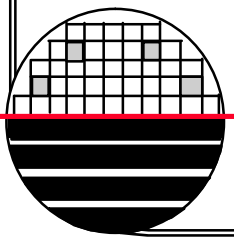
ROCHESTER INSTITUTE OF TECHNOLOGY
MICROELECTRONIC ENGINEERING

Process Improvement Projects
May 2006

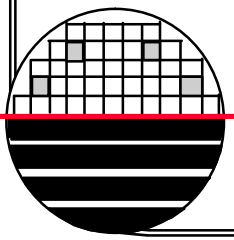
Dr. Lynn Fuller

Microelectronic Engineering
Rochester Institute of Technology
82 Lomb Memorial Drive
Rochester, NY 14623-5604
Tel (585) 475-2035
Fax (585) 475-5041
Dr. Fuller's Webpage: http://www.rit.edu/~lffeee
Email: LFFEEE@rit.edu
Dept Webpage: http://www.microe.rit.edu



OUTLINE

Selective STI CMP Process Using Ceria Slurry
Resist Removal After Chlorine Plasma Etch
Ti Deposition in Perkin Elmer 2400
Ti Deposition in CVC Evaporator
Improved SPC
Improved CMOS Testing
Use of Drytek Quad as Backup for Lam 490



PROCESS IMPROVEMENT FOR STI CMP

Motivation: Past attempts at doing CMP for shallow trench (STI) using a generic oxide slurry (silica and high pH slurry) gave unsatisfactory results. Uniformity was especially poor. Wafer edge always over polished and wafer center was incomplete. The rate of removal of TEOS trench fill was low and the selectivity was low, ie. rate of polish of densified TEOS trench fill and rate of polish of nitride polish stop seemed to be equal.

A new slurry (**Rodel Corp., CeO2, KOH, ph=10**) made especially for STI was investigated. Excellent results were obtained and a new process was developed.

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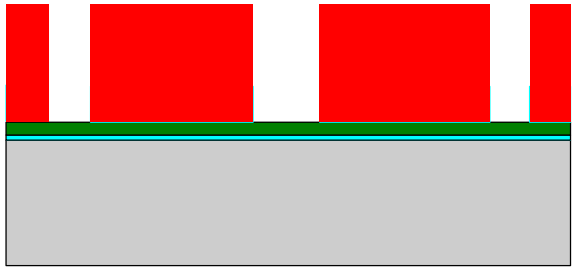
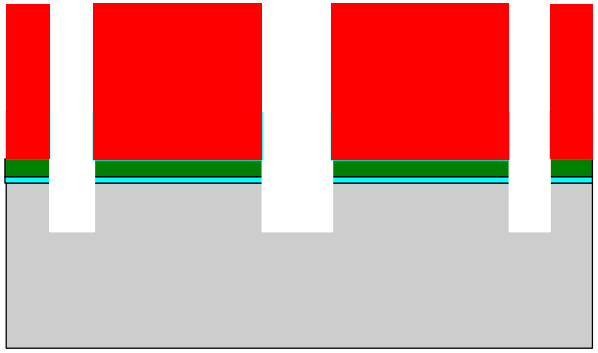
PROCESS FLOW

- **Grow 500A Pad Oxide (thermal)**
- **Deposit 1500A Si3N4 by LPCVD**

- **Level 1 Lithography to protect Active areas with photoresist**



- **STI Trench Etch**
- **RIE in Drytek Quad**
- **Target: 4000A Si Trench**



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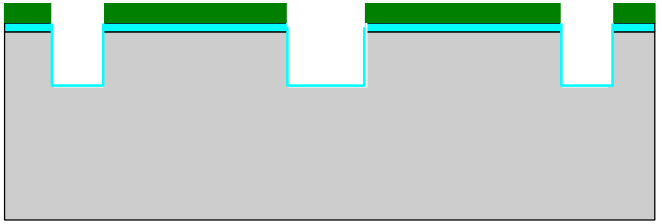
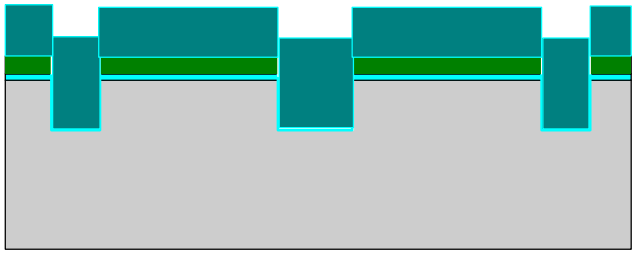
PROCESS FLOW

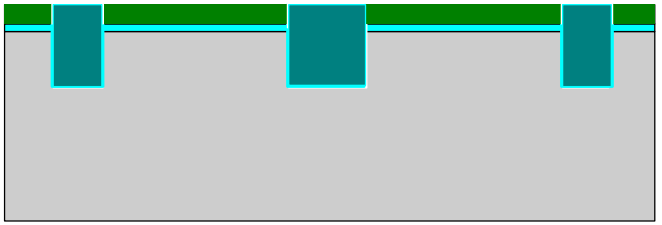
- **Remove photoresist**
- **Grow 500A Liner Oxide (thermal)**
- **Repair damage to sidewalls**



- **Deposit 6500A TEOS SiO2 by PECVD in Applied Materials P5000**



- **CMP TEOS with Westech 372**
- **Nitride is stopping layer**



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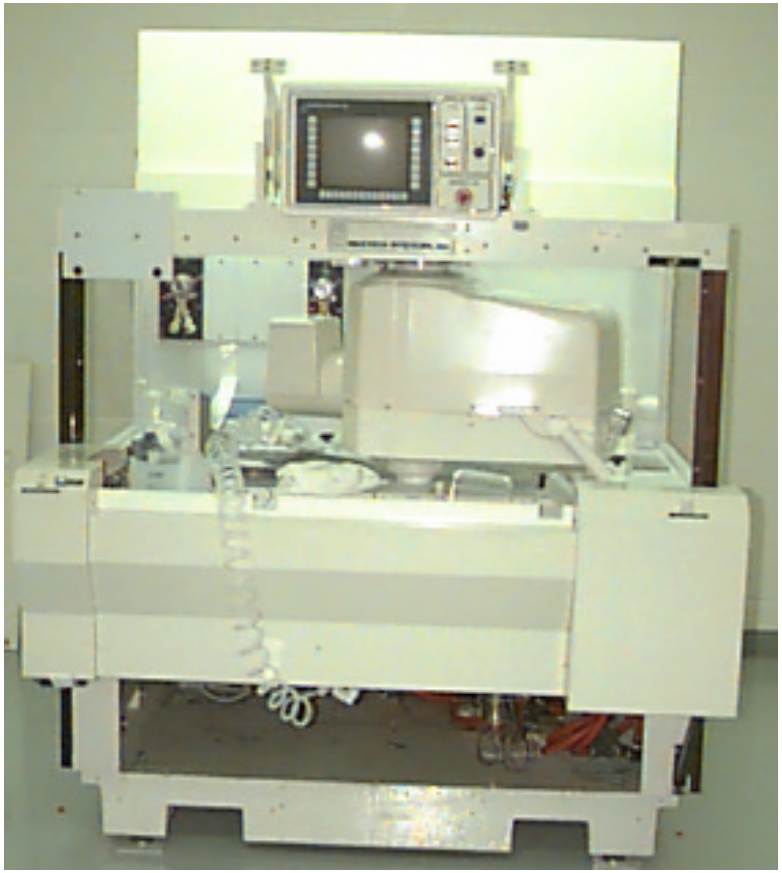
TOOLS AND MATERIAL



