Correlation between dishing/erosion and electrical properties in copper interconnects after chemical mechanical planarization

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Agenda

A leading semicon materials supplier

Versum Materials

Versum Materials is working on the next thing. The next product. The next technology. The next breakthrough that boosts efficiency. Versum Materials is ready for the future and ready to help customers advance.

Versum Materials had been pushing boundaries to create next-generation **CMP slurries, ultra-thin dielectric and metal film precursors,** formulated **cleans and etching products,** and **delivery equipment** that have revolutionized the semiconductor industry.

Intermolecular at a Glance

Leading innovator of new materials for future generations of electronic components

1. **Materials Innovation**
2. **Materials Improvement**
3. **Materials Replacement**
4. **Materials Screening**
5. **Materials Safety**

INTERMOLECULAR®

Founded 2004
Aquired by EMD 2019

Flexible, outsourced R&D materials services

537 patents + applications

Located San Jose, CA

Unique high-throughput experimentation platform

Our position and capability now

Performance Materials

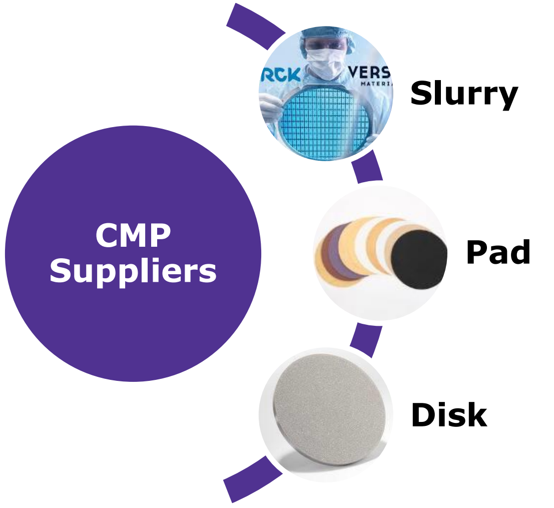
- Liquid crystals and OLED materials for displays & lighting
- Effect pigments for coatings and cosmetic products
- **Specialty chemicals for the semiconductor industry**
- Functional materials for solar panels

