Testing of Our Mechanistic Model for Copper CMP in Acidic Slurry Containing BTA

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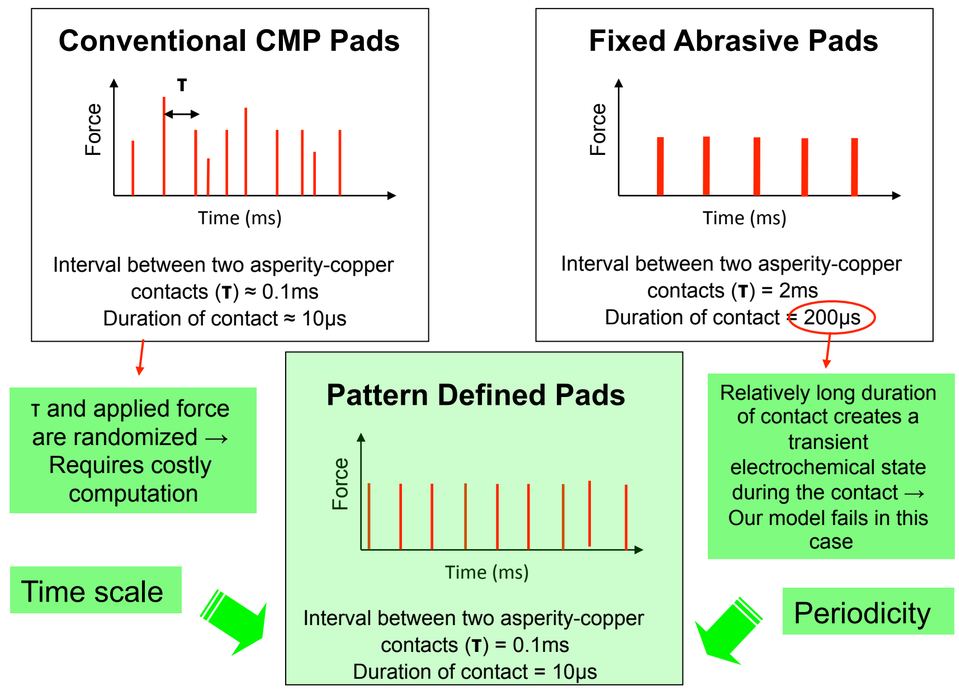
Seungchoun Choi © 2011 LMAS contact email: choisch@berkeley.edu

