COPPER CMP SLURRIES FOR ADVANCED NODE APPLICATIONS

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OUTLINE

- Why develop low dishing Cu bulk CMP Slurry?
- Cu Bulk Metal CMP polish mechanism
- Low dishing Cu CMP slurries
- Key factors to reduce Cu line dishing
- Summary

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WHY DEVELOP LOW DISHING CU CMP SLURRY?

- At advanced node (10nm or <10nm nodes) Cu CMP applications, Cu line dishing level impacts more on the fabrication yield of the integrated circuit chips.

- The deep Cu line dishing may cause the electrical signal loss through interconnecting materials in the fabricated electronic devices.

- The deep Cu line dishing cannot be fully corrected through subsequent Cu Barrier CMP processes.

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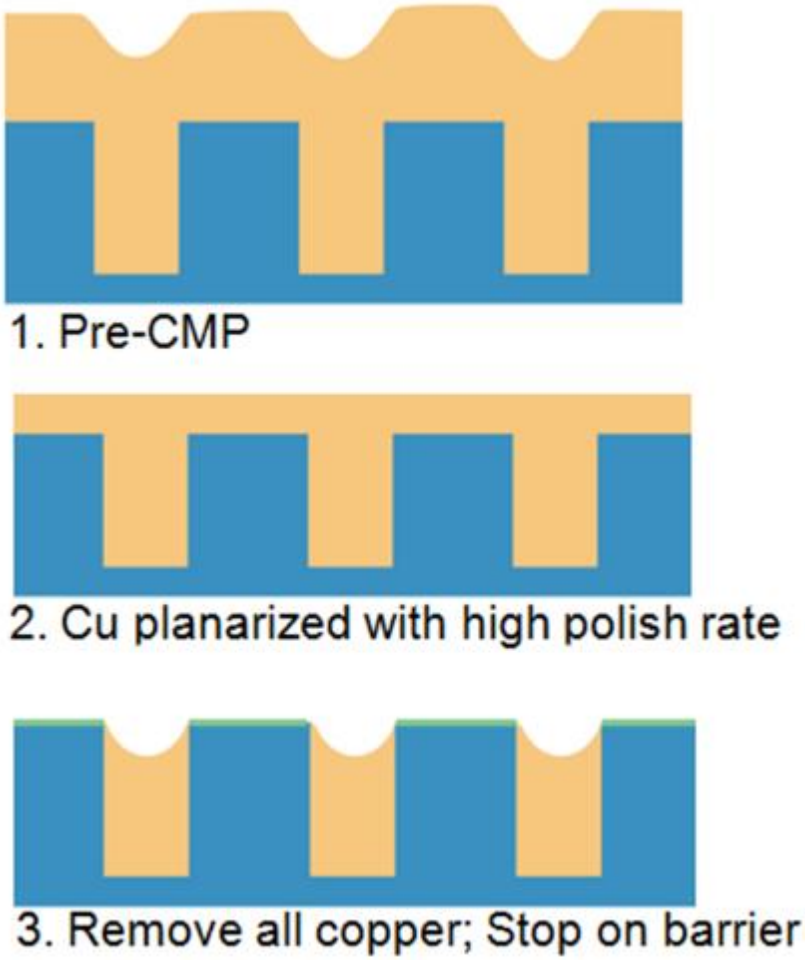
TWO-STEP CU CMP OVERVIEW



Step One:

- Remove copper overburden
- High removal rate
- High planarization efficiency
- Low corrosion damage

Step Two:

- Clear copper to barrier
- Low defects, corrosion, scratching, residue, etc.
- Low etching/dishing

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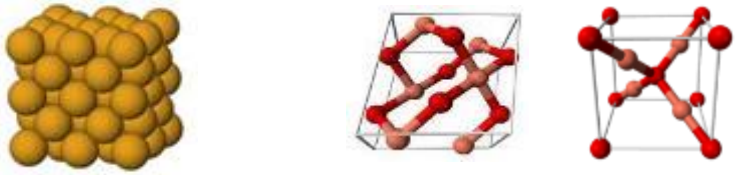
GENERAL CU POLISH MECHANISM