Healthcare

Life Science

Objective

How to bridge gaps between CMP suppliers and Foundry customers



Pattern Wafers
- Commercial testing vehicles, e.g. MIT754

CMP Process
- Cu CMP
- Barrier CMP

Polishing Output
- Removal Rate
- Dishing / Erosion
- Defectivity

- Different layout/design

Gaps inevitable as resulted by all process variables

- Different metrology & outputs

- Customers' products

- Cu CMP
- Barrier CMP

- WAT(wafer acceptance test)
- Defectivity

Objective
Advantage and disadvantage comparison between eTest and profiler

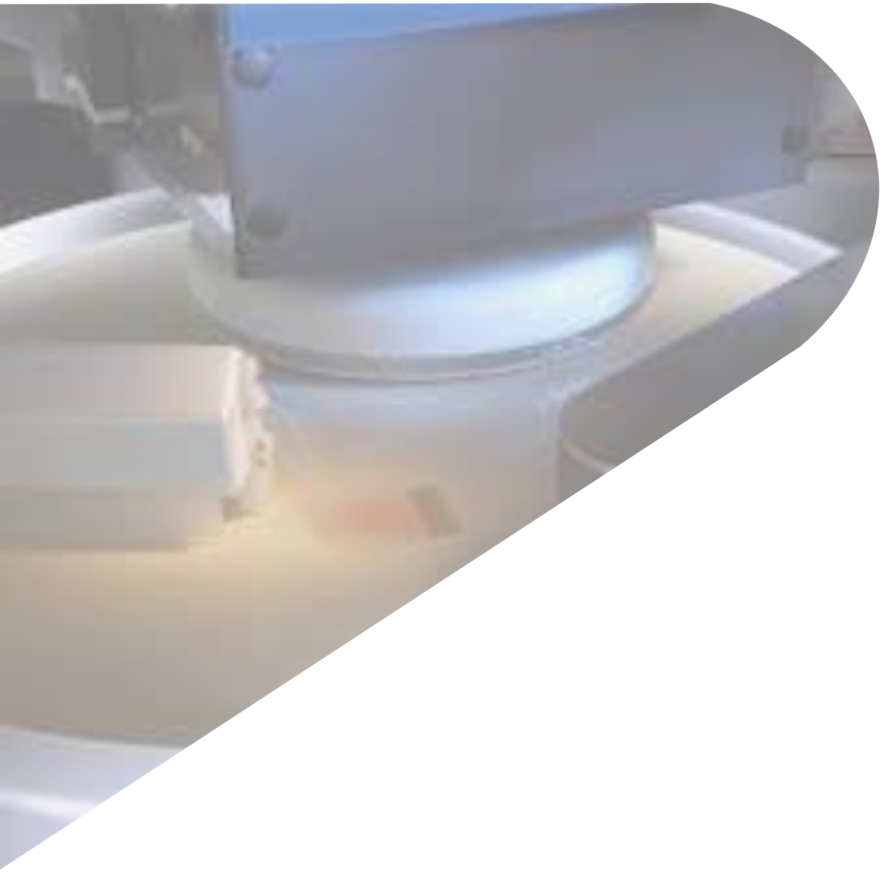
	Electrical Test	Dishing/Erosion by AFM/Profiler
Advantages	• High throughput for responsiveness: Typical throughput - **32 dies for 16 features in 4-5 hours** • Correlates and links to true Cu thickness • Capable for all features concerned	• Metrology tool(s) are far more accessible from 3rd-party lab; most of CMP suppliers own their AFM or profiler, more intuitive/flexible in data collection
Disadvantages		• In general lower throughput therefore less responsive: typically takes >**6 hours to complete 3 dies for 16 features by semi-automatic setup** • An indirect measurement anyway for device performance evaluations

The integration of Versum Materials and Intermolecular could provide not only dishing/erosion data but also electrical data in terms of CMP slurry performance.

We bring more value to customers compared with other slurry suppliers.

Experimental

Test conditions for Cu MIT754 pattern wafers

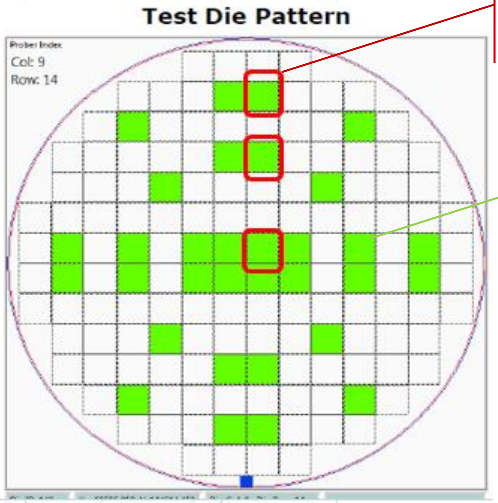


Testing Consumables & Conditions

	Cu CMP	Barrier CMP
Pad	Dow VP9280	Fujibo H7000
Disk	Kinik I-PDA31G-3N	3M A82-AF
Slurry	• Cu-HH (Extra high Cu dishing) • Cu-H (High Cu dishing) • Cu-L (Low Cu dishing)	• Bar-H (High Cu/TEOS selectivity) • Bar-L (Low Cu/TEOS selectivity)
Polishing Down Force	• 1.5psi	• 1.1psi
Data Collection	• MRR • Dishing	• MRR, Selectivity • Dishing / Erosion • Rs

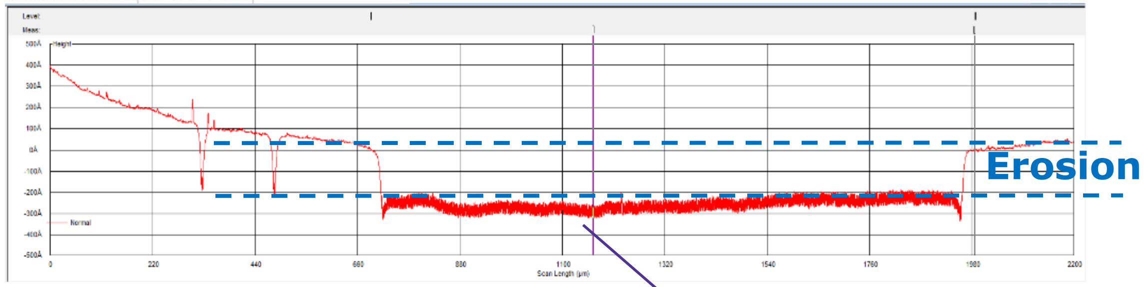
Experimental
Testing vehicle measurements

