

CMPUG Meeting

June 5, 2003

Cu-Based Interconnect Post-CMP Cleaning Technology Update



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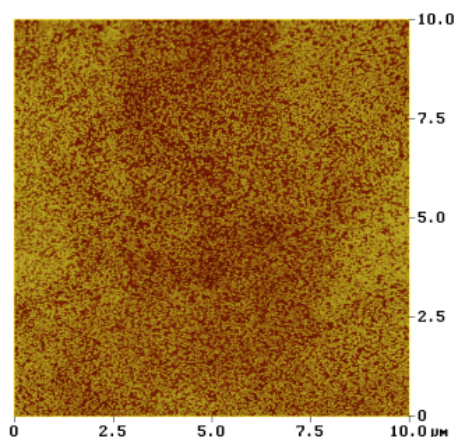
Cu/Low k CMP Cleaning

- **Cu cleaning**
 - **AFM characterization**
- **Cu contamination**
 - **TOF SIMS**
- **Carbon residues**
 - **Looks the same but different**
- **Watermarks**
 - **A chemical solution to this major issue**

Use of AFM for Cleaning Characterization

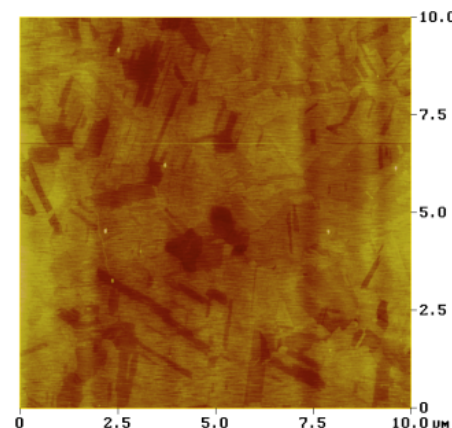
- **Atomic Force Microscope (AFM) has been used to characterize post-Cu CMP cleaning with regards to**
 - **Particle defects**
 - **Cu cleaning**
 - **Cu pitting**
 - **Cu recess**
- **Post-CMP patterned wafers are processed with various chemicals and recipes**
 - **Customer provided with DI clean only, no chemicals**
 - **Heavy contamination - particle and Cu oxides**

Cu Roughness and Cleaning



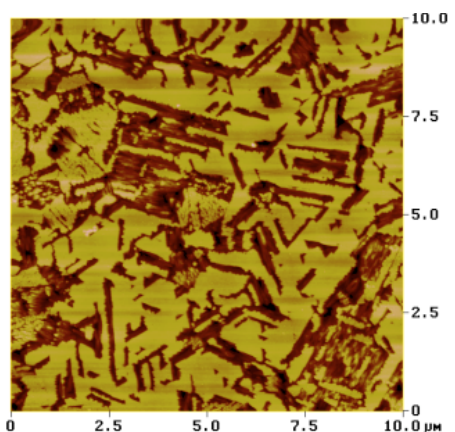
**DI only
Contamination
indicated by
roughness**

RMS = 2.32 nm



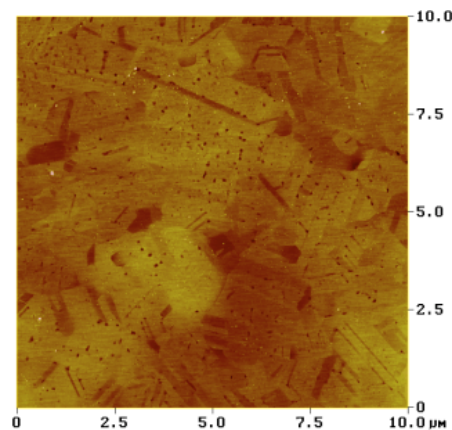
**After treatment
Some defects
seen, low
roughness**

