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Development of Copper Slurries for Advanced Technologies

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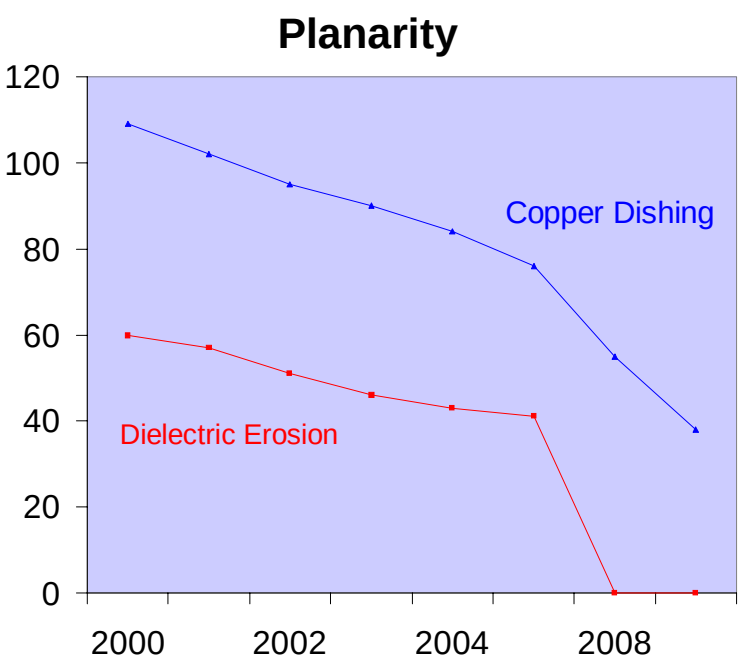
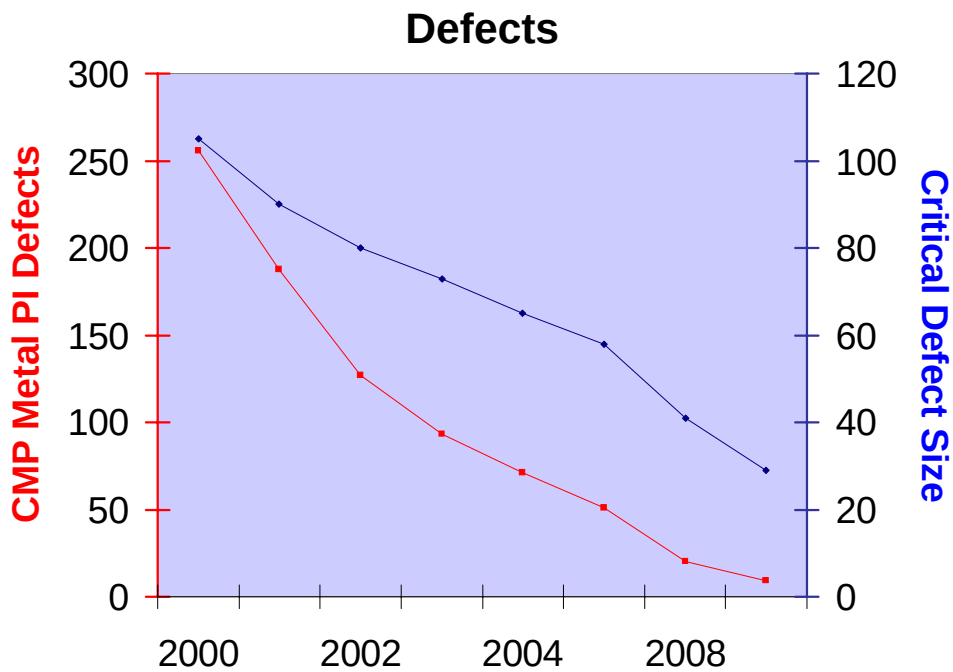
Outline

- Introduction
- Copper CMP
  - New removal mechanism for copper CMP
  - Planarity
  - Defectivity after copper CMP
- Barrier CMP
  - Tunability of removal rates
  - Planarity results
  - Defectivity after barrier removal
- Summary

Future Interconnect Requirements





- Technology Trends
  - Increasing planarity
  - Decreased defectivity
  - Increased Aspect Ratios: lower metal loss

