SUNY POLYTECHNIC INSTITUTE

SUNY Polytechnic Institute
Advanced Planarization
Center of Excellence

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July 16, 2015
SEMICON West 2015 – CMP Technical and Market Trends

Agenda

- Advanced Planarization Center Overview
  - Industry-Standard Mask Set and Baseline Process Flows
- Open Innovation Business Model
  - Joint Development and Benchmarking
- Summary

Advanced Planarization Overview

- SUNY Poly SEMATECH and SUNY Poly CNSE established a state-of-the-art Advanced Planarization Center with full foundry services for advanced-node CMP technology development
  - Industry-standard mask set with structures for process fingerprinting, dummy fill evaluations, e-test and reliability structures, and advanced metrology features
  - Robust fully integrated baseline process flows for all front-end-of-the-line (FEOL) CMP levels and advanced back-end-of-the-line (BEOL) CMP levels
  - Trusted framework for benchmarking among nominal industry competitors
  - Suite of leading-edge characterization techniques for CMP consumables and wafer surfaces

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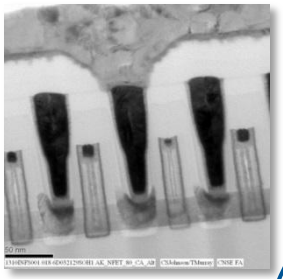
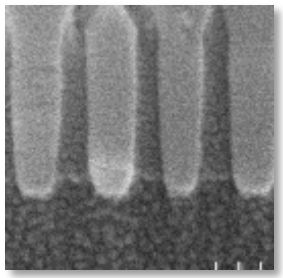


Robust baseline process flows

Multi vendor CMP platforms



Leading edge materials

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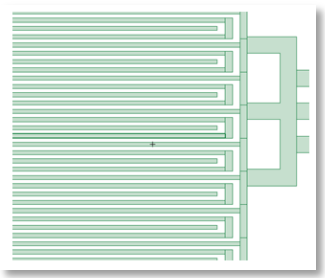
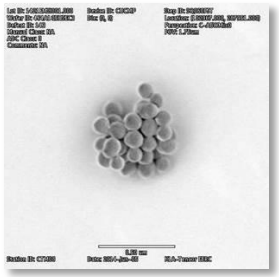


Fund. Learning

State of the art defect metrology



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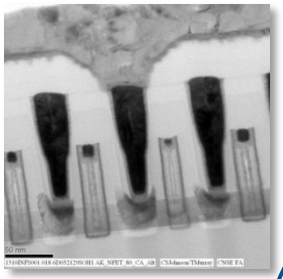

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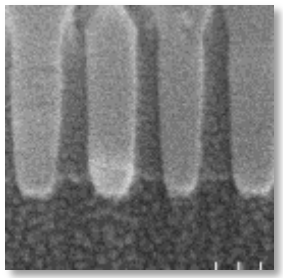

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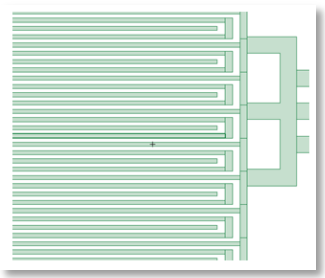

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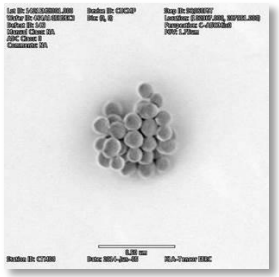

Multi-Vendor CMP Platforms

- Applied Materials Reflexion LK
  - Profiler and Contour Heads
  - Endpoint - Motor Torque, FullVision RTPC, FullScan ISRM
  - IPA Dryer
  - NOVA, iMap on-board metrology

- Ebara F-Rex 300S
  - GII and GIII Heads
  - Endpoint - Eddy Current, SOPM
  - IPA Dryer

- Dedicated III-V CMP platform

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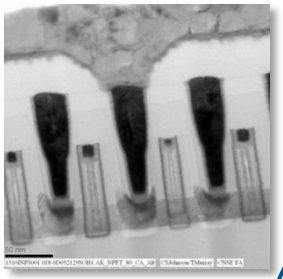

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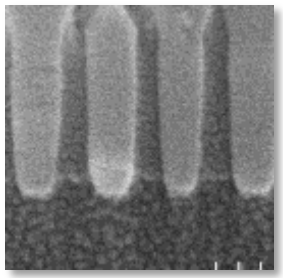

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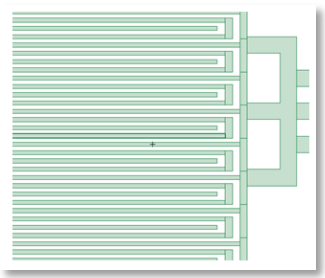

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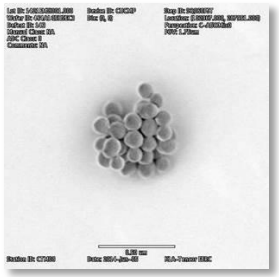
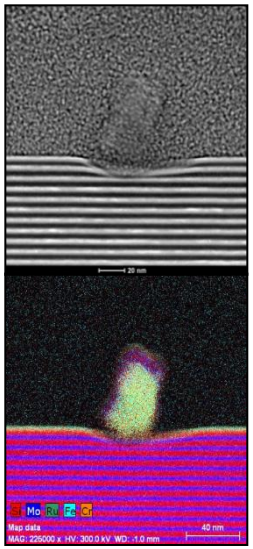


State-of-the-Art Defect Metrology

Defect Inspection	
KLA SP1	Blanket Defect Inspection >120nm
KLA SP2	Blanket Defect Inspection >60nm
KLA SP3	Blanket Defect Inspection >34nm
KLA2835	Particle Defects on Pattern Inspection >65nm
KLA2915	Particle Defects on Pattern Inspection >45nm
Defect Review	
KLA eDR 5200	Automated SEM Review
KLA eDR 7000	Automated SEM Review w/ EDX
AMAT G2 SEM	Semi-Automated SEM Review

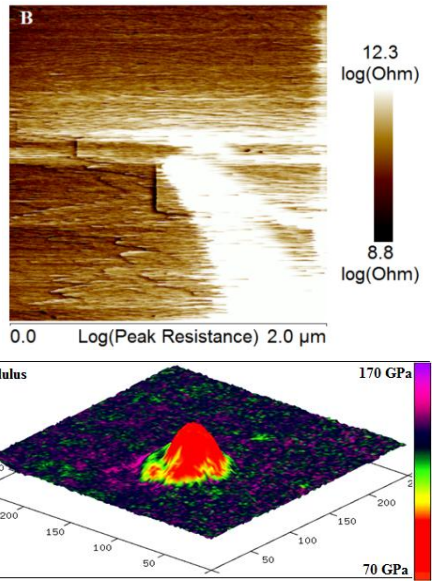
Other Metrology and Characterization

- Full set of surface analysis and metrology tools including:
  - Electron Microscopy (TEM, S/TEM, FIB-SEM, SEM)
  - Scanning Probe Microscopy (Bruker Icon, Veeco 3D Insight)
  - Electrical Testing (multiple semi/automated stations)
  - Surface Spectroscopy (AES, XPS, ToF-SIMS, XRD/XRR, Raman, Ellipsometry)