RMS = 0.83 nm



**After treatment
Very clean with
roughening**

RMS = 8.40 nm

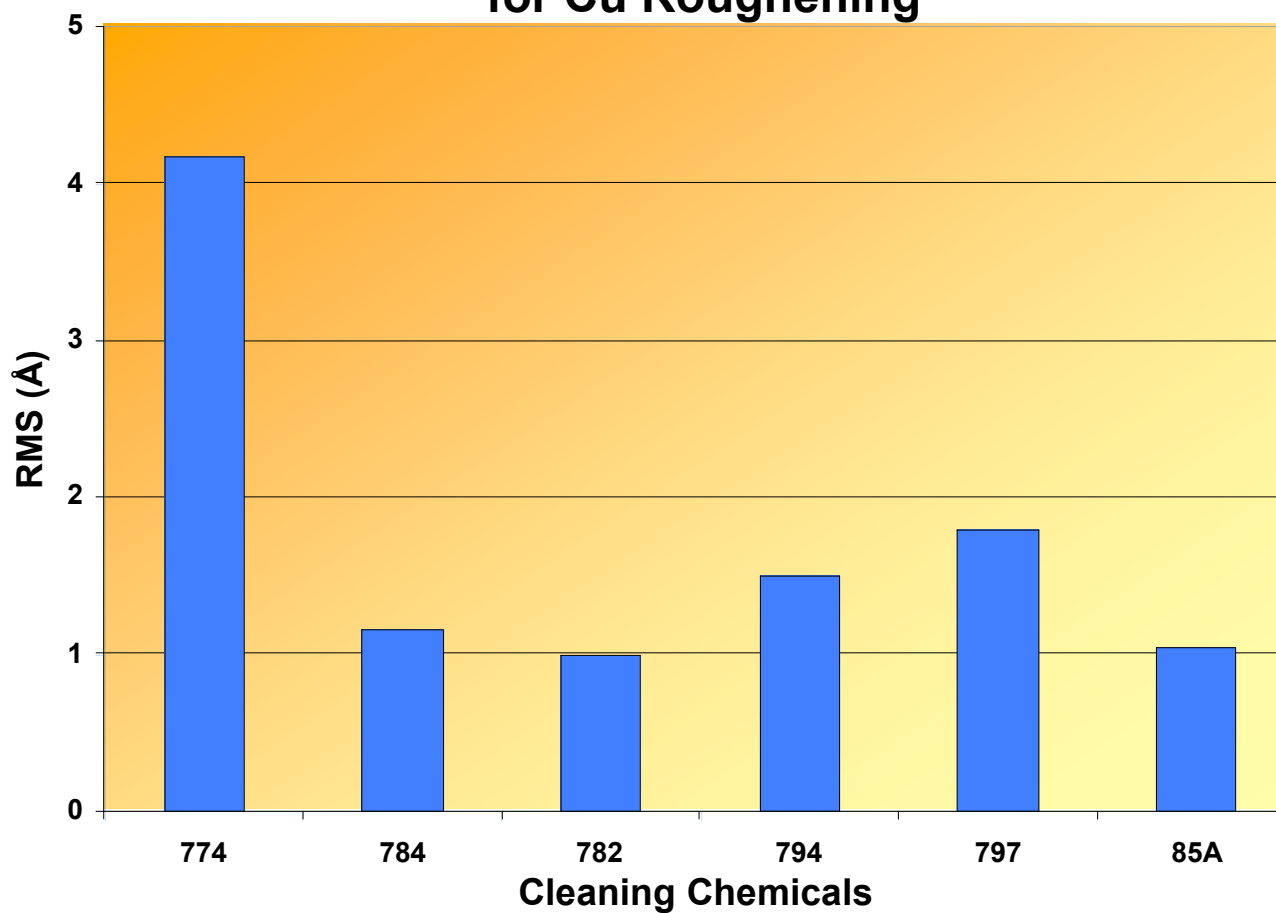


**After treatment
Some pitting
seen, low
roughness**

RMS = 0.95 nm

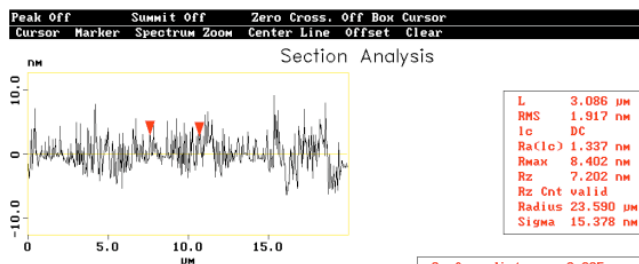
Cu Roughness Comparison

**Comparison of Various Chemicals
for Cu Roughening**

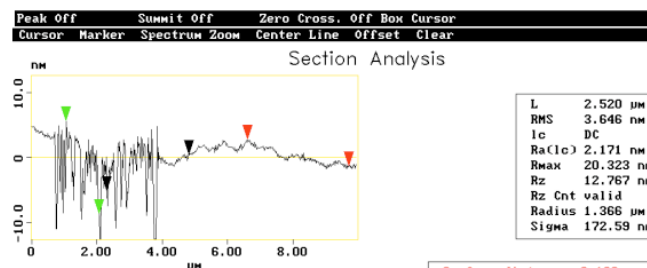
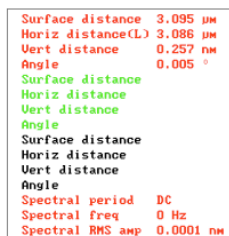


Cleaning Characterization

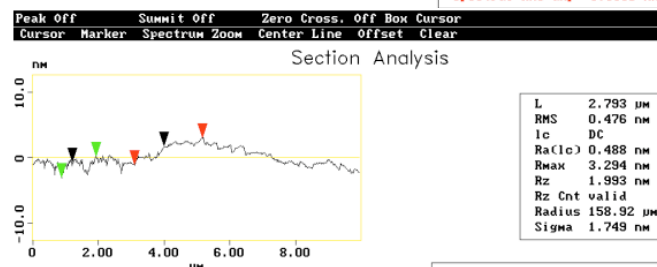
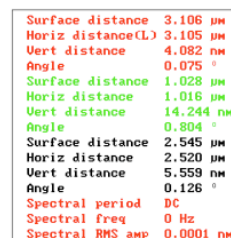
AFM scans across Cu lines with Coral dielectric after various treatments



