MEMORANDUM

To: William Flounders, Marvell Nanolab Manager
From: **Jimmy Chang,** Development Engineer IV
cc: Sia Parsa, Process Engineering Manager
Subject: 2011 Year-End Report
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Lam Etchers Start-up

Marvell Nanolab received three dry etchers from Lam Research Inc. All of them are automatic, cassette-to-cassette (6”), Rainbow platform® plasma etchers that operates under Envision® GUI software. Although all three etchers have similar outlooks and operating procedures, their internal chamber designs are significantly different, so that they can etch different thin films.

Lam6 is dedicated to etch oxide and nitride films. The model has been famous as the industry’s work horse for 0.5 micron technology node. It differs from other traditional dry etchers by using low frequency RF power that is split evenly to top and lower electrodes with opposite wave phases. This feature maximizes the life time of etching radicals and the plasma bias. Lam6 uses a mechanical clamp for helium backside cooling and uses mechanical dry pumps.

Lam7 is a metal, i.e. aluminum film and its thin cap layers, TCP etcher for 0.25 micron technology node. It has two RF generators: top TCP electrode generates high density plasma with process radicals and ions; bottom bias electrode to attract plasma to the wafer. The chamber design and top/bottom RF phase difference provide strong bias needed for metal film etching. Lam7 uses static electric chuck, ESC, for helium backside cooling and a turbo pump for high process gas throughput and below 10 mtorr etching pressure.

Lam8 is dedicated for poly-silicon film etching. It is a TCP etcher too. The chamber and top/bottom RF phase difference are specially designed to reduce the radiation damage caused by poly-silicon gate etch. It uses HBr and small amount of oxygen to make the extreme high selectivity over under-laying gate oxide.

The first step of start-up of dry ether is to season the etch chamber. Because the plasma etch process is sensitive to the etch chamber wall condition, 25 dummy wafers with film specific to the etcher were first etched using the main etch recipe to season the chamber. Then 3 test wafers (with oxide film) were etched to obtain the initial etch rate data. Afterward, 25 more dummy wafers were etched again. Then 3 more test wafers were etched to make sure the etch rate has not shifted. All three Lam etchers went through this process before the standard recipes were fine tuned. The final development results are listed below.

LAM6 START-UP PROCESS RESULTS

Main Etch 200mT/750W/1.2cm/25CF4/25CHF3/150Ar/4T				
	Etch Rate	Unif%	W-W	Selectivity
Oxide	4622	1.22%	0.17%	
Poly	482	4.15%	0.46%	9.6
Nitride	2742	7.34%	1.19%	1.7
I-line PR	744	5.80%	2.07%	6.2
Over Etch 300mT/600W/1.2cm/20CF4/30CHF3/200Ar/4T				
	Etch Rate	Unif%	W-W	Selectivity
Oxide	4396	2.16%	1.00%	
Poly	343	2.75%	2.11%	12.8
Nitride	1535	8.31%	0.84%	2.9
I-line PR	580	5.60%	2.33%	7.6
Main Etch(2) 200mT/750W/1.2cm/45CF4/15CHF3/150Ar/4T				
	Etch Rate	Unif%	W-W	Selectivity
Oxide	5158	1.93%	0.07%	
Nitride	2734	3.90%	0.75%	1.9

LAM7 PROCESS START-UP RESULTS (poly-silicon)

Main Etch 12mT/T300W/B150W/50Cl2/100HBr/4T				
	Etch Rate	Uniformity	W-W	Selectivity
Poly-Silicon	3641	1.14%	0.20%	
Oxide	535	13.11%	3.44%	6.8
Over Etch 40mT/T200W/B120W/100HBr/4O2/100He/4T				
	Etch Rate	Uniformity	W-W	Selectivity
Poly-Silicon	1607	11.84%	1.92%	
Oxide	13	91.35%	175.00%	125.6

Note: Lam7 was first started up as a poly-silicon etches as a temporary substitute of decommissioned Lam5. Due to the different chamber designs, the selectivity of poly-silicon over oxide was at 125, instead of over 300 of Lam5 or Lam8

LAM7 PROCESS START-UP RESULTS (aluminum)

Main Etch 8mT/T800W/B100W/90Cl2/45BCl3/4T				
	Etch Rate	Uniformity	W-W	Selectivity
Aluminum	4371	3.89%	3.93%	
Oxide	1689	7.90%	0.21%	2.6
Over Etch 8mT/T700W/B100W/45Cl2/60BCl3/4T				
	Etch Rate	Uniformity	W-W	Selectivity
Aluminum	3433	10.81%	2.45%	
Oxide	1800	7.51%	0.02%	1.9