FEI Titan S/TEM

70pm resolution, Super-X EDS chemical characterization



Bruker Icon AFM

Electrical measurements, material property mapping, surface-particle interactions, adhesion, friction

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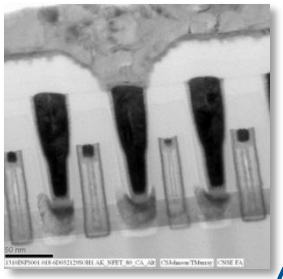

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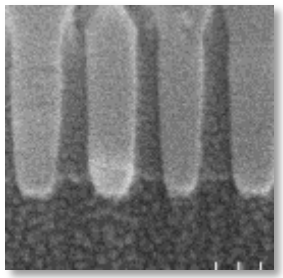

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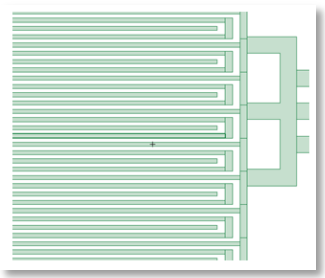

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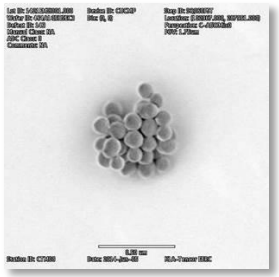
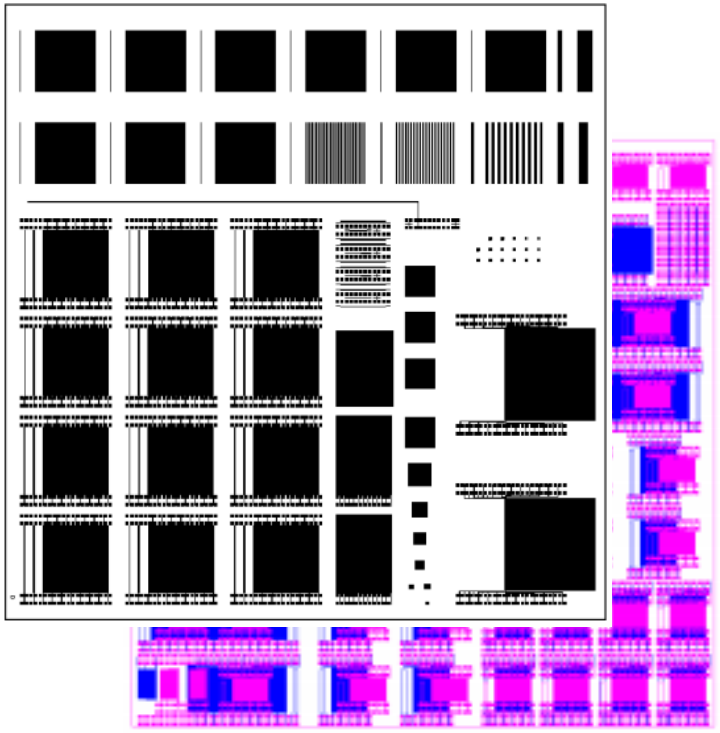


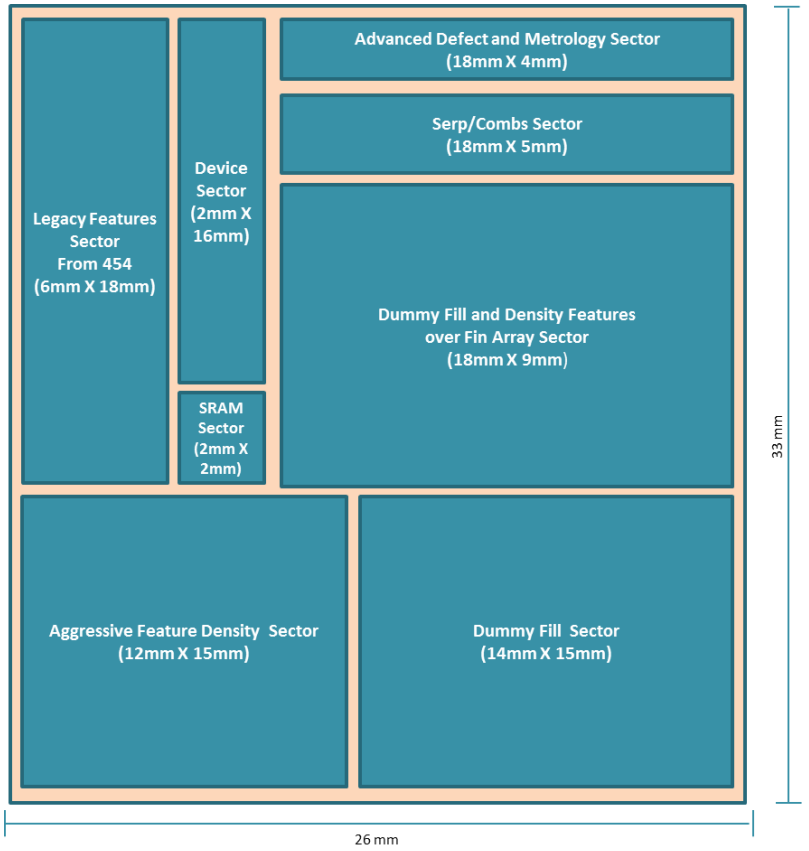
Industry-Standard Mask Set: Past

- SEMATECH/MIT mask set became the de facto CMP workhorse for the industry in the late 1990's
- Twenty years of scaling & new materials demand an updated industry-standard mask set to meet sub-14nm challenges



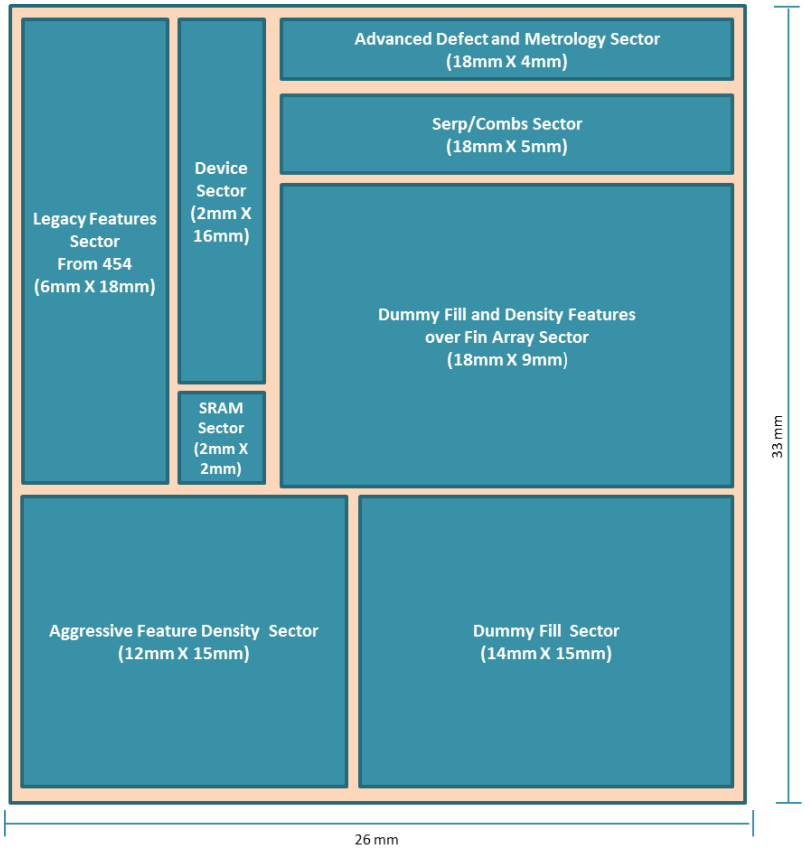
Industry-Standard Mask Set: Present

- Features FEOL and BEOL structures for process fingerprinting, dummy fill evaluations, e-test and reliability, and advanced metrology
- Allows for CMP process and consumables testing at relevant critical dimensions