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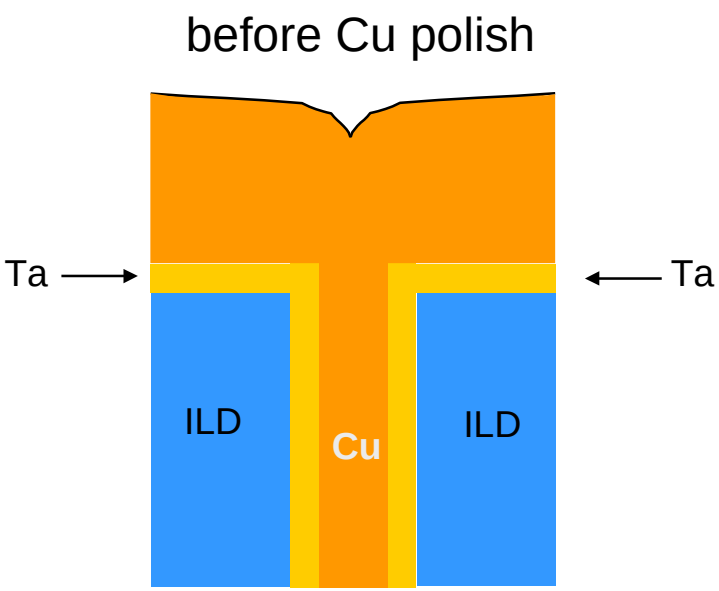
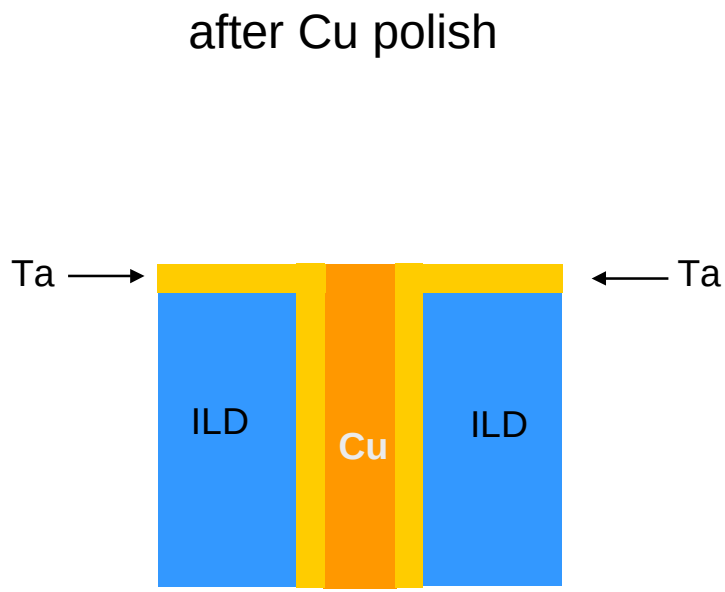
Future Directions for Copper CMP

- Increasing planarity requirements
  - Improved topography dictated by shrinks
- Tighter copper & oxide loss budgets
  - Increasing aspect ratios
- Migration to low κ
  - Material compatibility: chemical/mechanical
- New and thinner barriers
  - Tighter requirements
- Reduced defects

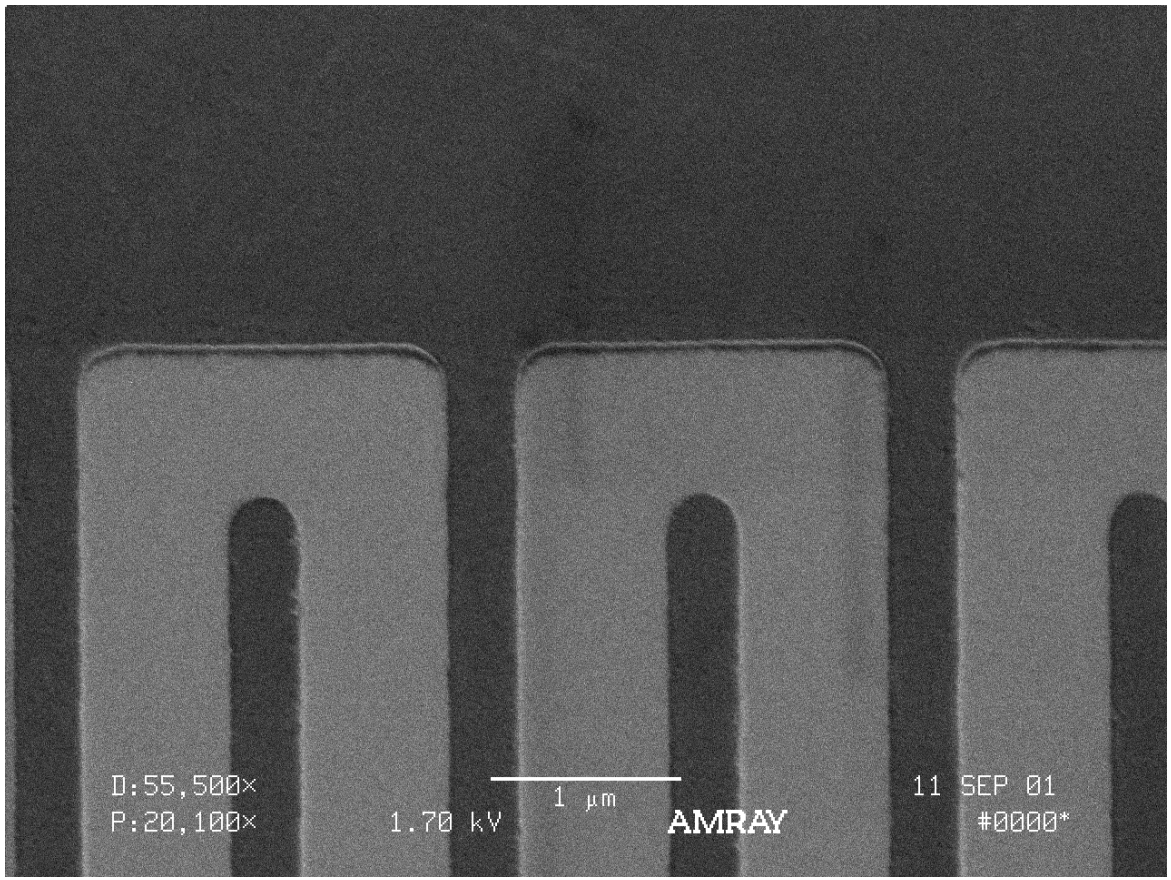
Goals of Cu Polish

- Remove the bulk of the Cu layer
- Planarize the Cu layer
- Stop on the barrier film
- Achieve low defectivity





