistance of the Office of Environment, Health and Safety are: development of safety, injury and illness prevention plans, toxic compliance management, fume hood inspection and maintenance program, and review of environmental compliance training modules. Both Bob Hamilton, the Microlab's Safety Officer and I have reviewed and commented on material concerning the above issues.

Public Relations

The Microlab had 252 visitors inside the lab in 1992, according to the list registered on the computer. In addition we had many others, who received a window tour and video presentation.

Microlab supervisors and I are spending considerable time in dispensing information about facilities, processes, safety and all matters concerning running and financing a lab like ours. It is hard to believe, but the "new" lab will be 10 years old this Spring. During these years we have accumulated a fair amount of experience in laboratory management, which we are glad to share with others in the hope it will help them.

We are assisting ILP in the process of assembling a new Microlab booklet for publication in 1993.

FISCAL MANAGEMENT

MICROLAB INCOME
FROM RESEARCH GROUPS

Figure 2.
Figure 2. shows Microlab income for the last five fiscal years and also indicates contributions by the various research groups. The gradual increase from $620K to $975K in five years is partially due to inflation, but also to increased membership and higher lab use by each member. Income per member increased by ~23%, from $5,170.00 to $6,370.00, only half of which can be attributed to inflation. The fact is, that the lab is being used more.

The Microlab is maintained on recharge income, which must cover all costs pertaining to operations. The budget contains salaries and benefits for 12 FTE's, allocations for supplies and expenses, including utilities, computers, and debt recovery payments. (For details see my Financial Report, Fiscal Year 91/92.) The Microlab receives additional support from EECS/ERL in the form of salaries and benefits of three FTEs. OPR provides and maintains power, air conditioning, city water, and compressed air.

Because we are a recharge unit the budget cannot include new equipment appropriations. Equipment purchases have been made by research groups from their own grants, and to a limited extent from donations and Departmental funds. Our resources for equipment replacement are woefully inadequate and as our facility is aging, should be of concern to all member PIs.

The operating budget is under control and we have met our goals for the sixth year in a row. Although we have been paying off our debt at a regular rate of $40-50K/year since 1988, we still owe the University $187K. Half way into the current fiscal year we are on target. (See R. Spivey's year-end report.)

FACILITIES DEVELOPMENT

OPR Utilities

The Microlab is facing several utilities problems. Items that fall under the jurisdiction of the Office of Physical Resources (OPR):

Environmental Control
- The MPS (medium pressure steam) delivery to the Microlab is insufficient; therefore, during the winter months the temperature of supply air falls far below the ± 2° tolerance of the Microlab. OPR has promised improvement for several years (first request was made in 1989); however, corrective actions proved insufficient so far.
- The air conditioning system (McQuay chiller) has become so problematic that it should be replaced. This year we had monthly failures. Every time the air conditioner fails photolithography and mask making has to be suspended. Exposure tool tolerances fall out of spec and it takes 24 hours for the wafer stepper and pattern generator to stabilize.

Water Supply
- Marginal industrial water capacity coming into the Microlab continues to plague operations. ICW pressure dips below the minimum required by the Microlab, in spite of efforts to reduce and minimize water usage by equipment. In 1988, OPR had arranged for partial replumbing of incoming lines; however, the problem persists and needs attention.

Drains
- The city of Berkeley and UC's Office of E, H & S place stringent requirements on effluents, with which we have been in compliance since the new lab was built. Unfortunately, the building's plumbing has seen decades of unregulated service and shows signs of decay. Past sins caught up with us when one of our main drain pipes developed a leak early last year. Replacement required cutting the concrete basement floor, at a total cost of $18,500.00. OPR accepted half of the expenses, with the other half coming from EECS/ERL and the Microlab. We ended up paying $2,312.00 — an unexpected encumbrance.
Power

- With the addition of a new transformer and some judicious planning we were able to add needed power in the VLSI area. We now have capacity to complete all four furnaces in tylanbank5 and to continue with the Cryo expansion.
- Frequent campus power interruptions during the last three years prompted us to look into back-up power generation. The cost estimate given by OPR is $100 - $150K, which we do not have. OPR is not willing to pick up the tab. They promise however, that with the campus power upgrade nearly completed service should improve.

Custodial Support

- This past year we have seen a serious reduction in custodial support. This problem has become worse towards the end of the year and custodial support of the Microlab has fallen below acceptable levels. We have been informed that OPR reduced the number of custodians assigned to Cory Hall; however, the situation is untenable. I will send a memorandum to OPR stating the above concerns.

Equipment

Bob Hamilton’s year-end report details equipment installations and upgrades. Major additions this year:

- Construction of new LPCVD tube for deposition of low stress Si-nitride films (for BSAC).
- Addition of second GCA wafer stepper (refurbished g-line for Cryo).
- Redesign and completion of magnetron sputtering system for deposition and recrystallization of PZT films (for BSAC).
- Facilities modification for and installation of refurbished Lam Rainbow etcher (for standard poly-Si etch, motivated by CIM). This project is nearing completion.

Computers

Since building of the new lab CIM research has been the motivating force behind the Microlab’s efforts in keeping up with computer developments. At first we shared machines but later, as Microlab operations matured, computers were separated into two independent but related systems. Now, the major component of our support of CIM research is providing equipment communications with computers. This task, however, proves to be more difficult than it might seem. 67% of lab equipment have manual/mechanical controls, and do not communicate at all. 25% are controlled by some kind of dedicated computer which enables data access but not two-way communications. 8% have SECS II ports (Semi Equipment Communications Standard). This means that CIM researchers can work with nine (six processing, three analytical) machines. (A complete cnos process, not counting mask making, requires 32 different pieces of equipment, each with multiple controls and sensors.) Data can be down-loaded in one direction from 29 machines. Thus, equipment upgrades are important not only for advanced device/circuit processing but also for CIM research.

Computer improvements in 1992:

- Upgrading a Sun3 to Sparc2 (arsenic), for development work.
- CD-ROM addition to arsenic to facilitate upgrades.
- Installation of two x-terminals for staff members.
- Additional memory for gallium (16 MB).
- Video frame grabber board for gallium (CIM).
- Acuraex/BLIMP expansion to additional sensors.
- Ingres upgrade to 6.4.
- Computer manual update/additions.
- BCIMS software release to ILP.
- Equipment communication (autoprobe, C-V system, lam1&2, photoresist inspector, SEM image, tylan18, 20).
LOOKING FORWARD

As part of dealing with reduced budgets and in the interest of developing strategies to handle related issues, Chancellor Tien asked for submission of five-year unit plans. In my memo to the ERL Director, (5-Year Plan, dated August 24, 1992) I discuss the questions, as I see them, of where we are going to be in five years, what changes in space, major and minor capital improvements will be necessary, and will we be able to support our graduate student research demands?

After reading this report, the answers can be clearly deduced. The Microlab embarked on a steady course of action and in five years we will still be in this mode. Our major supporters will remain the same, with some groups increasing, and others decreasing their activities, but still in balance, without domination of any one group.

The Microlab is a service unit and its well-being depends on the vitality of the research programs in EECS/ERL. All indications are that we can plan on their continued, steady support, with perhaps a low-rate growth within existing boundaries. There is simply no space for expansion, nor should it be necessary. We see no increase in our user base without which we could not maintain a larger lab.

Continued high quality support of our members’ research projects will require significant improvements in environmental control, utilities upgrade, equipment replacement at a higher rate than we were able to do until now, and more sophisticated computerization. I am addressing these issues daily and will continue to request faculty assistance in meeting our needs. I can say with all earnestness that support has been forthcoming and I have no doubt that it will continue in the coming years. The staff of the Microlab is ready for the challenge.

RS
1/93
MICROLAB STAFF
December, 1992

Katalin Voros
Laboratory Manager
Principal Development Engineer

Ping K. Ko
Faculty Director

MAINTENANCE
Robert Hamilton
Maintenance Supervisor
Senior Development Engineer

Phillip Guillory
Development Technician V

Robert Hahn
Development Technician IV

Mike Linan
Development Technician IV

James Parrish
Principal Laboratory Mechanic

Evan Stateler
Development Technician V

Ken Vavrousek
Student, Laboratory Assistant I

ADMINISTRATION
Rosemary Spivey
Administrative Supervisor
Administrative Assistant III

Susan Kellogg-Smith
Purchasing Assistant I

Jun Okada
Student, Clerk

Todd Stepp
Student, Laboratory Assistant I

PROCESS
Debra Hebert
Process Supervisor
Assistant Development Engineer

Marilyn Kushner
Staff Research Associate I

Maria Perez
Staff Research Associate II

Daniel Cullen
Student, Engineering Aide I

Vadim Gutnik
Student, Laboratory Assistant II

Robert O'Donnell
Student, Laboratory Assistant II

COMPUTER SUPPORT
Christopher Hyland
Programmer/Analyst II

Mark Krutchman
Programmer/Analyst II

ASSOCIATED RESEARCHERS

<table>
<thead>
<tr>
<th>STAFF</th>
<th>RESEARCH/PRINCIPAL INVESTIGATOR</th>
</tr>
</thead>
</table>
| John Benasso
Associate Development Engineer | Plasma: M. Lieberman |
| James Rustillo
Senior Development Engineer | Berkeley Sensors and Actuators Center R. Howe, R. Muller, A. Pisano, R. White |
| S. Fang
Associate Development Engineer | Baseline CMOS Process C. Spanos |
| Kim Chan
Staff Research Associate II
Richard Hsu
Associate Development Engineer | Deep UV Lithography A.R. Neureuther, W.G. Oldham |
| Tariq Haniff
Assistant Development Engineer | Device Group C. Hu, P.K. Ko |
| To be filled
Development Technician V
David Hebert
Senior Development Engineer | Cryoelectronics T. Van Duzer |

Figure 1.
1993 Year End Report

MEMORANDUM

To:        M. Lieberman, ERL Director
From:      Katalin Voros, Microlab Manager
Subject:   1993 Year-End Report
Date:      15 January 1994
cc:        D. Messerschmitt, C. Spanos

INTRODUCTION

The following pages comprise the year-end reports of the Microlab's professional staff. The first group, as shown on the cover page, is responsible for maintaining equipment, utilities, processes, administrative operations, and for supervising and managing the Microlab.

The second set of reports is by associated researchers, who are not directly involved with the daily maintenance of the Microlab. Associated researchers receive project assignments directly from professors they work for and are responsible to them. Associated development work enhances the overall capabilities of the Microlab as well and helps all members interactively. We have had this joint system in place since the opening of the "New Lab", and we consider it a successful arrangement for all concerned.

This is the seventh year-end review I am submitting as manager of the Microlab and am happy to report that the Microlab's affairs are in good order. Two major events took place in 1993: Professor Costas J. Spanos succeeded Professor Ping K. Ko as Microlab Faculty Director, and we celebrated the 10th Anniversary of the dedication of the "New Lab".

Professor Ko served as our Faculty Director for eight years, since 1984. Under his leadership, with the support of his faculty colleagues, the Microlab developed into a university facility known world-wide. We, the staff appreciated his forward thinking and commitment to education, along with his direct, no-nonsense style.

EECS/ERL established its integrated circuits fabrication laboratory in 1962. A major renovation, expansion and modernization was completed in 1983 and the "New Lab", as we called it then, was dedicated during the Industrial Liaison Program Conference in March 1983. We took the opportunity of the same conference to celebrate the 10th anniversary on 11 March 1993. With many lab alumni attending and recalling their experiences, the event was a great success.

MANAGEMENT OF STAFF PERSONNEL

The number of direct support staff remained constant for the last four years, 15 FTE's. After some personnel changes, the total number of associated researchers also remains the same as last year, 8 FTE's. (See Figure 2.)

Personnel highlights of 1993:
- Phillip Guillory received a Special Performance Award.
- Bob Hamilton received the Wil Zeilinger Staff Excellence Award.
- Janice Parrish received a Special Performance Award.
- Evan Stutler received a Special Performance Award.
- Vadim Gutnik, an undergraduate student assistant for the past three years, received a Bechtel Foundation Scholarship Award. Also, he was selected to participate in the Department's Honors Program in the Spring and Fall Semesters of 1993.

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UC's budget problems continue to adversely affect employee compensation. Although the Microlab is a recharge unit and staff salaries are covered from research funds, merit increases could not be given last year because of University policy. In the middle of 1993 a second Time Reduction Incentive Plan (TRIP) was offered. Two technicians took this second offer (one took it last year) at 10%. Staff salaries were reduced by 5%, (partially restored in November) regardless of funding. These kinds of actions make it difficult to retain talent and do not encourage loyalty. Microlab supervisors deserve credit for maintaining a smooth running operation and providing leadership. (See reports by Bob Hamilton, Debra Hebert, and Rosemary Spivey.)

INTERACTIONS WITH FACULTY AND RESEARCH GROUPS

Baseline
By all accounts the baseline process turned out to be a success. We have maintained a stable CMOS process and provided several groups with working circuits. Process and equipment problems were quickly identified, and corrective actions taken. We are well underway in selected statistical process control (SPC) projects, which will further improve reliability. At the same time, we are developing new modules, such as double metal for interconnections and reduced device sizes, and schedule runs in such a way that we may accommodate all supporting groups. (See S. Fang’s report for details.)

Berkeley Sensor and Actuator Center (BSAC)
BSAC membership continues to be a strong presence in the Microlab. Jim Bustillo’s report (attached) illustrates the wide range of activities covered by the group. Most noteworthy is the successful development of Modular Integration of CMOS and Microstructures (MICS), comprised of baseline cmos circuits on the front-end with sensor/actuator-specific back-end processes. Significant advances were made in improving robustness, standardization of process flow and geometric design rules. Our joint efforts during the previous years to provide sensors research with appropriate equipment have paid off and allowed the excellent progress made this year. The Microlab now supports a full complement of sensor-specific LPCVD tubes (poly-Si, Si-nitride, LTO/PSG) with variable process conditions, a good combination of plasma/RIE etchers, and various specialized equipment, such as temperature controlled etch baths and a critical point drying apparatus. In addition to buying their own dedicated equipment, BSAC has been contributing $50K for the second year, to the general equipment fund. With contributions from other groups this allowed us to replace and upgrade the photore sist dispense/develop systems. There is now good synergism between BSAC and other activities in the Microlab.

Berkeley Computer-Aided Manufacturing (BCAM) Research
Within the larger sphere of computer integrated manufacturing (CIM) Professor Spanos’s research group is concerned with Computer-Aided Manufacturing (CAM) applications. The BCAM system is a framework built to facilitate various CAM applications, such as: communication with processing equipment, real-time monitoring, real-time statistical process control (SPC), etc. The Microlab’s role in supporting this group’s research is to provide a test site and practice projects for CAM. Besides adding enabling technology we look for processes where CAM projects can be piggy-backed to other groups’ work. For example: in response to BCAM’s demonstration that in-situ particle monitoring can be used as a metrology tool, we are installing a particle counter, on loan from High Yield Technology (HYT), in the poly-Si etcher (Lam Rainbow) exhaust manifold. These types of projects are continuing and are the major motivating force behind keeping the Microlab current in computer developments.

Cryoelectronics
Cyro expansion progressed according to the well planned time-line we negotiated last year. Dave Hebert’s report (attached) describes the major system installations and moves: a refurbished G-line 10X wafer stepper, a new room-temperature plasma deposition system; the upgrade of their 3-target sputterer (topgun) and moving it into a cleaner location within the Microlab. All these activities involved cooperation and support from the staff. Dave Hebert managed the projects with concern for the smooth operations of the
rest of the laboratory and he was successful in completing each installation causing minimal disturbance. Addition of a second 10X wafer stepper was clearly a judicious choice; besides giving cryo researchers complete control over their own exposure tool, it serves as a back-up system for the general stepper, and handles overflow capacity. On another front, we have learned a great deal about mix-and-match of exposure tools and the experience helped us expedite the GIT/MIT/UCB interlaboratory project (described below) with great dispatch.

Devices and Technologies

- Professors Hu and Ko's group activities in building devices for modeling, reliability and novel structures studies have always provided the Microlab with useful feedback about process conditions and cleanliness. Before the advent of the baseline they were our sole metrology group. This year, the device professors motivated yet another improvement in our analytical capabilities. Joining with the Cryo group, they purchased an atomic force microscope and made it available to all lab members. The Topometrix AFM has been installed and tested; we are working on further isolating it from acoustical noise.

The device group went through a personnel change when Tariq Haniff, Assistant Development Engineer, resigned to accept another position. Subsequently, Peter Guo was hired; he started working with the group in November. (See report attached.)

- When the NSF proposal (91-140) received funding for the project titled Acquisition of Instrumentation to Fabricate Low-Dimensional Artificial Materials, technology research interests branched out in a new direction for us, namely e-beam direct writing. This proposal was submitted jointly by several professors from EECS, MSME, and Physics, all supporters of the Microlab. The grant provides for the installation of a nano-structure lithography system for e-beam writing with modified SEM, in the first year. Although located on the first floor of Cory Hall, in a dedicated environment-controlled room (107), the new instrument became part of the Microlab infrastructure and is being managed as such. The new JEOL JSM 6400 SEM with JCN Lithography Systems Pattern Generator software is going through final acceptance procedures. The "Nanolab" project is being managed by Dr. Nathan Newman, MSME staff. Facilities preparation was completed in-house with the assistance of EECS's Technical and Computer Services group, Alex Para project coordinator, Microlab staff, and Campus Services Stationary Engineer, Scott McNally. The instrument is now a Microlab equipment, with login name: jeol107. All those who wish to use it must become Microlab members and follow standard equipment qualification procedures.

Laboratories' Network Proposal (NNUFIN)

In October 1992 the National Science Foundation published a call for proposals to form a National Nanofabrication Users Facility Network (NSF 93-43). In early 1993, after many discussions with PIs at several other universities we decided to submit a joint proposal with MIT, Georgia Institute of Technology, Purdue University, University of Minnesota, University of Texas (Austin), University of Wisconsin. To demonstrate our ability to work on joint projects, we completed an NMOS process with sensor back-end in three weeks. The test was designed and laid out at GIT; MIT and Berkeley did mix-and-match processing, GIT added back-end and testing, all done during July, 1993.

NSF conducted a site visit at MIT (proposed main node) on 2 August, and at Berkeley on 6 August 1993. The full day program consisted of presentations by the proposing institutions in the morning, and facilities tour and question-and-answer sessions in the afternoon. The 12-member reviewing team of experts was comprised of participants from several universities, companies and NSF. I worked with Professors Spenos and Bokor who were the major PIs involved from here. In addition, we had tremendous support from many others on the faculty, EECS Chairman and Dean of Engineering. Although NSF opted to fund the Stanford-Cornell network proposal, we all believe that the work invested in establishing contacts is not lost and will enable us to foster further cooperation.
Competitive Semiconductor Manufacturing Survey (Sloan)
In 1993 I continued to participate in this joint research project, headed by college of Engineering Dean D. Hodges and Prof. Lenchman of IEOR. The first report on results of the Main Phase came out in April 1993; we are currently writing the second one. The group visited a total of 15 semiconductor manufacturing facilities in two years, (I participated in seven visits,) collected and analyzed data and presented a summary and discussion of effective manufacturing practices. The program received funding to continue next year.

Laboratory Operations and Safety Committee (LOSC)
I continue to serve as a member of the Campus Laboratory Operations and Safety Committee, during the 1993-94 fiscal year. Professor Richard Anderson of Chemistry is the new Chairman. We have worked on the following issues this past year: oversight of safety committees and plans for departments/units with laboratories; Injury and Illness Prevention Program (IIPP) regulatory requirements; regulated carcinogen survey; City of Berkeley toxics compliance program; health and safety programs and informational materials to Campus. Bob Hamilton, the Microlab’s Safety Officer and I have reviewed and commented on material concerning these issues.

EECS/ERL Supervisors Group
In the interest of maintaining communications among the various staff groups working in the Department and ERL, last year we decided to continue the regular monthly supervisors meetings, which Wil Zeilinger originated a long time ago. I was elected chairman of this group for 1993, which involved moderating of meetings and e-mailing out the minutes. Besides transferring information pertinent to all groups we discuss timely issues and problems, and look for solutions. Among the subjects last year were the following: building matters (Cory, Evans, Sode); campus utilities and custodial services, computer services and networking, shops and Microlab operations, staff and administrative issues, safety and other regulatory requirements, employee development.

Microlab Members’ Meetings
We have been holding regular monthly laboratory members’ meetings for four years now with beneficial results. We found that these meetings are a good forum for minor, sometimes irritating issues which often are not reported on the computer officially as a problem. We also give members a chance to come up with ideas for improvements. Sometimes, these happen during general discussions. Although attendance is not overwhelming, 10-15 members on the average, the minutes, e-mailed to all students and their professors, provide information to everyone. We follow up on each item left open, in the next issue. Microlab supervisors alternate with me in moderating these meetings.

Public Relations
- The Microlab had 295 visitors inside the lab in 1993, according to the sign-in list on the computer. As usual, we had many others, who received a window tour and video presentation.

- The great event of the year of course, was our 10th anniversary celebration. Dean David A. Hodges initiated the occasion by saying thanks publicly to our outgoing Faculty Director, Professor Ping K. Ko and welcoming the new, Professor Costas J. Spanos. Professor Oldham, who was the driving force behind the creation of the "New Lab" contributed stories and a time-lapse film of the construction. Media Services copied the film to video tape, dubbed it with an appropriate sound track, effectively making it an entertaining short-subject motion picture. Reminiscing — both official and personal — went back all the way to the roots, the 1960’s, when the Department first established an early integrated circuits laboratory. The present Microlab is a direct descendent of that first facility.

- Our attractive new brochure, Microfabrication at Berkeley came out in March 1993, ready for the anniversary celebration. It was published by the Industrial Liaison Program, EECS, in collaboration with the Microlab and with support from the Department Chairman. We had 2000 copies printed which should last for two years.
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- At the invitation of Dr. Chi-Ming Chang, Deputy Director of ERSO/ITRI, I participated in the Semiconductor Manufacturing Technology Workshop, March 22-26, 1993/Hsinchu, Taiwan and presented the seminars: R&D Laboratory Management I-II. I also visited the National Nano Device Laboratory (NDL seminar: Equipment control in the Berkeley Microlab), and the facilities of ERSO/ITRI, and National Chiao Tung University.

FISCAL MANAGEMENT

Support from our various research groups remained strong, in fact increased in the current fiscal year. In the interest of serving our members better and to streamline accounts administration we reviewed charging policies and procedures. We were also looking for options within the University’s administrative structure to allow more flexibility in handling outside requests. This was in light of the NSF proposal we jointly submitted with PIs from seven other institutions, for the support of a network of laboratories.

The outcome of our discussions with David Brown of the Campus Recharge Committee was, that the Sponsored Projects Office (SPO) reiterated the policy that sundry accounts be charged standard UC overhead; however, moneys received from overhead may remain in the recharge account of the Microlab. This of course is good news and we are planning to use the reserve to upgrade equipment. Because this savings policy took effect in November 1993 we cannot provide an estimate of amounts accrued, but by the end of the current fiscal year (June 1994) we shall have a better idea. Also, only about half of our outside users are overheaded, as universities are exempt on a reciprocity basis. Figure 1. shows the proportions of contributing groups to the Microlab’s recharge income. For further details see R. Spivey’s report.

UCB Microlab
Income from Research Groups
FY 92/93

Figure 1.
FACILITIES

Physical Plant-Campus Services

We have addressed several facilities/utilities problems this past year, which are under the jurisdiction of the campus department now called Physical Plant-Campus Services. (Campus Services for short; they prefer not to use an acronym.)

• Power Delivery

Campus power interruptions (planned or unplanned) reached an intolerable level during 92-93 and prompted us to send a memorandum to J. Torrez, Director, Physical Plant-Campus Services, requesting improvement of power reliability. (Memo from C. J. Spanos and K. Voros, dated 21 April 1993.) After Mr. Torrez's written reply we had a joint meeting with his high level staff and Cory Hall managers. (Follow up memo dated 3 June 1993.) The high-level meeting was followed by a visit of 16 employees of Campus Services, representatives from each trade, to the Microlab on 18 July. Microlab Management gave an informative presentation, after which we had an open discussion of problems and took the visitors on a laboratory tour. The most important outcome of the correspondence and meetings was that we established communications with Campus Services, from trades people to directors, and brought the critical nature of our operation to their attention. (Further details in R. Hamilton's report.)

• Environmental Control

The Microlab's air conditioning system (McQuay chiller) is on its last leg. A poor design to begin with, it limped along for 10 years, never giving optimum performance. This past year has been disastrous. Frequent failures caused such temperature excursions that experiments and delicate equipment were ruined and proper laboratory environmental control became nearly impossible. We have provided Campus Services Director of Deferred Maintenance Projects, Peter Lin, with extensive data and replacement justification; however, no response has been forthcoming. (Memo by R. Hamilton, 15 March 1993.) In the meantime Campus Services is spending an unreasonable amount of resources maintaining a piece of equipment which is energy inefficient, a noise polluter, and unreliable.

Further details on campus utilities can be found in R. Hamilton's report.

Microlab Equipment

Robert Hamilton's report details equipment maintenance, upgrades and installation. 1993 highlights were:

• Replacement of the old, problematic wafer track with a refurbished, but much later model SVG wafer track. Most importantly, this system has computer communication capability, which will support BCAM research projects.
• Bringing on-line a refurbished Lam Rainbow etcher. This system provides additional plasma etching capacity and computer support for BCAM projects.
• A new Tepomertec atomic force microscope, to strengthen the laboratory's materials characterization capability.
• A new Plasma Quest plasma deposition system for room temperature deposition of SiO2 films, for low temperature superconductor devices (dedicated to cryo).
• New JEOI SEM installation in a separate room on the first floor of Cory Hall (107). The primary use of this instrument will be e-beam writing.

Except for dedicated equipment, all acquisitions were jointly funded by several research groups. In each case the Microlab provided staff assistance in researching, purchasing, partial funding, site preparation, installation and process characterization; again, showing success of the cooperative approach.
Microlab Computers

- With the resignation of Christopher Hylands who accepted another position within ERL, we have reorganized argon/radon system administration, to provide more direct support to BCAM research. The position had been reclassified into a Programmer/Analyst III with emphasis on research software design, development, and support. Administrative duties for Microlab machines were reduced and funding assigned at 70/30 BCAM/Microlab. Dave Mudie started working in this new position on 15 November. (See D. Mudie's report, attached.)

- Mark Kraitchman has been assigned the additional duties of argon system administration and hardware support. Accordingly, a reclassification request to PA III has been submitted to reflect the change. The two programmer/analysts provide back-up to each other and assist the BCAM group and all Microlab members effectively and efficiently. (See Kraitchman's report, attached.)

- Systems uptime was at an all-time high all during last year. The rewards of the efforts of our computer support people in automating maintenance, improving robustness and reliability are showing and continue to pay off. I am satisfied with the status of our systems and will continue to develop plans to keep abreast with demand.

Computer improvements in 1993:

- Upgrade of a Sun-3 server to a Sparc server (krypton).
- Automatic probe station computer upgrade (lead).
- Color NCD terminal installation for CAD work by technicians.
- Ingres database tuning.
- Systems security improvements.
- Network Improvements:
  IS&T-DCNS installed a new router to service our subnet.
  TCS wiring crew installed a 10Base-T hub (connected to the Microlab segment of the subnet) on the 5th floor and ran twisted pair drops to the workstations in 524.

COMMENTS

My association with the Microlab began at about the time of the dedication of the "New Lab", 10 years ago. It seems as if it was only yesterday. When we are so involved in our daily work that there never seems to be enough time to rest, it is good to halt for a moment at a milestone. The anniversary celebration of the Microlab was such an occasion — a time to take stock, to reflect, and to gather strength for the coming tasks from what we accomplished. And thus, each year we build upon last year's achievements, standing on the shoulders who were before us, and hope to contribute towards the progress of the larger unit. We strive for nothing less, and hope to accomplish more, in the next decade.

RS
1/94
MICROLAB STAFF
December, 1993

Katalin Voros
Laboratory Manager
Principal Development Engineer

Costas J. Spanos
Faculty Director

MAINTENANCE

Robert Hamilton
Maintenance Supervisor
Senior Development Engineer

Phillip Gallory
Development Technician V

To be filled
Development Technician V

Mike Linan
Development Technician IV

James Parrish
Principal Laboratory Mechanician

Evan Stateler
Development Technician V

Daniel Cutten
Student, Laboratory Assistant II

ADMINISTRATION

Rosemary Spivey
Administrative Supervisor
Administrative Assistant III

Susan Kellogg-Smith
Purchasing Assistant II

Maria Cheng
Student, Clerk

Han Tran
Student, Laboratory Assistant I

COMPUTER SUPPORT

Mark Kraitchman
Programmer/Analyst II

PROCESS

Debra Hebert
Process Supervisor
Assistant Development Engineer

Marilyn Kushner
Staff Research Associate I

Maria Perez
Staff Research Associate II

To be filled
Staff Research Associate II

Howard Woo
Student, Laboratory Assistant I

ASSOCIATED RESEARCHERS

RESEARCH/PRINCIPAL INVESTIGATOR

Advanced photolithography
A.R. Neureuther, W.G. Oldham

Baseline CMOS process
C.J. Spanos, K. Voros

Berkeley Sensor and Actuator Center (BSAC)
R.T. Howe, R.S. Muller, A.P. Fosso, R.M. White

Computer Aided Manufacturing (BCAM)
D.A. Hodges, C.J. Spanos

Cryoelectronics
T. Van Duzer

Devices and Technologies
C. Hu, P.K. Ko

Plasma-assisted processing
N. Cheung, M. Lieberman

STAFF

Kim Chan
Staff Research Associate II

Shenqing Fang
Associate Development Engineer

Vadim Gutnik
Student, Laboratory Assistant II

James Busillo
Senior Development Engineer

David Mudie
Programmer/Analyst III

David Hebert
Senior Development Engineer

Xiaofan Meng
Development Technician V

Peter Guo
Staff Research Associate II

To be filled
Senior Electronics Technician

Figure 2.
EXECUTIVE SUMMARY

This document contains the 1994 Year-End Reports by the professional staff of the UC Berkeley Microfabrication Laboratory, EECS/ERL. Together, these reports reflect the full scope of staff activities in support of teaching and graduate research in the Department.

The first five reports, written by the manager and supervisors, describe functions necessary for operating the Microlab. These functions are carried out by a direct support staff of 15. The support staff maintains a separate undergraduate teaching laboratory for processing integrated circuits, and takes active part in departmental facilities development projects.

The second group of reports were submitted by associated researchers who work for various research groups and are not involved in general Microlab maintenance. Associated researchers receive assignments directly from their principal investigators, develop equipment and processes and manage or assist research projects for their groups.

Included in the Appendix is a detailed description of the newly established Integrated Materials Laboratory. Microlab staff was actively involved in this facility’s construction phase and continues to provide infrastructure assistance.

The Berkeley Microlab is an established operation supporting a standard CMOS baseline process and providing facilities to a wide range of research projects in sensors and actuators, compound semiconductors, and superconductors. Equipment and process maintenance is provided through a staff structure tailored for efficiency and for optimum resource allocation. The Microlab operates within a balanced budget comprised of $1M recharge income and contributions in the form of salaries of three staff personnel (FY 93/94). Average lab membership is 160, with 45 professors participating.

The 4 inch Si VLSI processing line in the Microlab was established over 11 years ago and is continuously upgraded and capabilities enhanced. Several of the original equipment have been replaced with newer models or went through major upgrades. Development plans include gradual replacements and additions, and modular expansion into satellite facilities. Financing is planned through direct contributions from research groups, joint research and equipment replacement grant proposals.

K. V.
Figure 1.
MEMORANDUM

To:        Michael Lieberman, ERL Director
From:      Katalin Voros, Microlab Manager
Subject:   1994 Year-End Report
Date:      17 January 1995
cc:        D. Messerschmitt, C. Spanos

This past year the affairs of the Microlab continued to proceed in the usual, organized and balanced fashion, as can be seen from the following, eighth year-end review.

I. MANAGEMENT OF STAFF PERSONNEL

Microlab Direct Support

The number of direct support staff remained constant the last five years, 15 FTEs. See top portion of Figure 1.

Personnel highlights of 1994:

We celebrated the following employment anniversaries:

- Kim Chan 15 years of service,
- Phill Guillery 10 years of service,
- Marilyn Kushner 10 years of service.

- James Bustillo was reclassified to Principal Development Engineer.
- Shenqing Fang received an A&PS Job Mastery Award.
- Mark Kraitchman was reclassified to Programmer/Analyst III.
- Mike Linan was reclassified to Principal Laboratory Mechanic.
- Maria Perez was promoted to Process Supervisor.
- Rosemary Spivey was reclassified to Administrative Specialist.
- Professor Spanos nominated the staff of the Microlab for the Chancellor's Outstanding Staff Award. Everyone contributed to the 30-page nominating document. We did not win but we felt good to have gone through the effort.

In March, Debra Hebert, the Microlab's Process Supervisor resigned to accept a position with Lam Research Corporation. Debra was an outstanding employee, an excellent engineer and her departure slowed down the development activities of the processing staff. The transfer of supervision to Maria Perez went smoothly, although while Maria was learning to be a supervisor she also had to train her own replacement and another staff research associate for an open process staff position. Equipment and process monitoring, however, stayed on schedule. (See report by M. Perez, p. 22).
The equipment maintenance staff also went through personnel changes. With the open position from last year filled, and Evan Stateler’s resignation in August, Bob Hamilton’s group had two technicians in training through last year, continuing into 1995. In spite of personnel turnovers we were able to support lab operations with a minimum of disturbance, which enabled us to meet our recharge income goal. (See R. Hamilton’s report, p. 11.)

A large part of the credit goes to our administrative support group supervised by Rosemary Spivey. With streamlining office operations they were able to handle the additional administrative work involved in personnel changes, meet all deadlines and provide detailed expenses documentation required by professors and grant auditors. (See R. Spivey’s report.) Also, Rosemary arranged for a very successful employee development workshop, presented exclusively for Microlab staff by campus CARE Services, titled, “Responding to difficult situations at work.” Another major accomplishment was establishing office operations for the Machine Shop, which came under Microlab supervision in the middle of 1994. (See below.) To render it commensurate with her responsibilities, Rosemary’s position had been reclassified to Administrative Specialist.

Microlab supervisors continued to alternate with me, in moderating the monthly lab members’ meetings. The meetings are a good forum for discussing lab operations, policy and safety issues, and provide another means of communication with our graduate student and staff researchers. Since initiating these meetings five years ago, complaints have diminished greatly.

Associated Researchers

Two of our associated research groups had personnel changes. The plasma group hired a technician in January; the Device group did not retain their SRA in training and now has an opening. These positions are directly under my supervision and Microlab supervisors help to train them, coordinate equipment and process support with them and generally administer the positions. Six major research groups employ dedicated engineers, (see lower portion of Figure 1.) who require direct Microlab staff assistance to varying degrees, depending on projects and professional level of associates. Involved groups continue to find the arrangement advantageous and efficient.

Machine Shop

Effective 1 July 1994, administration of the EECS Machine Shop had been transferred to the Microlab. (Memo by ERL Director dated 20 June 1994.) Ben Lake, Machine Shop supervisor reports directly to me and administrative matters are managed by Rosemary Spivey. Earlier in the year discussions were started between the departments of Materials Science and Mineral Engineering and EECS to consolidate their machine shops. Shop personnel in both departments had been reduced to two people due to budget cuts and the chairmen were exploring options to maintain an efficient joint shop. We have worked out a shop consolidation agreement (see my memo dated 18 July 1994.) and started moving MSME staff and equipment into Cory Hall by August. On 9 December we held an open house in the remodeled joint shop to inaugurate the operation.

So far, the joint machine shop works well; basically each group is serving their own department. A 0.75 FTE clerical position is maintained, half and half, by the two departments. Development of this position was essential to efficiently utilize machinists’ time. The joint Machine Shop is dedicated to provide both departments with high-quality, fine-scale machine shop services, in a timely manner.
II. INTERACTIONS WITH FACULTY AND RESEARCH GROUPS

Baseline

Our CMOS baseline process has been running successfully for the third year, with support from four of our major research groups, Sensor, Device, CIM/BCAM, Process (1 year), Cryo (2 years) and the Microlab. We have completed seven lots per year, with additional short loop and process development experiments (double metal). To keep the supporters informed we distributed four progress reports each year and S. Fang just completed an ERL Memorandum including design rules. Two new test chips were developed by the participating groups for their own requirements, one for Sensor and one for BCAM. These utilize scribe lines and have additional test structures for special processes. Lots are processed alternating the mask sets, depending on group requirements. After having stabilized the 2μm, 2-poly, p-well process, we have changed to n-well design in anticipation of shrinking. (See S. Fang’s report on p. 38)

Berkeley Sensor and Actuator Center (BSAC)

A major equipment acquisition for dedicated sensors use was a donated multi-target evaporation system (bigblue). The Microlab assisted in placing and upgrading this equipment, by donating technician time and various parts from surplus and inventory (listed in J. Bustillo’s report, dated 22 July 1994). This machine will provide extended capability for thin films applications in sensors. Another equipment, a vacuum packaging system (vacpack) was designed by Jim Bustillo and assembled from surplus parts. Although BSAC fulfilled their commitment to develop dedicated equipment, contributions toward general-use equipment had not been forthcoming.

Successful development of joint projects with BSAC member companies resulted in lower processing activities by the Sensor group in the Microlab, indicated by decreased share of support (25% in FY 93/94 vs. 29% in FY 92/93). BSAC is still our largest group by far. (See Figure 3.)

Berkeley Computer-Aided Manufacturing (BCAM) Research

A major BCAM project requiring staff assistance and equipment availability schedule coordination was the incorporation of metrology instruments in the poly-Si plasma etcher (iam4). Transparent to the general user, an RF power monitor, a particle counter, and an optical emission spectrometer dump data during processing into a dedicated PC, which is then transferred on line into the main database. This activity requires considerable software/hardware development and support, which is jointly supplied by the BCAM system manager D. Mudie, and Microlab technical and computer staff. (See D. Mudie’s report, p. 44).

The baseline process is supported and extensively utilized by their statistical process control projects. A new test chip was developed using optionally the scribe line area or the whole chip. Last year we have upgraded the automatic testing system, developed software for testing and data collection, and a general database for all applications. Baseline wafers are now tested on the autoprobe.

Devices and Technologies

For two years, until June 1994 the group employed a staff research associate. At that time the position was suspended until research needs demand dedicated staff and funding can be reestablished. Students in the device group remain active.
Cryoelectronics

Equipment installation progressed and was completed on time, according to plans developed by D. Hebert in 1992. With the addition of a Trion plasma etcher Cryo's dedicated processing line had been realized for low temperature Josephson Junction circuits. At the same time, Cryo's 10X wafer stepper, identical to the general-use stepper serves as a back-up system and provides additional photolithography capacity. This arrangement proved indispensable when the general-use stepper was down for a month for major upgrading of its electronics system. Cryo also initiated and put together a joint funding proposal (Cryo, Microlab, InfoPad) to procure a new wire bonder. When approval was given D. Hebert followed through with the project and brought up the bonder for general use. The Westbond is capable of wedge bonding of both aluminum and gold wires, and can be used for chip on board bonding.

III. MICROLAB RELATED ACTIVITIES

Solid State Devices and Technology Seminars

Members of the Microlab are regularly attending the weekly EECS290-12 seminars, sponsored by Professors Bokor, Cheung, Hu, Neureuther, Oldham and Spanos. Speakers are invited from outside, from industry, academic and research institutions. Over the years I became involved informally by recommending Microlab visitors for seminar speakers and advertising the topics through our e-mail aliases. A year ago Prof. Hu asked me to take over organizing the schedule. As I believe that these seminars are important for both students and staff, I accepted. Participating professors are asked to invite and host three or four speakers, while my staff handle follow-ups and postings. This system works smoothly; we had interesting speakers and well attended seminars during the past two semesters.

EECS/ERL Supervisors Group

I was again elected to be the chairperson of the monthly supervisors' meetings. Major issues on the agenda: various problems concerning the move of the CS division to Soda Hall; building matters and Campus Services' responses to problem reports; safety requirements; laboratories and computer support. We spent an inordinate amount of time discussing deteriorating custodial services and how to abate the situation. We were told budget cuts hit Custodial Services severely and they have been struggling all year to develop modified schedules. While we all have to manage our units with diminished funds and understand the difficulties of the custodial unit, we find it hard to look at accumulating trash and dust balls for weeks in the stairwells of Cory Hall and that laboratory floor stripping has to be requested weeks in advance and followed up several times. The issue is not resolved and will be on the agenda until improvements are implemented.

Campus Laboratory Operations and Safety Committee (LOSC)

I have agreed to continue to serve on this committee for the third year (FY 94/95). We have worked with the Office of Environment, Health, and Safety on the following issues: Oversight of safety committees and emergency response plans for department/units with laboratories; Injury and Illness Prevention Program (IIPP) regulatory requirements; Risk Management and Prevention Program (RMPP); toxic air contaminants regulations; City of Berkeley campus chemical inventory sites inspections; review of the E.H.& S newsletter, Flash Point!
Competitive Semiconductor Manufacturing Survey (Sloan)

In my third year of participation in this joint research project I attended three additional site visits. The Second Report on Results of the Main Phase came out in August 1994. I was a co-author of two sections in the report, Section 4. Yield Improvement: Results and Best Practices and Section 5. Process Control: Results and Best Practices. Also with S. Cunningham and C. Spanos we submitted a paper to the IEEE Transactions on Semiconductor Manufacturing, accepted for publication in the May 1995 issue.

University Laboratories Network

We continue to maintain and develop friendly cooperation with other university laboratories. Our most appreciated ties are with MIT and Stanford because they are able to reciprocate. Our facilities are very similar and maintain the same type of research activities; thus, assistance can be received/provided easily. Because of almost identical organizational structures, MIT’s MTL and the Berkeley Microlab can cooperate almost seamlessly. Stanford’s CIS does not employ a laboratory director/manager, therefore contacts are established directly with professors and/or research scientist.

Last January, Dr. L. Cordes, MTL Assistant Director at MIT spent a week with us familiarizing himself with our operation. (I am scheduled for the same at MIT at the end of January 1995.) While Dr. Cordes was here, together we visited Prof. S. Wong at Stanford. We toured the CIS laboratory and discussed common problems and interests with the staff. On another occasion, BSAC organized a successful graduate student visit to Prof. Kovacs’s group at Stanford; they returned the visit later in the year. We find these type of contacts beneficial for all concerned.

Public Relations

• The Microlab had 255 visitors inside the lab in 1994, according to the sign-in list on the computer. As usual, we had many others, who received the “window tour” and video presentation.

• We have been using our video extensively for visitors, class introductions, lab orientation, etc. successfully for the past five years (produced in 1989). Notwithstanding some changes in equipment and laboratory membership the video still describes our operations well. It has saved us tremendous effort in dealing with new lab members, visitors, public relations and media people, many of them unfamiliar with this type of research. To compliment our first video, this year we embarked upon producing a second one, this time concentrating on research groups and their work in the Microlab. We hired a Summer assistant to expedite the project. Rosemary Spivey managed it and I provided technical input and other necessary information. The new video is at post production, scheduled to be ready for the ILP conference in March 1995.

• A second project handled by the Summer assistant was the compilation and publication of an equipment manual, containing a photo and one page specification of each equipment in the Microlab. This booklet was produced both in hard copy and on-line for the WWW. Although we sent copies to our member professor and other interested groups, the primary motivation for collecting the information was to be able to distribute it through the infonet. We now have a Microlab home page from which equipment, staff, and various other information is accessible. We are a station on the “Semiconductor Subway”.

Look for us at URL: http://argon.eecs.berkeley.edu:8080/
IV. FACILITIES

Integrated Materials Laboratory (IML)

In my 1993 Year-End Report I described the involvement of the Microlab with an EECS/MSME/Physics joint instrumentation grant funded by NSF. The first one of four instruments, an SEM with e-beam writing capability, had been installed last year in a dedicated room (107 Cory) and completely integrated in the Microlab infrastructure. Facilities construction and installation of the others: an x-ray diffractometer, a connected MBE growth and UHV thin film deposition system, and a laser ablation system, were completed in 1994 continuing into 1995.

The working title of this project was “nanolab”, however, the name Integrated Materials Laboratory (IML) describes the facility much more appropriately. Microlab staff continues to provide technical and administrative assistance, and recharges are handled through our accounting program. The IML is a separate cost center and all recharges are returned to be used for maintenance of the facility. Reiterating my stance stated in the grant proposal: a dedicated technician will be needed to safely operate and maintain this facility. The manager of IML is Dr. N. Newman, MSME research engineer; his report describing the facility in more detail is included in the Appendix.

Laboratories Managed by the Microlab

![Graphic Diagram of Laboratories Managed by the Microlab]

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**Figure 2.**
Satellite Facilities

Over the past years the Microlab’s clean room space had been filled to capacity. During the same time we gradually acquired additional laboratories to maintain. This was due partly to the success of the Microlab and partly to shrinking departmental funds and efforts to streamline operations. With the establishment of the Integrated Materials Lab the Microlab became the center for various satellite laboratories, as depicted in Figure 2.

The Microlab is already operating much like a distributed computer system with a central server. Given the space constraints within the main lab (420), and the high cost of clean room construction, a workable option to expand research space will be modular addition of satellite facilities. Start up of the IML is proof of the viability of this concept.

Microlab Equipment

Robert Hamilton’s report (p. 11) details equipment upgrades during 1994. Major items were:

- The old mini developer was replaced with a refurbished SVG developer track. This system has communications capability.
- The general-use wafer stepper went through a $51K electronics system upgrade. The I-line and G-line steppers are now completely matched.
- Two optical measurement systems (nanoline and nanoduvin) were upgraded for extended measurements and improved data handling.
- A new plasma etcher (Trion) was installed for dedicated cryo work.
- A donated 5-target sputter/e-beam evaporator system was installed and modified/upgraded for producing thin films for optical coatings. This was a major project by the sensors group, assisted by the Microlab.
- A special vacuum packaging system was designed and installed by BSAC.
- A new wedge bonder was procured jointly by three groups: site, i.e., ml.
- Three Sun3 workstations were upgraded to SPARCstations.

Equipment replacements and upgrades were partly financed by interested research groups. We were able to utilize equipment donations and trade-ins successfully this year.

Physical Plant - Campus Services

A major improvement in facilities occurred when Physical Plant replaced the Microlab’s ailing air conditioner. We have had several meetings and communications with the director and associate directors of Physical Plant - Campus Services during the year. They were understanding of our plight with frequent air conditioner failures but with reduced budgets for deferred maintenance they had to adhere to stringent priority rankings. Fortunately, Campus Services came through for us when they were able to redirect two unused 75-ton air conditioners, surplussed at another project, to replace our failing 100-ton McQuay. Installation was well prepared and completed in a week during the Christmas holidays. We were able to keep the Microlab open, with only photolithography disabled. We appreciate the cooperation of Physical Plant - Campus Services in this project and the extra effort they expended in completing the project on time. A memo is forthcoming to this effect.
V. FISCAL MANAGEMENT

The Microlab continued to maintain strong fiscal performance in FY 93/94, which means that income covered expenditures and a $48K deficit recovery was achieved. The total budget was slightly over $1M. For details see R. Spivey's report, p. 25.

Figure 3 shows changes in income from various research groups during the last five years. Several trends can be observed: income from our largest group, Sensor, decreased for the second year; other, traditionally steady ERL groups all decreased somewhat, while MatSci, LBL and Physics participation increased. The slack was picked up by outside users, both Sundry and University. Although I am not concerned about whether we will be able to maintain Microlab income to meet the budget, the trend indicates a change in weight of contributors, away from our traditional EECS base.

Microlab Income from Research Groups
1989 - 1994

Figure 3.
VI. FUTURE DIRECTIONS

ERL Director, Prof. Lieberman requested a review of developments since the 5 Year Plan I submitted two years ago. In my report, Development Plans for the Microfabrication Laboratory, (dated 1 June 1994) I discuss current developments and how I see the near future. We also had extended discussions with Professors Howe and Spanos, who presented some of these ideas at a Strategic Directions in EECS seminar (EECS298-42, J. Bokor, R. Newton).

A short summary of issues addressed follows:

Research in the Microlab: Our main groups will remain healthy. (However, support from non-EECS researchers is on an increasing trend. See comments under Fiscal Management.) We will facilitate exploration and integration of advanced technologies into current activities.

Equipment: Financing strategies of upgrade/replacement will continue to be contributions from interested groups, dedicated equipment purchase by one group, used equipment donations from industry, and joint grant proposals. Microlab contributes limited overhead funds generated by income from sundry users.

Utilities: We will continue to lobby Physical Resources - Campus Services for necessary upgrades. Equipment grant proposals must have provisions for facilities upgrades.

Staffing: Direct Microlab support will likely remain the same. However, to maintain satellite facilities additional staff must be hired.

Environment, Health, and Safety: Mandated regulatory requirements will place additional burden on finances.

COMMENTS

Over the years we have demonstrated that the Microlab is a successful operation within ERL. We have met our budget for eight consecutive years, and almost paid off our inherited debt. We provided full support to our members and assistance in many other activities in the Department. The Microlab's success relies on the dedicated performance of its staff and on the supportive environment provided by EECS/ERL. We are confident that both will continue in the future.
MEMORANDUM

To: M. Lieberman, ERL Director
From: K. Voros, Microlab Manager
Subject: Development Plans for the Microfabrication Laboratory
Date: 1 June 1994
cc: D. Hodges, D. Messerschmitt, C. Spanos

A review of developments since the 5-Year Plan I submitted two years ago, verifies the Microlab remained on a steady course of action, as outlined. We are providing full service to our members while the range of areas covered has been widening at a noticeable rate. In this report, I will discuss these developments and present projections for the next five years. The following issues are considered: research in the Microlab, extended infrastructure, equipment requirements, utilities needs, staffing, and environmental and safety concerns.

The first and overriding issue is: what kind of research will be conducted in the Microlab? No matter what we plan, the fact remains that resource requirements have been and will be driven by the projects undertaken by supporting members of the laboratory. We deal with this fact daily; equipment that was crucial yesterday is not needed today, or changed half way through the project. This is the nature of our "business", research, and we strive to be as responsive as possible. It is enough to consider how the "new lab" changed from a planned IC foundry into a facility supporting a wide range of programs, then took another turn towards ICs by establishing the baseline "foundry". Changes hinge on the research goals and can be projected only as a function of these.