Industry-Standard Mask Set: Present

- 14nm FEOL Design
  - Macro definitions completed
    - Seven process levels
    - Supports SADP, FIN, RMG, Gate/Contact LE, & High-K process development
  - Layout completed design rule check at mask house
  - Taped out July 2015
- 14nm BEOL Design
  - Technical team defining macros and reliability test structures
    - Electromigration
    - TDDB
  - Tape out on schedule for 15Q4



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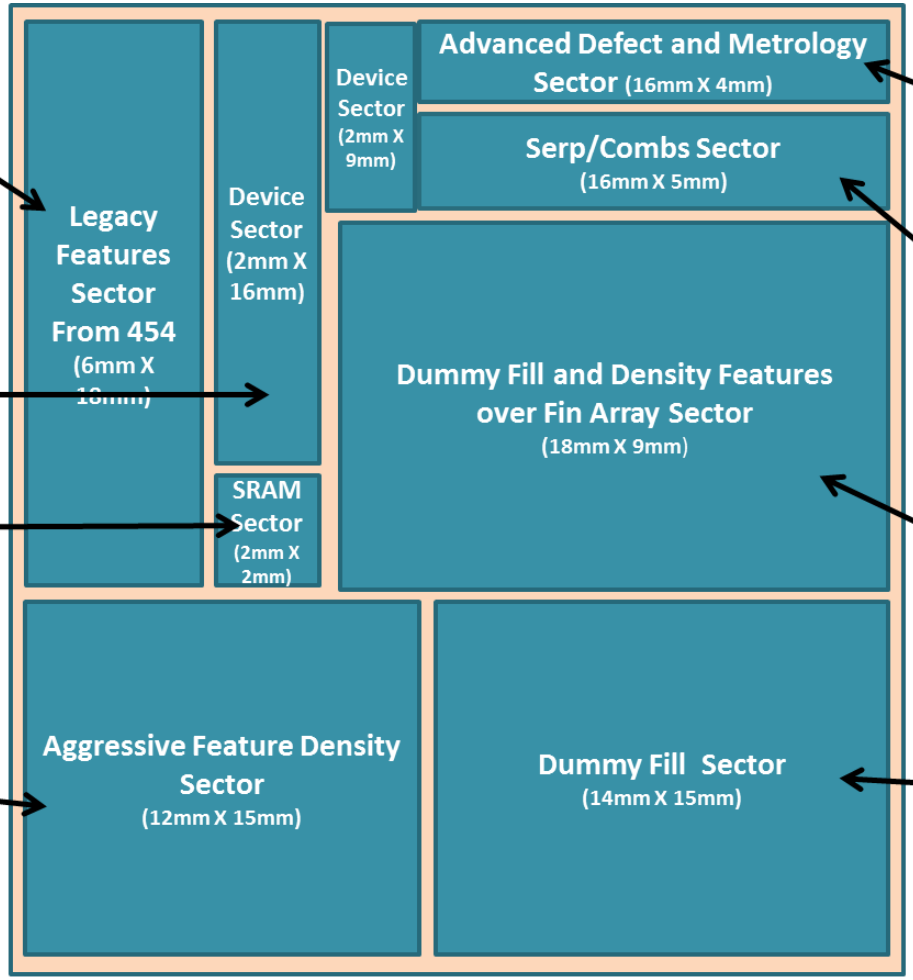

Range of large CD and pitch features for learning transfer from legacy mask

Selection of simplified, e-testable devices for validation of CMP effects on devices

Structural SRAMs with geometries relevant to different technology nodes

Range of aggressive, industry relevant CD and pitch features for CMP evaluation

Miscellaneous metrology structures for state of the art metrology

Serp/Combs structures with underlying STI level topo for opens/shorts defectivity e-testing

Combination of dummy fill test structures and aggressive features for testing effects of underlying fin topography

Range of small and large CMP features surrounded by dummy fill for testing effects of DF type and exclusions

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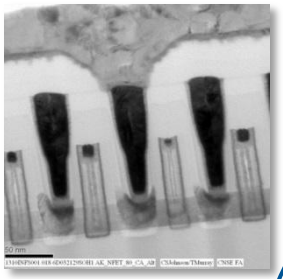

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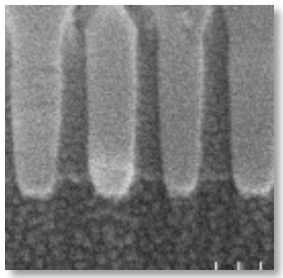
Multi vendor CMP platforms



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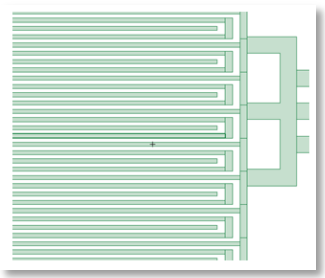

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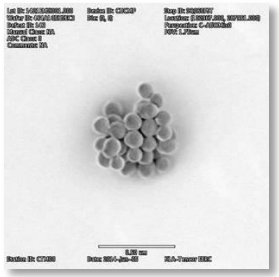

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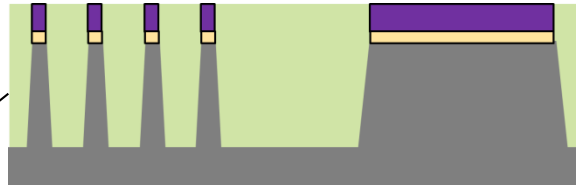
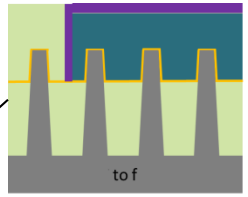
Robust Baseline Process Flows: FEOL

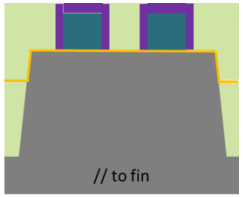
- HM1, HM2 & mandrel dep
- Mandrel litho & etch (stop on HM2)
- SIT spacer dep and etch
- Cut mask litho & etch (stop on HM2)
- Block litho
- Etch HM2, HM1 and fin/active
- Oxide fill and **CMP**
- Poly dep & **CMP**
- Gate litho (40/96nm) & etch
- Spacer dep & etch (SiN)
- ILD 0 dep & POP **CMP**
- HK/MG dep & CMP (TiN/W)
- MG recess, SiN dep & **CMP**
- ILD 1 dep
- Contact litho
- Contact etch & fill (Ti/TiN/W)
- IMD dep
- M1 litho & etch
- M1 fill (TaN/Ta/Cu) & **CMP**