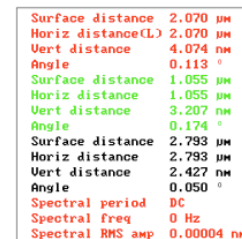
Untreated



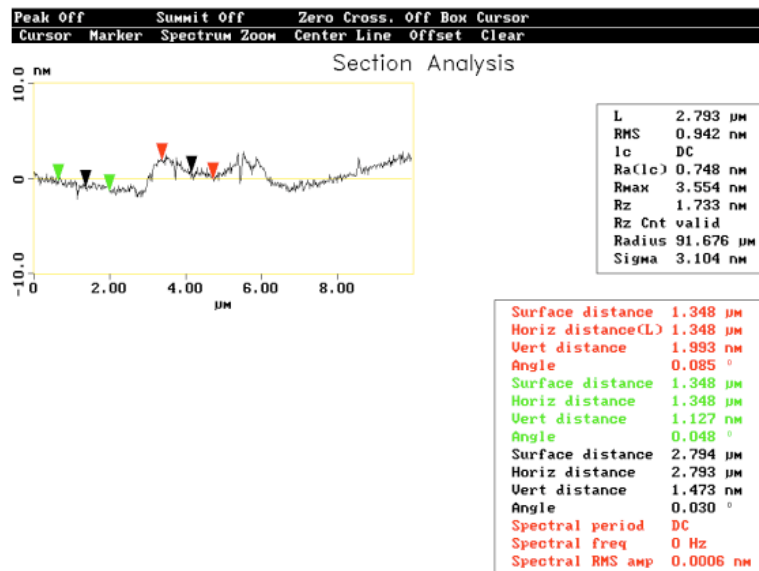
Treated with aggressive chemistry



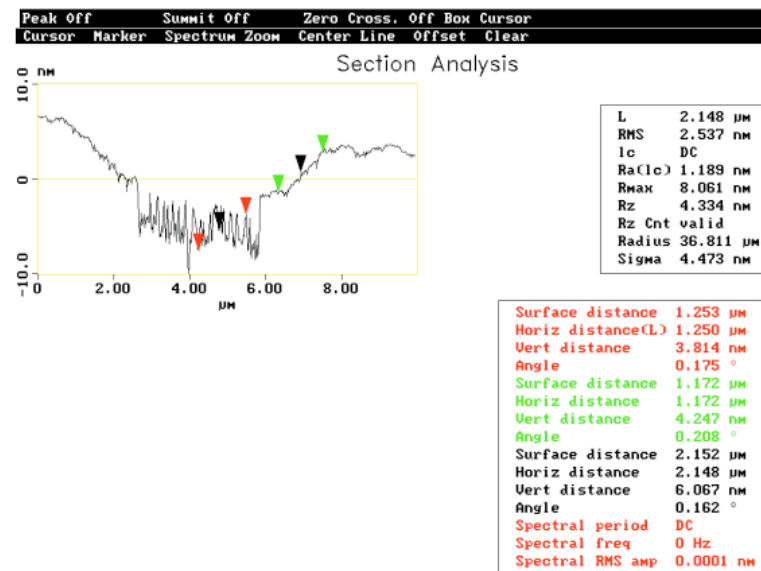
Treated with less aggressive chemistry



Cu Feature Profiling



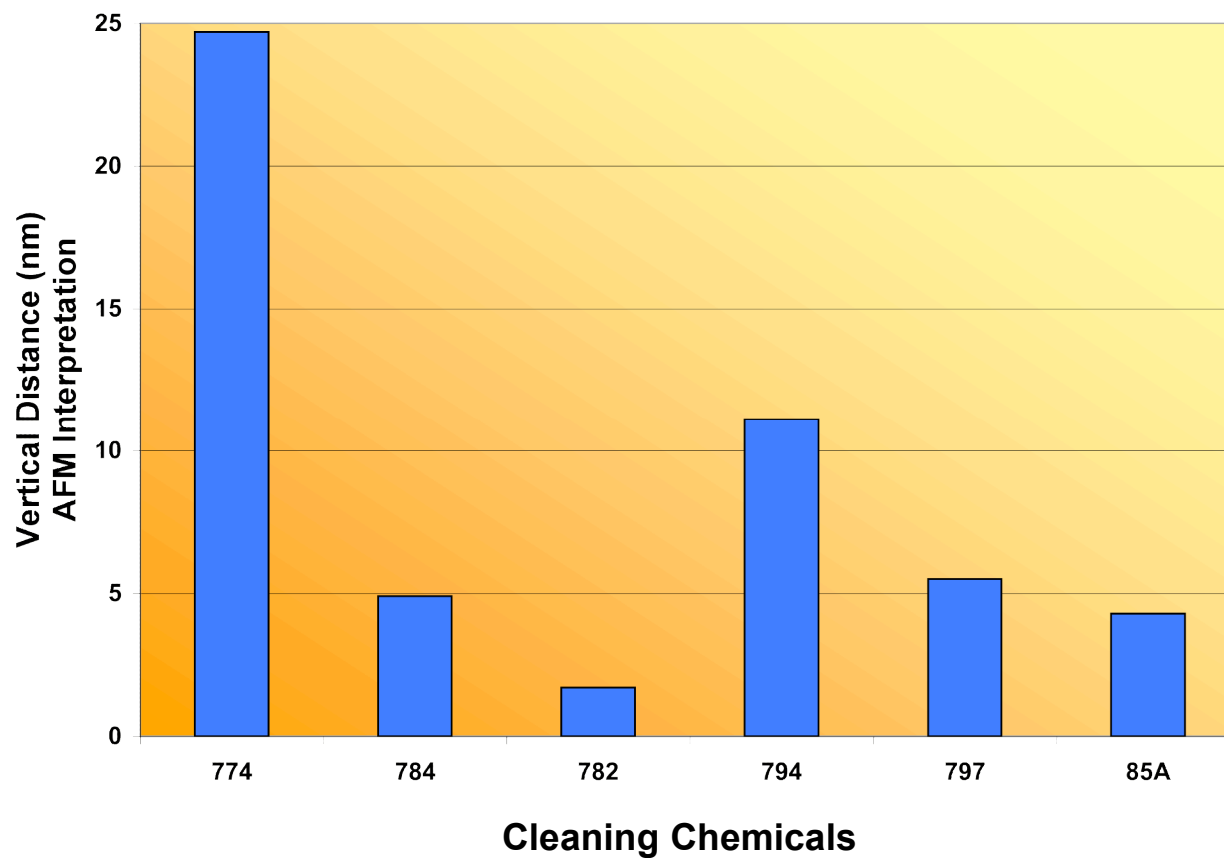
Raised Cu Feature



Cu Dishing

Cu Loss Comparison

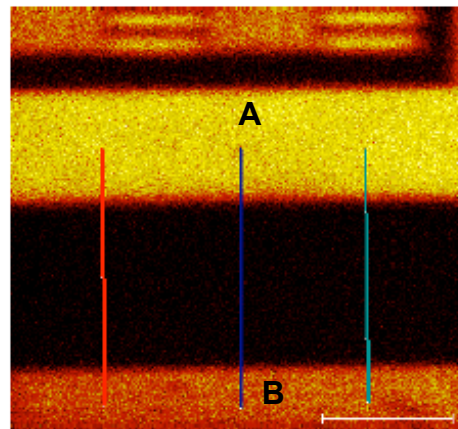
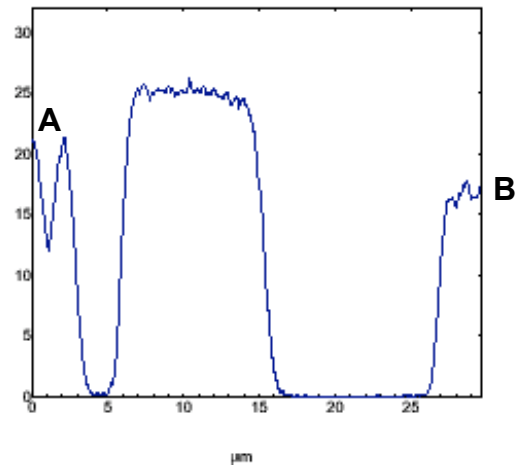
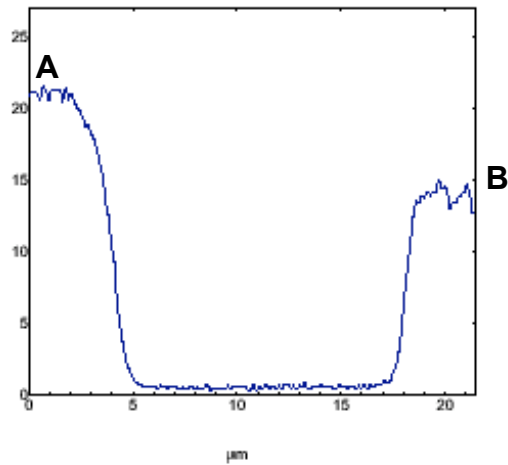
Comparison of Various Chemicals for Recess of Cu Lines



