Novel Particles and Matching Chemistry in CMP Slurries for 22 nm Technology Node

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Presentation Outline

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- Why functionalized particles?
  - Increase removal rate?
  - Enhance planarization efficiency?
  - Lower defect level?
- Why matching chemistry?
  - Allow surface functionality to express
  - Balance the need for material removal and transport
  - Lower defect level

Ta Removal Using Various Particles: Silica, Alumina, Diamond, h-BN, and Abrasive Free System (AFS) Vesicles

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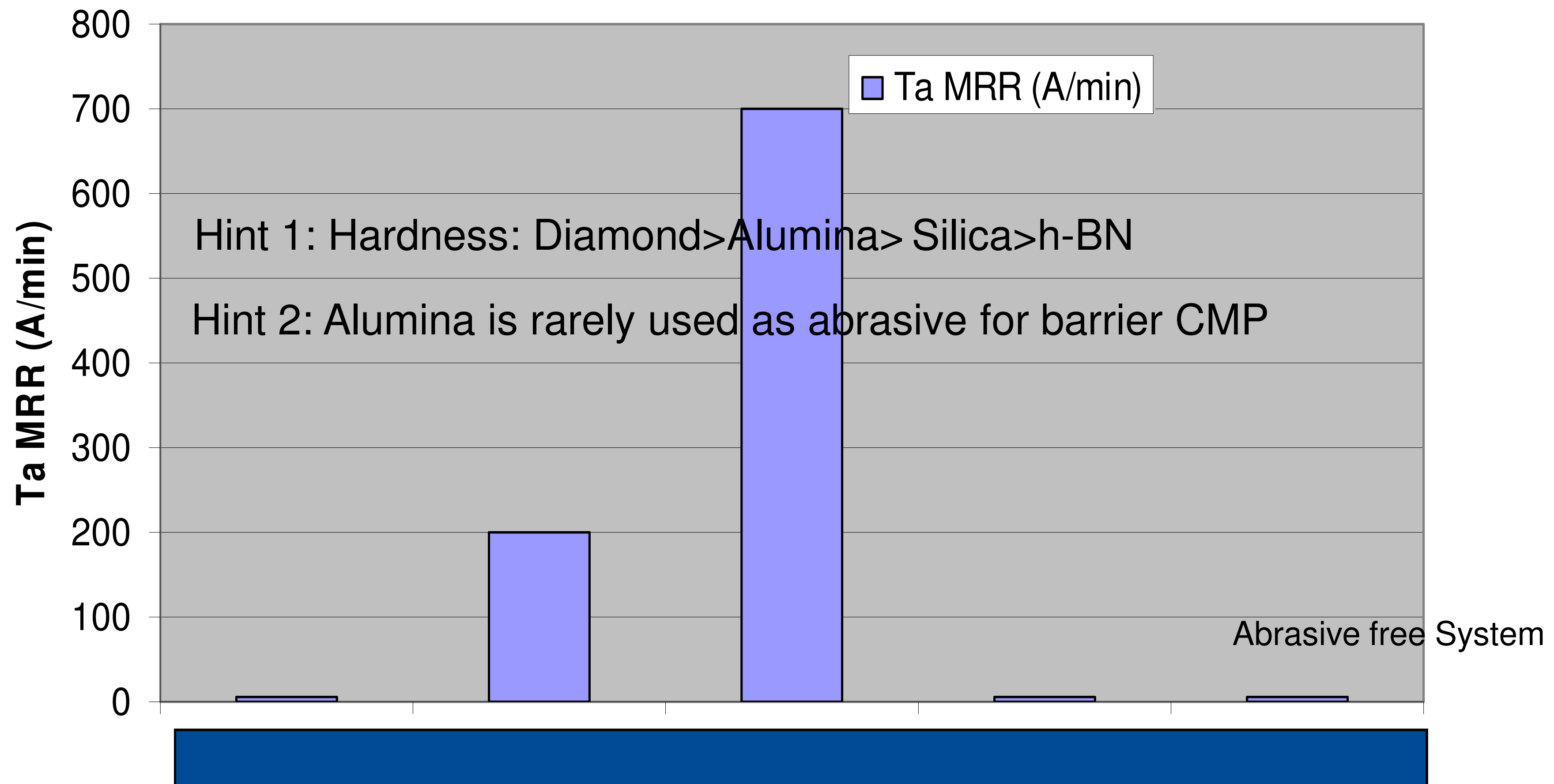

Ref: N. Wang, J. Keleher, Y. Li, BN particles for Cu CMP, VMIC 2003

For effective material removal, surface tribochemical reactions must take place

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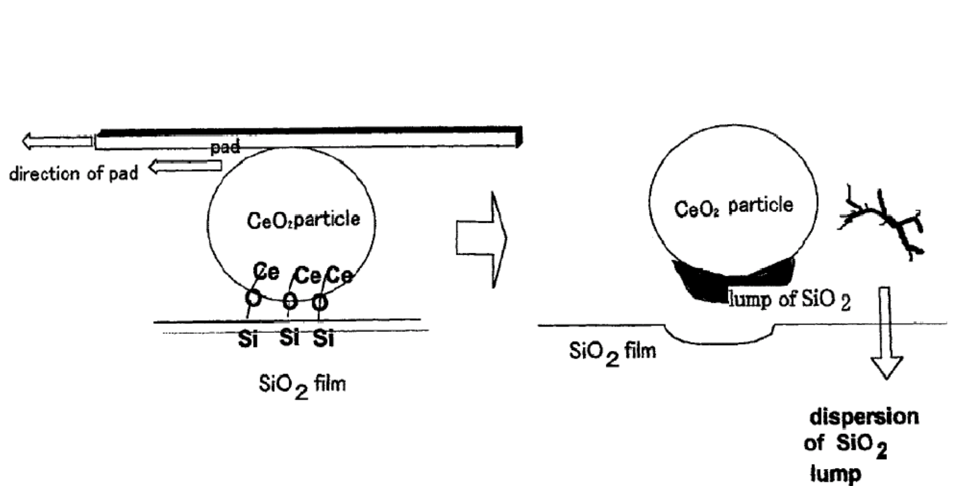

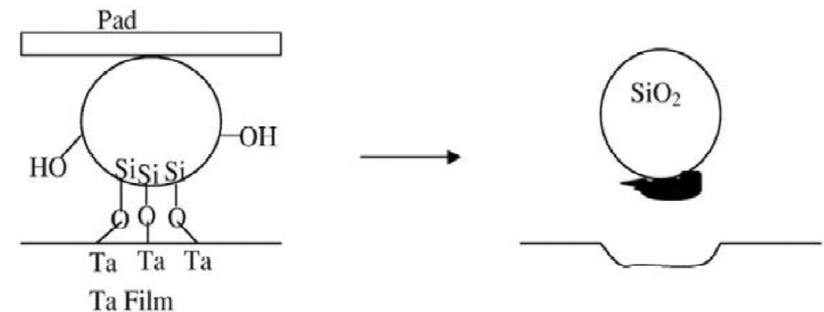

Using Ceria to Polish SiO_2

Using silica to polish Ta (Ta_2O_5)

Form efficient multiple bonds between the abrasive particle and polished surface

Tetsuya Hoshino, Yasushi Kurata, Yuuki Terasaki, Kenzo Susa, Mechanism of polishing of SiO2 films by CeO2 particles Journal of Non-Crystalline Solids 283 (2001) 129-136

A. Vijayakumar, T. Du, K.B. Sundaram, V. Desai, Polishing mechanism of tantalum films by SiO_2 particles, Microelectronic Engineering 70 (2003) 93-101