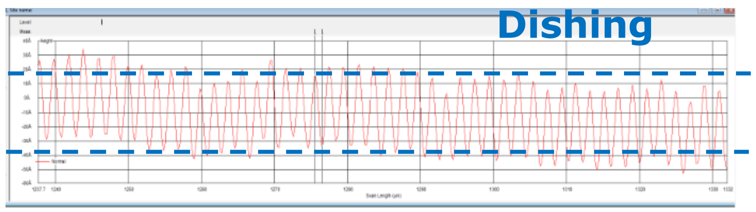
32 dies

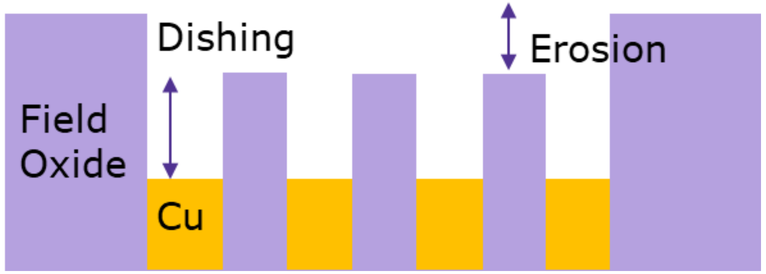


Measuring point for topography by profiler

Measuring point for sheet resistance by 2-terminal probe







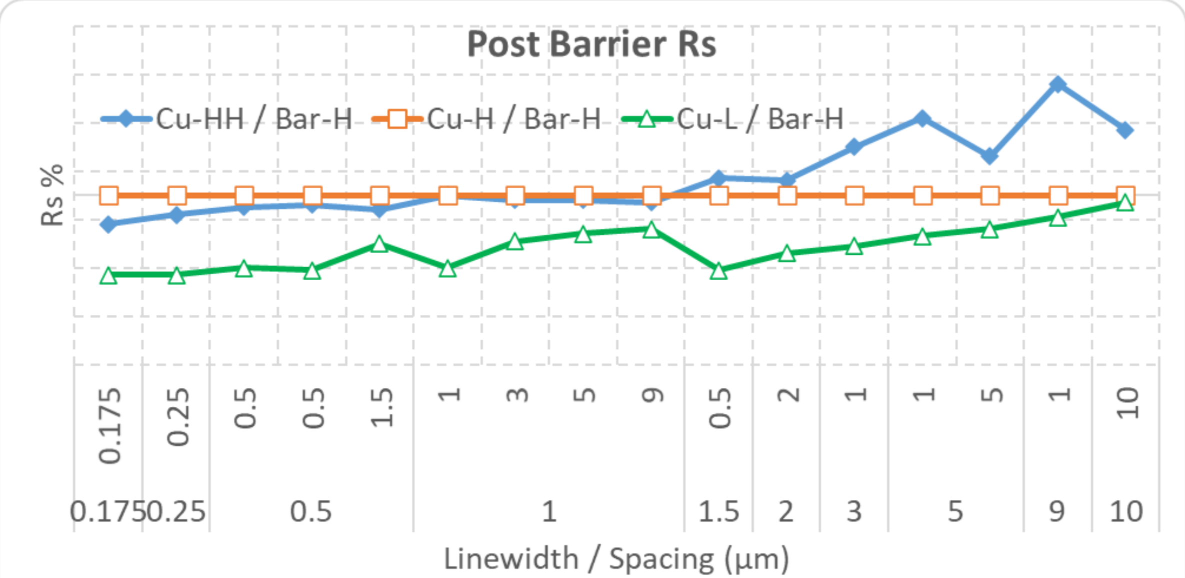
Testing Results

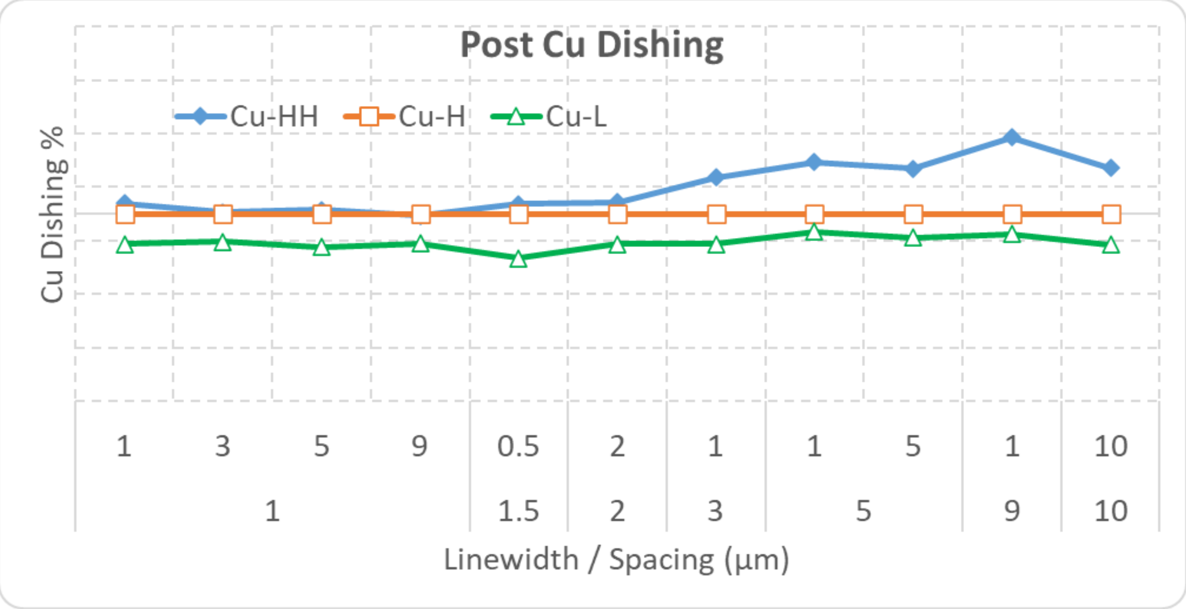