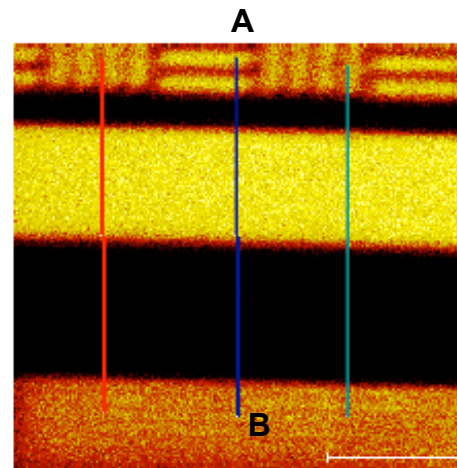
TOF SIMS for Cu Contamination

- Time of Flight SIMS used to measure Cu contamination
- Correlation with leakage current sought
- Measurements in large areas and between lines
 - Large areas: 100 μ m x 100 μ m
 - Between Lines: 8 - 12 μ m spacing
- Dielectric tested were USG, Coral and Black Diamond
- Conclusions and customer feedback
 - All cleaning solutions show similar cleaning capability
 - Line pitch is critical for leakage current differences
 - <0.1 μ m spacing is more sensitive for leakage current testing

TOF SIMs Line Scans on USG

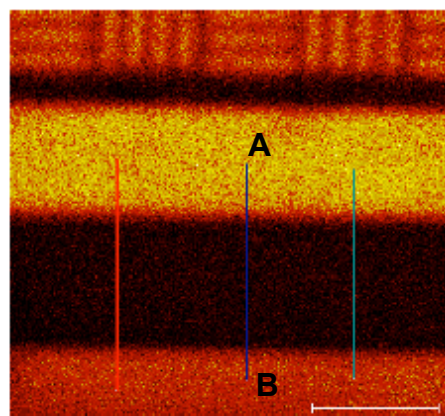
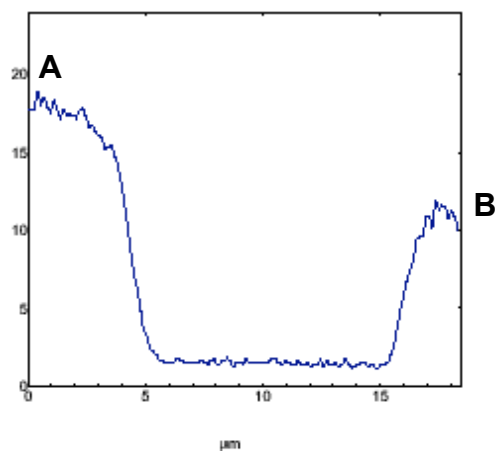


Before treatment

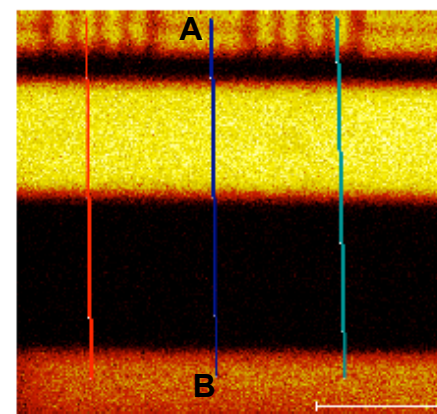
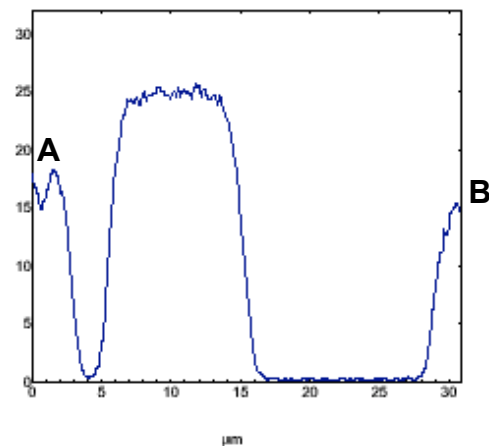


After chemical treatment

TOF SIMs Line Scans on Black Diamond

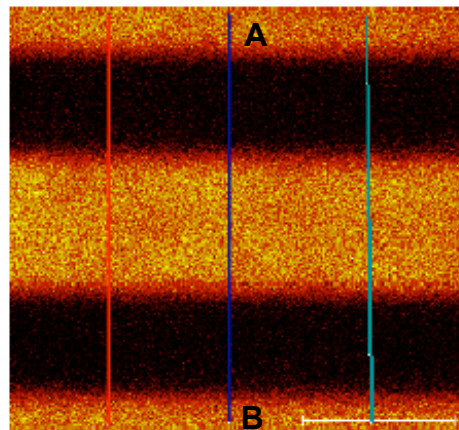
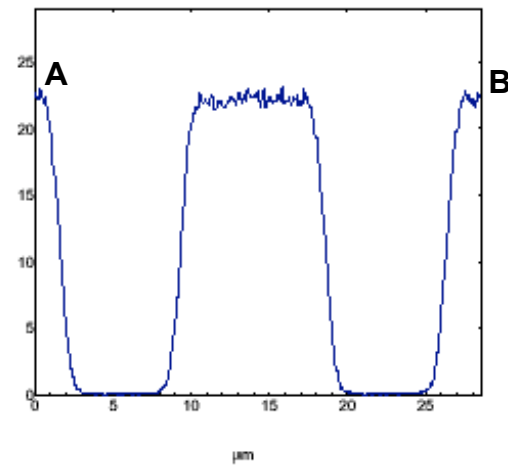
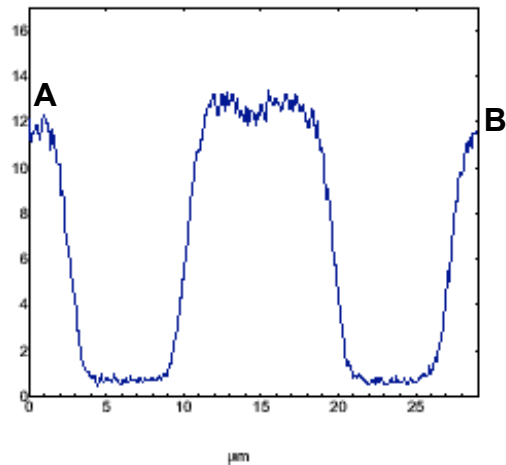