Oxidation (through Fenton-Like Reaction)

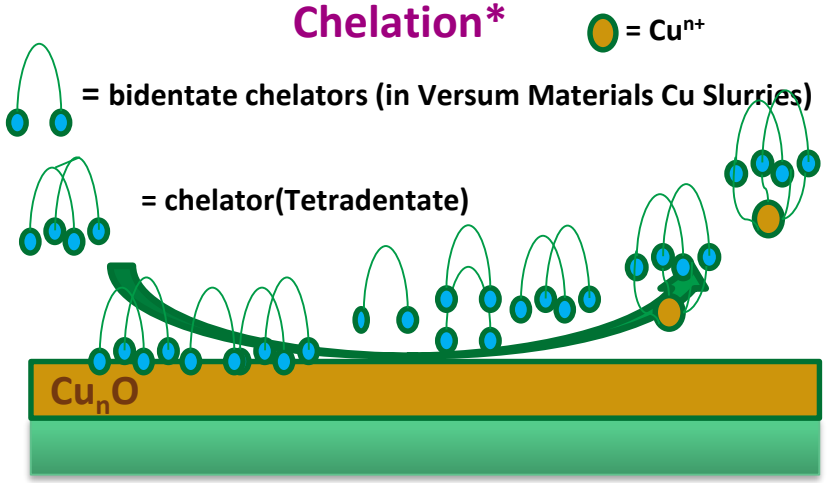
a). $Cu^{+1} + H_2O_2 \rightarrow Cu^{+2} + {}^{-}OH + {}^{*}OH$

$Cu^{+2} + H_2O_2 \rightarrow Cu^{+1} + {}^{*}OOH + H^{+}$

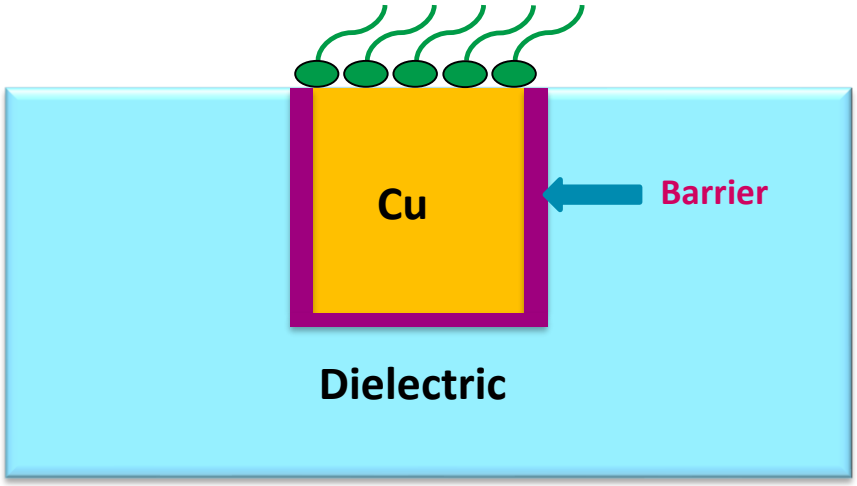
b). $3\ Cu(S) + 2\ [O] \rightarrow CuO + Cu_2O$