Research in the Microlab

Activities of our major research groups remain healthy and indications are that they will remain so. This does not mean, however, that they should become static; we will foster the exploration of new areas to integrate strategically into current activities. The most immediate example of this is providing sensors, device and materials science researchers with equipment to develop various thin films for optical, ferromagnetic, piezo-electric, and other applications. Another example will be flexible systems for producing porous and amorphous silicon. Again, possibilities cover a wide range, from TFTs to optical devices and sensors.

Integration of new and different technologies such as advanced lithography using lasers and the Advanced Light Source at LBL, plasma immersion ion implantation, sub-micron baseline, planarization, laser ablation, thick film technology, etc., into existing processes is another area where we can take advantage of and further develop our expertise. These new capabilities will provide enabling technologies for many of the groups and the rate of development will depend on the extent of group cooperation. We will continue to be the facilitators of such projects and channel them into effective activities. Thus, the Microlab’s multi-disciplinary nature will be further enhanced in the future.
Extended Microlab Infrastructure

Over the past years the Microlab's expensive clean room space has been filled to capacity. Besides the standard Si VLSI processing line we have a dedicated superconductor processing line and a host of back-end processing tools for sensor integration with standard CMOS circuits. In addition, we provide space and support to advanced lithography equipment, compound semiconductors and various materials processing tools and testing instrumentation. Incorporation of new equipment will require removal of some of those currently in use.

Addition to the Microlab's high-overhead space is both prohibitive and undesirable; thus, future expansion will have to take place by modular addition of satellite facilities. We were able to develop a workable model last year when we added the e-beam writer, the first phase of the "Nanolab", to the Microlab infrastructure. The refurbished room which houses the instrument is physically separate from the Microlab, yet completely integrated into its operational structure.

The Microlab is already operating much like a distributed computer system with a central server and client workstations. We are in the planning stages of establishing a second satellite to house a multi-chamber CVD cluster tool, again serving several groups. It seems that expanding the concept of modular additions to the Microlab infrastructure will be a viable option to meet future needs.

Equipment

The Microlab has a long history of dealing with capital equipment financing without a dedicated equipment fund. Because we are a recharge unit we are not allowed to collect extra fees to finance upgrades and additions. Also, the nature of a cooperative laboratory is such that not all members are interested in purchasing equipment they will not use. Thus, the only way we are able to keep up with upgrade/replacement demands is by approaching the financing of each new machine in an informal manner. Variations of this strategy are:

- **Cash contributions** from several research groups for purchasing a new/refurbished machine. Microlab provides site preparation, utilities connections, parts, and components available from donations. Often the Department contributes from BMA funds. (Examples: replacement of resist dispense and development systems, Al plasma etcher.)

- **Restricted contributions.** One group promotes the purchase of a machine needed for their research but will make it available for others, depending on compatibility. In this case the promoting group will provide the majority of the funding, and the Microlab is heavily involved in rebuilding, changing/adding components and developing processes. (Examples: three LPCVD furnace systems for BSAC research, atomic force microscope for device work, advanced poly-Si plasma etcher with additional computer capability for BCAM work.)

- **Used equipment donation from industry.** Often we lobby our company contacts for a needed machine, or we are offered one. In both cases extreme caution is in order. System contamination, 4" wafer handling components, and general condition of the machine are of great concern. Over the years we have turned down many such offers, and lost some to other institutions. Some we accepted and traded for services or parts (with the donor's permission). In any case, this workable option for equipment acquisition is by no means free. We have spent operating funds and staff time to render donated equipment usable. (Examples: Tegal plasma etcher, CPA aluminum sputterer.)
- 3 -

- **Dedicated equipment purchase.** Groups who wish to restrict equipment for their own exclusive use purchase them from their own funds. In this case the space issue has to be resolved by developing plans mutually agreeable for all concerned. Microlab is a contributor by assisting with site preparation, installation, and donated spare parts. The most prominent example of this is the development of a dedicated process line for cryoelectronics. We also support other important restricted equipment, such as advanced lithography tools and compound semiconductor equipment.

- **Joint grants.** A more recent development in financing equipment installation is the winning of the NSF grant titled *Acquisition of Instrumentation to Fabricate Low-Dimensional Artificial Materials*. The proposal had been submitted jointly by several professors from EECS, MSME, and Physics, all supporters of the Microlab. It included a management plan which stated that the new instrumentation requested will become part of the Microlab infrastructure and technically managed as such. We agreed to this with one caveat: dedicated staff will be hired to maintain the new facility.

Financing of equipment and facilities upgrades in the coming years will follow the options above. Our immediate needs are:

- a tungsten CVD system,
- additional amorphous Si deposition capability,
- low temperature (TEOS) oxide CVD system,
- upgrading/replacing of our Al sputtering system,
- planarization equipment (type depends on strategy adopted),
- additional thin films deposition system (optical, ferromagnetic, pzt, etc.),
- new metrology tools (Nanometrics defect mapping system, HYT in-line particle counter, optical thin film characterization system),
- additional sensors and tools for BCAM applications,
- computer hardware/software upgrades,
- wafer stepper control computer upgrade.

The photolithography and mask making equipment will carry us through the next five years. With the addition of a second stepper (financed by cryo) we have a good complement of g-line and i-line printing capability, but upgrading the control computer on the old stepper will be necessary. We have upgraded the pattern generator and with stringent preventive maintenance it will last for a good many more years. Research needs for deep sub-micron capability were abated with the addition of the e-beam writer.
Utilities

- The Microlab’s most immediate need is the replacement of the air conditioning unit (McQuay Chiller on the rooftop of Cory Hall), for which the Department submitted a Minor Capital Improvement request to Campus Services last year. Unfortunately the list of such requests from the whole campus contains 886 items, and our chiller replacement ranks 128. Campus Services informed me that considering their reduced deferred maintenance budget, they can probably fund the first 30 requests next year. After another evaluation, our proposal may be considered in fiscal year 95/96 or 97. This is unfortunate because if the air conditioner fails the Microlab is out of business. I am beseeching a higher ranking with Campus Services, with not much promise. In the meantime we have instituted careful monitoring of all indicators of chiller performance. Scott McNally, our Stationary Engineer, is aware of the critical nature of the chiller and we have his cooperation in obtaining emergency repair response.

- Other utilities limiting expansion are industrial water delivery, building air supply and exhaust hood fan capacity, and the lack of drains at required locations. Each expansion and/or remodeling project must include funds for upgrading these. Fortunately, with the Campuswide Electrical Distribution Project completed, power capacity is not a problem. The need for back-up power remains, but with the improvement of power delivery reliability this past year, it is of lesser urgency.

Staffing

The Microlab’s direct support staff should remain at the current level, 15 FTEs. Even with the equipment installation projects outlined above we will be able to manage if EECS/ERL support is held the same, 3.25 FTEs. To protect Microlab operations we took on many building utilities monitoring functions during the past years. Besides supporting teaching labs, Microlab staff also participates in laboratory construction projects.

The extended infrastructure model for the addition of laboratory space requires that the Department retain a project facilitator. Microlab staff can be a knowledgeable resource but managing a construction project with the current number of staff is not feasible. Also, the continued existence of a machine shop under departmental control is crucial.

As discussed earlier, the Nanofabrication Laboratory proposal (NSF 91-140) stipulates that “The University will hire two additional staff engineers for the Microlab, with specific expertise in MBE and electron-beam instrumentation, to support the new equipment.” Even if MSME contributes a research scientist staff to this project, a dedicated technician/engineer will be needed to run and maintain the facility. With the addition of a second MBE system and other equipment the Nanolab cannot be operated only with graduate students. It would be an inefficient use of funds, an unsafe operation, and would place undue burden on the technical staff of Cory Hall.

Finally, the staff compensation issue must be discussed. With the recent freezes and cuts we are falling behind competitive salaries in the Bay Area and technical staff will be more difficult to retain. As the semiconductor industry is climbing out of recession, we already lost one highly valued engineer to an outside firm.
Environment, Health, and Safety

The rapid growth of our obligations under environmental, health and safety laws made it imperative that we at the Microlab assume a forward looking attitude and promote good practices. We have developed new programs to keep the Laboratory up-to-date on environmental and safety issues, and provide appropriate training for lab members and members of staff. Our staff are active participants in Cory Hall’s Safety Committee and the Campus Laboratory Operations and Safety Committee. We intend to remain in a leadership position in this area.

Summary

The Microlab expects to remain in good shape for the next five years. Research needs will be met by moderate expansion through satellite facilities. Equipment replacement and upgrades will be financed through joint contributions and donations. Immediate attention is needed to provide utilities upgrades and staffing of the expanded Microlab infrastructure.

RS
EXECUTIVE SUMMARY

This document contains the 1995 Year-End Reports by the professional staff of the Microfabrication Laboratory, ERL, of the University of California at Berkeley. Together, these reports reflect the wide scope of support staff provided to research and teaching laboratories in the Department of Electrical Engineering and Computer Sciences.

The first five reports describe functions necessary for operating the Microlab infrastructure, which also provides services to satellite laboratories. The second set of reports were submitted by associated researchers who work for various research groups and are not involved in general Microlab maintenance. Associated researchers receive assignments directly from their principal investigators, develop equipment and processes and manage or assist research projects for their groups.

The Berkeley Microlab is an established operation supporting a standard cmos baseline process and providing facilities to a wide range of research projects in sensors and actuators, compound semiconductors, and superconductors. Equipment and process maintenance is provided through a staff structure (14 FTEs) tailored for efficiency and for optimum resource allocation. The Microlab operates within a balanced budget of $1.23M (FY 94/95.) Average lab membership is 162, with 45 professors participating.

K. V.
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Executive Summary

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MEMORANDUM

To:       D. Angelakos, ERL Director
From:     K. Voros, Microlab Manager
Subject:  1995 Year-End Report
Date:     16 January 1995
cc:       M. Lieberman, D. Messerschmitt, C. Spanos, and Microlab Member Professors

This is the ninth year-end report I am submitting as manager of the EECS/ERL Microfabrication Laboratory. As before, in 1995 the Microlab operated within established guidelines and within budget.

I. MANAGEMENT OF STAFF PERSONNEL

The number of direct support staff had been reduced in 1995 from 15 FTE to 14. (See top part of Figure 1.) This reduction of force occurred by attrition. In anticipation of further UC budget reductions a vacated position was not filled.

Personnel highlights of 1995:

- James Bustillo received a Staff Incentive Award.
- Phillip Guillory was reclassified to Principal Laboratory Mechanician.
- Marilyn Kushner was reclassified to Staff Research Associate II.
- James Parrish retired after 18 years of service.
- We celebrated Katalin Voros’ 10-year employment anniversary.
- Katalin Voros received a Certificate of Excellence in Management from the UC Berkeley Staff Assembly.

The Microlab had increased staff turnover in 1995, mostly because of the lucrative boom in the semiconductor industry. We had four resignations from the process and associated engineering staff; we hired four new people to fill the open positions. This activity placed additional burden on the rest of the staff, but we managed to sustain our expected high quality service in the interim.

Keeping staff motivated is a continuous activity. Maintaining bidirectional communications greatly helps promote interest in fulfilling our unit’s mission. During my monthly staff meetings I discuss issues that effect our work environment, provide updates on the financial status of the Microlab, and convey whatever information I receive concerning the Department, ERL, and the University. Other subjects include progress of various research groups we are involved with and student’s successes. In 1995 we discussed videos produced by BSAC and BCAM of their projects, and safety videos such as the review of Safe Mechanical Procedures.

After several budget cutting years the University allowed restoration of deferred rate adjustments and merit increases and reactivated performance awards. This provided a boost in employee morale, but was attenuated by the fact that technicians could not be included. Unfortunately, negotiations between UPTE, newly representing the technical staff, and the University did not result in a contract in 1995. As a consequence seven of our high level, well performing technical staff have not had a salary raise in three years.
MICROLAB STAFF
December 1995

Katalin Voros
Laboratory Manager
Principal Development Engineer

Costas J. Spanos
Faculty Director

MAINTENANCE

Robert Hamilton
Maintenance Supervisor
Senior Development Engineer

Phillip Guillory
Principal Laboratory Mechanic

Mike Linan
Principal Laboratory Mechanic

Patrick Wehrly
Principal Electronics Technician

Charles Williams
Development Technician V

Ebo Croffie
Student, Laboratory Assistant

ADMINISTRATION

Rosemary Spivey
Office Supervisor
Administrative Specialist

Susan Kellogg-Smith
Purchasing Assistant II

Eileen O'Neil
Student, Senior Clerk

Leif Jordan
Student, Laboratory Assistant

COMPUTER SUPPORT

Mark Kraitchman
Programmer/Analyst III

PROCESS

John Knodell
Process Supervisor
Associate Development Engineer

Gloria Bruner
Staff Research Associate II

Marilyn Kusher
Staff Research Associate II

W. Ryan Berger
Student, Laboratory Assistant II

Norton Mitchell
Student, Laboratory Assistant I

ASSOCIATED RESEARCHERS

Kim Chan
Staff Research Associate II

Shuqing Fang
Associate Development Engineer

Guobin Wang
Visiting, Jr. Specialist

James Bustillo
Principal Development Engineer

David Mudie
Programmer/Analyst III

Xiaofan Meng
Senior Development Engineer

James Parrish
Principal Laboratory Mechanic

David Baca
Senior Electronics Technician

Advanced Photolithography
A.R. Neureuther, W.G. Oldham

Baseline CMOS Process
C.J. Spanos, K. Voros

Berkeley Sensor and Actuator Center (BSAC)
R.T. Howe, R.S. Muller, K.P. Piston, R.M. White

Computer Aided Manufacturing (BCAM)
C.J. Spanos

Cryoelectronics
T. Van Deur

Integrated Materials Laboratory
N. Newman

Plasma-assisted Processing
N. Cheung, M. Lieberman

Figure 1.
One of our goals as supervisors is to encourage and enable employee development. We make every effort to arrange work assignments such that these include a learning component and allow for interest generating special projects. At the yearly performance evaluations we review job descriptions for proper classification and development content. We maintain high performance standards and provide all that is necessary for the employee to meet the challenge. Over the years the staff of the Microlab developed into a well respected unit within ERL and are often called upon when technical advice and assistance is needed outside their area of responsibility.

**Maintenance Staff** – For details of this group’s activities see report by R. Hamilton, Maintenance Supervisor, Safety Officer. (p. 12)

**Administrative Staff** – See report by R. Spivey, Administrative Supervisor, Office Manager. (p. 17)

**Computer Support** – See report by M. Kraitchman, System Manager. (p. 22)

**Process Staff**
For the second year in a row we lost our Process Supervisor to Silicon Valley. Additionally, a junior development engineer, well advanced in training to be a contributing process staff member, found better paying employment there. Both positions have been filled, and are currently in training. M. Kushner was the only process staff for several months. Marilyn rose to the occasion and did an outstanding job of covering and training new staff. Accordingly, her position was expanded and reclassified to Staff Research Associate II. (See M. Kushner’s report, p. 26)

**Associated Research Staff**
Several of our associated research groups had personnel changes in 1995.

- S. Fang, baseline engineer resigned to continue his studies in our department. G. Wang, Junior Specialist, has been hired for replacement; S. Fang trained him and transferred the baseline project.
- BSAC took a new course of action in expanding their process support staff, under the direction of J. Bustillo, Principal Development Engineer. Jim moved out of the Microlab office (406), into 495 Cory, next to the BSAC office.
- Dave Hebert, Senior Development Engineer, resigned from the Cryo-group after close to nine years of service with them. After a hiatus of seven months, X. Meng had been hired for the position.
- The integrated Materials Lab needed a support technician and when J. Parrish retired from the Microlab, Dr. N. Newman, manager of the IML, took the opportunity to secure an experienced staff for the unit. James had been working part-time for the IML for the past six months.

**Machine Shop**
Operations in the joint MSME/ERL Machine Shop stabilized this past year, the first full year under Microlab management. With systems and controls in place, budget and recharge hours accounting under close monitoring, the shop is on a steady path to recover losses accumulated during the previous years, and the confidence of our clients. For details see report by B. Lake, Machine Shop Supervisor (p. 48.)
II. INTERACTIONS WITH FACULTY AND RESEARCH GROUPS

Microlab Status Reports
Over the years we had learned that communicating with our membership is extremely important in providing efficient support and maintaining safe operations. We have several channels through which we can reach lab members. Besides personal contacts we use e-mail extensively, receiving FAULTS problem reports and sending repair updates and "equipment up" reports. We post issues needing immediate attention to "messages", which are displayed to members upon logging into the lab. Mail sent to equipment name aliases and research aliases reach targeted groups and enable members to communicate with other lab users directly.

Over the past five years since 1990, we held regular monthly lab member meetings. Last year we tried something different. Because of diminishing interest in meetings, I sent out monthly Microlab Status Updates instead (via e-mail.) These reports contain equipment status updates and planned changes, staff news, and general announcements, and are archived on the Microlab Gopher. To maintain a safe and well functioning lab, students have to be reminded of rules, protocols, and lab etiquette. As good habits erode, with each new crop of members we have to reinvigorate enthusiasm for keeping our tradition of help and cooperation.

For prospective new members we hold lab orientation seminars monthly (except December.) During the four-hour morning program they receive a general introduction to the lab; instructions in computer communications, safety, administrative matters, processing capabilities, and laboratory etiquette.

In the afternoon session prospective new members receive a laboratory tour with emphasis on safety and emergency equipment. We provide full documentation and instruction on how to find on-line information. Attendance in lab orientation seminars is around 15-18 persons, students, visiting scientists, postdocs; anyone who wishes to work in the Microlab or in the satellite labs must attend. Following orientation new lab members can begin training within the Microlab.

Berkeley Sensor and Actuator Center (BSAC)
Although somewhat diminished the past two years, BSAC researchers' use of the Microlab provides by far the largest proportion, 27%, of total income. BSAC activities place a heavy burden on LPCVD systems and etchers; however, members of this group are great contributors to process development and characterization, equipment trouble shooting and improvements. Examples: A major problem of particle generation was jointly resolved by BSAC and Microlab staff. Currently we are upgrading one of the LPCVD systems for improved control of amorphous poly-Si growth. Other projects are described in J. Bustillo's report, p. 31. In spite of the excellent cooperation between BSAC and the Microlab, I am somewhat concerned that BSAC is not budgeting sufficient funds for equipment development for their own projects.

Baseline
We were successful in maintaining our cmos baseline process in 1995, our fifth year, with generous contributions from Professors Cheung, Ferrari, Gray, Howe, Muller, Pisano, White, and Spanos. Microlab provided laboratory and special equipment time, administrative support and supervision. After a change in staff we continue to process our standard 2 μm n-well cmos while developing a 1.3 μm twin-well cmos process. (See S. Fang's report, p. 35.)
Berkeley Computer-Aided Manufacturing (BCAM) Research

BCAM is a major supporter and user of the baseline. All the lots we processed in 1995 were done with the BCAM special test chip mask for collecting statistical data. This test chip is composed of two parts; a scribe lane section to be included in all runs and a drop-in chip which can be interchanged with any other design. (The baseline had no other chip requests in 1995.) The layout of the test chip is available for inclusion, with instructions at argon:/cad/examples/rodriguez/kic. (Documented in Memorandum No. UCB/ERL M94/63.) For more complete data extraction to establish device parameters for circuit simulators, work is in progress with BSAC's cooperation to improve instrumentation and accessibility of parametric extractor software. This project continues into next year.

Professor Spanos' research group continued to extend metrology tooling of fabrication equipment. This year the photolithography cell was connected through equipment/computer interfacing and BCAM software, for recipe transfer, process monitoring, and control. (See D. Mudie's report, p.37.) These projects along with the requirements imposed by the cmos baseline make it necessary to monitor equipment performance on a regular basis. Process staff executes test runs on 22 pieces of equipment and records results. SPC charts are maintained on-line (see http://argon.eecs.berkeley.edu:8080/) for the lam etchers, LPCVD systems, and photoresist coating tracks. Figure 2. shows an SPC chart for the standard Si nitride deposition system.

![SPC chart for tylan9](chart.png)

**Figure 2.**

Microfabrication Research in ERL

The Office of the Vice Chancellor for Research conducted detailed reviews of organized research units (ORU) on campus, among them the Electronics Research Laboratory (ERL). One of the major programs within ERL is the operation of the Microfabrication Laboratory; thus, Prof. Lieberman, ERL Director, requested a summary of our accomplishments, to be incorporated in his report. In my memo, Microfabrication Research in ERL — Notes for ORU Program Review, dated 5 September 1995, I discuss the contributions of the MicroLab with respect to program significance, graduate student support, leveraging extramural funds, and unique contributions to the campus's research mission.
III. MICROLAB RELATED ACTIVITIES

Solid State Technology and Devices Seminars
We continued to participate in organizing the EECS 298-12 seminars in 1995. Professors Bokor, Cheung, Hu, Neureuther, Oldham, Spanos and I take turns inviting speakers, with the Microlab office following-up contacts, postings, parking arrangements, etc. Subjects cover a wide range of interests within the semiconductor field and the seminars are always well attended (30-40 people regularly.)

EECS/ERL Supervisors Group
I have served for the third year as the chairperson of the monthly supervisors’ meeting. Major issues we discussed this past year: Cory and Soda Hall facilities problems, Cory Hall computer network upgrade, Campus Services response to requests, deferred maintenance by Campus Services (Cory central courtyard project), status of teaching and research laboratories, staff and union issues, campus “Deans and Directors” memoranda, emergency response plans, and activities of units within the Department. Minutes of the monthly meetings were also sent to the Chairman of EECS and the Director of ERL.

Campus Laboratory Operations and Safety Committee (LOSC)
The Laboratory Operations and Safety Committee, appointed by the Vice Chancellor for Research on behalf of the Chancellor has the delegated authority and responsibility for formulating and recommending campus policy on laboratory operations and safety, to the Environmental, Health and Safety Policy Committee. The LOSC participates in the development of the campus program to comply with the Cal/OSHA Laboratory Standard and reviews informational materials developed by the Office of Environment, Health and Safety, addressing laboratory health and safety issues.

Members normally serve for a 3-year term. Having completed my term in 1995, I accepted membership on this committee for a second term because I believe in the importance of providing a safe research environment on campus. The Microlab, with the leadership of our Safety Officer, R. Hamilton, has always been pro-active in this area and continues to demonstrate a progressive and responsible attitude in environmental and safety issues.

University Laboratories Network (Labnetwork)
Professor Spanos and I were active participants this past year in organizing and contributing to two, one-day meetings of representatives of university laboratories. The Labnetwork is an informal organization to provide a forum for discussion of common issues of interests. Also, the Labnetwork will be an appropriate group to speak with a unified voice when the need arises to present our case to funding agencies and industry organizations.

At the first meeting in February 1995 we discussed: Linking of academic fabrication facilities, and Organization/common voice, and established an Internet discussion list. The agenda of the December meeting, in conjunction with IEDM, included Research interaction infrastructure and the Common voice.

Since then a Mission Statement of the University Microfabrication Laboratory Network was sent to several industry organizations. Detailed information and meeting minutes are available on the WWW at http://www-mlt.mit.edu/labnetwork.
Public Relations

- The Microlab had 308 visitors inside the lab in 1995, according to the sign-in list on the computer. As usual, we had many others who received the "window tour" and video presentation.

- Our new 28 min. video is a great success. This time, instead of presenting the equipment, we focus on the activities of our major research groups. (8 in all: Advanced Devices, Advanced Lithography, Computer Aided Manufacturing, Compound Semiconductors, Superconductors, Physics, Materials Science and Berkeley Sensors and Actuators.)

The video contains interviews with group members, discussing and demonstrating their projects. With assistance from the staff of the Microlab, Campus Media Services provided us with an excellent public relations tool.

- During the first half of last year Prof. Spanos, Microlab Faculty Director and I embarked upon an outreach program, to inform other campus engineering and science departments of activities in the Microlab and invited their faculty to explore research tools and joint project opportunities offered by the Microlab. I have received several exploratory calls and visits in response. Dealing with these in a positive manner is another facet of laying the ground work for increased activity in the Microlab by researchers from other departments. (See Figure 5.)

- In 1995 we invested a major effort in upgrading the Microlab's WWW home page, and included practically all information necessary for working in the lab. (See Figure 3.) This went a long way in handling questions with respect to what is available in the Microlab, what are the charges and how can one become a member. A streamlined home page makes it easy to find required information. Address: http://argon.eecs.berkeley.edu:8080/.

![Microlab Home Page](image)

**General Microlab Information**

- Microfabrication at Berkeley (informational booklet)
- How to become a Microlab member
- Microlab Recharge Rates
- Summary of Microlab capabilities and processes available
- Microlab Equipment Manual
- Microlab Equipment Photos
- Process and Equipment Operating Manual
- Process Monitoring Tests
- Microlab Staff (warning 390K)

- People from the Microlab

Figure 3.
IV. FACILITIES

Physical Plant – Campus Services

Campus Services provides Cory Hall the following utilities necessary to operate the Microlab:

- electrical power
- air conditioning
- exhaust (hood) fans
- industrial water (ICW)
- recirculating cooling water
- drains
- compressed air
- steam heating
- custodial service

Having reliable delivery of these utilities is critical to successful semiconductor processing. Failure of any one can crash sensitive equipment and ruin experiments – and they have. During the past years we have worked hard to protect the Microlab and instituted extensive monitoring and preventive measures. We have over 40 sensors placed in strategic locations; our in-house monitoring program, BLIMP, sends alarm messages when readings fall out of specifications. We understand that utilities in Cory Hall were not designed to support modern semiconductor processing; however, if we receive reliable delivery we can manage.

Every year I review our Campus Services requests and report on those which need special attention. Campus Services has been cooperative in resolving the most critical problems, such as reducing the number of power failures and replacing a troublesome air conditioner. This year it was the air compressors.

Compressed air, needed to operate solenoids and valves in complex equipment, is supplied by two Sullair compressors in the basement of Cory Hall. Insufficient maintenance results in random pressure drops and automatic compressor shut downs, leaving valves in normal (open or closed) positions. In 1989, to protect the Microlab we replumbed the incoming compressed air line such that when air pressure fails N₂ backup flow, at ~90 psi, is automatically enabled. However, the rest of Cory Hall is effected, most notably the 5th floor, where steam valves are left in N/O position, allowing room temperatures to become unbearably hot. Complaints by Cory Hall’s building manager resulted in a Campus Services proposal for corrective action; however, the planned changes were unacceptable. R. Hamilton submitted a memo to Campus Services proposing workable modifications, to which they agreed. Compressor upgrade is scheduled for Spring 1996.

Microlab Equipment

R. Hamilton’s report details equipment development in 1995. No major equipment was added; our activities concentrated on upgrades and incremental improvements in existing instruments. We were successful in receiving and judiciously utilizing donated equipment, and we were able to supply parts to satellite labs.

We successfully maintained and expanded our computer system by utilizing hardware donations from other units in EECS. Uptime reliability, already high, was further improved by adding an uninterruptable power supply, also donated, to Argon, our main server. This year we are looking at a major expense of connecting to the new fiber optic network, installation of which is planned for the Summer 1996.
Satellite Laboratories

In the 13 years the present Microlab has been in operation we have accumulated a great deal of knowledge in all areas of facilities management and learned through hard earned experience how to work with limited resources. The idea of supporting, under the umbrella of the Microlab, various other laboratories scattered throughout the building evolved slowly, the result of need and creative thinking.

The need arose because as research and teaching laboratories were upgraded and equipped with more sophisticated equipment they required high level technical support and a means of shared funding. Establishment of the new Integrated Materials Laboratory in 1993 gave impetus to the expansion of an already existing laboratories infrastructure, namely technical, accounting and management support as provided by the Microlab. New equipment at other locations were installed with computer access control, which also provides usage information for sharing maintenance costs. We had invested a considerable amount of effort to modularly expand BCIMS, the Berkeley Computer Integrated Manufacturing System software, with which we run the Microlab. Charges accumulated from users are returned to the IML without overhead, for the maintenance of that facility. Users of other satellite labs (Figure 4.) are charged staff rates when they request technical assistance. We are glad to be in the position that enables us to provide these services as part of our overall goal, support of research and education in EECS.

![Laboratories Managed by the Microlab](image)

Figure 4.
V. FISCAL MANAGEMENT

The Microlab had a lackluster fiscal performance in 94/95. Because of strict cost containment measures (one employee was on a 2 month temporary furlough, and the number of direct support staff was reduced by one FTE through attrition,) we were able to meet expenses; however, the projected deficit recovery of $50K was not achieved. Thus, the Microlab’s remaining debt at the end of FY 94/95 was still at $91K.

Analysis indicates that income from our traditional ERL research groups decreased for the third year in a row. What saved the budget was an increase in outside income, both from other departments on campus and off campus researchers. (See Figure 5.) I made a point of this trend in my year-end report last year (p. 9.) Early this year the numbers began to look alarming and I went to great lengths to call the attention of the faculty to the situation. After the University closed its ledger for FY 94/95 and all the numbers were in I wrote a memo to the Chair, Director, and Dean on Trends in Microlab Support (dated 18 August 1995), in which I supported with charts my claim that the Microlab’s support base in EECS/ERL is eroding.

It appears that lab use is on the rebound. Whether it is temporary or real remains to be seen. Income during the first half of FY 95/96 was on target and it looks like we will meet performance-to-budget expectations by 30 June, the closing of the current fiscal year.

SUMMARY

This report, along with those following by the professional staff, provides an overview of Microlab operations in 1995. Our goal of supporting semiconductor research and education in our department had been attained through maintaining a well functioning facility, keeping operations within budget, providing high quality staff assistance and efficient management. Interactions with faculty and research groups and other Microlab related activities allow us to keep on track and up-to-date on developments. UC Berkeley’s reputation as a first class educational institution mandates us to demonstrate leadership in cooperating with other universities involved in microfabrication research.

Percentages of Total Income Shown by Research Groups

![Bar Chart](chart.png)

Not shown in above chart: BAC 92/93 29%, 94/95 26.6%.

Figure 5.
EXECUTIVE SUMMARY

This document contains the 1996 Year-End Reports by the professional staff of the Microfabrication Laboratory, ERL, of the University of California at Berkeley. Together, these reports reflect the wide scope of support staff provides to research and teaching laboratories in the Department of Electrical Engineering and Computer Sciences.

The first six reports describe functions necessary for operating the Microlab infrastructure, which also provides services to satellite laboratories. The second set of reports were submitted by associated researchers who participate in various research groups and are not involved in general Microlab maintenance. Associated researchers receive assignments directly from their principal investigators, develop equipment and processes, manage or assist research projects, and are not included in the Microlab’s budget.

The Berkeley Microlab is an established operation supporting a standard cmos baseline process and providing facilities to a wide range of research projects in sensors and actuators, compound semiconductors, and superconductors. Equipment and process maintenance is provided through a staff structure (16 FTEs) tailored for efficiency and for optimum resource allocation. The Microlab operates within a balanced budget of $1.35M (FY95/96), of which $1M is collected recharge income. Average lab membership increased to over 200 this past year, with 65 PIs participating.

During the past ten years the Microlab had become a well managed, successful, cooperative recharge operation within ERL. Systems and controls we had developed are directly applicable to other recharge units and had been extended to satellite laboratories. Thus, the original Microlab grew into a system of facilities, providing infrastructure support for collaborative research in the College of Engineering and departments in the sciences.

K. V.
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## Executive Summary

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Figure 1.
MEMORANDUM

To: S. Sastry, ERL Director
From: K. Voros, Microlab Manager
Subject: 1996 Year-End Report
Date: 16 January 1997
cc: D. Angelakos, R. Katz, A. Neureuther, C. Spanos, and Microlab Member Professors

This is the tenth year-end report I am submitting as manager of the EECS/ERL Microfabrication Laboratory. As before, in 1996 the Microlab maintained its established operations and met its budgetary goals.

I. MANAGEMENT OF STAFF PERSONNEL

The number of direct support staff had been increased in 1996 to 16. (See top part of Figure 1.) A technician’s position, left open last year for budgetary reasons, had been filled, and a Programmer/Analyst I position had been opened. Increasing lab membership and use of facilities required additional staff for support.

Personnel highlights of 1996:
* David Baca was reclassified to Assistant Development Engineer.
* Bob Hamilton received a Certificate of Excellence in Management from the UC Berkeley Staff Assembly.
* Susan Kellogg-Smith received a Distinguished Service Award.
* Marilyn Kushner received a Distinguished Service Award.
* Rosemary Spivey received the departmental Zeilinger Staff Excellence Award.

Keeping staff motivated is a continuous activity. Maintaining bidirectional communications greatly helps promote interest in fulfilling our unit’s mission. During my monthly staff meetings I discussed issues that effect our work environment, provided updates on the financial status of the Microlab, and conveyed whatever information I received concerning the Department, ERL, and the University. Other subjects included progress of various research groups we are involved with and student’s successes. In 1996 we discussed two videos produced by other universities. The Microlab participated in the “Take Your Daughter To Work” movement, hosting daughters of two employees.

A new and interesting activity this past year had been a staff visit to the Stanford National Laboratory in August. Stanford staff initiated by inviting the staff of the Berkeley Microlab for a tour of Stanford’s microfabrication facility and a barbecue lunch. We reciprocated in November with a tour and potluck lunch. These visits provided opportunities for staff to meet counterparts and to develop contacts for exchange of information and assistance. Both occasions were successful in strengthening our “friends in research” concept.

After several budget cutting years the University allowed merit increases again and reactivated performance awards. Unfortunately, negotiations between UPTE, representing the technicians and the University did not result in a contract in 1996. As a consequence our high level, well performing technicians, have not had a salary raise in two years.
Maintenance Staff – For details of the activities of this group see report by R. Hamilton, Maintenance Supervisor, Safety Officer. (p. 14)

Administrative Staff – See report by R. Spivey, Administrative Supervisor, Office Manager. (p. 21)

Computer Support – See report by M. Kraitchman, System Manager. (p. 27)

Process Staff
After having lost our process supervisor to Silicon Valley twice in two years, the position was filled again in September 1995. John Knudsen came with semiconductor industrial experience; thus, he had to become familiar with our academic laboratory environment. While in training, requests for staff processing increased considerably and John had an opportunity to develop a well controlled system for handling ETRs (Engineering Test Requests). Process staff continues to run standard process monitoring (on 22 individual process modules) and to maintain up-to-date process documentation and equipment operating instructions.

Associated Research Staff
Major research groups associated with the Microlab continue to employ dedicated research staff successfully. These researchers receive their assignments from the PIs and work with graduate students on projects. Administratively they are under Microlab management. (See individual reports starting p. 41)

In 1996 BSAC added a second development engineer and the Integrated Materials Laboratory (IML) hired a manager; thus we had a total of 9 associated researchers.

Machine Shop
The joint MSME/ERL Machine Shop closed its second full year under Microlab management successfully. With systems and controls in place, budget and recharge-hours accounting under close monitoring, the shop is slowly recovering losses accumulated during the previous management. However, even with no lack of work, and recharge-hours optimized, it is extremely difficult to maintain a 2-man shop at reasonable rates and to provide debt reduction. For details see report by B. Lake, Machine Shop Supervisor. (p. 64)

II. INTERACTIONS WITH FACULTY AND RESEARCH GROUPS

Microlab Membership
• Over the years we had learned that communicating with our membership is very important in providing efficient support and maintaining safe operations. We have several channels through which we can reach lab members. Besides personal contacts and appointments, we use e-mail extensively, receiving FAULTS problem reports and sending repair updates and “equipment up” reports. We post issues needing immediate attention to “messages”, which are displayed to members upon logging into the lab. Mail sent to equipment name aliases and research aliases reach targeted groups and enable members to communicate with other lab users directly. (Respective PIs are included in the research groups and “allgroups” aliases.)

We hold regular monthly lab member meetings and send out meeting minutes with equipment status updates. To maintain a safe and well functioning lab, students have to be reminded of rules, protocols, and lab etiquette. As good habits erode, with each new crop of members we have to reinvigorate enthusiasm for keeping our tradition of help and cooperation.
• Among the traditions since the original IC laboratory was established in 1963 and continued in the new lab (dedicated in 1983) was cooperation among researchers and teaching each other. New lab members still learn from each other how to operate machinery and experienced students act as superusers for every equipment.

Another tradition is the October Clean Fest, where members scrub down the laboratory, sort through left over parts and accessories, and assist in a very thorough clean up. While staff organizes the sign up and provides cleaning equipment, lab members cooperate in high numbers. In 1996 we had the highest participation, 66% of total membership.

Our mandate of providing a safe research environment requires documentation that we educate our members in safe laboratory practices. Thus, we assigned February as safety month, during which all members must take the refresher safety quiz. No one is allowed to reenter the Microlab without passing the quiz.

• For prospective new members we hold lab orientation seminars monthly (except December.) During the four-hour morning program they receive introduction and general information to computer communications, safety, administrative matters, general processing and laboratory etiquette. In the afternoon session they receive a laboratory tour with emphasis on safety and emergency equipment. We provide full documentation and instruction on how to find on-line information.

Attendance in lab orientation seminars is around 15 persons, students, visiting scientists, postdocs; anyone who wishes to work in the Microlab and/or in the satellite laboratories must attend. After passing the safety quiz new lab members receive a computer account on argon and can begin training within the Microlab. During the past ten years 1012 prospective members attended lab orientation seminars (free) and with the exception of a few, all became lab members.

Berkeley Sensor and Actuator Center (BSAC)
BSAC researchers in the Microlab comprise by far the largest group, providing 28% of recharge income. BSAC activities place a heavy demand on equipment; however, members of this group are great contributors to process development and characterization, equipment trouble shooting and improvements. To assist with the widening range of research, BSAC hired a second development engineer this past year. See J. Bustillo’s report for further details. (p. 41)

Baseline Cmos Process
We were successful in maintaining our cmos baseline process in 1996, our 6th year, with contributions from Professors Cheung, Ferrari, Gray, Howe, Muller, Pisano, White, and Spanos. The Microlab provided laboratory and special equipment time, administrative support and supervision. We continue to process in our standard 2 μm n-well cmos technology. In 1995/96 we developed a 1.3 μm twin-well cmos process. (See G. Wang’s report for details, p. 47)

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BCAM is a major supporter and user of the baseline; they have developed two special test chips for collecting statistical data. The test chips contain a scribe lane section to be included in all runs and a drop-in chip which can be interchanged with any other design. The layout of the test chip is available for inclusion, with instructions at argon/cad/examples/rodriguez/kic. (Documented in Memorandum No. UCB/ERL M94/63.) For more complete data extraction to establish device parameters for circuit simulators, work continues with cooperation from BSAC to improve instrumentation and accessibility to parametric extractor software.
Microfabrication Research in ERL

One of the major programs within ERL is the operation of the Microfabrication Laboratory; thus, Professor Sastry, ERL Director, requested a summary of our accomplishments, to be incorporated in his annual report. In my memo, ERL Research Facilities – Update for ERL Annual Report 1995-1996, dated 16 September 1996, I discuss our contributions with respect to laboratories infrastructure management, research facilities, including the central Microlab, Device Characterization Laboratory, Plasma Assisted Processing Laboratory, Machine Shop, Integrated Materials Laboratory, interdisciplinary research and outreach activities.

III. MICROLAB RELATED ACTIVITIES

Solid State Devices and Technology Seminars

In 1996 we continued to organize the EECS 298-12 graduate seminars, Semiconductor Devices and Technology. Professors Bokor, Cheung, Hu, Neureuther, Oldham, Spanos participated inviting outside speakers, with the Microlab office following-up contacts, postings, parking arrangements, etc. Subjects cover a wide range of interests within the semiconductor field and the seminars are always well attended (30-40 people). Listings are shown on the web at http://www.eecs.berkeley.edu/EE/Seminars/.

EECS/ERL Supervisors Group

I had served for the fourth year as the chairperson of the monthly supervisors’ meeting. Major issues we discussed this past year: faculty changes, new faculty space/research equipment requirements, status of teaching and research laboratories, Cory and Soda Hall facilities problems, Cory Hall computer network infrastructure upgrade. Campus Services response to requests, staff and union issues, campus “Deans and Directors” memoranda, emergency response plans, and activities of units within the Department. Minutes of the monthly meetings were sent to the Chairman of EECS and the Director of ERL.

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The Laboratory Operations and Safety Committee, appointed by the Vice Chancellor for Research on behalf of the Chancellor has the delegated authority and responsibility for formulating and recommending campus policy on laboratory operations and safety. The LOSC participates in the development of the campus program to comply with Cal/OSHA Laboratory Standards, and reviews informational materials developed by the Office of Environment, Health, and Safety, addressing laboratory health and safety issues.

Members normally serve for a 3-year term. Having completed my term in 1995, I accepted membership on this committee for a second term because I believe in the importance of providing a safe research environment on campus. The Microlab, with the leadership of our Safety Officer, R. Hamilton, has always been pro-active in this area and continues to demonstrate a progressive and responsible attitude in environmental and safety issues.

In 1996 the LOSC reviewed an ongoing campus program requiring that all laboratory departments and ORUs have in place a complete and up-to-date Injury and Illness Prevention Program (IIPP). Also, deliberated on the toxic gas control program, heat and shock sensitive chemicals, fume hood labeling, electrophoresis safety. Communications with the campus occur through the Office of Environment, Health, and Safety, such as the proposed campuswide Laboratory Safety Manual, which the LOSC approved, and the EH&S Newsletter – Flash Point!
University Laboratories Network (Labnetwork)

Two years ago representatives from university laboratories formed the University Laboratories Network, an informal organization to provide a forum for discussion of common issues of interests. Academic microfabrication facilities serve as a unique national resource by advancing the state-of-the-art in a range of competitive microfabrication technologies. The Labnetwork intends to organize the academic microfabrication communities – both facilities and users – to leverage our complementary capabilities to promote and expand our role in advance technology education and precompetitive research.

- Among the activities of the Labnetwork was to provide a communiqué to the Semiconductor Industry Association (SIA) with comments on their new plan to establish a network of research centers at universities. These centers would address research issues that are 5-7 years beyond present practice. Labnetwork representatives, among them leaders of the Berkeley Microlab, forwarded a letter to the SIA in which several recommendations concerned physical facilities, research management, networks of excellence, industrial assignees, role of focus center manager, and capital equipment.

- Upgrading facilities to handle 6" diameter Si wafers is of major concern to participating laboratories. The motivation to upgrade from 4" to 6" diameter comes from not wanting to fall too far behind industry, (which is mostly in 8" by now,) to maintain some compatibility with research laboratories of industrial consortia members, and the increasing difficulty in obtaining state-of-the-art processing equipment for 4" wafers. Because it is important that we do not lose compatibility, MIT, Stanford, and Berkeley representatives had a meeting in August to discuss upgrade plans and status. The main subject of the general Labnetwork meeting during the IEDM in December was also the 6" conversion. Most university laboratories have upgrade plans, but none have funding in place, including Berkeley.

- Another important activity is the Labnetwork Software Project. This was initiated in recognition of a need for universities to share the development and support effort needed to maintain state-of-the-art laboratories information and management systems. The Berkeley Microlab has been computerized since its inception and an advanced management system was developed early. The software (BCIMS) was expanded modularly to equipment control, environmental monitoring, and a series of infrastructure management functions. Joint and shared development across institutions provides not only higher returns for our efforts but enables connectivity. Thus, Labnetwork representatives from UC Berkeley, Stanford and MIT developed a position paper outlining joint software project plans and soliciting interest in supporting this activity from the semiconductor industry and government agencies.

- Information and meeting minutes are available on the WWW at http://www-mtl.mit.edu/labnetwork.
Public Relations

- The Microlab had 428 visitors inside the lab in 1996, according to the sign-in list on the computer. As usual, we had many others who received the “window tour” and video presentation.

- Our 28 min. video, Microfabrication Research at Berkeley focuses on the activities of the Microlab’s major research groups. (8 in all: Advanced Devices, Advanced Lithography, Computer Aided Manufacturing, Compound Semiconductors, Superconductors, Physics, Materials Science and Berkeley Sensors and Actuators.) It contains interviews with group members, discussing and demonstrating their projects.

- In 1996 we continued to update the Microlab’s WWW home page, including practically all information available for members working inside the lab: what is available in the Microlab, what are the charges and how can one become a member. Our home page had 20,212 visitors since its inception in June 1994. Address: http://www-microlab.eecs.berkeley.edu/.

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Every year we review our Campus Services requests and report on those which need special attention. Campus Services has been cooperative in resolving the most critical problems, such as reducing the number of power failures and replacing a troublesome air conditioner. In 1996 air compressors maintenance received greater attention. Also, one of the original transformers supplying the Microlab needed replacement and upgrade. Campus Services installed a modern 3-phase transformer at our request but the Microlab had to pay for half the cost.

Microlab Equipment

R. Hamilton’s report details equipment development in 1996. No major equipment was added; our activities concentrated on upgrades and incremental improvements in existing instruments. We were successful in receiving and judiciously utilizing donated equipment, and we were able to supply parts to satellite labs.

We successfully maintained and expanded our computer system by utilizing hardware donations from other units in EECS. We have upgraded two more workstations to Sparks, thus providing faster machines to our members. This year we are looking at a major expense, connecting to the new fiber optic networking Cory Hall. Full connection is now planned for the Summer 1997.
Laboratory Infrastructure - Satellite Laboratories

Establishment of the new Integrated Materials Laboratory in 1993 gave impetus to the expansion of an already well-developed laboratories infrastructure, which means that technical, accounting and management support are provided through the Microlab. New equipment at other locations are installed with computer access control; this also provides usage information for sharing maintenance cost. We had modularly expanded BCIMS, the Berkeley Computer Integrated Manufacturing System software, with which we run the Microlab. Charges accumulated from users are returned to the IML without overhead, for the maintenance of that facility. Users of other satellite labs (Figure 2.) are charged staff rates when they request technical assistance.

Laboratories Managed by the Microlab

![Diagram of Laboratories Managed by the Microlab]

Figure 2.
V. FISCAL MANAGEMENT

The Microlab had an excellent fiscal performance in FY 95/96. We were able to meet expenses and a debt recovery of $59.5K was achieved. Thus, the Microlab’s remaining debt at the end of FY 95/96 was only $22K. For further details see Financial Report, FY 95/96 by Rosemary Spivey (12 September 1996).

Activities of all of our research groups increased during FY 95/96 and continue on strongly. We reached 200 in membership in May and collected recharge income surpassed $1M in June 1996.

Eliminating the debt was a 10-year long arduous process, and the occasion would call for some kind of celebration. However, our budget watchdog and rules-enforcer hiding behind Rosemary Spivey’s most pleasant demeanor, does not allow such frivolity until she sees the ledger reset to zero at the end of the current fiscal year in June 1997.

THE PAST DECADE

At the end of the tenth year of the Microlab under my management it is enlightening to revisit the issues we were concerned with as we established operations in the new lab. With Professor Ko, then Faculty Director of the Microlab, we wrote an ERL memorandum¹ about how we built the new laboratory, what are critical factors in maintaining it and how we are managing with available resources. The memo was distributed widely among university laboratories and visitors from all over the world who were interested in building and operating a facility like ours.

Interestingly, our observations and statements about running a university microfabrication facility are still valid; our predictions turned out better than estimated.

- With lab membership around 150 in 1989 we suggested that we would reach capacity at around 200 depending on the rate at which each group will grow. (p. 7 of the ERL memo)

We were successful in managing growth without any group becoming dominant, and balancing space and equipment demands without detriment to the research goals of any group. Lab membership surpassed 200 in May 1996 and traffic in the Microlab, although visibly increased, is still manageable.

- We estimated that it would take eight years to pay back the debt the Microlab incurred during construction. (p. 9)

With a couple of tight years along the way it took us ten years, but we have accomplished paying back the debt.

In the Looking into the Future section (p. 22) we listed four areas in which we deemed our position weak.

1. After the necessary cost containment measures to stabilize finances had been completed, direct support staff was at a minimum and process development activities effectively halted. We were concerned that this will be detrimental to our efforts to support graduate student research in a meaningful way.

   - As it turned out, as soon as all basic Si process modules had been in place, development of new processes shifted to the research groups. We were able to assist whenever the new process could be used by more than one group. This was especially true for VLSI process modules, in which the device, sensors, and process technology groups were the drivers. Staff assisted with test runs for standard CMOS applications, monitoring, and documentation. This joint development procedure is still in place and works effectively.

   - With the leadership of Professor Spanos, we were successful in 1992 in re-establishing the CMOS baseline process. Funding for a dedicated process engineer is provided by five interested research groups, who submit designs for processing. (The baseline also processes wafers for other groups for a fee.) The baseline went through a successful shrink already and we are examining various technology improvements to expand the baseline’s usefulness via support of our members.

2. We were also concerned that we had no program in place to provide new equipment and staff help for advanced projects.

   While it is true we do not have a specific equipment fund and as a recharge unit the Microlab is not allowed to collect extra fees to finance equipment, we were successful in developing several strategies to support advanced projects. These are:

   - **Cash contributions** from several research groups for purchasing a new/refurbished machine. Microlab provides site preparation, utilities connections, parts, and components available from donations. Often the Department contributes from BMA funds. (Examples: replacement of resist dispense and development systems, Al plasma etcher.)

   - **Restricted contributions.** One group promotes the purchase of a machine needed for their research but will make it available for others, depending on compatibility. In this case the promoting group will provide the majority of the funding, and the Microlab is heavily involved in rebuilding, changing/adding components and developing processes. (Examples: three LPCVD furnace systems for BSAC research, atomic force microscope for device work, advanced poly-Si plasma etcher with additional computer capability for BCAM work.)

   - **Used equipment donation from industry.** Often we lobby our company contacts for a needed machine, or we are offered one. In both cases extreme caution is in order. System contamination, wafer handling components, and general condition of the machine are of great concern. In every case we have spent considerable operating funds and staff time, to render donated equipment usable. (Examples: CPA aluminum sputter, plasma etcher, spindryer.)

   - **Dedicated equipment purchase.** Groups who wish to restrict equipment for their own exclusive use purchase them from their own funds. In this case the space issue has to be resolved. The Microlab is always a contributor by assisting with site preparation, installation, and donated spare parts. The most prominent example of this was the development of a dedicated process line for superconductors.
• Joint grants. A more recent development in financing equipment installation is the winning of the NSF grant titled *Acquisition of Instrumentation to Fabricate Low-Dimensional Artificial Materials*. The proposal had been submitted jointly by several professors from EECS, MSME, and Physics, all supporters of the Microlab. The proposal included a management plan which stated that the new instrumentation requested will be managed through the Microlab’s infrastructure. Thus the Integrated Materials Laboratory (IML) came into being in 1993.