Before Treatment

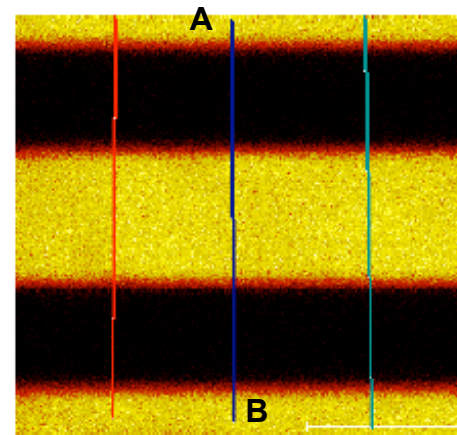


After Chemical Treatment

TOF SIMs Line Scans on Coral



Before Treatment



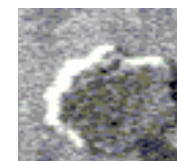
After Chemical Treatment

C Residue from OSG polishing

- **C residue remains an issue for OSG**
- **Source could be different than in FSG processes**
 - **BTA and other consumables**
 - **Equipment issues**
- **For OSG, some customers suspect this residue to be from the OSG film itself**



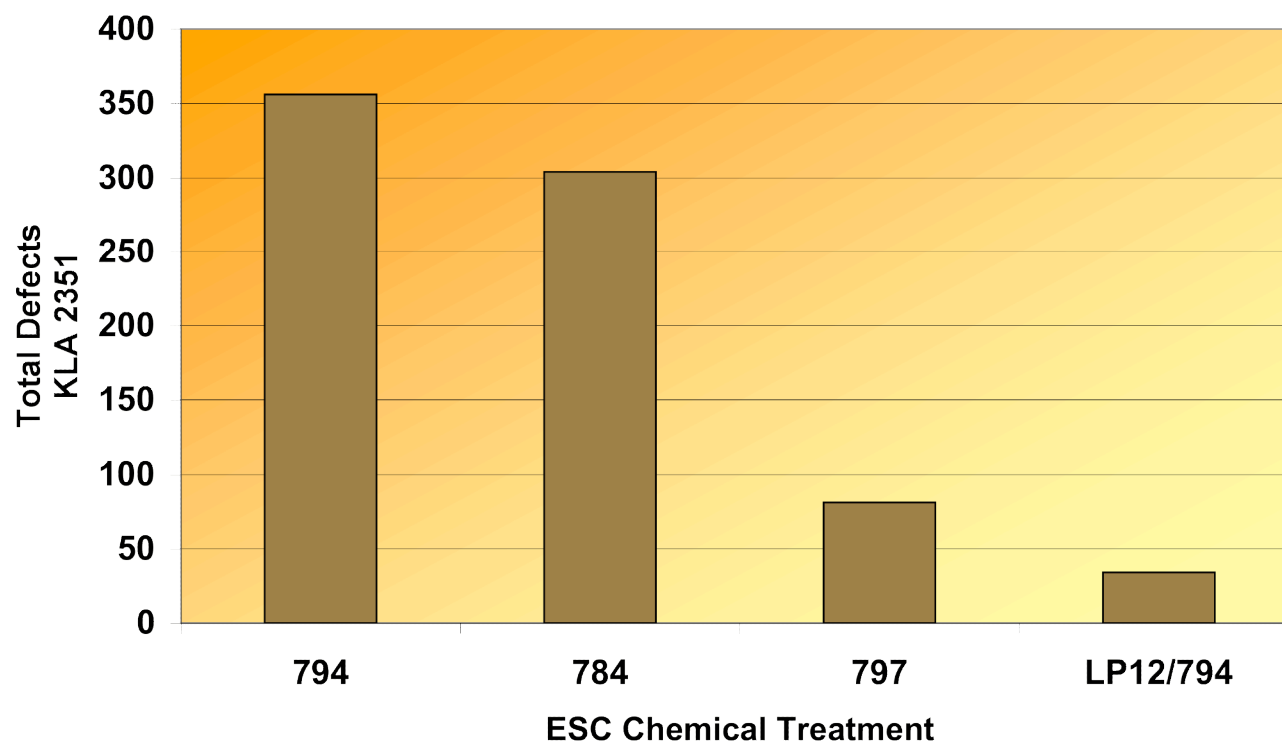
C residue in FSG process



C residue in OSG process

Carbon Residue Removal

Patterned Wafer Test
Carbon Defects after Cu/Coral CMP Process

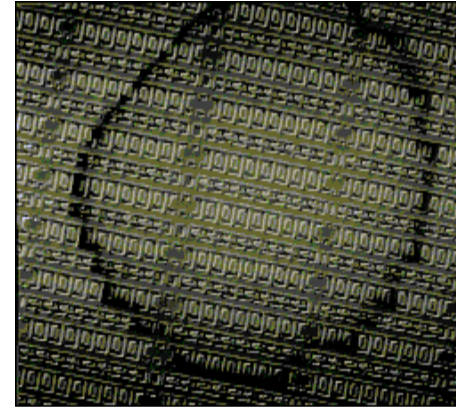


Watermarks

- **Appear with Hydrophobic surfaces**
 - OSG, SiOC, CDO, Coral, Black Diamond, Aurora, etc.
- **Mechanism for creation**
 - Surface reaction with water
 - DI water contaminants
- **Detection**
 - Metrology sensitivity is a factor
 - Blanket and patterned
- **Why are they bad?**
 - Defectivity issue
 - Yield/Reliability issue