Removal rates and selectivity of Cu and Barrier slurries for polishing

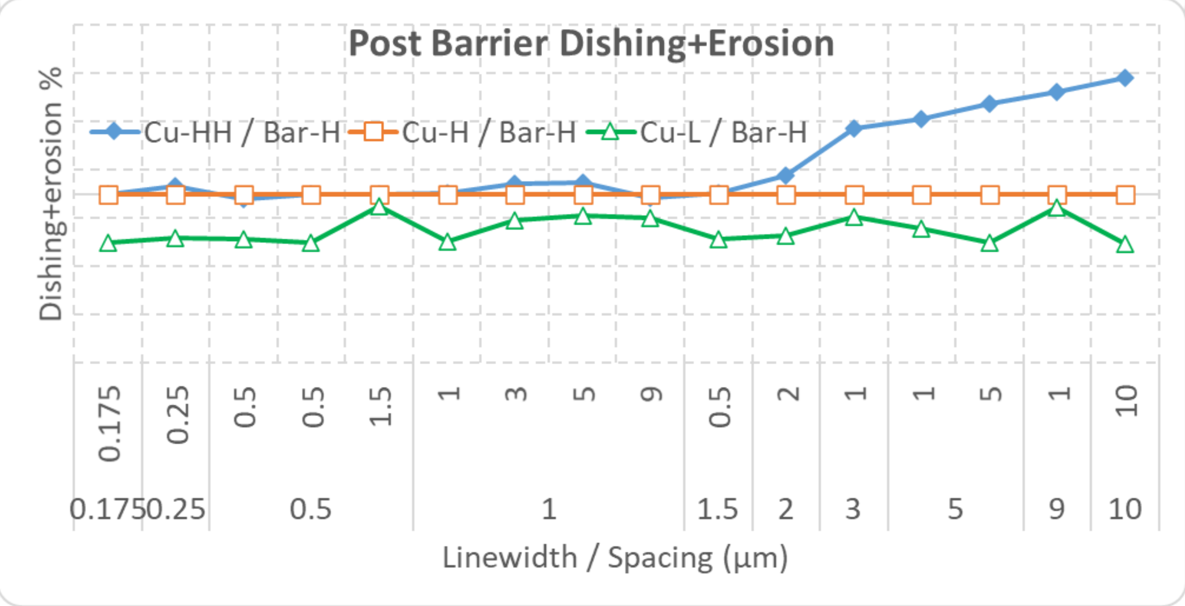
Cu Slurry	Cu MRR (Å/min)	Dishing@ 10x10μm	Barrier Slurry	Cu / TEOS selectivity
Cu-HH	5295	468	Bar-H	1:5.2
Cu-H	6514	328	Bar-H	1:5.2
Cu-L	4466	233	Bar-H	1:5.2
Cu-H	6514	328	Bar-L	1:1.6
Cu-L	4466	233	Bar-L	1:1.6