Post Cu Polish Defectivity

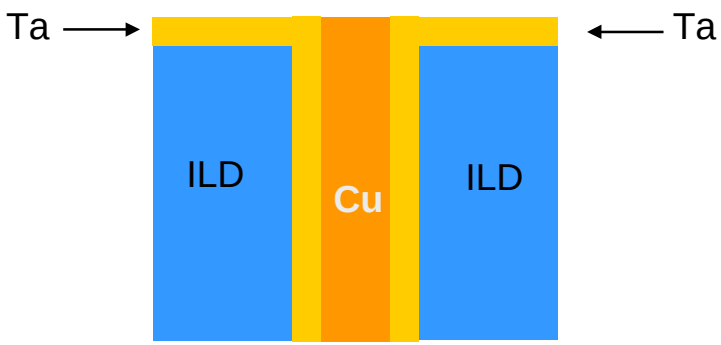


No scratches, no Ta barrier loss

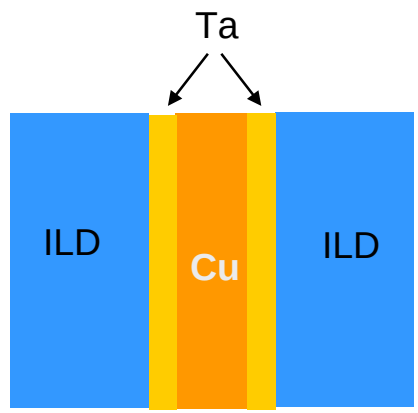
Goals of Barrier Polish

- Remove the barrier film
- Planarize the wafer (by polishing exposed barrier, Cu, and dielectric/cap films)
- Leave no CMP defects

before Barrier polish



after Barrier polish



Blanket Porous SiLK™ v(9) Film Polish Evaluation

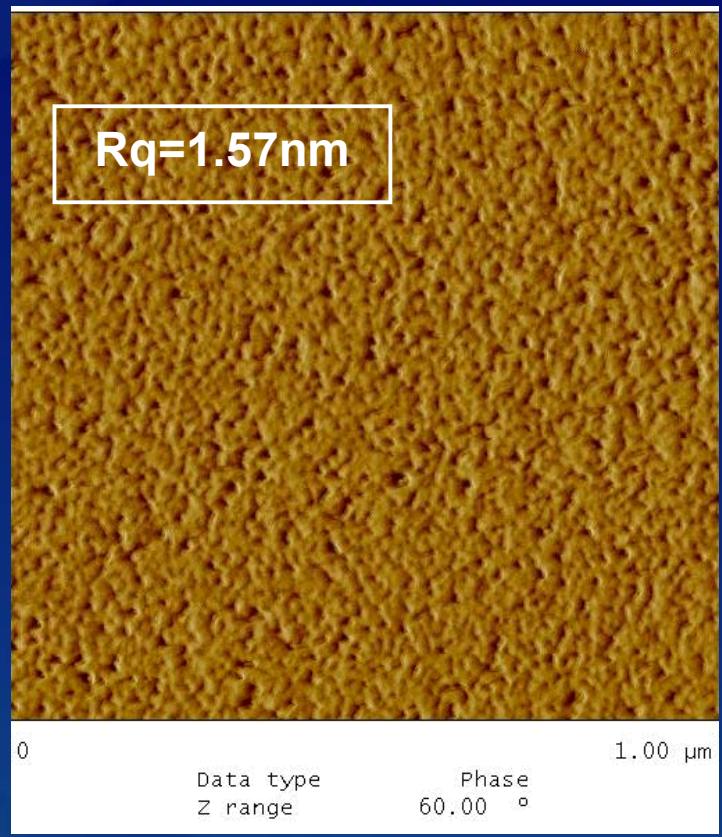
CMP process MP : PS : CS	Cu Removal Rate Å/min	Ta Removal Rate Å/min	SiLK (V(9)) Removal Rate Å/min
3psi : 68rpm : 27rpm	4667	-	170
1psi : 68rpm : 27rpm	1320	29	109

Results of blanket wafers polished with an experimental copper slurry
Applied Materials Mirra polisher was used
MP – membrane pressure
PS – platen speed
CS – carrier speed

Porous SiLK™ Films Polished Edge Fast

Pre-Polished Porous SiLK™ Film Surface

V(7)



V(9)

v(9) possess higher porosity, smaller pore size, lower surface roughness and dielectric constant (2.0) comparing to v(7) (k = 2.35)