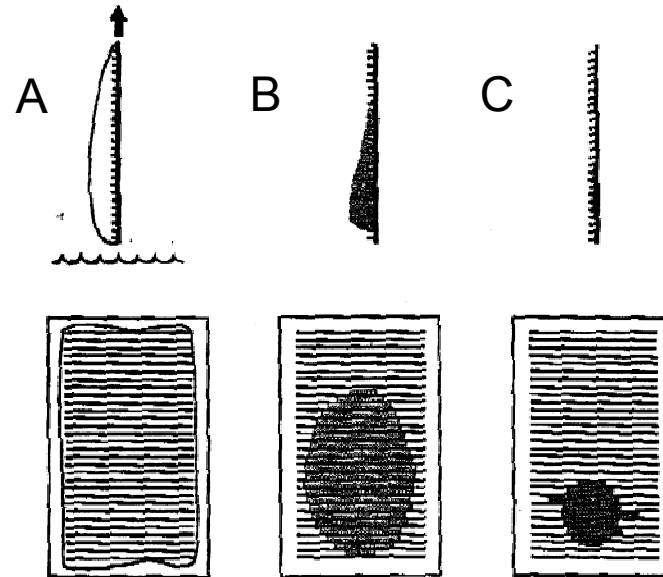
Watermarks

- Well known problem in front end of line
- HF last wet clean steps
- H-Terminated silicon
- Mixed hydrophilic and hydrophobic surfaces



Watermark formation - FEOL

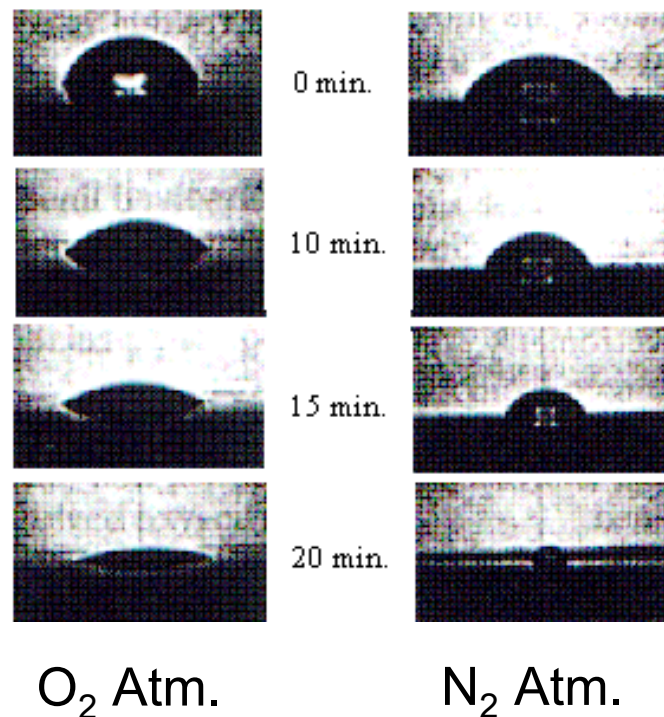
- A. Water droplet trapped by surface topography
- B. Droplet evaporates
- C. Residue precipitates and deposits on surface



Reference: MacKinnon, S., *Proceedings, Microcontamination*, 94, 174 (1994).

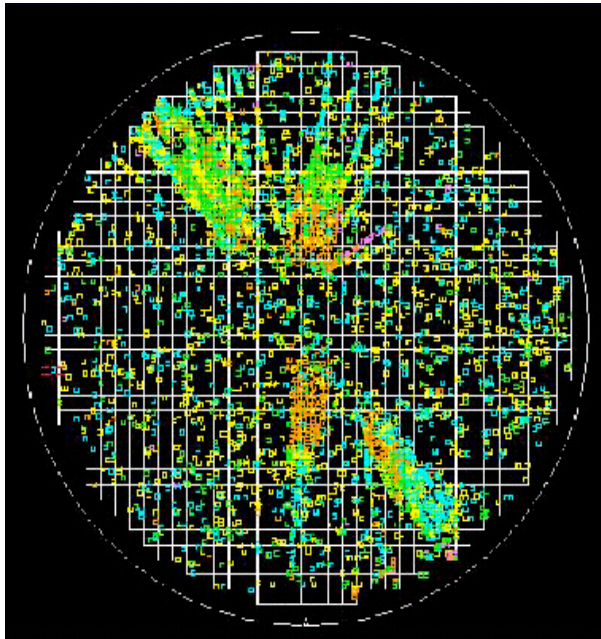
Role of O_2 - FEOL

- In the presence of O_2 silicic acid forms
- As evaporation occurs the silicic acid becomes concentrated
- Hydrated silica precipitates to form stains

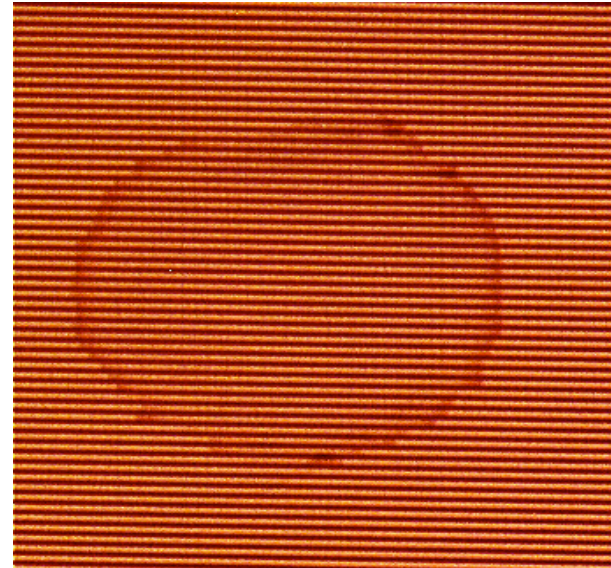


Reference: M. Watanabe, M. Hamano and M. Harazono, *Materials Science and Engineering*, B4 (1989) 401-405.