LAM8 PROCESS START-UP RESULTS (poly-silicon)

Main Etch 12mT/T300W/B150W/50Cl2/100HBr/4T				
	Etch Rate	Uniformity	W-W	Selectivity
Poly-Silicon	3158	2.11%	0.29%	
Oxide	313	7.35%	4.85%	10.1
Over Etch 80mT/T200W/B150W/100HBr/1O2/100He/4T				
	Etch Rate	Uniformity	W-W	Selectivity
Poly-Silicon	1303	2.98%	0.90%	
Oxide	4	74.28%	82.46%	315.3

Tystar Furnaces Process Validation

Four banks of Tystar furnaces, 16 tubes total, were relocated from Microlab to Marvell Nanolab. Thanks to the dedications of the equipment engineers and the support of the machine shop staff, all of them were up after minimum down time. All the standard processes were tested and the test results validated posted on the process monitor web pages.

The only major process re-start problem was related to Schumacher vapor delivery systems, which were installed in Tystar1, 2, 3 for TLC and Tystar13 for $POCl_3$. After several tests, it was found that due to lower room temperature of Marvell Nanolab, chemical vapor condensed on the delivery tube wall and not into the furnace. The vapor bath temperature was adjusted and the problem was solved.

Tystar7 Boron Doping Process Start-up for Nanowires Application

Tystar7 is the first furnace, in the new Tystar 8” bank, to be released for lab members to use. The bank uses WINDOWS GUI software, and a touch screen panel for furnace operations,

Tystar7 is a high temperature atmospheric pressure tube dedicated nano-wire applications. It uses 1%BCl_3 balanced with Helium for doping process and 10%H_2 balanced with N_2 to prevent nano-wire from oxidation during temperature ramp period. An Oxygen purge process was also developed to remove the Boron byproduct deposited on the quartz ware.

Stoke Ellipsometer Start-up

The LSE Stokes Ellipsometer, made by Gaertner Scientific Corporation, uses the patented StokesMeter technology to measure the thickness and/or the refractive index of transparent films. There is no moving parts and no modulators in this system. It uses a 6328 Å HeNe laser at a 70° incidence angle.

GEMP Windows software can calculate the film thickness and refractive index of a layer on a substrate or on top of a film stack that consists of three layers with known film thicknesses and refractive indices. The measurement and calculation time of a single layer film is fast, only a fraction of a second.

The following table shows the comparison of measurements of Stoke Ellips, NanoDUV, and NanoSpec on 5 oxide films with different thicknesses, 1 regular nitride and 1 low stress nitride films. In General, Ellipsometry can measure film thickness more accurately because it can measure film refractive index at the same time.

	Oxide					Nitride	LSN
	STOKE Ellipsometer						
Fix RI	6859	2928	1108	338	85	881	744
Calculate RI	6818	N/A	1101	350	N/A	880	761
RI Measured	1.461	N/A	1.461	1.430	N/A	2.002	2.176
	NanoDUV						
Fix RI	6830	2909	1178	353	N/A	879	775
Calculate RI	6842	2938	1178	N/A	N/A	882	932
RI Measured	1.454	1.444	1.433	N/A	N/A	1.997	1.761
	NanoSpec						
Fix RI	6886	2924	1112	338	88	880	833

Training of New Baseline Engineer

I have shared the training responsibility of the new baseline engineer 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.
- Various analytical tools for measurement of film thickness, stress, and etc.

Summer Internship – Develop High/Low Frequency RF PECVD Nitride Process to Adjust Film Stress, And Post Deposition Cleaning Process

In the past, Microlab offers summer 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.

This year, Marvell Nanolab has two high school female student interns. The internship started in June. Both interns were exposed to all the safety laboratory rules, disciplines and various Nanolab process modules. They learned wafer cleaning procedure, furnace operation for oxide growth, and LPCVD process for nitride deposition.

The intern, whom I mentored, worked on Oxford2 on PECVD processes. She developed a high/low frequency RF pulse process to adjust the film stress. She also developed a cleaning process which uses high/low frequency RF simultaneously. The processes has been verified and used as standards in the future.

Engineer Test Requests

- Deposited thick LPCVD and PECVD oxide films on laser lenses.
- Deposited LPCVD nitride on small MEMS chips with mirrors.
- Other miscellaneous runs, e.g. amorphous silicon PECVD, LSN, thermal oxide and etc.

Process Support and Miscellaneous

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