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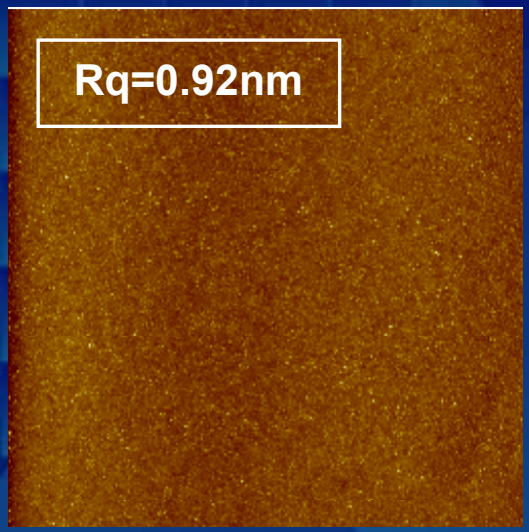
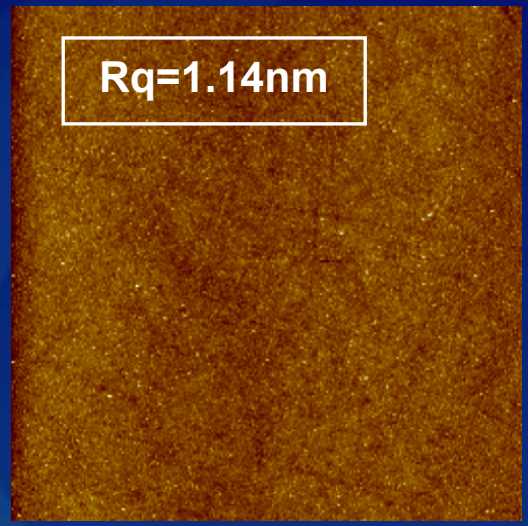
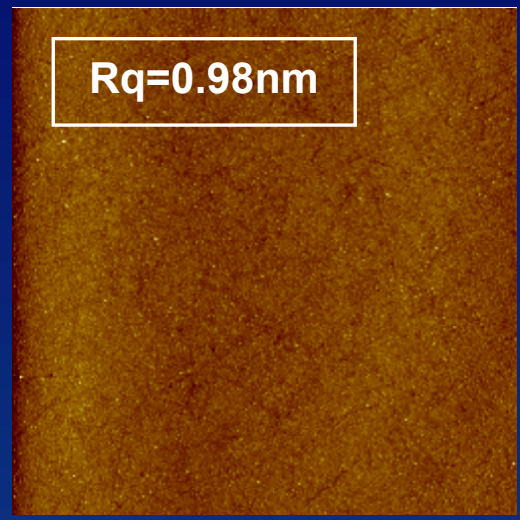
Porous SiLK™ (v9) Film Surface Evaluation



(a)
Unpolished



(b)
Polished at 3psi
68 rpm PS
27 rpm CS



(C)
Polished at 1psi
68 rpm PS
27 rpm CS

The experimental copper slurry of EP-C6000 series was used

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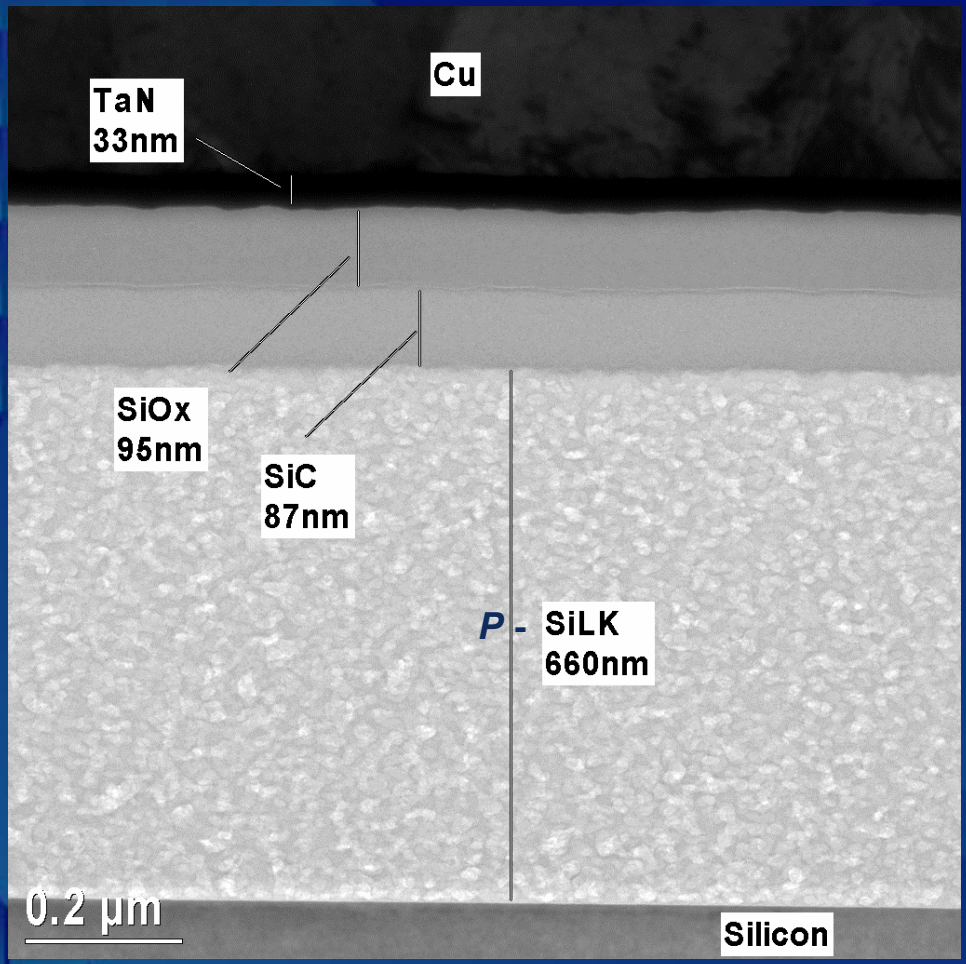
Blanket Porous SiLK™ (v9) Polish Overview