Correlation between surface hydroxyl groups and Ta removal rate

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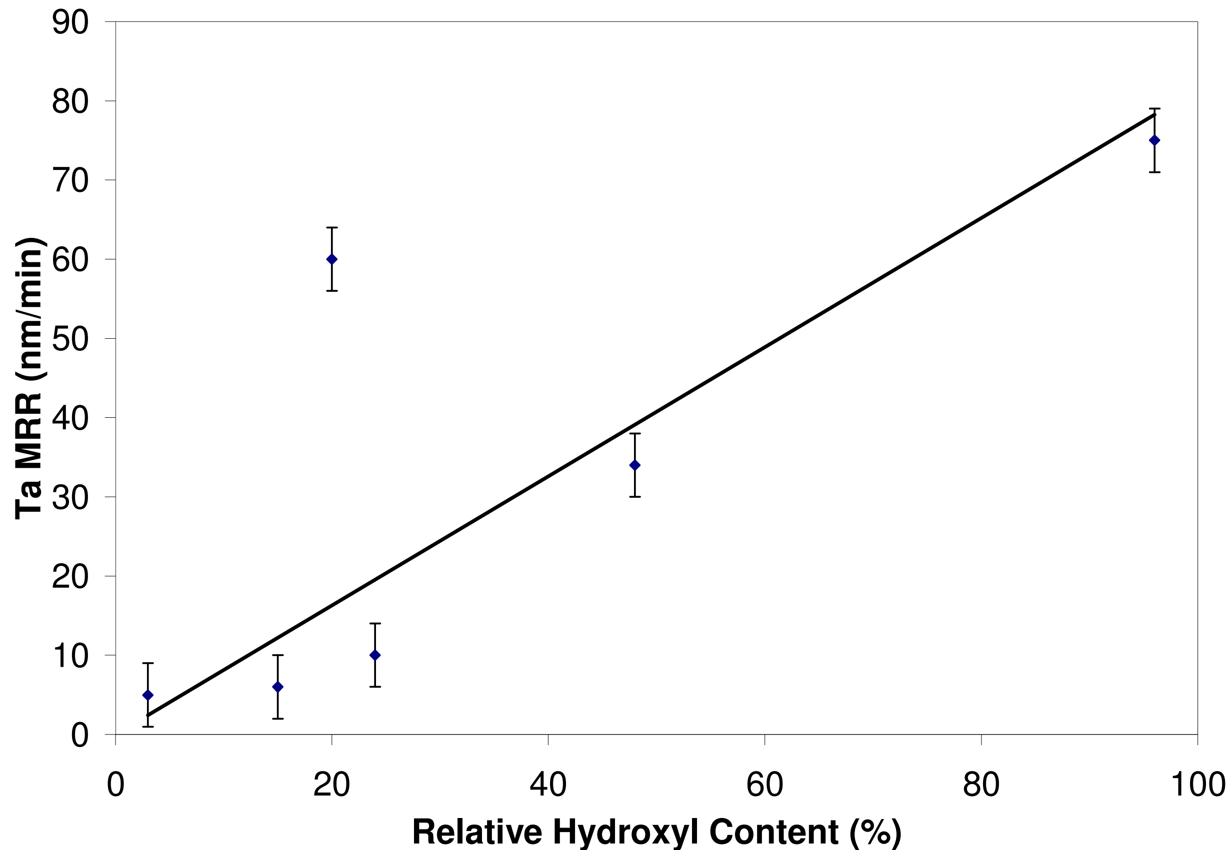

Y. Li et al Thin Solid Films, 497, 1-2, 2, 2006, pp 321-328.

Ta MRR (A/min) and surface OH content and NMR relaxation time slopes

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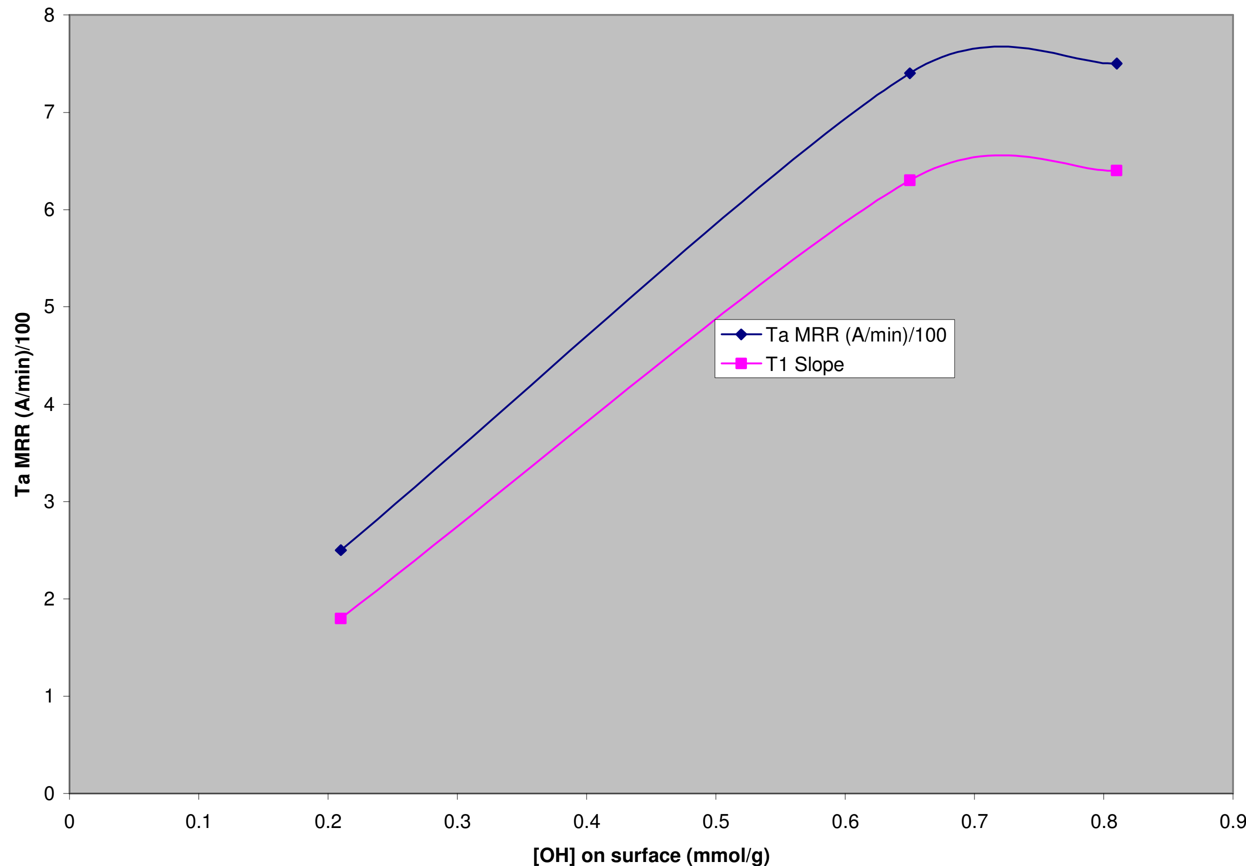

R. Mackay, J. Zhang, Q. Wu and Y. Li, *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 2004, 250, 1-3, pp343-348.

Tribochemical Reaction Enhances Planarization Efficiency

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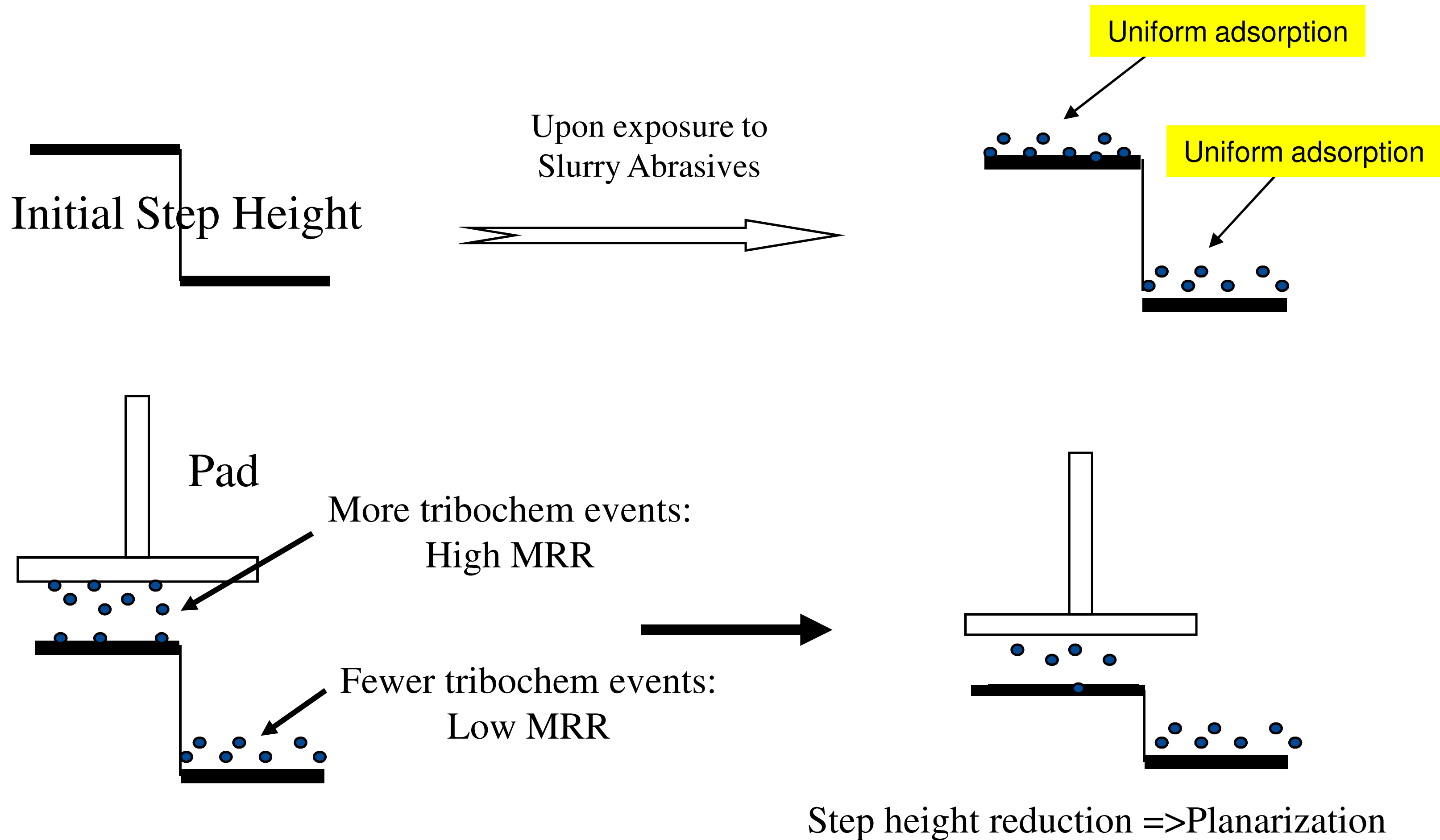