Fin/Active

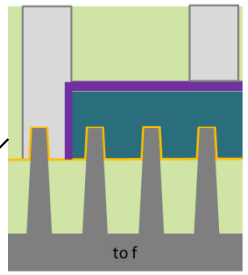


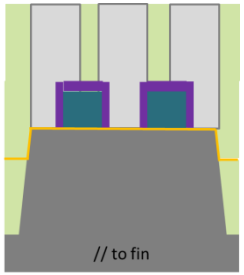
RMG



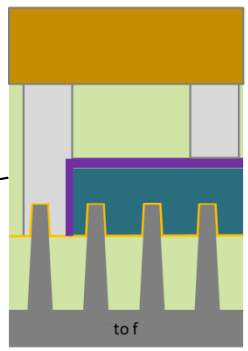


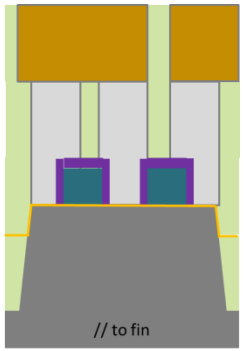
Contact





M1





Robust Baseline Process Flows

- 14nm FEOL
  - STI CMP
  - Poly CMP
  - POP CMP
  - W CMP
  - Contact CMP
- 14nm BEOL
  - M1 CMP
  - M2\V1 CMP
  - M3\V2 CMP
  - Al CMP

- Health-of-the-line (HOL) maintained, monitored, and record by SPC
  - Process, Defectivity, E-test

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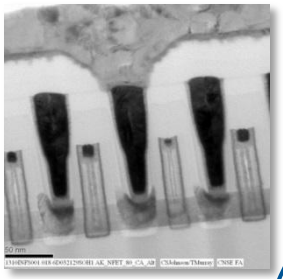

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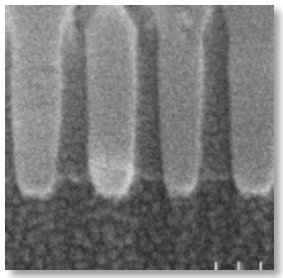

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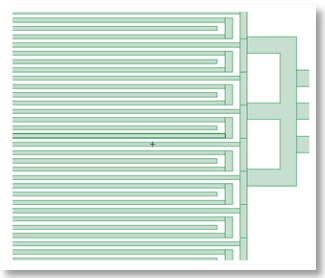

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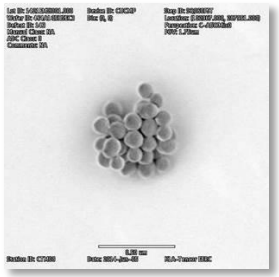

Leading Edge Materials

- Leading-edge deposition process capability at SUNY Poly CNSE
  - Including TEL, Applied Materials, Lam Research
- Industry-relevant materials and materials stacks for integrated learning
  - Including III-V, SiC, high-k, low-k, W, Co, Ru, TaN/Ta, TiN/Ti, Cu

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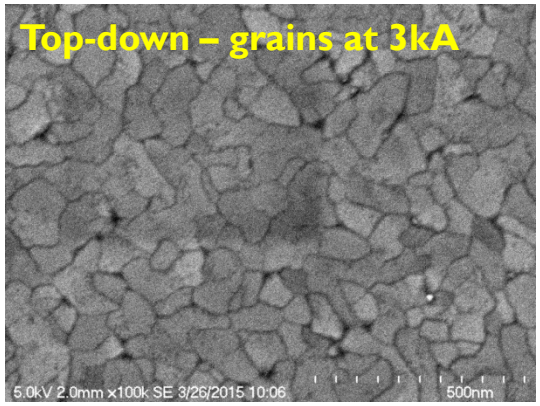
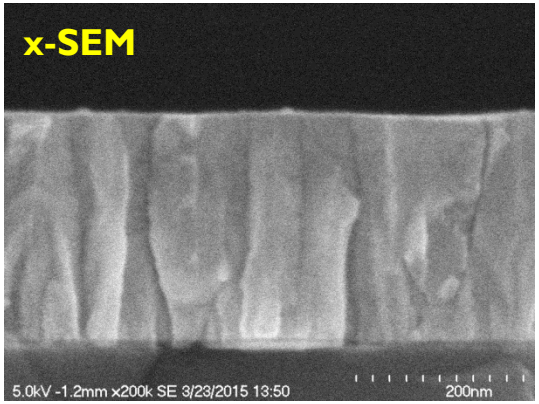
Leading Edge Materials: Case Study

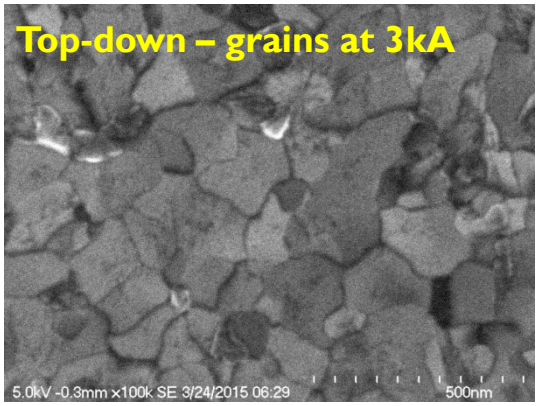
Tungsten films difference and CMP performance impact

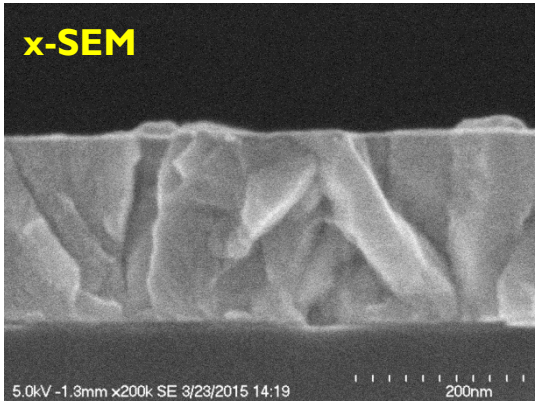
Process A





Process B





CMP center provides access to processes for W CMP evaluation on both patterned and blanket test structures.

Blanket Tungsten Film Properties:

	Process A	Process B
Grain Size at 3000A thickness, nm	80-100	166-200
Grain size at 500A thickness, nm	40-50	90-100
3000A W film Wafer Bow, um	380	275
3000A W Film Resistivity, Ohms/sq	0.325	0.316
2000A W film Wafer Bow, um	280	194
2000A W Film Resistivity, Ohms/sq	0.61	0.510
500A W Film Resistivity, Ohms/sq	3.16	2.58

W films properties are significant in determining CMP performance: including initiation phase, removal rates and residual roughness.