- Westech 372 Wafer Polisher
- Tencor SpectraMap SM300
- Nanospec

- Ceria-based slurry (CeO_2)

PROCESS VARIABLES (TOOL SETTINGS)

- **Slurry (Rodel Corp., CeO_2, KOH, ph=10)**
- **Slurry flow rate (60 mL/min)**
- **Back pressure**
- **Carrier speed**
- **Platen Speed**
- **Down force**
- **Temperature (80°C)**
- **Polish time (2 min)**
- **Pad conditioning (1min per 4 wafers)**

Back Pressure (PSI)	Carrier Speed (RPM)	Platen Speed (RPM)	Down Force (PSI)
0	10	70	4
1.5	30	100	8

P.S. Down Force/Wafer Pressure is controlled by gauge on side of tool. 80 PSI on gauge is 500 lbs of down force distributed over the area of 6" wafer (28.26 sq. in.) Thus Wafer Pressure = 0.2211 * Gauge Pressure

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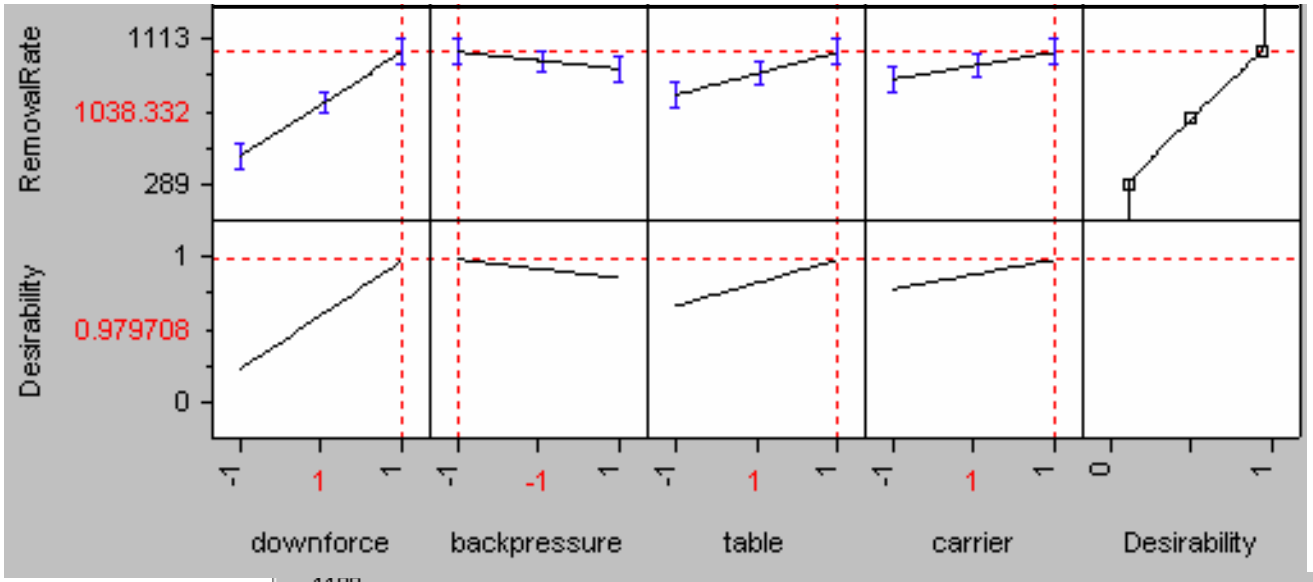
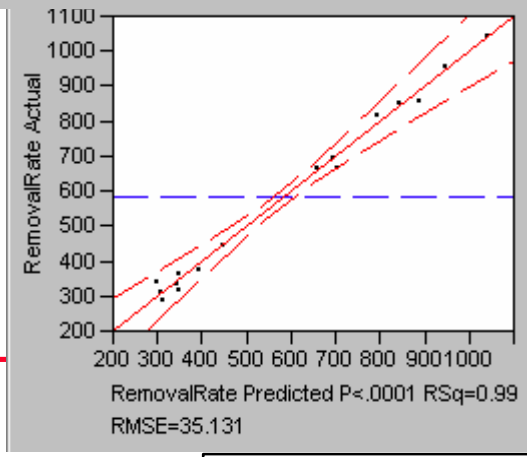
DOE RESULTS (JUMP)

Best Results for Removal Rate



- High downforce
- Without back pressure
- High table speed
- High carrier (platen) speed
- (Rodel Corp., CeO2, KOH, ph=10)



Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	581.41812	8.782854	66.20	<.0001
downforce	235.66813	8.782854	26.83	<.0001
backpressure	-23.20688	8.782854	-2.64	0.0458
table	70.456875	8.782854	8.02	0.0005
carrier	36.293125	8.782854	4.13	0.0091
downforce*backpressure	-10.70687	8.782854	-1.22	0.2772
downforce*table	37.706875	8.782854	4.29	0.0078
backpressure*table	-1.418125	8.782854	-0.16	0.8780
downforce*carrier	14.293125	8.782854	1.63	0.1646
backpressure*carrier	-13.08187	8.782854	-1.49	0.1965
table*carrier	14.081875	8.782854	1.60	0.1698

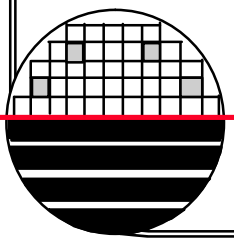
BLANK WAFER RESULTS USING BEST TOOL SETTINGS

Tool Settings

- Carrier speed: 30 RPM
- Platen speed: 100 RPM
- Without back pressure
- 8 PSI down force
- Slurry (Rodel Corp., CeO_2, KOH, ph=10)
- Slurry flow rate (60 mL/min)

Results

- Oxide etch rate: 1040 A/min
- Nitride etch rate: 192 A/min
- Giving selectivity of 5.4:1
- Edge etches slower than the center!
- Poor uniformity (46%)



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ACTUAL FACTORY WAFER F050905

F050905 (oxide thickness = 6542 A)

CMP for 2 min 30sec

Slurry (Rodel Corp., CeO_2, KOH, ph=10)

Slurry flow rate (60 mL/min)

Clear all the dies except at the very edge two dies

Nitride etch rate: 170 A/min

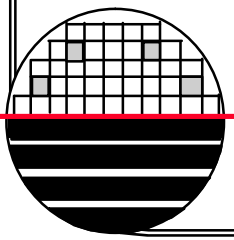
Oxide etch rate: >3271 A/min

Selectivity: >19:1

Small dishing: 4493 A at 2 min

Observation: Higher selectivity and etch rate observed on patterned wafers (because effective down pressure is higher)

CMP is highly pattern related!!!