Uniform Surface Chemical Reactions Lower Planarization Efficiency

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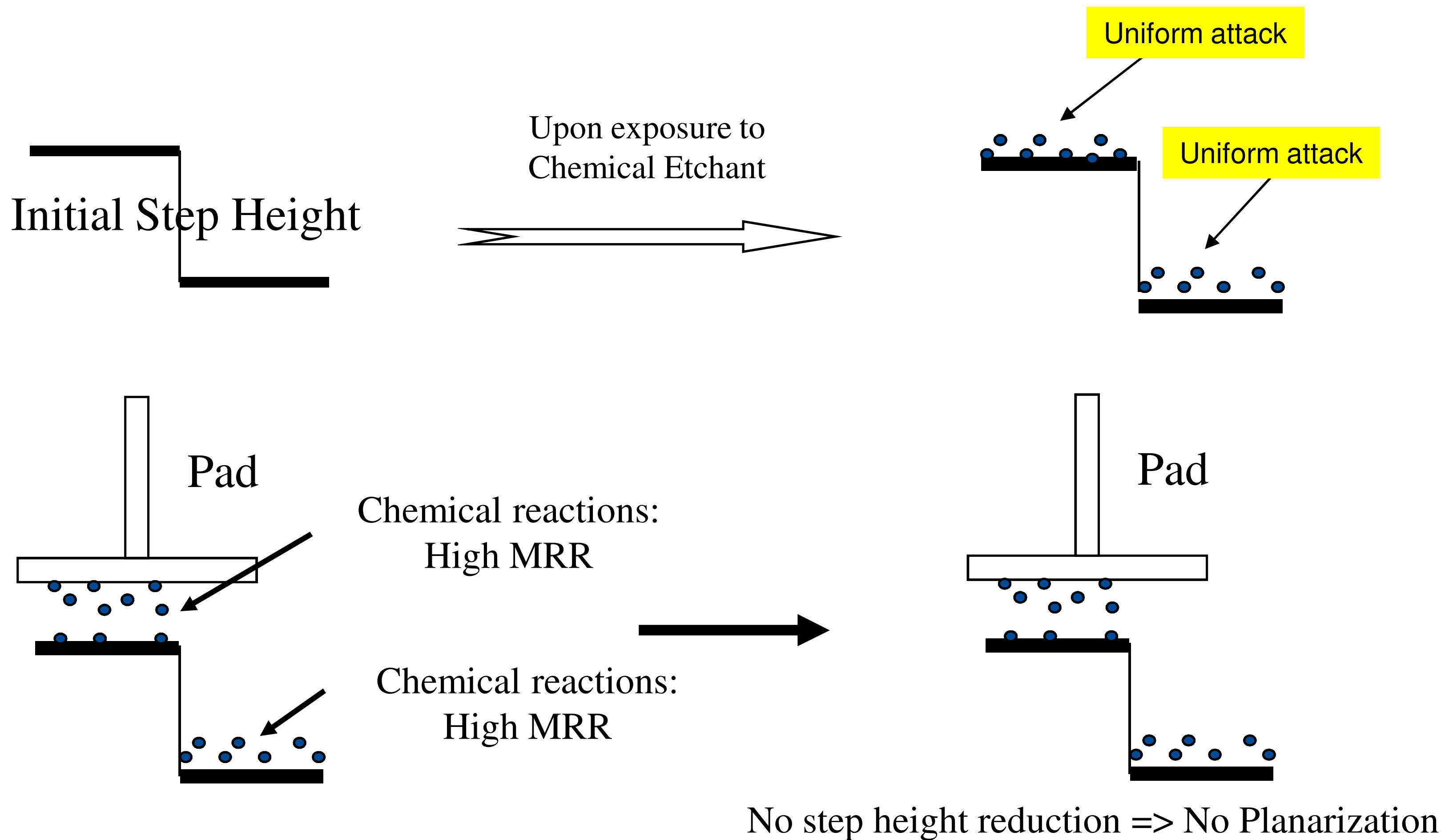

For oxide CMP, silica is abundantly functionalized with hydroxyl groups

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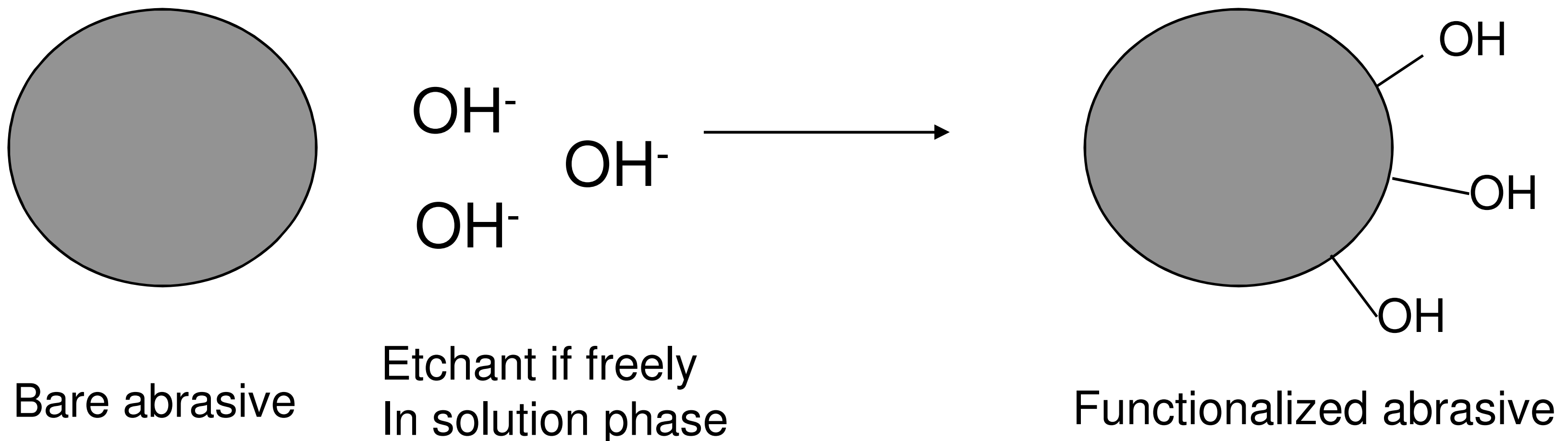

Other factors to be considered, for examples:

- How close these functionalized particles can get to the surface to be polished?
  - Relative surface charges: silica vs. ceria
  - Relative thickness of protective sphere: variation in hydrated layer on silica
- How rigid the multiple contacts between the particles and surface has to be?
  - Relative force distribution: polyvinyl alcohol vs. silica