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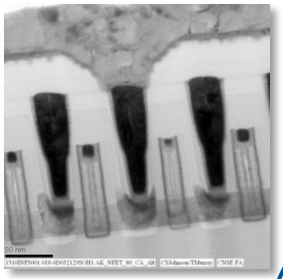

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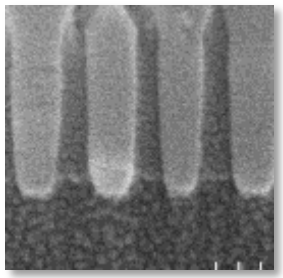

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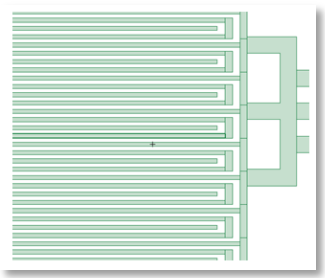

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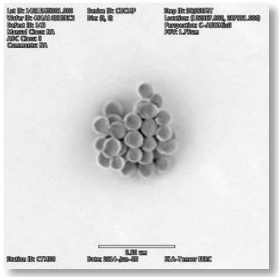
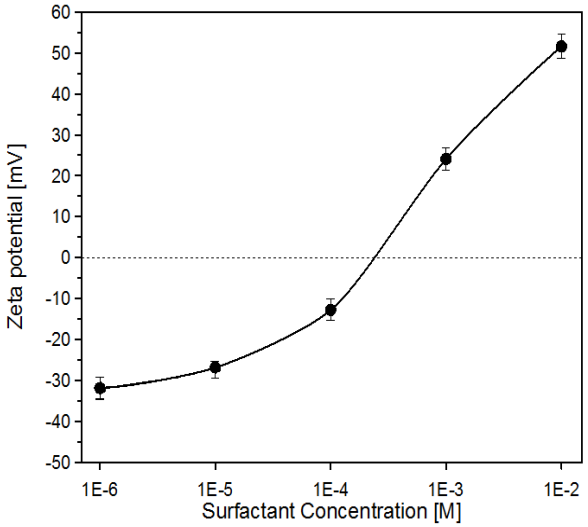


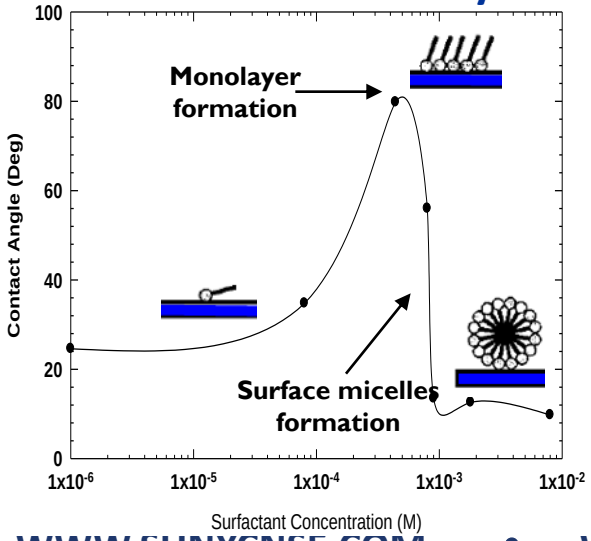
Fundamental Learning

- Analysis of surface state of slurry particles, pad and wafer surfaces for fundamental understanding of CMP and post-CMP cleaning systems
- Studies of influence of surface active slurry and cleaner components on:
  - Surface charge/zeta potential
  - Wettability/interfacial energy
  - Film formation/steric barrier

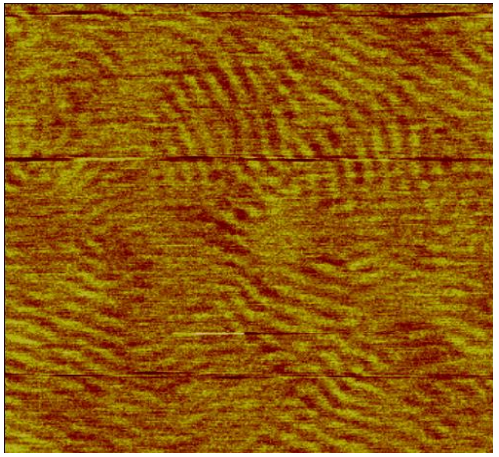
Particle/Surface Charge



Surface Wettability



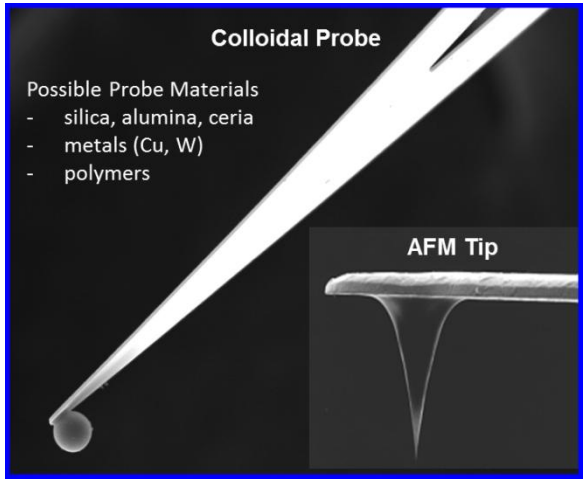
Surface Film Formation



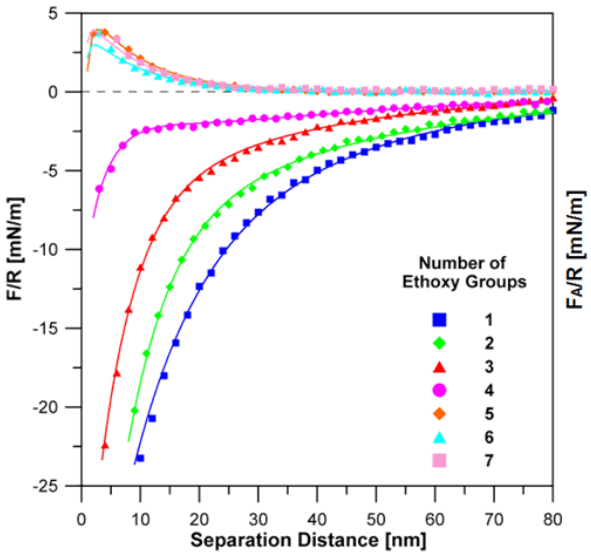
in situ AFM – 200nm scan

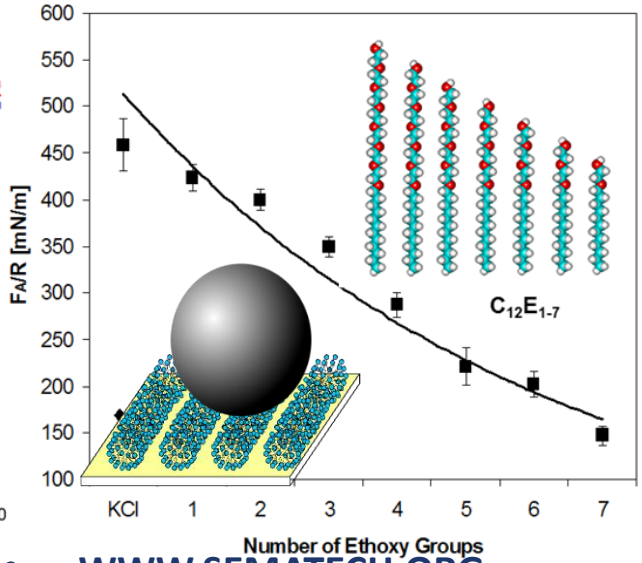
- Comprehensive analysis of interaction forces, adhesion, and nanoscale friction between components in CMP and post-CMP cleaning using state-of-the art AFM system
  - Influence of slurry and cleans chemistry on interaction forces and adhesion
  - Characterization of surface state (surface charge/potential, surface energy)
  - Characterization of surfactants and water soluble polymers
  - Adhesion mapping and nanoscale friction analysis