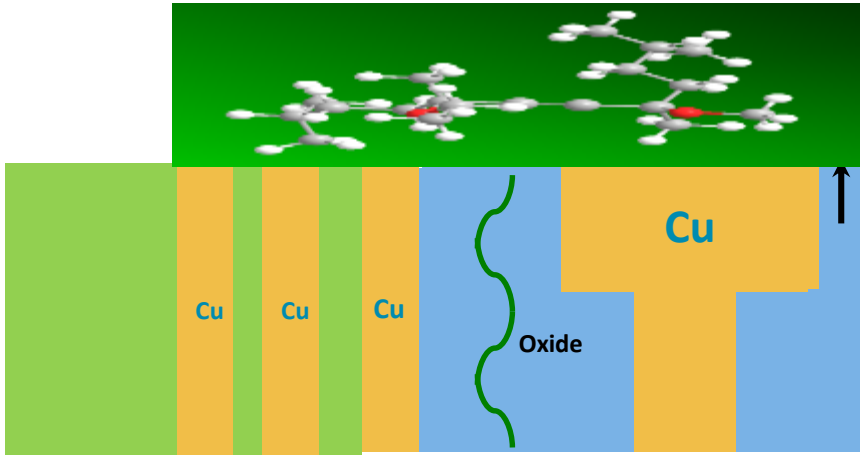
Chelation*



Passivation by Corrosion Inhibitor

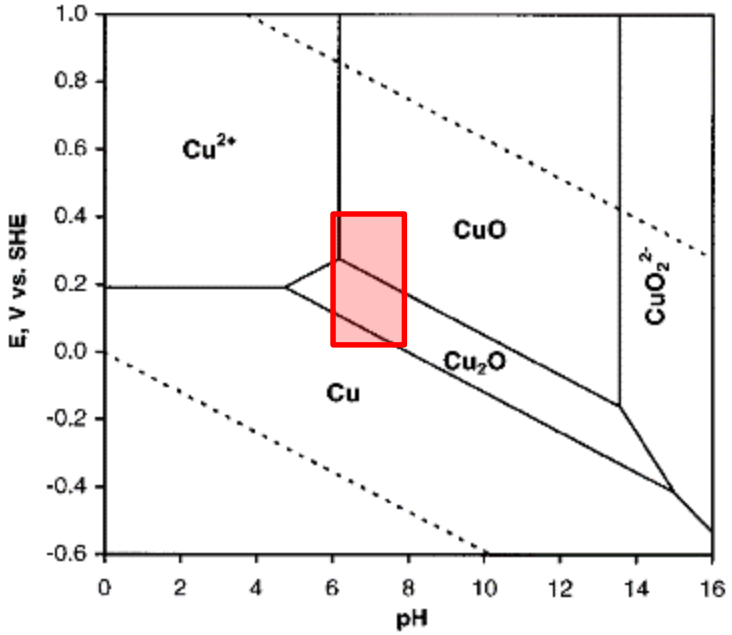


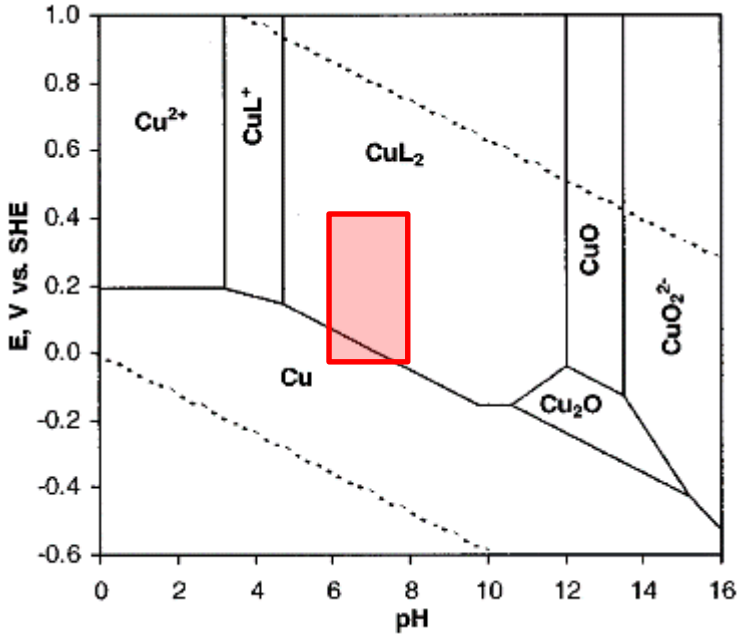
Dishing Reduction (used in new commercial Cu slurries)



POURBAIX DIAGRAM OF CU-H_20 WITHOUT AND WITH CHELATOR, L

Instead of formation Cu_2O/CuO passive film, most of the oxidized Cu ions are dissolved in the presence of the chelating ligand, L.





