Survival of the Fit-up

The Evolution of the Berkeley Microlab

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***Abstract*— In July, 2009, the University of California, Berkeley commissioned a new 15,000 square foot clean room – the Berkeley Marvell Nanofabrication Laboratory. This laboratory will be the successor to The Berkeley Microlab. All equipment from the Berkeley Microlab and several satellite laboratories is being relocated to the new facility. Lab management has defined an 18 month tool-by-tool migration process; not a lab shutdown and restart to minimize equipment downtime for the 500 plus researchers that use the facility. All necessary tool connections are prepared in the new lab then a tool is moved, restarted, qualified and released for general use in the new facility. This translates into running two operations during this transition process. The construction project delivered a clean room with house utilities distributed throughout all chases but no utility drops for tool connection. Selected strategies to facilitate this effort such as crimp tooling for house utility and exhaust connections, flex conduits and extra length cabling, will be presented and discussed. The new Marvell Lab will maintain and expand the Berkeley Microlab tradition of a professionally managed, self supporting, shared laboratory resource open to all academic researchers and selected industry members. The lab operates on a recharge basis with transparent billing, assuring the lowest possible barrier to entry.**

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I. INTRODUCTION

The University of California, Berkeley takes great pride in the fact that it opened the first university integrated circuit lab in 1962. This modest 1200 ft^2 facility utilized ¾ - 2 inch silicon wafers (cut and polished in-house), spin on dopants, rubylith masks, manual alignment and thermal evaporators to construct a wide range of IC devices. As Professor David Hodges, former Dean of the Berkeley College of Engineering describes, “It was pretty primitive in those days… but we got some working circuits and we learned an awful lot.” This facility was upgraded and expanded in 1982 to a 10,000 ft^2 Class100 cleanroom – The Berkeley Microlab. Since 1983, the Microlab has supported over 2300 graduate and post-graduate researchers and more than 90 local companies.[1]

The Microlab has now served the Berkeley micro/nanofabrication research community for more than 25 years. Laboratory utility systems are all operating at or in excess of their design capacity and the lab has been in need of overhaul and upgrade for many years. In 2005, UC Berkeley broke ground for a new California Institute of Science and Innovation -The Center for Information Technology Research in the Interest of Society - CITRIS. For a compelling introduction to the societal scale issues CITRIS research has already been addressing, see: http://www.citris-uc.org/. A key component of the CITRIS headquarters building is the Berkeley Marvell Nanofabrication Laboratory – the successor facility to the Berkeley Microlab. After more than eight years of fund raising, design, planning, demolition and construction, the Marvell Lab was finally released for occupancy in July, 2009.

II. EQUIPMENT FIT UP

A. Utility Distribution

Early in the new lab design and planning stage, it was decided that the NanoLab staff, not the construction project, would take on fit up of each individual tool. This decision was based upon several factors. First, the tool list of a university clean room is dynamic. Equipment purchases often depend on Federal grants; faculty research directions change which necessitates equipment change; and, vendor donations vary with the economic climate. If the construction project provided detailed plumbing design and installation for every tool each time there was a change to the tool list, the project would incur significant change order fees; or, lab staff would end up removing or modifying newly installed fixtures upon move in. Second, lab experience has shown that manufacturers often over specify utility requirements for their equipment to insure a tool is never lacking a utility which might restrict productivity or result in liability issues for the equipment manufacturer. General and specialty contractors will follow these excessive demands even if lab management is willing to accept policy or engineering controls that would enable a more modest specification.

For example, a tool vendor may define an electrical need for a cluster tool at 300amps to enable running multiple chambers of a cluster tool simultaneously; but, lab staff might prefer a 100amp service, well aware that only a single chamber will be run at a time. In a lab with over 100 complex pieces of equipment, over rating utility demands for each equipment quickly results in excessive lab wide utility systems and an unaffordable utility distribution network. Third, final equipment connections can not really be tested and verified until the tool is in place. This means the general and specialty contractors for all lab utilities would have to remain mobilized and in-house until all tools were connected. Keeping specialized trades ‘on-call’ while staff moves and connects equipment is simply not tenable for cost and logistics reasons.