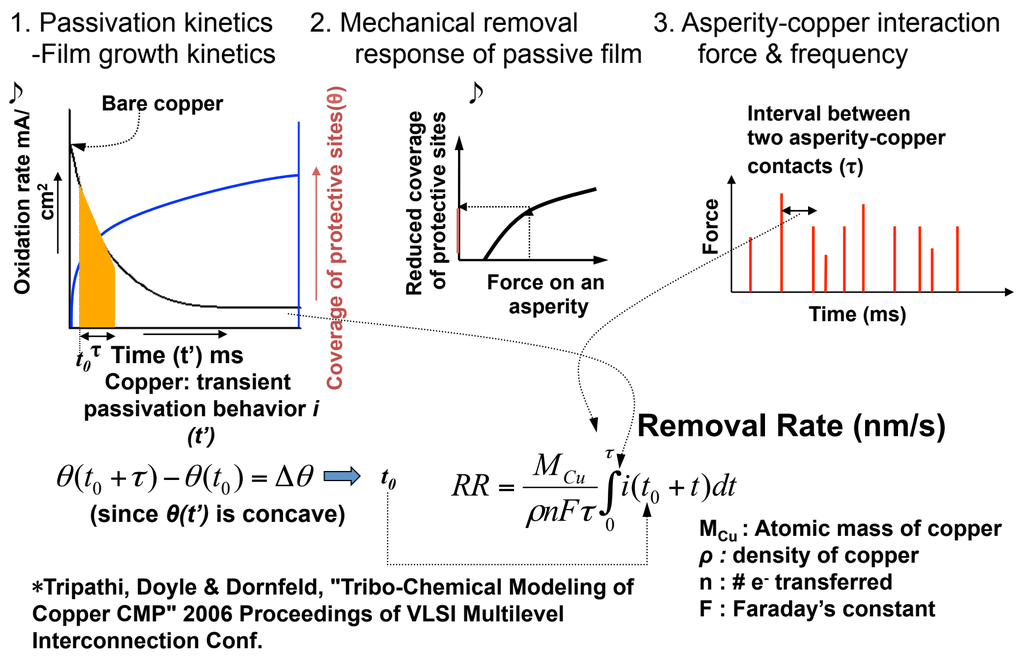
Motivation

- A robust copper CMP (Chemical Mechanical Planarization) model is essential for successful design for manufacturing (DfM) and optimization of the CMP process.
- The integrated, mechanistic tribo-chemical model for copper CMP considers abrasive and pad properties, process parameters (speed, pressure etc.), and slurry chemistry to predict material removal rates.
- A pattern-defined CMP pad whose distribution of asperities is known gives an important input parameter to our previously reported mechanistic copper CMP model, namely the interval between consecutive asperity and copper interactions.
- Such a pad will also facilitate testing the extended model on patterned surfaces
- Chronoamperometry can be used to measure the oxidation rate of copper in a solution whose potential is controlled by a potentiostat.

Pattern Defined CMP Pad



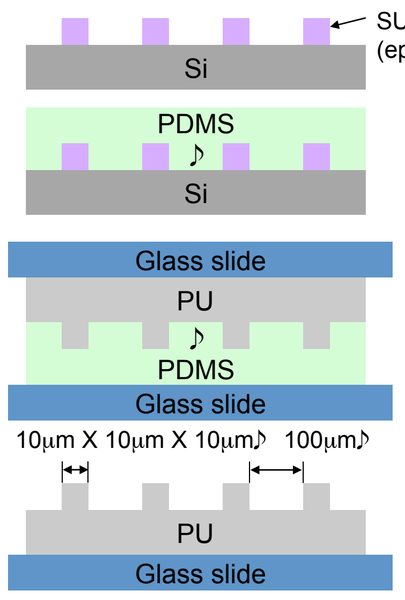
Mechanistic Copper CMP Model



*Tripathi, Doyle & Dornfeld, "Tribo-Chemical Modeling of Copper CMP" 2006 Proceedings of VLSI Multilevel Interconnection Conf.