Testing Results

Strong correlation between normalized Rs and topo among Cu slurries



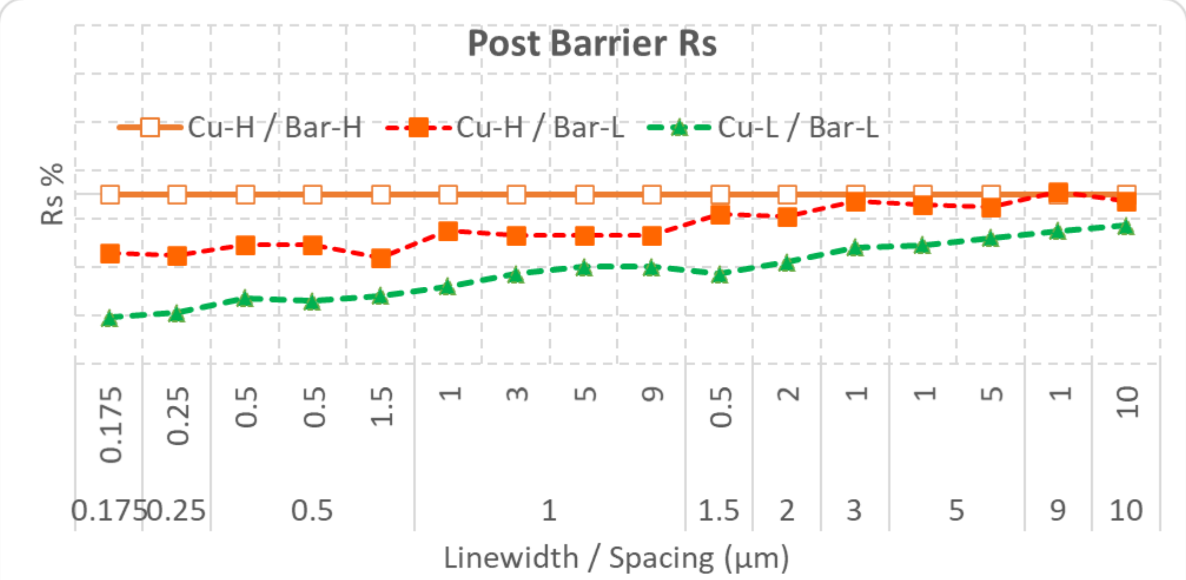


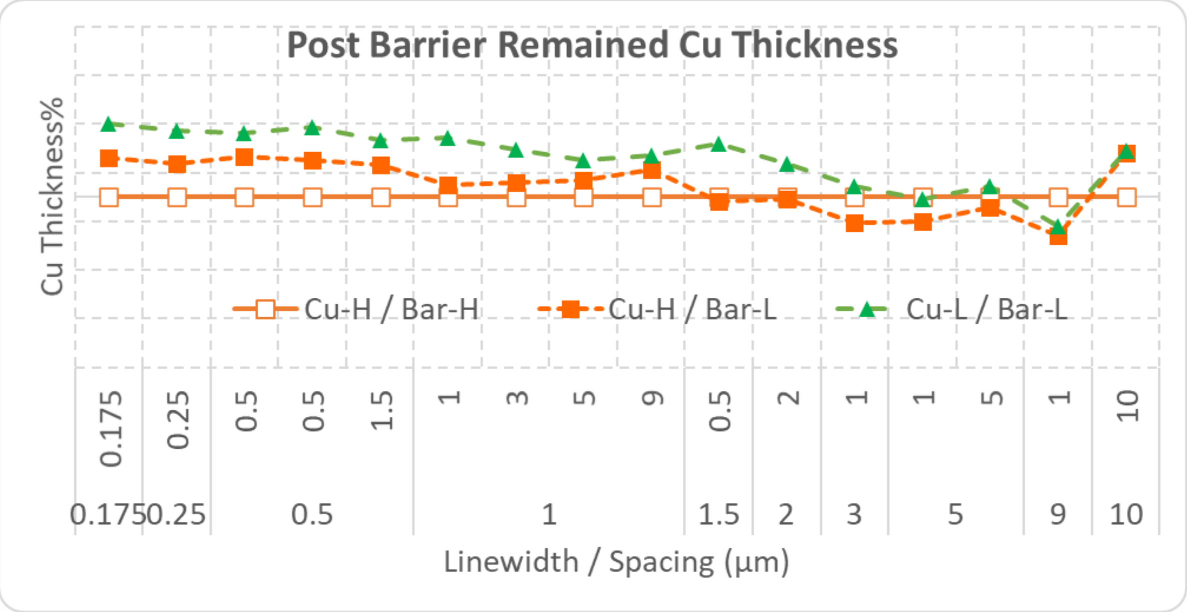


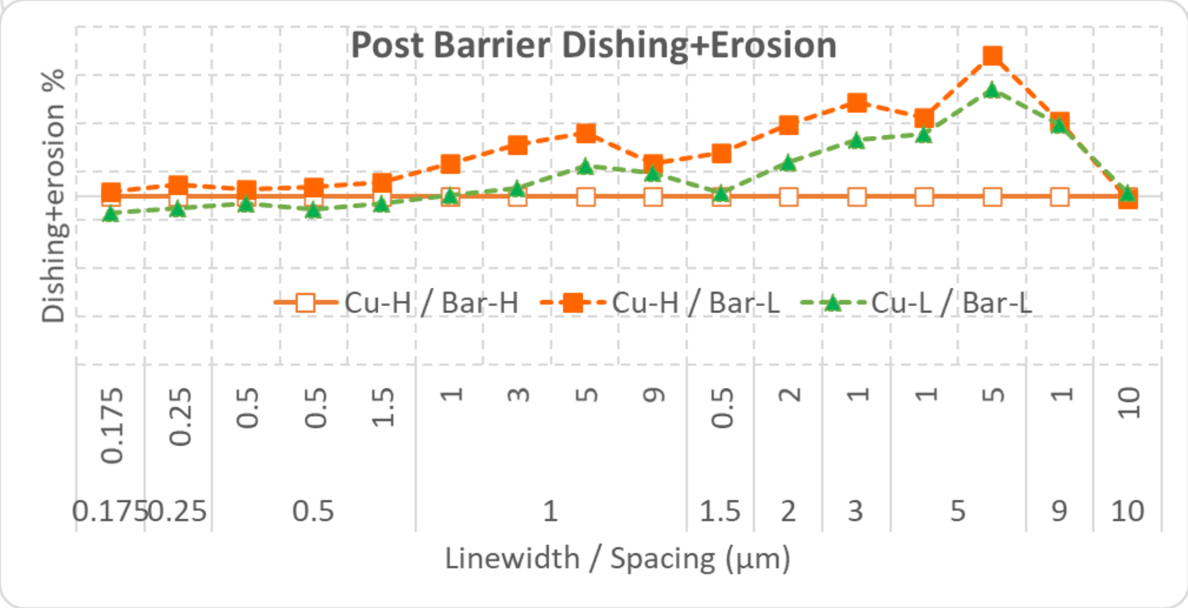
- The output of post barrier Rs measurement exhibits the same trend as the dishing performance after Cu CMP.
- Dishing and erosion are both considered as the topography performance attributes.

Testing Results

Strong correlation between normalized Rs and Cu thickness







- The correlation between Rs and topo is reversed when low-selectivity barrier slurry was used for polishing.
- The actual Cu thickness shows strong correlation with the sheet resistance.