Watermarks on OSG dielectric



Radial “spinout” pattern on blanket wafer defect map

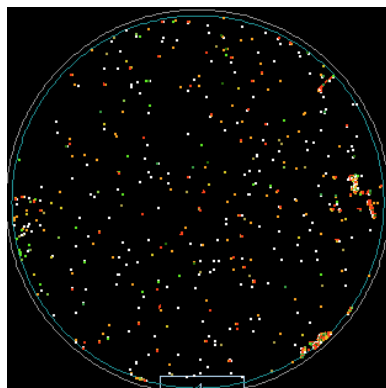


Optical image of defect on patterned wafer

Watermarks on Blanket Coral - SP1

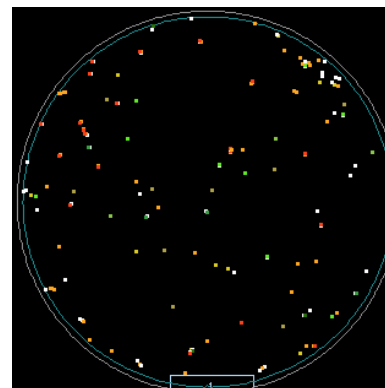
Blanket Coral
wafer before
polishing

1100 defects
 $\geq 0.16\mu\text{m}$



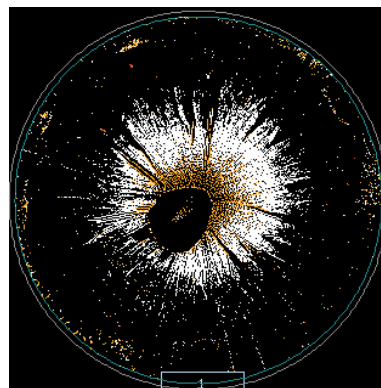
Post-polish
and cleaning
with ESC 794
solution

172 defects
 $\geq 0.16\mu\text{m}$



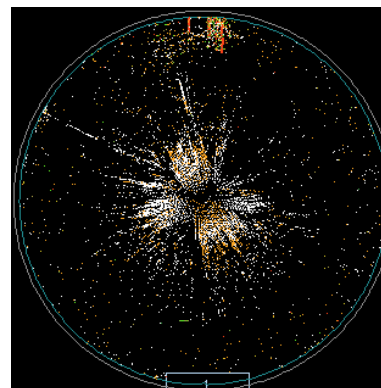
Post-polish and
cleaning with
low pH solution

14,675 defects
 $\geq 0.16\mu\text{m}$

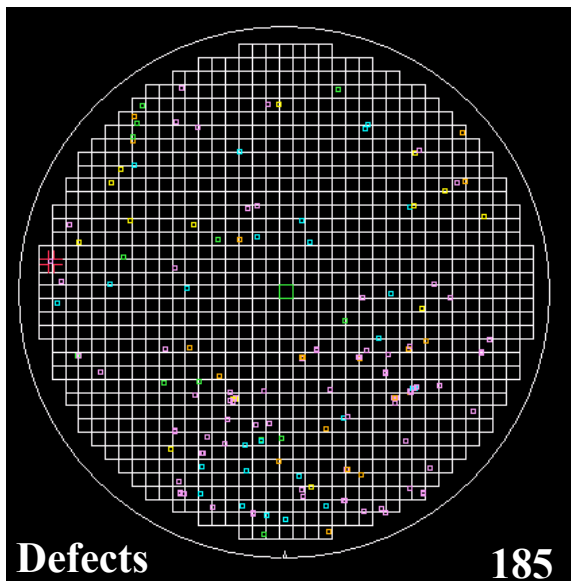


Post-polish and
cleaning with
Low pH solution

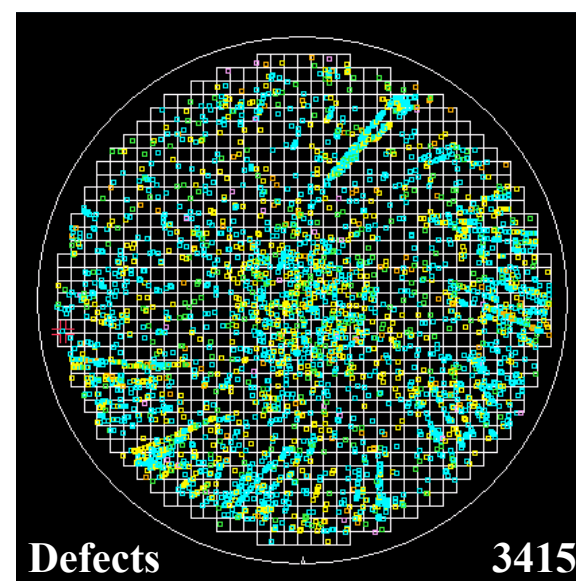
5,580 defects
 $\geq 0.16\mu\text{m}$



Compass Scans on OSG

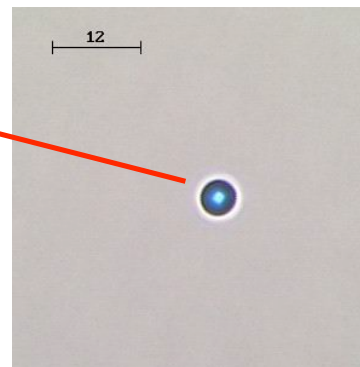
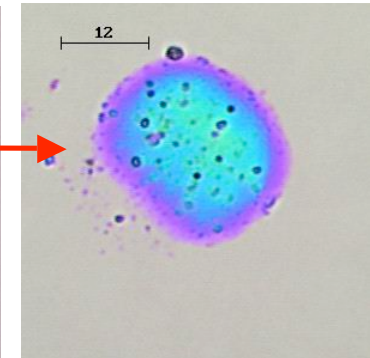
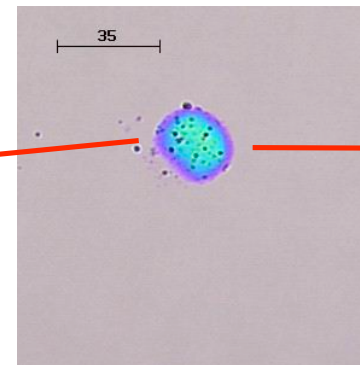
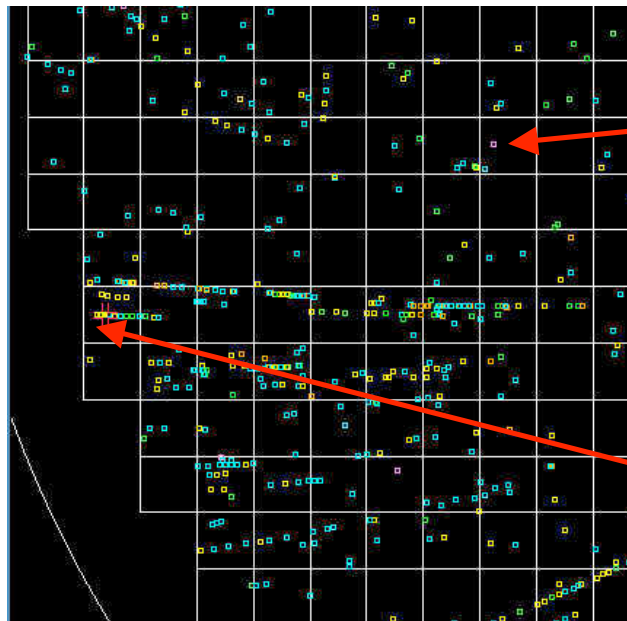