Colloidal Probe Technique



Particle-Surface Interaction Force and Adhesion





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Open Innovation Business Model

- The world of R&D collaboration has fundamentally changed
  - There are very few places in the world with access to leading edge CMOS manufacturing that are open to truly collaborative research
  - There is no supplier today that can afford the leading edge manufacturing infrastructure that chip makers use today for in-house development
  - Given the industry consolidation it has become more difficult for supplier to directly partner with chip manufacturers without their development becoming "captive"
- SUNY Poly enables truly collaborative research in a leading R&D facility
  - Access to state of the art equipment and processes
  - A business model that enables suppliers to develop their material, products and IP without becoming captive to a single company
  - Opportunity to engage in collaborative research at desired levels – from infrastructure access only to fully engaged collaborative research projects
  - Flexibility to grow R&D efforts at the desired pace driven by economic development and available opportunities at SUNY Poly SEMATECH

JDPs and Benchmarking

- Typically multi-year JDP engagements with projects mutually selected to deliver highest ROI
  - Near-term goals chosen to be consistent with long-term strategic goals
  - Mix of JDP and benchmarking projects may be run concurrently
- The Advanced Planarization Center's platform provides a framework for the entire CMP community to participate in benchmarking exercises
  - Perform on site evaluation of consumables (eg pads) with other selected commercially available consumables (eg slurries)
  - Conduct post-CMP metrology and provide appropriately sanitized reports

Summary

- The SUNY Poly Advanced Planarization Center is the global leader for CMP research and development and has the experts, resources and open innovation business model to support the industry
  - Industry-standard mask set with structures for process fingerprinting, dummy fill evaluations, e-test and reliability structures, and advanced metrology features
  - Robust fully integrated baseline process flows for all front-end-of-the-line (FEOL) CMP levels and advanced back-end-of-the-line (BEOL) CMP levels
  - Trusted framework for benchmarking among nominal industry competitors
  - Suite of leading-edge characterization techniques for CMP consumables and wafer surfaces

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450mm CMP Update

Christopher Borst
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July 16, 2015
SEMICON West 2015 – CMP Technical and Market Trends

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G450C Key Messages

- The Program and Suppliers continue to achieve excellent technical results
  - 51 Tools in Albany
- Nikon Scanner arrived in Albany – First Patterned wafers in September 2015
- Notchless wafers with 1.5mm edge exclusion is the Semi standard
- All partners supporting equipment set in NY through Q1 2017

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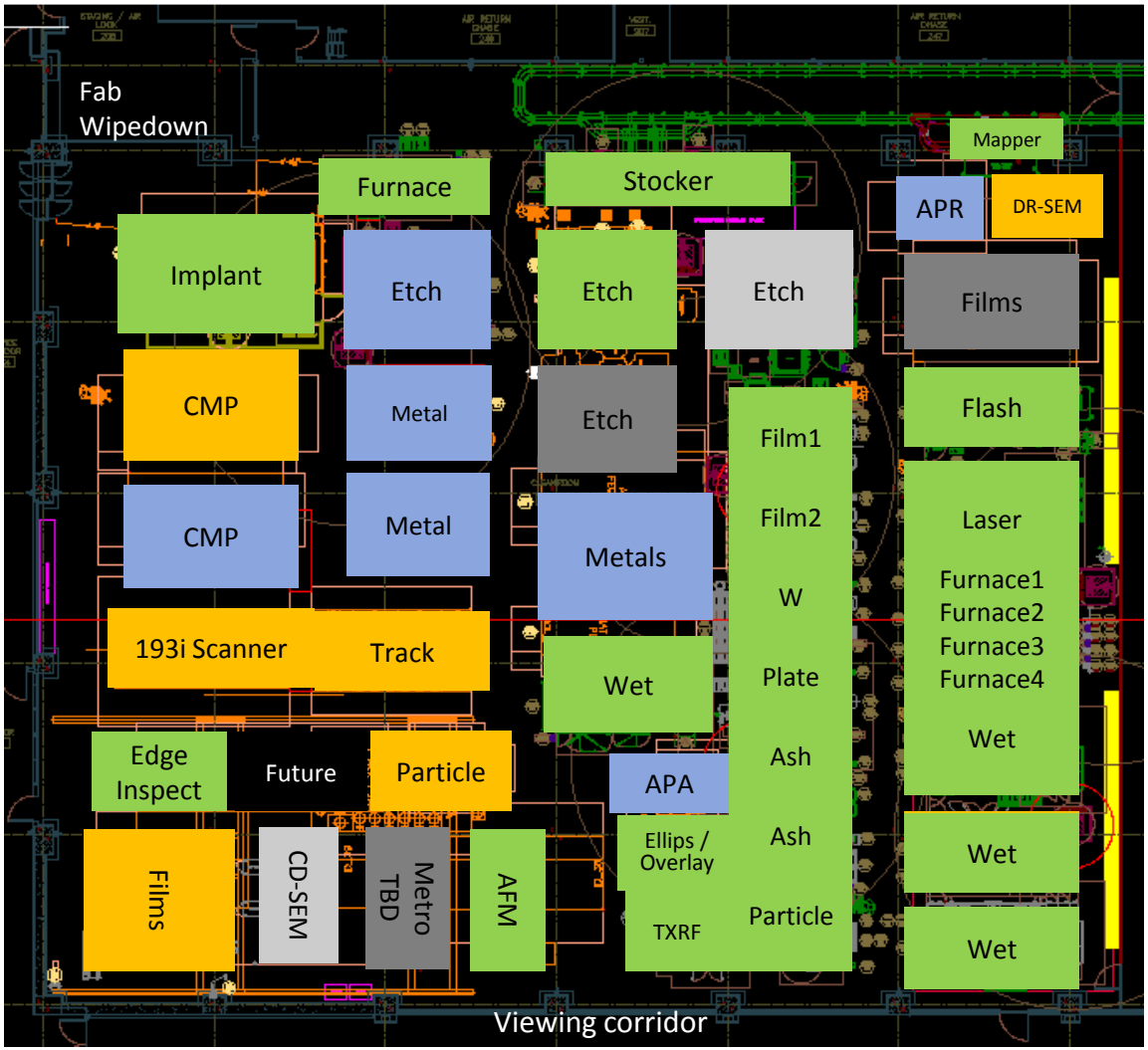
G450C Fab Layout



Installed

Active Install

2015

2016

FUTURE

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CMP Tool Status - Albany

- Two 450mm CMP Tools are to be installed at G450C
- Both tools will have process demos on Oxide, STI, Cu, and W

- The 1st 450mm CMP tool installation completed Jun'15
  - Tool process qualification on Oxide CMP is on-going
  - Qual of STI & Cu processes will follow