Functions of Key Components in Copper CMP

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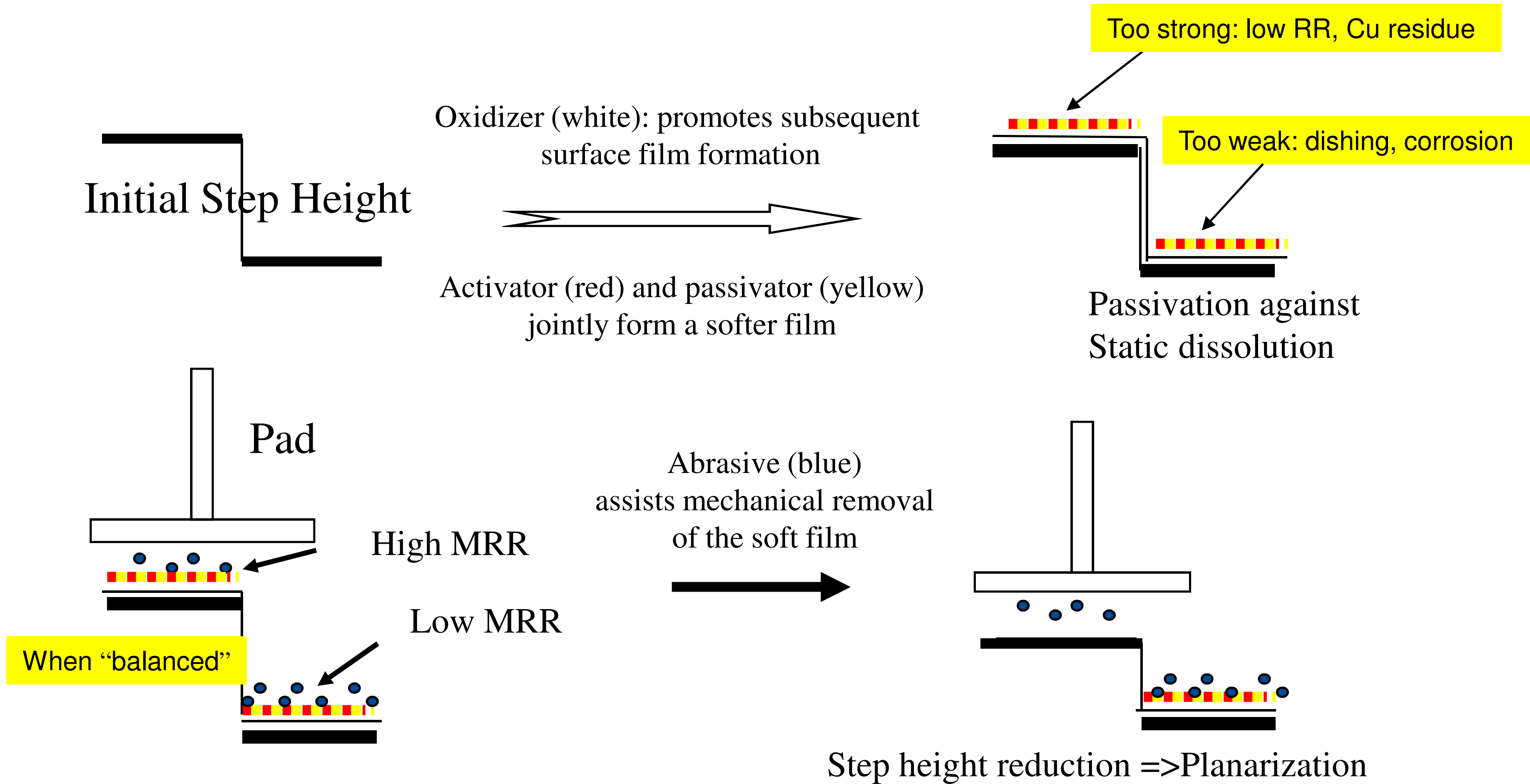

Free vs. Fixed Complexing Agent: Functionalized Particles

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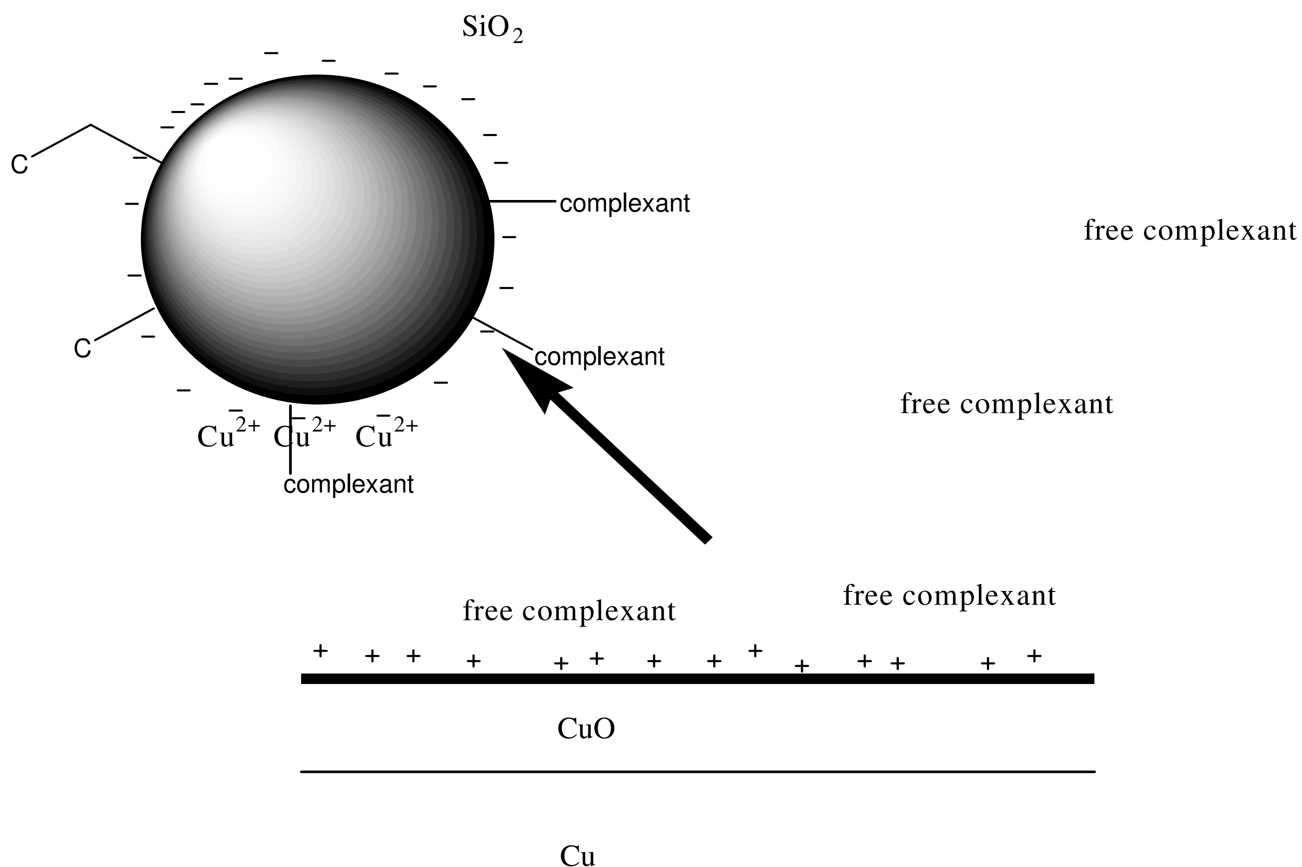