3. Because of lack of plans and funding for facilities upgrade we were concerned that the Microlab will become obsolete in 3-4 years. (The report was written in 1989.)

The Microlab did not quite become obsolete, and in some areas it will not be for a long time, but in Si wafer processing we are rapidly approaching obsolescence. Upgrading to 6" diameter wafer processing is a high priority goal for the near future. Although we do have workable update plans, lack of funding and space remain major obstacles.

4. We cautioned that we will not be able to maintain a balanced budget if research grants, our funding base, will not grow at the same rate as expenses.

This concern is somewhat alleviated by the fact that when recharge income from ERL PI’s grants dropped, we were successful in broadening our outside use base; by servicing affiliated external researchers we were able to compensate for the revenue gap. It seems that there is a steady need for non-conventional services which we can support and control as necessary.

Finally, I would like to summarize what I see as the major components of the success of the Microlab during the past decade.

Starting with the original idea of pooling resources in a cooperative laboratory, faculty demonstrated unflagging support throughout. With the leadership of the faculty directors the Microlab was able to respond to research needs, to grow with a willingness to accept additional responsibilities, thereby assuring its own success.

First, we took over managing our finances. Then we stabilized operations by monitoring and/or assuming control of functions that affect Microlab operations, such as utilities, computers, services, etc.

As our own unit gained experience in facilities management and developed expertise in managing a recharge operation, we were called upon, indeed offered assistance to other units in the Department and ERL. We began servicing laboratories outside the Microlab informally, then they became recognized as satellites. This activity culminated in the formation of the Integrated Materials Laboratory, with its own manager and separate recharge account, operated through the Microlab’s infrastructure.

When the Department considered closing down the machine shop because of financial difficulties, we took over management. We considered the machine shop indispensable for smooth operation of the Microlab and invested extra effort in developing a successful strategy for its survival.

Thus, at the end of the first decade under my management the Microlab is in a propitious position for new initiatives.
Departmental Reorganization

In October 1996 the Department of EECS reorganized its technical support staff structure, and transferred computer service recharge activities to ERL. A new, independent recharge unit, the Computer Services Group (CSG) was formed with R. McNicholas as supervisor. I was asked to manage this group and another smaller one, Special Projects, through which facilities upgrades, rearrangements and new laboratory installations are expedited.

To allow me to handle the additional responsibilities we restructured management of the Microlab along functional lines. This also gave us an opportunity to involve our largest research group, BSAC, in leading the facility, unimpeached operation of which is in BSAC’s paramount interest. Thus, we invited J. Bustillo, Principal Development Engineer for BSAC, to take charge of technology development (process, baseline, IML, associate researchers). Jim retains engineering management for BSAC development efforts 50% of his time.

My responsibilities include directing administrative support for all groups including four independent recharge units (in excess of $2M); the Microfabrication Laboratories Infrastructure, Machine Shop, the Computer Services Group, and Special Projects. Jim Bustillo and I report to the Faculty Director of the Microlab. Jim reports to the BSAC directors 50% of his time. I coordinate with EECS on special projects and computer recharge services.

Figure 3. shows the organizational chart of ERL’s Research Infrastructure. Final decisions rest with the Director of ERL in consultation with the Chairman of EECS.

LOOKING FORWARD

There are several areas in which we laid the ground work for future developments in the Microlab.

• A modular upgrade of the silicon fabrication line to handle 6" (150 mm) diameter wafers should happen during the next two years.

• Our laboratory CIM environment needs to be upgraded to the latest computer technology, to manage shared facilities and to provide graphical user interface.

• As space limitations in the central facility preclude its physical growth, we will be further developing the satellite laboratories strategy, including laboratories in other buildings, even off campus.

• Plans for a joint facility with researchers at LBNL, at their site, are under development. This cooperative effort comprises the possibility of burgeoning in scope.

• Cooperative activities among university facilities will continue to grow and strengthen to the point where process specifications will routinely include equipment at other sites.

• We are proposing to be strong contributors in the planned SIA centers for pre-competitive research in SIA roadmap topics.

To sustain the above developments we need to reinvigorate Microlab support through the Berkeley Microelectronics Affiliates (BMA). This consortium had been instrumental in creating the new Microlab 15 years ago. Now we are poised for yet another major initiative and I trust we will be able to marshal our resources to continue to be among the major players in academic research in the coming decades.
EXECUTIVE SUMMARY

This document contains the 1997 Year-End Reports by the professional staff of the following units of Electronics Research Laboratory (ERL): Microfabrication Laboratories (ML), Integrated Materials Laboratory (IML), Computer Services Group (CSG) and Special Projects. Together, these reports reflect the wide range of support, staff provides to research and instructional laboratories in the Department of Electrical Engineering and Computer Sciences.

The reports are grouped into Operations and Technology, according to the staff organizational structure established at the end of 1996. Operations, including the laboratories infrastructure, computer services, machine shop, special projects, and administration, are under the management of K. Voros; technology support and development, including process staff in the Microlab, baseline and materials engineering, and staff attached to research groups, are directed by J. Bustillo.

Operations and Technology represent 35 career employees in four independent recharge centers with a total budget of approximately $3M. Users of the laboratories and other services come from seven departments in three colleges on campus, from the UC system, other universities, and from industry.

K. V.
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*Microfabrication Laboratories 1997 Year-End Report*

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Director’s Message

The original Microfabrication Facility was created at Berkeley in 1962 and was in use for 20 years, until the present facility was planned, funded, built and released to users in 1983. Back then, the “new” Microlab offered unprecedented capabilities to the campus community: a contiguous, class 100 space, near state-of-the art equipment, 4 inch, cassette to cassette wafer automation, and a flexible layout that allowed continuous upgrades over time. For the past 15 years, the Microlab was proven to be a huge success. Today it accommodates more than 250 world class researchers. It has contributed to the education of over 1,500 graduate and 1,200 undergraduate students that are now in leading positions in industry and in academia. It has helped spawn 8 companies. It is now the main area of research for more than 60 PIs across the UC system. Along the way, Microlab members have pioneered applications from high speed IC’s, to innovative biomedical devices, to amazing microstructures that promise to revolutionize every aspect of engineering in the years to come.

The Department, the University and the technical environment around us in Industry and Academia have changed greatly in the past 15 years. The flexible design of the Microlab has allowed us to grow and evolve. As the present facility approaches its 20th birthday, however, our room to grow and evolve further is limited. We have led the world in Microfabrication technology for almost 4 decades. If we are going to be leaders in this field in the future, we must again plan and take the next bold step: design and build a new Microfabrication Facility.

History suggests that the planning for a major new facility will take several years. Microfabrication costs can be astronomical, so we must carefully assess future research opportunities and prioritize infrastructure needs. Flexibility, ease of access, and multidisciplinary appeal were values that served us well in the past; they should be designed into the new facility. What type of technology should the new facility target? How much will it cost? Who will use it? These are important questions. The discussion is already underway. I invite you all to participate, so that we can continue our tradition of leadership well into the next century.

Costas J. Spanos
Faculty Director

January 1998
MEMORANDUM

To: S. Sastry, ERL Director
C. Spanos, Microlab Faculty Director
From: K. Voros, Operations Manager
Subject: 1997 Year-End Report
Date: 23 January 1998
cc: R. Katz, A. Neureuther, and Microlab Member Professors

In 1997, we operated under a new organizational structure established by EECS/ERL for research support staff at the end of 1996 (see Fig. 1). The technology side under Jim Bustillo and the laboratories infrastructure under Bob Hamilton continued to run smoothly, efficiently, and within budget. The new units under my management, the Computer Services Group (CSG) and Special Projects, required more attention than I expected; however, with effective cooperation from Rosemary Spivey and her administrative staff, we made good progress in streamlining the computer services operation and in evaluating the viability of a one-FTE Special Projects unit.

With the leadership of Faculty Director Costas Spanos, we made great strides in developing external contacts, support, and long range plans. To promote contacts and support, we established stronger ties with industrial users of the Microlab, in the form of a consortium, the Berkeley Microfabrication Laboratory Affiliates (BMLA); to develop future plans, we invited Microlab PI's for discussions at regularly scheduled lunch meetings. Both of these activities continue strongly.

Microfabrication Laboratories

The Microlab remains the center of the laboratories operation of ERL, which now includes 7 satellites, the Integrated Materials Laboratory (IML), and the EE143 instructional laboratory. The Microlab comprises a knowledge base for semiconductor processing and applications of microfabrication technology in a wide range of disciplines, expertise in facilities, and recharge operations management. This unit is a success by all measures due to a great extent to the unflagging support by faculty.

Microlab membership leveled out around 250 in 1997, from 80 participating PI's. This high level of activity translates into relative financial stability but it is a strain on resources, especially staff, space and utilities. Bob Hamilton's report details that much of the year we spent dealing with equipment upgrade projects while maintaining all capabilities and an aging facility.

Laboratory utilization can be grouped into the following categories based on income: BSAC and outside companies (mostly MEMS) ~25% each; device, Physics/cryo, external academics (including UC system) ~10% each; compound/optics, materials science, Chem./Chem.E./Mech.E. ~5% each. Regrouping the data based on departmental affiliation reveals that income from EECS PI's fell below 50% of total, for the first time since we operate the Microlab. One of the reasons for this trend is clearly the highly interdisciplinary nature of advanced semiconductor research. Thus, the Microlab grew
into a facility supporting numerous related scientific activities. Another reason is that we actively encouraged external use, to lighten the load on finances. It is also true that semiconductor processing technology progresses at such a rate that we are facing increasing difficulties in supporting our core clientele in EECS.

To address these issues and to plan for the future, Prof. Spanos initiated monthly lunch meetings with Microlab PI's. It is a welcome sign of continued faculty cooperation that these meetings are well attended and we are progressing toward formalizing long range development plans.

**Computer Services Group (CSG)**

The Computer Services Group provides a vital service to EECS/ERL, faculty, students, and staff, in the form of computer systems management, hardware/software support and Internet access. The group includes 7 FTE's, 3 programmer/analysts, 3 technicians and an administrative assistant, and has ~$0.8M budget. It is a recharge unit with income from over 360 contracts and almost 1,100 network access accounts, non-contractual labor and back-up charges. Billing and administration of accounts is a major task and requires constant attention to the accounts database (see G. Spear's Year-End Report).

After analyzing the first year of independent operation, it is clear that staff allocation within the group needs to be adjusted toward increasing software support. This issue will be addressed in the recharge rate proposal for FY 98/99. CSG started out as a UNIX-based operation; however, the proliferation of PC technology in both instruction and research, demands that we build up PC service and administration. This activity already began with providing back-up services and it is of high priority in filling open positions and development of current staff.

CSG staff participated in several major departmental projects in 1997. These were:
- Consolidation of computer servers in 165 Cory (space efficiency),
- Cory Hall network infrastructure upgrade,
- Special Projects, such as renovation of 373 Cory and construction of the MOCVD laboratory.

The network upgrade is continuing and, although over 90% of the original connection orders had been completed, it will continue for some time because of new orders and requests to move already connected machines to different locations. Also, the new network is still under testing and troubleshooting. This departmental project is managed by Fred Archibald but CSG staff is involved with both hardware and software assistance.

**Machine Shop**

The consolidated ERL/MSME machine shop continues to serve both departments successfully. Finances are maintained separately and maintenance costs shared equally. The ERL side of the shop operated within budget, including part of a prorated amount of deficit recovery. This 2-man shop is a small, precarious, recharge unit, $112K in FY 96/97, which requires tight control over recharge accounting and optimization of recharge-hours. There is more than enough work in the department, at campus competitive rates of $52.00/hr; in fact, customer demand required that we increased staffing by 0.5 FTE starting 1998.
Special Projects

1997 was the first year the Department operated an independent unit for Special Projects, with a charter to manage construction and refurbishing research laboratories and graduate student workspace. As research activities change, facilities must also change to accommodate them; thus, there is a real need for in-house renovation, remodeling in a timely and organized fashion. This type of local control, however, requires a critical investment of resources to ensure success. In 1997 we operated with limited manpower, 1 FTE and some student help, which is below what I would estimate as sufficient for the extensive projects we were asked to carry out. The only reason we were able to complete them, albeit with repeated pushing out of deadlines, was the pro-forma contributions made by the Computer Services Group and the Microlab. Additional support came from the building maintenance group and the Department’s pro-forma share from the Machine Shop.

The Special Projects unit worked on 10 major projects in 1997, with a total budget of $700,000. These were: Cory 373 renovation, construction of the MOCVD laboratory, installation of a sprinkler system on the first floor of Cory Hall, remodeling projects in 330, 337, 484, 550 Cory Hall, informational kiosk, and security system upgrade. (See Alex Para’s report for details.) Most of these projects are just now nearing completion, in the first quarter of 1998. Installation of the new security system is planned for the Summer.

Administration

A central administrative unit managed by Rosemary Spivey provides administrative support to the Microlab and its satellites, Integrated Materials Laboratory, Machine Shop, Special Projects, and the Computer Services Group. Two of the units, CSG and the Machine Shop, have dedicated administrative staff; the rest are serviced out of the Microlab’s office in 406 Cory Hall.

Administration includes four independent recharge units with a total recharge income of approximately $3M, generated from over 600 grants and contracts. Laboratories related accounts are managed through the Microlab’s database (over 330). CSG maintains its own for more than 350 contracts and over 1,000 network access accounts. Rigorous billing and ledger reconciliation are maintained for the recharge accounts, each with several cost centers.

Purchasing services for all units and individual laboratory members are provided out of the main office, and an extensive laboratories parts and chemicals inventory is maintained from there. CSG and the Machine Shop maintain their own parts inventory.

Personnel actions, performance evaluations are handled from the 406 central office for 35 career employees. Administration of the affiliates program, BMLA, and other external contacts, seminar arrangements, soliciting and acceptance of donations, public relations activities, visitors, are taken care of by this group. The administrative unit has developed into a highly valued group that manages its resources efficiently and effectively.
ERL Research Infrastructure

Administration: R. Spivey (Mgr.), S. Kellogg-Smith, M. Leullier, Eileen O'Neill, Student

Jan-98

Fig. 1
EXECUTIVE SUMMARY

This document contains the 1998 Year-End Reports by the professional staff of the following units of Electronics Research Laboratory (ERL): Microfabrication Laboratories (ML), Integrated Materials Laboratory (IML), Computer Services Group (CSG) and Special Projects. Together, these reports reflect the wide range of support, staff provides to research and instructional laboratories in the Department of Electrical Engineering and Computer Sciences.

The reports are grouped into Operations and Technology. Operations, including the laboratories infrastructure, computer services, machine shop, special projects, and administration, are under the management of K. Voros; technology support and development, including process staff in the Microlab, baseline and materials engineering, and staff attached to research groups, are directed by J. Bustillo.

Operations and Technology represent 41 career employees in four independent recharge centers with a total budget of approximately $3M. Users of the laboratories and other services come from seven departments in three colleges on campus, from the UC system, other universities, and from industry.

K. V.
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MEMORANDUM

To: S. Sastry, ERL Director
C. Spanos, Microlab Director
From: K. Voros, Operations Manager
Subject: 1998 Year-End Report
Date: 10 March 1999
Cc: R. Katz, A. Neureuther

In 1998 we continued to manage both sides of the organizational structure successfully — technology development under J. Bustillo and general laboratory operations and other support services under my management (see Staff Organizational Chart on opposite page). This is the twelfth year-end report I am submitting as a record of our ongoing work and accomplishments. Further details on each of the sections below can be found in the attached reports by professional staff.

Microfabrication Laboratories

The Microlab represents the center of semiconductor fabrication facilities supported by ERL and the Department of EECS. Microlab membership increased this past year to over 300 (representing more than 80 principal investigators from the UC System and 26 from other institutions), placing a tremendous burden on all resources, facilities and staff. The financial situation of this unit is healthy with a generated recharge income of $1.44M. However, an increase in membership (i.e. income) represents linearly increasing expenditures and not accumulated revenue. University regulations do not allow recharge accounts to include reserves for future development; thus, we have to find other sources of funding for equipment upgrades and replacement.

Facilities Upgrade

Plans for modular upgrade to handle 6” wafers were worked out in detail. The final impetus came from an opportunity to apply for used equipment from a manufacturing facility to be decommissioned by Intel in the middle of 1999. We were assigned most of the equipment we applied for, most importantly a Nikon 5x stepper that will form the basis of the 6” lithography module. Unfortunately, space in the Microlab is fully utilized and moving additional equipment in requires major planning, consolidation of dedicated activities into smaller areas, reconfiguration of walls and utilities and removal of lesser used equipment. At the same time operations must continue as usual, aging infrastructure attended to more frequently, and demands by the highest number of users we have ever had satisfied. It is a challenge.

We have increased the number of technical staff by two, administration by one, the process supervisory position was reclassified to a higher level, Senior Development Engineer, and filled, and a new engineering position was opened to service the distributed MEMS project funded by DARPA, (administered through CNRI). We had to create space for new support staff by rearranging, sharing current office space, and borrowing from other units. The Microlab Office, among the highest occupancy areas in the building, (56 sqft/person), simply cannot support more people.
Microfabrication Laboratories
Staff Organizational Chart

ERI Dir.
S. Sastry

ML Faculty Dir.
C. Spanos

BSAC Dirs.

K. Voros
Principal Dev. Engineer

J. Bastillo
Principal Dev. Engineer

Special Projects
A. Para
Students
B. Lake
(Sup.)
R. Amaral
R. Baeza
J. Gavazza
K. Yee
R. Kubota

Machine Shop

Computer Services

Microlab Computer
D. Medie
Student

Lab. Infrastr.
R. Hamilton
(Mgr.)

Operations

Microlab Process

Satellites
Plasma Lab
D. Baca
Planar. Lab
EE143
QE Lab
Laser Lab
Dev. Char. Lab

Staff

J. Donnelly
S. Gidden
P. Guillory
P. Kaksonen
S. Larrieu
M. Linan
C. Williams
P. Wehrly
Students

S. Parsa
(Mgr.)
M. Kushner
R. Su
Students

Research Projects
X. Meng
(Cryo)
K. Chan
(DUV)
E. Koo
(DMEMS)
G. Wang
(CMOS)
Student

Integrated Mat. Lab
R. Prohaska
(Mgr.)
J. Parrish
Student

BSAC
A. Singh
(HDDS)
TBF

Administration: R. Spivey (Mgr.), S. Kellogg-Smith, M. Connor, F. Crane, M. Leullier, Students
New Laboratory

During last year we have discussed with participating faculty planning for a new Microlab. The need arises from several factors, most importantly the need for new equipment for advanced research. Microfabricaton technology proliferated into a wide range of disciplines, among them life sciences, which require a broader range of instrumentation. Finally, but not less importantly, the success of the Microlab shows the necessity and validity of a campus-wide resource, available to all researchers on a recharge basis. Based on the strong support we received from member PI's we formalized our request to the Dean and continue to pursue it this year.

Microlab Computers

The Microlab's computer environment is a real-time, dynamic system which provides laboratory and equipment access control, operational management (equipment reservation, problem reporting, process and equipment operation documentation, recharge accounting) and facilities management. The system, with continuous upgrades, has been in operation since the new lab opened 15 years ago. With the rapid advance of computer technology we are facing yet another challenge, incorporating PC's (most processing equipment comes with PC control) into the Unix environment, and implementing a windows based user interface.

Two years ago we started a joint development program, LabnetSoftware, with laboratory computer system managers from Stanford and MIT. After a detailed design period we are into modules development. The equipment control module, which also required design of special hardware (done at Stanford), is close to completion and testing. We have designed this module such that it can be implemented as a stand-alone system, running on a PC with special boards. We had several inquires from other universities wanting to install such a system in their lab.

Other modules worked on are reservations, process control, and facilities management. We opted to develop the accounting module for the new system and use the Informix database. This work continues with participants working at their respective locations and joining for weekly intensive workshops every 2-3 months.

The Microlab maintains its own computer support group (total of 2 FTE) for internal operations, including accounting, inventory and purchasing. We also have a service contract with CSG for the main server, argon, and for several newly installed PC's. The Microlab's computer support staff is responsible for the continuous operation of the system and Y2K compliance. Additionally, David Mudie is one of the main contributors to the LabnetSoftware project.

Computer Services Group (CSG)

We have closed the second year of CSG as an independent recharge unit under my management, with reasonable success. While not fully staffed throughout the year, the group provided timely service to our clients and was instrumental in bringing the new network infrastructure in Cory Hall to full production. While the computing environment is moving more and more into PC based technology, the importance of Unix does not seem to diminish. Skills in merging the two and supporting users who wish to use applications in both systems in a transparent fashion, are highly valued and absolutely necessary for this service operation. CSG has made important strides in developing staff to meet these requirements.
CSG's five programmer analysts, including the technical supervisor, provide software support, both in Unix and NT environments. Two principal electronics technicians deliver hardware service and network support.

- A major project in 1998 was rendering Cory Hall's new network infrastructure fully productive. This required both hardware and software support with the leadership of Fred Archibald. As of 1 July 1998 the new network is considered fully in "production mode".

- Consolidation of servers into 165 Cory continued throughout the year, with additional racks. The UPS was brought online.

- CSG developed an extensive PC service with installations, setups and configurations, on a time and materials basis. A new PC contract was offered in the middle of the year; however, only one research group opted to buy it.

- Software support for 300+ contracts continued to be the main service mode in the Unix environment.

- CSG staff provided extensive assistance with system administration and migration of accounts for the Titan group.

- CSG management has invested considerable time and effort into developing the framework for a new computing infrastructure across the Department. We worked with Prof. Culler, Vice-Chair for Computer and Networking Needs and Resources, and a newly emerging infrastructure development group, on reorganizing the existing support structure with well defined responsibilities for each group and additional staff to provide planning for future technologies.

The new organization is targeted to go into effect starting the new fiscal year, 1 July 1999 and CSG as a unit is preparing for transfer under the newly created position of Computer Resources Manager.

**Special Projects**

This unit continues to operate with limited manpower, one FTE and two student assistants. In April 1998, I submitted a memorandum concerning the viability of such a unit, with analysis and proposed options. The decision was to maintain the unit as is, with expectations that need for facilities remodeling will subside and that a major upgrade of security systems in both Cory and Soda Halls will take precedence.

Cory Hall was the first building on campus to adopt electronic access controls with a card key system 15 years ago. Now EECS, with both buildings converted, represents approximately 30% of the doors under electronic control by the UC Police Department. Upgrading our system to newer electronics, expanding it to additional doors coincided with the need for Y2K compliance and provided the impetus to install a new system. This involved new controllers, pulling new wiring to the currently controlled doors (64) and to additional doors requested (14), and installation of new card readers at each door. Transfer to the new system went smoothly and was mostly completed by the beginning of the spring '99 semester. Planning for the upgrade in Soda Hall is in progress with anticipated completion by the end of the year.
Machine Shop

The joint ERL/MSME Machine Shop continued to operate successfully for the fourth year. There is a definite need for the shop’s recharge services; in fact, we had to increase staffing by one FTE. The special coexistence of two shops, from two departments, under separate budgets, is a tribute to creative cooperation by staff and can serve as an example of open-minded departmental leadership.

Central Administration

This unit provides administrative management to four recharge accounts, the Microlab (ML), the Computer Services Group (CSG), the Machine Shop, and the Integrated Materials Laboratory (IML), representing a total budget of over $3M. Meticulous accounting and careful monitoring is required to keep each account within projected expenditures and revenues. Two of the accounts, CSG and the Machine Shop are still working off inherited deficits, and IML is struggling not to accumulate any.

Central administration also provides purchasing services to the units under my management. With the explosive growth of activities in the Microlab, procurement and inventory control became a major activity. We have 1586 items in inventory, and place 150 orders/month on the average. These have to be expedited, received, some shipped to outside services. EH&S regulatory requirements must be observed for shipping and storing chemicals, and laboratories must be stocked for around the clock operation. It is a credit to staff that these activities went seamlessly and transparent to lab users throughout the year.

Other Activities

Microlab Membership

- In 1998 we continued to hold our monthly lunch meetings with Microlab member PI’s. Discussions included development of a joint proposal for the newly established State of California research initiative, SMART; space and equipment issues, special concerns, and future plans.

- The Microlab’s affiliates program (BMLA) continues to flourish. Thirteen companies, mostly small startups are actively participating. We hold meetings periodically for this special group, but mostly they are indistinguishable from general membership. Our first BMLA member company grew out of the Microlab into its own facility. We also had one that went out of business. We are proud of both.

- Monthly lab member meetings are held by Bob Hamilton, with minutes sent out to all, including PI’s. We often utilize suggestions and resolve conflicts through open discussions.

Solid State Devices and Technology Seminars

In 1998, I continued to organize the EECS 298-12 graduate seminars, Semiconductor Devices and Technology. Professors Bokor, Cheung, Hodges, Hu, King, Neureuther, Oldham, Spanos and the Microlab are sponsors, inviting outside speakers. The Microlab office follows up with postings, parking arrangements, etc. Subjects cover a wide range of interests within the semiconductor field and the seminars are always well attended (30-40 people). Listings are shown on the web at http://www.eecs.berkeley.edu/EE.Seminars/.
EECS/ERL Supervisors Group

I continue to serve as the chairperson of the monthly supervisors’ meeting. Major issues we discussed this past year: faculty changes, new faculty space/research equipment requirements, status of teaching and research laboratories, Cory and Soda Hall facilities problems, impact of HMMB construction on Cory Hall residents, and activities of units within the Department. Minutes of the monthly meetings were sent to the Chairmen of EECS and the Director of ERL.

Hearst Mining Project

One of the major projects in the Campus’s Capital Improvement Program involves the Hearst Mining Memorial Building (HMMB), immediately adjacent to Cory Hall. The HMMB project impacts Cory Hall activities in several areas: noise and vibration are directly experienced in class rooms, offices and labs on the south side of Cory Hall; building access is restricted and/or eliminated at the south entrances. This required rerouting Shipping and Receiving, pedestrian traffic and disabled access. The Microlab is especially vulnerable because disturbances in utility lines could shut down operations. We started discussions with the HMMB project team early on and worked out an acceptable plan for installation of a temporary fill line and relocation of our liquid nitrogen vessels. Another concern is the installation of a new power line (12 KV, 2300 Amp) between Cory Hall and HMMB, not part of but coincident with the HMMB renovation project. The electron microscopes located in first floor labs are sensitive to electromagnetic interference. Establishing communications and working creatively with the project team were important activities this past year, and will continue for the duration of the project (until 2001) to protect Cory Hall operations.

Campus Laboratory Operations and Safety Committee (LOSC)

The Campus-wide Laboratory Operations and Safety Committee has the delegated authority and responsibility for formulating and recommending campus policy on laboratory operations and safety. The LOSC participates in the development of the campus program to comply with Cal/OSHA Laboratory Standards, and reviews informational materials developed by the Office of Environment, Health, and Safety, addressing laboratory health and safety issues.

I am completing my second 3-year term at the end of the 98/99 school year on this committee. The Microlab has always been pro-active in this area and continues to demonstrate a progressive and responsible attitude in environmental and safety issues; thus, I will nominate a candidate for membership at the end of my term.

Outreach and Public Relations

- Microlab management spends a fair amount of time and effort in advising visitors from other institutions about laboratory management. During the past fifteen years we have accumulated extensive experience in building, operating, and staffing such a facility, as well as in organizing a coordinated method of support and financing. Invariably, our visitors leave impressed, armed with a package of reports and other information. Last year we had over 500 individual visitors from academia and industry; more extensive, management type of visits from twelve institutions.

- We handle technical inquiries from outside daily. The Labnetwork e-mail list, now including over 200 addresses, that we established with MIT and Stanford three years ago, developed into a useful and uncluttered resource for information on operating microfabrication laboratories. We make an effort to reply to specific questions sent to the list; most of the question involve problems we experienced and are likely to have the answer.
• The Microlab extends the courtesy to other academic institutions to assist with standard processing at our regular recharge rates. Last year we filled requests from 23 institutions. (Tables 2. & 3.) We were also instrumental in developing the DARPA financed distributed MEMS fabrication environment, managed by CNRI. We were the first site to offer 25 process modules for the program.

• At the initiation of John Fong, Semiconductor Manufacturing Instructor at Heald College, Sacramento, we developed a program to facilitate training of Technician College Educators in California. As part of this pilot program Mr. Fong became a Microlab member and learned to process a simple 4-mask device. This was jointly funded by his own grant and the Microlab. Mr. Fong then incorporated the processing into his class at Heald and came with his small class four times Saturday mornings. We are evaluating this program with plans to improve and continue it.

CONCLUSION

Laboratory operations supported by ERL are managed through the central facility, the Microlab. The Microlab is not only a campus-wide resource (see Table 1.) but has members from five other campuses system-wide (Table 2.) and assists nineteen other academic institutions. (Table 3.) Successful continuation of the research programs supported by the Microlab will depend on our ability to renew our facilities. We have initiated planning for a new Microlab and will pursue all available avenues to bring this issue to the forefront. We have no other choice if we are to meet future research challenges and to remain a prominent educational institution in this field.
### UCB Microlab Member Professors from Campus Departments

<table>
<thead>
<tr>
<th>Name</th>
<th>Department</th>
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<tbody>
<tr>
<td>Paul Alivisatos</td>
<td>Chemistry</td>
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<td>Jean Frechet</td>
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<td>David Graves</td>
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<td>Roya Maboudian</td>
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<td>Marcin Majda</td>
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<td>Richard Mathies</td>
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<td>Robert Schultz</td>
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<td>Gabor Somorjai</td>
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<td>Raymond Stevens</td>
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<td>Mauro Ferrari</td>
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<td>Kenneth Goldberg</td>
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<td>Thomas Devine</td>
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<td>Andreas Glaeser</td>
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<td>Ronald Gronsky</td>
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<td>Eugene Haller</td>
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<td>J. W. Morris</td>
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<td>Robert Richie</td>
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<td>Tim Sands</td>
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<td>Eicke Weber</td>
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<td>Stanley Berger</td>
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<td>George Johnson</td>
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<td>Dorian Liepmann</td>
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<td>Arun Majumdar</td>
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<td>Albert Pisano</td>
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<td>Boris Rubinsky</td>
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<td>Chang-Lin Tien</td>
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<td>John Clarke</td>
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<td>Daniel Chemla</td>
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<td>Mark Hurwitz</td>
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<td>Oswald Siegmund</td>
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Table 1.
Table 2.

### Academic Institution Principal Investigators

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<tr>
<th>University</th>
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<tbody>
<tr>
<td>CalTech</td>
<td>Y-C Tai</td>
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<tr>
<td>Case Western Reserve U.</td>
<td>J. Melzak</td>
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<td>EE/Microel. Res. Ctr.</td>
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<td>P. Fisher</td>
<td>E&amp;AS</td>
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<td>J. Fong</td>
<td>SMTP</td>
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<tr>
<td>Max-Planck Institut/Germany</td>
<td>E. Kreysa</td>
<td>Radio Astronomy</td>
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<td>Nanyang Technological U.</td>
<td>D. Hejun</td>
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<td>Ohio State U.</td>
<td>H. Kagan</td>
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<td>Simon Fraser U.</td>
<td>A. Parameswaren</td>
<td>Engineering Science</td>
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<tr>
<td>Stanford U.</td>
<td>M. Tang</td>
<td>CIS</td>
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<tr>
<td>U. of Canterbury/New Zealand</td>
<td>M. Alkaisi</td>
<td>EE</td>
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<tr>
<td>U. of Chicago/Argonne Natl Lab</td>
<td>J. Ralph</td>
<td>Materials Research Lab</td>
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<tr>
<td>U. of Houston</td>
<td>J. Mill</td>
<td>TX Cntr. For Superconductivity</td>
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<tr>
<td>U. of Illinois, Urbana-C.</td>
<td>C. Lansford</td>
<td>School of Chemical Sci.</td>
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<td>U. Jyvaskyla/Finland</td>
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<td>D. DeVoe, R. C. Skhhar</td>
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<td>K. Edinger</td>
<td>Inst. for Plasma Research</td>
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<td>R. Esser</td>
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<td>O. Milor</td>
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<td>T. Owens</td>
<td>Inst. for Sys. Research</td>
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<td>U. of Michigan</td>
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<td>U. Wisconsin-Madison</td>
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Table 3.
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*Microfabrication Laboratories 1999 Year-End Report*

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<td>Siavash Parsa, P. Sup.</td>
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<td>Marilyn Kushner, P. Sup.</td>
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<td>James Bustillo, A. Dir.</td>
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<td>Xiaofan Meng, Sr. Dev. En.</td>
<td>39</td>
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<td>Kim Chan, Staff Res. Assoc., Advanced Lithography</td>
<td>42</td>
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<td>Robert Prohaska, IMI. M.</td>
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SUMMARY

This document contains the 1999 Year-End reports by the professional staff of the Microfabrication Laboratories (ML) and Integrated Materials Laboratory (IML). Together, these reports reflect the wide range of support that staff provides to research and instructional laboratories in the Department of Electrical Engineering and Computer Sciences.

The reports are grouped into Operations and Technology. Operations, including the laboratories infrastructure, Machine Shop, and Central Administration, are under the management of K. Voros. Technology Support and Development are directed by J. Bustillo.

Microlab Operations and Technology represent 41 career employees in three independent recharge centers with a total budget of approximately $2.5M. Users of the laboratories come from seven departments in three colleges on campus, from the UC system, other universities, and from industry.

1999
6" upgrade - full wip, all equipment for baseline proc.
Novellus install
CMC rom 150 cong - facilities, tool inst.
Argon main server mig. to silicon (Solaris 2.6)
Bob Connelly, Kevin McNeal hired; Eileen Bagdan -off; larry Voros baseline off.
Fem. 2 shrink
Tg-2 female
Moxonix caser
Sopra ellips
MEMS Echange participation
Impact of HMB construction
MEMORANDUM

To: M. Lieberman, ERL Director
From: K. Voros, Microlab Manager
Subject: Microfabrication Research in ERL — Notes for ORU Program Review
Date: 5 September 1995
cc: D. Messerschmitt, C. Spanos

One of the major programs within ERL is the operation of the Microfabrication Laboratory in Cory Hall; a recharge facility with a budget of about $1.2M. It is one of only three university laboratories in the country that support a standard cmos baseline process.

Program Significance

ERL has a long history of maintaining programs in experimental microelectronics. We established an early integrated circuits processing laboratory soon after the invention of the chip and had produced working devices and circuits by 1963. In subsequent years we graduated many students with advanced degrees, whose research subjects included novel IC designs and processing techniques.

Establishment of an advanced laboratory was supported by our faculty 15 years ago, when we put together a proposal to develop funding for a new, modern facility. Rapid advances in the industry warranted that by the time we had the new lab completed in 1983 the original goal of fabricating advanced circuits had to be modified and reassessed. Because we included flexibility as one of the design specifications, we were able to redirect our support to respond to new needs and to develop a much wider user base than originally planned. This flexibility and a well organized and managed staff structure allows us to maintain the Microlab at about half the cost of comparable labs at MIT and Stanford. At the same time, we serve twice as many researchers as either of the above. The significance of this program lies in the fact that it enables EECS to deliver a modern and highly recognized program in microelectronics.

Graduate Student Support

Educational and research objectives are closely interwoven in the Microlab. The lab provides site for advanced graduate courses in processing technology, statistical process control and experimental design, and fabrication of novel devices. The courses are updated each year and new courses are created to keep pace with the state of the art.

Students are expected to become personally competent in modern engineering methods for analysis, design, simulation, fabrication, and application of electronic devices and systems. Students carry out all fabrication of experimental devices themselves. The architecture of the Microlab reflects its educational emphasis by providing not only ultra-clean areas for high-level research, but also learning areas for beginning students. A policy of sharing laboratory facilities promotes technical exchanges among students from different specialties, a situation that has proven highly beneficial.
Students may also participate in planning laboratory policy. Basic policy is set by laboratory management in consultation with Microlab members during monthly membership meetings. Students have a unique opportunity to participate in maintaining the best and safest possible research environment. A highly cooperative spirit had been achieved, and researchers from diverse disciplines can work in harmony. It is a well-known fact that Berkeley graduates have been and continue to be major contributors in the development of the semiconductor industry.

**Leveraging of Extramural Funds**

- ERL's success in attracting research grants is enhanced by the existence and successful operation of the Microlab. Many of the grants proposals include research which can only be done in an advanced fabrication facility. Two years ago we were able to obtain a $1.6M NSF instrumentation grant, based on the strength of our laboratories infrastructure centered around the Microlab. Microlab staff provide management, technical and administrative support to several satellite labs, depicted in Figure 1.

![Diagram](image)

**Figure 1.**

- One of our strongest research efforts is in integrated sensors and actuators. Because we had the facilities to develop several key technologies, including fabrication of micromotors, we are among the world wide leaders in this research area. We were the first to develop low stress silicon nitride films, essential for membrane based sensors applications and x-ray lithography. We are among the very few laboratories who can offer this service to other institutions. Based on these advances the Berkeley Sensors and Actuators Center, an NSF/Industry/University Cooperative research center was established five years ago. Among the most desirable features of BSAC for industrial partners is the existence of a facility where new ideas can be turned into working devices and tested.
- 3 -

- The same applies in superconductor research. We have a dedicated processing line for low temperature Josephson Junction circuits. Our cryoelectronics group has been a recipient of steady funding from ARPA.

- SRC is a major supporter of semiconductor research. ERL received over $3M for various projects, in many of which the Microlab is a key factor.

- The Microlab provides services not generally available in industry, to other institutions and companies. As these services are available only through becoming a consortium member, we are leveraging our unique capabilities to attract industrial members to any of the several consortia in the Department and College of Engineering.

- Equipment donations by semiconductor companies is a major resource for upgrading our facilities. We are able to attract valuable equipment donations because our research advances and successful laboratories operations are well known. Thus we can keep abreast of developments and provide our students with new opportunities.

Unique Contributions to the Campus’s Research Mission

ERL’s Microfabrication Laboratory is the only facility on campus that provides research space and knowledge in state of the art semiconductor technology. Microfabrication has wide range of applications in various fields of engineering and sciences. 32% of our membership originates from departments other than EECS, such as Chemistry, Chemical Engineering, Geophysics, Industrial Engineering and Operations Research, Materials Science and Mineral Engineering, Mechanical Engineering and Physics. Our staff and students actively participate in campus-wide committees, such as the Laboratories Operations and Safety Committees.

We have students from other UC campuses, including Davis, Los Angeles, San Diego, San Francisco and other academic institutions, among them U. of Minnesota, Michigan, Case Western, and Maryland; currently we are working with 16 students from seven outside universities.

We are one of the organizers of a nationwide university semiconductor laboratories network, and continuously provide information and advice to other university facilities. Visiting professors and laboratory organizers spend considerable time with us learning how to establish and run such a facility. We are an easily accessible resource, with information on the WWW for anyone who is interested. We can say without exaggeration that the UC Berkeley Microlab is known world wide, enhancing the University of California’s reputation for high quality education and research.
MEMORANDUM

To: Prof. D. Messerschmitt, EECS Chair
Dean D. Hodges, College of Engineering

From: K. Voros, Microlab Manager

Subject: Trends in Microlab Support

Date: 18 August 1995
cc: C. Spanos, Microlab Faculty Director

After discussing the Microlab’s financial situation with you earlier this year, Prof. Spanos and I started an outreach program to expand our user base. Informational letters were sent to the chairmen of the departments of Chemistry, Chemical Engineering, Civil Engineering, Geology and Geophysics, Industrial Engineering and Operations Research, Materials Science and Mineral Engineering, Mechanical Engineering, Nuclear Engineering, and Physics. (See attached sample.) Taking into consideration research orientation, we also sent a total of 58 letters to selected faculty in the above departments. In addition to these mailings, Prof. Spanos and I personally take every chance to encourage interested PI’s to explore the opportunities and tools provided by the Microlab, for their own research and/or joint projects.

Income figures at the closing of FY 94/95 indicate that our outside business (other departments, other UC campuses, academic institutions, and companies through SPO) is healthy and on an upward trend. It is our departmental support that is of concern to us; it has weakened during the last three years. Enclosed you will find charts taken from the Microlab’s Fiscal Year End report that indicate income trends from various research groups.

The Microlab is an excellent and efficient facility and a great resource for EECS/ERL. I am confident that EECS/ERL will continue to support it; however, if the above trend continues we may be facing major problems financially and may have to reassess the justification for maintaining a microfabrication facility. Please give thought to these concerns when you are developing future plans for EECS/ERL.
June 23, 1995

Prof. D. Ashley, Chair
Dept. of Civil Engineering

Dear Professor Ashley,

We are writing you to relay current information about the EECS/ERL Microfabrication Laboratory in Cory Hall. Over the years many professors from other departments have been involved with active student members in the Microlab. With engineering research becoming more and more interdisciplinary, we would like to invite your faculty to explore research tools and opportunities offered by the Microlab.

The Berkeley Microlab is an established operation supporting a standard cmos baseline process and providing facilities to a wide range of research projects in sensors and actuators, compound semiconductors, superconductors, and various applications in microfabrication technologies. Equipment and process maintenance is provided through a staff structure tailored for efficiency and for optimum resource allocation. The Microlab operates within a balanced budget comprised of $1M recharge income and EECS/ERL contributions in the form of salaries of three staff personnel (FY93/94). Average lab membership is 160, with 45 professors participating.

We are pleased that from all accounts faculty finds the service we are providing excellent and we aim to continue it. We are maintaining close contacts with our research groups to accommodate changing research needs and requirements. A recent example of such activities was obtaining a joint NSF equipment grant by PI’s from EECS/ERL, Materials Science and Physics. Through this grant we were able to provide a much needed e-beam writer, a high-resolution X-ray diffractometer, an UHV MBE growth system, and a laser ablation system for groups in the participating departments.

We hope to continue developing successful joint projects in the future. We would like to ask your assistance in informing your faculty of resources available here and encourage them to explore the opportunities provided by the EECS/ERL Microfabrication Laboratory.

Enclosed please find additional informational material. We also have a 28 minute video titled Microfabrication Research at Berkeley, which you are welcome to request by sending e-mail to kellogg@argon.eecs.berkeley.edu.

Sincerely,

C. J. Spanos, Faculty Director

K. Voros, Manager
ABSTRACT

This document contains the 2000 Year-End Reports by the professional staff of the Microfabrication Laboratories, EECS/ERL. Together, these reports reflect the wide range of support staff provides to research and instructional laboratories in the Department of Electrical Engineering and Computer Sciences, University of California, Berkeley.

Activities of direct Microlab (ML) operations support staff, described in the sections Facilities, Administration, Computers, and Process include 24 career employees and 10 undergraduate student assistants. Various research groups support 5 additional engineers, working on assigned projects. The Integrated Materials Laboratory (IML), a separate recharge center, employs 2 engineers and the Machine Shop operates with 5 staff as an independent recharge unit. The three recharge centers operated within their budgets last year, $2.3M, $140K, and $196K, respectively.

The Microlab had an average monthly membership of 340, of whom 62 were also IML members. Participating PIs: 72. The Machine Shop completed 204 jobs from 44 PIs. The Berkeley Microlab Affiliates program (BMLA) comprises 25 industrial members. Detailed Microlab information can be found at www-microlab.eecs.Berkeley.edu.

K. V.
MEMORANDUM

To: A. Pisano, ERL Director
    T. King, Microlab Faculty Director
From: Katalin Voros, Operations Manager
Subject: 2000 Year-End Report
cc: S. Sastry, C. Spanos
Date: 20 February 2001

I. INTRODUCTION

The year 2000 was a change in many respects. Most notably, the Microlab's Faculty Director for seven and a half years, Prof. Costas Spanos forwarded the torch to Prof. Tsu-Jae King, effective 1 July. Prof. King conducts research in advanced devices and is a major user of the Microlab through her students. We are honored to have her as our new Faculty Director. We also have a new ERL Director, Prof. Al Pisano who as one of the BSAC directors and PI of a large number of students in the Microlab, is closely familiar with lab operations.

On the staff side, Jim Bustillo, Technology Manager of the Microlab and Assistant Director of Technology for BSAC, resigned in June after nine years of outstanding service. We are fortunate that both faculty and staff remain dedicated to the Microlab for long periods of time; our two faculty directors stayed with this assignment close to eight years each, and our technology manager, a principal development engineer, for 9 years.

We, current senior staff with Bob Hamilton and Rosemary Spivey, accumulated 71 service years with the University (33, 20, 18). Undoubtedly, a major component of the success of the Microlab is that it has had continuous, long-term leadership and management.

This document is the fourteenth year-end report we are submitting on behalf of the Microlab.

Operational Management

![Diagram of Operational Management](image)

Figure 2
II. OPERATIONAL MANAGEMENT

The Microlab represents the center of semiconductor and microfabrication research supported by ERL and the Department of EECS. Microlab operations require management of resources (facilities, staff, and finances); management of communications, control, and development plans (Fig. 2). These activities are carried out by several mutually dependent support groups (Figs. 1 and 3) in the main facility on the 4th floor of Cory Hall and at several satellite locations (Fig. 4). This report details each of the management areas, with references to the reports by professional staff, on the following pages.

Interaction of Support Groups

![Interaction of Support Groups Diagram]

Figure 3

III. MANAGEMENT OF RESOURCES

Facilities

**Microlab**

The UC Berkeley Microlab supports facilities with a full complement of equipment for silicon-based microfabrication processes, including 1μm CMOS IC technology, surface- and bulk-micromachined MEMS devices; niobium superconductive devices and IC's, and compound semiconductor optoelectronic devices. To enable research activities in all these areas we are maintaining 130 operating systems. The main facility which was constructed 20 years ago (1981-1983) includes the [then] new lab, the old lab and the main office, together about 10,000 sq ft. By now this space is 150% utilized — as one of our visitors observed.
Equipment additions, as required by new research, can be accommodated only by removing older, less used systems and/or by upgrading existing ones. Neither of these options is very satisfactory because newer equipment always requires more space, more utilities and upgrades require squeezing available resources to their limits.

To accommodate equipment received through the SMART program the past two years, we had to renovate rooms outside of the main lab and establish satellite labs, such as the Thin Films Lab (144AB) and the Planarization Lab (190). Support staff for the satellite labs shares office space in 178M with researchers.

Lack of space is not the only problem. Cory Hall utilities, such as industrial water, re-circulating cooling water, drains, compressed air, air conditioning, exhaust, and power are insufficient to support any additional load. We had to develop work-arounds for the past several years; however, these are only trade-offs, some times wasteful, such as using industrial water for equipment cooling because the cooling water loop is at capacity.

Reports by Bob Hamilton, Facilities Manager, and Phill Guilly, Supervisor, provide details on upgrades, installations, and facilities maintenance.

Computers

Our efforts to keep up with rapidly developing computer technology culminated in several important decisions and implementations this past year.

1. Migration of the Microlab's main server to the Solaris platform had been completed. All applications are now running on Silicon; however, the database had to remain on Argon. Solaris does not support our old version of Ingres. The upgrade included a new Sparc Station 20 platform for Argon, which greatly improved performance and reliability of BCIMS, the Microlab's management information system.

   Considering the magnitude and complexity of BCIMS the upgrade was a major activity for our computer support staff. (1.5 FTE). The move had to be done with the "production system" running the Microlab in full operation. It was accomplished with virtually no down time. The upgrade was the first step to be completed before we could implement a new graphical user interface to replace the alphanumeric Wand.

2. While the migration to Solaris was in progress we have investigated database options to run on the new platform. After reviewing the pros and cons of several systems we decided to take another look at Ingres. Our database, an older version of Ingres, served us very well indeed for the past 20 years and we invested considerable manpower making it robust for our environment. As it turns out, Ingres has kept up with developments since we bought our version; it now runs on Solaris and supports all modern applications such as JDBC. We are testing it favorably on a development machine.

3. Integration of PCs in our UNIX environment is complete and transparent to users. This process received a major impetus when the new financial management system on Campus was rolled out and administrative staff had to be equipped with PCs to access it. Staff terminals had been replaced with PCs during this past year. The trend continues.

4. Our joint project with Stanford and MIT resulted in the completion of the equipment control module, with Bill Murray at Stanford taking the lead and the majority of the software
development activity. The equipment controller is running on a PC (Linux OS) with windows-based interface and individual control boxes at each processing equipment. Basically, the system performs the same functions as our old Taurus (equip. control) and Acrex (facilities sensor data acquisition) systems together, both in operation since the Microlab was built. We have purchased the new hardware, including an industrial-strength PC, and the system had been tested.

Currently the WIS (Walker Interlock System, from Walker Manufacturing, designer/vendor of the controller boards and boxes) is being deployed in the Microlab to control access to 45 machines. The old Taurus system remains in place, running parallel with the WIS, until all old machine control boxes are replaced and connected to the new system. At this time the WIS is using the Wand interface.

An identical but independent WIS is already up and running in the Integrated Materials Laboratory (IML) at the Davis Hall location. The WIS supports accounting by providing enable/disable data, which is time-stamped by the accounting program running on the Microlab's main server, Silicon. The WIS also has the ability to detect wiring errors in the system. Todd Merport developed software to override the controller, such that equipment can be used in case the network or servers are down. The next step in this project is installation of GUI.

5. During the design phase of our joint project with Stanford and MIT, we have invested major effort into the flexibility and adaptability of the architecture to enable it to work in different environments. This joint project, called Coral (Common Object Representation for Advanced Laboratories) employs the OMG (Object Management Group) CORBA (Common Object Request Broker Architecture) interface definition language to support various databases and a web-based front end.

Coral is already implemented at the Stanford Nanofabrication Facility, where our colleagues selected the SunRay network appliance for a dedicated local area network. Tim Duncan, the Microlab's Computer Systems Support Supervisor, designed our system using Neoware's Winterm terminals connected to Windows 2000 Terminal Server operating system, a 3COM 24-port switch for local area networking, flat panel displays and a DELL server, which is also the gateway to the Internet. We call it the CAPE, Common and Personal Environment system; modifications to network wiring are currently in progress to roll out CAPE.

Concept illustration of CAPE and details concerning computer issues can be found in the reports by Tim Duncan and Todd Merport.