- Summary
  - No film delamination under normal CMP process
  - Direct polish on porous SiLK™ v(9) yielded good surface quality
    - no increase in roughness after CMP
    - Minor scratches were observed - < 100Å
- Defect characterization suite at CMC
  - KLA-Tencor Surfscan SP-1 TBI^{II}
  - KLA-Tencor Confocal Review Station (CRS)
  - Digital Instruments AFM
  - KLA-Tencor 4200 DRT SEM
- Film characterization at Dow Chemical
  - Tunneling Electronic Microscope
  - Nanoindentation

Higher Demand in CMP Process Capabilities for Ultra Low-k Materials

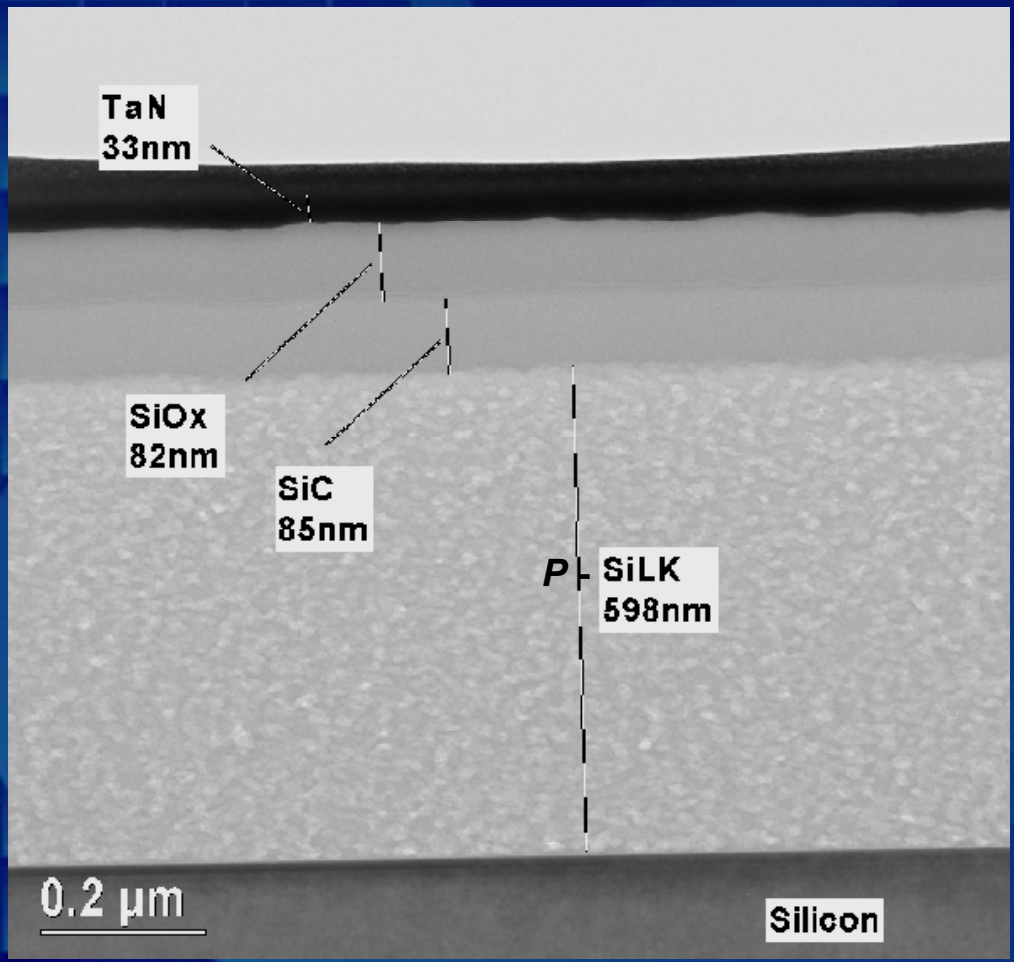
- Complicated integration scheme calls for better controlled process capability
  - Multiple choices of materials
    - Ultra low-k films
    - Alternate barrier technology
    - Capping layers and hard masks
  - Different device design roles call for different integration scheme
  - Controlled removal of or stop on selected materials become focus of CMP process for ultra low-k adoption