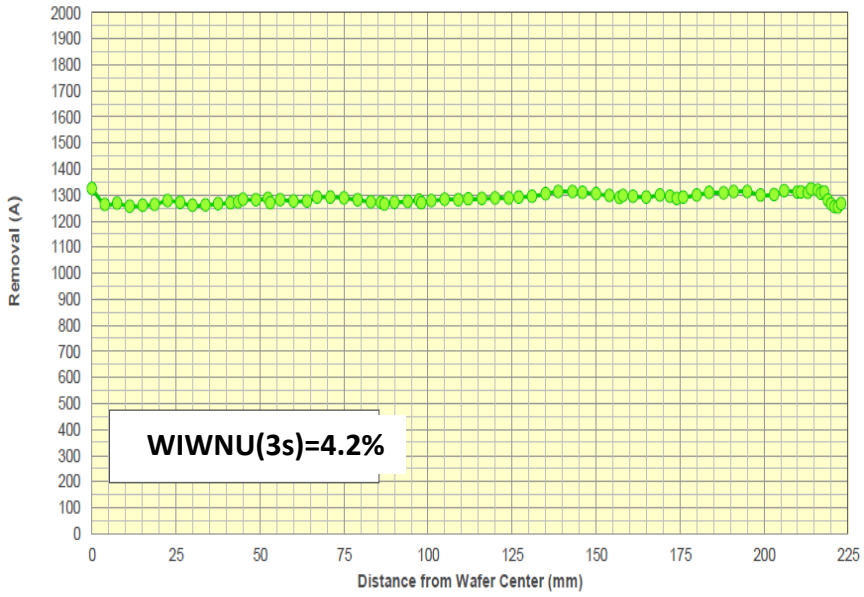
- The 2nd 450mm CMP tool starts installation 4Q'15
  - Tool is still used for Cu process demos at supplier site

- Qual of W CMP processes on both tools will start 2Q'16

GTC01 Performance

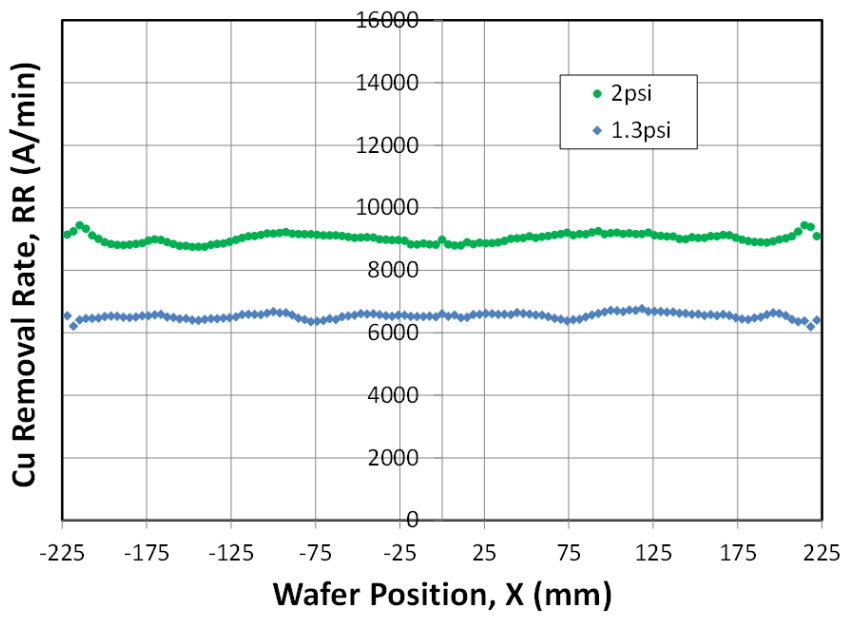
Oxide CMP Process

- Best performance at 1.4psi
  - 1.4psi: Removal Rate = 1300 A/min
  - WIWNU% (3σ) = 4.2% @ 2mmEE



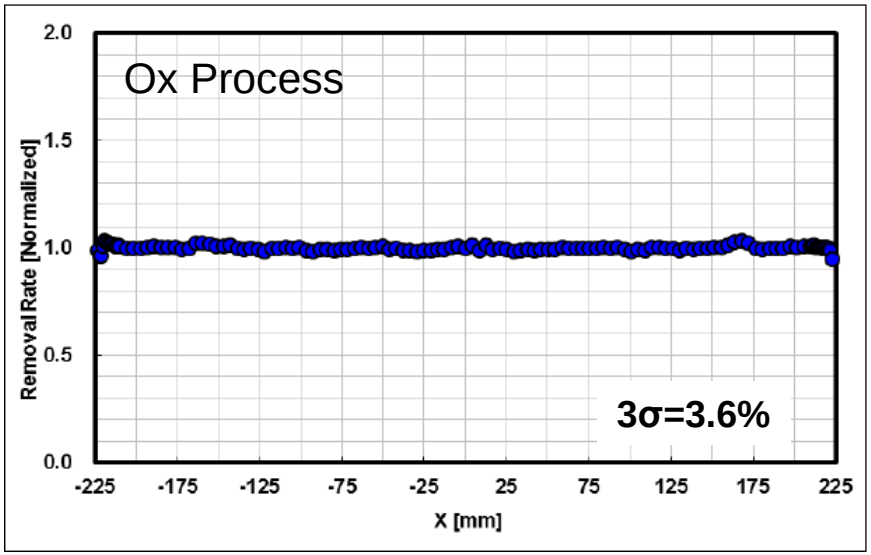
Cu CMP Process

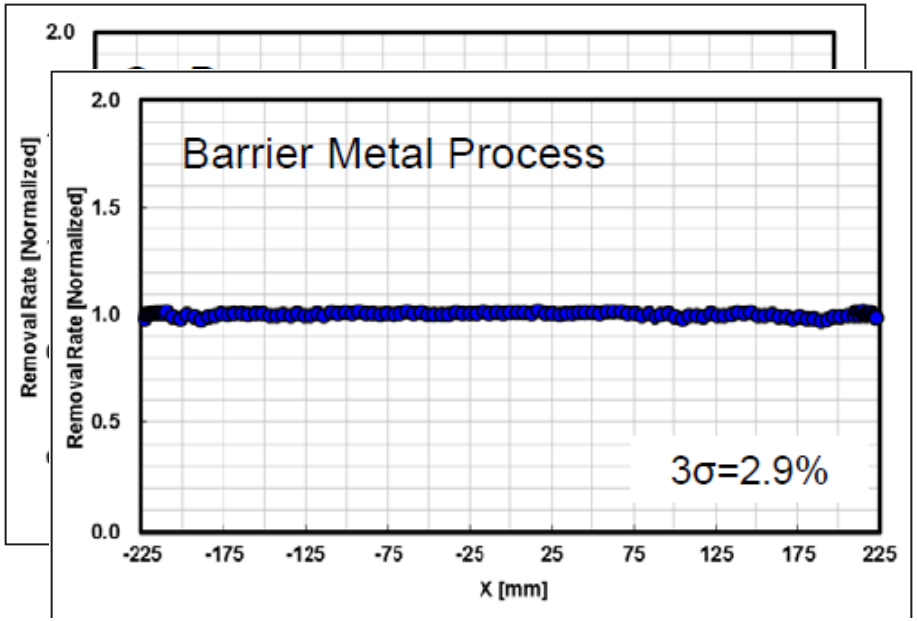
- Best Cu performance
  - 2.0psi: Removal Rate = 8970 A/min
  - WIWNU% (3σ) = 6.3% @ 3mm EE
  - 1.3psi: Removal Rate = 6540 A/min
  - WIWNU% (3σ) = 5.5% @ 3mm EE