Projects

1. Device Characterization and Metrology Laboratory Renovation (407/409)

This laboratory, adjacent to the Microlab in Rooms 407 and 409 Cory Hall, supports testing and measurement equipment for devices and instrumentation testing for process in-line metrology. At the request of the Device, BSAC, and BCAM research groups, a major renovation project was implemented. Microlab contributed heavily by providing project management and staff assistance throughout the project. A total operating budget of $70K was allotted and the cost was distributed to PIs on per-student use rate. 58 GSRs use this
facility. Project leaders were Phill Guillory, staff supervisor, and Kevin J. Yang, graduate student of Prof. Hu. The beautiful, newly renovated laboratory was opened officially this month.

2. Design and Construction of an RTCVD System

We were requested by Profss. Hu and King to provide equipment for investigating high k dielectrics. Their research engineer, Hideki Takeuchi, provided conceptual equipment and process specifications for a rapid thermal low-pressure chemical vapor deposition system. As such a system does not exist on the market and anything that could have been applied would have required major modifications, we decided to build it from components. Members of the design and implementation team are: Bob Hamilton, Mike Linan, Evan Stateler equipment engineering; Ben Lake and Joe Gavazza mechanics from the ERL Machine Shop; Hideki Takeuchi, process engineering, and myself. Project leader: Evan Stateler.

Basic features of the system are: a load-locked vacuum chamber with several feed-throughs, dry pump, 6/8" wafer capability; lamp heating for deposition and in-situ annealing; computer controlled source/gas delivery; mechanical and process control by PC. At this time the system is well into the assembly stage.

3. Retooling to 150 mm (6") Wafer Processing

- Photolithography Module

In 2000 we continued with facilities preparation for 6" equipment installation. When a donation offer of an ASML 5X DUV stepper system came in we decided to make this tool the basis of our 6" photo module (instead of the Intel donated Nikon Body8). Important factors in this decision were: 1) The Advanced Lithography research group indicated a major interest in this tool and Professors Neureuther and Oldham arranged for the donation. 2) The 2.1x2.1 cm² exposure field is very attractive for the MEMS people who wish to fabricate chips with large real estate and small features. Installation of this tool is completed. We are waiting for laser repair by Cymer.

Other components of the 6" photo module are: SVG wafer track/developer (donated by VLSI Research, refurbished by AIO), CD-SEM (donated by Intel), DUV inspection microscope with measurement software, Fusion photoresist stabilizer (donated by Intel), Matrix photoresist ash.

Except for some critical masks we will still be able to make masks for the ASML, a 5X reduction system, on our GCA optical pattern generator. The smallest features the PG can produce are 2 µm, which will result in 0.5 µm on the wafer. While this is not quite good enough for advanced device work, it is still a great improvement in our lithography capability.

Project leaders on the 6" lithography module are Evan Stateler, Associate Dev. Engr. from equipment engineering and Sia Parsa, Process Engineering Manager, who is also the liaison to the Advanced Lithography research group.
• **Furnaces**

Bank3 of the of the old Tylan furnaces had been upgraded to 6" LPCVD capability. After the conversion we changed the tube names to Tystar, our current vendor. These are:

- tystar9 - MOS silicon nitride,
- tystar10 - MOS poly-silicon,
- tystar11 - MOS LTO/PSG,
- tystar12 - MEMS LTO/PSG.

Bank5 includes the following 6" tubes:

- tystar17 - MOS dry/wet oxidation,
- tystar18 - MEMS low stress nitride (6" capable, currently with 4" quartz ware),
- tystar19 - SiGe, currently used for both device and MEMS work,
- tystar20 - shut down in preparation for a SiGe tube for MEMS.

Bank1 - 6" upgrade ordered for four atmospheric tubes.

During furnace upgrades we maintained operations in the rest of the tubes. Baseline CMOS and device work suffered somewhat during bank3 shut down, which halted nitride, poly-Si and LTO depositions for MOS-clean processes. Process staff expended quite a lot of effort in characterizing the upgraded tubes. Unfortunately, the new 6" furnace elements needed to be replaced soon after startup because they did not meet temperature performance specifications.

• **Wet processing**

One wet bench (sink9) had been refabricated to accommodate cleaning/etching of 6" wafers. Two sets of tubes and rinsers were installed, one for MOS and one for MEMS work. Also, a spin rinsing/drying (Intel donation) was added. Again, 4" capability is maintained in sinks6,7,8 in the VLSI area. Next on the schedule is the upgrade of sink7 to accommodate nitride etching and other etches for 6" wafers. Handling cassettes are in place, although it took a while to work out a protocol to keep tool sets clean and separate for device work. We are addressing the concerns of the device research group, who are anxious that the proliferation of MEMS activity results in erosion of cleanliness. We will eventually dedicate sinks separately for devices and MEMS wafers.

• **Plasma Etching**

Although we have one system upgraded to 6", lam4 for poly/nitride plasma etching, the etch module lags behind the other process modules in the upgrade timeline. The main reason is that we have been unable to obtain donations of an oxide and an Al etcher. Although these were on the original Intel donation list, they were withdrawn later. Our efforts in following up other leads have been unsuccessful so far. We are working with a used equipment dealer to trade/buy a Lam 9500 (oxide) and Lam 9600 (metal) RIE system. Because of our space limitations we cannot consider systems with larger footprints.
• **Other Equipment**

Aluminum metallization is available on our current system (cpa), which utilizes wafer trays for wafer handling. New trays have been ordered with recessed areas for 6" wafers. Planarization equipment, cmp and scrubber, need only minor modifications, which will be done as required by the 6" process upgrade.

As soon as the wafer stepper is in operation we will start a 6" cmos baseline run, which will drive the modifications, process characterizations for the 6" line. We will utilize outside services for missing steps, such as metal etch.

**Integrated Materials Laboratory (IML)**

The Integrated Materials Laboratory was created in 1993, based on an NSF Academic Research Infrastructure grant. The proposal was submitted jointly by the departments of Materials Science and Engineering, Physics, and EECS. The 5-year grant required separate accounting for this unit; it was stipulated that by the time the grant expires in 1997, the IML will be a self-supporting recharge facility. This goal was met, but for accounting reasons we continue to administer the IML as a separate entity. The separation is transparent to the users however, and membership entitles them to use equipment regardless of location. The IML has its own Faculty Director, Prof. Eicke Weber of MSE is currently in his 5th year in this position.

The IML concluded a very successful year. Of the 340 lab members 62 were also users of the IML. Although equipment is located in 3 different buildings, management is folded in seamlessly with that of the Microlab.

Bob Prohaska's report describes capabilities and operations well. Highlights this past year were: addition of an e-beam deposition system (moved from the Microlab), a parylene specialty coating system (purchased by BSAC researchers for MEMS work) at the Davis Hall site (MSE). Also we installed a new WIS equipment controller at this location.

The Analytical lab section of the IML in Cory Hall now includes the Microvision system, a computer controlled stroboscopic microscope for testing MEMS. This unit was transferred from the BSAC/Photonic research group to IML management and opened up for use by general lab membership.

**ERL Machine Shop**

The ERL/MSE joint Machine Shop continued to operate successfully and delivered timely and high-quality product to customers in both departments. Several research groups depend our machine shop for its fine machining capability, the largest among them is Robotics. The shop is a major contributor to the 6" upgrade activities in the Microlab. We rely heavily on the expertise of the mechanicians to develop solutions to problems that arise during remodeling and facilitization of the new/upgraded tools. Ben Lake's report contains details.
Staff

Microlab staff groups are organized along functional lines as shown below. Groups 1-5 include staff directly responsible for maintaining the facility and processes. Groups 6-7 are operating independently, under Microlab management.

1. Facilities (13 FTE):
   Bob Hamilton, Manager, with five technicians, 2 student assistants, and 2 development engineers; Phill Guillory, Supervisor, with three technicians.

2. Process (8 FTE):
   Sia Parsa, Manager, with 2 engineers, 7 student assistants, and 2 staff research associates.

3. Administration (6 FTE):
   Rosemary Spivey, Manager, with 2 administrative assistants; Susan Kellogg-Smith, Procurement Manager with one purchasing assistant, and 1 student assistant.

4. Training Engineering (1 FTE):
   A one-year temporary position to develop training material, quizzes, a new safety video, and updating the current informational video, working with the Operations Manager.

5. Computer Support (2 FTE):
   Tim Duncan, Supervisor (works 20% for Microlab, 80% for BCAM,) with one P/AIII for UNIX support and administration, 0.5 FTE for PC support, and 1 student assistant.

6. Research Engineering (5 FTE):
   BSAC - 2, Cryo - 1, MEMS Exchange - 2.

7. IML (1.5 FTE):
   Bob Prohaska, Manager, with one half-time development engineer.

8. Machine Shop: (4.5 FTE)
   Ben Lake, Superintendent, with three mechanics and an administrative assistant.
   Ben Lake also supervises ERL Shipping and Receiving, and Inventory, a total of 4 FTE.
   Administration of S/R and Inventory is managed through central ERL.

The position of Technology Manager, parallel to that of the Operations Manager, is shared by BSAC and the Microlab 50/50; staff management is shared accordingly (see Fig. 1). Until the position is filled, I have been acting as manager for the research staff. This, however, is all too much for one person. We have completed the search for a new technology manager, in the same arrangement with BSAC; his scheduled start date is 2 July 2001. Details of staff activities can be found in the reports of respective managers.

As the user membership of the Microlab increased steadily the last 5 years the number of direct support staff also grew. Figure 5 shows that staff increase kept up with membership growth during the last 4 years.
Financial Resources

All three recharge accounts under Microlab management, (ML, IML, MS) continued to show excellent fiscal performance this past year. Rosemary Spivcy's separate reports after the closing of the fiscal year, show details of income and expenditures, financial analysis and new recharge rates for each unit.

Recharge Accounting Summary, FY 99/00

<table>
<thead>
<tr>
<th>Unit</th>
<th>Income</th>
<th>Expenditures</th>
<th>Performance</th>
<th>No. of Grants Billed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microlab</td>
<td>$2,318,980</td>
<td>$2,338,854</td>
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<td>161</td>
</tr>
<tr>
<td>IML</td>
<td>$388,914</td>
<td>$276,999</td>
<td>37% [+      ]</td>
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</tr>
<tr>
<td>Machine Shop</td>
<td>$176,592</td>
<td>$176,402</td>
<td>- 0 -</td>
<td>40</td>
</tr>
</tbody>
</table>

Machine Shop

When the Microlab took over management of the Machine Shop in July 1993, we started with a deficit of $42.5K on the books. This past year we successfully retired the debt and started the new FY clean. The scheduled $7K/year debt reduction was a difficult task for a 2-man shop, requiring careful accounting of recharge times and tight cost control measures. We could not have done it without sharing the cost of administrative overhead with the MSE side of the joint Shop. Recently EECS/ERL business increased to the level where we had to hire two additional mechanics to keep up with demand. The Machine shop is fully a recharge operation providing high quality services at competitive rates.
**IML**

This unit was established in 1993 from an NSF infrastructure grant. The IML started out as a new recharge operation; at first with subsidies from the grant, then we slowly increased rates to cover actual costs. At the time the grant expired in 1997 the IML was fully self-supporting and breaking even in subsequent years. This past year, income from industrial members exceeded projections by 37%. During the first half of the current fiscal year, however, industrial use subsided and now we are below the projected target income.

**Microlab**

Along with the steady growth of active user membership, Microlab income and expenditures also grew at about the same rate. What changed, however, very clearly, is the proportion of income from research groups. Figure 6 illustrates this trend well.

**Microlab Income by Research Groups**

FY 1994/95 - 1999/00

![Microlab Income by Research Groups](image)

The dramatic increase in BMLA/sundry income is the result of the success of our Berkeley Microlab Affiliates (BMLA) program, discussed in the next section of this report. The group shown as sensors in Figure 6 comprises students involved in MEMS research through the Berkeley Sensors and Actuators Center (BSAC). A very important and strong group in providing balance and a healthy mixture to the operation is the silicon based Device group. About one quarter of the income originates from the rest of the constituency, a very nice composition of various disciplines.
The two pie charts in Figure 7 show income from and number of people (active members) in each research group. It is clear that the relative size of research groups does not translate directly into the same income proportions. The following observations can be made:

1. Approximately 1/2 of the membership generates 3/4 of the income.
2. About half of the membership is EE-based.
3. Distribution of non-EE based members is roughly even among related departments.

This is good balance, which we established early on when we were actively working on broadening our user base. The multidisciplinary environment has beneficial effects for all members and creates a cooperative spirit.

IV. COMMUNICATIONS AND CONTROL

Membership
As we define it, lab membership includes all people who are connected one way or another to the Microlab (ML) and the Integrated Materials Laboratory (IML). They are student researchers and their professors, industrial affiliates, direct support staff and research group-affiliated staff. "Active" members are those who are on the books and were charged "access" fee for the month. "Inactive" members suspended their charge accounts; however, they retained their computer accounts and remain on the mail aliases for information distributed. All faculty principal investigators (PIs) who have active/inactive students in the ML/IML also receive communications concerning lab activities. We apply the terminology "member" as opposed to "user" because membership conveys the ideas we want to nurture such as community, responsibility and ownership, cooperation and contribution.

Microlab membership has been steadily increasing, in fact, it more than tripled in 15 years; from an average of 107 active members in a month in 1986 to 354 in 2001. The most challenging assignment for staff is to keep members informed and advised of activities, what changes we are planning that might effect their project; to keep their equipment operating skills current and safe, and to motivate them to help each other observe policy, rules and regulations.

Membership meetings:
In our efforts to keep equipment and processes up to specifications and to keep projects and research interests from colliding, we are constantly looking for input from the researchers. Our monthly membership meetings, conducted by Bob Hamilton and Sia Parsa, serve this purpose. Requests for changes, improvements, complaints are openly discussed, minutes mailed and posted on our web site.

This is not enough, however. Often, when there is an equipment and/or process problem we need to look into who used the machine and for what process and is the person properly trained. Invariably, we find non-compliance and have to institute corrective action. Disqualifying the person from using an equipment works in most cases.
Safety Committee:

Two years ago a grass roots interest started to grow among members, which culminated in the formation of the Labmembers Safety Committee. Bob Hamilton, the Microlab's Safety Officer, is an ex-officio member. We have had many excellent proposals by the Safety Committee, safecom@silicon.eecs.berkeley.edu, most of which were instituted. They motivated and participated in producing a 20 minute safety video, which we show at lab orientations and at other occasions with great success. We are also working on reevaluating and strengthening our evacuation procedures.

Equipment Qualifications:

The Safety Committee also addressed the broader issue of equipment training and qualifications. With a large membership the quality of information transfer, rigorous training and testing slowly eroded, and our time-honored method of members training each other and supernusers qualifying new users, was not sufficient to foster good practices. Thus, we instituted training classes, such as on the SEMs and some etchers; extended the number of written tests to cover most sensitive equipment, and required all users to re-qualify when warranted. This is placing additional burden on the administrative staff, but the returns justify the effort.

Document Control

In conjunctions with our efforts to enhance equipment training we embarked on the project of reviewing and updating the equipment operating manuals. This is a major undertaking, as the manual contains 134 chapters (for 134 operating systems,) comprising 733 pages in hard copy.

Additionally, as we are replacing ASCII terminals with graphics terminals, as part of our computer upgrade project, we are migrating the on-line lab manual from the WAND interface to the Microlab's web site. The migration is proceeding as follows:

New and updated chapters appear only in the web format and are not accessible from the WAND. The Table of Contents on the WAND shows the complete listing; however, the new/updated chapter titles include the comment: See web site.

Madeleine Leullier had been assigned responsibility for document control and web site management.

Training Engineers

In September we hired a high school physics teacher on sabbatical, in a temporary position to assist with developing training material. Laurel Reitman reports:

I have been working on the following projects:

Coordinated the production of the Microlab's Safety Video. This involved meeting with the Safety Committee to determine the content of the video, writing the script, coordinating and shooting the video, and assisting in the editing process.
I have written and/or edited fourteen qualification exams for Microlab machines. To accomplish this, I read the lab manual, learned how to use the machine from a superuser, then created a written test on key usage and safety information. These tests now serve as a gateway to lab members looking to be qualified to use new machines.

Other projects include aligning the Microlab chemical inventory database with that of the Office of Environment, Health, and Safety, and coordinating an outreach program for high school girls interested in science. The latter is in conjunction with the office of Undergraduate Matters of EECS. See http://buffy.eecs.berkeley.edu/Programs/doublex.html.

When Mike Young, Senior Development Engineer started working for BSAC in September one of the first projects we discussed was the creation of a short course for new members who are neither EECS majors nor took a device course. Since many of the students from BSAC fall in this category and Mike already taught such courses at Purdue, in his previous employment, this was a great opportunity to further our training/educational goals. Mike reports:

We needed to establish some mechanism for bringing new Microlab members "up to speed" on the basics of microelectronic fabrication, especially for those who did not have this background from course work or other outside experience. To address this need, I developed a four-hour short course called "Microlab Fundamentals for New Users". The topics covered in this course are:

- Introduction; Motivation
- Dopants and Junctions
- Other Hi-temp processing: Oxidation
- Wet & Dry Chemicals In the Microlab
- Lithography Specifics for Device Work
- Thin Film Deposition Issues
- Wet & Dry Etching
- MOS Device Fundamentals

Included with the course are three short quizzes and one slightly longer test at the end. As a result of the availability of this short course, Microlab new member policy has been amended to require the taking of this course if the applicant has no previous microfabrication experience, EE143 for example.

**Industrial Members**

The Microlab since its inception, has served as a place for technical collaboration with the industrial community, by giving industry researchers access to our clean room. This practice has been highly beneficial to both sides and created a conducive environment for start-ups.

As technology advances, and as our infrastructure is becoming more complex, we were looking for ways to establish a more productive collaboration. Thus, in 1997, with the leadership of Prof. C. Spanos, we established the "Berkeley Microfabrication Laboratory Affiliates" (BMLA) specifically addressing the relationship with our industrial partners and users of our facility. The cost of membership, that includes the privilege of accessing the Microlab, is $15K/year/person. BMLA members pay standard laboratory fees with overhead, and do not have the monthly cut-
off faculty members enjoy. Membership fees are applied to equipment upgrades and currently to the retooling to 150 mm (6") wafer capability.

The program has been very successful. We review each applicant's project for compatibility and impact they will have on utilization. If the project fits and will not cause undue burden on graduate research the company will be allowed to join. Currently we have 25 BMLA member companies, comprising mostly of small start-ups and alumni. Effectively, the Microlab acts as an incubator for California high-tech industry.

**Other Communications and Activities**

1. **Control unit, ERL**

   The Microlab's control unit is the Electronics Research Laboratory, an organized research unit (ORU) under the office of the Vice Chancellor for Research. The Microlab's Faculty Director, Prof. King and I are keeping ERL Director Pisano informed and up-to-date on Microlab issues through our monthly one-on-one meetings with him. Rosemary Spivey attends the monthly meetings of ERL administrative supervisors, chaired by MSO Renate Valencia.

2. **Instructional Support**

   Microlab staff are supporting the following courses:

   - C133 Microfabrication Equipment Laboratory
   - EE143 Microfabrication Technology
   - EE298-12 Solid State Technology and Devices Seminar

3. **Department of EECS**

   Monthly meetings of the technical supervisors in EECS/ERL serve as conduit for information to all units, a forum to discuss staff policy issues, events, problems, to look for and give advice and help to each other. Meeting minutes are sent to the Chairman, Associate Chairs, CS Vice Chair, and ERL Director. I have been leading these meetings for eight years now, since Jan. 1993.

   Bob Hamilton and I are on Cory Hall Safety Committee. I am on the following departmental ad-hoc committees: Building Manager selection, Cory Facilities, Technical Services Staff (Chair).

   When Prof. Katz became Chairman of the Department he initiated monthly senior staff management meetings (1996). Subsequent chairmen continued these meetings on a semi regular basis. I have been representing the Microlab since the inception.

   Microlab staff representatives have been on the Chairman's Staff Advisory Board, since it was initiated, also by Prof. Katz. Marilyn Kushner's proposal of Newsbytes for the staff newsletter had been accepted. Madeleine Leullier served as one of the editors for two years; Leon Tsao is in that position currently. Microlab staff are active contributors and participants in departmental events.
4. **College/Campus**

Renovation of the Hearst Mining Memorial Building continues to require constant vigilance on our part. Restricted access to Cory Hall hampers all deliveries to the building, moving equipment in and out, all of which place Microlab operations in jeopardy. Most importantly, we missed liquid nitrogen deliveries several times because of blocked access to the filling station, now in front of Cory Hall.

Bob Hamilton and I have been participating in reviewing the plans for the Biotechnology Center (BNC), a new laboratory proposed for Bioengineering in the Stanley replacement building.

Currently Bob Hamilton is our representative on the Campus Laboratory Operations and Safety Committee. Also, Bob is working closely with the Office of Environment, Health, and Safety, on compliance with regulatory standards.

5. **Outreach**

We are participating in an outreach program to high school girls, in conjunction with the EECS Center for Undergraduate Matters. Laurel Reitman initiated and coordinates this extracurricular activity for high school girls who are interested in science. She recruited volunteers from science and engineering women students at UCB to participate and act as program leaders.

We encourage mentors in the SUPERB program, who are Microlab members, to introduce the participants to research in the Microlab and we assist in training for their project.

---

**V. FUTURE PLANS**

The origin of the present Microlab was the Integrated Circuits Laboratory established by the Department in 1962. Twenty years later the lab was reborn as the Microlab in its present form. It is time again for rebirth in a new form.

The new lab that is a major feature of the proposed new engineering building (CITRISII) will be an 8" facility providing research space for our three major groups, MEMS, Device/Process, and BMLA, about half of our membership.

However, the 8" facility will not be able to support the other half of the projects, which are not or cannot be done on 8" Si wafers. We are planning to accommodate non-8" research by migrating them to other facilities, such as the IML, the planned Bio-Nanotechnology Center (BNC) in the Stanley replacement building, and a technology development laboratory we propose to construct in the center area on the first floor of Cory Hall (140, 144, 178, 188).

When the HMMB labs are completed, some of the IML equipment may move; however, a large portion of the current equipment in IML will remain in place in Cory Hall. Specifically, the MBE systems, which are very expensive to move and cannot operate without liquid nitrogen. There are no plans for liquid nitrogen lines in HMMB at this time. We have submitted these plans to the Cory Hall Renovation Task Force.

**VI. SUMMARY**

Microlab operations cover a broad spectrum of activities, including management of resources, communication, control, and planning. Each of these areas were covered in detail, showing a healthy organization supporting a wide range of silicon and compound semiconductor based research. The units managed are under three separate recharge accounts; however, all aspects of the operation are very similar and based on a philosophy that fosters cooperation.
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ABSTRACT

This document contains the 2001 Year-End Reports by the professional staff of the Microfabrication Laboratories. Together, these reports reflect the wide range of support staff provides to research in ERL and to instructional laboratories in EECS.

Activities of direct Microlab (ML) operations support staff, described in the sections Facilities, Administration, Computers, and Process include 24 career employees and 10 undergraduate student assistants. Various research groups support 5 additional engineers, working on assigned projects. The Integrated Materials Laboratory (IML), a separate recharge center, employs 2 engineers and the Machine Shop operates with 5 staff as an independent recharge unit. The three recharge centers operated within their budgets last year, $2.7M, $166K, and $280K, respectively.

The Microlab had an average monthly membership of 345, of whom 83 were also IML members. Participating PIs: 81. The Machine Shop completed jobs from 35 PIs. The Berkeley Microlab Affiliates program (BMLA) comprises 25 industrial members. Detailed Microlab information can be found at www.microlab.eecs.Berkeley.edu.

K. V.

Microfabrication Laboratories
Staff Organizational Chart
Effective 7 January 2002

Figure 1
I. INTRODUCTION

Microlab operations continued in 2001 in the usual busy manner, with the 6" upgrade nearing completion. Towards the middle of the year planning for the new micro lab as part of the CITRIS project started in earnest. It was a most opportune moment for Dr. William Flounders to join us as Technology Manager of the Microlab and of BSAC. Development of the new facility became Bill's assignment, which he accepted with great enthusiasm.

This document is the fifteenth year-end report I am submitting on behalf of the Microlab.

II. MANAGEMENT OF RESOURCES

Facilities

Microlab

Reports by Bob Hamilton, Equipment and Facilities Manager, and Phill Guillory, Technical Supervisor, provide details on upgrades, installations, and facilities maintenance.

1. Retooling to 150 mm (6") Wafer Processing

   In 2001 we completed most of the capabilities for 6" wafer processing. In August 2001 we started the first 6" baseline run to push completion of the upgrade. Components of the 6" modules are:

   ➢ Photolithography Module
   
   ASML 5X DUV wafer stepper (asm1)
   SVG wafer track/developer (svgcoat6, svgdev6)
   Hitachi CD-SEM (cdsem)
   Leica DUV inspection microscope with measurement software (uvscope)
   Fusion photoresist stabilizer (uvbake)
   Matrix photoresist asher (matrix)

   ➢ Mask Making
   
   GCA 3600 pattern generator for 0.5 µm final features (gcapg)
   (external service for more critical masks)
   APT mask developer/etcher holder modified to handle 6"sq masks (aptechrome, aptemui)

   ➢ Wet Processing
   
   sink9 -- cleaning/etching of 6" wafers
   two sets of tubs and rinsers for MOS and MEMS work
   sink7 -- nitride/misc. etch (conversion Q1 02)
   sink5 -- MEMS etch (conversion Q1 02)
   sr6d -- 6" spin rinser/dryer
   6" cassettes, single wafer holders, vacuum wands, tweezers in stock

   ➢ Thermal Processing

       Atmospheric furnaces
       tystar1-7 - dry/wet oxidation (MOS)
       tystar1-4 dry/wet oxidation/anneal, to be completed Q3 02
LPCVD
- tystar9 - MOS silicon nitride
- tystar10 - MOS poly-silicon
- tystar11 - MOS LTO/PSG
- tystar12 - MEMS LTO/PSG
- tystar18 - MEMS low stress nitride (6" capable, currently with 4" quartz ware, to be upgraded Q2 02)
- tystar 19 - SiGe (MOS)
- tystar20 - SiGe (MEMS)

RTP
- heatpulse3 - dual paddle for 4"/6" wafers (MOS)

- Etch Module
  - 6" only: lam4 (4400 Rainbow) nitride/poly-Si etch
  - lam5 (9400 Rainbow TCP) poly-Si etch (conversion Q2 02)
  - 4"/6" dual handle conversion to be completed Q1 02:
    - lam1 (490 Autoetch) nitride/poly-Si etch
    - lam2 (590 Autoetch) oxide etch
    - lam3 (690 Autoetch) Al etch

- Thin Films
  - Al/Si, W, Ni deposition: cpa with 6" trays
  - Other: Novellus -- Al, Ti, silicides
  - Conformal oxide: Applied p5000 (TEOS)

- Planarization
  - Strausbaugh CMP, 4"/6" interchangeable pad
  - SSEC Post CMP Cleaner, 4"/6" (conversion Q2)

- Measurements
  - Electroglass autoprobe upgraded (autoprobe)
  - Alphastep 200 profilometer (as200)
  - Nanospec film thickness measuring system (nanospec)

Summary of Outstanding Jobs

Q1 --
- sink5 (MEMS), sink7(nitride/misc)
- 4"/6" dual handle conversion
- lam1 (490 Autoetch) nitride/poly-Si etch
- lam2 (590 Autoetch) oxide etch
- lam3 (690 Autoetch) Al etch

Q2 --
- tystar18 - MEMS low stress nitride
- lam5 (9400 Rainbow TCP) poly-Si etch
- Post CMP Cleaner, 4"/6"

Q3 --
- tystar14 dry/wet oxidation/anneal
- tystar16 MEMS poly-Si

2. Computers

Cape
We have completed the migration to all graphic (flat panel) terminals inside the lab. These are running on a Windows 2000 server dedicated to the local area network for the lab. The Common And Personal Environment (CAPE) application was developed in-house by Tim Duncan and deployment completed by Todd Merport, after Tim resigned effective 1 May 2001.
Upon login the new CAPE terminals provide lab members with a common PC environment with several windows, one of them an xterm window for the original Wand character-based interface. All Wand functions, among them equipment enable/disable, behave exactly like before. In addition, CAPE provides access to the user's eecs and/or research account and to the internet.

CAPE is persistent in that users can disconnect their session while maintaining state, by clicking on the HIDE YOUR CAPE icon, and re-connect to their session from another terminal located elsewhere within the Microlab. Time accounting is maintained through the Wand on the Unix server (silicon) and Ingres database.

Database

We continued testing the Ingres II database in the Solaris environment on a development machine, while operations are still running on Sun OS (argon). We are ready to transfer "production" to Solaris (silicon). This will provide a good training opportunity for our new database programmer, who will then continue with interfacing to Coral.

Coral

The architecture of CORAL (Common Object Representation for Advanced Laboratories), our joint project with Stanford's and MIT's microlabs, employs a CORBA (Common Object Request Broker Architecture) interface definition language to support various databases and a web-based front end. Stanford has a prototype running to which we have remote access. Adaptation of CORAL as our main management system will depend on how soon we will be able to create additional modules to enable local-specific applications in accounting and management of resources. With our recently extended computer staff we should be able to move on this project in a more timely fashion than during the past year.

Phases of preparation for a complete system changeover to CORAL include:

- Server upgrade to Solaris platform (completed)
- Ingres II database (supporting CORBA) roll out (in progress)
- WIS equipment controller (installed)
- CAPE, graphics terminals with local area network (installed)
- Testing of CORAL through remote from Stanford (in progress)
- Running CORAL on local test bed (in progress)

3. Development Projects

Design and Construction of an RTCVD System

We continued with the construction of an in-house designed rapid thermal low-pressure chemical vapor deposition system for investigating high k dielectrics. Basic features of the system are: a load-locked vacuum chamber with several feed-throughs, dry pump, 6" wafer capability; lamp heating for deposition and in-situ annealing; computer controlled source/gas delivery; mechanical and process control by PC/Labview. The system is close to completion. Details are available in Evan Stateler, Project Leader's report.

"Oldlab" Upgrade

The "oldlab" section of the Microlab (432 A-E) required a major upgrade of the power panels and rearrangement of equipment, to accommodate new equipment, including the laser source for the ASML stepper and the high-k RTCVD system. Gas storage was reorganized to improve safety and labmember storage lockers added. This project is continuing in 2002.

New Lab

After the CITRIS proposal was accepted for funding by the State of California planning began immediately for the new engineering building, which includes a new microlab. Bill Flounders accepted the responsibility for carrying this project from the Microlab's side and had a major role in selecting AGI as the laboratory consultant firm working with the building architects. With AGI we have developed an excellent plan for the new microlab, which will provide research facilities for the next 20 years (see William Flounders' Report for details).
Integrated Materials Laboratory (IML)

We added two systems: a Wyko interferometric profilometer (wyko) for dynamic characterization of MEMS devices and a focused ion beam system (FIB) donated by LSI Logic. The FIB required about $15K for start up by a manufacturer's engineer and it is just coming on line. Because of the interest indicated by several research groups in this tool we invested the required expenditure from BMLA funds.

We are preparing plans for the move back to HMHB.

ERL Machine Shop

The ERL/MSE joint Machine Shop continued to operate successfully and delivered timely and high-quality product to customers in both departments. Several research groups depend on our machine shop for its fine machining capability, among them our newest research area, organic electronics, under the direction of Professor Subramanian. The Shop is a major contributor to the 6" upgrade and equipment development activities in the Microlab. Ben Lake's report contains details.

Staff

Microlab staff groups are organized along functional lines as described below. Groups 1-4 include staff directly responsible for maintaining the facility and processes. Groups 5-7 are operating independently, under Microlab management (also see Figure 1).

Microlab Operations:

Katalin Voros, Operations Manager

1. Equipment and Facilities (13 FTE):
   Bob Hamilton, Manager,
   with four development engineers and two technicians,
   Phill Guillery, Supervisor, with three technicians, and
   Mike Linan, Supervisor, with one technician.

2. Process (9 FTE):
   Sia Parsa, Manager,
   with two engineers, a two staff research associates,
   a programmer/analyst, and 7 student assistants.

3. Administration (4.5 FTE):
   Rosemary Spivey, Manager,
   with one administrative assistant and a student assistant,
   Susan Kellogg-Smith, Procurement Manager with a purchasing assistant.

4. Computer Support (2.5 FTE):
   Todd Merport, Supervisor
   with two programmer/analysts.

5. Technology Management (5 FTE):
   Bill Flounders, Technology Manager for the Microlab and BSAC
   with research engineers: BSAC - 2, MEMS Exchange - 2.

6. IML (1.5 FTE):
   Bob Prohaska, Manager, with one half-time development engineer.

7. Machine Shop (4.5 FTE):
   Ben Lake, Superintendent,
   with three mechanics and a part time administrative assistant.
   Ben Lake also supervises ERL Shipping, Receiving and Inventory, a total of 4 FTE.
   Administration of S/R and Inventory is managed through central ERL.
Financial Resources

All three recharge accounts under Microlab management, (ML, IML, MS) continued to be closely monitored for budgetary requirements throughout the year. Rosemary Spivey's report shows details and financial analysis for each unit.

Recharge Accounting Summary, FY 00/01

<table>
<thead>
<tr>
<th>Unit</th>
<th>Income</th>
<th>Expenditures</th>
<th>Performance</th>
<th>No of Pls Billed</th>
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</thead>
<tbody>
<tr>
<td>Microlab</td>
<td>$2,659,220.00</td>
<td>$2,655,547.00</td>
<td>0.1% [+ ]</td>
<td>81</td>
</tr>
<tr>
<td>IML</td>
<td>$166,452.00</td>
<td>$257,862.00</td>
<td>35% [- ]</td>
<td>25</td>
</tr>
<tr>
<td>Machine Shop</td>
<td>$269,662.00</td>
<td>$280,131.00</td>
<td>3.4% [- ]</td>
<td>35</td>
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</tbody>
</table>

Microlab

- General Microlab Operations were on budget.
- So far we have spent $1.02M out of BMLA and overhead funds on the 6" upgrade.
- An additional $420K came from BSAC grants for 6" furnaces.
- Total estimated (1999) conversion cost: $1.2M
- We have the budget to cover it.

IML

The IML continued to operate well with an average monthly membership of 85, an increase from last year's 62. Unfortunately, in spite the increased number of users most of the IML equipment was under-utilized, and the unit did not meet its budgetary goals. This past year, income from industrial members dropped off drastically and we are below the projected target income.

Machine Shop

The shop ended with a minor deficit, which continues into this year. For extended and more valuable service to our customers we invested Microlab overhead funds in purchasing a CNC milling machine.

III. COMMUNICATIONS AND CONTROL

Membership

Microlab membership had leveled out this past year at an average of 340 active members/month. Both laboratory use-hours and special equipment use-hrs declined somewhat (7% and 3% respectively) in FY 2000-01.

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Membership/Month</th>
<th>Lab Use (Hrs)</th>
<th>Sp. Equip. Use (Hrs)</th>
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</thead>
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<tr>
<td>1999-00</td>
<td>340</td>
<td>48,878</td>
<td>40,655</td>
</tr>
<tr>
<td>2000-01</td>
<td>345</td>
<td>45,413</td>
<td>39,383</td>
</tr>
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</table>

Document Control and Training

Currently we are maintaining 127 manual chapters on-line, half of them in the new web-format. 30 chapters have study guides for written qualification tests.

Mike Young, Senior Development Engineer for BSAC continues to present "Microlab Fundamentals for New Users" once a semester for new members, who are not EECS majors nor took EE143 or E133. "Fundamentals" is a 4-hour short course, with topics including: dopants and junctions; high-temperature processing; chemicals in the Microlab; lithography specifics for device work; thin film deposition; wet and dry etching; MOS device fundamentals. Included with the course are three short quizzes and one slightly longer test at the end.
**Industrial Members**

Our Berkeley Microfabrication Laboratory Affiliates (BMLA) program for industrial membership continues successfully. Although we lost a couple of start-ups to economic difficulties, we regularly receive inquiries for new memberships. The cost of membership, which includes the privilege of accessing the Microlab, is $15K/year/person. BMLA members pay standard laboratory fees with overhead, and do not have the monthly cut-off faculty members enjoy.

Membership and overhead fees are applied to equipment upgrades and to the retooling to 150 mm (6") wafer capability. So far we have financed the 6" upgrade almost fully from these funds, just over $1M. Currently we have 23 BMLA member companies.

**Outreach**

Last Summer we developed an outreach program for high school girls, in conjunction with the EECS Center for Undergraduate Matters. We had three Summer interns working with us who completed real projects and gave a presentation at the end of the internship.

We encourage mentors in the SUPERB program who are Microlab members to introduce the participants to research in the Microlab and we assist in training for their project.

**IV. FUTURE PLANS**

We are well on our way in specification and design of the new lab in the new engineering building (CITRIS!). The facility will provide processing capabilities for 8" wafers and also maintain 6" and other capabilities. The design incorporates flexibility and ease of maintenance.

We are also planning migration of the IML back to the Hearst building, after construction is completed.

**V. SUMMARY**

Microlab operations continued to thrive, in spite of periodic disruptions necessitated by the 6" upgrade. Installation of the donated ASML DUV stepper gave a major impetus to retooling projects and enabled the start of 6" processing. We also completed installation of graphics terminals and local area network inside the lab, a prerequisite to a complete modernization of our computer system.

The units managed under the three separate recharge accounts (Microlab, IML, Machine Shop) are financially stable.
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<td>Susan Kellogg-Smith, Purchasing Manager</td>
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<td>COMPUTERS</td>
<td>Todd Merport, Supervisor</td>
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<tr>
<td>PROCESS/BASELINE</td>
<td>Siavash Parsa, Process Engineering Manager</td>
</tr>
<tr>
<td></td>
<td>Jimmy Chang, Associate Development Engineer</td>
</tr>
<tr>
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<td>Marilyn Kushner, Junior Development Engineer</td>
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<td>Kim Chan, Staff Res. Assoc., Advanced Lithography</td>
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<td>TECHNOLOGY</td>
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<td>Eunice Kim, Assistant Development Engineer</td>
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<td>Xiaofan Meng, Sr. Dev. Engineer, Cryoelectronics</td>
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<td>IML</td>
<td>Robert Prohaska, IML Manager</td>
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<tr>
<td>MACHINE SHOP</td>
<td>Ben Lake, Machine Shop Sr. Superintendent</td>
</tr>
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ABSTRACT

This document contains the 2002 Year-End Reports by the professional staff of the Microfabrication Laboratories. Together, these reports reflect the wide range of support staff provided to research in ERL and to instructional laboratories in EECS.

Activities of direct Microlab (ML) operations support staff, described in the sections Facilities, Administration, Computers, and Process/Baseline include 24 career employees and 9 undergraduate student assistants. Various research groups support 5 additional engineers, working on assigned projects. The Integrated Materials Laboratory (IML), a separate recharge center, employs 2 engineers and the Machine Shop operates with 5 staff as an independent recharge unit. All three recharge units ended up in a negative budget situation.

The Microlab had an average monthly membership of 315, of whom 36 were also IML members. Participating PIs: 90. The Machine Shop completed jobs from 38 PIs. The Berkeley Microlab Affiliates program (BMLA) comprises 17 industrial members. Detailed Microlab information can be found at http://microlab.eecs.berkeley.edu.

K. V.

Microfabrication Laboratories
Staff Organizational Chart
Effective 1 Dec. 2002

ML Faculty Dir.
T. King

K. Voros
Operations Manager

K. Chen (0.5)
(DUV 0.5)
J. Chang
M. Kushner
M. Leullier
Students

S. Parsa

R. Spivey
Admin. Mgr.

R. Hamilton
Equipment &
Facilities Mgr.

R. Prohaska
IML Manager

Research Projects
New Microlab

Equipment Engineering

Facilities Engineering

Facilities/Equipment

P. Guillory
(Sup.)

J. Donnelly
P. Kaksonen
D. Lo
E. Stateler
P. Wehrly

L. Voros
(Baseline Engineer)
A. Horvath
(Baseline Ass't. Specialist)

M. Linan
(Sup.)

X. Meng
(Cryo)

A. Ruff
Students

R. Merport
Comp. Sys. Mgr.

T. K. Chen (0.5)
T. Duncan (temp)
F. Varju

S. K-Smith
Procurement Mgr.

J. Parrish (0.5)

B. Lake
(Sup.)

K. Barr

B. McNeil

R. Amaral
W. Carlisle
J. Gavazza
N. Pezeshko (0.5)

Inventory
R. Ramos

Facilities
Computers

G. Monino (0.5)

E. Koo
R. Su

BSAC
Directors

BSAC
Engineering

MEMS
Exchange

TBF
MEMORANDUM

To: A. Pisano, ERL Director
T. King, Microlab Faculty Director

From: K. Voros, Operations Manager

Subject: 2002 Year-End Report

Cc: S. Sastry

Date: 20 February 2003

---

I. INTRODUCTION

Microlab operations continued in 2002 in the usual busy manner, with the 6" upgrade going on in full swing. The retooling was considered completed for the CMOS process line by the end of the year, when we finished processing and testing the first 6" CMOS baseline lot. We still have a few items on the upgrade agenda for MEMS work.

Planning for the new microlab as part of the CITRIS project continued throughout the year, with Bill Flounders attending every step of the way. We are in the "value engineering" phase now, which means that cuts have to be made to bring the project within the allotted budget. We are trying to defend the facility from having less than full capability upon opening.

This document is the sixteenth year-end report I am submitting on behalf of the Microlab.

---

II. MANAGEMENT OF RESOURCES

Facilities

Microlab

- Reports by Bob Hamilton, Equipment and Facilities Manager, Phill Guillory, Technical Supervisor, and Evan Stateler, Development Engineer, provide details on upgrades, installations, and facilities maintenance.
- Reports by Sia Parsa, Process Engineering Manager, and his staff comprise details of process support and 6" process development.
- Todd Merport, Computer Operations Manager, reports on developments in computer support and our activities in design and development of a new management information system.
- Rosemary Spivey, Administrative Manager, reports on financial status, accounts and members administration, purchasing and inventory management.

1. Retooling to 150 mm (6") Wafer Processing

In 2002 we completed the upgrade for 6" CMOS wafer processing. The first 6" baseline run, cmos150, was completed, tested, and report submitted by baseline engineering in December 2002.

Process engineering expended major effort in re-characterizing tools for 6" processes, while maintaining full 4" capability. As the new/upgraded tools came on line, operating manuals were upgraded, reformatted in the new web-based, standard form.

Components of the 6" modules are, with the upgraded manual chapters:

---
Photolithography
- ASML 5X DUV wafer stepper (asml), Ch. 4.12
- Karl Suss MA6 front/back-side mask aligner (ksaligner), Ch. 4.17
- SVG wafer track/developer (svgcoat6, svgdev6), Ch. 4.1
- Hitachi CD-SEM (cdsem)
- Fusion photoresist stabilizer (uvbake), Ch. 4.19
- Matrix photoresist asher (matrix), Ch. 7.16

Mask Making
- Mask making for ASML stepper, Ch. 3.1, Appendix C
- GCA 3600 pattern generator for 0.5 μm final features (gcapg), Ch. 3.3
- APT mask developer/etcher (aptchrome, apternal), Ch. 3.5 and 3.4

Wet Processing
- sink9 -- cleaning/etching 6" wafers, Ch. 2.9
- two sets of tubs and rinsers for MOS and MEMS work
  6" spin rinse/dryer
- sink7 -- nitride/misc. etch, Ch. 2.10
- sink5 -- resist strip, Ch. 2.11
- 6" cassettes, single wafer holders, vacuum wands, tweezers, wafer boxes (stock)

Thermal Processing
- Atmospheric furnaces
  Overview: Ch. 5.1
  tystar1-2 MOS clean dry/wet oxidation/anneal, Ch. 5.17, 5.18
  tystar18 MOS sinter (in progress, to be completed Q1)

- LPCVD
  Overview: Ch. 5.2
  tystar9 - MOS silicon nitride, Ch. 5.9
  tystar10 - MOS poly-silicon, Ch. 5.10
  tystar11 - MOS LTO/PSG, Ch. 5.11
  tystar19 - SiGe (MOS), Ch. 5.13

- RTP
  heatpulse5 -- dual paddle for 4"/6" wafers (MOS) Ch. 5.7
  -- second chamber for silicidation (MOS)

Etch Module
- Overview: Ch. 7.6
  lam1 (490 Autoetch) - nitride/poly-Si etch, 4"/6" dual, Ch. 7.1
  lam2 (590 Autoetch) - oxide etch, 4"/6" dual, Ch. 7.2
  lam3 (690 Autoetch) - Al etch, 4"/6" dual, Ch. 7.3
  lam4 (1400 Rainbow) - nitride/poly-Si etch, 6" only

Thin Films
- cpa - Al/Si, W, Ni deposition, with 6" trays
- novellus - Al, Al/Si,Ti

Planarization
- cmp - Strausbaugh CMP, 4"/6" interchangeable pad, Ch. 10.1
- cmpwce - SSEC Post CMP Cleaner, 4"/6", Ch. 10.2

Measurements
- autoprobe - Electroglass autoprobe upgraded, Ch. 8.18
- asqi - KLA Tencor Alphastep QI profilometer (to be installed Q1)
218

nanospec - Nanospec film thickness measuring system
nanoduv - Nanospec DUV film thickness measuring system
uvscope - Leica DUV inspection microscope with measurement software, Ch. 8.26

MEMS Specific
sink3 - TMAH/KOH (isotropic) etching, Ch. 2.3
cpd - critical point dryer, Ch. 2.8
ksalign - Karl Suss MA6 front/back mask aligner, Ch. 4.17
ksba6 - Karl Suss BA6 bond aligner, Ch. 4.18
ksbonder - Karl Suss SB6 wafer bonder
tystar2-3 non-MOS clean dry/wet oxidation/anneal, Ch. 5.19, 5.20
tystar12 - MEMS LTO/PSG, Ch. 5.12
tystar13 - POC13 deposition (to be completed Q2)
tystar14 - Boron+ diffusion (to be completed Q2)
tystar15 - Si/LPCVD (to be completed Q2)
tystar16 - MEMS amorphous/poly-Si (to be completed Q2)
tystar20 - MEMS SiGe, Ch. 5.16
centura - deep Si/oxide etch (to be completed Q2)
p5000 - conformal oxide deposition, PECVD TEOS (to be completed Q2)
xetch - XeF2 etch (to be completed Q1)

Summary of Outstanding Jobs

Q1 --
tystar17 - MEMS low stress nitride
tystar18 - MOS sinter
xetch - XeF2 etch

Q2 -- lam5 (9400 Rainbow TCP) poly-Si etch 6" only conversion
tystar13 - POC13 deposition
tystar14 - Boron+ diffusion
tystar15 - Si/LPCVD
tystar16 - MEMS amorphous/poly-Si LPCVD
centura - deep Si/oxide etch
p5000 - conformal oxide deposition, PECVD TEOS

This will complete the upgrade to full 6" processing lines for both MOS and MEMS applications. Equipment for processing partial wafers remains unchanged.

2. Computers

New Lab Management System (Mercury)

After evaluating our extensive efforts to design and develop a new laboratory management system collaboratively with the Stanford and MIT labs, we came to the conclusion that the Berkeley Microlab will be best served by developing a more local-specific set of tools than a general system to be tailored to fit our environment. Thus, in July 2002 at a meeting with all participants present, we informed our colleagues that the Berkeley Microlab is resigning from the joint project to develop a more targeted, therefore simpler system. This decision made life for the CORAL developers immediately easier, because now they could abandon all the special requirements we were imposing on the project.

Results of the efforts we invested in the joint project are being well utilized in development of our own new system. These phases were:
- Server upgrade to Solaris platform (completed).
- Installation of Ingres II database, supporting extended GUI, (completed).
- Equipment controller upgrade (WIS); new installation, both server and equipment control boxes.
- CAPE, graphics terminals with local area network (completed)
- Hardware platform for development (established)
- Resource utilization management system (RUMS) (in progress)

We are calling the new system Mercury. Although no acronym, we hope the name will conjure the qualities of eloquence, ingenuity, or thievishness attributed to the god Mercury. T. Merport and F. Varju are well into the application programming phase and regularly conduct meetings with staff who are the users of a particular module. During our bi-weekly meetings we review current and needed future capabilities, historical and new data availability, session management, etc. and design improvements that can be made with the latest tools. We are estimating alpha testing within a year, and full roll out and robust operation by the time the new lab comes up in 2006.

3. Development Projects

RTCVD System for High-K Dielectrics

We completed construction of an in-house designed rapid thermal low pressure chemical vapor deposition system for investigating high-k dielectrics. Basic features of the system are: a load-locked vacuum chamber with several feed-throughs, dry pump, 6" wafer capability; lamp heating for deposition and in-situ annealing; computer controlled source/gas delivery; mechanical and process control by PC/Labview. The system had been tested by device researchers with good results. We also allocated programmer/analyst time to write user-friendly process recipes and temperature management software. This project is considered completed as far as staff is concerned and the system is ready for advanced gate-stack engineering research.

Facilities Upgrade

The "oldlab" section of the Microlab (432 A-E) required a major upgrade of the power panels to accommodate new and upgraded equipment. After power upgrade was completed, rooms 432A-B received a face lift. New sink, chemical storage cabinets were installed in 432A and a protective divider around the ASML exposure laser. Renovation of the "oldlab" area is continuing in 2003.

Gas cylinder management was reevaluated, which was made possible by reclaiming our cylinder pad in the rear of Cory Hall, after HMBB construction wound down. As part of the 6" upgrade we had new, larger LN vessels installed: a 5000 gallon vessel for N2 gas delivery to the Microlab and various other labs in Cory Hall, and a 3000 gallon vessel for liquid nitrogen delivery to the MBE systems on the 1st floor of Cory. Cost of the LN vessel upgrade was shared by the HMBB project, which required the relocation of these vessels. Relocation required installation of new vessels because the old vessels, once moved did not meet seismic safety codes. The new vessels have sufficient capacity to supply the new CITRIS lab currently at advanced planning.