Y. Li, CMP-MIC Short Course on Metal CMP, 2003

Functionalized Silica for Cu CMP

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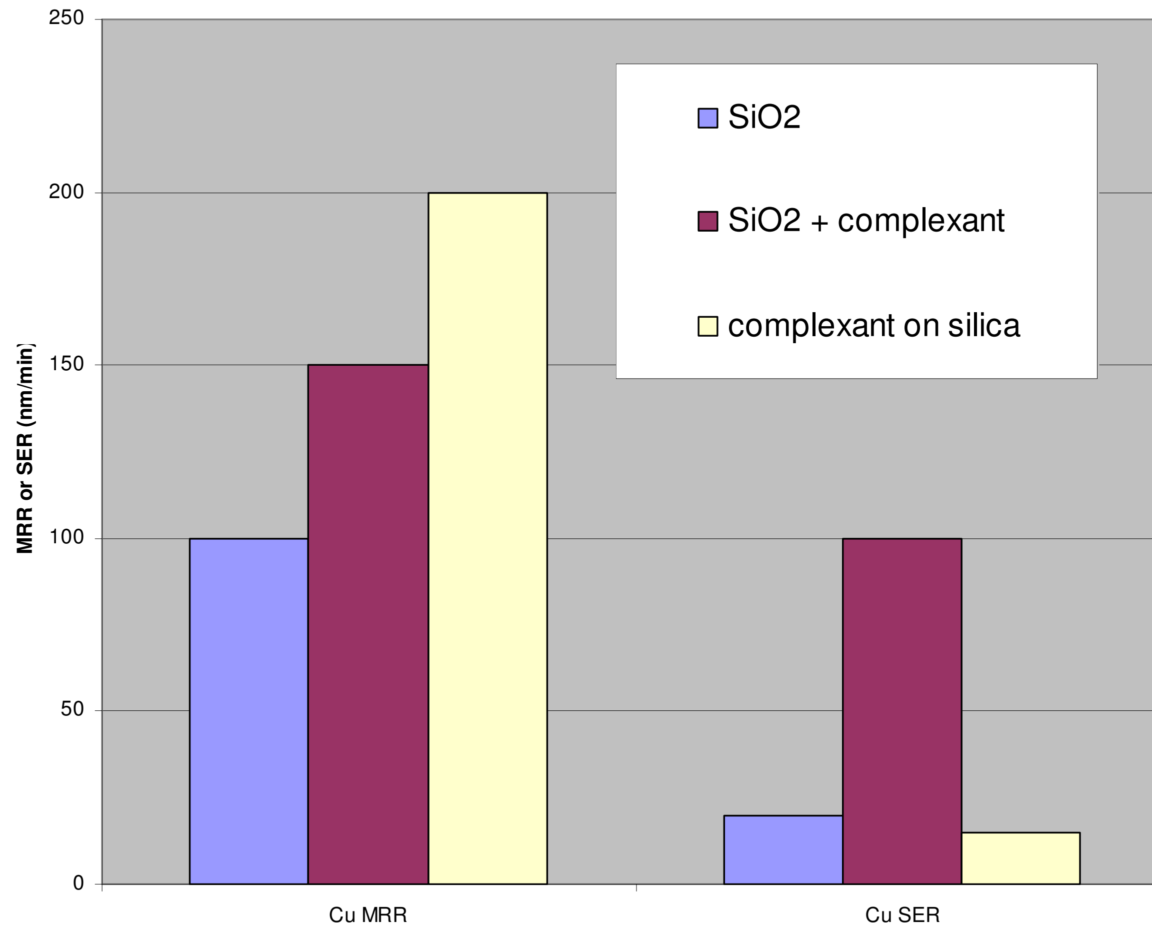
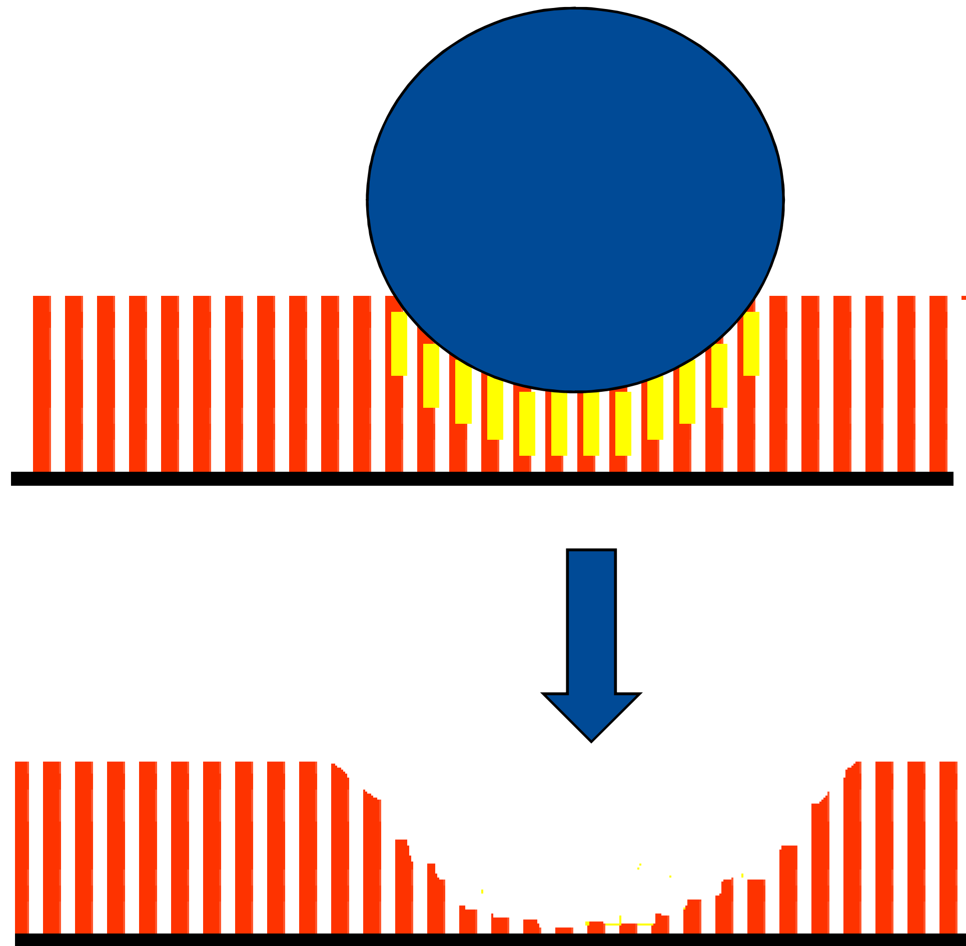


Y. Li, CMP-MIC Short Course on Metal CMP, 2003

Effective Removal of Cu Containing Soft Film



Particle Mophorlogy Change on Demand for Cu CMP

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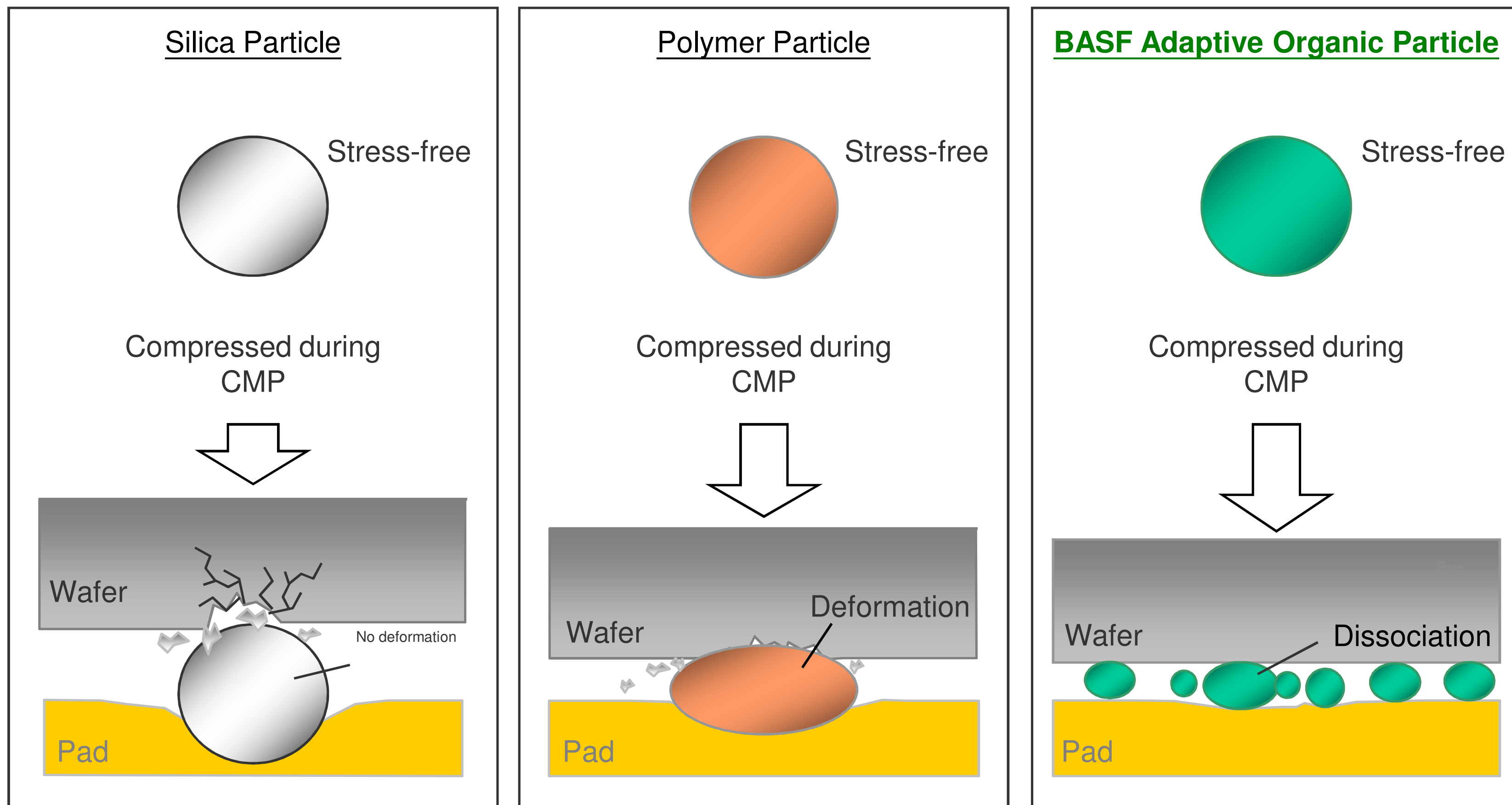