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ACTUAL FACTORY WAFER F051010

F051010 (oxide thickness = 5286 A)

CMP for 2 min 15sec

Slurry (Rodel Corp., CeO_2, KOH, ph=10)

Slurry flow rate (60 mL/min)

Clear almost every die even at the edge

Nitride etch rate: 170 A/min

Oxide etch rate: >2350 A/min

Selectivity: >14:1

Small dishing: 3800 A at 2 min 30sec

Observation: Higher selectivity and etch rate observed on patterned wafers (because effective down pressure is higher)

CMP is highly pattern related!!!

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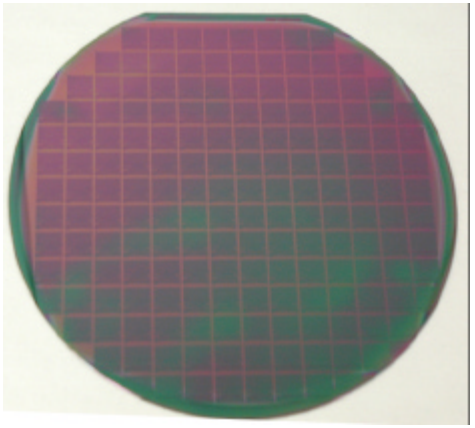
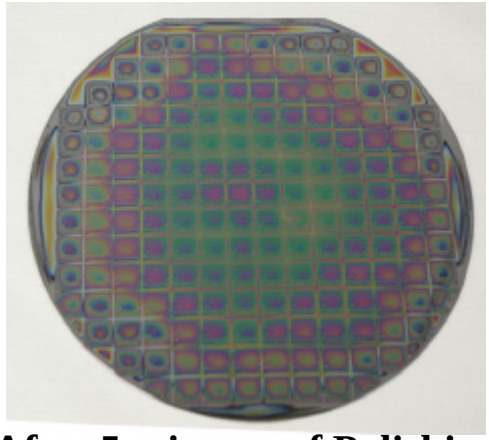
COMPARISON BETWEEN OLD CMP SLURRY AND PROCESS AND NEW SLURRY AND PROCESS

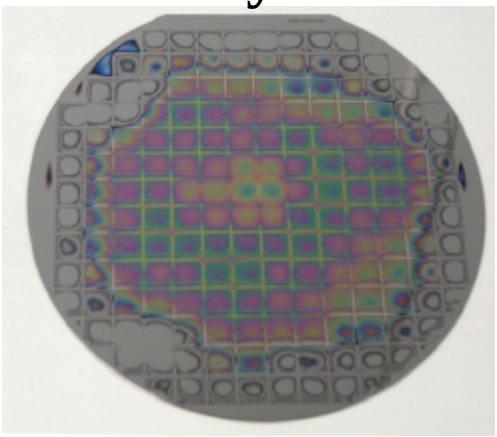
Old Process and Slurry

Wafer before CMP





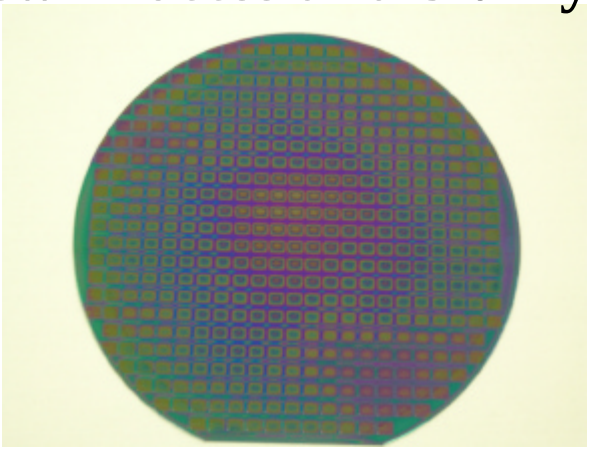
After 5 minutes of Polishing
Center not done



After 9.5 minutes of Polishing
Center done, Edges Bare

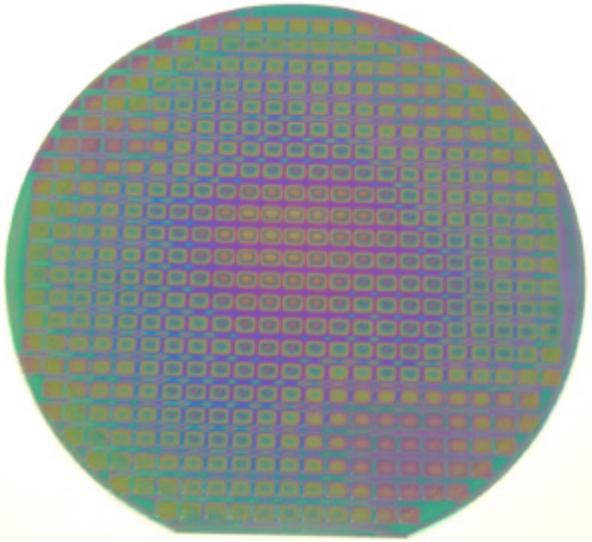
New Process and Slurry

After 2.25 minutes of Polishing
Clear almost every die
Even edge die



NEW FACTORY STI PROCESS (FACTSTI)

- Carrier speed: 30 RPM
- Platen speed: 100 RPM
- Without back pressure
- 8 PSI down force (36 PSI on the gauge)
- Slurry (Rodel Corp., CeO_2, KOH, ph=10)
- Slurry flow rate (60 mL/min)
- Pad conditioning: before every run
- Temperature: 80°C
- Polishing time: 2min 30 sec for 6500A oxide



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Peng Xie and Mike Aquilino

CMP SLURRY

Eminess Technologies, Inc.
1620 West fountainhead Pkwy, Suite 510
Tempe, AZ 85282
Tel (408)505-3409, 888-899-1942,
fax (480)951-3842