Versum's New Generation Cu slurries have been optimized at pH close to neutral where a mixture of $Cu(OH)_2$,Cu_2O & CuO co-exist, but with more Cu_2O & CuO to quickly react with chelating agents for achieving high Cu RRs and low Cu corrosion performances.

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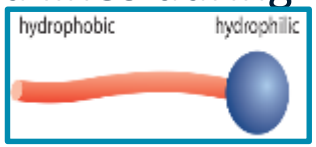
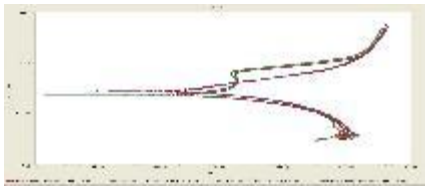
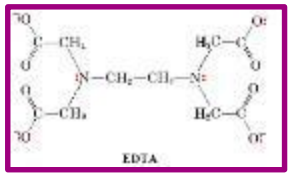
KEY FACTORS TO REDUCE CU LINE DISHING

- Dishing reducing agents that are able to form temporarily passivation layer on the surface of various widths of Cu lines during Cu CMP process

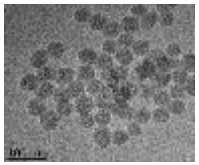


- Selection of chelating agents: Does impact Cu removal rates and Cu dishing. e.g.



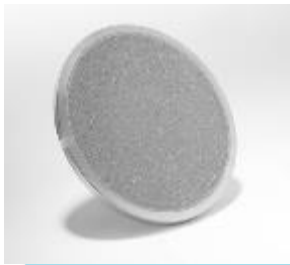


- Selection of Cu corrosion inhibitor: Impacts Cu RR and dishing



- Abrasives: Types, sizes, shapes, and modals (mono-, bi-, or multi-) of distribution, hardness, surface morphology and %: Impact Cu RR and Cu dishing

- Consumable Parts: Pads and Conditioning Disks



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Performance improvements over prior generation copper slurries were achieved by making changes in abrasive type, chelators and dishing additives as shown in the table below.

Component	Prior Generation of Cu slurry	Advanced New Generation Cu Slurries
Abrasive	Type A	Type B
Corrosion inhibitor	Yes	Yes
Chelator	Yes	Improved
Dishing Reducer	No	Yes

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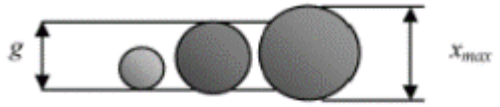
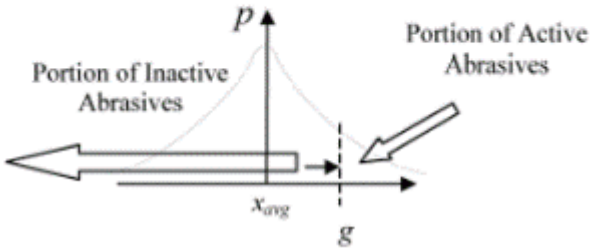
ABRASIVES IN CMP SLURRIES

DISTRIBUTION/PLANARIZATION THEORY

Comprehensive model suggests[1&2]:

- Abrasive size distribution influences the material removal from two aspects: The **number** of active abrasives and the s**ize** of the active abrasives.





Definition of "Active Abrasive" (must meet two requirements):

1. Should be located on the contact area between the wafer and pad
2. The abrasive should be large enough

1. J. Luo, D. Dornfield, "Material Removal Mechanism in Chemical Mechanical Polishing: Theory and Modeling", *IEEE-Trans. Semiconduct. Manufact*., vol 14, pp. 112-133, May 2001.
2. J.Luo, D. Dornfield, "Effects of Abrasive Size Distribution of Chemical Mechanical Planarization: Modeling and Verification", *IEEE-Trans. Semiconductor Manufact*., vol 16, pp. 469-476, August 2003.