Hazardous Materials (Hazmat) Management Upgrade

We have invested a great deal of effort in reviewing and upgrading our hazardous materials management system. This activity started already early in 2001 and was given impetus by the external safety review after the duct fire mid-2001. During 2002 we progressed through an itemized list of fire safety, hazardous gases management, and other miscellaneous safety improvement items. The list of goals and progress was reviewed by EH&S in July 2002. Major improvements completed in 2002 were upgrade of the Zellweger chemical monitoring system by adding a second sensor unit for extended coverage; moving the control and display unit just outside of the lab entrance; connection of the monitoring system to an independent alarm company ADT; and the addition of a local hazmat alarm system, which can be activated by lab members from inside the lab. Extended documentation is part of the hazmat upgrade activity.
New Laboratory

The new engineering building under planning includes the new microlab, which we are calling CNC - Citris Nanotechnology Center. We participated in a year of intensive and detailed design, during which AGI, the laboratory consultant firm retained by the building architects, provided professional services. Although second phase working drawings had been postponed a few months, the project is still considered on time line, with ground breaking in December 2003, and construction ending March 2006. Internal utility fit up is estimated Oct. 2005 – Mar. 2006.

With AGI we have developed an excellent plan for the new nano/microlab, which will provide research facilities for the next 20 years. (Bill Flounders’ report has details.)

Integrated Materials Laboratory (IML)

The much anticipated move back to the renovated HMMB did not happen in 2002, although we went through several planning phases for the moves. We continued to operate in three buildings, as we have done the past five years. Unfortunately, demand for IML equipment, specifically the MBE systems fell drastically, and the unit operates in the red. More importantly, the IML does not have any reserves to fall back on when unexpected major repair needs occur.

We had such an event in October 2002, when the mbe2 growth chamber flooded through a failure in the cooling line. We believe that fluctuating building water pressure contributed to the event and we are following up with Risk Management.

ERL Machine Shop

The ERL/MSE joint Machine Shop continued to operate successfully and delivered timely and high-quality product to customers in both departments. The Shop’s fine machining capability was greatly expanded by the purchase of a CNC mill, utilization of which significantly increased in 2002. This enabled the increase of both volume of jobs completed and the number of PIs served in 2002. We also introduced an on-line shop management system for higher efficiency. The Shop remains a major contributor to the 6” upgrade and equipment development activities in the Microlab. While the operation finished FY 2001/02 with a negative balance, the financial performance of the Machine Shop this year is on target and likely will make up the arrears.

Staff

Microlab staff groups are organized along functional lines as described below. Groups 1-4 include staff directly responsible for maintaining the facility and processes. Groups 5-8 are operating independently, under Microlab management. (Also, please see the Staff Organizational Chart.)

Microlab Operations:

Katalin Voros, Operations Manager

1. Equipment and Facilities (12 FTE):
   
   Bob Hamilton, Manager,
   with 3 development engineers and 2 technicians;
   Phill Guillory, Supervisor, with 2 technicians, one development engineer, and a student assistant;
   Mike Linan, Supervisor, with one technician.

2. Process/Baseline (10 FTE):
   
   Sia Parsa, Manager,
   with 3 development engineers, 2 research specialists, a programmer/analyst, and 7 student assistants.

3. Administration (4.5 FTE):
   
   Rosemary Spivey, Manager,
with one administrative assistant and a student assistant,

Susan Kellogg-Smith, Procurement Manager with a purchasing assistant.

4. Computer Support (3.5 FTE):
   Todd Merport, Supervisor,
   with 3 programmer/analysts.

5. Technology Management (5 FTE):
   Bill Plounders, Technology Manager for the Microlab and BSAC
   with research engineers: BSAC - 2, MEMS Exchange - 2.

6. IML (1.5 FTE):
   Bob Prohaska, Manager,
   with one half-time development engineer.

7. Cryo-engineering (1 FTE):
   Xiaofan Meng, Sr. Development Engineer

8. Machine Shop (4.5 FTE):
   Ben Lake, Superintendent,
   with three mechanics and a part time administrative assistant.
   Ben Lake also supervises ERL Shipping, Receiving and Inventory, a total of 4 FTE.
   Administration of S/R and Inventory is managed through central ERL.

Financial Resources

All three recharge accounts under Microlab management (ML, IML, MS) continued to be closely monitored for budgetary requirements throughout the year. Rosemary Spivey's report shows details and financial analysis for each unit.

Recharge Accounting Summary, FY 00/01

<table>
<thead>
<tr>
<th>Unit</th>
<th>Income</th>
<th>Expenditures</th>
<th>Performance</th>
<th>No. of PIs Billed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microlab</td>
<td>$2,603,209</td>
<td>$2,748,357</td>
<td>5% [-]</td>
<td>90</td>
</tr>
<tr>
<td>IML</td>
<td>121,501</td>
<td>170,035</td>
<td>29% [-]</td>
<td>37</td>
</tr>
<tr>
<td>Machine Shop</td>
<td>255,266</td>
<td>308,408</td>
<td>17% [-]</td>
<td>35</td>
</tr>
</tbody>
</table>

Microlab

- General Microlab Operations were approximately one half month's of income in arrears. (Recharge operations are allowed to go into debt one month's worth of income or to accumulate.) As we are not improving on our debt this year so far, the Campus Recharge Committee issued a warning to us to be more diligent about diminishing our arrears.
- So far we have spent $1.3M out of BMLA and overhead funds on the 6" upgrade.
- An additional $420K came from BSAC grants for 6" furnaces.
- Total estimated (1999) conversion cost: $1.2M.
- With additional grant contributions from BSAC we have the funds to complete the 6" upgrade.
IML

IML use declined to an average monthly membership of 36 (from 85 last year). As a result, most IML equipment was under-utilized, and the unit did not meet its budgetary goals. Income from industrial members dropped precipitously and we are continuing to be below our targeted income this year.

Machine Shop

The shop ended with a deficit, which we already made up and are on the plus side of the balance sheet this year. Investments made last year in training and stream-lining the operation are paying off.

III. COMMUNICATIONS AND CONTROL

Membership

Microlab membership had dropped somewhat this past year to an average of 315 active members/month. Both laboratory use-hours and special equipment use-lhs declined, 14% and 7% respectively in FY 2001/2002. Some of the decline in lab/equipment-use can be attributed to two furnace banks (4 LPCVD and 4 atmospheric tubes) being down, each for over a month for the 6" upgrade.

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Membership/Month</th>
<th>Lab Use-Hrs</th>
<th>Sp. Equip. Use-Hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999/2000</td>
<td>340</td>
<td>48,878</td>
<td>40,655</td>
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<tr>
<td>2000/2001</td>
<td>345</td>
<td>45,413</td>
<td>39,383</td>
</tr>
<tr>
<td>2001/2002</td>
<td>315</td>
<td>39,288</td>
<td>36,738</td>
</tr>
</tbody>
</table>

Document Control and Training

We have been aggressively updating our Process and Equipment Operating Manual. Currently we have 144 manual chapters on-line, 2/3 of them in the new web-format. 30 chapters have study guides for written qualification tests.

Industrial Members

The Berkeley Microfabrication Laboratory Affiliates (BMLA) program for industrial membership continues successfully. We lost several companies to economic difficulties, but were able to sign up new ones. The cost of membership, which includes the privilege of accessing the Microlab, is $15K/year/person. BMLA members pay standard laboratory fees with overhead, and do not have the monthly cut-off faculty members enjoy. Membership and overhead fees are applied to equipment upgrades and to the retooling to 150 mm (6") wafer capability. So far we have financed the 6" upgrade almost fully from these funds, over $1M. Currently we have 17 BMLA member companies.

IV. FUTURE PLANS

We are well on our way in the design of the new lab in the new engineering building (CITRIS). The construction project is slated to start in December 2003, to be ready for fit-up in March 2006. The facility will provide processing capabilities for 8" wafers and also maintain 6" and manual processing capabilities. The design incorporates flexibility and ease of maintenance.

Construction of the Stanley replacement building, which will house the new Bio-Nanotechnology Center (BNC), has started, to be equipped in 2005/06.

We hope to complete migration of IML equipment from LeConte back to the Hearst MM Building, in 2003.

V. SUMMARY

Microlab operations are well under control, in spite of periodic disruptions necessitated by the 6" upgrade. Processing and testing of the first 6" cmos lot was completed and report issued. Retooling projects continue for MEMS related equipment. Development of a new management information system is well under way. The units managed under the three separate recharge accounts (Microlab, IML, Machine Shop) while somewhat behind in meeting projected income goals, are financially stable.
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Microfabrication Laboratories 2003 Year-End Reports

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<td>OPERATIONS: Katalin Voros, Operations Manager</td>
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</tr>
<tr>
<td>FACILITIES: Robert Hamilton, Facilities Manager</td>
<td>10</td>
</tr>
<tr>
<td>ADMINISTRATION: Rosemary Spivey, Administrative Manager</td>
<td>17</td>
</tr>
<tr>
<td>Susan Kellogg-Smith, Purchasing Manager</td>
<td>24</td>
</tr>
<tr>
<td>COMPUTERS: Todd Merport, System Support Supervisor</td>
<td>26</td>
</tr>
<tr>
<td>Jimmy Chang, Associate Development Engineer</td>
<td>40</td>
</tr>
<tr>
<td>Marilyn Kushner, Junior Development Engineer</td>
<td>44</td>
</tr>
<tr>
<td>Kim Chan, Asst. Dev. Engineer, Advanced Lithography</td>
<td>48</td>
</tr>
<tr>
<td>TECHNOLOGY: William Flounders, Technology Manager</td>
<td>54</td>
</tr>
<tr>
<td>BSAC ENGINEERING: Matthew Wasil, Senior Development Engineer</td>
<td>60</td>
</tr>
<tr>
<td>Ning Chen, Assistant Development Engineer</td>
<td>64</td>
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<tr>
<td>MEMS EXCHANGE: Eunice Kim, Associate Development Engineer</td>
<td>69</td>
</tr>
<tr>
<td>Roger Su, Assistant Development Engineer</td>
<td>71</td>
</tr>
<tr>
<td>CRYO ENGINEERING: Xiaofan Meng, Sr. Dev. Engineer, Cryoelectronics</td>
<td>73</td>
</tr>
<tr>
<td>IML: Robert Prohaska, IML Manager</td>
<td>75</td>
</tr>
<tr>
<td>MACHINE SHOP: Ben Lake, ERL/MSE Machine Shop Sr. Superintendent</td>
<td>79</td>
</tr>
</tbody>
</table>
ABSTRACT

This document contains the 2003 Year-End Reports by the professional staff of the Microfabrication Laboratories. Together, these reports reflect the wide range of support staff provides to research campus wide and to instructional laboratories in EECS.

Activities of direct Microlab (ML) operations support staff, described in the sections Operations, Facilities, Administration, Computers, and Process/Baseline include 24 career employees and 8 undergraduate student assistants. Various research groups support 5 additional engineers, working on assigned projects. The Integrated Materials Laboratory (IML), a separate recharging center, employs 2 engineers and the Machine Shop operates with 5 staff and an independent recharging unit.

The Microlab had an average monthly membership of 326. Participating PIs: 90. The Machine Shop completed 228 jobs from 41 PIs. The Berkeley Microlab Affiliates program (BMLA) comprises 13 industrial members. Detailed Microlab information can be found at http://microlab.eecs.berkeley.edu.

K.V.
MEMORANDUM

To: A. Pisano, ERL Director
    T. King, Microlab Faculty Director
From: K. Voros, Operations Manager
Subject: 2003 Year-End Report
Cc: S. Sastry
Date: 30 January 2004

I. INTRODUCTION

Microlab operations continued in 2003 in the usual busy manner, with the 6" upgrade in its final phase. Retooling was considered completed for the CMOS process line by the end of last year, when we finished processing and testing the first 6" CMOS baseline lot. In 2003 the upgrade agenda comprised tools for MEMS work.

Financial difficulties were our main concern in 2003, resulting from lower than expected laboratory use, i.e. recharge income, and higher than budgeted expenses. Details on this are presented under the Management of Financial Resources section of this report.

Planning for the new Microlab as part of the CITRIS project continued throughout the year, with Bill Flouders attending and following up every meeting concerning the new lab. The "value engineering" phase was especially painful, because we had to give up installing items that are considered "facilities" such as sinks. Planned start, however, remains Spring 2004.

This document is the seventeenth year-end report I am submitting on behalf of the Microlab.

II. MANAGEMENT OF RESOURCES

Facilities

1.0 Microlab

- Bob Hamilton, Equipment and Facilities Manager, and Safety Officer of the Microlab, provides details on upgrades, installations, facilities maintenance and development in his report. Safety issues and HazMat monitoring improvements are also discussed.
- Rosemary Spivey, Administrative Manager and her staff report on financial status, accounts and members administration, purchasing and inventory management.
- Todd Merport, Computer Operations Manager reports on developments in computer support and our activities in design and development of the new management information system, Mercury.
- Reports by Sia Parsa, Process Engineering Manager and his staff comprise details of process support and 6" process development. Also, development of the 0.35 μm cmos baseline process is discussed.

1.1 Retooling to 150 mm (6") Wafer Processing

After completing the upgrade for 6" CMOS wafer processing in 2002, we spent 2003 following up the outstanding items for MEMS research. Process engineering continued their effort in re-characterizing tools for 6" processes, while maintaining full 4" capability. Also, operating manuals were rewritten as the new/upgraded tools came on line.
Outstanding tools to be upgraded at the end of 2002 were:

Bank 4
- tystar13 - POCI₃ deposition
- tystar14 - Boron+ diffusion
- tystar15 - SiC LPCVD
- tystar16 - MEMS amorphous/poly-Si LPCVD

Bank 5
- tystar17 - MEMS low stress nitride
- tystar18 - MOS sinter

Etchers/Thin film
- xetch - XeF₂ etch
- centura - deep Si/oxide etch
- p5000 - conformal oxide deposition, PECVD TEOS
- lam5 (9400 Rainbow TCP) poly-Si etch 6” only conversion

Completed in 2003

Furnace Bank 4 and Bank 5
- All tubes listed above, with respective standard processes.

Etchers/Thin film
- xetch - XeF₂ etch 6” upgrade completed, resulting in better uniformity
- lam1 - nitride etcher converted to dual 4”/6” use
- lam5 - conversion on hold pending centura etcher completion
- centura - in progress; oxide etch shows good performance,
  - deep Si etch under development;
  - tool has not been released yet after installation by AMAT.
- p5000 - one etch and one deposition chamber characterized with TEOS/O₂;
  - boron and phosphorous dopant sources installed;
  - waiting for ozone process (hardware problem)

Additional tools converted
- Sink 5, 6, 8 - upgraded to 6” capability;
  - spin-rinse-dryers replaced with 4”/6” dual stack at each sink
- CMP wafer cleaner - upgraded to 6”
- Profilometer - old as200 replaced by 6” capable asiq (KLA-Tencor), BSAC donation

We started the 6” upgrade effort effectively in 1999 (planning began in 1996) and will be completing it in 2004. General operations were maintained during this 5-year project, with occasional shut down of furnaces and miscellaneous tools. Process staff characterizes all new 6” processes and in the case dual 4”/6” use, recharacterized the 4” process in the upgraded tool.

Financing was provided fully from Microlab funds, our savings from industrial membership fees and overhead (BMLA). Total spending so far was $ 1.9M, which does not include staff time spent on the project (see Table 1). We also utilized donated tools, all of which had to be modified for our use.
## 150mm Retooling Expenditures

<table>
<thead>
<tr>
<th>Photo/Mask</th>
<th>Wet Processing</th>
<th>Thermal Processing</th>
<th>Computers</th>
<th>Utilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASML</td>
<td>sink9 $45,400.00</td>
<td>tystar16 $7,680.00</td>
<td>CAPE $77,900.00</td>
<td>Acid Waste Disp Syst $12,023.00</td>
</tr>
<tr>
<td>uvbake</td>
<td>sink5/7 $107,500.00</td>
<td>tystar17 $129,020.00</td>
<td>Server Upgrade (silicon)</td>
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<tr>
<td>matrix</td>
<td>sink3/4/6/8 $33,806.00</td>
<td>tystar18 $24,300.00</td>
<td>Equip Control (WIS)</td>
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<tr>
<td>svg8800 coat/dev</td>
<td>cassettes/handling equip $4,990.00</td>
<td>tystar9-12 $356,570.00</td>
<td>Sensor Control (RUMS)</td>
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<tr>
<td>svgcoat3</td>
<td>hf disposal (pump cart) $12,300.00</td>
<td>tystar1-4 $347,600.00</td>
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<tr>
<td>apt chrome/emu</td>
<td>drain/plumbing upgrade $4,210.00</td>
<td>tystar bank4 (Fauc) $31,500.00</td>
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<tr>
<td>optiphot</td>
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<td>bpulse $5,196.00</td>
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<tr>
<td>mask aligner (Quintel)</td>
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<tr>
<td><strong>Total to date</strong> $168,288.00</td>
<td><strong>Total to date</strong> $208,206.00</td>
<td><strong>Total to date</strong> $924,186.00</td>
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<td><strong>Etch</strong></td>
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<td><strong>Computers</strong></td>
<td><strong>Utilities</strong></td>
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<tr>
<td>lams $25,300.00</td>
<td>cpa $3,000.00</td>
<td>CAPE $77,900.00</td>
<td>Acid Waste Disp Syst $12,023.00</td>
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<tr>
<td>lame1-5 $10,025.00</td>
<td>Novellus (rm 144) $76,500.00</td>
<td>Server Upgrade (silicon)</td>
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<tr>
<td>Centura $127,770.00</td>
<td>P5000 (rm 190) $89,400.00</td>
<td>Equip Control (WIS)</td>
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<tr>
<td></td>
<td>Ewards EB3 evaporator $13,800.00</td>
<td>Sensor Control (RUMS)</td>
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<td><strong>Total to date</strong> $163,095.00</td>
<td><strong>Total to date</strong> $187,700.00</td>
<td><strong>Total to date</strong> $77,900.00</td>
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<tr>
<td><strong>Pianarization</strong></td>
<td><strong>Measurements</strong></td>
<td><strong>Utilities</strong></td>
<td><strong>Utilities</strong></td>
<td></td>
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<tr>
<td>cmp (strausbaugh) $18,600.00</td>
<td>asiq $1,235.00</td>
<td>Acid Waste Disp Syst $12,023.00</td>
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<td>cmp (sec) $15,000.00</td>
<td>autoprobe $5,900.00</td>
<td>LN Vessels $19,500.00</td>
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<tr>
<td></td>
<td>cdsem $20,400.00</td>
<td>(1/3 of $57,460)</td>
<td></td>
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<tr>
<td></td>
<td>nanospec $1,558.00</td>
<td>LN Line $20,300.00</td>
<td></td>
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<tr>
<td></td>
<td>uvscope $2,666.00</td>
<td>Tank Install $11,100.00</td>
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<tr>
<td><strong>Total to Date</strong> $33,600.00</td>
<td><strong>Total to Date</strong> $31,759.00</td>
<td><strong>Total to Date</strong> $62,923.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Grand Total To Date $1,857,657.00

Table 1
1.2 Facilities Upgrade

*Drains and Acid Waste Neutralization*

An unexpected result of the 6" upgrade was that we exceeded the limits of the lab's wastewater handling capacity. The new 6" capable sinks use a great deal more water and chemicals than the old sinks and we had to design a number of economizing features to ameliorate escalating costs. Along with this, the vacuum drain system, a unique design implemented when the lab was built, had to be modified extensively to handle the increased volume of effluents. Finally, the acid waste treatment system turned out to be inadequate for the larger volumes. Thus, following the advice of Environment, Health, and Safety, we ended up implementing an acid waste neutralization system, to be located in the rear of Cory Hall. This project will be completed Q1 2004.

*New Cooling Water Loop*

Another issue needing attention as a result of the 6" upgrade was cooling water capacity. We were already at the limit before the upgrade, but the upgrade forced us to address the problem.

Bob Hamilton and his staff came up with another resourceful solution: we obtained a large capacity Neslab chiller, as new from a second-source vendor, and created a completely new cooling water loop in the Microlab. Because the chiller is located in the 5th floor utilities room, plumbing had to penetrate the floor/ceiling between the floors. This involved inspection by the Fire Marshal, which we passed successfully.

*432 Upgrade*

In 2003 we continued renovating the "oldlab" section of the Microlab (432 A-E). A large part of the project was consolidating gas cylinders in one area and installing hazmat sensors. Several processing tools were relocated for better space efficiency. This involved extensive replumbing of gas lines, exhaust, and cooling water and installation of additional hepa-filters to provide a cleaner environment. These types of moves always involve sorting through and discarding material left by labmembers who graduated.

1.3 Computers

*MERCURY — New Lab Management System*

Design and framework were implemented this past year by F. Varju. The new, streamlined and clean design, consisting of a database server, an application server and clients, takes full advantage of modern software technology. Many useful features of the old Wand system are utilized in the new form; however, the accounting system had been completely redesigned based on business accounting procedures. A real-time journal is maintained of all laboratory activities, providing a clear view of status at any time. After F. Varju resigned in November 2003, T. took over the project lead. We have assigned ourselves an aggressive deadline of mid-year for beta-testing by staff.

*RUMS — Resource Utilization Management System*

A major step forward in upgrading the Microlab's computer control system was the release of RUMS in June 2003. The old facilities monitoring system was completely replaced with new hardware and in-house developed software. 32 sensors are monitoring various utilities, such as N2 pressure, air pressure, temperature, etc., which have to be in spec for the lab to operate properly. Collected data with graphs are available not only by directly connecting to the RUMS server but also on the Microlab's web site. The efforts of our software and hardware engineers, Duncan, Chen, Pestal, and Merport, resulted in a great system, which is described in detail in Memorandum No. UCB/ERL 03/43.
Gas Management System

When renovation of the Hearst Memorial Mining Building was completed and we regained access to the rear of Cory Hall, we were able to consolidate and upgrade our cylinder-gas storage space there. Consolidation provided a perfect opportunity to reorganize our cylinder management system, enhancing order tracking capability and leveraging just-in-time delivery. At that time we transferred cylinder management to the administrative staff and implemented a new software application, designed and developed by Merport and Varju for this purpose. The Microlab Gas Management System has been used with great success since April 2003.

Website Updates

The Microlab's new, streamlined web portal is on-line now. All the information that was available on the old home page had been updated and is accessible through one of the nine panels of the new portal. We also set aside a Staff Only section, which requires a password for access. http://microlab.eecs.berkeley.edu. We also updated the IML web site and established a new web page for the Machine Shop, designed by shop personnel. http://mshop-erl.berkeley.edu.

2.0 New Laboratory

The new engineering building, CITRIS, which contains the new lab, called CNC - Citris Nanotechnology Center, for the time being, underwent several rounds of value engineering in 2003. The project is still considered on time line to commence in Spring 2004. At this point, however, lab plans were moved forward with only one floor of the two built out, with an add-on option of the second floor. This proposed half-solution is unacceptable to EECS and discussions are continuing. (Bill Flounders' report has details.)

3.0 Integrated Materials Laboratory (IML)

The much anticipated move back to the renovated HMMB finally happened in 2003. It went unexpectedly smoothly, with little down time. We were able to move equipment from LeConte back into the HMMB and the FIB from Cory; these were the only tools for which space was allotted for in HMMB. Systems from Davis were consolidated in 155 Cory. One tool, bigblue, was decommissioned.

Demand for IML equipment, specifically the MBE systems remained low throughout 2003, and the unit operated in the red. We closed FY 02/03 within the limit of arrears allowed by.recharge policy, only because we were able to recoup some funds from Risk Management after a disastrous water line failure, which flooded mbe2. This helped to bring back the system to operating conditions, and the fact that we borrowed parts from mbe1. At the end of 2003, by joint agreement, mbe1 was returned, as is, to Prof. Chang-Hasnain as a research tool restricted to be used and maintained by her own group. IML/Microlab agreed to assist the start-up with available spare parts and advantageous second-source acquisitions of missing components.

4.0 Machine Shop

With the completion of the seismic retrofit of HMMB, MSE mechanics were able to set up shop there again. Sharing of ERL machines in Cory Hall continues, however, and MSE contributes to Shop maintenance expenses proportionately to the number of their personnel. (35%).

ERL's Machine Shop continued to operate successfully, made up the arrears carried over from last year and ended FY 02/03 on budget. Of the 223 jobs completed, over half came from the Microlab. With the winding down of the 6" upgrade it is anticipated that Shop orders from the Microlab will decrease; thus, we have made preparations to broaden the customer base to other departments. The on-line shop management system was upgraded for easy submission of orders and higher time management efficiency. A new web portal was designed by Machine Shop staff, listing capabilities and showing representative job samples. Flyers are ready to be sent out to extend invitations to external customers.
Staff

Microlab staff groups are organized along functional lines as described below. Groups 1-4 include staff directly responsible for maintaining the facility and processes. Groups 5-7 are operating independently, under the Microlab Operations Manager. (Also, please see the Staff Organizational Chart, dated 1 Dec. 2003.)

Microlab/IML Operations: (26.5 + 7.5 FTE)
  Katalin Voros, Operations Manager, (9 direct reports)
  one (0.75 FTE) Computer Resource Specialist

1. Equipment and Facilities: (12 FTE)
   Bob Hamilton, Manager, (7 direct reports)
   4 development engineers and 1 technician
   Phil Guillory, Supervisor, 2 technicians, 1 dev. engineer, 0.5 P/A, 2 student assistants
   Mike Linan, Supervisor, 1 technician

2. Process/Baseline: (6.5 FTE)
   Sia Parsa, Manager
   2.5 development engineers, 1 research specialists, and 4 student assistants

3. Administration: (4.5 FTE)
   Rosemary Spivey, Manager,
   1 administrative assistant and 1 student assistant,
   Susan Kellogg-Smith, Procurement Manager, 1 purchasing assistant.

4. Computer Support: (2.5 FTE)
   Todd Merport, Supervisor
   2 programmer/analysts

5. Technology Management: (5 FTE)
   Bill Flouders, Technology Manager for the Microlab and BSAC
   research engineers: BSAC - 2, MEMS Exchange - 2

6. IML: (1.5 FTE)
   Bob Prohaska, Manager, 1 half-time development engineer

7. Cryo-engineering (1 FTE)  Xiaofan Meng, Sr. Development Engineer

Also under Microlab Management:

Machine Shop: (4.5 FTE)
   Ben Lake, Superintendent, three mechanics and 0.5 FTE administrative assistant.
   Ben Lake also supervises ERL Shipping, Receiving and Inventory (3 FTE).
   Administration of S/R and Inventory is managed through central ERL.
Financial Resources

All three recharge accounts under Microlab management, (ML, IML, MS) continued to be closely monitored for budgetary requirements throughout the year. Rosemary Spivey's report shows details and financial analysis for each unit.

Recharge Accounts Summary
30 June 2003

<table>
<thead>
<tr>
<th>Unit</th>
<th>Income</th>
<th>Expenditures</th>
<th>Performance</th>
<th>No of Pls Billed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microlab</td>
<td>*$2,701,499</td>
<td>**$2,869,611</td>
<td>6% [-]</td>
<td>87</td>
</tr>
<tr>
<td>IML</td>
<td>$ 125,724</td>
<td>$ 140,086</td>
<td>11% [-]</td>
<td>39</td>
</tr>
<tr>
<td>Machine Shop</td>
<td>$ 344,451</td>
<td>$ 333,563</td>
<td>3% [+ ]</td>
<td>41</td>
</tr>
</tbody>
</table>

Microlab: * Income includes a BMLA subsidy of $253,203.
** Expenditures include the carry-forward deficit from FY 2001/2002 of $164,167.

IML: Expenditures include the carry-forward deficit of $29,834 from FY 2001/2002.

Microlab operations were in the negative every month the first half (July – Dec.) of the current fiscal year (03/04), a total of $298,562. This does not include the debt carried forward from last year, $168,111. Thus, the Microlab’s recharge account is in the red for $466,673 as of January 2004. We have reviewed both sides of the equation, where we can cut expenditures and why is our income below the projected value. It is clear that with the 6" upgrade we incur higher maintenance costs, such as nitrogen/oxygen and specialty gases; DI water use and chemical waste disposal; quartz ware and 6" furnace tubes are more expensive and pumps need more frequent maintenance. Effective 1 July 2003, ERL withdrew support of 1.25 FTE administrative position, which was provided in lieu of the Microlab providing for its own accounting and purchasing instead of central ERL.

Concurrent with increased expenses our income from external users decreased precipitously. This was the result of BMLA member companies dropping out or reducing their use of the Microlab. Also, MEMS Exchange has been sending very few requests for processing. When external users stay away we lose income not only from reduced lab fees but also from BMLA membership fees and overhead. The latter were a good source of funds for upgrades and we indeed financed the 6" retooling from these; however, by now the funds are exhausted and are not being replenished. Yet, the upgrade has not been fully completed.

We have implemented cost savings measures were possible and reduced staff by 3 FTEs, by the end of December. Faculty support has been relatively steady; thus, it is clear that we have to regain some of our external business to show improvement by the end of this FY, 30 June 2004. We have increased efforts in developing new contacts.

III. COMMUNICATIONS AND CONTROL

Membership

Microlab membership remained basically the same this past year, at an average of 326 active members/month. Both laboratory use-hours and special equipment use-hrs increased somewhat since last year; however, we are still below the level of 2000/2001.
<table>
<thead>
<tr>
<th>1/3</th>
<th>Dr. J. Stetter – Nanomix</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/16</td>
<td>T. Kalil – COE/UCB</td>
</tr>
<tr>
<td>1/17</td>
<td>Prof. Y. Nishi, J. Shott - Stanford</td>
</tr>
<tr>
<td>1/27</td>
<td>Jiri Matek – Robert Bosch Corp.</td>
</tr>
<tr>
<td>1/27</td>
<td>Prof. H. Zappa – U. Freiburg</td>
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<tr>
<td>1/28</td>
<td>Yu Chen - Kovio</td>
</tr>
<tr>
<td>1/29</td>
<td>Prof. Ramadge - Princeton</td>
</tr>
<tr>
<td>1/30</td>
<td>Prof. Roka – SZTAKI, Hungary</td>
</tr>
<tr>
<td>2/8</td>
<td>Prof. Bajcsy - CITRIS</td>
</tr>
<tr>
<td>2/10</td>
<td>Prof. A. Katz – ChemE/UCB</td>
</tr>
<tr>
<td>2/14</td>
<td>C. Chui - Stanford</td>
</tr>
<tr>
<td>2/21</td>
<td>Dr. Levinson – AMD</td>
</tr>
<tr>
<td>2/21</td>
<td>Dr. G. Whitney – IBM</td>
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<td>2/24</td>
<td>&quot;Nano – Giants&quot; event, SF</td>
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<tr>
<td>2/25</td>
<td>Prof. A. Chakraborty – ChemE/UCB</td>
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<tr>
<td>2/28</td>
<td>Dr. Kolics – Blue29</td>
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<tr>
<td>3/3</td>
<td>Prof. Dravid – Northwestern U.</td>
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<td>3/3</td>
<td>V. Vogel – U. of Washington</td>
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<td>3/6</td>
<td>Dr. V. Czikan – LBNL</td>
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<td>3/6</td>
<td>Prof. O. Nalmasu – RBI</td>
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<tr>
<td>3/19</td>
<td>EECS Advisory Board Meeting</td>
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<tr>
<td>3/21</td>
<td>Prof. E. Jones – Oregon State U.</td>
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<tr>
<td>3/25</td>
<td>Prof. Y. Suzuki – MSE/UCB</td>
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<td>3/25</td>
<td>EVG Visit (Nanoinprint)</td>
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<tr>
<td>3/26</td>
<td>Dr. M. Cohn – Microassembly</td>
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<tr>
<td>4/2</td>
<td>ORU Survey – Off. of VCR/UCB</td>
</tr>
<tr>
<td>4/4</td>
<td>Prof. Wallace – U. of N. Texas</td>
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<tr>
<td>4/4</td>
<td>Dr. J. Hsu – Fac. Cand. Physics</td>
</tr>
<tr>
<td>4/7</td>
<td>Korean Inst. Of Tech. visitors</td>
</tr>
<tr>
<td>4/7</td>
<td>Chinese Academy visitors</td>
</tr>
<tr>
<td>4/8</td>
<td>Dr. Sorensen – Proxair</td>
</tr>
<tr>
<td>4/8</td>
<td>Am. Plating Society visit</td>
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<tr>
<td>4/11</td>
<td>Dr. M. Hankinson – KLA-Tencor</td>
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<tr>
<td>4/18</td>
<td>Prof. C. Li – UC Irvine</td>
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<td>4/25</td>
<td>Dr. C. Jungemann – Stanford</td>
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<tr>
<td>5/21</td>
<td>Prof. C. Mastrangelo – U. of Michigan</td>
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<td>5/30</td>
<td>Dr. S. Cho – U. of Houston</td>
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<tr>
<td>6/3</td>
<td>V. Novotny – Active Optical Networks</td>
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<tr>
<td>6/26</td>
<td>Dr. D. Steingard, J. Evans – MSE</td>
</tr>
<tr>
<td>6/27</td>
<td>Visitors from Sensarray</td>
</tr>
<tr>
<td>6/30</td>
<td>Presentation at UGIM</td>
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<tr>
<td>7/6</td>
<td>Sematech visitors</td>
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<td>7/17</td>
<td>Samsung visitors</td>
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<td>7/17</td>
<td>NRC/NAS survey visit</td>
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<td>7/22</td>
<td>Prof. O. Cho – Hanhuh U. Korea</td>
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<tr>
<td>7/24</td>
<td>Prof. A. Horvath – CE/UCB</td>
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<td>8/5</td>
<td>S. Koh – Peta Communications</td>
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<td>8/15</td>
<td>Visitors from Cal Poly</td>
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<tr>
<td>8/29</td>
<td>Swiss visitors</td>
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<tr>
<td>9/8</td>
<td>Prof. F. Tian – Shanghai</td>
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<tr>
<td>9/11</td>
<td>L. Salmon, A. Bowling – TI</td>
</tr>
<tr>
<td>9/12</td>
<td>K. Srinivasan – Intel</td>
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<tr>
<td>9/16</td>
<td>Prof. S. Parke – Boise State U.</td>
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<tr>
<td>9/18</td>
<td>Prof. H. Lu, Bartman – UCSF</td>
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<tr>
<td>9/19</td>
<td>T. Sonderman – AMD</td>
</tr>
<tr>
<td>9/26</td>
<td>Dr. M. Meyyappan – NASA/Ames</td>
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<tr>
<td>10/3</td>
<td>Prof. Alkire – U. of Illinois</td>
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<td>10/7</td>
<td>T. Yen – Semtronics</td>
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<td>10/10</td>
<td>Prof. S. Carter – UCSC</td>
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<td>10/23</td>
<td>MSE visitor</td>
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<td>10/24</td>
<td>Prof. D. Fletcher – BioEng.</td>
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<tr>
<td>10/27</td>
<td>K. Doctor – SJSU</td>
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<tr>
<td>10/29</td>
<td>Prof. N. Tien – UCD</td>
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<tr>
<td>10/31</td>
<td>Dr. D. Groupp – Acorn Techn.</td>
</tr>
<tr>
<td>11/7</td>
<td>Prof. A. Delton – CalTech</td>
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<tr>
<td>11/7</td>
<td>J. Wu – HP Taiwan</td>
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<td>11/7</td>
<td>K. Chu – Nanomix</td>
</tr>
<tr>
<td>11/11</td>
<td>Dr. G. Gruener – UCLA</td>
</tr>
<tr>
<td>11/13</td>
<td>Dr. J. Shott, W. Murray – Stanford</td>
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<tr>
<td>11/21</td>
<td>Dr. A. Fazio – Intel</td>
</tr>
<tr>
<td>12/9</td>
<td>Prof. D. Hess – Georgia Tech</td>
</tr>
<tr>
<td>12/18</td>
<td>Dean Lavernia, Prof. White, K. McDonald - UCD</td>
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### Microlab Utilization

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Membership/Month</th>
<th>Lab Use-Hrs</th>
<th>Sp. Equip. Use-Hrs.</th>
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<tbody>
<tr>
<td>1999/2000</td>
<td>340</td>
<td>48,878</td>
<td>40,655</td>
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<tr>
<td>2000/2001</td>
<td>345</td>
<td>45,413</td>
<td>39,383</td>
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<tr>
<td>2001/2002</td>
<td>315</td>
<td>39,288</td>
<td>36,738</td>
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<tr>
<td>2002/2003</td>
<td>326</td>
<td>43,455</td>
<td>37,676</td>
</tr>
</tbody>
</table>

### Document Control and Training

We continued updating our Process and Equipment Operating Manual. Currently we have 147 manual chapters on-line, 80% of them in the new web-format. All systems upgraded to 6" capability were brought on line with the manual chapter updated by process staff. Currently we have written tests for qualification on 29 tools.

We have completed a major redesign and implementation of the Microlab’s web portal. The goal was to make information access simple and straightforward. We have transferred many of the features of the old WAND to the web and instituted Active Members and For Staff Only pages accessible with password only.

### Outreach

During the Summer of 2003 we had another participant in the Microlab Summer Internship for High School Girls program. B. McKeon from Bishop, CA worked with process staff learning to operate processing tools and had a process characterization assignment. At the end of Summer she gave a Power Point presentation of her results. This program is described in the Outreach section of our website.

### IV. FUTURE PLANS

We continue on the path of quest for a new microlab in the new engineering building (CITRIS). The construction project is slated to start in the Spring 2004, but it is still in the funding approval phase. We have invested a lot of energy and effort into containing the scope of the design, because we are concerned about maintenance in the future. At the same time we need to be flexible in anticipation of development in research that we will need to support in the new facility.

Construction of the Stanley replacement building, which will house a new Bio-Nanotechnology Center (BNC), has started, to be equipped in 2005/06. We are looking forward to cooperate in this project and help build a new laboratory to complement UCB’s capabilities in bio-sciences.

### V. SUMMARY

Microlab operations continue under financial difficulties, caused by several factors: 6" upgrade resulted in a greater burden than anticipated, including increased regulatory requirements. At the same time, Microlab use decreased and income fell below projected levels. We are implementing corrective actions both in the Supplies and Expenses and Salaries and Benefits categories. Also, we will extend extra effort to increase the use of the facility.

The recharge accounts of the Microlab and IML are well in the negative and will not be able to meet recharge budgets by the end of this fiscal year (June 30 2004). The Machine Shop is financially stable and is meeting its goals.
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COMPUTERS: Todd Merport, System Support Supervisor .......... 25


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Microfabrication Laboratory 2004 Year-End Reports
ABSTRACT

This document contains the 2004 Year-End Reports by the professional staff of the Microfabrication Laboratory. Together, these reports reflect the wide range of support staff provided to research campus-wide and to instructional laboratories in EECS.

Activities of direct Microlab (ML) operations support staff, described in the sections Operations, Facilities, Administration, Computers, and Process/Baseline, include 23 career employees and 8 undergraduate student assistants. The Microlab reached a major milestone in its continuous evolution: the upgrade to process 6" (150 mm) wafers has been completed.

The Microlab had an average monthly membership of 331. Participating PIs: 94. The Machine Shop, which operates with 5 staff as an independent recharge unit, completed 243 jobs from 37 PIs. The Berkeley Microlab Affiliates program (BMLA) comprises 17 industrial members. Detailed Microlab information can be found at http://microlab.eecs.berkeley.edu.

K.V.

Microfabrication Laboratory
Staff Organizational Chart
Effective 3 February 2005
MEMORANDUM

To: C. Spanos, ERL Director
    N. Cheung, Microlab Faculty Director
From: K. Voros, Operations Manager
Subject: 2004 Year-End Report
Date: 30 January 2005

I. INTRODUCTION

Microlab operations reached a major milestone by the end of 2004, when the 6" upgrade was completed. We now support a full 6" CMOS and MEMS process line, while maintaining complete 4" capability.

At fiscal closing in the middle of the year, the Microlab ended with a deficit. However, by the end of 2004, the financial situation stabilized. Details on this are presented under the Financial Resources section of this report.

Planning for the new Microlab, as part of the CITRIS project, continued. Ground breaking in the fall and the increasing size of the hole in the ground next to Cory Hall (observable from our office window), reinforced our hope in the eventual completion of a new nanofabrication facility.

This document is the 18th year-end report that I have submitted on behalf of the Microlab.

II. MANAGEMENT OF RESOURCES

Facilities

1.0 Microlab

- Bob Hamilton, Equipment and Facilities Manager and Safety Officer of the Microlab, provides details on upgrades, installations, facilities maintenance and development in his report. Safety issues and HazCom improvements are also discussed.

- Rosemary Spivey, Administrative Manager and her staff, reports on financial status, accounts and members administration, purchasing, and inventory management.

- Todd Merpord, Computer Operations Manager, reports on developments in computer support and our activities in design and development of the new management information system, Mercury.

- Reports by Sia Parsa, Process Engineering Manager and his staff, comprise details of process support and 6" process characterization. Also, development of the 0.35 μm CMOS baseline process is discussed.
1.1 **Retooling to 150 mm (6") Wafer Processing Completed**

After more than 6 years of continuous work we have completed the 6" upgrade, resulting in full 6" capabilities for both CMOS and MEMS processing. In December 2004, I submitted to the Faculty Director the 6" Upgrade — Final Report, documenting the activities, timeline, and costs of this long-term effort. The report was also sent to all Microlab PIs and is posted on line at http://microlab.berkeley.edu/text/6inchup/finalreport.html.

1.2 **Computers**

*MERCURY — New Lab Management System*

Tim Duncan led the design and development of this ongoing project. The database schema design has been completed, along with the major applications user interfaces. The main modules are: account management, equipment management, problem reporting and utilities dependencies, purchasing and inventory, reservations, qualifications and calendars. We are planning extensive testing early 2005 and full implementation with the start of the new fiscal year, 1 July 2005.

2.0 **New Laboratory**

The new engineering building, CITRIS, which contains the new lab, called CNC - Citris Nanotechnology Center (for the time being), underwent a major redesign. Also, the project had been divided into two phases: I) Demolition and Excavation, and II) Construction. Phase I is well underway; projections show that there will be about a 6-month postponement of the start of construction. This point, however, with the ever-deepening hole next door, we are hopeful that the new building and our new lab will become a reality (Bill Flounders' report has details).

3.0 **Machine Shop**

The Machine Shop completed 243 jobs for 37 PIs in FY 2003/2004. This represents a 16% increase in the volume of jobs, a further proof that we can operate a self-maintaining shop. About half of the jobs were submitted from the Microlab. With the completion of the 6" upgrade, the Shop is working hard to broaden its customer base. The updated website, which lists capabilities, contact information, job request forms and general information such as photographs of completed jobs, has streamlined operations by answering some general customer questions and giving customers an easy way to make contact. http://mshop-erl.berkeley.edu

4.0 **Integrated Materials Laboratory (IML)**

At the end of the fiscal year, in July 2004, I submitted a proposal to the Directors of the Microlab and IML to combine operations of these two recharge units. My report, Integrated Materials Laboratory, dated 15 July 2004, included justification for the proposal and how the merger will be executed, if approved. In Integrated Materials – Final Report, dated 15 August 2004, submitted after approval was obtained, the final disposition of equipment is listed as follows:

**Deposition Systems**

1. Mbe1 - 155 Cory Hall – Prof. Chang-Hasnain
2. Mbe2 - UHV-connected with a metalization and a characterization chamber (mbe2-implant-ichar) - 157 Cory Hall – Prof. Weber
3. Pulsed Laser Deposition System - 100 HMMB – Prof. Ramesh
4. The MRC RF/DC Magnetron Sputterer for zinc oxide and the Poly Para-Xylene Thin Film Deposition system - 188 Cory – Microlab
Analytical Systems
1. Auger Electron Spectrometer - 140 HMMB – no taker, surplus
2. The Seiko 8800 Focused Ion Beam - 140 HMMB – on loan to Dr. T. Schenkel, LBNL
3. The JEOl 6400 SEM/E-Beam Wilter – 107 Cory Hall - Microlab
5. X-Ray Diffractometer - 145 Cory – Microlab

Staff
Microlab staff groups are organized along functional lines as described below. The Machine Shop operates independently, under the Microlab Operations Manager. (Also, please see the Staff Organizational Chart, Effective 3 February 2005.)

Microlab Operations (23.5 FTE)
Katalin Voros, Operations Manager, (7 direct reports)
1. Equipment and Facilities (10 FTE)
   Bob Hamilton, Manager, (7 direct reports)
   4 development engineers and 1 technician;
   Phill Guilling, Supervisor, 1 technician, student assistants;
   Mike Linan, Supervisor, 1 technician.

2. Process/Baseline (6.5 FTE)
   Sia Parsa, Manager,
   2.5 development engineers, 1 research specialist, and 4 student assistants.

3. Administration (3.5 FTE)
   Rosemary Spivey, Manager, 2 student assistants,
   Susan Kellogg-Smith, Procurement Manager, 1 purchasing assistant.

4. Computer Support (2.5 FTE)
   Todd Merport, Supervisor
   2 programmer/analysts.

5. Technology Management: Bill Flounders

Financial Resources
All three recharge accounts under Microlab management (ML, IML, MS) continued to be closely monitored for budgetary requirements throughout the year. Rosemary Spivey's report shows details and financial analysis for each unit.

Recharge Accounts Summary
30 June 2004

<table>
<thead>
<tr>
<th>Unit</th>
<th>Income</th>
<th>Expenditures</th>
<th>Performance</th>
<th>No. of Pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microlab</td>
<td>$2,642,891</td>
<td>$2,843,551</td>
<td>7% [-]</td>
<td>94</td>
</tr>
<tr>
<td>IML</td>
<td>$114,663</td>
<td>$133,570</td>
<td>14% [-]</td>
<td>40</td>
</tr>
<tr>
<td>Machine Shop</td>
<td>$312,449</td>
<td>$333,170</td>
<td>6% [-]</td>
<td>37</td>
</tr>
</tbody>
</table>

Microlab: *Income includes a BMLA subsidy of $179,480.
**Expenditures include the carry-forward deficit from FY 2002/2003 of $168,111.
Microlab operations ended the 6" upgrade with a deficit of about $200K in operating funds, mostly because of additional staff. With the upgrade completed, we have reduced staff to normal levels. Also, with the end of major disruptions, laboratory use is again slowly increasing.

IML: At the close of IML operations in October 2004, a total outstanding deficit of $40,433.22 remained. Through the process of Financial Journal Zero-Adjustment, the outstanding negative balance of the IML was transferred to the Microlab operating funds and the IML account was closed permanently.

Cost of the 6" Upgrade
The 6" Upgrade – Final Report includes funding details of this 6-year project.
http://microlab.berkeley.edu/text/6inchup/finalrpt.html
In addition to the funds provided by PIs through research grants, the Microlab spent close to $2M from savings (BMLA, overhead, cash gifts) and $700K in additional salaries and benefits. The total cost of the upgrade, including recorded values of equipment donations, was $12.25M.
This represents a respectable added value to the Microlab.

III. COMMUNICATIONS & CONTROL

Membership
Microlab membership remained at the same level this past year as in preceding years, with an average of 331 active members/month. Both laboratory use-hours and special equipment use-hrs increased somewhat since last year. However, we are still below the level of 2000/2001.

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Membership/Month</th>
<th>Lab Use-Hrs</th>
<th>Sp. Equip. Use-Hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999/2000</td>
<td>340</td>
<td>48,878</td>
<td>40,655</td>
</tr>
<tr>
<td>2000/2001</td>
<td>345</td>
<td>45,413</td>
<td>39,383</td>
</tr>
<tr>
<td>2001/2002</td>
<td>315</td>
<td>39,288</td>
<td>36,738</td>
</tr>
<tr>
<td>2002/2003</td>
<td>326</td>
<td>43,455</td>
<td>37,676</td>
</tr>
<tr>
<td>2003/2004</td>
<td>331</td>
<td>40,823</td>
<td>34,692</td>
</tr>
</tbody>
</table>

Document Control and Training
The Microlab’s operating manual consists of 1,653 pages, compiled in 156 chapters, available on-line from the web portal of the Microlab, http://microlab.berkeley.edu/.

The listing of 6" Equipment Capability is shown in the Equipment panel.

As part of the 6" upgrade, we expended considerable effort to keep documentation up-to-date, because we expect lab members to use the on-line manual (and hard copy) as the first step in finding operational and process information.

The task of writing new manuals, appending, updating existing ones with the latest information, is shared by staff and expert users of the tools, with process staff carrying most of the burden. Madeleine Leullier, Computer Resource Specialist, has the assignment of document control, i.e. editing and installation of both on-line and hard copy manuals.
Outreach

During the Summer of 2004, we suspended the Microlab Summer Internship for High School Girls program. However, we posted it again for 2005. We have already selected a good candidate who will be able to contribute to the Mercury deployment project.

IV. SUMMARY

After more than 6 years of continuous activity we have completed the 6" upgrade, resulting in full 6" capabilities for both CMOS and MEMS processing. A summary report was compiled to document the activities, timeline, and costs of this long-term effort. The success of the 6" upgrade was the result of building on our strengths, the talents of our capable staff and the support of our member PIs.

At the end of the upgrade activities, the Microlab incurred a debt of $200K. However, we were able to develop a recharge rate proposal without raising rates. This includes reduction of expenses (less FETs) and plans for increased utilization.
MEMORANDUM

To: Prof. N. Cheung, Microlab Faculty Director
From: K. Voros, Microlab Operations Manager
Subject: 6" Upgrade – Final Report
Date: 20 December 2004
Cc: T. King, C. Spanos,
    W. Flounders, R. Hamilton, S. Parsa, R. Spivey

INTRODUCTION

In February 1995, a group of colleagues from several universities met to discuss in a workshop atmosphere the “Future of Academic Microfabrication Facilities”. As a result, a loose organization, Academic Labnetwork was formed, to provide a discussion forum and common representation for academics and staff involved in supporting university microelectronics facilities. Among the agenda items were two of special concern to us:

- wafer size and compatibility, including the need and possibility to upgrade to handle 6" wafers, and
- upgrading laboratory management software.

A year and a half later, in December 1996, at another Labnetwork meeting, UCB and MIT presented upgrade plans for equipment to handle 6" wafers and Stanford presented their plans for software upgrade.

Motivating factors for the 6" upgrade included the need to:

- promote interaction with industrial researchers affiliated through consortia;
- promote academic-to-industry technology transfer;
- validate device research in a more advanced technology environment;
- maintain process relevance and improve performance with better equipment;
- to take advantage of the availability of 6" equipment donations;
- standardize wafer size among university laboratories so that we could leverage our processing capabilities;
- avoid possible lack of 4" wafers.
PLANNING

Phasing and Scheduling of Upgrade Plans

We developed a three-phase plan based on discussions with UCB Microlab faculty and industrial affiliate members, focusing on CMOS device and MEMS processing capabilities.