Darlene Werkmeister
Dwerkmeister@eminess.com

http://www.EMINESS.com
http://www.electronicmaterials.rohmhaas.com

1/05/06 Order:
N-2350-P Nalco 2350, 5 gal pail $166 each, Mfg by Rohm and Haas,
Silica, 70-100nm particle size, weight % 28, KOH, pH 11.4-12.4

R-10027556 Klebosol 1501-50 Colloidal Silica 5 gal pail $255 each,
Mfg AZ Electronic Materials, Clariant's Klebosol line of silica slurrys,50nm particles, KOH pH 10.9 50% solids

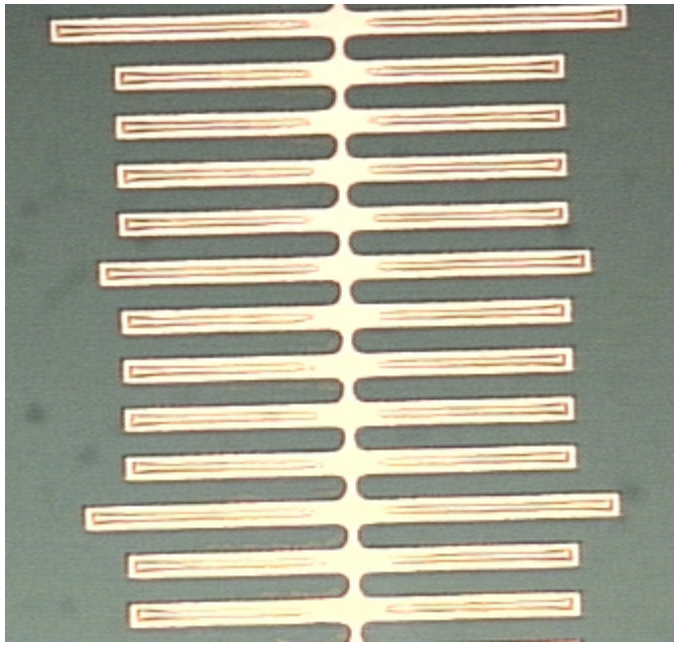
R-10087555 EXP CELEXIS CX94S Single Component Slurry, 20Liter pail $235 each, Mfg by Rohm and Haas Ceria 20nm particles, STI, pH ~7

RESIST REMOVAL POST CHLORINE RIE ALUMINUM ETCH

Problem: Photoresist is hardened (and chemically changed) in Chlorine RIE during Aluminum etch and ashing is ineffective in removing the resist.

Solution: Use a Solvent based photoresist stripper process. (similar to Baselinc CMOS process at U of California at Berkeley)

Picture of aluminum wafers post chlorine RIE and after ashing. Note resist remaining on aluminum. Even very long ashing (60 min.) does not remove residue.



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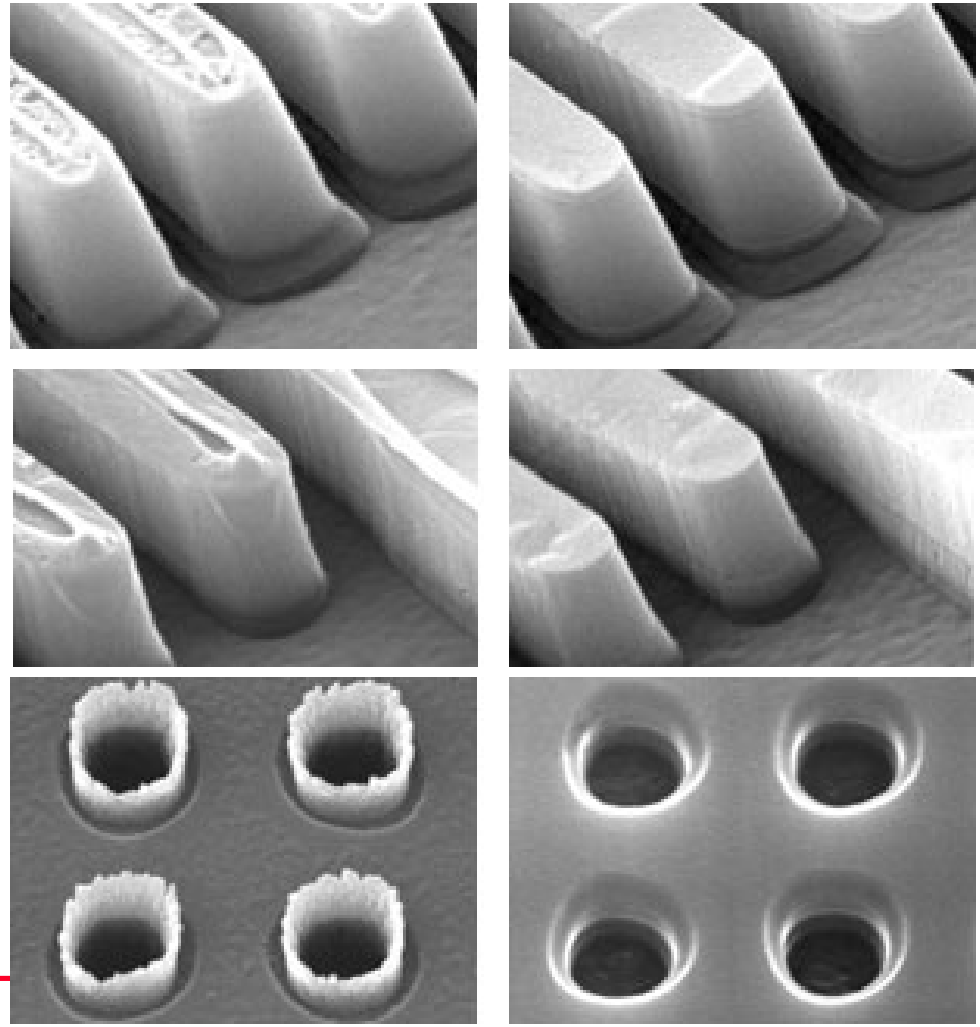
MORE PICTURES OF RESIST SCUM PROBLEM

Pictures on left show resist residue after ashing. Pictures on right show effectiveness of ACT 935 solvent strip process.