Conclusion

Generally, dishing/erosion exhibits similar a trend as Rs renders

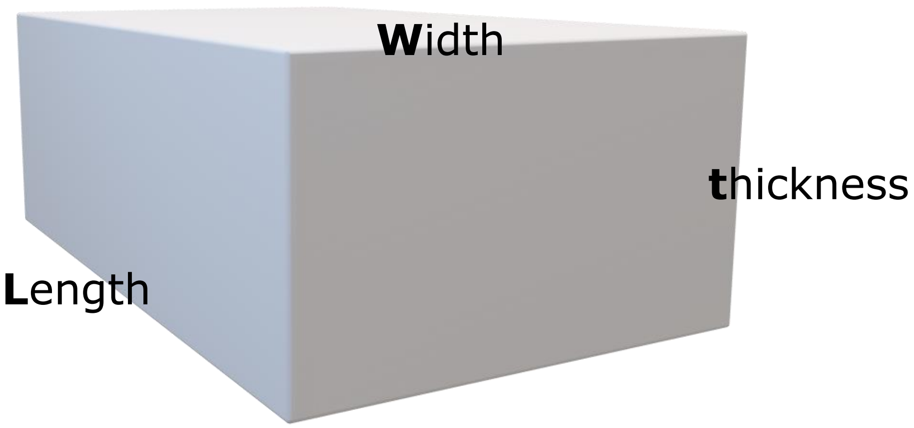
- After barrier polishing, erosion also plays an important role to Rs, dishing and erosion both need to be taken into consideration.
- Topography (in terms of dishing and erosion) correlates well with Rs using the same barrier slurry to remove barrier layer. Topography as an indirect measurement is still a widely-used protocol and reference for evaluating Cu slurry.
- Care must be exercised using topography as the protocol/reference to evaluate barrier slurry, as the selectivity and material removal rate can be pattern dependent. For process simplicity, fixed-time process is usually employed for barrier CMP, unfortunately, it is difficult to control the exact oxide loss and Cu remaining thickness. Therefore, electrical measurement appears to be a better approach to validate barrier CMP performance than topography.

Thank You

EMD
Performance
Materials

Fundamental

The correlation between Rs and Cu thickness

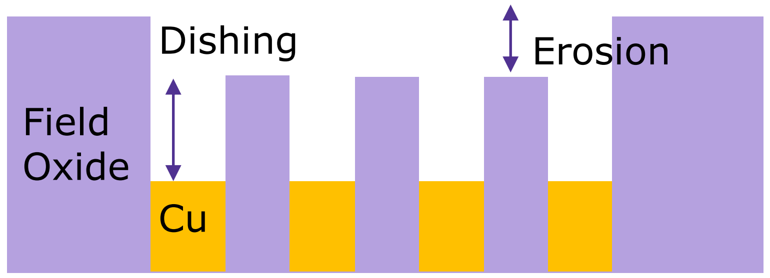


$$R = \frac{\rho}{t}\frac{L}{W} = Rs\frac{L}{W}$$

$$Rs \propto \frac{1}{t}$$

ρ is bulk resistivity, L is Length, W is width, and t is sheet thickness

Cu dishing after barrier CMP



Cu protrusion after barrier CMP

Actual Cu thickness= Field Oxide thickness – dishing - erosion

Shirley Yu Chuang Lin

Shirley Lin is currently the lab manager at Asia Technology Center of Versum Materials (a business of Merck KGaA), and is in charge new slurry and CMP (Chemical Mechanical Planarization) process development with scale-up scope in mind serving both internal and external customers. Shirley started her CMP related professional experiences since 2007 at Rohm & Haas Electronic Materials as an applications engineer, then joined DA Nanomaterials (Now Versum Materials, a business of Merck KGaA) in 2010. During the past 10 years, she has worked as a lead CMP process engineer, applications specialist, marketing specialist, and recently become lab manager for her profound CMP background and know-hows. Shirley has a master’s degree in Chemical and Material Engineering at National Central University in Taiwan and has been staying in electronic and semiconductor material field(s) since acquiring her degree. Critical milestones include successfully scaling up copper slurries for logic advanced node needs.