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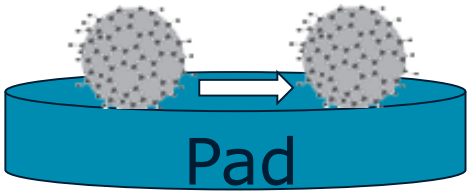
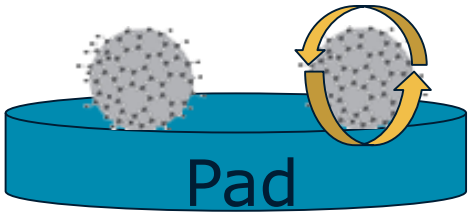
ABRASIVES IN CU CMP SLURRIES

ABRASIVES MOTIONS IN CU CMP PROCESSES

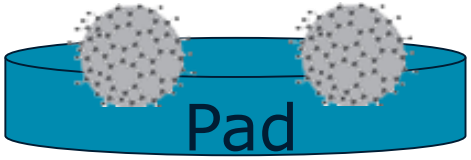
Abrasions had to be created through those particles contacting pad and wafer surfaces at the same time during a CMP process.



Sliding on Pad/Wafer Surface

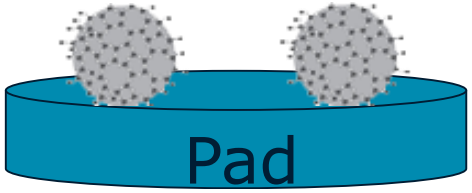


Rolling on Pad/Wafer Surface



Embedded on Pad

Trapped underneath Pad Surface



Laying Down on Pad Surface

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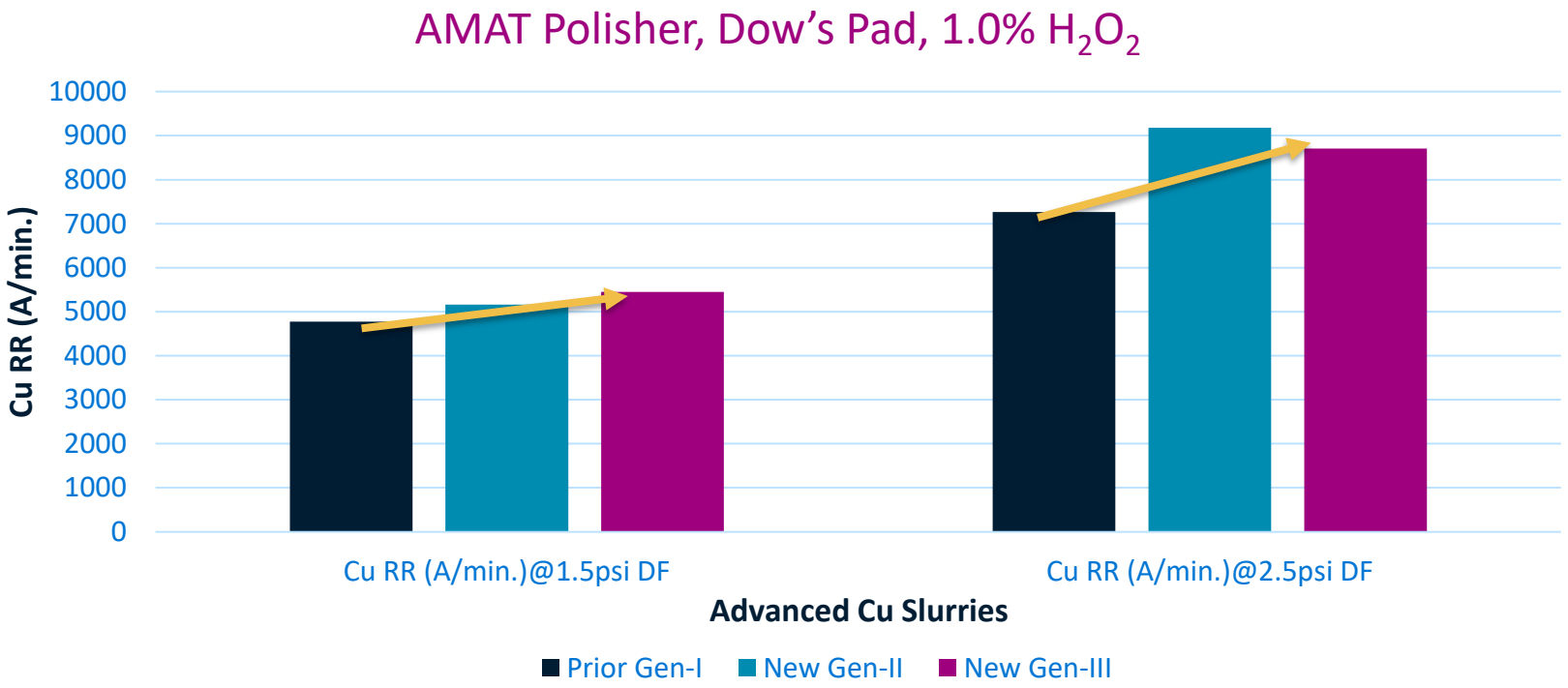
ADVANCED COPPER SLURRIES CU REMOVAL RATE COMPARISON