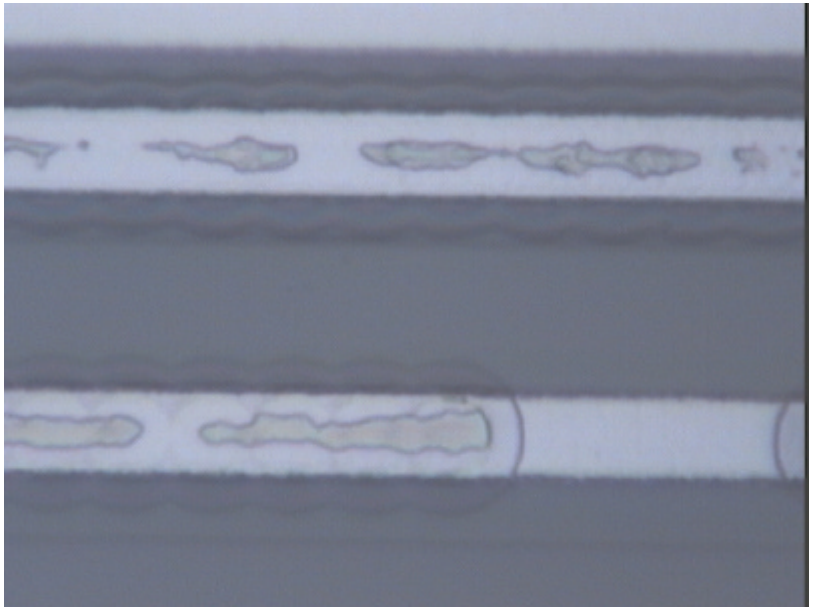
From: [ACT-CMI Data Sheet]

EXPERIMENT

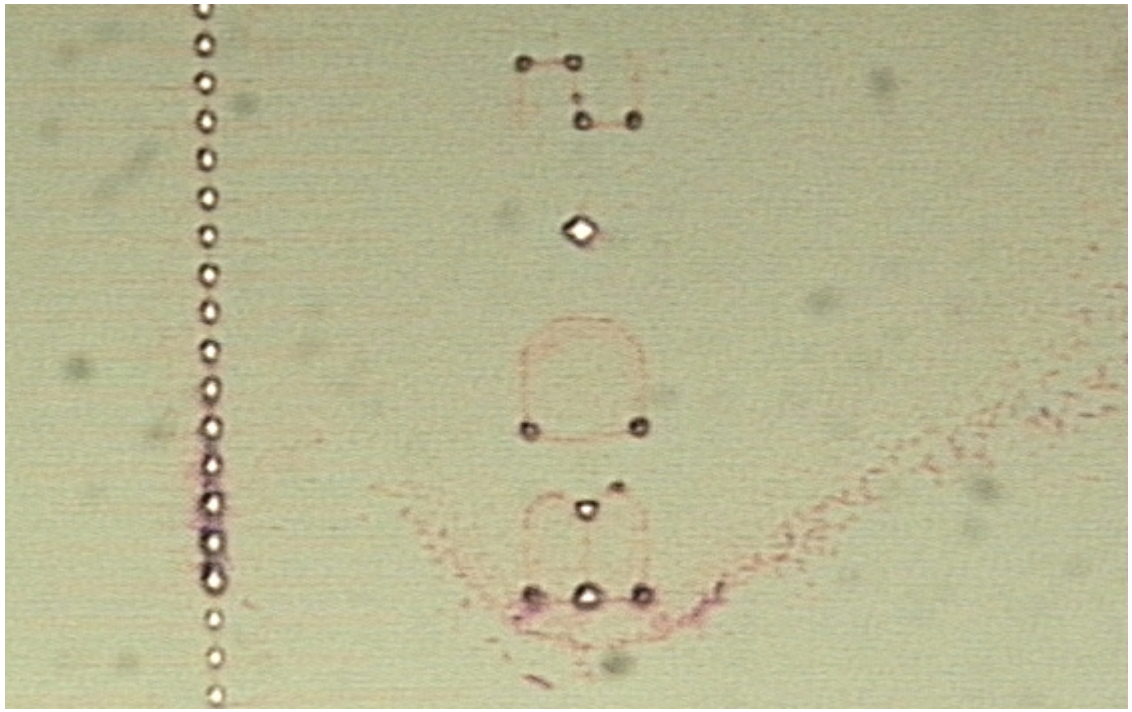
Germain Fenger

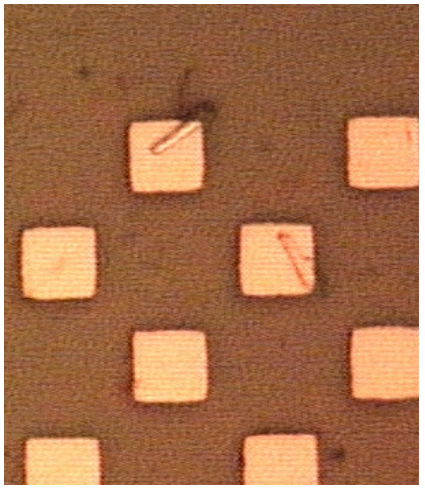
Deposit TEOS
Deposit Aluminum
Metal Litho
Metal Etch
Resist Strip
- ACT-CMI, 75C for 15 or 30 min
- or PRS2000, 90C for 30 min