Phase I: limited 6" capability: CMOS process with specific component modules: litho, LPCVD nitride, poly-Si, oxide; basic wet and dry etch.

Phase II: simultaneous 4"/6" capability, MEMS processing.

Phase III: new facility, fully 6" and selected 8" modules.

The three-phase upgrade strategy was designed to minimize impact on labmembers' projects. In our proposal to faculty we made timing conditional on funding; however, we ventured the overly optimistic projection of:

Phase I: 1997-98,

Phase II: by 2000,

Phase III: development parallel to Phase II and beyond.

We completed Phase I during 1998-2000 and Phase II by the end of 2004. Phase III will become a reality with the construction of the new engineering building, CITRIS, which will house a new nanofabrication facility.

Development of Funding

In my 1996 Microlab Year End Report I wrote: "Most university laboratories have upgrade plans but none have funding in place, including Berkeley." After considering the available options to us - none too promising - we arrived at a realistic plan relying on bootstrapping, equipment donations and procuring targeted tools through faculty grants.

Berkeley Microlab Affiliates (BMLA)

In 1997, with the leadership of Professor Costas Spanos, we established the Berkeley Microlab Affiliates program (BMLA), as a vehicle to give access to our industrial partners to equipment in the Microlab. Companies pay a membership fee, according to the number of employees working in the Microlab. (Details at http://microlab.berkeley.edu/text/bmla.html)

In addition, BMLA members pay standard lab fees plus a 50% overhead charge on lab fees. While lab fees are part of the operating budget, the overhead and membership fees are retained for laboratory improvement and upgrade. After allowing for the College of Engineering and departmental gift tax withholdings, the collected BMLA fees were saved and fully applied to provide for the 6" upgrade. The total amount collected from 1998 through 2004 and applied to Phases I-II was just over $2M, (cash layout for equipment and facilities upgrade + FTEs).
MEMS Exchange

This was another program to leverage our Microlab facilities investments.

We participated from the start (1998) in the DARPA-funded MEMS Exchange fabrication program administered by the Corporation for National Research Initiative (CNRI) utilizing the resources of several academic and industrial participants. (http://www.mems-exchange.org) Since we offered full capability processing modules from the start of the program, CNRI funded 2 FTE's for 5 years. Staff provided the processing service at the approved module charges, which included overhead. While all operating expenses for MEMS Exchange processing were recoverable from the collected module charges, we were also able to apply the overhead portion of the MEMS Exchange income to the 6" upgrade.

Equipment Donations

There is no such thing as free equipment. Donations come in all shapes and forms and accepting them is a tricky business. Because we had a definite idea of what we needed for the upgrade we selected only specific tools from the long lists that were offered from several decommissioned plants. In most cases we had to cover crating, shipping, transportation insurance costs, followed by facilities modifications and installation expenses. In some cases purchase of missing parts, (i.e. gas purge panels and vacuum pumps) and software upgrades were also required. Still, if the tools matched our needs we accepted.

Three companies provided cash donations to enable use of the donated tools: Intel and Renesas Technology Corp. gave cash to assist with installation and start-up and FANUC with decommissioning and storage. These funds we leveraged with in-house talent for most efficient use and to cover costs of items in Table 4.

Equipment through Research Grants

The most successful equipment acquisitions are research driven. This method requires close coordination between lab management and PIs, which in our case was not a problem – research needs and lab upgrade plans matched.

We received our most expensive 6" tools through grants obtained by the device, process/manufacturing, and BSAC research groups. As early as 1992, when BSAC grants paid for a low-stress nitride LPCVD furnace, we were able to install a 6" compatible furnace bank, with the plan that the rest of the tubes would be financed from other sources. In 1998 the device group paid for the Si-Ge system, in the same bank, and we filled up the rest of the slots during Phase II of the 6" upgrade.

By far the most expensive equipment was the ASM Lithography tool, donation value $2.37M. This was obtained through the UC SMART program, which also provided partial matching research funds for equipment donations. The Small Feature Reproducibility (SFR) grant in which several of our process/manufacturing PIs participated, with Professor Spanos at the lead, arranged for the donation of the tool from ASML and provided the facilities improvement, installation, and start up from matching funds. The SFR has been supplemented by the Feature Level Compensation and Control (FLCC) effort, led by Professor Neureuther; this partially funded the donation of the Centura etcher and its associated installation and start-up costs. Donations are detailed in Table 1.
### 150mm Retooling Expenditures

#### a) Paid by Non-Microlab Sources

<table>
<thead>
<tr>
<th>System</th>
<th>PI</th>
<th>Fund Source</th>
<th>Expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASIQ</td>
<td>Pisano</td>
<td>BSAC</td>
<td>$ 41,051</td>
</tr>
<tr>
<td>ASML Installation</td>
<td>Spanos/Neureuther</td>
<td>SMART</td>
<td>$ 40,791</td>
</tr>
<tr>
<td>CM4 - Toxic Gas Monitor</td>
<td>King/Hu</td>
<td>DARPA</td>
<td>$ 14,056</td>
</tr>
<tr>
<td>CMP</td>
<td>Pisano</td>
<td>BSAC</td>
<td>$ 159,084</td>
</tr>
<tr>
<td>CMP wafer cleaner</td>
<td>Spanos</td>
<td>SMART/VDON</td>
<td>$ 257,770</td>
</tr>
<tr>
<td>Centura Installation</td>
<td>Pisano/Neureuther</td>
<td>DARPA/FLCC</td>
<td>$ 134,304</td>
</tr>
<tr>
<td>Heatpulse3</td>
<td>King/Hu</td>
<td>VDON</td>
<td>$ 92,013</td>
</tr>
<tr>
<td>LN Vessels (1/3 share)</td>
<td>Spanos</td>
<td>Capital Projects (HMMB)</td>
<td>$ 19,500</td>
</tr>
<tr>
<td>LN Vessels (1/3 share)</td>
<td>Spanos</td>
<td>COE (HMMB)</td>
<td>$ 19,500</td>
</tr>
<tr>
<td>Tystar Bank 1</td>
<td>Howe</td>
<td>CNRI/DARPA</td>
<td>$ 233,875</td>
</tr>
<tr>
<td>Tystar17</td>
<td>Howe</td>
<td>DARPA</td>
<td>$ 94,692</td>
</tr>
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<td>Tystar19</td>
<td>King/Hu</td>
<td>DARPA</td>
<td>$ 222,240</td>
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<td>Tystar20</td>
<td>Howe</td>
<td>CNRI/DARPA</td>
<td>$ 260,098</td>
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<tr>
<td><strong>Total Expenditures</strong></td>
<td></td>
<td></td>
<td><strong>$ 1,588,974</strong></td>
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</tbody>
</table>

#### b) 150mm Equipment Donations

<table>
<thead>
<tr>
<th>System</th>
<th>PI</th>
<th>Donation Source</th>
<th>Equip. Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antistatic emitters/controllers</td>
<td>ML/R. Hamilton</td>
<td>Ion Systems</td>
<td>$ 3,670.00</td>
</tr>
<tr>
<td>ASML 5500/90 Stepper</td>
<td>Spanos/Neureuther</td>
<td>SMART/ASML</td>
<td>$ 2,370,000.00</td>
</tr>
<tr>
<td>Applied Materials P5000</td>
<td>Spanos</td>
<td>SMART/Intel</td>
<td>$ 372,000.00</td>
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<tr>
<td>Autoprobe</td>
<td>Spanos</td>
<td>SMART/Intel</td>
<td>$ 45,000.00</td>
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<tr>
<td>Centura</td>
<td>Pisano/Neureuther</td>
<td>SMART/AMAT</td>
<td>$ 1,540,000.00</td>
</tr>
<tr>
<td>CD80 Drypumps</td>
<td>ML/R. Hamilton</td>
<td>BOC Edwards</td>
<td>$ 168,857.00</td>
</tr>
<tr>
<td>Edwards E-Beam Evaporator</td>
<td>Pisano/Flounders</td>
<td>Fanuc</td>
<td>$ 13,013.00</td>
</tr>
<tr>
<td>Edwards RF-DC Sputterer</td>
<td>Pisano/Flounders</td>
<td>Fanuc</td>
<td>$ 14,053.00</td>
</tr>
<tr>
<td>Filmetrics Thin Film Metrology</td>
<td>Pisano/Flounders</td>
<td>Fanuc</td>
<td>$ 5,997.00</td>
</tr>
<tr>
<td>GCA Wafer Stepper6</td>
<td>ML/R. Hamilton</td>
<td>LLNL</td>
<td>$ 245,571.00</td>
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<tr>
<td>H-P Sinks (2 ea.)</td>
<td>ML/R. Hamilton</td>
<td>Hewlett-Packard Labs</td>
<td>$ 10,000.00</td>
</tr>
<tr>
<td>Matrix PR Asher</td>
<td>ML/R. Hamilton</td>
<td>National Instruments</td>
<td>$ 10,000.00</td>
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<tr>
<td>Nanometrics Nanospec</td>
<td>Spanos</td>
<td>Nanometrics</td>
<td>$ 70,000.00</td>
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<tr>
<td>Novellus M2i</td>
<td>Spanos</td>
<td>SMART/Novellus</td>
<td>$ 950,000.00</td>
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<td>Oxford 80 RIE</td>
<td>Pisano/Flounders</td>
<td>Fanuc</td>
<td>$ 65,335.00</td>
</tr>
<tr>
<td>Photore sist</td>
<td>ML/S. Parsa</td>
<td>Shipley/Rohm and Haas El. Mat.</td>
<td>$ 27,000.00</td>
</tr>
<tr>
<td>Quintel Mask Aligner</td>
<td>ML/R. Hamilton</td>
<td>Quintel</td>
<td>$ 125,000.00</td>
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<tr>
<td>Ultra Fab Sinks4,6,7,8</td>
<td>Pisano/Flounders</td>
<td>Fanuc</td>
<td>$ 31,306.00</td>
</tr>
<tr>
<td>Semi Test Surface Charge Analyzer</td>
<td>ML/R. Hamilton</td>
<td>Intel</td>
<td>$ 250,000.00</td>
</tr>
<tr>
<td>Suss MA/Ba6 Aligner</td>
<td>BSAC</td>
<td>Suss Micro Tech/Trade</td>
<td>$ 234,265.00</td>
</tr>
<tr>
<td>Suss SB6 Bonder</td>
<td>BSAC</td>
<td>Suss Micro Tech/Trade</td>
<td>$ 202,485.00</td>
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<tr>
<td>Tubing (SS) for Gas Lines</td>
<td>ML/R. Hamilton</td>
<td>UltraClean Technologies</td>
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<td>Tystar bank4</td>
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<td>$ 139,145.00</td>
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<tr>
<td>Verteq Spin Rinser/Dryers</td>
<td>ML/R. Hamilton</td>
<td>Intel, LSI Logic</td>
<td>$ 12,000.00</td>
</tr>
<tr>
<td>Wafers, 6&quot; Silicon</td>
<td>ML/R. Hamilton</td>
<td>Intel</td>
<td>$ 65,500.00</td>
</tr>
<tr>
<td>Wafers, 6&quot; Silicon</td>
<td>ML/R. Hamilton</td>
<td>Nova Electronic Materials</td>
<td>$ 3,300.00</td>
</tr>
<tr>
<td>Westbond2</td>
<td>Pisano/Flounders</td>
<td>Fanuc</td>
<td>$ 3,002.00</td>
</tr>
<tr>
<td><strong>Total Value</strong></td>
<td></td>
<td></td>
<td><strong>$ 7,053,499.00</strong></td>
</tr>
</tbody>
</table>

Table 1.
Budgeting

In addition to equipment donations and procuring targeted tools through faculty grants, we estimated the following cash layout, to be covered from our own funds, BMLA membership fees, overhead on industrial use:

Phase I: est. $850K plus 1 additional FTE
- litho - 6" wafer stepper, resist track/developer, 2 sinks
- furnaces - 2 LPCVD, 1 atmospheric tube, RTP
- etch - conversion of 2 Lam etchers
- misc. - insp. microscope, dicing saw mod., pallets for cpa
- computers - new LAN terminals

Phase II: est. $1,325K plus two additional FTEs (total 2 FTE for equipment upgrade and 1 FTE for software upgrade)
- litho - second 6" wafer stepper, wafer track for thick PR
- furnaces - 4 LPCVD, 4 atmospheric, clean/etch sinks
- etching - 3 Lam etchers converted, Centura added
- misc. - profilometer, handling equipment
- computers - 1 programmer FTE

Phase III: 1 FTE for 3 years

THE UPGRADE PROCESS

The progress of the 6" upgrade project is shown in Table 2. The work spanned six years: 1998-2004. During this time the Microlab operated at full capacity, with the exception of the machines that were being worked on at any one time. Microlab use and equipment hours remained relatively level throughout the 6" upgrade effort. We kept the 4" system up until its replacement was installed and fully characterized. Finally, we added equipment for capacity and for easing process specification demands on some tools. (Ex: asml and svgcoat6 for DUV litho vs. gcaw56 and svgcoat3 for 1-line litho.)

Facilities Upgrade

New Construction
Before installation of 6" equipment, extensive renovation of facilities had to take place. We constructed separate rooms on the 1st floor of Cory Hall for the Planarization Lab (190), with the CMP, the cmp wafer cleaner and P5000 TEOS/Ozone PECVD tool. Room 144 was built for the Novellus cluster tool for thin films deposition. The space in each case had to be made available by decanting old equipment, rerouting power and other utilities and constructing walls and mini-cleanroom environments.
### 6" (150 mm) Upgrade Timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>Discussion of upgrade need/plans at the 1st and 2nd Labnetwork meetings</td>
</tr>
<tr>
<td>1996</td>
<td>Incremental upgrade plan developed for 6&quot; CMOS processing 3-phase plan presented at Labnetwork meeting in December – no funding model</td>
</tr>
</tbody>
</table>
| 1997 | Funding plans:  
BMLA established  
Overhead on external user fees  
MEMS Exchange proposal (for higher rate of lab utilization)  
Equipment and material donation opportunities  
Research groups’ grant proposals to include 6" equipment |
| 1998 | Funding development:  
UC SMART grant (donated equipment value partially matched by grant)  
Intel donation (equipment & installation expenses)  
Facilities preparation: Rm 190 |
| 1999 | Facilities preparation: Rm 144, GL4 |
| 2000 | Mask making and lithography module completed  
PolySi/nitride etch  
Furnace bank3: all LPCVD, CMOS and MEMS |
| 2001 | Furnace bank1: atmospheric tubes, CMOS and MEMS  
CAPE – new computer LAN and software  
WIS – new equipment control hardware and software  
First 6" CMOS run started (1 μm process)  
4" capability maintained: developed dual 4"/6" handling on etchers  
Measurement tools |
| 2002 | 6" CMOS tools completed:  
First 6" CMOS run (CMOS 150 1μm techn.) completed, tested, report submitted  
New lab management software design started (Mercury)  
Utilities upgrades:  
New liquid nitrogen (LN) vessels  
Specialty gas storage  
New lab planning |
| 2003 | Operating manuals updated  
Web site updated  
MEMS-specific tools upgrade continuing  
Process development for 0.35 μm CMOS  
RUMS: facilities monitoring hardware, software  
New lab planning |
| 2004 | Additional wafer stepper, etching capability  
MEMS-specific tools upgrade completed  
0.35 μm process completed, cmos 161 tested – high yield  
Final report on 6" upgrade  
New lab value engineering and redesign |

Table 2.
Within the Microlab (420 Cory Hall)
There was no room untouched by the upgrade. Starting with decanting GL4 to accept the ASML stepper, for which the laser is located in 432A, (and piped through the wall to GL4!) we had to play musical chairs with equipment. 6" equipment was mostly added, only a few tools were decommissioned; thus, space is utilized to maximum. For the addition of the Centura cluster tool we had to eliminate walls and combine service chases with the room GL1.

Utilities
Major activity was invested in utility upgrades. Six inch capable equipment and the addition of equipment without equivalent decommission means more of all utilities are required:

- Power: new transformer, additional feed and break out panels
- Cooling water: a separate new cooling loop with its own chiller
- DI water: increased number of RO membranes
- Drains: major re-plumbing of drain lines; elimination of untenable vacuum drain system
- Acid waste neutralization: new system installed (outside Cory Hall)
- Compressed air: building compressor replaced by Campus Services
- Exhaust: duct lines redesigned, separated for each bank of furnaces, rebuilt in non-corrosive material
- Nitrogen gas: increased capacity vessel (9000 gal) installed; new 1" nitrogen gas line plumbed to Microlab
- Specialty gases: storage space rebuilt outside Cory Hall meeting tighter regulatory requirements
- HAZCOM: second toxic gas monitoring system installed, display moved outside of Microlab; new HAZCOM (blue) alarm system for local evacuation added

Equipment Upgrade

No new tools were obtained for the 6" upgrade. All equipment new to the Microlab came in as upgrade of previously owned Microlab equipment or refurbished used tools, including all tools donated directly by companies. Some tools were purchased on the used market then sent to local refurbishing vendors who modified them to Microlab staff defined specifications.

We have installed, modified, or improved for the 6" upgrade 16 furnace tubes and 44 other tools, or about half of the total equipment in the Microlab. As a result we have full 6" CMOS and MEMS processing capability. Equipment installation time line is shown in Table 3.

The list of equipment and size compatibility is available on-line on the Microlab's web site, http://microlab.berkeley.edu/labmanual/chap1/1.13.html. Of the 116 operating systems in the Microlab, 80 are both 4" and 6" capable, 28 handle only 4" Si wafers and eight can handle only 6" Si wafers.
### 6" (150 mm) Equipment Installation Timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>6&quot; compatible <strong>furnace bank</strong> (4 stack): 4&quot; tube for LSN (t18), MEMS LTO (t20)</td>
</tr>
<tr>
<td>1997</td>
<td>Electroglass 2001 – 6&quot; autoprobe</td>
</tr>
<tr>
<td>1998</td>
<td>Si-Ge LPCVD for device – 6&quot; compatible (t19)</td>
</tr>
<tr>
<td></td>
<td>432B sink upgrade for 6&quot; tube cleaning</td>
</tr>
<tr>
<td></td>
<td>Leo SEM (6&quot; upgrade)</td>
</tr>
<tr>
<td></td>
<td>Room 190 upgrade; (for Strasbaugh CMP)</td>
</tr>
<tr>
<td>1999</td>
<td>Matrix PR asher</td>
</tr>
<tr>
<td></td>
<td>Karl Suss aligner/wafer bonder</td>
</tr>
<tr>
<td></td>
<td>Strasbaugh CMP and wafer cleaner</td>
</tr>
<tr>
<td></td>
<td>Dry/wet oxidation (t17)</td>
</tr>
<tr>
<td></td>
<td>Rmi 144 refurbished (thin films – Novellus)</td>
</tr>
<tr>
<td></td>
<td>GL4 renovation (for ASML, litho tools)</td>
</tr>
<tr>
<td>2000</td>
<td>Photomask developers</td>
</tr>
<tr>
<td></td>
<td>ASML wafer stepper; SVG 880 wafer track/develop; Ion Systems</td>
</tr>
<tr>
<td></td>
<td>CDSEM; DUV inspection microscope, DUVPR Stabilizer, sink9</td>
</tr>
<tr>
<td></td>
<td>Lam4: (nitride, poly etch) converted to 6&quot;</td>
</tr>
<tr>
<td></td>
<td>Novellus: Al, Ti sputter</td>
</tr>
<tr>
<td></td>
<td><strong>Furnace bank</strong> upgrade: LPCVD nitride, poly-Si, CMOS-LTO, MEMS-LTO</td>
</tr>
<tr>
<td>2001</td>
<td><strong>Furnace bank</strong>1: atmospheric tubes (CMOS and MEMS)</td>
</tr>
<tr>
<td></td>
<td>CPA thin film sputterer</td>
</tr>
<tr>
<td></td>
<td>Heatpulse3 RTP</td>
</tr>
<tr>
<td></td>
<td>Lam1, 2, 3 – dual handling; cpa (Al, W, Ti, thin films) 6&quot; tray</td>
</tr>
<tr>
<td></td>
<td>Sink5, 7, srd6, wafer cassettes, holders</td>
</tr>
<tr>
<td></td>
<td>Profilometer, Nanospec thin film measurement</td>
</tr>
<tr>
<td></td>
<td>Power distribution upgrade</td>
</tr>
<tr>
<td></td>
<td>HAZCOM upgrade</td>
</tr>
<tr>
<td>2002</td>
<td><strong>Furnace bank</strong>4: POCl3, B+ diffusion, SiC LPCVD, MEMS Poly Si LPCVD</td>
</tr>
<tr>
<td></td>
<td>Quintel aligner</td>
</tr>
<tr>
<td></td>
<td>Sink3 (MEMS), critical point dryer (MEMS), cpd2</td>
</tr>
<tr>
<td></td>
<td>XcF2 etch (MEMS)</td>
</tr>
<tr>
<td></td>
<td>Exhaust lines</td>
</tr>
<tr>
<td></td>
<td>New N2 delivery line (1&quot; diameter) to Microlab</td>
</tr>
<tr>
<td>2003</td>
<td>P5000 completed with O2 only</td>
</tr>
<tr>
<td></td>
<td>Edwards, Edwardseb3/thin film</td>
</tr>
<tr>
<td></td>
<td>Sinks6, 8; 2 srd dual stacks</td>
</tr>
<tr>
<td></td>
<td>ASIQ profilometer</td>
</tr>
<tr>
<td></td>
<td>Lam5 etcher</td>
</tr>
<tr>
<td>2004</td>
<td>Acid waste neutralization system installed.</td>
</tr>
<tr>
<td></td>
<td>P5000 TEOS/ozone process on line</td>
</tr>
<tr>
<td></td>
<td>GCAWS6 – 5X T-line stepper (6&quot;)</td>
</tr>
<tr>
<td></td>
<td>SVG3 – thick resist wafer track</td>
</tr>
<tr>
<td></td>
<td>Centura deep Si etcher, oxide etch</td>
</tr>
<tr>
<td></td>
<td>Oxford2 – PECVD oxide, nitride</td>
</tr>
</tbody>
</table>

Table 3.

12/10/04
Role of the Machine Shop

I cannot overstate the importance for the 6" upgrade project the availability of a machine shop. It simply could not have been done or only at an exorbitant expense of time and funds. The ERL Machine Shop became an extension of the Microlab, especially at times of high activity such as installation of furnace banks and various complex equipment. Many of our modifications relied on the fine design and machining capabilities of the staff of the Machine Shop. The availability of additional personnel, tools and materiel was indispensable to the flow of upgrade work and operation of the Microlab at the same time.

One of the lessons of the 6" upgrade is clear: successful completion of Phase III of ongoing Microlab evolution – fitup of the new laboratory, and ongoing flexible operation of the new facility – mandates maintaining the ERL Machine Shop. The Machine Shop is key to enabling the Microlab to respond rapidly to the ever changing needs of faculty and researchers.

Process Characterization and Upgrade

Process Modules
Throughout the 6" upgrade project our approach was that equipment installation and/or upgrade was followed immediately by process characterization on the upgraded system. A standard process was established and operating manuals were updated before equipment was released to members.

- The first module completed was lithography based on the ASML DUV stepper. The module also included a new 6" resist dispense track and developer, new photoresist, CD-SEM, DUV microscope and upgrading of mask making equipment. This first major effort resulted in a very impressive 0.35 μm lithography capability.

- Substantial effort was expended on characterizing the furnaces. Temperature profiling, boat design and load distribution, for both 4" and 6" processes, required many iterations and careful experimental design. Not only did we have to develop the 6" process in all the atmospheric (7) and LPCVD (9) furnaces, but 4" processes also had to be re-characterized in the larger diameter tubes. At the end, we have all our furnace process modules reestablished, both in the CMOS and MEMS tubes.

- Upgrading the Lam auto-ethers turned out to be the least disruptive. A clever redesign of the handling mechanism by our technical staff and the Machine Shop, resulted in 4"/6" dual capability with the flip of a switch. On the Rainbows the 4" wafer transport module was replaced with a 6" module, purchased from Lam. All etch processes, however, had to be re-characterized for both 4" and 6" wafers. A major process performance improvement resulted from the installation of the Centura etcher (6" only).

- Cleaning and wet etch processes were developed in the new sinks, with larger tubs for 6" wafers. Dual size wafer handling equipment went through several modifications before arriving at a user friendly solution, with dedicated MEMS and MOS sinks in the cleaning area.
CMOS Baseline
The Microlab maintains a CMOS baseline, which specifies standard process modules across the operation. During the 6” upgrade the baseline actually pushed the agenda by requiring the completion of upgrades for the next step. The first 6” run (CMOS 150) played an important role in gauging the success of the upgrade.

CMOS 150 reproduced our 1 μm process, (well established on 4” wafers) on 6” wafers (150 mm). This lot was completed and report published in 2002. (Available at http://microlab.berkeley.edu/baseline/index.html) A great advantage provided by the 6” upgrade was that the performance of the new equipment is several generations better than that of the 1980 vintage tools. Specifically, because the ASML deep UV lithography tool is capable of 0.35 μm technology, we were able to skip a few shrinks and design a 0.35 μm process. The Centura etcher provided the other key process module, by being able to etch SiO2 uniformly over a 6” wafer, with good selectivity.

The first 0.35 μm cmos run (CMOS 161), which included a complete process redesign, produced on 6” wafers was completed in December 2004. Results were excellent and the wafers tested have a high yield. This we attribute to the improved tool set provided by the 6” upgrade.

The data for the run CMOS 161 is posted on-line at: http://microlab.berkeley.edu/baseline/index.html Our baseline engineering group, Attila Horvath, Sia Parsa and graduate student Hiu-Yung Wong, are developing data for a formal report, including process and device parameters.

Computers

CAPE – Local Area Network
Equipment upgrade included a computer systems upgrade. In 2001 we had completed the migration to all graphic (flat panel) terminals inside the lab. These are running on a Windows server dedicated to the LAN for the Microlab. The Common And Personal Environment (CAPE) application was developed in-house by Tim Duncan. Lab members can now work in a common PC environment, with one window for the original lab control function (ascii).

WIS – Equipment Control
The obsolete Taurus equipment control system was upgraded to an industrial PC server (with Linux OS) and new control boxes at each equipment. The interlocks are turned on and off through the WIS server and activity information is stored in a single database on the central host. The new WIS system is extremely reliable and is protected from compromises with a high level of security measures.

Gasinven – Microlab Gas Management System
With the 6” upgrade and process development enabled by the new tools, specialty gas cylinder inventory increased considerably. This necessitated the in-house development of a gas cylinder management system. Gasinven utilizes MS Access on an SQL server. 56 different specialty gases are managed in this system, accessible to staff on a password protected web site.
RUMS – Resource Utilization Management System
A major step forward in upgrading the Microlab’s computer control system was the release of RUMS in June 2003. The old facilities monitoring system was completely replaced with new hardware and in-house developed software. Thirty-two sensors are monitoring various utilities, such as N2 pressure, air pressure, temperature, etc., which have to be in spec for the lab to operate properly. Collected data with graphs are available not only by directly connecting to the RUMS server but also on the Microlab’s web site. The efforts of our software and hardware engineers Duncan, Chen, Pestal and Merport resulted in a great system, which is described in detail in Memorandum No. UCB/ERL 03/43.

Mercury – New Laboratory Management System
Microlab operations are controlled by BCIMS, Berkeley Computer Integrated Manufacturing System, a set of in-house developed software. The system, which was installed 20 years ago as a research project, consists of components for equipment and facilities control, accounting, purchasing and inventory, reservations and maintenance. Because we kept up with developments in computer technology, BCIMS served us extremely well during the past 20 years; however, by now it needs a major upgrade. In 1998 we embarked on a collaborative effort with Stanford and MIT to develop a new laboratory management and information system, but our diverging needs for local-specific software tools lead us to the conclusion that the Microlab will be best served by developing our own.

In 2002 we started design and development of Mercury, a system using industry standard technologies, with platform and database vendor independence. All functionalities of the well-tested Wand system were retained in Mercury; the accounting module was redesigned based on the double-entry paradigm. We are currently testing the new system; roll-out target is the start of Fiscal Year 2005/2006.

Documentation
As part of the 6" upgrade we expended considerable effort to keep documentation up to date. Reason: we expect lab members to use the on-line manual (and hard copy) as the first step in finding operational and process information.

The task of writing new manuals, appending, updating existing ones with the latest information, is shared by staff and expert users of the tools, with process staff carrying most of the burden. Madeleine Leullier, Computer Resource Specialist, has the assignment of document control, i.e. editing and installation of both on-line and hard-copy manuals.

Extent of Documentation
The Microlab’s operating manual consists of 1,653 pages, compiled in 156 chapters, available on-line from the web portal of the Microlab, http://microlab.berkeley.edu/. The listing of 6" Equipment Capability is shown in the Equipment panel.

Reformatting and Standardizing
We started compiling our on-line lab manual in 1982, when the present Microlab was built and computer control was introduced. This first manual was in ascii format, without specific structure. When we started to move information to the WWW the manuals were gradually reformatted. At the same time, Sia Parsa introduced a rigorous standard format for all chapters.
As part of the 6" upgrade we established the goal of completion of the transfer of all manual chapters into the new form, with updated information. This in itself was a monumental task; however, it is now complete and we receive comments, requests for permission to copy, from all over the world on a regular basis.

New Chapters
With the addition of 6" equipment 30 new chapters were added. Twelve of these were the result of separating manuals for previously grouped equipment, such as LPCVD furnaces, atmospheric furnaces and sinks. Now all 20 furnace systems and 10 sinks have separate chapters. This was necessary because of the different operating procedures, restrictions and policies for each of the tools.

Microlab Web Portal—http://microlab.berkeley.edu
As part of the 6" upgrade we also upgraded our web portal in 2003. The most important goal of this change was to streamline the portal to make information easily available. A search function was also added. The end result is a very plain-looking, nine-panel front page, without pictures, pop-ups, or other flourishes.

FINANCIALS

Table 4 (next page) shows the expenditures from Microlab funds. We also needed to increase the number of staff for the duration of the 6" upgrade project. Salaries and benefits for the additional FTEs were covered from different sources, shown in Table 5 below.

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Operation’s Closing Balance $</th>
<th>Microlab Operations (FTE)</th>
<th>BMLA Overhead (FTE)</th>
<th>CNRI (FTE)</th>
<th>SMART (FTE)</th>
<th>BSAC (FTE)</th>
<th>Sub Total Other</th>
<th>Total (FTE)</th>
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</thead>
<tbody>
<tr>
<td>1998/1999</td>
<td>400.00</td>
<td>25.0</td>
<td>–</td>
<td>1.8</td>
<td>–</td>
<td>0.5</td>
<td>2.3</td>
<td>27.3</td>
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<tr>
<td>1999/2000</td>
<td>-19,000</td>
<td>25.0</td>
<td>–</td>
<td>2.0</td>
<td>1.0</td>
<td>1.0</td>
<td>4.0</td>
<td>29.0</td>
</tr>
<tr>
<td>2000/2001</td>
<td>-16,000</td>
<td>27.6</td>
<td>–</td>
<td>2.0</td>
<td>0.3</td>
<td>0.5</td>
<td>2.8</td>
<td>30.4</td>
</tr>
<tr>
<td>2001/2002</td>
<td>-161,000</td>
<td>29.6</td>
<td>–</td>
<td>2.0</td>
<td>–</td>
<td>0.5</td>
<td>2.5</td>
<td>32.1</td>
</tr>
<tr>
<td>2002/2003</td>
<td>-168,000</td>
<td>29.6</td>
<td>2.7</td>
<td>2.0</td>
<td>–</td>
<td>0.5</td>
<td>5.2</td>
<td>34.8</td>
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<tr>
<td>2003/2004</td>
<td>-201,000</td>
<td>25.8</td>
<td>2.2</td>
<td>1.6</td>
<td>0.3</td>
<td>1.3</td>
<td>5.1</td>
<td>30.9</td>
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<tr>
<td><em>2004/2005</em></td>
<td>-120,000</td>
<td>22.9</td>
<td>2.5</td>
<td>1.0</td>
<td>0.8</td>
<td>–</td>
<td>4.3</td>
<td>27.2</td>
</tr>
</tbody>
</table>

*FY 04/05 estimated

Table 5 - Staffing During the 6" Upgrade

Figure 1 shows various indicators during the years of the 6" upgrade.
   a) Balance at fiscal closing each year
   b) Machine Shop expenses (these were included in Table 4 in each item when applicable.)
   c) Staffing changes during the upgrade
## 150mm Retooling Expenditures
### Paid by Microlab Funds

<table>
<thead>
<tr>
<th>Photo/Mask</th>
<th>Wet Processing</th>
<th>Thermal Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>APT chrome/emul</td>
<td>$19,500.00</td>
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</tr>
<tr>
<td>ASML</td>
<td>$8,609.00</td>
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<tr>
<td>GCA wafer stepper6</td>
<td>$16,272.00</td>
<td></td>
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<tr>
<td>SVO 8000 coat/dev</td>
<td>$71,300.00</td>
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<tr>
<td>SVG coat3</td>
<td>$2,672.00</td>
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</tr>
<tr>
<td>Matrix asher</td>
<td>$6,600.00</td>
<td></td>
</tr>
<tr>
<td>uv bake</td>
<td>$12,700.00</td>
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</tr>
<tr>
<td>Quintel mask aligner</td>
<td>$5,800.00</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td>$143,453.00</td>
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</tr>
<tr>
<td>Etch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lams1-5</td>
<td>$35,325.00</td>
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<tr>
<td>Centura</td>
<td>$127,954.00</td>
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<tr>
<td>XeF2 Etcher</td>
<td>$7,056.00</td>
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<tr>
<td><strong>Total</strong></td>
<td>$170,335.00</td>
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<tr>
<td>Thin Films</td>
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<tr>
<td>CPA</td>
<td>$3,000.00</td>
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</tr>
<tr>
<td>Novellus (rn 144)</td>
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<tr>
<td>P5000 (rn 190)</td>
<td>$89,490.00</td>
<td></td>
</tr>
<tr>
<td>Edwards EB3 evaporator</td>
<td>$13,800.00</td>
<td></td>
</tr>
<tr>
<td>Edwards sputterer</td>
<td>$5,000.00</td>
<td></td>
</tr>
<tr>
<td>Oxford2 PECVD</td>
<td>$1,900.00</td>
<td></td>
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<tr>
<td><strong>Total</strong></td>
<td>$189,600.00</td>
<td></td>
</tr>
<tr>
<td>Planarization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straussbaug cmp</td>
<td>$18,600.00</td>
<td></td>
</tr>
<tr>
<td>SSEC cmp wafer cleaner</td>
<td>$31,504.00</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$50,104.00</td>
<td></td>
</tr>
</tbody>
</table>

**Grand Total** $1,716,907.00

Table 4.
MICROLAB STATISTICS DURING 6" UPGRADE

(a) Fiscal Year-End Balances

(b) Machine Shop Expenses

(c) Staffing during 6" Upgrade

Figure 1
Cost of the 6” Upgrade

- Cash paid out of Microlab funds (BMLA, Overhead) $1,716,907.00
  Summarized in Table 4, including Machine Shop charges

- Additional staff Salaries and Benefits
  Microlab operations, 2000-2003 $701,547.00
  Microlab funds (BMLA, Overhead), 2002-2004 $162,698.00
  Funded by research groups (CNRI, SMART, BSAC) $1,017,161.00

- Cash provided by research grants
  For equipment shown in Table 1a) $1,588,974.00

- Recorded value of donated equipment
  Summarized in Table 1b) $7,053,499.00

The numbers above represent an added value of $12.25M to the Microlab. Microlab PI’s who were especially interested in and supportive of the 6” upgrade participated by brunting the burden and accepting higher equipment charges on the 6” tools. Increased staff costs showed up as debt at the end of the fiscal year, during the past five years, accumulating to $200K at the end of 2004. This debt, ~2% of the total value of the upgrade will be recovered from increased use during the next five years. Recharge rates during the past 10 years increased only by the rate of inflation, issued by the U.S. Department of Labor, Bureau of Labor Statistics. We intend to adhere to this guideline in the coming years.

SUMMARY

After more than 6 years of continuous work we have completed the 6” upgrade, resulting in full 6” capabilities for both CMOS and MEMS processing. This report was compiled to document the activities, timeline, and costs of this long term effort. The Microlab 6” upgrade demonstrates the extensive finances and the meticulous planning required to accomplish such complex undertaking without disrupting research services.

The success of the 6” upgrade was the result of building on our strengths, the talents of our capable staff and the support of our member PIs. Faculty who requested the upgrade participated by investing time and effort in obtaining equipment donations and providing cash from their grants.

The 6” upgrade also serves as a benchmark for the on-going Microlab evolution; it gives a measured taste of the financial, personnel and infrastructure resources needed for start-up of the new laboratory in the CITRIS building, equipment migration from Cory Hall to CITRIS, and decommission of the existing Microlab.
ACKNOWLEDGEMENTS

This major project could not have been accomplished without the creativity and hard work of the staff of the Microlab, the Cory Hall Machine Shop, the support of Microlab PIs and the faculty leadership we are privileged to enjoy.

Jim Bustillo, Technology Manager of the Microlab and BSAC from 1991-2000, was instrumental in developing the upgrade plans, selecting equipment from Intel donation lists and seeing the upgrade through execution, until 2000.

Bill Flounders followed up since mid-2001; he arranged for the FANUC donation, which enabled upgrade of many general-use lab capabilities, in addition to the specialized tools of the Device Group and BSAC. Bill also oversees Phase III of the on-going Microlab evolution.

Bob Hamilton successfully solicited equipment donations from industry in a total value of nearly $1M. He also introduced advantageous parts procurement through the on-line auction site, E-Bay. Bob also provided enthusiastic leadership during the 6" upgrade and with his Equipment Engineering staff carried the brunt of the work – in addition to keeping daily operations going.

The Machine Shop, and Microlab equipment engineer David Lo, designed and built custom wafer handling tools for several of the Lam etchers. The Berkeley Microlab is the only facility in the world with Lam Autoetchers capable of both 4" and 6" wafer handling.

Joe Donnelly managed the installation and start-up the Novellus and P5000 PECVD tools, overcoming various difficulties and the problem of missing and/or wrong parts.

Phill Guillory, with his staff, Bob Connolly, Danny Pestal, Mario Lizardo and student assistants was the driving force behind facilities upgrades, constructions of new space and upgrading utilities, including the HAZCOM alarm system, and RUMS.

Mike Linan, with Brian McNeil, provided gas line upgrades and installation of the additional HAZCOM system. Management of the greatly increased number of vacuum pumping systems is the responsibility of Mike's group. The pump inventory contains 145 units.

Evan Stateler's outstanding troubleshooting skills were called upon throughout the upgrade projects and continue to be in demand in the expanded operation. In addition, Evan managed to site equipment in the Microlab, which exceeded the dimensions of Cory Hall elevators and hallways.

Patrick Wehrly provided meticulous care during the furnace upgrades.

Sia Parsa and his Process Engineering staff, Kim Chan, Jimmy Chang, Marilyn Kushner, were instrumental in bringing up processes in the newly upgraded systems. They also carried the burden of updating manuals. Baseline Engineer Attila Horvath was instrumental in 0.35um baseline process development.
Rosemary Spivey provided ongoing financial accounting of all aspects of the 6” upgrade from 1998 to present.

Susan Kellogg-Smith purchased equipment related to 6” wafer processing as well as parts required for equipment installation and facilities upgrade and modification in support of the project. Additionally, inventory was updated to include spare parts for 6” wafer processing equipment and materials required by lab members to process 6” wafers.

Scott McNally, Director of Space, Planning and Facilities in EECS since 2001, provided great support during facilities upgrades which involved the building (Cory Hall); specifically, he guided (through Campus Project Management) the installation of the acid waste neutralization system.

Faculty actively involved in soliciting donations and providing grant funds for installations are included in Table 1. They were also instrumental in keeping us going by the unrelenting demands of their graduate students’ projects.

Prof. Spanos provided initiative and leadership during the planning phase, which was continued by Prof. King when she took over as the Faculty Director of the Microlab in 2000. She kept her eyes vigilantly on our upgrade activities and focused us on the path of integrity for device processing.

Finally, I am satisfied and proud of the fact that we were able to complete the tall order of the 6” upgrade, Phase II of the Microlab evolution, without special fundraising. Our next goal is completion of Phase III, building and fit-up of the new nanolab in the CITRIS building. For Phase III we will embark on development of dedicated funds.
MEMORANDUM

To: R. Howe, EECS Associate Chair  
   F. Doyle, MSE Chair  
   M. Shapiro, Physics Chair

From: K. Voros, Microlab Operations Manager

Subject: Integrated Materials Laboratory – Final Memo

Date: 15 August 2004

Ce: N. Cheung, T. King, C. Spanos, E. Weber, C. Chang-Hasnain,  
   N. Newman, R. Ramesh, W. Flounders, R. Hamilton, S. McNally,  
   R. Prohaska, P. Specht, R. Spivey


The proposed plan, that the Integrated Materials Laboratory be merged with the Microlab effective 1 July 2004 has been approved by the current chairs of the three establishing departments, R. Howe (EECS), F. Doyle (MSE), M. Shapiro (Physics), and Faculty Directors T. King of the Microlab and E. Weber of the IML.

The date of the merger was established to be 1 July 2004, to coincide with the start of the new fiscal year. This will facilitate a seamless start for the Microlab recharge account, which now includes the inherited debt of $33,269. Bob Prohaska, Development Engineer, has been included in the Microlab account.

Final Disposition of Equipment

Deposition System

1. Mbe1 – 155 Cory Hall -- Prof. Chang-Hasnain
2. Mbe2 – UHV-connected with a metallization and a characterization chamber (mbe2-imetal-cham) – 157 Cory Hall -- Prof. Weber
3. Pulsed Laser Deposition System – 100 HMB -- Prof. Ramesh
4. The MRC RF/DC Magnetron Sputterer for zinc oxide and the Poly Para-Xylene Thin Film Deposition system – 188 Cory -- Microlab

Analytical Systems

2. The Seiko 8800 Focused Ion Beam – 140 HMBM -- Prof. Ramesh -- (declined) moved to T. Schonherr – LBNL
3. The JEOL 6400 SEM/E-Beam Writer – 107 Cory Hall -- Microlab
5. X-Ray Diffractometer – 145 Cory -- Microlab

Thank you for your agreement to this merger.
MEMORANDUM

To: Prof. C. Spanos, ERL Director, Prof. E. Weber, IML Faculty Director, Prof. T. King, Microlab Faculty Director
From: K. Voros, Microlab Operations Manager
Subject: Integrated Materials Laboratory
Date: 15 July 2004
Cc: R. Howe, EECS Associate Chair, F. Doyle, MSE Chair, M. Shapiro, Physics Chair
W. Flouders, R. Hamilton, R. Prohaska, P. Specht, R. Spivey

INTRODUCTION

The National Science Foundation, through the "Academic Research Infrastructure Program", funded a $1.6M grant in 1993, titled "Acquisition of Instrumentation to Fabricate Low-Dimensional Artificial Materials". A matching fund of $2.3M was provided by the University of California, Berkeley. Principal Investigator was Prof. R. Gronsky, Chair of MSMB at that time, with Chairs P. Gray, EECS and H. Steiner, Physics as co-PIs.

The 5 year grant provided for three major pieces of equipment forming the core of the new Integrated Materials Laboratory (IML). These were: Jeol SEM with Nabhly software for e-beam writing, a high resolution X-ray diffractometer, and a UHV-connected system of MBE growth, metal deposition, and characterization system. UCB matching enabled renovation of the facilities to accept the new instruments, and provided one FTE support. It was stipulated that the facility become a self-supporting recharge operation after expiration of the grant in 1997.

ESTABLISHING THE INTEGRATED MATERIALS LABORATORY (IML)

Cory Hall

Dr. Nate Newman developed the new laboratory, with the help of Microlab staff. EECS agreed to locate the new MBE system (mbe2), the UHV connected metal deposition (metal) and characterization (ichar) chambers in 157 Cory Hall, next to the existing MBE tool (mbe1) in 155 Cory. We also obtained an additional liquid nitrogen holding vessel outside Cory Hall, for direct delivery of liquid nitrogen.

The Jeol SEM/e-beam writer (jeol107) was installed in room 107 Cory Hall, in place of two decommissioned old SEMs.

Hearst Memorial Mining Building

The Department of Materials Science and Mineral Engineering gave space for the X-ray diffractometer (xdiff). In addition, Prof. T. Sands joined IML with opening his laser ablation system for general use. The grant provided for an excimer laser and and additional chamber for 4" substrate compatibility.

Thus, the new Integrated Material Laboratory had an official opening in January 1995, with four working systems offered for materials research.

Le Conte Hall

In 1996 IML equipment located in Materials Science space were moved to Le Conte Hall's Physics space, in preparation for the decanting and renovation of the Hearst Memorial Mining Building (HMMB).

The equipment was moved back in the newly renovated HMMB in 2003 and the space returned to Physics. The chronology of events concerning the IML is listed in Table 1.
Personnel

Dr. Nate Newman, Research Engineer in MSME, did an excellent job of establishing the IML. Microlab staff alone could not have managed without the leadership of an outstanding materials researcher. When Dr. Newman was ready to leave in 1996 for a faculty position at Northwestern University, (now at Arizona State University, Tempe,) he ensured continued materials science expertise by hiring Dr. Prashant Patak, a recent UCB graduate, as his replacement.

In preparation for a self supporting recharge operation, the position of the IML manager was posted as a staff title (Senior Development Engineer) and came under ERL/Microlab management in 1996.

After Dr. Patak resigned in 1998, we hired Bob Prohaska, who came with over 15 years of research experience, most of it in the Physics department at UC Irvine.

James Parrish, Associate Development Engineer provided half time technical support from 1997-2003.

Faculty Directors of the IML:

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tim Sands</td>
<td>MSE</td>
<td>Jan. - Sep. 2002</td>
</tr>
<tr>
<td>Eicke Weber</td>
<td>MSE</td>
<td>Sep. 2002 - 2004</td>
</tr>
</tbody>
</table>

Equipment

Over the years several previously owned equipment were donated, and/or transferred to the IML with the intent that they provide additional income through multiple users. This approach, however, is valid only for certain types of instruments, mainly measurement tools. MBE systems are notoriously single-user machines, which require intimate knowledge by the operator. Disturbing each other's experiments and cross contamination are of further concerns.

After multiple moves, dispersion and reconsolidation, as of the end of 2003 IML maintained the following equipment:

<table>
<thead>
<tr>
<th>Login Name</th>
<th>Description</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>mbe1</td>
<td>Varian Molecular Beam Epitaxy</td>
<td>157 Cory Hall</td>
</tr>
<tr>
<td>mbe2</td>
<td>Intevac MBE, UHV-Conn. to imetal, ichar</td>
<td>157 Cory Hall</td>
</tr>
<tr>
<td>ichar</td>
<td>UHV-Connected Characterization Chamber</td>
<td>157 Cory Hall</td>
</tr>
<tr>
<td>imetal</td>
<td>UHV-Connected E-Beam Metallization Chamber</td>
<td>157 Cory Hall</td>
</tr>
<tr>
<td>lextra</td>
<td>Lextra Excimer Laser</td>
<td>100 HMBB</td>
</tr>
<tr>
<td>pld1</td>
<td>Pulsed Laser Deposition Chamber 1</td>
<td>100 HMBB</td>
</tr>
<tr>
<td>pld2</td>
<td>Pulsed Laser Deposition Chamber 2</td>
<td>100 HMBB</td>
</tr>
<tr>
<td>bigblue</td>
<td>5-source Deposition System</td>
<td>decommissioned</td>
</tr>
<tr>
<td>mrc8600</td>
<td>MRC RF/DC Magnetron Sputterer</td>
<td>155 Cory Hall</td>
</tr>
<tr>
<td>parylene</td>
<td>Poly Para-Xylene Thin Film Deposition</td>
<td>155 Cory Hall</td>
</tr>
</tbody>
</table>

Analytical Systems

<table>
<thead>
<tr>
<th>Login Name</th>
<th>Description</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>xdf</td>
<td>X-Ray Diffractometer</td>
<td>124 HMBB</td>
</tr>
<tr>
<td>auger</td>
<td>Auger Electron Spectrometer</td>
<td>140 HMBB</td>
</tr>
<tr>
<td>fib</td>
<td>Seiko 8800 Focused Ion Beam System</td>
<td>140 HMBB</td>
</tr>
<tr>
<td>ftir</td>
<td>Fourier Transform Spectrophotometer</td>
<td>decommissioned</td>
</tr>
<tr>
<td>jeol107</td>
<td>JEOL 6400 SEM/E-Beam Writer</td>
<td>107 Cory Hall</td>
</tr>
<tr>
<td>microvision</td>
<td>Microvision Stroboscopic Microscope</td>
<td>163 Cory Hall</td>
</tr>
<tr>
<td>wyko</td>
<td>Wyko Optical Profilometer</td>
<td>163 Cory Hall</td>
</tr>
</tbody>
</table>
CURRENT IML OPERATIONS

Members

For labmembers IML and Microlab boundaries are transparent. The same safety and laboratory controls and procedures apply for both operations. Regardless of the location of the equipment, computer control of equipment and the software interface make it look like one operation.

Administration

The Integrated Materials Laboratory is administered through the Microlab. Membership in the IML is automatic for any one in the Microlab. Those who use only IML equipment still become Microlab members so that lab orientation and account administration can be done uniformly.

Because each equipment has its own enable control and associated equipment fees, recharges can be easily sorted into the IML accounts. Separate monthly statements are posted for the IML, through the Microlab's accounting system. Purchasing and inventory is also handled through the Microlab.

Staffing

Bob Prohaska, Senior Development Engineer, Manager is the sole staff remaining to support operations in the IML. Assistance is provided by Microlab staff in the areas of safety, lab orientation, administration and management.