Untreated Virgin,
Blanket Coral Wafer



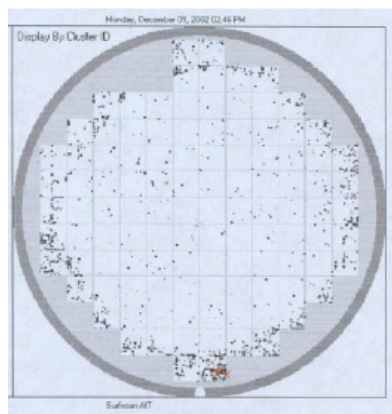
Virgin, Blanket Coral
Wafer after DI rinse
and spin dry

Watermarks on Blanket OSG

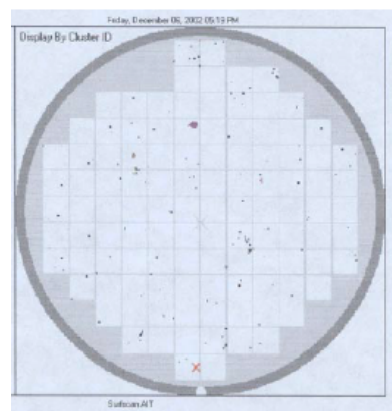


SEM's of
"watermark
defects"

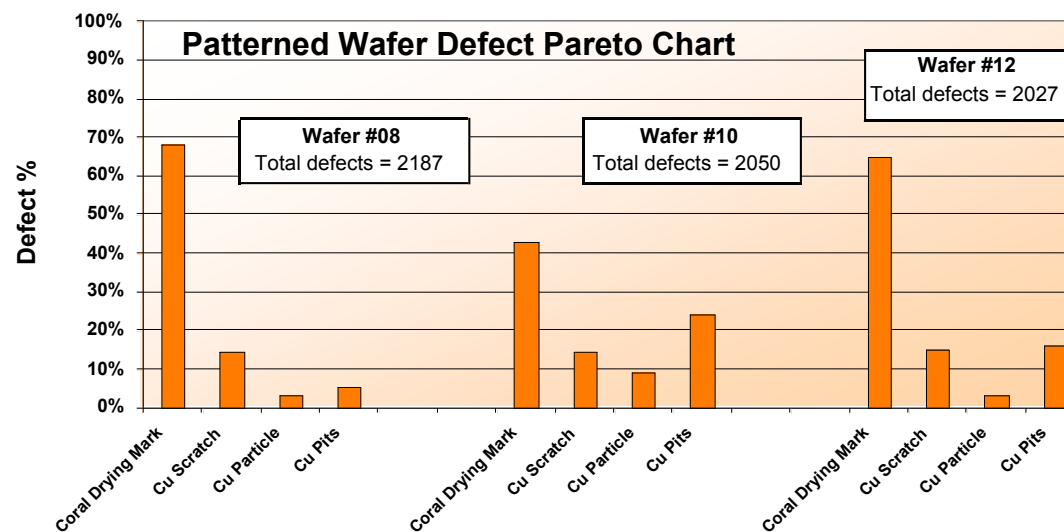
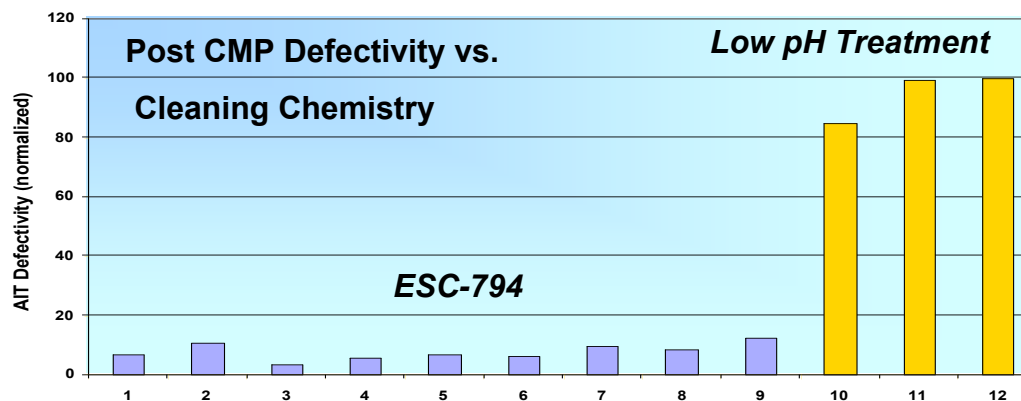
AIT Scans for Cu/Coral Wafers



Low pH Treatment



ESC-794



Summary

- **Watermarks are a major hurdle in moving to 90nm with CVD OSG's**
- **The proper chemical solution can prevent watermarks without the need for extensive hardware modifications or the use of surfactants**
- **Cu cleaning and roughness can be evaluated using AFM analysis as a screening process**
- **TOF SIMS is effective at measuring Cu contamination, however, leakage current testing is ultimate metric**
- **C residues are still here but different. Cleaning seems to be chemical and process dependent.**