Plasma Ash
- 6” Factory Recipe
- or 6” Descum Recipe



RESULTS FOR ACT CMI 75C for 15 or 30 min





Longer time did not make a difference

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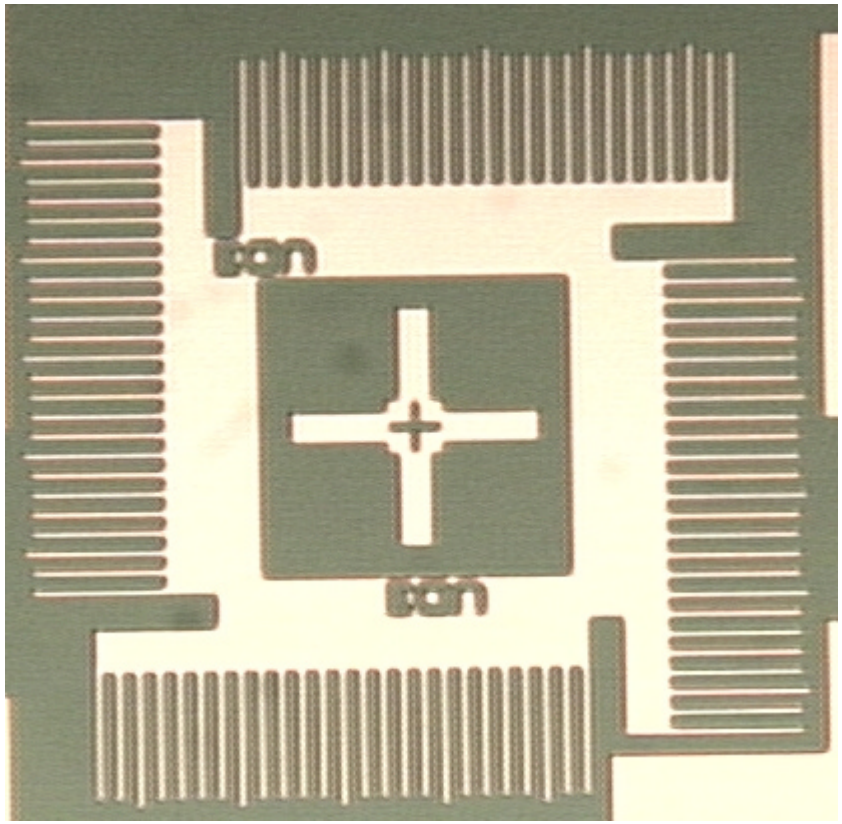
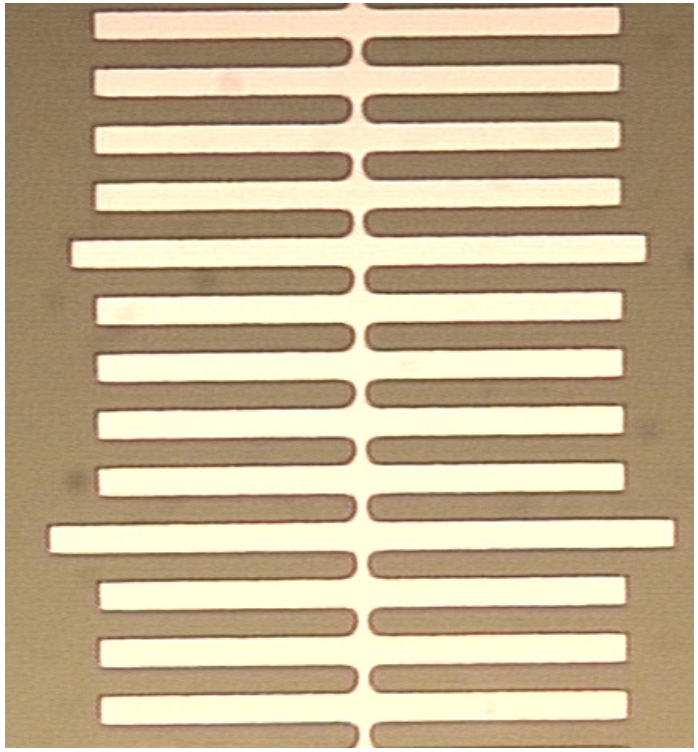
RESULTS for Post Solvent Strip PLUS 6" Factory Plasma Ash





No photoresist was found on wafers

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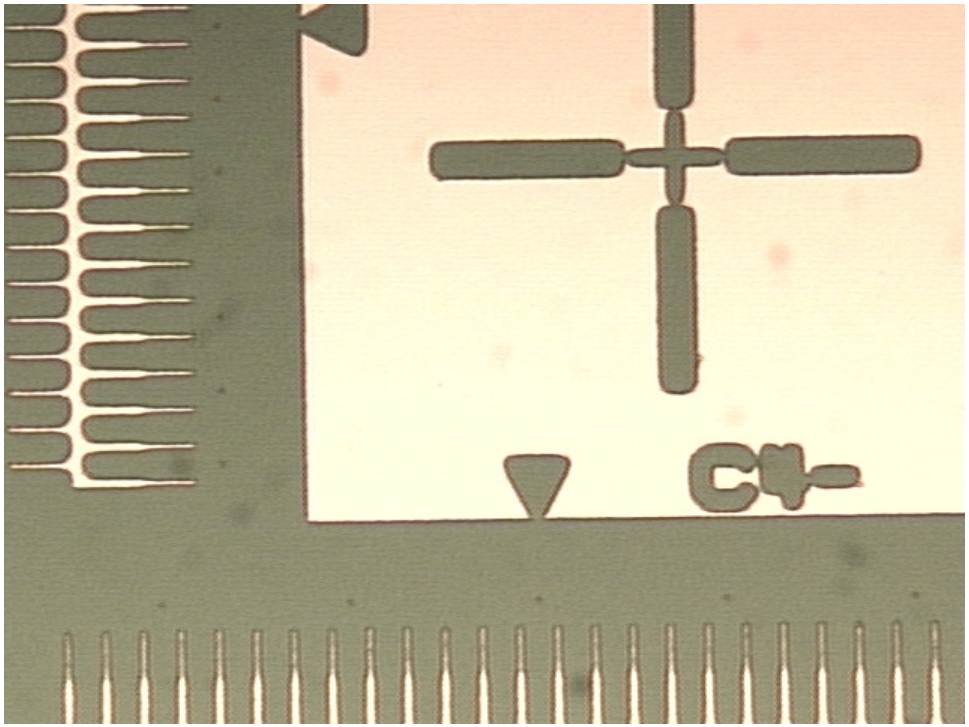
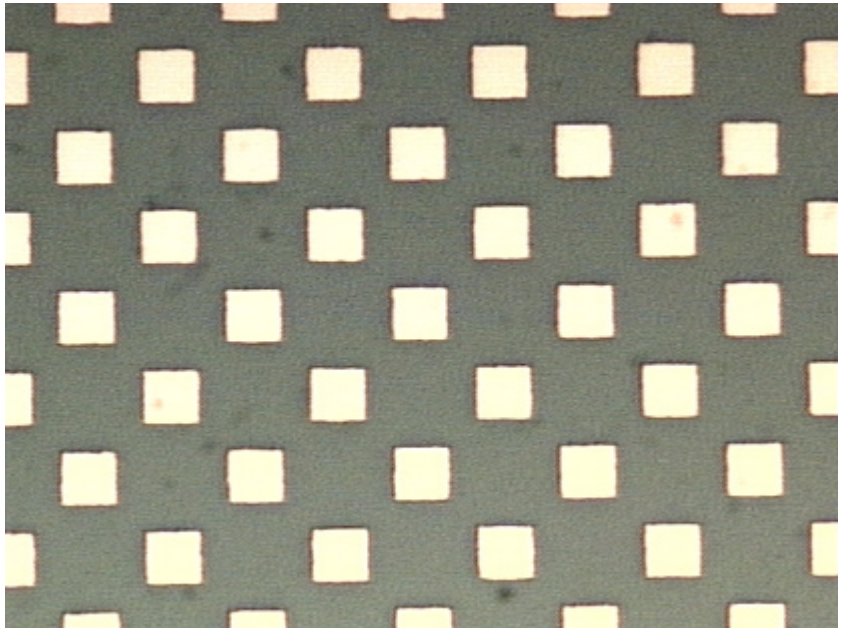
RESULTS FOR PRS2000 90C for 30min





Much less photoresist on wafers then the ACT-CMI process

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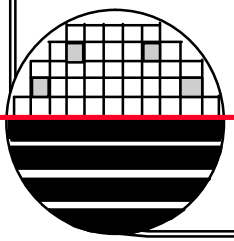
RECOMMENDATIONS