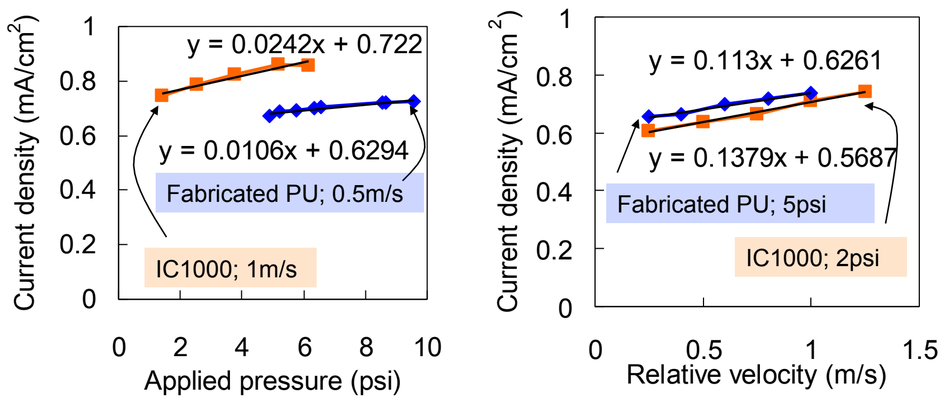
Fabrication of Pattern Defined Pad

- Replica Molding



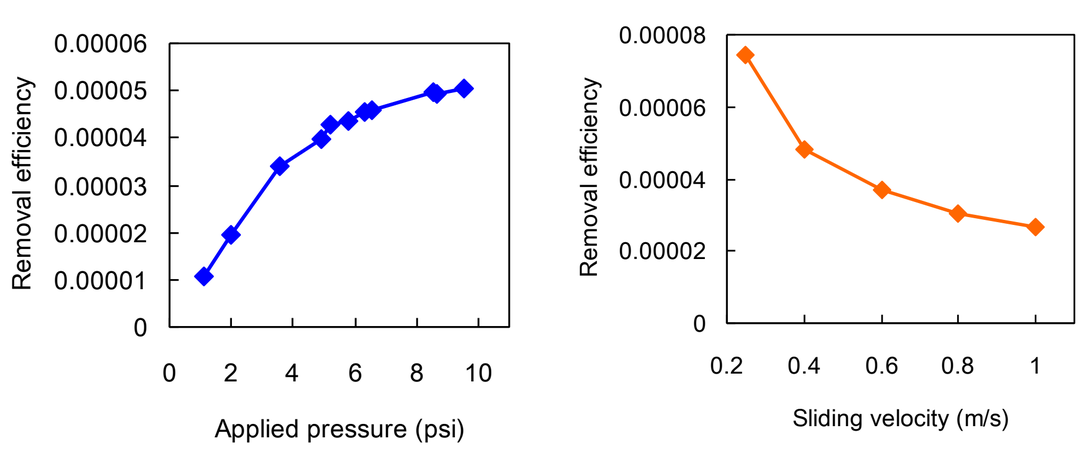
- Master fabricated by photolithography using SU-8 negative photoresist
- PDMS (Sylgard® 184) applied to the master and cured
- Polyurethane applied to the PDMS mold and cured
- PU replicated

In-situ Electrochemical Measurement



- MRR obtained from the fabricated PU pads was less dependent on the applied pressure than that from IC1000 CMP pad
  - Slight increase in the MRR for fabricated PU is due to the slight increase in the contact area (thus slight decrease in the interaction interval, τ, or the removal efficiency
  - MRR increase for increased pressure for IC1000 is attributed to the increased real contact area ratio (thus, decreased τ)
- Similar trends for varied relative velocity
  - Reflects the change in the interaction interval

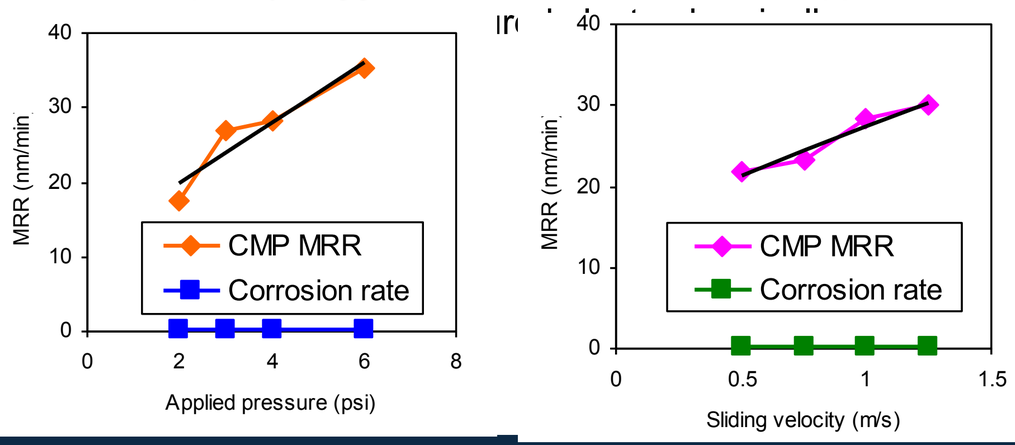
Evaluated Removal Efficiency



- Removal efficiency increases with increasing applied pressure and decreasing sliding velocity
- This trend clearly shows that the removal efficiency is closely related to the duration of the asperity-copper contact

Unexpected Effects of Mechanical Removal

- Polish rate of copper was evaluated by measuring sheet resistance of copper film and corrosion rate was electrochemically measured
- Polish rate of copper was nearly two orders of magnitude larger than the corrosion rate of copper in pH4 slurry containing 0.01 M BTA, 0.01 M glycine, 10^{-4} M $Cu(NO_3)_2$, 2 wt% abrasives and 0.5 wt% H_2O_2.
- This discrepancy suggests the direct removal of copper atoms from ir



Conclusion and Future Work

- The developed mechanistic copper CMP model qualitatively explains the material removal behavior during copper CMP
- The small electrochemically measured corrosion rate suggests the contribution of direct mechanical removal of copper
- New mechanistic copper CMP model that addresses this new finding needs to be developed

Pattern defined pads	Conventional CMP pads
Bulk MRR (We are here now.)	Bulk MRR
Local MRR (wafer pattern dependency)	Local MRR (wafer pattern dependency)

Apply this copper CMP model to modeling of the pattern-dependence of CMP, and to DfM.

Berkeley UNIVERSITY OF CALIFORNIA