Blanket Film Stack Simulating Damascene Structure



- TEM of unpolished film
- Integrated with SiLK™ v(7) film

Blanket Film Stack Simulating Damascene Structure



- TEM of polished film stopping on TaN
- EP-C6000 series was used

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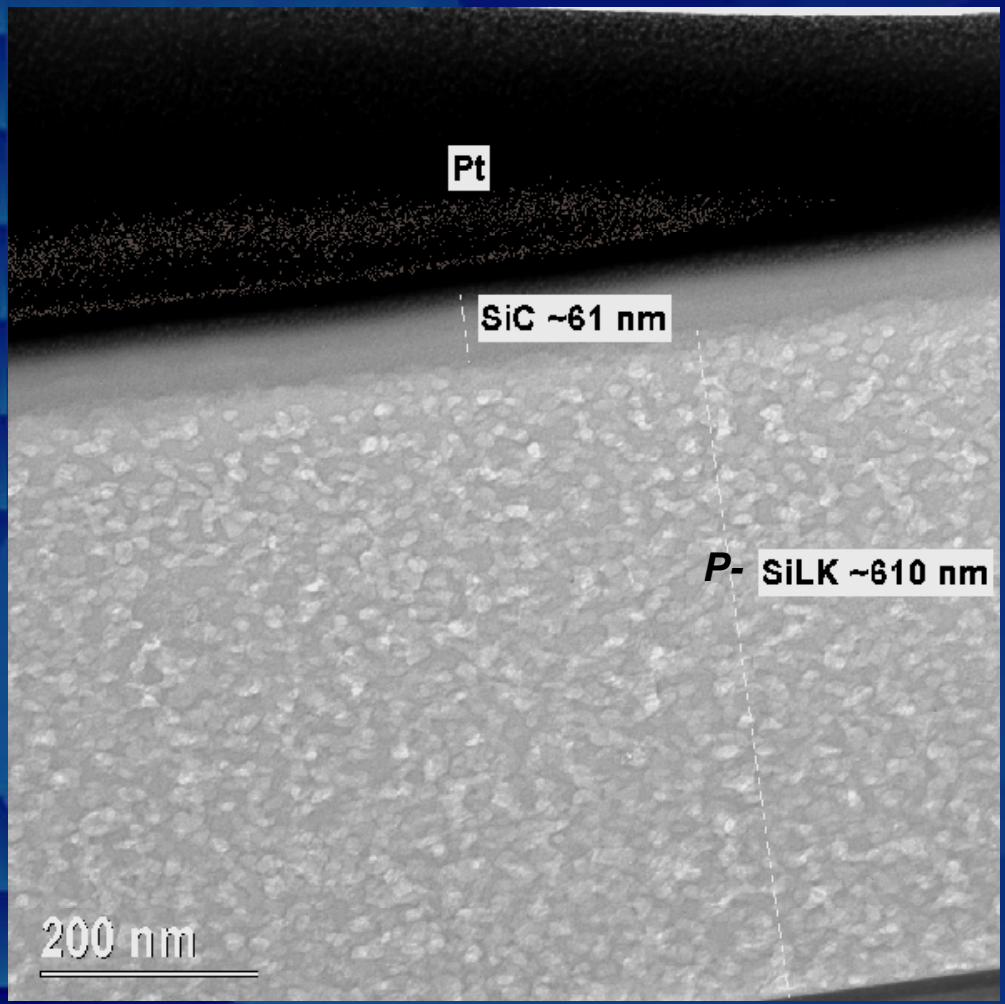
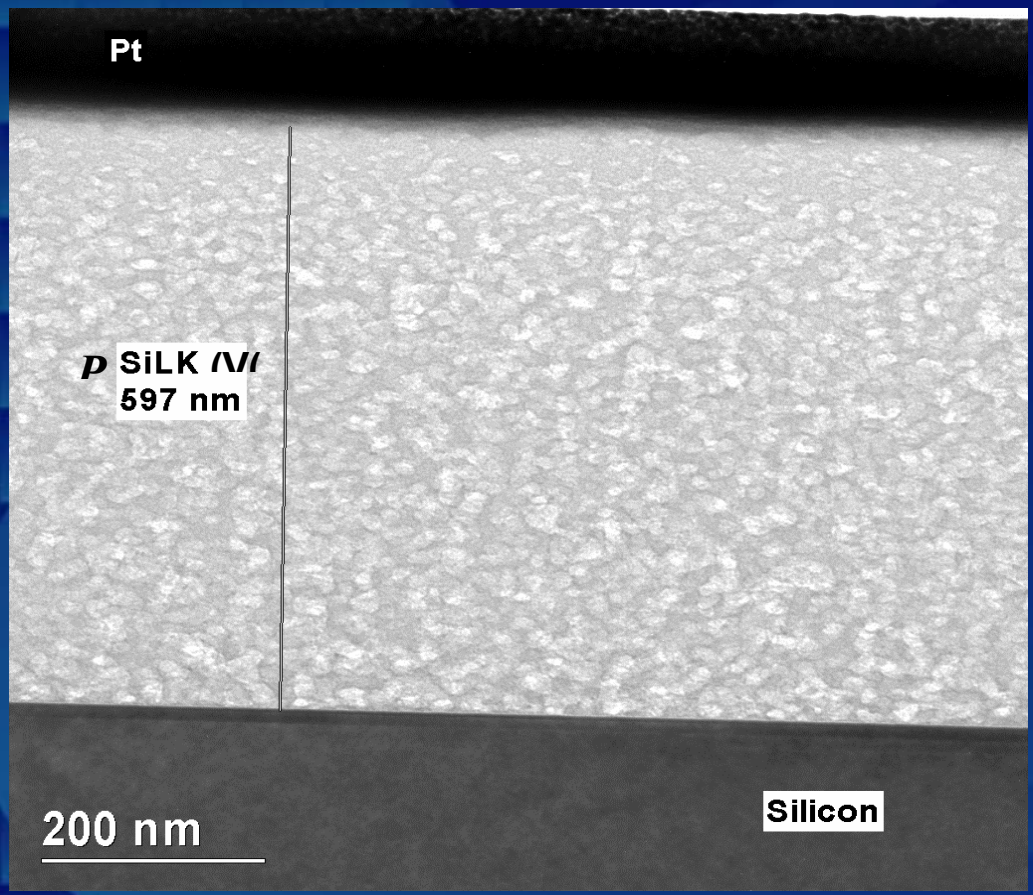
Blanket Film Stack Simulating Damascene Structure