OBSERVATIONS:

- A solvent based photoresist stripper followed by a plasma ash is effective at removing Cl burn resist
- The PRS2000 strips resist better than the ACT-CMI solvent stripper and is currently in use in the solvent stripper bench

RECOMMENDED PROCESS:

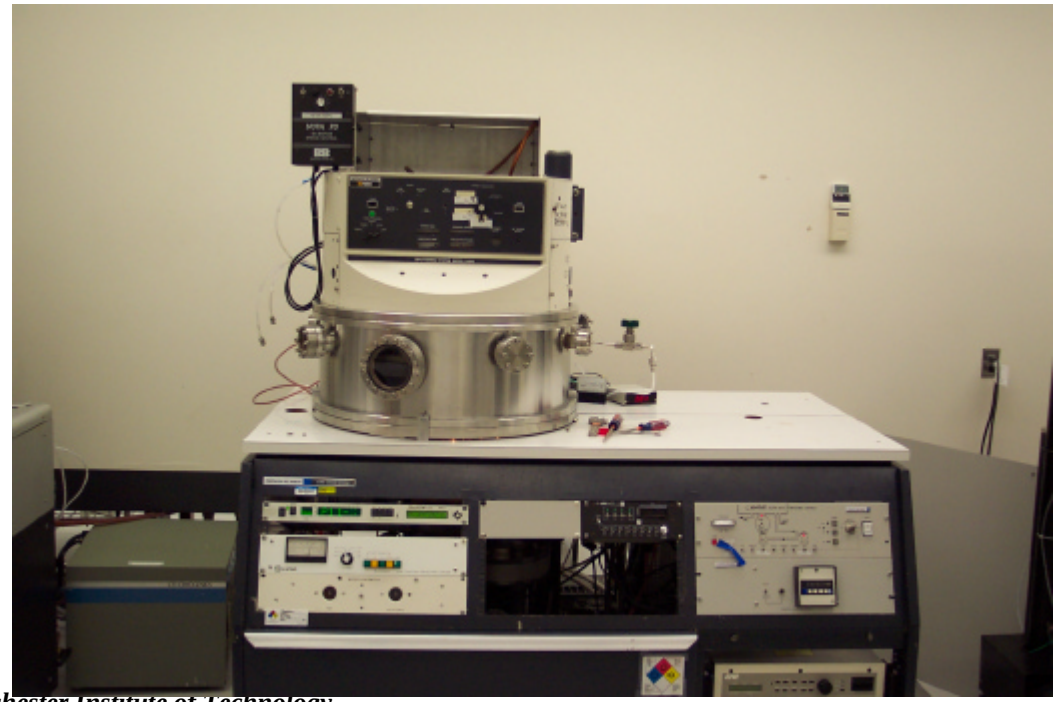
- PRS2000 at 90C for 15 min
- Follow up with 6” Factory ash on the Branson Asher



Ti DEPOSITION USING P&E 2400B

OBJECTIVE

To develop a Ti Deposition process using Perkin Elmer 2400B sputtering tool (a factory backup process for CVC 601 tool)



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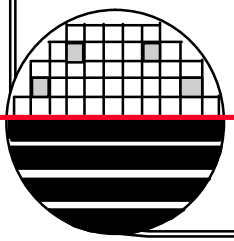
Shrinivas J Pandharpure

Ti DEPOSITION USING P&E 2400B

RESULTS

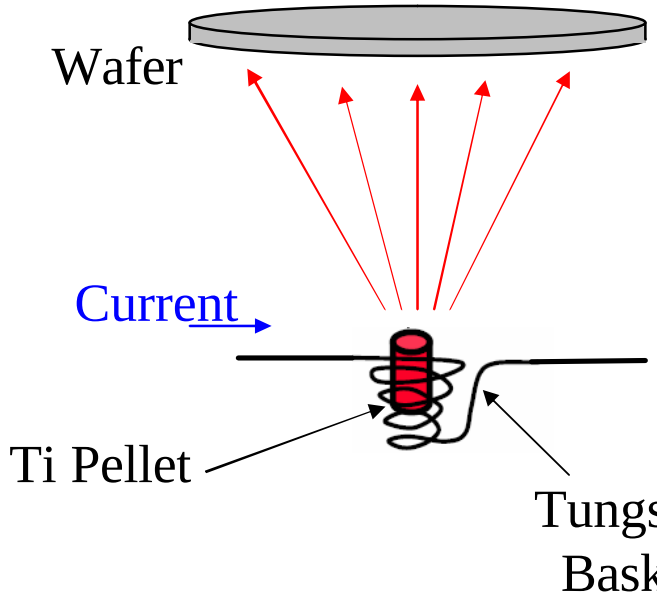
- **Sputtering Power: 500 W for 158 Å/min**
- **Base Pressure: < 5 x 10^{-6} Torr**
- **Sputtering Pressure: 8 mTorr (Argon flow:15 sccm)**
- **Deposition Time: 380 Seconds to get 1000Å Thickness**
- **Thickness standard deviation 4% (30 Å)**
- **Pre-Sputtering: 5 minutes same power**



Ti DEPOSITION USING CVC EVAPORATOR

OBJECTIVE

To develop a Ti Deposition process using CVC Evaporator (a factory backup process for CVC 601 tool)