Finances

During the 5 year period of the grant only minimal charges were applied for using IML equipment. Starting with fiscal year 1997/98 a recharge account was created to fully support the operation. Financial data for each of the fiscal years since the start are as follows:

<table>
<thead>
<tr>
<th>FY</th>
<th>Income</th>
<th>Expenditure</th>
<th>Balance/Year</th>
<th>Carry Forward Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997/98</td>
<td>$78,433</td>
<td>$83,374</td>
<td>$-4,941</td>
<td>$-4,941</td>
</tr>
<tr>
<td>1998/99</td>
<td>$143,467</td>
<td>$141,956</td>
<td>$1,511</td>
<td>$-3,430</td>
</tr>
<tr>
<td>1999/00</td>
<td>$378,914</td>
<td>$265,378</td>
<td>$113,536</td>
<td>$110,106</td>
</tr>
<tr>
<td>2000/01</td>
<td>$166,452</td>
<td>$257,862</td>
<td>$-91,410</td>
<td>$18,695</td>
</tr>
<tr>
<td>2001/02</td>
<td>$121,506</td>
<td>$170,035</td>
<td>$-48,529</td>
<td>$-29,834</td>
</tr>
<tr>
<td>2002/03</td>
<td>$125,724</td>
<td>$110,252</td>
<td>$15,472</td>
<td>$-14,362</td>
</tr>
<tr>
<td>2003/04</td>
<td>$114,663</td>
<td>$133,570</td>
<td>$-18,907</td>
<td>$-33,269</td>
</tr>
</tbody>
</table>

Figure 1 is the graphical representation of income and expenditures for the past 7 years. Figure 2 includes balances for each year and carry forward amounts.

It is clear that IML operations closed FY 2003/04 with a deficit of $33,269, almost 3 times the monthly income. A recharge operation is allowed to fall below the targeted budget in the amount of one month income needed to sustain operations.

Discussion

The IML was established through an NSF grant, with the idea that it become a self supporting facility after the expiration of the grant. During the first two years as an independent recharge operation, we were able to meet expenses because the engineer/manager's position was partially covered from other sources.

In 1998 we initiated the Berkeley Microlab Affiliates (BMLA) program, with a membership fee, to allow industrial affiliates to use Microlab/IML equipment. In FY 1999/2000 IML income doubled, solely due to an industrial member utilizing the mbel system extensively.
Our expenses also grew considerably, liquid nitrogen costs, for example. We also increased staff to 2 FTEs to accommodate increased use. We closed FY 1999/2000 with a surplus, which kept the operation in the black the following year.

In 2000/01 mbe use dropped off precipitously, also expenses decreased but at a much slower rate. By shutting down mbe1, for lack of use, and reducing staff, we were able to lower costs the following years but not low enough to achieve fiscal balance.

With the departure of Prof. Sands in 2002 the use rate of the pulsed laser deposition systems fell below the level of self support. Other equipment are being used at a variable rate but the operation is not large enough to carry the associated overhead.

PROPOSED PLAN

I propose that the Integrated Materials Laboratory be merged with the Microlab effective 1 July 2004.

Reasons

1. With the end of the initial grant the reason for independent accounting no longer exists.

2. We had no input from major research groups that they are planning a large scale use of any of the IML equipment or that they are proposing to expand capabilities in this area of materials research.

3. With changes in the research agendas of the participating departments (MSE/EECS/Physics) use of the original equipment fell to levels where maintenance for general use is no longer justifiable.

4. MBE systems do not easily lend themselves to multiple users. These tools are extremely sensitive to special practices and treatments. Our experience shows that MBE projects are most successful when use is restricted to one group. Accommodating even two different projects is at least tedious.

5. The IML operation as is, is too small to carry the associated overhead required of a separate recharge account.

6. Distribution of technical talent and support staff can be much more effective and efficient in a larger operation.

7. There is nothing in the IML operation that is not or cannot be covered in a single operation with the Microlab; thus, I propose that we merge the IML and Microlab operations.

Disposition of Resources

Deposition Systems

1. Mbe1 - 155 Cory Hall
   After about a year of idling, mbe1 was placed in a dormant mode in March 2001. Prof. Chang-Hasnain requested start-up in December 2003. As the IML was in no position to invest about $40K in the restart, Prof. Chang-Hasnain offered to accept the machine as is, for sole use by her research group. After discussing it with the respective directors, this transfer was made by the end of 2003.

2. Mbe2 - UHV - connected with a metallization and a characterization chamber (mbe2-imetal-ichar) - 157 Cory
   The mbe chamber is being used, at a low rate, by Prof. Weber's research group. One member is using the metallization chamber off and on, and the SEM in the characterization is being used perhaps once a year.

   Control of this complex system should be transferred to Prof. Weber's research group.
3. Pulsed Laser Deposition System - 100 HMBB
When Room 100 HMBB was assigned to Prof. R. Ramesh for his laser processing center, we discussed merging the lexta-pld1-pld2 system into his operation. This seemed beneficial for both sides: Prof. Ramesh has an experienced group of researchers who are maintaining his systems capably. He offered to take over maintenance of the IML system in return for free use. We accepted this as a good deal and are operating on this basis since Prof. Ramesh's equipment arrived from the University of Maryland in March of this year. Microlab members have access as usual, through the equipment enabling computer, which also records use rate.

4. The MRC RF/DC Magnetron Sputterer for zinc oxide and the Poly Para-Xylene Thin Film Deposition system will have to be moved yet again, from 155 Cory to 188 Cory, at which time these will be returned to Microlab ownership.

Analytical Systems

1. The Auger Electron Spectrometer (in 140 HMBB) is out of commission for repair. There is no interest at this time to resuscitate this old instrument. If no takers can be found we can surplus it.

2. The Seiko 8800 Focused Ion Beam (in 140 HMBB) is in working order, however, there is no interest on the part of Microlab members for its use. We would like to offer it to MSE to fold it into their SEM center and operate it with staff.

3. The JFOL 6400 SEM/E-Beam Writer (in 107 Cory Hall) will become a Microlab tool, remaining in its current location.

4. The two MEMS-application instruments, the Microvision Stroboscopic Microscope and the Wyko Optical Profilometer (both in 163 Cory Hall) will have to be moved to 145 Cory to make space for other departmental projects. These tools will be folded into the Microlab's tool set.

5. The X-Ray Diffractometer (in 124 HMBB) will also be relocated to 145 Cory and will become a Microlab instrument.

Financial

IML operations will merge with that of the Microlab. As far as lab members are concerned this has already happened. We will save resources by discontinuing administration and management of two separate recharge accounts and by more efficient allocation of technical staff. The Microlab will inherit IML's accumulated deficit, which we hope to recoup by continuing recharge operation of retained equipment.

SUMMARY

The IML met the goal of the originating grant, to provide a facility for low-dimensional material growth and characterization. The proposed plans were based on and realized through the model and management of the Microlab. We have learned that the model works only as long as the equipment can support multiple processes and users. This is the case for the SEM/e-beam writer, stand alone characterization tools and laser deposition systems. Molecular beam epitaxy systems do not lend themselves to multiple users and projects and are best operated as single group machines. They are also a great sink of resources, which need to be financed through continuous grants, and expenses cannot be averaged over other types of machines.

In the final analysis, there was no interest in the three establishing departments to continue jointly this type of laboratory. Research needs can be met in more efficient ways, and we continue to strive to meet those needs within the well working frame of the Microlab.

Your agreement is requested to this proposal, merging the Integrated Materials Laboratory with Microlab operations.
# Integrated Materials Laboratory (IML) Chronology of Events

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>Grant received</td>
</tr>
<tr>
<td></td>
<td>Founding Agency: National Science Foundation NSF 91-140:</td>
</tr>
<tr>
<td></td>
<td>&quot;Academic Research Infrastructure Program&quot;</td>
</tr>
<tr>
<td></td>
<td>Grant title: &quot;Acquisition of Instrumentation to Fabricate Low-</td>
</tr>
<tr>
<td></td>
<td>Dimensional Artificial Materials&quot;</td>
</tr>
<tr>
<td></td>
<td>Pls: Ronald Gromsky, Paul R. Gray and Herbert M. Steiner,</td>
</tr>
<tr>
<td></td>
<td>MSE/EECS/Physics</td>
</tr>
<tr>
<td></td>
<td>NSF grant amount: $1,607,560</td>
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<tr>
<td></td>
<td>UCB cost sharing: $2,331,842</td>
</tr>
<tr>
<td></td>
<td>Effective date: January 1, 1993</td>
</tr>
<tr>
<td></td>
<td>Expiration: December 31, 1997</td>
</tr>
<tr>
<td>1993</td>
<td>January -- Integrated Materials Laboratory (IML) established,</td>
</tr>
<tr>
<td></td>
<td>Director: Prof. Jeff Bokor, EECS</td>
</tr>
<tr>
<td></td>
<td>Manager: Dr. Nate Newman</td>
</tr>
<tr>
<td>1993-1995</td>
<td>Facilities renovation, 157 Cory Hall (for mbe2-metal-ichar)</td>
</tr>
<tr>
<td></td>
<td>107 Cory Hall (for SEM/e-beam writer)</td>
</tr>
<tr>
<td></td>
<td>Equipment order and installation</td>
</tr>
<tr>
<td>1995</td>
<td>January -- Grand opening of the Integrated Materials Laboratory</td>
</tr>
<tr>
<td></td>
<td>Manager: Dr. Nate Newman</td>
</tr>
<tr>
<td></td>
<td>Equipment in place in Cory Hall:</td>
</tr>
<tr>
<td></td>
<td>jeol107 (SEM/e-beam writer)</td>
</tr>
<tr>
<td></td>
<td>mbe2 (connected UHV growth and characterization system)</td>
</tr>
<tr>
<td></td>
<td>In HMB: xdf (X-ray diffractometer) and</td>
</tr>
<tr>
<td></td>
<td>pld (pulsed laser deposition system)</td>
</tr>
<tr>
<td>1996</td>
<td>April -- Dr. Prashant Patank, new IML manager</td>
</tr>
<tr>
<td>1996</td>
<td>May -- Dr. Nate Newman leaves a faculty position</td>
</tr>
<tr>
<td>1996</td>
<td>June -- Move to Leconon from HMB:</td>
</tr>
<tr>
<td></td>
<td>xdf, pld (Excimer laser)</td>
</tr>
<tr>
<td>1997</td>
<td>January -- Director: Prof. Eicke Weber</td>
</tr>
<tr>
<td>1997</td>
<td>February -- New NSF Proposal:</td>
</tr>
<tr>
<td></td>
<td>&quot;Acquisition of Instrumentation for the Fabrication and Characterization of Integrated Materials Systems and Devices&quot;</td>
</tr>
<tr>
<td></td>
<td>Date: Feb. 20, 1997</td>
</tr>
<tr>
<td></td>
<td>grant to start Sep. 15, 1997</td>
</tr>
<tr>
<td></td>
<td>Pls: Randy Katz, Thomas Devine, Roger Falcone</td>
</tr>
<tr>
<td></td>
<td>EECS/MSE/Physics</td>
</tr>
<tr>
<td></td>
<td>1997 December- Original NSF grant expired; IML supporting</td>
</tr>
<tr>
<td></td>
<td>New grant proposal denied, May 1998</td>
</tr>
<tr>
<td>1998</td>
<td>April -- Dr. Prahant Patank, IML manager resigns</td>
</tr>
<tr>
<td>1998</td>
<td>July -- Bob Proskaska, new IML manager</td>
</tr>
<tr>
<td>1998</td>
<td>August -- Mbe1 transferred to IML ownership</td>
</tr>
<tr>
<td>1998</td>
<td>-- Equipment additions from donations: aguer, fib</td>
</tr>
<tr>
<td>1999</td>
<td>-- With new tools added, equipment list:</td>
</tr>
<tr>
<td></td>
<td>e-beam writer: jeol107</td>
</tr>
<tr>
<td></td>
<td>growth: mbe1, mbe2 + metal + ichar (connected);</td>
</tr>
<tr>
<td></td>
<td>pulsed laser processing: pld1, pld2, lestra</td>
</tr>
<tr>
<td></td>
<td>analytical: xdf, auger, ftr, FIB, Wyco, microvision,</td>
</tr>
<tr>
<td>2010</td>
<td>-- For additional income new equipment added:</td>
</tr>
<tr>
<td></td>
<td>mre$600, bigblue, parylene located in Davis Hall</td>
</tr>
<tr>
<td>2001</td>
<td>-- Mbe use-rate diminishing considerably</td>
</tr>
<tr>
<td>2002</td>
<td>-- Prof. Sands, director, Jan-Sep. (left for Purdue)</td>
</tr>
<tr>
<td></td>
<td>Prof. Weber resumes directorship in September</td>
</tr>
<tr>
<td>2002</td>
<td>April -- Mbe1 is powered down, under vacuum</td>
</tr>
<tr>
<td>2003</td>
<td>-- Equipment moves: from LaConete - pld1, pld2, letra to 100 HMB;</td>
</tr>
<tr>
<td></td>
<td>xdf to 100 HMB; from Cory -- auger, FIB to 140 HMB;</td>
</tr>
<tr>
<td></td>
<td>from Davis -- mre$600, parylene to 125 Cory</td>
</tr>
<tr>
<td></td>
<td>bigblue, for decompositionan.</td>
</tr>
<tr>
<td></td>
<td>Mbe1 ownership returned to Prof. Chang-Hastrain (Dec. 2003)</td>
</tr>
<tr>
<td>2004</td>
<td>March -- pld/laser system consolidated with MSE Prof. R. Ramesh's</td>
</tr>
<tr>
<td></td>
<td>laser center in 100 HMB</td>
</tr>
<tr>
<td>2004</td>
<td>July -- At end of fiscal year consolidation with Microlab proposed</td>
</tr>
</tbody>
</table>

Table 1
IML Income vs. Expenditures
FY 97/98 – 03/04

Figure 1

IML Fiscal Year-End Balances including Carry-Forward Amounts
FY 97/98 – 03/04

Figure 2
# Table of Contents

Microfabrication Laboratory 2005 Year-End Reports

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<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ABSTRACT</strong></td>
<td></td>
</tr>
<tr>
<td><strong>OPERATIONS:</strong></td>
<td>Katatin Voros, Operations Manager</td>
</tr>
<tr>
<td><strong>FACILITIES:</strong></td>
<td>Robert Hamilton, Facilities Manager</td>
</tr>
<tr>
<td><strong>ADMINISTRATION:</strong></td>
<td>Rosemary Spivey, Administrative Manager</td>
</tr>
<tr>
<td></td>
<td>Susan Kellogg-Smith, Purchasing Manager</td>
</tr>
<tr>
<td><strong>COMPUTERS:</strong></td>
<td>Todd Merport, Computer Systems Manager</td>
</tr>
<tr>
<td><strong>PROCESS/BASELINE:</strong></td>
<td>Slavosh Parsa, Process Engineering Manager</td>
</tr>
<tr>
<td></td>
<td>Dan Bucher, Asst. Dev. Engineer, MEMS Exchange</td>
</tr>
<tr>
<td></td>
<td>Kim Chan, Asst. Dev. Engineer, Advanced Lithography</td>
</tr>
<tr>
<td></td>
<td>Jimmy Chang, Associate Development Engineer</td>
</tr>
<tr>
<td></td>
<td>Marilyn Kushner, Junior Development Engineer</td>
</tr>
<tr>
<td><strong>TECHNOLOGY:</strong></td>
<td>William Hounders, Technology Manager</td>
</tr>
<tr>
<td><strong>BSAC ENGINEERING:</strong></td>
<td>Matthew Wasilik, Senior Development Engineer</td>
</tr>
<tr>
<td><strong>MACHINE SHOP:</strong></td>
<td>Ben Lake, ERL/MSE Machine Shop Sr. Superintendent</td>
</tr>
</tbody>
</table>

Microfabrication Laboratory 2005 Year-End Reports
ABSTRACT

This document contains the 2005 Year-End Reports by the professional staff of the Microfabrication Laboratory. Together, these reports reflect the wide range of support staff provides to research campus wide and to instructional laboratories in ECEs.

Activities of direct Microlab (ML) operations support staff, described in the sections Operations, Facilities, Administration, Computers, and Process/Baseline include 23 career employees and 8 undergraduate student assistants. The Machine Shop operates with 5 staff as an independent recharge unit. After the completion of equipment upgrade to process 6" (150 mm) wafers in 2004, Microlab operations continued on a steady path, supporting process technology also on 4" and partial wafers.

The Microlab had an average monthly membership of 315. Participating PIs: 103. The Machine Shop completed 299 jobs from 56 PIs. The Berkeley Microlab Affiliates program (BMLA) comprises 22 industrial members. Detailed Microlab information can be found at www.microlab.berkeley.edu.

K.V.

Table 1

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MEMORANDUM

To:       Professor C. Spanos, Associate Dean for Research
          Professor N. Cheung, Microlab Faculty Director
From:    Katalin Voros, Operations Manager
Subject: 2005 Year-End Report
Date:    30 January 2006

I. INTRODUCTION

After conclusion of the upheaval caused by the 6" upgrade during the previous several years, Microlab operations settled down on a peaceful, steady course in 2005. By fiscal closing in the middle of the year, we made up a good portion of the deficit accumulated during the upgrade. We are on the path to break even, half way through the current fiscal year. Details on this are presented in the Financial Resources section.

Planning for the new Microlab as part of the CITRIS project continued. Excavation (observable from our office window) was completed. However, construction was suspended for six months for various reasons. We have been informed that the activities will resume in Spring 2006.

This document is the 19th year-end report I have submitted on behalf of the Microlab.

II. MANAGEMENT OF RESOURCES

Facilities

Microlab

- Bob Hamilton, Equipment and Facilities Manager and Safety Officer of the Microlab, provides details on upgrades, installations, facilities maintenance and development in his report. Safety issues and HazCom improvements are also discussed.

Equipment and facilities problem reports were attended satisfactorily throughout the year, in a timely manner. The number of equipment down was less than 20 at any one time (out of 192 operating systems) and problem reports were updated/cleared on critical equipment in most cases by next day. Microlab staff is keenly aware that equipment uptime is a critical metric of our operations.

- Process engineering activities were in high gear throughout the year. Process optimization, new process introduction are ongoing activities. Assisting students with processing problem, clearing up compatibility issues, testing and ramping up new equipment, are additional responsibilities process staff handles. The new, composite baseline chip, containing devices from three different research groups, progressed half way through the process. At the same time, we trained a new baseline engineer.

Reports by Sia Parsa, Process Engineering Manager, and his staff, comprise details of process support and process optimization. Also, development of the 0.35 μm CMOS baseline process is discussed.

- In 2005 reorganization of our control unit was completed and ERL morphed into ERSO by the end of June. This was a major change in central administration, effects of which touched all units within the organization. Rosemary Spivey, Administrative Manager and her staff ensured, however, that Microlab operations were not impacted. The administrative staff attended all necessary meetings and training classes, to learn about new procedures, channels of communications and interfacing requirements. Their report includes discussion of our financial status, accounts and members administration, purchasing, and inventory management.
- Todd Merport, Computer Operations Manager, reports on developments in computer support and our activities in design and development of the new management information system, Mercury. Staff resignations made Todd’s work difficult but our systems were maintained at the highest levels of uptime and integrity.

Our PC/Windows manager, TK Chen, whom we shared 50/50 with the FLCC research group, took another position in ERSO; thus management of 97 PCs fell to Todd, in addition to the main SUN servers, silicon/argon, and the BCIMS software. We were able to retain Changrui Yin in September for the position, who is now working on PC support in the Microlab.

In 2005, the Mercury project had a major setback with the departure of our lead developer, Tim Duncan. Tim was familiar with our operations even before we started the project and made good progress in implementing several modules of the design. Our new P/A III, Eniko Seen, after learning about and reviewing what had been produced so far, proposed to redesign the user interface, to reduce bulkiness, make it more robust and easier to debug and maintain.

We have a long way to go before we have a useful product and I will need to reinforce this development aspect of our operations.

**New Laboratory**

The new engineering building, CITRIS, which contains the new lab, (no final name yet) underwent a major redesign. The project had been divided into two phases: I. Demolition and Excavation, and II. Construction. Phase I is completed. After about a 6-month hiatus, Phase II is just being resumed. At this point, we can be hopeful that the new building and our new lab will become a reality. (Bill Flounders' report has details.)

**Machine Shop**

The Machine Shop completed 299 jobs for 56 PIs in FY 2004/2005. This represents a 23\% increase in the volume of jobs, a further proof that we can operate a self-maintaining shop. Only 40\% of the jobs were submitted from the Microlab, indicating that the Shop is successful in broadening its customer base. The updated website, which lists capabilities, contact information, job request forms, and general information such as photographs of completed jobs, has streamlined operations by answering some general customer questions and giving customers an easy way to make contact: [http://mshop-erso.berkeley.edu](http://mshop-erso.berkeley.edu) (see Ben Lake’s report).

**Staff**

Microlab staff groups are organized along functional lines, as described below. The Machine Shop operates independently under the Microlab Operations Manager (see Table 1 - Staff Organizational Chart, Effective 15 January 2006).

The Microlab has been successful in retaining and developing staff well tuned to the laboratory’s needs. Cross-training, back-ups and multiple responsibilities in all positions ensure that lab operations have broad coverage and problems are attended on a timely manner. Table 2 lists UC employment years of Microlab and Machine Shop (MS) staff. (Three people with less than one year employment are not listed.)
Table 2 - UC Service Years of Microlab and Machine Shop Staff

<table>
<thead>
<tr>
<th>Name</th>
<th>Years</th>
<th>Name</th>
<th>Years</th>
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</thead>
<tbody>
<tr>
<td>Bob Hamilton</td>
<td>38</td>
<td>Madeleine Leullier</td>
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<td>Bob Amaral (MS)</td>
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<td>Evan Staterler</td>
<td>23</td>
<td>Jimmy Chang</td>
<td>15</td>
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<td>Marilyn Kushner</td>
<td>21</td>
<td>Susan Kellogg-Smith</td>
<td>15</td>
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<td>Phill Guillyory</td>
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<td>Joe Gavazza (MS)</td>
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<td>Ben Lake (MS)</td>
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<td>Katalin Voros</td>
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<td>Adrienne Ruff</td>
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<td>Sia Pasa</td>
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<td>Bob Connelly</td>
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<td>Joe Donnelly</td>
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<td>David Lo</td>
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<td>Bryan McNeil</td>
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<td>Matt Wasilik</td>
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<td>Bill Flounders</td>
<td>4</td>
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<td>Nancy Peshette (MS)</td>
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<tr>
<td>Danny Pestal</td>
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</tr>
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</table>

Microlab Operations (24 FTE)

Katalin Voros, Operations Manager (7 direct reports)

1. **Equipment and Facilities** (9 FTE)
   - Bob Hamilton, Manager (7 direct reports)
   - 4 development engineers and 1 technician
   - Phill Guillyory, Supervisor - 1 technician and student assistants
   - Mike Linan, Supervisor - 1 technician

2. **Process/Baseline** (7.5 FTE)
   - Sia Pasa, Manager
   - 3.5 development engineers, 1 research specialist and 4 student assistants

3. **Administration** (4 FTE)
   - Rosemary Spivey, Manager - 2 student assistants
   - Susan Kellogg-Smith, Procurement Manager - 1 purchasing assistant

4. **Computer Support** (2.5 FTE)
   - 2 programmer/analysts

5. **Technology Management**: Bill Flounders

   - Development staff employed by research groups: 2 FTE, 2 student assistants

   - **Machine Shop** (4.5 FTE)
     - Ben Lake, Senior Superintendent
     - 2 principal mechanics, 1 development technician and 0.5 administrative assistant

Table 3 - Operational Staff Groups

Table 3 shows the well established core groups, on which Microlab operations are based. We start from here with our development plans in preparation for the new lab. The eventual move is at least two years away; however, we will need time to build up staff for the move, for the ramp up of the new lab and ramp down of the old. While there will be unavoidable disruptions, we have every intention to keep those to a minimum and to the absolute necessary events. The key to such a plan is tedious preparation and swift execution, not only of the physical move but also of the re-characterization of processes. Thus, new hires, staff development, and reclassifications are being made with this goal in mind.
Financial Resources

Recharge accounts under Microlab management continued to be closely monitored for budgetary requirements throughout the year. Rosemary Spivey's report shows details and financial analysis for each unit (see Table 4 below).

<table>
<thead>
<tr>
<th>Unit</th>
<th>Income</th>
<th>Expenditures</th>
<th>Performance</th>
<th>No. of Pls Billed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microlab</td>
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<td>$2,639,909</td>
<td>5% [+</td>
<td>103</td>
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<tr>
<td>Machine Shop</td>
<td>$327,168</td>
<td>$347,342</td>
<td>6% [-</td>
<td>56</td>
</tr>
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</table>

Table 4 - Recharge Accounts Summary
30 June 2005

The Microlab spent, over a period of 6 years, $2.6M in cash on the 6" upgrade. This amount came from savings of industrial membership fees. Additionally, we ended FY 2003/04 with a deficit of about $200K in operating funds. Half of the deficit was eliminated in FY 2004/05 and it looks like we will be able to eliminate the rest in 2005/06. This means that we can set aside BMLA membership fees for the next development phase, moving into the new laboratory.

III. COMMUNICATIONS & CONTROL

Membership

Microlab monthly membership was over 300 this past year, same as in preceding years. Overall, we dealt with 518 members during FY 2004/05. Special equipment use-hrs increased, after the 6" upgrade upheaval simmered down, to the level of FY 2000/2001 (see Table 5 below).

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Membership/Month</th>
<th>Lab Use-Hrs</th>
<th>Sp. Equip. Use-Hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000/2001</td>
<td>345</td>
<td>45,413</td>
<td>39,383</td>
</tr>
<tr>
<td>2001/2002</td>
<td>315</td>
<td>39,288</td>
<td>36,738</td>
</tr>
<tr>
<td>2002/2003</td>
<td>326</td>
<td>43,455</td>
<td>37,676</td>
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<td>2003/2004</td>
<td>331</td>
<td>40,823</td>
<td>34,692</td>
</tr>
<tr>
<td>2004/2005</td>
<td>315</td>
<td>40,394</td>
<td>38,798</td>
</tr>
</tbody>
</table>

Table 5 - Microlab Utilization

Berkeley Microlab Affiliates (BMLA)

Industrial membership, BMLA is on the rise again, currently numbering 22. In 2005 we reviewed and tightened up the Memorandum of Cooperative Agreement, with the cooperation and sign-off by the UCB Business Contracts Office.

Document Control and Training

The Microlab's operating manual consists of 1300 pages, compiled in 152 chapters, available on-line from the web portal of the Microlab, http://microlab.berkeley.edu/. The listing of 6" Equipment Capability is shown in the Equipment panel.

We expend considerable effort to keep documentation up to date, because we expect lab members to use the on-line manual (and hard copy) as the first step in finding operational and process information. The oldest date on equipment operating manuals is 2001; this year we will
update those with dates of 2002. In addition, 33 equipment have written test requirements for qualifications, which we also maintain and update regularly.

The task of writing new manuals, appending, updating existing ones with the latest information, is shared by staff and expert users of the tools, with process staff carrying most of the burden. Madeleine Leullier, Computer Resource Specialist, has the assignment of document control, i.e. editing and installation of both on-line and hard-copy manuals and written tests.

Outreach

During the summer of 2005 we had another excellent student, as participant in our Summer Internship for High School Girls program. This time, the intern worked successfully with the computer support group, under Todd Merport’s supervision. We will continue the program this coming summer, http://microlab.berkeley.edu/text/MLOutreach.html, for which we already selected two outstanding candidates from Bay Area high schools.

IV. SUMMARY

The year of 2005 was spent with quiet recuperation in the Microlab. After more than 6 years of continuous upheaval finally we had a chance to return to steady state operation. Microlab activity remained high throughout the year, which meant that we were able to eliminate the deficit without raising rates.

We are formulating plans and looking forward to the eventual realization of the new laboratory.
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<tr>
<td>Operations:</td>
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<td>Katalin Vuro, Operations Manager</td>
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<td>Robert Hamilton, Facilities Manager</td>
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<td>Susan Kellogg-Smith, Purchasing Manager</td>
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<td>Todd Merport, Computer Systems Manager</td>
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<td>Siavash Parsa, Process Engineering Manager</td>
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<td>Daniel Bucher, Asst. Dev. Engineer, MEMS Exchange</td>
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<td>Kim Chan, Asst. Dev. Engineer, Advanced Lithography</td>
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<td>Jimmy Chang, Associate Development Engineer</td>
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<td>Marilyn Kushner, Junior Development Engineer</td>
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<td>William Flounders, Technology Manager</td>
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<td>BSAC Engineering:</td>
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<tr>
<td>Matthew Wasilik, Senior Development Engineer</td>
<td></td>
</tr>
<tr>
<td>Machine Shop:</td>
<td>76</td>
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<tr>
<td>Ben Lake, ERL/MSE Machine Shop Sr. Superintendent</td>
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</tr>
</tbody>
</table>

Microfabrication Laboratory 2006 Year-End Reports
ABSTRACT

This document contains the 2006 Year-End Reports by the professional staff of the Microfabrication Laboratory. Together, these reports reflect the wide range of support staff provides to research campus wide and to instructional laboratories in EECS.

Activities of direct Microlab (ML) operations support staff, described in the sections Operations, Facilities, Administration, Computers, and Process/Baseline include 25 career employees and 10 undergraduate student assistants. The Machine Shop operates with 5 staff as an independent recharge unit. The Microlab supports 0.35 µm process technology on 6" (150 mm) silicon wafers. Equipment is also available for processing 4" and partial wafers.

The Microlab had an average monthly membership of 345 in 2006; participating PIs: 101. The Machine Shop completed 290 jobs from 42 PIs. The Berkeley Microlab Affiliates program (BMLA) comprises 22 industrial members. Detailed Microlab information can be found at http://microlab.berkeley.edu/.

K.V.

Microfabrication Laboratory
Staff Organizational Chart
Effective 2 January 2007

Table 1

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MEMORANDUM

To: Professor Costas Spanos, Associate Dean for Research
Professor Tsu-Jae King, Microlab Faculty Director
From: Katalin Voros, Operations Manager
Subject: 2006 Year-End Report
Date: 23 January 2007

I. INTRODUCTION

Microlab operations continued on a steady course in 2006. By fiscal closing in the middle of the year we made up the deficit accumulated during the 6th upgrade and closed FY 2005/06 in balance. The numbers are presented in the Financial Resources section.

Planning for the new Microlab as part of the CITRIS project continued; construction resumed in middle of 2006 and it is progressing on schedule, with a beneficial occupancy date, Fall 2008, as target.

In August 2006, we welcomed back Professor Tsu-Jae King as the Microlab’s Faculty Director. While she was on industrial leave, 2004-2006, Professor Nathan Cheung acted as Interim Faculty Director with great success. Both transitions were smooth and reassuring that our faculty support remains strong.

I have completed my 20th year as Microlab Operations Manager; this is the 20th year-end report I am submitting.

II. MANAGEMENT OF RESOURCES

Facilities

Microlab

- Bob Hamilton, Equipment and Facilities Manager, and Safety Officer of the Microlab, provides details on upgrades, installations, facilities maintenance and development in his report. Safety issues and HazCom improvements are also discussed.

- Equipment and facilities problem reports were attended satisfactorily throughout the year, in a timely manner. Problem reports were updated/cleared on critical equipment in most cases next day. Microlab staff is keenly aware that equipment up-time is a critical metric of our operations; it is the main factor in providing income to cover operational expenses.

- Process engineering activities were in high gear throughout the year. Process optimization, new process introductions are ongoing activities. Assisting students with processing problems, clearing up compatibility issues, testing and monitoring equipment, are additional responsibilities process staff handles. The current baseline run, CMOS 170, containing a composite chip of devices from three different research groups, had been completed with good results. A report is forth coming.

- Sia Parsa, Process Engineering Manager and his staff detail process support and development activities.

- Rosemary Spivey, Administrative Manager and her staff’s reports include discussion of our financial status, accounts and members administration, purchasing, and inventory management.

- Todd Merport, Computer Operations Manager describes systems maintenance, operational improvements and upgrades. Our computers and lab control software were maintained at the highest levels of uptime and integrity. There was another server upgrade which enabled retiring of our old argon server. Several migrations occurred at the same time, to distribute load more evenly.
In 2006 the *Mercury* project moved at a somewhat improved rate. Our new PAIII, Eniko Seen, redesigned the user interface, for a more advanced look-and-feel than what we had had before. Mid-year we hired Olek Proskurowski, PA III, to enhance overall progress, to work on the database and server side, and also to act as back up to Todd in Unix administration.

**New Laboratory**

Construction of the new engineering building, CITRIS, including our new lab, resumed in 2006 and continues at a rapid rate. Bill Flounders’ report details the difficult value engineering phase; however, it looks like the new lab will become reality.

We were saddened at the end of the year by the illness of our visionary Dean of Engineering, EECS Professor Richard Newton, who passed away on 2 January 2007. He was 55. Dean Newton was the driving force behind the CITRIS project and a great supporter of the new lab. Among his last acts he was able to conclude negotiations for naming the building as the Sutardja-Dai Hall and the new lab in it, the Marvell Nanofabrication Laboratory.

I could not be more pleased with the name of the new laboratory. Pantas Sutardja (PhD ’88), as an undergraduate, was my project mate when I worked on my MS degree in the current lab. His brother, Sehat was a graduate student at the same time, and a good friend; I attended Sehat’s wedding with Weili Dai when they both just finished their studies. Together the two brothers and their wives co-founded the extremely successful Marvell Semiconductor, Inc. We will be happy to call our new lab the marvelous Marvell Lab.

**Machine Shop**

The Machine Shop completed 290 jobs for 42 PIs in FY 2005/2006. The Shop has been successful in broadening its customer base and can maintain operations fully on recharge basis. By the end of 2006 the increase in the number of job requests warranted the addition of a 0.5 FTE. An up-to-date website, which lists capabilities, contact information, job request forms and general information such as photographs of completed jobs, gives customers an easy way to make contact. http://mshop-erso.berkeley.edu (see Ben Lake’s report).

We were all very pleased that Ben Lake, Machine Shop Sr. Superintendent received the prestigious Will Zeilinger Staff Excellence Award 2006. This award is presented annually to a staff member of the EECS Department or the Engineering Research Support Organization (ERSO) who exemplifies a spirit of *service cheerfully given for the general good*. For Ben – a well deserved award, indeed.

**Staff**

Microlab staff groups are organized along functional lines as described below. The Machine Shop operates independently, under the Microlab Operations Manager (see Table 1 - Staff Organizational Chart, Effective 2 January 2007).

The Microlab has been successful in retaining and developing staff well tuned to the laboratory’s needs. Cross training, back-ups and multiple responsibilities in all positions ensure that lab operations have broad coverage and problems are attended on a timely manner (Table 2).
**Microlab Operations (25 FTE)**
Katalin Voros, Operations Manager (7 direct reports)

1. **Equipment and Facilities (9 FTE)**
   - Bob Hamilton, Manager (7 direct reports)
   - 4 development engineers and 1 technician
     - Phill Guillery, Supervisor - 1 technician and student assistants
     - Mike Linan, Supervisor - 1 technician

2. **Process/Baseline (7 FTE)**
   - Sia Parsa, Manager
   - 3 development engineers, 1 research specialist and 4 student assistants

3. **Administration (4 FTE)**
   - Rosemary Spivey, Manager - 2 student assistants, 1 Administrative Assistant III
   - Susan Kellogg-Smith, Procurement Manager - 1 purchasing assistant

4. **Computer Support (3.5 FTE)**
   - Todd Merport, Supervisor
   - 3 Programmer/Analysts

5. **Technology Management: Bill Flounders**

   - Development staff employed by research groups: 2 FTE, 2 student assistants

   - Machine Shop (5 FTE)
     - Ben Lake, Senior Superintendent
     - 2 principal mechanics, 1.5 development technician and 0.5 administrative assistant

**Table 2 - Operational Staff Groups**

**Financial Resources**

Recharge accounts under Microlab management continued to be closely monitored for budgetary requirements throughout the year. Rosemary Spivey's report shows details and financial analysis for each unit (see Table 3 below).

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<thead>
<tr>
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<th>Expenditures</th>
<th>Performance</th>
<th>No. of PIs Billed</th>
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</thead>
<tbody>
<tr>
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<td>$2,946,320</td>
<td>1 % [+]</td>
<td>101</td>
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<td>Machine Shop</td>
<td>$ 353,339</td>
<td>$ 335,393</td>
<td>5 % [+]</td>
<td>42</td>
</tr>
</tbody>
</table>

**Table 3 - Recharge Accounts Summary**
30 June 2006

Both units are financially stable and again closed the fiscal year within recharge operation specifications.
III. COMMUNICATIONS & CONTROL

Membership
Microlab monthly membership was over 300 this past year, same as in preceding years. Overall, we dealt with 533 members during FY 2005/06 (see Table 4 below).

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<tr>
<th>Fiscal Year</th>
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<td>40,394</td>
<td>38,798</td>
</tr>
<tr>
<td>2005/2006</td>
<td>345</td>
<td>48,201</td>
<td>44,992</td>
</tr>
</tbody>
</table>

Table 4 - Microlab Utilization

Berkeley Microlab Affiliates (BMLA)
Industrial membership, BMLA is currently numbering 22.

Document Control & Training
The Microlab’s operating manual consists of 1342 pages, compiled in 159 chapters, available on-line from the web portal of the Microlab, http://microlab.berkeley.edu/.

We expend considerable effort to keep documentation up-to-date, because we expect lab members to use the on-line manual (and hard copy) as the first step in finding operational and process information. The oldest date on equipment operating manuals is 2003; this year we will update those with dates of 2004. In addition, 35 equipment have written test requirements for qualifications, which we also maintain and update regularly.

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Outreach
During the Summer of 2006 we again had two students participating in our Summer Internship for High School Girls program. They worked under the guidance of Daniel Queen, a graduate student labmember, who also worked part time during the Summer for the Microlab. We will continue the program this coming Summer, http://microlab.berkeley.edu/text/MLOutreach.html, for which we are currently interviewing candidates from Bay Area high schools.

IV. SUMMARY
The year of 2006 moved along smoothly in the Microlab. Steady state operations continued, along with anticipation of the realization of the new lab. Support from our PIs was strong throughout the year, which meant that we were able to end the fiscal year on target and did not have to raise fees. We are looking forward to our new lab to become reality.
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<tr>
<td></td>
<td>Susan Kellogg-Smith, Purchasing Manager</td>
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<tr>
<td>COMPUTERS:</td>
<td>Todd Merport, Computer Systems Manager</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>Jimmy Chang, Senior Development Engineer</td>
</tr>
<tr>
<td></td>
<td>Marilyn Kushner, Junior Development Engineer</td>
</tr>
<tr>
<td>TECHNOLOGY:</td>
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</tr>
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<td>BSAC ENGINEERING:</td>
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<td>Ben Lake, Cory Hall Machine Shop Sr. Superintendent</td>
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Microfabrication Laboratory 2007 Year-End Reports

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ABSTRACT

This document contains the 2007 Year-End Reports by the professional staff of the Microfabrication Laboratory. Together, these reports reflect the wide range of support staff provides to research campus wide and to instructional laboratories in EECS.

Activities of direct Microlab (ML) operations support staff, described in the sections Operations, Facilities, Administration, Computers, and Process/Baseline include 25 career employees and 10 undergraduate student assistants. The Machine Shop operates with 4 staff as an independent recharge unit. The Microlab supports 0.35 μm process technology on 6” (150 mm) silicon wafers. Equipment is also available for processing 4” and partial wafers.

The Microlab had an average monthly membership of 317 in 2007; participating PIs: 99. The Machine Shop completed 296 jobs from 47 PIs. The Berkeley Microlab Affiliates program (BMLA) comprises 26 industrial members. Detailed Microlab information can be found at http://microlab.berkeley.edu/.

K.V.

Table 1
MEMORANDUM

To: Professor Costas Spanos, Associate Dean for Research
   Professor Tsu-Jae King Liu, Microlab Faculty Director
From: Katalin Voros, Operations Manager
Subject: 2007 Year-End Report
Date: 23 January 2008

I. INTRODUCTION

Microlab operations continued in a holding pattern in 2007. Our goal was to keep operations moving smoothly, on target financially, in anticipation for the eventual move into the new facility. Construction of the Marvell Nanofabrication Laboratory is progressing on schedule, with a beneficial occupancy date, Spring 2009, as target.

This is the 21st year-end report I am submitting.

II. MANAGEMENT OF RESOURCES

Facilities

Microlab

- Bob Hamilton, Equipment and Facilities Manager, and Safety Officer of the Microlab, provides details on upgrades, installations, facilities maintenance and development in his report. Safety issues and HazCom improvements are also discussed.

Notable in 2007: Replumbing of nitrogen gas delivery lines such that Cory Hall laboratories are supplied separately from the Microlab; consolidation of equipment in room 145 into half of the space; move of the device characterization lab into 490 (both to make room for new faculty labs); major reliability improvement on the lam etchers and lam5 software upgrade; technics-e upgrade for improved 6" uniformity; replacement of the wafer saw with a donated unit, which also had problems; pumps database completed for improved pump management.

- Process engineering activities continued in high gear throughout the year. Sia Parsa, Process Engineering Manager and his staff detail process support and development activities.

Notable in 2007: mix and match photolithography using the ASML and GCA steppers, also with Standford's ASML tool; characterization of upgraded tools, technics-e, lam5, heatpulse4; process development for MEMS Exchange; and providing ETR service to other universities.


- Rosemary Spivey, Administrative Manager and her staff's reports include discussion of our financial status, accounts and members administration, purchasing, and inventory management. Recharge rate proposals were submitted on time for both the Microlab and the Machine Shop and scrutinized throughout the year by the Campus Recharge Rate Committee.

- Todd Merport, Computer Operations Manager describes systems maintenance, operational improvements and upgrades. Our computers and lab control software were maintained at the highest levels of uptime and integrity. There was another server upgrade which enabled retiring of our old argon server. Several migrations occurred at the same time, to distribute load more evenly.
In 2007 the *Mercury* project made good progress and the equipment user interface was finalized. We have made several decisions concerning what should be included in this part of the software and moved all the non-interactive details, such as reports and forms to web-based applications.

**New Laboratory**

Construction of the new engineering building, CITRIS, including our new lab, the Marvell Nanofabrication Laboratory, continues at a rapid rate. At this time the target for beneficial occupancy is Spring 2009, which means we can start moving in. We do not anticipate shutting down the Microlab for the move; however, there will be slow downs in selected areas. Planning is in progress. Details in Dr. Flounders’ report.

**Machine Shop**

The Machine Shop completed 296 jobs for 47 PIs in FY 2006/2007. Financially the Shop has been struggling to maintain operations fully on recharge basis. Because of the shift in the type of work requested of the Shop towards facilities maintenance and equipment repairs in situ, and the slow down of work for fine machining, staff had to be reduced by one principal laboratory mechanician by the end of 2007. Hopefully this will move finances of the Shop towards a positive outcome. The Shop’s website lists capabilities, contact information, job request forms and general information such as photographs of completed jobs, at [http://mshop-erso.berkeley.edu](http://mshop-erso.berkeley.edu). See Ben Lake’s report for details.

**Staff**

Microlab staff groups are organized along functional lines as shown in Table 1 and Table 2. The Machine Shop operates independently, under the Microlab Operations Manager.

The Microlab has been successful in retaining and developing staff well tuned to the laboratory’s needs. Cross training, back-ups and multiple responsibilities in all positions ensure that lab operations have broad coverage and problems are attended on a timely manner.

This past year we developed a 6-month internship program, at the end of which we were able to hire the intern into a Development Technician IV position.
<table>
<thead>
<tr>
<th>Equipment and Facilities (10 FTE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bob Hamilton, Principal Development Engineer, Manager</td>
</tr>
<tr>
<td>Joe Donnelly, Associate Development Engineer</td>
</tr>
<tr>
<td>David Lo, Associate Development Engineer</td>
</tr>
<tr>
<td>Jay Morford, Assistant Development Engineer</td>
</tr>
<tr>
<td>Danny Pestal, Assistant Development Engineer</td>
</tr>
<tr>
<td>Evan Stateler, Senior Development Engineer</td>
</tr>
<tr>
<td>Phill Guilory, Senior Development Engineer, Supervisor</td>
</tr>
<tr>
<td>Alan Briggs, Development Technician IV</td>
</tr>
<tr>
<td>Mike Linan, Associate Development Engineer, Supervisor</td>
</tr>
<tr>
<td>Brian McNeil, Development Technician V</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process/Baseline (8 FTE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sia Parsa, Principal Development Engineer, Manager</td>
</tr>
<tr>
<td>Kim Chan, Assistant Development Engineer</td>
</tr>
<tr>
<td>Jimmy Chang, Senior Development Engineer</td>
</tr>
<tr>
<td>Marilyn Kushner, Junior Development Engineer</td>
</tr>
<tr>
<td>Laszlo Petho, Associate Specialist – Baseline</td>
</tr>
<tr>
<td>Attila Szabo, Associate Specialist – MEMS</td>
</tr>
<tr>
<td>4 student assistants, 0.5 FTE each</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Administration (4 FTE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosemary Spivey, Administrative Analyst, Manager</td>
</tr>
<tr>
<td>Nancy Pesheste, Administrative Assistant III (0.5)</td>
</tr>
<tr>
<td>2 student assistants, 0.5 FTE each</td>
</tr>
<tr>
<td>Susan Kellogg-Smith, Buyer II, Procurement Manager</td>
</tr>
<tr>
<td>Adrienne Ruff, Administrative Assistant III</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Computer Support (3 FTE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Todd Merport, Programmer Analyst IV, Supervisor</td>
</tr>
<tr>
<td>Madeleine Leullier, Computer Resources Specialist II (0.75)</td>
</tr>
<tr>
<td>Olek Prokurowski, Programmer Analyst III</td>
</tr>
<tr>
<td>Changrui Yin, Programmer Analyst III (0.5)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technology Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bill Floinders, Principal Development Engineer, Manager</td>
</tr>
<tr>
<td>Xiaofan Meng, Senior Development Engineer – Cryoelectronics</td>
</tr>
<tr>
<td>Matt Wasilik, Associate Development Engineer – BSAC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Machine Shop (4.5 FTE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ben Lake, Senior Superintendent</td>
</tr>
<tr>
<td>Bob Amaral, Development Technician V</td>
</tr>
<tr>
<td>Robert Connolly, Development Technician V</td>
</tr>
<tr>
<td>Joe Gavazza, Principal Laboratory Mechanician</td>
</tr>
<tr>
<td>Nancy Pesheste, Administrative Assistant III (0.5)</td>
</tr>
</tbody>
</table>

Table 2 - Operational Staff Groups
Financial Resources

Recharge accounts under Microlab management continued to be closely monitored for budgetary requirements throughout the year. Rosemary Spivey's report shows details and financial analysis for each unit (see Table 3 below).

<table>
<thead>
<tr>
<th>Unit</th>
<th>Income</th>
<th>Expenditures</th>
<th>Performance</th>
<th>No. of PIs Billed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microlab</td>
<td>$2,880,295</td>
<td>$2,915,008</td>
<td>1% [-]</td>
<td>99</td>
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<tr>
<td>Machine Shop</td>
<td>$380,866</td>
<td>$398,085</td>
<td>4.5% [-]</td>
<td>47</td>
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</tbody>
</table>

Table 3 - Recharge Accounts Summary
30 June 2007

Both units are financially stable and again closed the fiscal year within recharge operation specifications.

III. COMMUNICATIONS & CONTROL

Membership

Microlab monthly membership was over 300 this past year, same as in preceding years. Overall, we dealt with 562 members during FY 2006/07 (see Table 4 below).

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Membership/Month</th>
<th>Lab Use-Hrs</th>
<th>Sp. Equip. Use-Hrs.</th>
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<tbody>
<tr>
<td>2000/2001</td>
<td>345</td>
<td>45,413</td>
<td>39,383</td>
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<td>2001/2002</td>
<td>315</td>
<td>39,288</td>
<td>36,738</td>
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<td>37,676</td>
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<td>40,823</td>
<td>34,692</td>
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<td>2004/2005</td>
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<td>40,394</td>
<td>38,798</td>
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<tr>
<td>2005/2006</td>
<td>345</td>
<td>48,201</td>
<td>44,992</td>
</tr>
<tr>
<td>2006/2007</td>
<td>317</td>
<td>45,696</td>
<td>45,699</td>
</tr>
</tbody>
</table>

Table 4 - Microlab Utilization

Berkeley Microlab Affiliates (BMLA)

Industrial membership, BMLA is currently numbering 26.

Document Control & Training

The Microlab’s operating manual consists of 1,391 pages compiled in 163 chapters, available on-line from the web portal of the Microlab, http://microlab.berkeley.edu/text/labmanual.html

We continue to expend considerable effort to keep documentation up-to-date. We expect lab members to use the on-line manual (and hard copy) as the first step in finding operational and process information; thus, we take care that the information is up-to-date. The oldest date on equipment operating manuals is 2005. In addition, 38 equipment have written test requirements for qualifications, which we also maintain and update regularly.
The task of writing new manuals, appending, updating existing ones with the latest information, is shared by staff and expert users of the tools, with process staff carrying most of the burden. Madeleine Leullier, Computer Resources Specialist, has the assignment of document control, i.e. editing and installation of both on-line and hard-copy manuals and written tests.

**Outreach**

During the Summer of 2007 we again had two students participating in our Summer Internship for High School Girls program. They worked under the guidance of Jimmy Chang, Process engineer, and Daniel Queen, a graduate student labmember, who also worked part time for the Microlab during the Summer. We will continue the program this coming Summer, http://microlab.berkeley.edu/text/MLOutreach.html, for which we have selected two applicants from Bay Area high schools.

**IV. SUMMARY**

The year of 2007 moved along smoothly in the Microlab. Steady state operations continued, along with anticipation of the realization of the new lab. Support from our PIs was strong throughout the year, which meant that we were able to end the fiscal year on target and did not have to raise fees. We are looking forward to our new lab to become reality.
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Microfabrication Laboratory 2008 Year-End Reports
ABSTRACT

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Activities of direct Microlab (ML) operations support staff, described in the sections Operations, Facilities, Administration, Computers, and Process/Baseline include 25 career employees and 8 undergraduate student assistants. The Machine Shop operates with 4 staff as an independent recharge unit. The Microlab supports 0.35 μm process technology on 6” (150 mm) silicon wafers. Equipment is also available for processing 4” and partial wafers.


K.V.

