MEMORANDUM

To: Katalin Voros, Microlab Manager
From: **Jimmy Chang,** Senior Development Engineer
cc: Sia Parsa, Process Engineering Manager
Subject: 2009 Year-End Report
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Process Support & Monitoring of Picosun Atomic Layer Deposition Tool

The Picosun Atomic Layer Deposition (ALD) was started up and released for Microlab members to use in December 2008. Since then, I have been monitoring the performance of the tool and found that the process has been very stable. Table 1 shows the current process parameters and deposition data for both aluminum oxide and titanium oxide. The film qualities have satisfied most of the tool users.

	Al2O3	TiO2
Process Temperature	300°C	280°C
Precursor	TMA (Trimethylaluminum)	TTIP (Titanium Tetrakis Isopropoxide)
Precursor Temperature	Room Temperature	80°C
Oxidizer	DI Water Vapor	DI Water Vapor
Pulse/Purge Time	0.1/4 seconds	0.2/4 seconds
Deposition Rate	1 Å/cycle	0.25 Å/min
Non-uniformity	<2%	<5%

Table 1 - Picosun ALD Process Parameters & Deposition Data

I have been working closely with the equipment engineer in charge of maintaining the tool. During the initial period of operation, I have been the first level of response of tool problems. After eliminating the user errors, I helped equipment staff in troubleshooting the problems. The Picosun tool has worked satisfactorily except for one major problem, the chamber door/wafer loader worm gear assembly locked up sometimes. The solution required rebooting the whole computer software. Eventually, the assembly was replaced and the problem has not occurred since.

After I got familiarized with the operations of the tool, I wrote the operational manual, incorporating the inputs of Microlab members who were also got trained and used the tool. Up to now, there are sixteen Microlab members, in both device group and MEMS group, qualified for the tool.

Thin and Thick High Temperature Oxide (HTO) Process Development in Tystar17

In the past, Device group researchers used Tystar9 for thin HTO film deposition due its excellent oxide quality and sidewall coverage (excellent conformality), some MEMS researchers also expressed the need for HTO process, both thin and thick HTO processes. These non-MOS applications are not allowed in Tystar9, therefore the need for developing Tystar17 similar processes arose, specifically designed to address non_MOS processes.

First, the same process parameters were copied to Tystar17 for thin HTO film deposition. Due to the different furnace configuration and pumping speed, the refractive index of the film was 1.42, about 0.03 below the target value for the oxide film. This indicated that the film was oxygen rich. The process parameters were tuned to reach the target value. A separate process with eight time higher deposition rate was also developed for thick HTO film deposition. The test parameters and the best deposition data are showed in Table 2.

	Thin HTO	Thick HTO
Deposition Temp	800°C	835°C
Deposition Press	300 mTorr	600 mTorr
DCS flow	10 sccm	40 sccm
N2O flow	30 sccm	100 sccm
Deposition Rate	3.1 Å/min	24.8 Å/min
Non-uniformity	<2%	<4%

Table 2 - Tystar17 HTO Process Parameters and Deposition Data

P5000 Tests for Trench Filling

In my previous year-end report, I showed the excellent sidewall coverage of trenches with less than 1 micron width using P5000 PECVD TEOS process. A BLMA member asked for a much more difficult process that required coverage of sidewall for trenches over 100 micron deep. Since ThCVD process was offline (ozonator not working at this time), a series of qualitative feasibility tests were performed using PECVD process. The following process parameters were explored and the findings are discussed as followings.

- Pressure – It has been well known that high pressure will decrease the mean free path of the process gases. The ThCVD process uses pressure in the hundreds of Torrs range. For PECVD process, the highest pressure can be used is 20 Torr.
- Temperature – Higher deposition temperature means higher mobility for the process gas and molecules absorbed on the wafer surface. The lamp heater assembly has been tested to achieve 500°C without harming the vacuum system.
- TEOS flow – Lower TEOS flow rate can reduce the deposition rate, hence increase the time for sidewall deposition before the trench opening closes. The lowest setting for the TOES injector to have a stable flow has been tested to be 250 milli-grams per minutes.
- Other parameters, e.g. electrode gap, and RF power are only limited by the tools set up. The parameter ranges are well within the tool limits.

All the test results are listed in Table 3. The parameters for the standard process are: 9Torr, 390°C, 550W, 500 mg/min of TEOS, and 200mils electrode gap. From the uniformity point of view, the low RF/high Pressure/high temperature combination looked most promising. Some wafers with deep trenches were tested. The BLMA member sent those wafer out for cross section SEM. The result will be the foundation of further process development.