$$f = \frac{m}{4d\,\pi\,h^2}$$

f = film thickness
d = density
h = height
m = mass


CVC 601

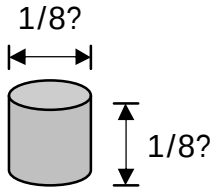
Jirachai Getpreecharsawas

PHYSICAL PROPERTIES OF TI AND W

§ **Titanium (Ti) : Melting point, T_{melt} = 1675 °C**

Vapor Pressure (Torr)	T_{vapor} (°C)
10^{-4}	1453
10^{-6}	1235
10^{-8}	1067

Note: Ti sublimes since **Tvapor < Tmelt**

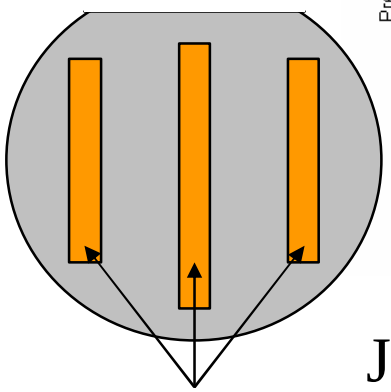


99.995% pure
0.108 gram/pellet

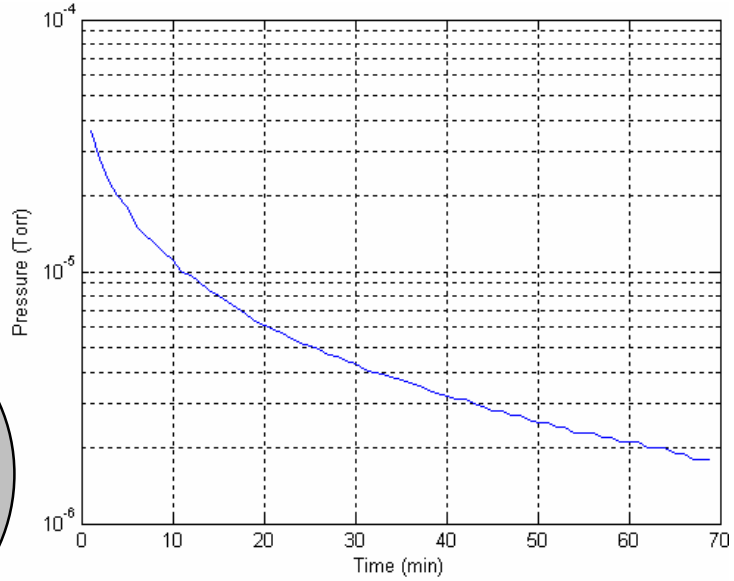
§ **Tungsten (W): Melting point , T_{melt} = 3410 °C**

Ti DEPOSITION USING CVC EVAPORATOR

Load wafer, 1 or 2 pellets of Ti in a tungsten b
Pump ~60 min to reach base pressure <2E-6T
Start deposition with shutter closed
(open after filament is hot)
Evaporate at Variac setting of ~245
Wait 5 min.
Turn down Variac to zero
Shut off filament power.
Remove wafer
Measure thickness on
Tencore alpha step 200



Kapton Tape



Jirachai Getpreecharsawas

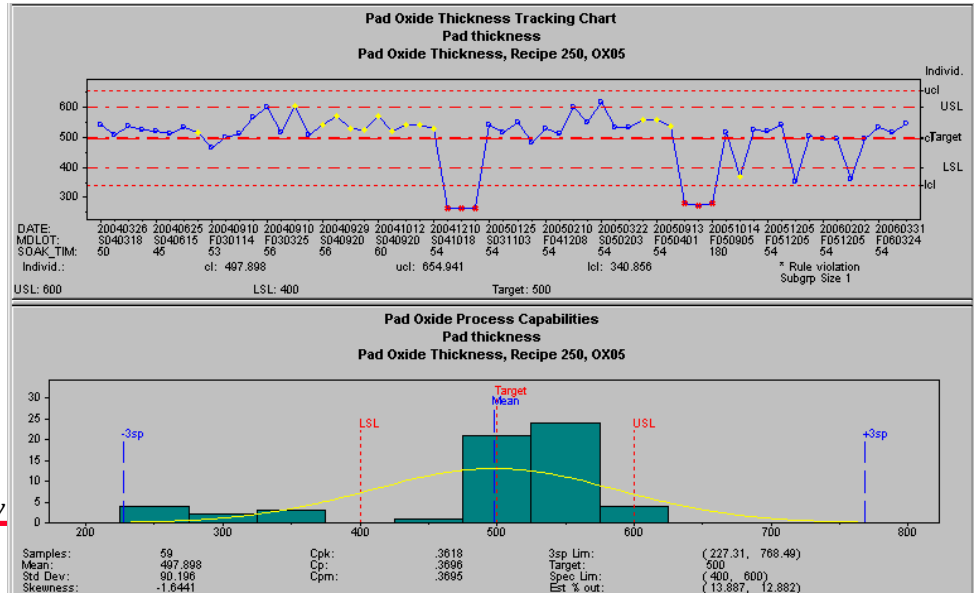
Pressure (Torr)	1 Pellet of Ti		2 Pellets of Ti	
	Mean (Å)	STD	Mean (Å)	STD
3.4×10^{-6}	321.67	176.16	469.44	138.48
1.6×10^{-6}	340.00	84.84	1366.67	163.58

IMPROVED SPC

Problem: SPC charts are that can be accessed from inside MESA need to be revised for the new processes (SMFL-CMOS and ADV-CMOS)

Solution: The SPC charts have been updated and a detailed document on how to create and edit SPC charts has been posted on Dr. Fullers webpage at http://www.rit.edu/~lffeee from the link for tools and processes

Katie McConky



IMPROVED CMOS TESTING

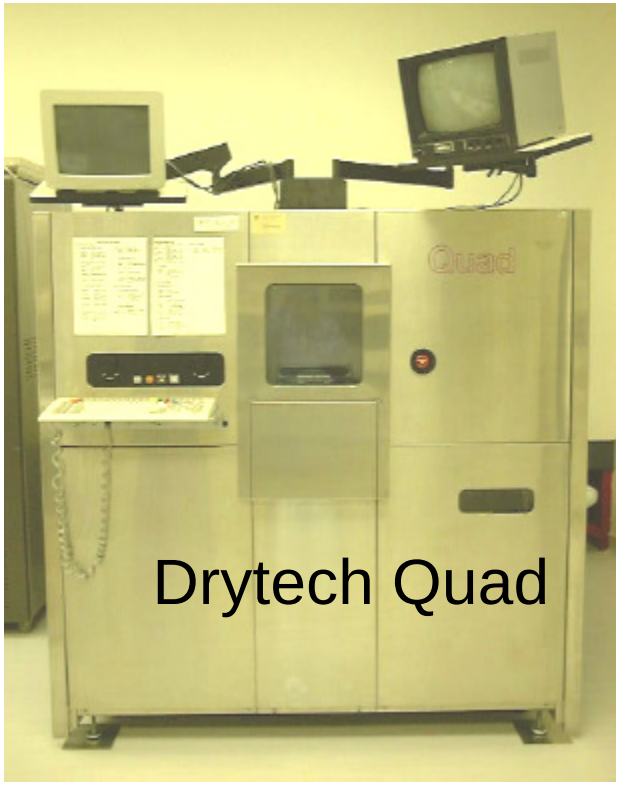
Problem: Documentation for wafer testing of completed CMOS devices is inadequate.

Solution: A complete, very detailed, set of instructions have been developed for basic testing of CMOS wafers. This document is available on Dr. Fullers webpage at http://www.rit.edu/~lffeee from the link for tools and processes

David Pawlik

USING THE DRYTEC QUAD AS A BACKUP FOR LAM 490

Problem: When the Lam490 is down wafers can be etched in the Drytech Quad however etch recipes giving similar etch rates and selectivity's need to be developed.



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Solution: Recipes have been developed and have been published in a document (Quad_recipes.ppt). This document is available on Dr. Fullers webpage at http://www.rit.edu/~lffeee from the link for tools and processes