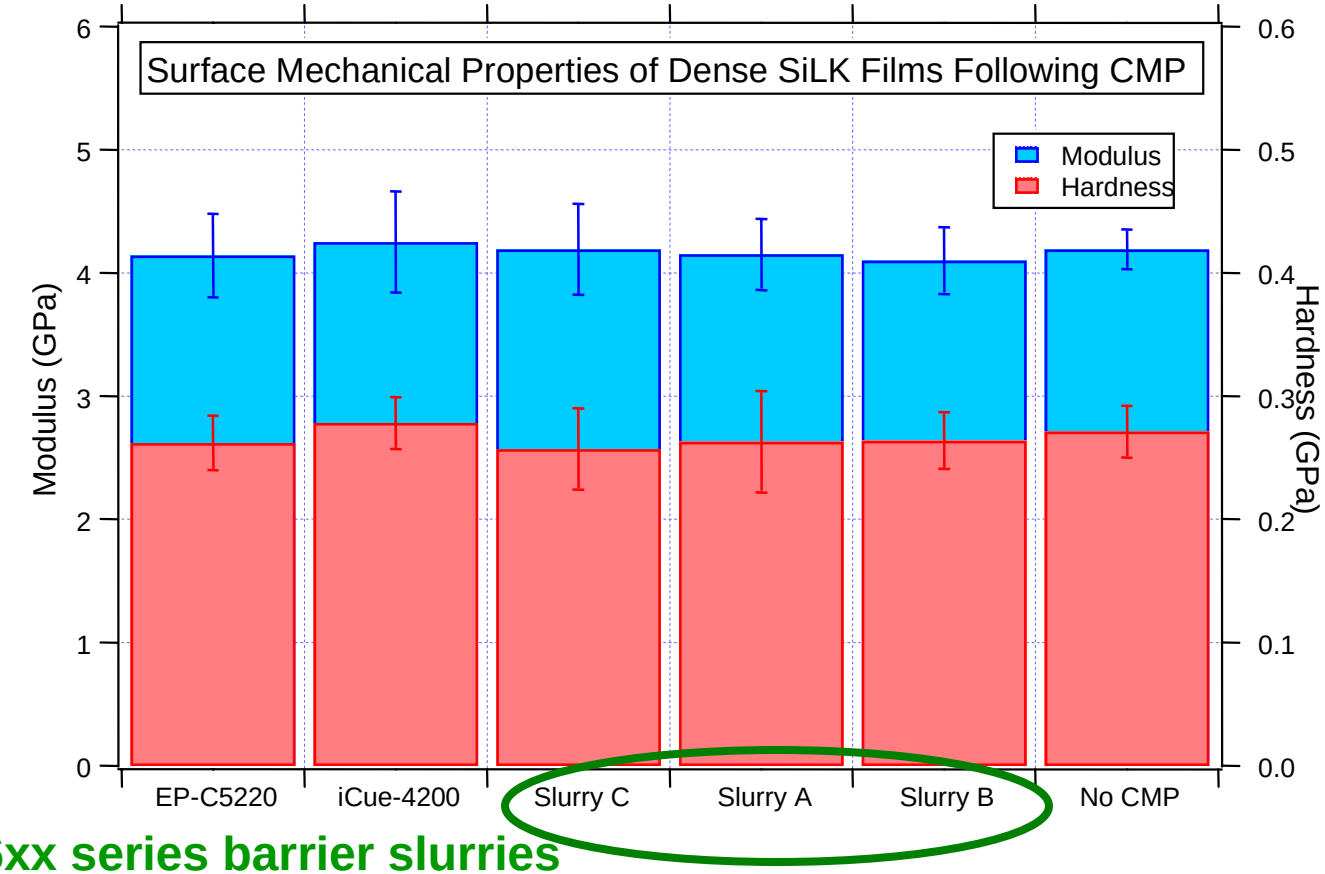
- TEM of polished film stopping on SiC
- iCue4200™ was used