Adaptive Organic Particles

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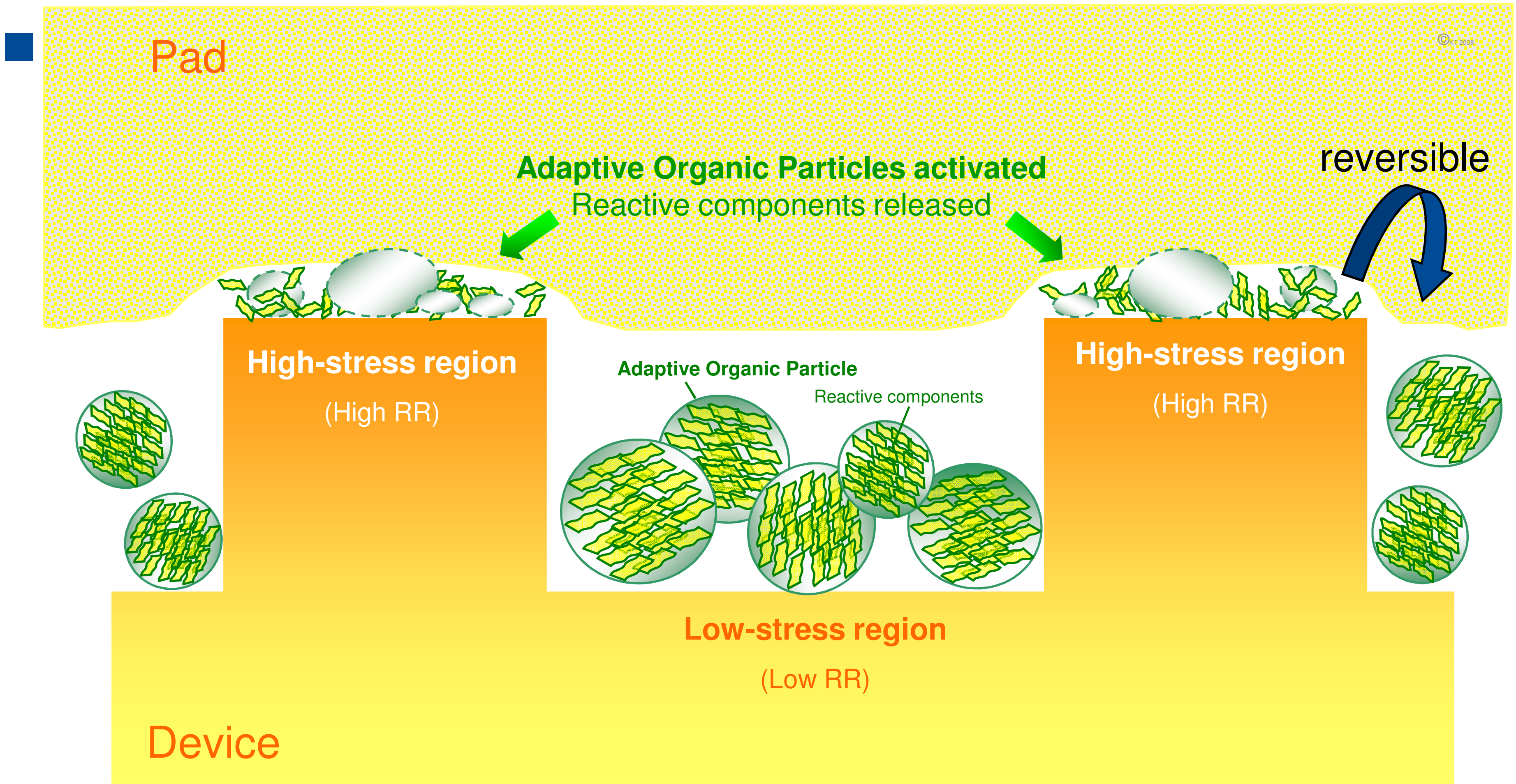

Potential Advantages

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- Reactive molecules are caged
  - Avoid using harsh activating agent in solution
  - Minimize corrosion
- Particles are deformable
  - No hard abrasive particles needed
  - Lower damage to fragile materials
- Particles can be fractured into much smaller particles on demand
  - Increase surface area to deal with polishing debris
  - Lower LPC
- Particles are also responsive to temperature
  - Elevated temperature and dilution dissolve small AP
  - Easy to clean after CMP

SEMATECH 854 Patterned Wafer Data
Average dishing on 100/100 um lines

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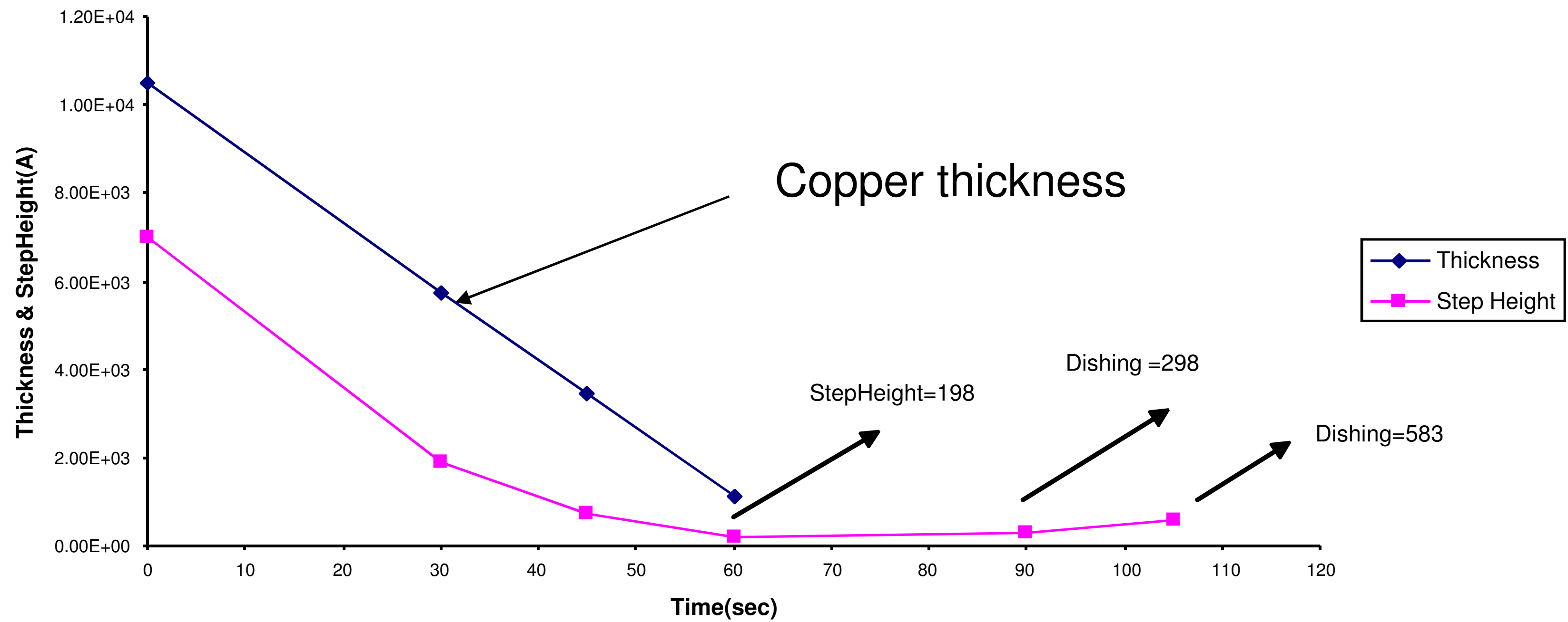

Adaptive Particle Design Minimize corrosion

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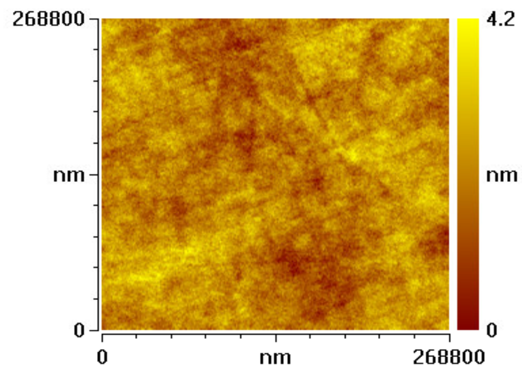
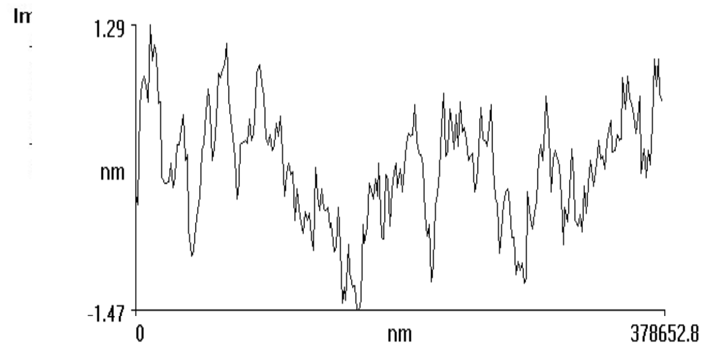
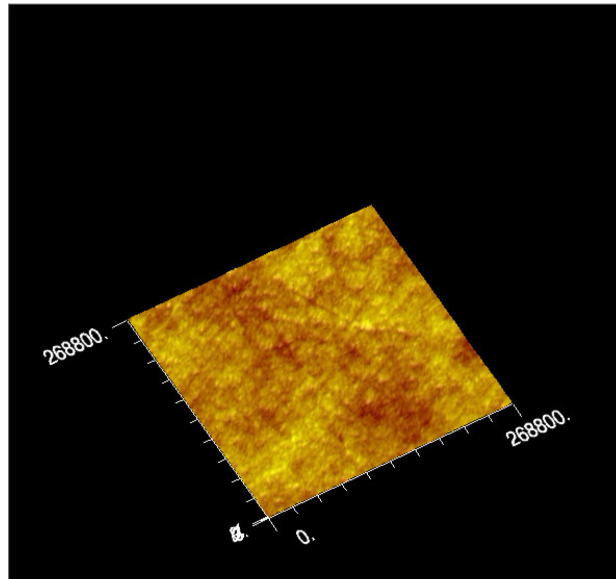