	Dep Rate (Å/sec)	Standard Dev.
Standard PECVD TEOS process	64.1	4.08%
High Pressure (20 Torr)	24.6	4.53%
High Temp (450°C)	41.4	4.32%
Low flow (250 mg/m TEOS)	27.6	3.85%
Low RF (300W)	72.9	2.86%
High Gap (400 mils)	28.2	5.49%
High Pressure & Low RF	40.0	2.04%
Low flow & Low RF	31.7	3.66%

Table 3 - P5000 TEOS PECVD Feasibility Test Results

Tylan8 Wet/Dry oxidation Startup for III/V Compound

A research group needed a fast and stable III/V compound oxide furnace. However, their samples were not compatible with silicon process and not allowed in Tystar furnaces. Equipment staff modified Tylan8 to suit the purpose. I started up and tested the furnace and worked closely with equip staff to trouble shoot problems not anticipated during design phase. Afterwards, I work closely with the researchers to program the recipes for their special requirements.

Preparation of Test and Dummy Wafers for New Lam Etchers

Two new plasma etchers were delivered to Marvell Nanolab last year. They are Lam7, a TCP metal etcher, and Lam6, an plasma oxide etcher. The new etchers both need to cycle etch dummy wafers to stabilize their process, and test wafers for fine tuning the process. One box of test wafers and one box of dummy wafers were prepared using CPA for Lam7. One box of test wafers and two boxes of dummies were prepared using Tystar furnaces for Lam6.

However, Lam7 was later decided to be temporarily used for poly-silicon etch. Due to the shut down of Tystar LPVDC furnaces, a box of test wafers were processed one at a time in Oxford2 PECVD system.

Training of New MEMX Engineer

Microlab employed a new MEMX engineer in the Spring 2009. I have shared the training responsibility in the area of:

- All Tystar furnaces which include atmospheric pressure (AP) and low pressure chemical deposition processes.
- All Lam plasma etchers which include Poly, Oxide, and Aluminum.
- Other thin film tools, e.g. CPA for aluminum, and P5000 for TEOS oxide.
- Various analytical tools for measurement of film thickness, stress, and etc.

I have also served as a mentor for all his MEMX projects that used the above tools.

Summer Internship – Baseline Process Monitoring of PVD & Evaporator Tools

Each summer, Microlab offers internship to high school female students. The purpose of the internship is to expose them to engineering environment so they will be interested in choosing engineering major in college.

The intern project for past year was to characterize the baseline process of PVD and Evaporator tools. These tools include CPA sputtering system, Edwards AC/RF sputter coater, NRC evaporator, Veeco 401 vacuum system, and Edwards E-beam evaporator. The choice of material was aluminum film.

The high school intern was exposed to all the safety laboratory rules, disciplines and various Microlab process modules. She learned wafer cleaning procedure, furnace operation for oxide formation on wafer surface. She also learned about the PVD and all the evaporators mentioned above, and metrology tool to measure film properties. Her test results can be used as references for these tools once they are moved to the new Marvell Nanolab.

Engineering Test Requests

- Multiple runs of Low Stress Nitride Deposition on 2" of substrates plus pre-deposition sink cleaning.
- Two runs of thick poly-silicon runs.
- PM marks etch for Stanford University.
- Other miscellaneous runs, e.g. amorphous silicon PECVD, LSN, and etc.

Process Support & Miscellaneous

- Provided general process support to lab members.
- Working with equipment staff in trouble-shooting problems of all Tystar furnaces and Lam plasma etchers.
- Graded equipment quizzes, train and/or qualified lab members on various tools.
- Conducted monthly laboratory safety tours for new lab members.
- Wrote, contributed, or revised the following equipment manuals:

  Chapter 5.0 - Tystar/Tylan Furnaces Overview
  Chapter 5.3 - Tystar3 Non-MOS Clean Dry/Wet Oxidation and Anneal Atmospheric Furnace (4" and 6")
  Chapter 5.4 - Tystar4 Non-MOS Clean Dry/Wet Oxidation and Anneal Atmospheric Furnace (4" and 6")
  Chapter 5.5 - Tylan5 MOS Clean Gate/Dry Oxidation and Annealing Atmospheric Furnace (4" Only)
  Chapter 5.6 - Tylan6 MOS Clean Gate/Dry Oxidation and Annealing Atmospheric Furnace (4" Only)
  Chapter 5.7 - Tylan7 MOS Clean Gate/Dry Oxidation and Annealing Atmospheric Furnace (4" Only)
  Chapter 5.10 - Tystar10 MOS Clean Polycrystalline Silicon LPCVD Furnace (4" and 6")
  Chapter 5.12 - Tystar12 Non-MOS Clean LTO LPCVD Furnace (4" and 5")
  Chapter 5.13 - Tystar13 Non-MOS Clean POCl3 Doping Furnace (4" and 6")
  Chapter 5.14 - Tystar14 Boron+ Doping Furnace
  Chapter 5.15 - Tystar15 Non-MOS Polysilicon Carbide LPCVD Furnace
  Chapter 5.16 - Tystar16 Non-MOS LPCVD Furnace
  Chapter 5.18 - Tystar16 Non-MOS LPCVD Furnace
  Chapter 5.19 - Tystar19 MOS Clean Si-Ge LPCVD Furnaces (4" and 6")
  Chapter 8.34 - Nanometrics 210 XP Scanning UV – Nanospec/DUV Microspectrophotometer