Blanket Film Stack Simulating Damascene Structure



- TEM of polished film stopping on Porous SiLK™
- iCue4200™ was used

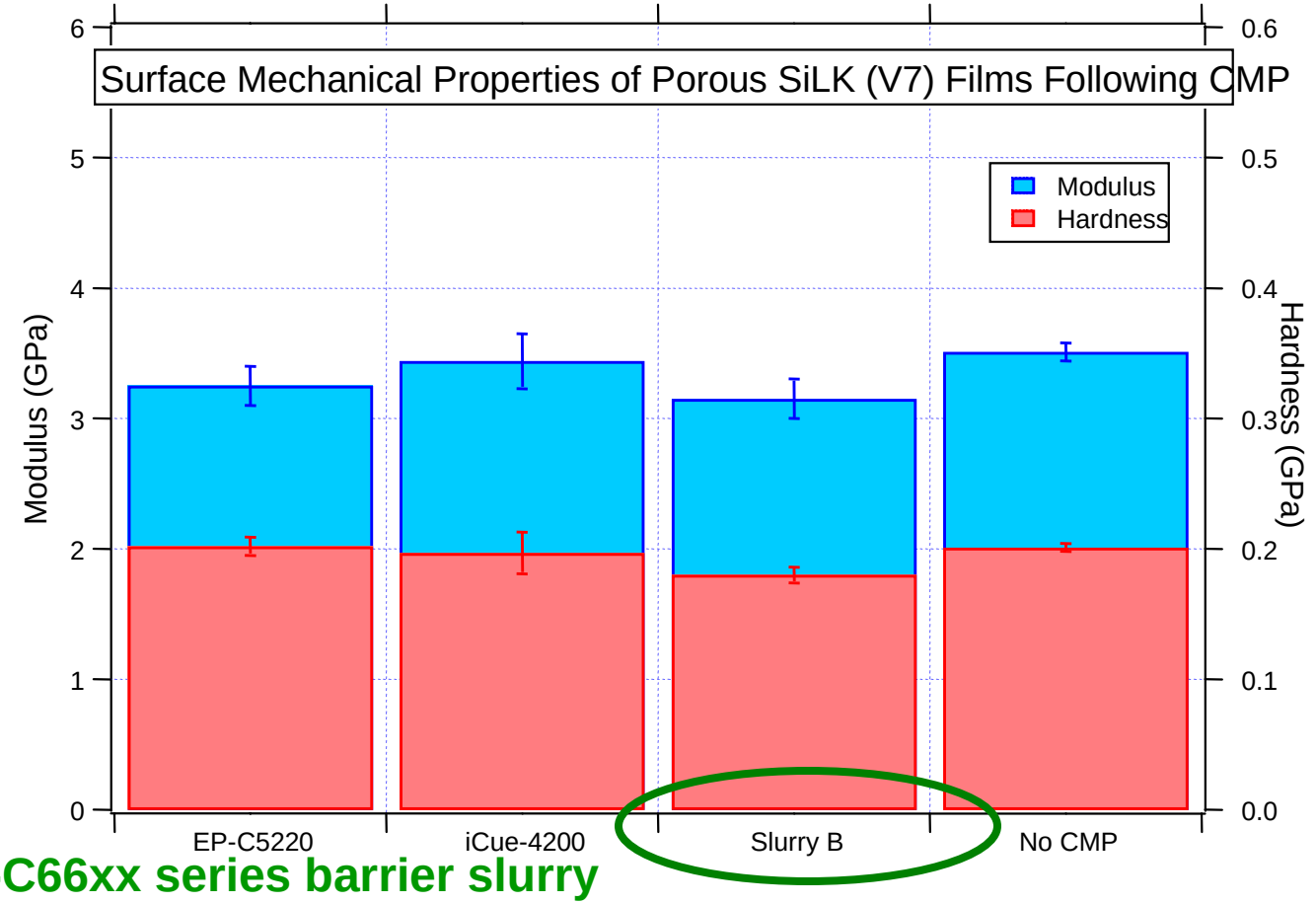
No change in surface mechanical properties is observed after dense SiLK* films are polished with various iCue™ slurries. Nanoindentation results measuring modulus and hardness after CMP are indistinguishable from tests on unpolished SiLK* films.



EP-C66xx series barrier slurries

Cabot Microelectronics iCue™ DOW® SiLK™

Even with added porosity in the dielectric, no significant change in surface mechanical properties is observed after CMP on porous SiLK* films after polishing with various iCue™ barrier slurries.



EP-C66xx series barrier slurry

Cabot Microelectronics iCue™ DOW® SiLK™

Summary

- Cu slurry development focused on low k materials
  - Less mechanical polishing mechanism
  - Improvements in planarity post-Cu polish are being seen
  - Defect improvements are seen with the less mechanical system
- Barrier slurry development
  - Slurry system is tunable for various integration schemes
  - Defect reduction achieved