1. Select introduction materials are excerpted from 2006 UGIM Conference Proceedings by the same lead author.

The construction project delivered a clean room with house utility systems in the mechanical support space and most house utilities distributed overhead of the service chases; but, utility 'drops' needed for each tool were not provided. There was no electrical distribution beyond 208V or 480V panels located at the head of each chase. There was no specialty gas distribution piping beyond valve manifold boxes located remotely from the tools. For the first two months, efforts focused upon installation of orbitally welded stainless steel tubing for specialty gases and the distribution of AC power from electrical panels via 6" square electrical troughs that run the length of each chase. With this work completed, there was the ability to drop any needed utility, at any location. Equipment installs could now begin.

B. MEPC Utility Sequencing

To minimize equipment downtime, tool connections were prepared in the new lab. Then, a tool was taken offline in the existing facility, moved, wiped down, and reconnected in the new lab. After reconnect, the tool was restarted, qualified and released for general use. Utility preparation in the new lab generally followed a sequence of mechanical(M), then electrical(E), then plumbing(P) followed by computer connect (C). The MEPC sequence was selected to minimize installation conflicts; i.e., put the biggest and least flexible elements in first then add the smaller and more flexible systems after. Mechanical (primarily exhaust) connections are largest diameter (1.5" to 8") and most rigid (epoxy (tnemic) coated galvanized or stainless tube). Electrical drops are typically 1" EMT (electrical metallic tubing) or <1" flexible liquid tight conduit that terminate at large (4" x 6") fused safety disconnect switches at wall locations behind a tool. Plumbing connections are 3/4" and smaller and a combination of rigid and flexible tubing depending upon fluid being delivered. Finally, computer connections for equipment access control and status monitoring are flexible Ethernet or simple twisted pair cabling. Regular review meetings among M, E, and P trade leads were critical.

The actual work was never as perfectly sequenced as the written description suggests. Often times it was more efficient to prepare an area for several tools at once. However, the main themes of MEPC sequencing to minimize utility conflicts and, tool-by-tool movement to minimize equipment downtimes were followed.

III. Specialty Piping Materials and Joining Systems

Laboratory staff reviewed several new materials and joining systems to facilitate equipment installations. Factors considered were cost, ease of installation, ability to serve multiple utilities with a single material, ability to install without 'hot work' permits and cost. Yes, cost was considered at least twice.

For more than two decades, Microlab staff has used flexible polyethylene or nylon tubing for most tool final utility connections. This polymer tubing has been used in all high purity applications without issue providing significant cost savings over industry selected polymers such as pvdf. Flexible tubing is convenient and cost effective; however, it lacks aesthetics and is a problem when lines need to be traced. Utility distribution can quickly become unprofessional, a 'tangle of spaghetti'. To bring utilities to equipment cost effectively, accelerate organized installations and avoid the need to solder or braze, lab management selected two Nibco® crimp connection systems.

The first was the Nibco® Pressystem® which enables flameless installation of copper pipe sizes ½" to 2". This system was used to bring PCW (process cooling water) and ICW (industrial cold water) to distribution manifolds located at less than 42" height. This is described as 'crimp copper' in Table 1. The second was the Nibco® Dura-pex® system which uses copper crimp rings and rigid or flexible cross linked polyethylene (pex) tubing from 3/8" to 1". This system was used to bring DI (deionized water), PV (process vacuum), CDA (compressed dry air), house N_2 and house O_2 to distribution manifolds. This is described as 'crimp pex-c' in Table 1.

Lab management debated before accepting pex-c for deionized water service. Ppm or ppb organic contamination for utilities such as PV or CDA are not issues. Organic leaching from fully cured thermoplastics such as pex which are handling room temperature house gases such as N_2 or O_2 is also unlikely. However, organic leaching from various polymer materials into water has been well documented e.g., drinking water bottles. After consideration, this possibility was considered remote with the DI distribution piping based upon two factors. First, pex tubing is cross linked by one of three different methods: pex-a via organic peroxides at elevated temperature, pex-b via organosilanes and steam; and, pex-c via beta, gamma or electron beam irradiation. Recent reports [1, 2] have demonstrated detectable amounts of VOC extracted from pex-a tubing. Authors of these reports were contacted to discuss results. While no studies have been identified that specifically compared pex-a, pex-b and pex-c, the potential for leaching from pex-c is minimized since no additional cross linking compounds are added to the polymer formulation. Therefore, pex-c products were explicitly specified for all Berkeley Marvell NanoLab applications. Second, the water in the DI distribution system, including the DI distribution manifolds is constantly recirculated. This is standard for a polished DI water loop as it avoids bacterial growth and maintains high resistivity. Therefore, water is never stagnant in the pex-c tubing or manifolds; rather, it is constantly being recirculated through deionizing resin beds, a TOC breakdown UV lamp and sub-micron filters.