Microfabrication Laboratory
Staff Organizational Chart
January 2009

ML Faculty Director
M. Wu

W. Flounders
Technology Manager

K. Verus
Operations Manager

R. Hamilton
Equipment & Facilities Mgr.

BSAC
Directors

R. Spivey
Admin. Mgr.

S. K. Smith
Purchasing Mgr.

M. Leullier
Comp. Sys. Mgr.

T. Menport

S. Calko
A. Postkanski
C. Tian

M. Leullier
(0.75)

B. Lake
(Sup.)

Baseline Process
L. Pertho

Machine Shop
R. Amaral
J. Gavazza
N. Peshette (0.5)
A. Peterson

R. Hamilton
Equipment Engineering

J. Donnelly
D. Lo
J. Marfori
D. Peral
E. Stankel

Equipment Engineering

J. Donnelly
D. Lo
J. Marfori
D. Peral
E. Stankel

M. Liman
Projects Mgr.

B. McNeil

Facilities / Equipment

Facilities

P. Gallany
Projects Mgr.

A. Briggs
Students

K. Chan (0.5)
J. Chang
M. Kushner
Students

A. Ruff
N. Peshette (0.5)
Students

S. K. Smith
Purchasing Mgr.

B. McNeil

Facilities

A. Briggs
Students

M. Liman
Projects Mgr.
I. INTRODUCTION

While Microlab operations continued in a steady state mode in 2008, many staff activities revolved around planning for the move to the new lab. Our goal is to keep operations running smoothly, on target financially, in anticipation for the eventual transfer to the new facility. Opening celebration of the CITRIS Headquarters is scheduled for 27 February 2009; we do not have a date yet to access for preparatory work the empty space of the Marvell Nanofabrication Laboratory.

This is the 22nd year-end report I am submitting.

II. MANAGEMENT OF RESOURCES

Facilities

Microlab

- Bob Hamilton, Equipment and Facilities Manager, and Safety Officer of the Microlab, provides details on upgrades, installations, facilities maintenance and development in his report. Safety issues and HazCom improvements are also discussed.

Notable in 2008: A successful deployment and start up of the Cresstec e-beam writer; new Picosun atomic layer deposition system installation; major reliability improvement on the Edwards sputterer and e-beam evaporator; software upgrade and reliability improvements on the heatpulse rapid thermal processing systems; upgrade of the 6" resist coater control; pumps database enhancements with maintenance schedule and notification capability.

- Process engineering activities continued in high gear throughout the year. Sia Parsa, Process Engineering Manager and his staff detail process support and development activities.

Notable in 2008: Process characterization, manual writing, user training on the two new tools, cresstec e-beam writer and picosun ald; updating all manual chapters with dates older than 2006; completion of a major MEMS Exchange run, mask making and ETR services.

Baseline activities are an integral part of process engineering. The report on the latest 0.35 μm run came out in December 2008. See

http://www.eecs.berkeley.edu/Pubs/TechRpts/2008/EECS-2008-168.pdf

- Rosemary Spivey, Administrative Manager and her staff’s reports include discussion of our financial status, accounts and members administration, purchasing, and inventory management. Recharge rate proposals were submitted on time for both the Microlab and the Machine Shop and scrutinized throughout the year by the Campus Recharge Rate Committee.

Notable in 2008: The Microlab’s recharge budget passed the $3M mark, again in compliance for the 21st year in a row. During the past five years we managed this with only a cost-of-living increase in rates.

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• Todd Merport, Computer Operations Manager describes systems maintenance, operational improvements and upgrades. Our computers and lab control software were maintained at the highest levels of uptime and integrity.

Notable in 2008: Servers and client systems are of recent vintage, all equipped with security programs; major improvements in the pumps database.

In 2008 the Mercury project made excellent progress and it is ready for deployment in the Marvell Nanolab. Equipment control hardware for the new lab was purchased and tested with the Mercury interface. The MercuryWeb includes all interactive programs, such as reports and forms, reservations and equipment qualifications, along with management tools restricted to staff.

The Marvell Nanolab website was established and activated in December 2008, 

http://nanolab.berkeley.edu/

New Laboratory

Construction of the new engineering building, CITRIS, including our new lab, the Marvell Nanofabrication Laboratory is just about complete. Opening Celebration of the CITRIS Headquarters is scheduled for 27 February 2009. At this time we have no date for beneficial occupancy of the Marvell Nanolab.

We do not anticipate shutting down the Microlab for the move; however, there will be slow downs in selected areas. Planning is in progress. Details in Dr. Flounders' report.

Machine Shop  http://mshop-erso.berkeley.edu

The Machine Shop completed 387 jobs for 53 PIs in FY 2007/2008. Financially the Shop has been struggling to maintain operations fully on recharge basis. Staff reduction by one principal laboratory mechanician by the end of 2007 helped move finances of the Shop towards a less precarious situation; however, by March 2008 the account was still out of compliance. We submitted a corrective action plan which was accepted by the Campus Recharge Committee and the Shop closed the FY within the allotted out of tolerance limit. During the first half of the current FY Shop finances are on schedule to meet the budget.

See Ben Lake's report for details.

Staff

Microlab staff groups are organized along functional lines as described below. See Staff Organizational Chart next page and Table 1 below. The Machine Shop operates independently, under the Microlab Operations Manager.

The Microlab has been successful in retaining and developing staff well tuned to the laboratory's needs. Cross training, back-ups and multiple responsibilities in all positions ensure that lab operations have broad coverage and problems are attended on a timely manner (Table 2)
### Microlab Operations (25 FTE)

Katalin Voros, Principal Development Engineer, Operations Manager

#### 1. Equipment and Facilities (10 FTE)
- Bob Hamilton, Principal Development Engineer, Manager
- Joe Donnelly, Associate Development Engineer
- David Lo, Associate Development Engineer
- Jay Morford, Assistant Development Engineer
- Danny Postal, Assistant Development Engineer
- Evan Stateler, Senior Development Engineer
- Phill Guillory, Senior Development Engineer, Supervisor
- Alan Briggs, Development Technician IV
- Mike Linan, Associate Development Engineer, Supervisor
- Brian McNeil, Development Technician V

#### 2. Process/Baseline (7 FTE)
- Sia Parsa, Principal Development Engineer, Manager
- Kim Chan, Assistant Development Engineer
- Jimmy Chang, Senior Development Engineer
- Marilyn Kushner, Junior Development Engineer
- Laszlo Petho, Associate Specialist - Baseline
- Attila Szabo, Associate Specialist - MEMS
- 4 student assistants, 0.5 FTE each

#### 3. Administration (4 FTE)
- Rosemary Spivey, Administrative Analyst, Manager
- Nancy Peshette, Administrative Assistant III (0.5)
- 2 student assistants, 0.5 FTE each
- Susan Kellogg-Smith, Buyer II, Procurement Manager
- Adrienne Ruff, Administrative Assistant III

#### 4. Computer Support (4 FTE)
- Todd Merport, Programmer Analyst IV, Supervisor
- Susan Calico, Programmer Analyst II
- Madeleine Leullier, Computer Resources Specialist II (0.75)
- Olek Prokurowski, Programmer Analyst III
- Changrui Yin, Programmer Analyst III (0.5)

#### 5. Technology Management
- Bill Flounders, Principal Development Engineer, Manager
- Xiaofan Meng, Senior Development Engineer – Cryoelectronics
- Matt Wasilik, Associate Development Engineer – BSAC

#### Machine Shop (4.5 FTE)
- Ben Lake, Senior Superintendent
- Bob Amaral, Development Technician V
- Robert Connolly, Development Technician V
- Joe Gavaza, Principal Laboratory Mechanic
- Alan Peterson, Development Technician V (ML)
- Nancy Peshette, Administrative Assistant III (0.5)

**Table 1 - Operational Staff Groups**
Financial Resources

Recharge accounts under Microlab management continued to be closely monitored for budgetary requirements throughout the year. Rosemary Spivey’s report shows details and financial analysis for each unit. (See Table 2 below.)

<table>
<thead>
<tr>
<th>Unit</th>
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<th>Performance</th>
<th>No. of PIs Billed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microlab</td>
<td>$3,016,506</td>
<td>$3,060,169</td>
<td>1.4% [-]</td>
<td>98</td>
</tr>
<tr>
<td>Machine Shop</td>
<td>$361,626</td>
<td>$343,469</td>
<td>1.3% [-]</td>
<td>53</td>
</tr>
</tbody>
</table>

Table 2 - Recharge Accounts Summary
30 June 2008

Both units are financially stable and again closed the fiscal year within recharge operation specifications.

III. COMMUNICATIONS & CONTROL

Change in Directorship
At mid-year we were surprised by a sudden change in Microlab Faculty Directorship. Prof. Tsu-Jae King Liu, our Faculty Director since June 2000, was assigned the position of Assistant Dean for Research/ERSO Director, and Prof. Ming Wu took over as Microlab Faculty Director. We are fortunate and pleased that again one of our major PIs became the director, who cares for the well being of the lab as much as we do. We are looking forward to a long and successful cooperation.

Membership
Microlab monthly membership was over 300 this past year, same as in preceding years. Overall, we dealt with 491 members during FY 2007/2008. (See Table 4 below.)

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Membership/Month</th>
<th>Lab Use-Hrs</th>
<th>Sp. Equip. Use-Hrs.</th>
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</thead>
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<tr>
<td>2000/2001</td>
<td>345</td>
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<tr>
<td>2006/2007</td>
<td>317</td>
<td>45,696</td>
<td>45,699</td>
</tr>
<tr>
<td>2007/2008</td>
<td>325</td>
<td>48,021</td>
<td>47,156</td>
</tr>
</tbody>
</table>

Table 3 - Microlab Utilization
Berkeley Microlab Affiliates (BMLA)

Number of Industrial members, BMLA, in January 2009: 22

Document Control & Training


Outreach

During the Summer of 2008 we again had two students participating in our Summer Internship for High School Girls program. They worked under the guidance of Jimmy Chang, Senior Development Engineer, and Daniel Queen, a graduate student labmember, who also worked part time for the Microlab during the Summer. We will continue the program this coming Summer, for which we have selected two applicants from Bay Area high schools.

http://microlab.berkeley.edu/text/MLOutreach.html

IV. SUMMARY

The year of 2008 moved along smoothly in the Microlab. Steady state operations continued, with anticipation of the move to the new lab. Support from our PIs was strong throughout the year, which meant that we were able to end the fiscal year on target. Regrettably no funding is in place for the move.
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Microfabrication Laboratory 2009 Year-End Reports

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Microfabrication Laboratory 2009 Year-End Reports
ABSTRACT

This document contains the 2009 Year-End Reports by the professional staff of the Microfabrication and the new Marvell Nanofabrication Laboratory. Together, these reports reflect the wide range of support staff provides to research campus wide and to instructional laboratories in EECS.

Preparation for the move from the Microlab to the Nanolab took up a good part of the past year. Operations in the Microlab, however, remained up and running without any changes, until December, when the furnaces had to be shut down because of a duct fire.

This event caused a major move schedule change and a slow-down in processing for many projects. Equipment migration to the new lab began in late in the year.

Activities of Microlab (ML) and Nanolab (MNL) operations support staff, described in the sections Operations, Facilities, Administration, Computers, and Process/Baseline include 25 career employees and 8 undergraduate student assistants. The Machine Shop operates with 4 staff as an independent recharge unit. The Microlab supports 0.35 μm process technology on 6" (150 mm) silicon wafers. Equipment is also available for processing 4" and partial wafers.

The Micro/Nanolab had an average monthly membership of 257 in 2009; participating PIs: 72. The Machine Shop completed 338 jobs from 56 PIs. The Berkeley Microlab Affiliates program (BMALP) comprises 19 industrial members. Detailed information can be found at:


K.V.

Microfabrication Laboratory
Staff Organizational Chart
January 2010

ML Faculty Director
M. Wu

K. Varos
Operations Manager

W. Flauders
Marvell Nanolab Manager

M. Lealier (@75)

T. Merport
(Sup.)

S. Canino
A. Proskurowski
C. Yin

S. Pura

R. Spivey
Admin. Mgr.

R. Hamilton
Equipment & Facilities Mgr.

Marvell
Nanolab

BSAC Eng.
M. Wasilk
Cryo Eng.
X. Meng

E. Chou
A. Reff
N. Peschette (0.5)

S. K.-Smith
Purchasing Mgr.

Facilities
P. Guillory
Projects Mgr.
L. Altay
L. Luq
Students

Facilities / Equipment
M. Lisan
Projects Mgr.

Equipment Engineering
A. Briggs
J. Donnelby
D. Le
M. Martin
B. McNeil
J. Merford
D. Pestal
E. Stateler

Process Engineering
E. Chan (0.5)
J. Chang
M. Kushner
Students

Baseline Process
L. Perko

R. Amsard
J. Gravaza
E. Hester
N. Peschette (0.5)
A. Peterson

R. Lake
(Sup.)

Machine Shop

294
MEMORANDUM

To: T. King Liu, Associate Dean for Research
    M. Wu, Microlab Faculty Director
From: K. Voros, Operations Manager
Subject: 2009 Year-End Report
Date: 23 March 2010

I. INTRODUCTION

Microlab operations began to move to the new facility around the middle of 2009. Staff activities revolved around planning and executing the move, with the goal of maintaining operations in both locations. We are on target financially. Grand opening of the CITRIS Headquarters in Sutardja Dai Hall was held on 27 February 2009; we received access for preparatory work of the empty space of the Marvell Nanofabrication Laboratory in June 2009.

This is the 23rd Year-End Report that I am submitting.

II. MANAGEMENT OF RESOURCES

Facilities

Microlab

Bob Hamilton, Equipment and Facilities Manager, and Safety Officer of the Microlab, managed upgrades, installations, facilities maintenance and development. Safety issues and HazCom improvements were also addressed.

Notable in 2009:

- A successful, major upgrade of our nitrogen gas delivery system was completed, to provide service for the new lab, also in anticipation of separating Cory building service from the labs.
- We purchased a good used truck from Academic Facilities when they closed shop.
- Three process tools had significant upgrades: pqcrr for deposition of amorphous Si, the ultek e-beam evaporator equipped with new 3-hearth gun and scanning capability, and a metal etch and resist strip chamber addition was competed on the Centura.
- The Crestec e-beam writer was the first tool to move to the new lab. The Leo SEM was the second to move, after which it received a major upgrade (~$100K).

In October 2009 the Microlab experienced major equipment loss due to a duct fire in the VLSI area. All furnaces had to be shut down; 3 lam etchers were damaged beyond repair because of the deluge created by the fire sprinklers. Lab clean up was completed in a few days but operations were limping along for the rest of the month until the remaining exhaust duct was approved by the FM. Since the furnaces could not be turned on without the exhaust duct, plans were formed to move them to the new lab immediately. Thus, our well prepared plans for the execution of the lab move were turned upside down and basically a new moving plan had to be developed. Loss claims were submitted; Risk Management approved facilities repairs and replacement tools for the Lam etchers.
Sia Parsa reports on Process Engineering activities as these continued in high gear throughout the year.

Notable in 2009:

- Equipment characterized and processes developed for aluminum etch in the Centura; high temperature oxide (HTO) process developed in tystar17; tin oxide (ITO) films were deposited by evaporation and compared to those prepared by sputtering, with excellent results; new I-line resist and developer introduced and standard processes established.

- **CMOS Baseline**: a new run included process improvements, more aggressive design rules and new drop-in chips; report published, available at


- Wet sinks designs and specifications submitted (CAD layouts and .pdf) for the new lab; two newly installed sinks tested and cleaning processes characterized; student work-storage inventory made; standard runs made on evaporators and sputterers for comparison with runs after the move.

Rosemary Spivey, Administrative Manager reports on our financial status, accounts, members administration, purchasing, and inventory management. Recharge rate proposals were submitted on time for both the Microlab and the Machine Shop and the accounts scrutinized throughout the year by the Campus Recharge Rate Committee.

Notable in 2009:

- The Microlab's recharge income, $3.3 M, within budget, again in compliance, for the 22nd year in a row.

- Preparation and submission of job descriptions for new Career Compass job titles for non-represented career Microlab staff.

- Development of an eight-year, $1.2M deficit recovery plan for projected Microlab/ Nanolab transition, included in the Fiscal Year 2009/2010 Microlab Recharge Rate Proposal.

- Development of plans for the move of office staff, inventory and administration related activities.

Todd Merport, Computer Operations Manager describes systems maintenance, operational improvements and upgrades. Our computers and lab control software were maintained at the highest levels of uptime and integrity.

Notable in 2009:

- With the move of two tools into the new lab, Mercury passing real-time implementation with flying colors; seamless acceptance by lab members.

- Refining of Mercury client-server communication speed by a factor of two.

- Mapping and synchronizing system to pull data from the Microlab activity table into the Mercury database and processing of data with the Mercury accounting system; administrative staff highly satisfied with the new unified accounting system.

- Migration of shared information from the Microlab website to the Marvell Nanolab website and new information for the Nanolab; fully functioning Nanolab site.
New Laboratory, http://nanolab.berkeley.edu/

Partial beneficial occupancy for the Marvell Nanofabrication Laboratory was granted in June 2009, meaning that utilities, such as power, cooling water, exhaust ducting, specialty gases distribution to planned machine locations could start. This turned out to be a huge job, although completely of our choosing. Besides value engineering demands, the motivating factor in managing fit up with Microlab and Machine Shop staff, was the flexibility we needed in making last minute changes in tool locations. In spite of the enormous additional work load on staff, this was a good decision because, as we suspected, changes were needed to be made from the original tool layout almost from the beginning. Additionally, 14 new tools, with high utilities demands and complex installation needs, not specified early in the design process, had to be accommodated. The biggest hit we took from value engineering was the elimination from the construction plans of the 12 sinks and their installation. This was a hard decision, because the other option was to give up outfitting of the gas vaults with gas delivery systems meeting the latest code requirements.

By the end of 2009 the Marvell Nanolab, with two tools, the Crestec e-beam writer and the Leo SEM, was open for operations. A new Marvell lab orientation program, in addition to the standard Microlab orientation, was instituted for lab members who were qualified on these two tools. As fit up progressed, slowly other equipment were moved in; thus, since last December we are operating two labs. Our plans are to close the doors of the Microlab in Cory Hall in December 2010, 27 years after they were opened and 48 years after the first integrated circuits processing lab started in Cory Hall.

Machine Shop, http://mshop-erso.berkeley.edu

The Machine Shop completed 338 jobs for 56 PI's in FY 2008/2009. Financially it rebounded, made up the accumulated deficit and finished the FY on target. This was possible because of the steady stream of jobs coming in conjunction with the Micro/Nanolab move, and available staff recharge time was fully booked all year. One staff was added to concentrate on the lab move; on the occasions of major equipment moves, the entire Machine Shop staff is mobilized. Without the Shop we could not have taken on the new lab fit up and Microlab move.

Staff

Microlab staff groups are organized along functional lines as described below. The Machine Shop operates independently, under the Microlab Operations Manager.

The Microlab has been successful in retaining and developing staff well tuned to the laboratory's needs. Cross-training, back-ups and multiple responsibilities in all positions ensure that lab operations have broad coverage and problems are attended on a timely manner.
Microlab Operations Staff (26.5 FTE)
Katalin Voros, R&D Engineering Mgr 2, Operations Manager

1. Equipment & Facilities (11 FTE)
Bob Hamilton, R&D Engineer 5, Manager
Joe Donnelly, R&D Engineer 3
David Lo, R&D Engineer 3
Michael Martin, R&D Engineer 1
Jay Morford, R&D Engineer 3
Danny Pestal, R&D Engineer 3
Evan Stateler, R&D Engineer 4
Phill Giullory, R&D Engineer 4, Supervisor
Alan Briggs, Development Technician
student assistant, 0.5 FTE
Mike Linan, R&D Engineer 3, Supervisor
Brian McNeil, Development Technician

2. Process/Baseline (7 FTE)
Sia Parsa, R&D Engineer 5, Manager
Kim Chan, R&D Engineer 2
Jimmy Chang, R&D Engineer 4
Marilyn Kushner, R&D Engineer 2
Laszlo Petho, Associate Specialist – baseline
4 student assistants, 0.5 FTE each

3. Administration (4.5 FTE)
Rosemary Spivey, Administrative Officer 4
Nancy Peshette, Administrative Assistant III (0.5)
Susan Kellogg-Smith, Buyer II, Procurement Manager
Eric Chu, Administrative Assistant II
Adrienne Ruff, Administrative Assistant III

4. Computer Support (4 FTE)
Todd Merport, Applications Programmer 4, Supervisor
Susan Calico, Information Systems Analyst 2
Madeleine Leullier, Computer Resources Specialist II (0.75)
Olek Prokurowski, Applications Programmer 3
Changrui Yin, Information Systems Analyst 3 (0.5)

Bill Flounders, R&D Engineer 5, Manager
Xiaofan Meng, R&D Engineer 4 – cryoelectronics
Matt Wasilik, R&D Engineer 4 – BSAC

► Machine Shop (4.5 FTE)
Ben Lake, Engineering Technical Supervisor 2
Bob Amaral, Development Technician V
Edward Hester, Development Technician IV
Joe Gavezza, Principal Laboratory Mechanic
Alan Peterson, Development Technician V
Nancy Peshette, Administrative Assistant III (0.5)
Financial Resources

Recharge accounts under Microlab management continued to be closely monitored for budgetary requirements throughout the year. Rosemary Spivey's report shows details and financial analysis for each unit.

Table 3 - Recharge Accounts Summary
30 June 2009

<table>
<thead>
<tr>
<th>Unit Billed</th>
<th>Income</th>
<th>Expenditures</th>
<th>Performance</th>
<th>No. of PIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microlab</td>
<td>$3,269,871</td>
<td>$3,261,756</td>
<td>0.25%[+]</td>
<td>93</td>
</tr>
<tr>
<td>Machine Shop</td>
<td>$303,964</td>
<td>$304,806</td>
<td>0.28%[-]</td>
<td>58</td>
</tr>
</tbody>
</table>

Both units are financially stable and again closed the fiscal year within recharge operation specifications.

III. COMMUNICATIONS & CONTROL

Management

As the Chief Scientists for CITRIS, Banatao Institute@CITRIS Berkeley, Prof. Ming Wu continues to be the Faculty Director of the Microlab and now also the Nanolab. The Marvell Nanolab is a research facility of CITRIS, Center for Information Technology Research in the Interest of Society, http://www.citris-uc.org/research/emphases/nanotechnology, located in the new Sutardja Dai Hall, CITRIS Headquarters.

Dr. W. A. Flounders is the Manager of the Marvell Nanolab and was involved with it since the start of the design phase. He worked closely with campus and construction project management and saw to it that our plans and requests were taken into consideration all through design and construction. Bill participated in a series of difficult value engineering (i.e. cost cutting) negotiations, discussing available options with Microlab management. He was involved with acceptance and contributed to the punch list concerning the lab. Finally, mid-year we were allowed in to start fit-up activities and now Bill has his own lab to manage. Phill Guillory and his staff, providing most of the electrical and plumbing installations, were transferred, along with Mike Linan, specialty gas lines designer and installer, under Bill's supervision. This was the first step in staff transfer. Next, as we started to move process equipment, Bob Hamilton and his equipment engineering staff were transferred to Bill, early in 2010.

In the mean time, the Microlab, under my management in Cory Hall, is sustaining operations as usual, providing recharge income for both labs. Engineering staff supports both labs, retaining equipment and process responsibilities as these were before the move. Three additional temporary staff and extensive use of Machine Shop staff allows us to operate and move simultaneously. Systems remain in place until the site in the new lab is prepared and are taken down-only for the move and process testing afterwards. In spite of periodic equipment shut downs lab use remained close to previous levels and we were able to meet our financial goal: closing the fiscal year in compliance with Recharge Committee rules.
Membership & Training

Microlab monthly membership remained over 300 this past year, same as in preceding years. Overall, we dealt with 512 members during FY 2008/2009. Number of Industrial members, BMLA, in January 2010 – 18.

As soon as the new lab opened, a Nanolab orientation seminar was initiated, which all active members had to attend before admittance. This was offered every two weeks at first, then as needed, to allow students to work in both labs.

The Microlab’s operating manuals have been updated and transferred to the Nanolab website, http://nanolab.berkeley.edu/labmanual/labmantoc.html, along with the transfer of equipment.

Outreach

During the Summer of 2009 we had three students participating in our High School Summer Internships program. They worked under the guidance of Jimmy Chang, Senior Development Engineer, Daniel Queen, a graduate student labmember, and Jay Morford, R&D Engineer.

The final reports can be seen at http://microlab.berkeley.edu/text/MLOutreach.html.

IV. SUMMARY

The year of 2009 saw the opening of the new Nanolab while operations continued as usual in the Microlab. Support from our PIs was strong throughout the year, which meant that we were able to end the fiscal year on target. We are looking forward to complete the move of the Microlab into the Marvell Nanolab by the end of 2010.
I. INTRODUCTION

Microlab operations wound down completely in 2010 until the lab closed at the end of December. The new facility, the Marvell NanoLab, 10 years in the making, is a reality, fully operational under new management. Staff activities revolved around completing the move and, at the same time, maintaining operations in both the Microlab and the new Marvell NanoLab. We were on target financially, with a solid deficit recovery plan in place.

This is the 24th yearly summary report I am submitting.

II. MANAGEMENT OF RESOURCES

Facilities

Operation of Two Labs Simultaneously Through 2010

By the end of 2009 the Marvell NanoLab, with two tools, the Crestec e-beam writer and the Leo SEM, was open for operations. 2010 went by under the motto of “maintain - move - maintain”, meaning that tools were maintained and used by lab members until the very last minute just before the move, moved to the new lab site and brought up in the shortest time we were able to manage, then maintained as usual at the new site.

Because of budgetary constraints and the fact that complete shut down for the move was not an option, we managed fit up and move with Microlab and Machine Shop staff, with only a three temporary positions added. Because there was no time pressure and we were able to execute the move with in-house staff, bootstrapping gave us the flexibility we needed in making last minute changes in tool locations. All this placed an enormous additional work load on staff. However, we came through with flying colors.

A new Marvell lab orientation program, in addition to the standard Microlab orientation, was instituted for lab members who were qualified on the initial two tools. As fit up progressed slowly other equipment were moved in; thus, from 2009 December through December 2010 we were operating two labs. Our plans to close the doors of the Microlab in Cory Hall in December 2010 were realized, 27 years after the Microlab and 48 years after the first integrated circuits processing lab opened in Cory Hall.
Equipment

Bob Hamilton, Equipment and Facilities Manager, and Safety Officer of the Microlab managed overall maintenance while preparing and executing equipment moves with his staff and the assistance of the Machine Shop, under the direction of Bill Flounders, NanoLab Manager.

Tool Moves in 2010-11:

- 128 semiconductor processing tools moved or newly installed in the NanoLab.
- 28 tools have been retired or decommissioned.
- Chemicals and parts storage areas were relocated as equipment move progressed.
- Equipment engineering completed their move to the David Hodges office Suite, attached to the new Marvell NanoLab in Sutardja Dai Hall, in October 2011.
- At the end of 2010 the Microlab was officially closed, with 8 tools remaining.
- The last tool to be moved was the Centura, starting in May 2011.
- In June 2011 Microlab chemicals inventory had been zeroed out in the EH&S database.

Processing

Sia Parsa’s Process Engineering group also worked in high gear throughout the transition period. Sustaining processes in the Microlab, at the same time characterizing, and qualifying recently moved equipment and processes created double duty for all.

Notable in 2010-11:

- A new (refurbished) ASML 5500/300 DUV stepper was installed in the new lab. Extensive work, involving lens qualification, software upgrade, mask generation, manual writing, student training, was invested in this tool. The new ASML allowed us to survive the move with relatively few interruptions, because we were able to maintain and operate (although limping) the old ASML system in the Microlab.
- Moving the general lithography module, involving two GCA steppers, 3 contact aligners, wafer tracks, both, dispensers and developers, various ancillary equipment required careful planning and synchronization. The Process Engineering group had to be on top of each move and step in for characterization the minute a tool was in place.
- Each of the furnaces, atmospheric and LPCVD went through the same procedure of cleaning, calibration and test runs, until results were in spec.
- Sinks for which designs and specifications were submitted (CAD layouts and .pdf) for the new lab, were installed and outfitted with lab ware, new lab manuals written and the sinks released for lab member use.
- Processes in 3 new Lam etchers were developed and released.
- CMOS Baseline: a new run, CMOS 200, was started in the new lab as machinery and processes became available.
**Administration**

**Rosemary Spivey,** Administrative Manager reports on our financial status, accounts, members administration, purchasing, and inventory management. Recharge rate proposals the Microlab/NanoLab were submitted the account scrutinized throughout the year by the Campus Recharge Rate Committee.

**Notable in 2010-11:**
- The Microlab’s recharge income, $4M, within budget, again in compliance, for the 23rd year in a row.
- Development of an eight-year, $1.2M deficit recovery plan for projected Microlab/NanoLab transition, included in the Fiscal Year 2010/2011 Microlab Recharge Rate Proposal and approved.
- Deficit came in below projected, which means that it may be paid off in there years.
- Move of office staff, inventory and administration related activities accomplished.

**Computers**

**Todd Merport,** Computer Operations Manager describes in his report the challenges of establishing and maintaining two, basically independent yet connected, computer systems supporting the Microlab and the NanoLab.

Our original software system was developed when the Microlab was built, 25 years ago and although constantly upgraded, the Wand/Staff software was based on 1990’s computer technology and provided an alphanumeric user interface. Soon after we started planning for the new lab we also started designing and developing a new management system for implementation as the new lab came up.

After we spent some time and effort in a joint development program with the Stanford and MIT labs, we decided to go alone. We found that the proposed joint design was not flexible enough to adapt it to local needs and also because our requirement for a sophisticated accounting module as first or of very high priority was not supported by the others. Thus, it took us longer to develop the new system, but we had time. The new lab was still a hole in the ground when we started. By the time we moved in, the software was ready and running like a charm. Todd Merport named it Mercury.

**Notable in 2010-11:**
- With the move of semiconductor processing tools into the new lab, Mercury was further tested and debugged in real time. Lab members accepted it without skipping a beat.
- Client-server communication speed was further improved.
- Running two systems parallel and ending up with combined reports required clever and careful mapping and synchronizing. The administrative staff was highly satisfied with the new, unified accounting system.
- Several new modules were added, required by NanoLab management, such as on-line tests, automatic upload of equipment manual updates.
- Improvements and upgrades in the facilities management modules, both hardware and software.
Machine Shop
http://mshop-erso.berkeley.edu

The Machine Shop completed 324 jobs for 56 PI’s in FY 2009/2010 and 329 jobs for 54 PIs in FY 2010/2011. Financially it rebounded, made up the accumulated deficit and finished the FY on target. This was possible because of the steady stream of jobs coming in in conjunction with the Microlab/NanoLab move, and available staff recharge time was fully booked all year. Two temporary staff, 6 months each, were added to facilitate the NanoLab move; on the occasions of major equipment moves, the entire Machine Shop staff was mobilized. (NanoLab jobs were billed at the standard recharge rate.) Without the Shop we could not have taken on the new lab fit up and Microlab to NanoLab move.

► Machine Shop Staff: (5.5 FTE)
   Ben Lake, Engineering Technical Supervisor 2
   Bob Amaral, Development Technician V
   Chris Bowen, Development Technician IV (temp.)
   Edward Hester, Development Technician IV (temp.)
   Joe Gavazza, Principal Laboratory Mechanician
   Alan Peterson, Development Technician V
   Nancy Peshette, Administrative Assistant III (0.5)

Staff

The last organizational chart of the Microlab, before the final transfer, can be seen on the Microfabrication Laboratory Archive Portal – In operation: 1983-2010, http://microlab.berkeley.edu/people/orgchart.htm.

Total number of staff increased by 6.5 FTE, from the end of 2009 to 2011, for the period of the move. Of these, 3 were temporary employees, for 6 months each, one was career, and the rest were students.

Microlab/NanoLab Operations Staff (33 FTE)
A. W. Flounders, R&D Engineering Mgr 2, Technology and Operations Manager, NanoLab
Katalin Voros, R&D Engineering Mgr 2, Operations Manager

1. Equipment and Facilities (14.75 FTE)
   Bob Hamilton, R&D Engineer 5, Manager
   Alan Briggs, Development Technician IV
   Joe Donnelly, R&D Engineer 3
   David Lo, R&D Engineer 3
   Brian McNeil, Development Technician V
   Jay Morford, R&D Engineer 3
   Evan Stateler, R&D Engineer 4
   Danny Pestal, R&D Engineer 3, Supervisor
   Michael Martin, R&D Engineer 1
   Phill Guillory, R&D Engineer 4, Supervisor
   Lou Ahtty (temp)
   Louis Lucq (temp)
   3 student assistants, 1.75 FTE
   Mike Linan, R&D Engineer 3, Projects Mgr.
2. Process/Baseline (8 FTE)
   Sia Parsa, R&D Engineer 5, Manager
   Kim Chan, R&D Engineer 2
   Jimmy Chang, R&D Engineer 4
   Marilyn Kushner, R&D Engineer 2
   Laszlo Petho, Associate Specialist – baseline
   4 student assistants, 0.5 FTE each
   Xiaofan Meng, R&D Engineer 4 – cryoelectronics

3. Administration (5 FTE)
   Rosemary Spivey, Administrative Officer 4
   Nancy Peshette, Administrative Assistant III (0.5)
   Susan Kellogg-Smith, Buyer II, Procurement Manager
   Eric Chu, Administrative Assistant II
   Adrienne Ruff, Administrative Assistant III
   student assistant, 0.5 FTE

4. Computer Support (3.25 FTE)
   Todd Merport, Applications Programmer 4, Supervisor
   Madeleine Leullier, Computer Resources Specialist II (0.75)
   Olek Proskurowski, Applications Programmer 3
   Changrui Yin, Information Systems Analyst 3 (0.5)

Financial Resources

The Microlab recharge account continued without change during the transfer period and became the NanoLab account effective 1 July 2010. This process was carried out under the advisement, approval and review by the Campus Recharge Rate committee.

There were no funds available for the move; however, we were allowed to submit to the Recharge Committee, an equipment depreciation reserve and payment plan. Additional expenses were covered from industrial donations, fund raising and BMLA/BNLA membership fees and surcharges. Because lab use remained high during the move and even increased somewhat after the transfer was completed, we were able to meet the NanoLab’s scheduled obligation to the reserve fund at the end of FY 2010/11.
Recharge Account Summary
30 June 2011

<table>
<thead>
<tr>
<th>Microlab/NanoLab</th>
<th>Income</th>
<th>Expenditures</th>
<th>Performance</th>
<th>PIsBilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY 2009/10</td>
<td>$ 3,204,031</td>
<td>$ 3,321,822</td>
<td>3.7% [-]</td>
<td>90</td>
</tr>
<tr>
<td>FY 2010/11</td>
<td>$ 4,039,102</td>
<td>$ 3,861,049</td>
<td>4.4% [+ ]</td>
<td>93</td>
</tr>
<tr>
<td>6/30/2011 Payment to Reserve Fund.</td>
<td>$ 178,000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Microlab/NanoLab transition expenditures totaled $ 3,177,948. A deficit of $416,252 was incurred in the Equipment Reserve Fund, which will be paid off over the next three years. (See NanoLab Operations Financial Report, Fiscal year 2010/2011, by Rosemary Spivey.)

III. COMMUNICATIONS AND CONTROL

Management

As the Chief Scientists for CITRIS, Banatao Institute@CITRIS Berkeley, Prof. Ming Wu continued as the Faculty Director of the Microlab and the NanoLab. The Marvell NanoLab is a research facility of CITRIS, Center for Information Technology Research in the Interest of Society, (http://www.citris-uc.org/research/emphases/nanotechnology,) located in a new engineering building, the Sutardja Dai Hall, which serves as CITRIS Headquarters.

Dr. W. A. Flounders, now the Executive Director of the Marvell NanoLab, was involved with the design and construction of the new lab and worked tirelessly with campus project management and the general contractor to ensure that our requests were taken into consideration. Bill participated in a series of difficult value engineering (i.e. cost cutting) negotiations, discussing available options with Microlab management. He was involved with acceptance and contributed to the punch list concerning the lab. Finally, mid-year 2009 we were allowed in to start fit-up activities. Phill Guillory and his staff, providing most of the electrical and plumbing installations, were transferred, along with Mike Linan, specialty gas lines designer and installer, under Bill’s supervision. This was the first step in staff transfer. Next, as we started to move process equipment, Bob Hamilton and his equipment engineering staff were transferred under NanoLab management, starting in April 2010. Computer staff moved early September, process staff at the end of September, inventory and office staff in October 2010. All Microlab staff had been transferred to NanoLab management, effective 15 October 2010.

During the move and transfer period, the Microlab, under my management in Cory Hall, was sustaining operations as usual, providing recharge income for both labs. Engineering staff supported both labs, retaining equipment and process responsibilities same as before the move. Three additional temporary staff and extensive use of Machine Shop staff allowed us to operate and move simultaneously. Systems remained in place until sites in the new lab were prepared and were shut down only for the move and process testing afterwards. In spite of the disruptions lab use remained close to previous levels and we were able to meet our financial goal: closing the fiscal year in compliance with Recharge Committee rules.
Membership and Training

Microlab/NanoLab monthly membership remained high, 336, during the move. Overall, we dealt with 469 members during FY 2009/2010 and 474 during FY 2010/2011. The number of industrial members, BMLA, was 18 in January 2010, and we had 21 BNLA members in June 2011.

Starting January 2010 as the new lab opened with a few tools, a NanoLab orientation seminar was initiated, which all active members had to attend before admittance to the new lab. This was offered every two weeks at first, then as needed, to allow students to work in both labs. As of January 2011 we offered only Marvell NanoLab orientations in Sutardja Dai Hall.

Along with the transfer of equipment the Microlab’s operating manuals have been updated and transferred to the NanoLab’s website, http://nanolab.berkeley.edu/labmanual/labmantoc.html. Manuals of decommissioned equipment over the years are archived at a site restricted to staff.

Outreach

Because of the lab move the Summer High School Internship program was suspended for the Summer of 2010. We had two students participating in 2011. They worked under the guidance of Jimmy Chang and Kim Chan, R&D Engineers of the NanoLab. Final reports by the interns can be seen at http://microlab.berkeley.edu/text/participants.html.

Closing Ceremony

In April 2011 we held a Microlab Closing Ceremony and NanoLab Open House. Master of Ceremonies was former Microlab Faculty Director and EECS Chair, Prof. Costas Spanos. Prof. David Hodges talked about the Integrated Circuits Lab (The Old Lab) 1962 – 1982; Prof. Tsu-Jae King Liu, immediate past Microlab Faculty Director, and Katalin Voros, Microlab Manager from 1983 – 2010, discussed successes and operations in the Microlab during the past 27 years. Katalin Voros received a Chancellor’s Outstanding Staff Award 2011. Then, Prof. Ming Wu, NanoLab Faculty Director and Dr. W. Flounders, NanoLab Manager, invited the audience for a tour of the new lab, with a reception afterwards.

IV. SUMMARY

The years of 2010-11 saw the opening of the new NanoLab while operations continued as usual in the Microlab. Support from our PIs was strong throughout the year, which meant that we were able to end the fiscal year on target. We have successfully completed the relocation of the Microlab into the Marvell NanoLab by the end of 2010. The move was done by lab staff, with heavy reliance on the Cory Hall Machine Shop; financed by the Microlab/NanoLab budget and took 18 months. We managed a smooth transfer, without disruption to ongoing research projects. We can all be proud of our beautiful new Marvell NanoLab in Sutardja Dai Hall – the third reincarnation of the first IC lab built in Cory Hall in 1962.
2011-2012 Year End Report

To: T. King Liu, NanoLab Faculty Director (Interim)
From: K. Voros, R&D Engineering Manager
Subject: June 2011 – July 2012 Report
Date: 31 August 2012

I. INTRODUCTION

Operations in the Microlab ceased at the end of December 2010 and the facility closed down permanently in mid-2011. The last tool was moved to the new facility, the Marvell NanoLab in Sutardja Dai Hall, in May 2011. I remained in my office in 406 Cory Hall until August 2012, when preparations began for the construction of Prof. Spanos’ new research center. I continue managing the Cory Hall Machine Shop from 201 Cory. This past year I worked on various ancillary projects, on a half time basis with the NanoLab.

This is the 25th and final yearly summary report I am submitting.

II. MANAGEMENT OF RESOURCES

Microlab Open Space

After the closing of the Microlab and the removal, during 2011, of the final 8 tools, I worked on clearing the space for the next project. Over 40 boxes of excess chemicals were submitted to and disposed of through standard procedures of the Campus Office of Environment, Health and Safety. A new small lab was constructed in the NE corner of the former Microlab for Prof. A. Arias’ research in printed electronics. After the walls and air handling were completed by outside contractors, Cory Hall Machine Shop staff installed equipment which Prof. Arias brought with her from Xerox PARC. The lab is run by Prof. Arias and her students; equipment repair/maintenance is performed by Machine Shop staff through job requests.

At this time most of the space previously occupied by the Microlab is empty. 406 Cory, the Microlab’s main office and the former lab lobby had been cleared in preparation for the construction of Prof. Spanos’ new Center for Research in Energy Systems Transformation – CREST, http://crest.berkeley.edu/.

I was assigned a new office, 201 Cory Hall, into which I moved, along with 27 years of Microlab documentation, at the end of August 2012.
Projects Related to the NanoLab

CMOS Baseline
After the construction of the Microlab was completed in 1983, the first CMOS process run was started as an EE290 graduate class project in the Fall 1983 semester and completed in Spring 1984. This very first baseline run drove equipment installation priorities and served as a starting platform for the continuous baseline activity through the life time of the Microlab.

In preparation for the startup of the NanoLab we applied the same methodology and used the baseline process to qualify the new lab for CMOS processing. The baseline run CMOS200 was started when the move of the Microlab from Cory Hall to Sutardja Dai Hall was not yet fully completed, and served as a basis for prioritizing equipment moves. Each tool needed had to be re-characterized after the move, prior to committing the baseline wafers to processing in that tool. Processes in equipment which were replaced with later models at the time of the move, were redeveloped. Because of time constraints only one wafer could be completed through metallization and tested; however, in spite of the upheaval, working CMOS transistors were produced. The appointment of baseline engineer, visiting research specialist, A. Szűcs, expired in December 2011 and she left to continue her studies in Grenoble, France. Anna submitted her final report in February 2012, which we reviewed with Sia Parsa, Process Engineering Manager, and published it as EECS Technical Report No. UCB/EECS-2012-118.

Computers
Todd Merport, Computer Operations Manager of the Microlab retired in March 2012. By this time Olek Proskurowski, Applications Programmer/Analyst was ready to take over management of computer operations, which he did without missing a beat. The two of them submitted a paper titled *Mercury Lab Management Software*, to the UGIM 2012 symposium (described below).

Because the attendees of the symposium comprised mostly of lab managers, i.e. users of information systems and not computer technologists, I gave the talk from the users’ point of view. Because I was involved with the design and development of the new Mercury system from the beginning I had sufficient background for giving this talk.

Our original software system was developed when the Microlab was built, 29 years ago. Although constantly upgraded, the Wand/Staff software was based on 1980’s computer technology, with an alphanumeric user interface. Soon after we started planning for the new lab we also started designing and developing a new management system for implementation as the new lab came up.

After we spent some time and effort in a joint development program with the Stanford and MIT labs, we decided to go alone. We found that the proposed joint design was not flexible enough to adapt it to local needs easily and also because our requirement of a sophisticated accounting module as first or of very high priority was not supported by the others. Thus, it took us longer to develop the new system, but we had time. The new lab was still a hole in the ground when we started. By the time we moved in, the software was ready and running like a charm. Todd Merport named it Mercury.
NanoLab Summer High School Internship Program
After one year of hiatus during the lab move we had two students participating in 2011 and three in 2012. They worked under the guidance of R&D Engineers in the NanoLab.

With Professor King Liu’s sponsorship we started the intern program in 2001 and ran it first every two years. After 2005 we ran it every year (with the exception of 2010). The call for applications is posted on our website. The selection process begins in January and out of the usual 20-25 applicants I invite the top five for an interview. The girls are highly accomplished and when selected, work enthusiastically on their projects. They describe their work and what they have learned in a computer-aided presentation at the end of 8 weeks. Final reports are posted at http://microlab.berkeley.edu/text/participants.html.

Machine Shop
http://mshop-erso.berkeley.edu

The Machine Shop completed 380 jobs for 56 PI’s in FY 2011/2012. Financially it finished the FY on target. This was possible because of the steady stream of jobs coming in in conjunction with completing the Microlab/NanoLab move, and available staff recharge time was fully booked all year. As the jobs in conjunction with the move wound down the Shop adjusted gradually to service an increased number of outside customers. At this time about 50% of the jobs come from non-NanoLab related orders, from all over Campus, including the recently opened Helios building. Development of Benjamin Lake into a fully capable engineering technical supervisor/manager is well underway.

Machine Shop Staff
Ben Lake, Engineering Technical Supervisor 2
Lou Ahtty, Development Technician V (0.5)
Bob Amaral, Development Technician V
Joe Gavazza, Principal Laboratory Mechanician
Bill King, Development Technician IV (temp.)
Alan Peterson, Development Technician V (on disability leave)
Nancy Peshette, Administrative Assistant III (0.5)

Machine Shop Summer High School Intern Program
In the Summer of 2012 we started an internship program, again with the sponsorship of Professor King Liu, in the Cory Hall Machine Shop. I developed this program based on our Microlab internship model, which we ran successfully for 10 years. In the Shop one high school student worked with alternating staff on various jobs. First he took the NanoLab orientation seminar, then received shop safety instructions from Ben Lake. He became hands-on familiar with major machine shop tools. This was a new experience for staff also; they enjoyed teaching the intern who was actually a good help in many areas. The Shop will continue the program if sponsoring faculty can be found in the coming years.
COMMUNICATIONS AND SPECIAL PROJECTS

Microlab/NanoLab External Communications

Effective January 2011 the Microlab’s web portal was renamed to:

Microfabrication Laboratory Archive Portal
In operation: 1983-2010
University of California, Berkeley

For current laboratory information, please go to The Marvell Nanofabrication Laboratory site.

In spite of the Archive designation and the hyperlink to the NanoLab site, I regularly receive inquiries about the capabilities of the lab, about BMLA membership details, process questions and various other requests for information. Most of these questions I can answer but some I forward to NanoLab management for up-to-date information. The frequency of the inquiries is declining and I suspect that after a year of closing the Microlab these will cease.

I gave a talk at the UGIM 2012 Symposium (see below) titled Financial Analysis of a Successful Multi-User Academic Laboratory – my favorite topic.

EE298-12 Solid State Technology and Devices Seminars

In 1993 Prof. Hu asked me to organize the Solid State Devices and Technology Seminar series, starting with the Spring 1994 semester. These seminars are important for student lab members as a seminar class and also for laboratory staff development. I accepted and continue to carry out this assignment; in 19 years we have had an invited speaker every Friday to give a seminar on all topics related to semiconductor research and industry.

Conference Organizing

For the past 15 years I have been active in the University, Government, Industry Micro/Nano Symposium, UGIM, a biennial meeting of university lab managers. I have been on the Steering Committee for the past 10 years; thus, Dr. Flounders and I felt comfortable to propose that we hold the Symposium in 2012 here at Berkeley. We also wanted to showcase our new laboratory.

At about the same time, Prof. King Liu accepted organizing the International Silicon-Germanium Technology and Device Meeting (ISTDM), also in Berkeley in 2012. As the two conferences were to be held only about a month apart, she asked me to help out with ISTDM.

Many of the organizational aspects were similar; thus, I went into high gear learning about conference organizing. Since both conferences were sponsored by the Electron Devices Society of the IEEE, I studied the publication by the IEEE Conference Business Services, How to Organize an IEEE Conference. Also I took a Berkeley Extension workshop, Special Events Planning. From both of these I learned that conference organizing is common sense
and lot of “legwork.” It turned out to be just that. Lots and lots of tiny details to take care of which do not show but if missed – a major problem. However, great team work made each conference a success.

- For both conferences we went with Active Network’s RegOnline for registration and fee collection. (http://www.regonline.com/) Rosemary Spivey obtained two separate UCB chart strings, into which registration fees were transferred and from which invoices were covered.
- We used IEEE Conference Publication Services in both cases, for on-line paper submission, final book product, and IEEE Xplore submission.
- Books were printed locally by Copy Central, which gave the best price, a good looking product, and delivered to the conference sites.

**ISTDM 2012**
Details to be researched and developed were: venue, contract review, budget, social events, transportation, board of directors events, meeting rooms, audio/video systems availability, poster sessions, food menu, beverages, postcards, decorations, badges, hand-outs, event staffing, website creation and maintenance.

This 3-day conference was held at the Hotel Shattuck Plaza in downtown Berkeley. A poster session was held at the Berkeley Wireless Center (BWRC), a sponsor of the conference, across the street from the hotel. Also, one of the directors’ meetings was held there; the other one was at the hotel, prior to the conference opening. The conference held plenary talks in the mornings and parallel sessions each afternoon. There was an evening session on Monday and a banquet on Tuesday. Social events included a Bay cruise from the Berkeley Marina.

**UGIM 2012**
Details to be researched and developed were: venue, hotels list, budget, sponsors, conference program, session chairs, invited speakers, social events, lab tours, transportation, meeting rooms, audio/video systems availability, lunch locations, banquet, food menu, beverages, postcards, decorations, badges, hand-outs, event staffing, website creation and maintenance, pre-conference meeting of the Steering Committee.

We held UGIM 2012 in Sutardja Dai Hall, Banatao Auditorium, the Kwamme atrium and outside patios. The banquet was in the Great Hall of the Durant Hotel. A very successful Bay cruise dinner was arranged by Dr. Flounders who found industrial sponsors to support UGIM 2012. Great team work from NanoLab staff made the event a success, including a positive ending financially. The surplus is forwarded to the next meeting site. We received many kudos for organizing UGIM 2012.

**SUMMARY**

The 25 year span, between my first and 25th Year End Reports includes the full life of the Microlab, from beginning to end. It was my good fortune to have had the chance to help develop this operation from a barely started facility into one of the best university microfabrication labs in the world. I will describe this development in a more detailed report, as my last project before retirement.

**END OF APPENDIX**