GTC02 Performance

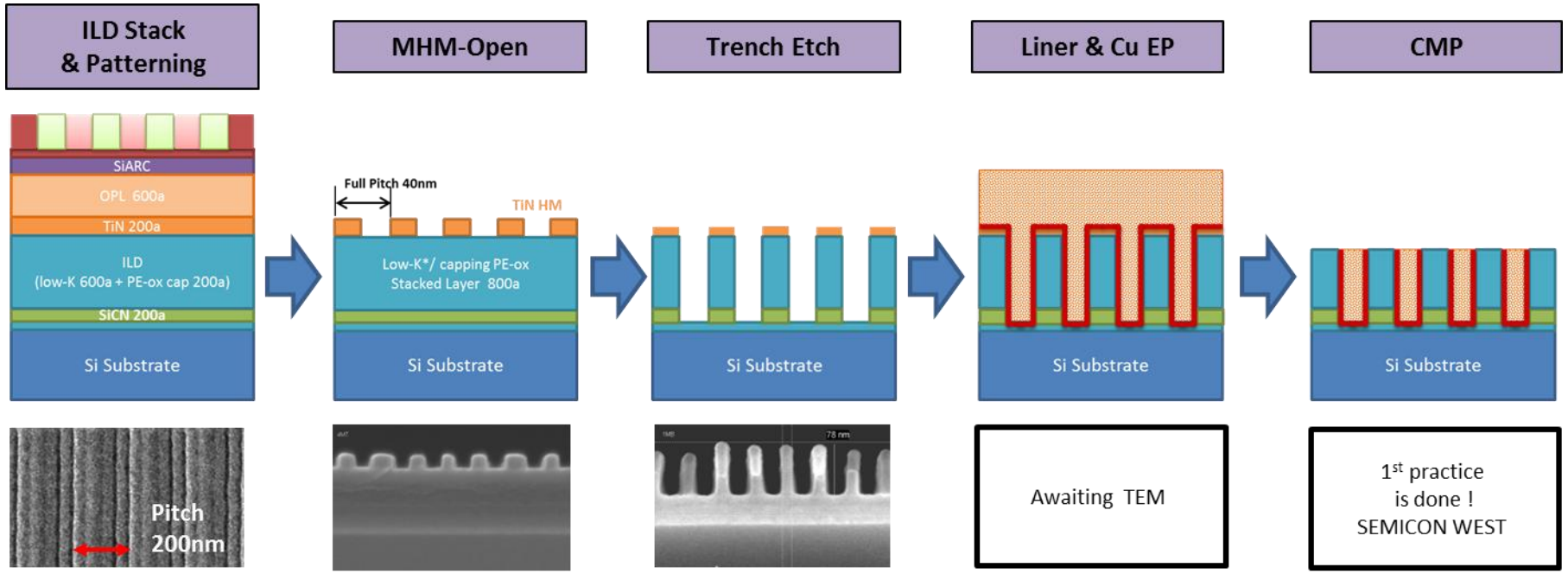
- Oxide CMP Process
  - Best performance at 2.0psi
    - WIWNU% (3σ) = 3.6% @ 2mm EE
- Cu CMP Process
  - Best Cu performance at 1.5psi
    - WIWNU% (3σ) = 5.5% @ 4mm EE
  - Best Barrier performance at 1.5 psi
    - WIWNU% (3σ) = 2.9% @ 2mm EE





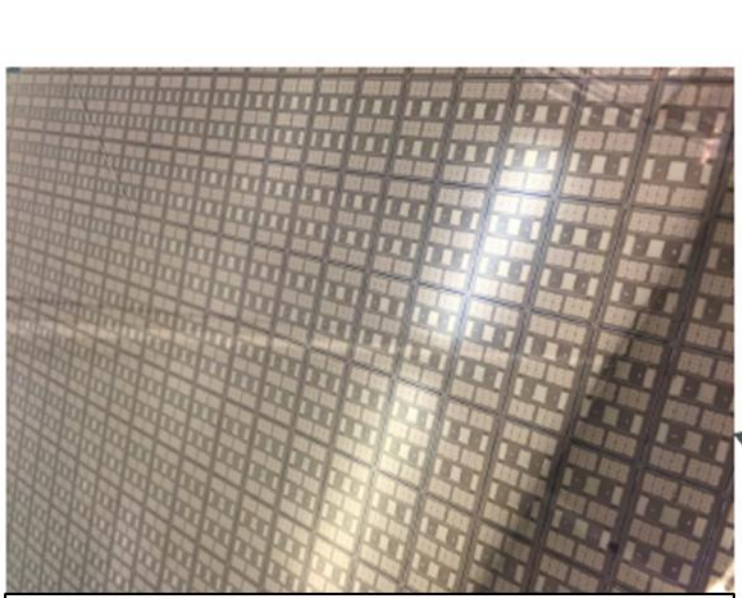
M1 Cu Damascene Module

- G450C Integration leading BEOL M1 Module Development
  - Best Cu and barrier CMP processes performed on program tool GTC01

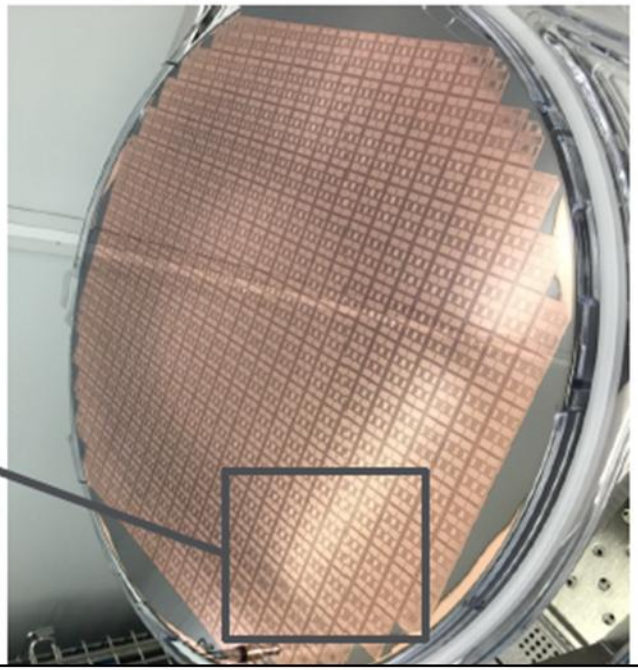


M1 Cu Damascene Module

- M1 CMP Complete
  - First wafer in the world through M1 Cu Damascene CMP
  - G450C test mask; smallest feature 20nm Cu line and space



Enlarged view



450mm Cu CMP Wafer

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450mm CMP Summary

- The first of two 450mm CMP tools is installed in the CNSE G450C Cleanroom
- Oxide and Cu demonstrations at supplier sites show excellent initial results
- The world's first Cu M1 BEOL 450mm wafer has been generated through G450C – Albany and supplier site equipment, including 450mm Cu / Barrier CMP
- G450C Albany in-house lithography ready for module wafer builds 3Q'15

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- For more information, please contact "Pops" Papa Rao at Satyavolu.PapaRao@sematech.org.