A separate crimp system was also selected for some vacuum manifolds and process exhaust installations. This product line is distributed by Evans Components, Inc®. and is marketed as the Victaulic Pressfit® system. Lab staff tested and verified that this system and these fittings were compatible with standard 304 SS (stainless steel) pipe rather than being captive to a specific SS pipe manufacturer. Staff further developed a mechanism to integrate a Pressfit® union with a KF (generic Kwik-Flange®) half nipple or elbow connector. In addition, EPDM o-rings originally supplied with the Pressfit® fittings were replaced with Viton. This strategy enabled rapid install of SS foreline and pump exhaust lines without the need to send every connection to a machine shop for weld attachment of KF vacuum flanges. This system is described as 'crimp SS' in Table 1.

TABLE 1 PIPING MATERIAL SELECTION BY UTILITY AND LOCATION

Material Selection per Utility	Piping Location		
	Primary Overhead Distribution	***Chase Drops to Valve Manifold***	***Tubing to tool***
exhaust	epoxy coated galvanized	(pump exhaust) haz: crimp SS non-haz: crimp SS	(foreline) haz: KF SS non-haz:crimp SS
DI Supply	fused pvdf	crimp pex-c	nylon-11
DI Return	fused pvdf	crimp pex-c	nylon-11
PCW Supply	brazed copper	crimp copper	nylon-11
PCW Return	brazed copper	crimp copper	nylon-11
ICW	brazed copper	crimp copper	nylon-11
Potable Water	brazed copper	NA	NA
acid waste drain	fused pvdf	NA	pvc
PV	brazed copper	crimp pex-c	nylon-11
CDA	brazed copper	crimp pex-c	nylon-11
N2	welded SS	crimp pex-c	nylon-11
O2	welded SS	crimp pex-c	nylon-11
Ar	welded SS	NA	welded SS
He	welded SS	NA	welded SS
Non-toxic specialty gas	welded SS	welded SS	nylon-11
ClassII / III pyrophoric gas	welded SS	welded SS	welded SS
Class1 gas	welded SS double contained	NA	welded SS double contained

IV. Conclusion

The Berkeley NanoLab staff undertook more than just the movement and restart of the lab tool set; they also completed the utility systems fit-up for all process tools. Some numbers help convey the magnitude of this effort: over 1mile of pex-c tubing, >50 6 channel plumbing distribution manifolds, >1/2 mile of copper conductor, >3000 ft of ¼" SS tubing, and >500 orbital gas welds. This effort has cost more than $2M and taken place over a period of 18 months. This effort is not just an investment in infrastructure; this effort is an investment in tooling, staff training and the ability to install and maintain our own equipment in the future. Work was done while lab staff serviced and maintained tools for researcher's constant use. This aspect was critical to maintaining research tools for faculty and to maintaining income during transition. This presentation focused exclusively upon specialized piping systems; however, fit-up efforts included the phone and paging systems installation, remote monitoring of all utility systems, Ethernet cabling to every tool for access control, furniture installation, wall modifications for bulkhead installation, and seismic bracing for all tools

Lab staff investigated and selected several specialty piping materials and joining systems not typically used by the semiconductor device fabrication industry. If any of these systems display a long term performance or materials issue, it will be modified or replaced. These selections were primarily cost driven but provided additional benefit. Use of crimp connections did not require shutdown of lab smoke detection systems. Therefore, these joining systems also enabled continuous lab operations during equipment installation. Only time will determine if these systems are fully suitable for their selected application but creative adaptation is the hallmark of the university research laboratory. The Berkeley Microlab will not only survive its fit-up effort; it will profit from this experience, continue to adapt and thrive. The evolution of the Berkeley Microlab into the Berkeley Marvell NanoLab is almost complete.

Acknowledgment

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References

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