Mean
Sq
Sa
Peak/Valley
Skewness
Kurtosis



Mean	-0.07
Rq	0.55
Ra	0.44
Peak/Valley	2.77
Skewness	-0.17
Kurtosis	2.73



A Good Cu CMP Slurry

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- MRR = 8,000A/min to start with
  - 100% Planarization Efficiency
  - Short or no induction period
- With soft landing
  - final dishing at 100/100 um lines: 200A (The Ratio is 40:1)
  - No
    - Corrosion spots
    - Pitting
    - Scratch
    - Stain
    - EOE
    - Particle residue
    - Pattern dependency

For TSV applications
If MMR = 36,000A/min
40:1 ratio gives 900A dishing
30:1 ratio gives 1200A dishing

Move from die stacking to 3D IC

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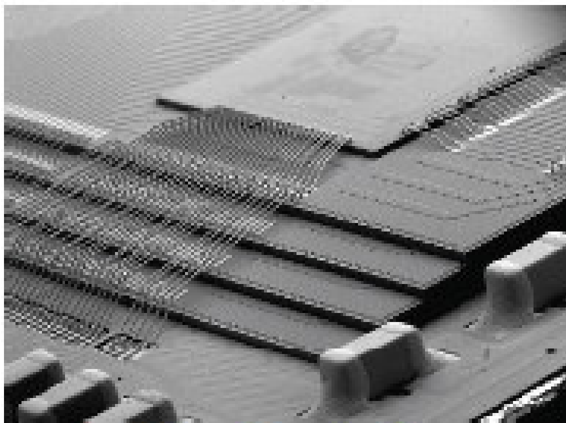
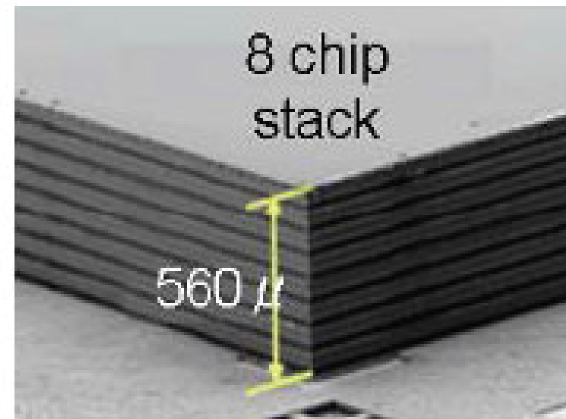


→ Stacked dies



→ 3D IC

Advantages:
- Form factor: to increase density (capacity/volume ratio)
- Electrical performance: to shorten interconnect length
- Heterogeneous integration (RF, memory, logic, MEMS, etc)

Representative Patterned Wafer Polishing Results

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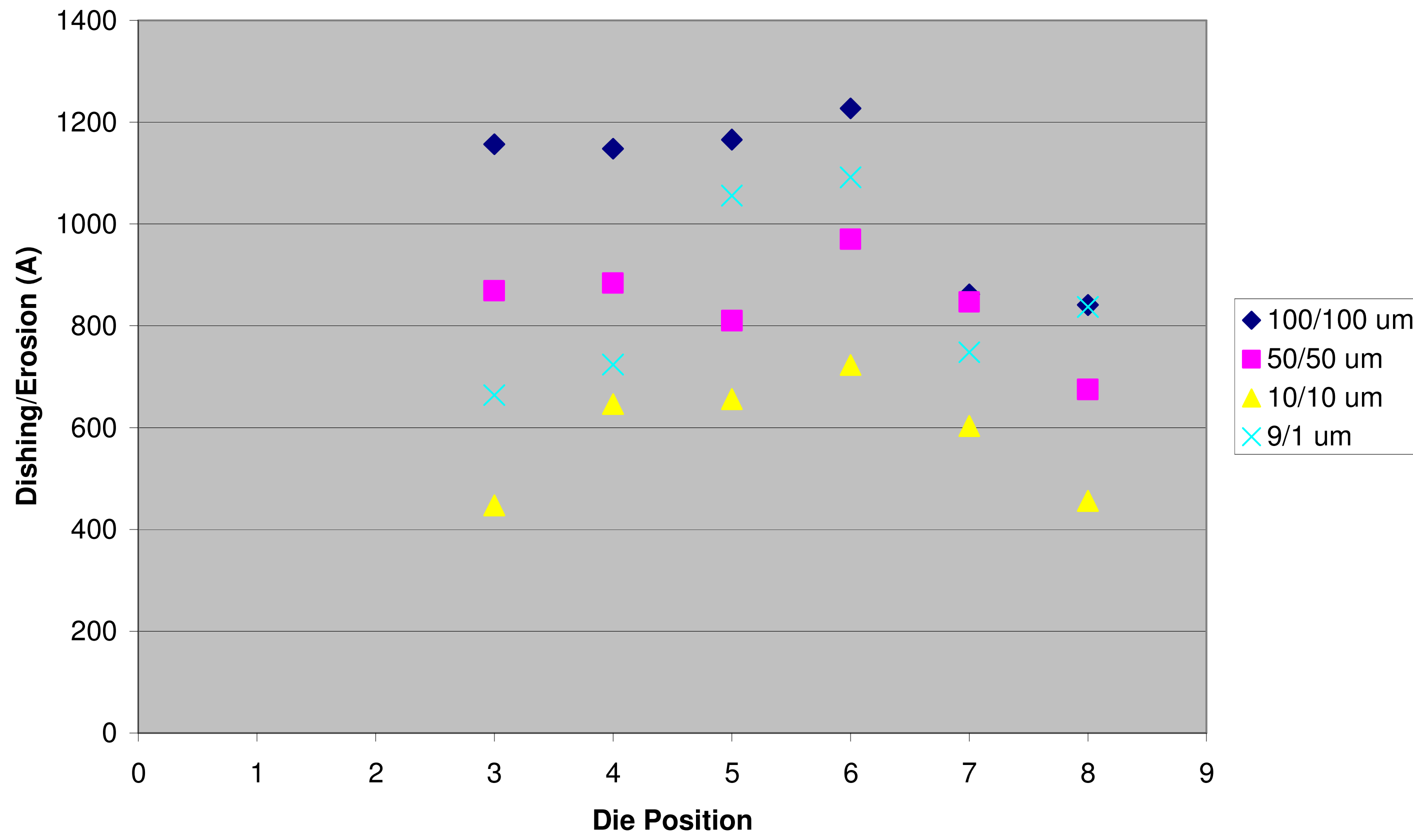

Total polishing time to clear 1.0 um over burden copper: 20 seconds
Removal rate for the first 10 sconds: 3.6 um/min
Removal rate for the remaining 10 seconds: 2.4 um/min

LPC and Surface Defects

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- Significant effort and progress have been made on
  - LPC reduction in incoming slurry
  - LPC minimization during slurry delivery (pumps, containers, etc)
  - POU filtration serves as a last defense
- The importance of LPC generated during polishing has received some attention lately
  - Low abrasive content slurry more vulnerable
    - Ceria based slurry
    - Copper is typically low abrasive
- How is functionalized particle handle polishing debris?
  - Fractured particles give great surface area

Particulate adsorption

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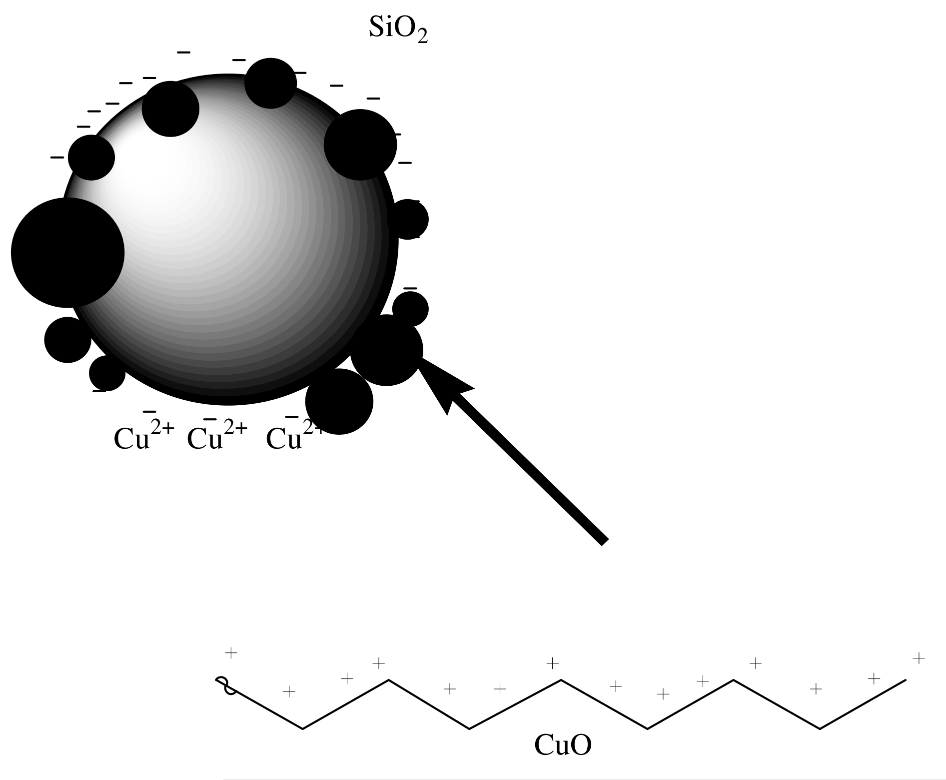

Yuzhuo Li, CMP-MIC 2004 Short Course

Fresh and Spent Slurry LPC

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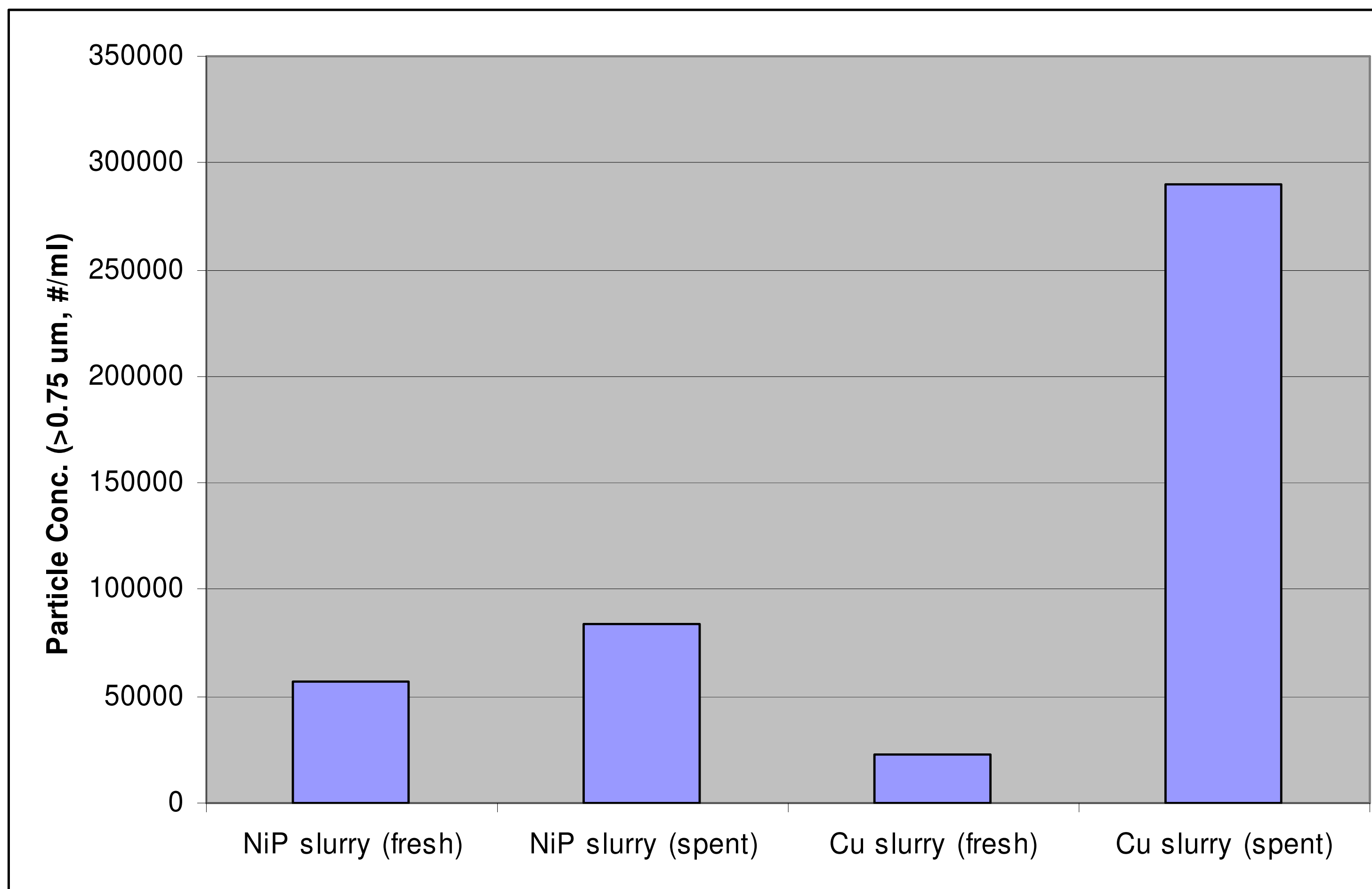

LPC Sources for Cu and NiP CMP

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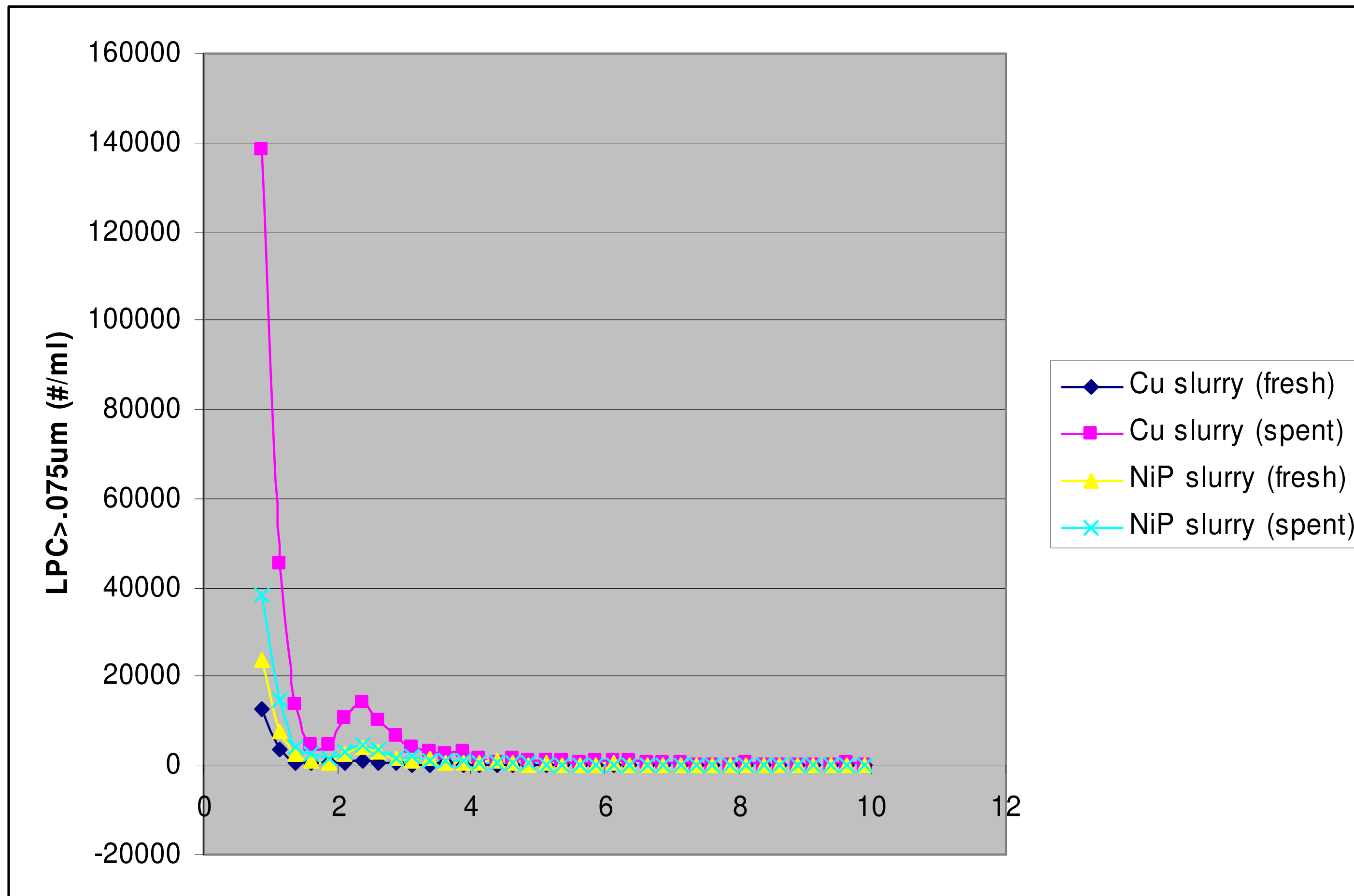

Summary

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- Why functionalized particles?
  - Increase removal rate? Not really
  - Enhance planarization efficiency? Yes
  - Lower defect level? Yes
- Why matching chemistry?
  - Allow surface functionality to express
  - Balance the need for material removal and transport
  - Lower defect level