Versum's New Gen-II and Gen-III advanced Cu slurries showed higher Cu removal rates than prior Gen-I slurry, due to the novel chelation chemistry being used in the new advanced Cu CMP chemistries.

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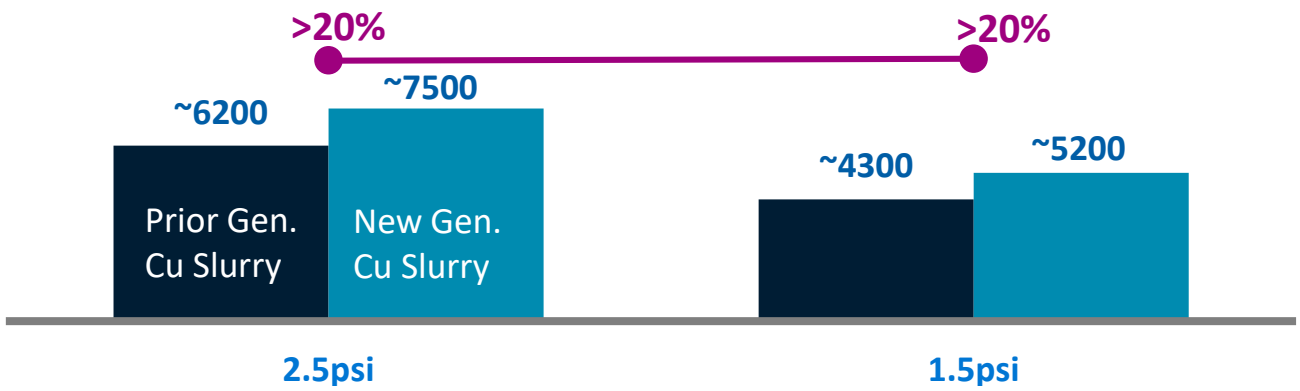
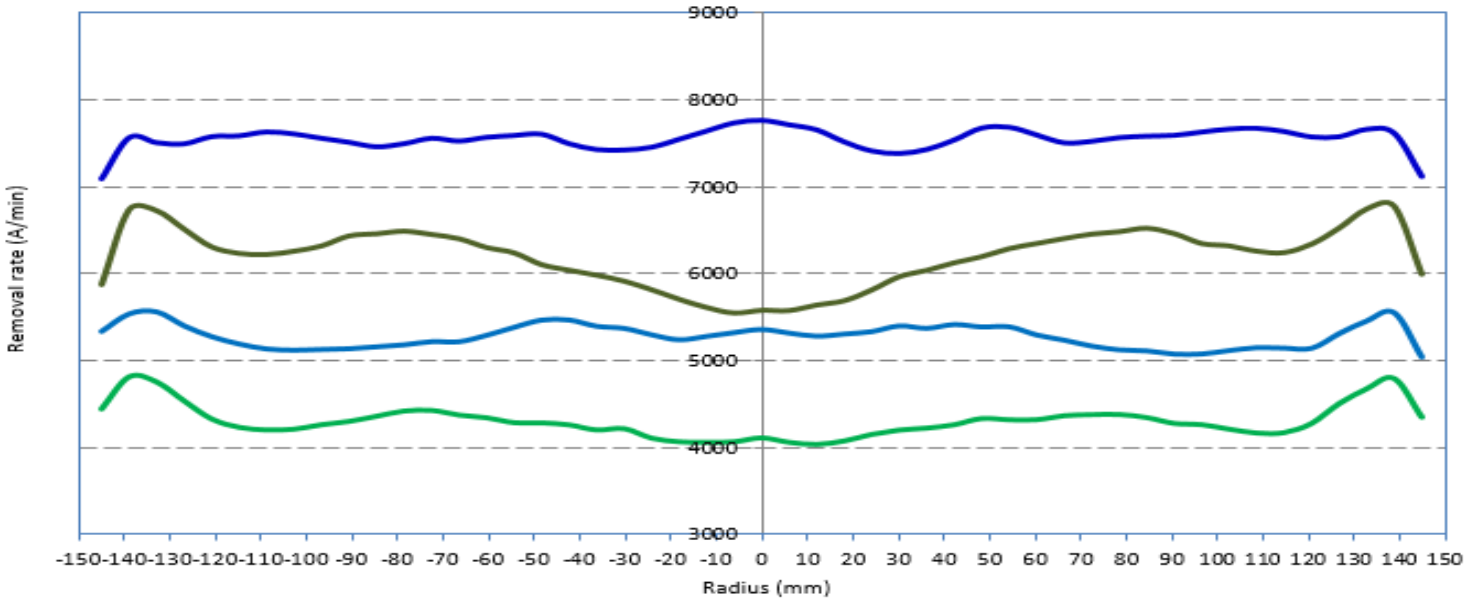
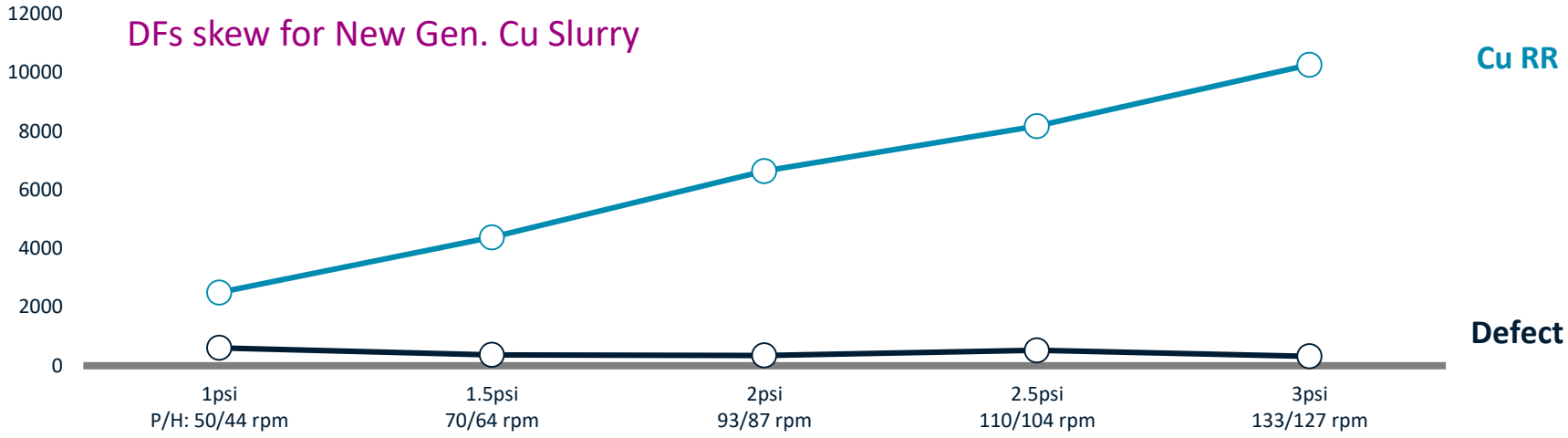
AT HIGH/LOW DFs, NEW GEN. ADVANCED CU SLURRIES PROVIDE HIGHER RRs THAN PRIOR GEN CU SLURRIES

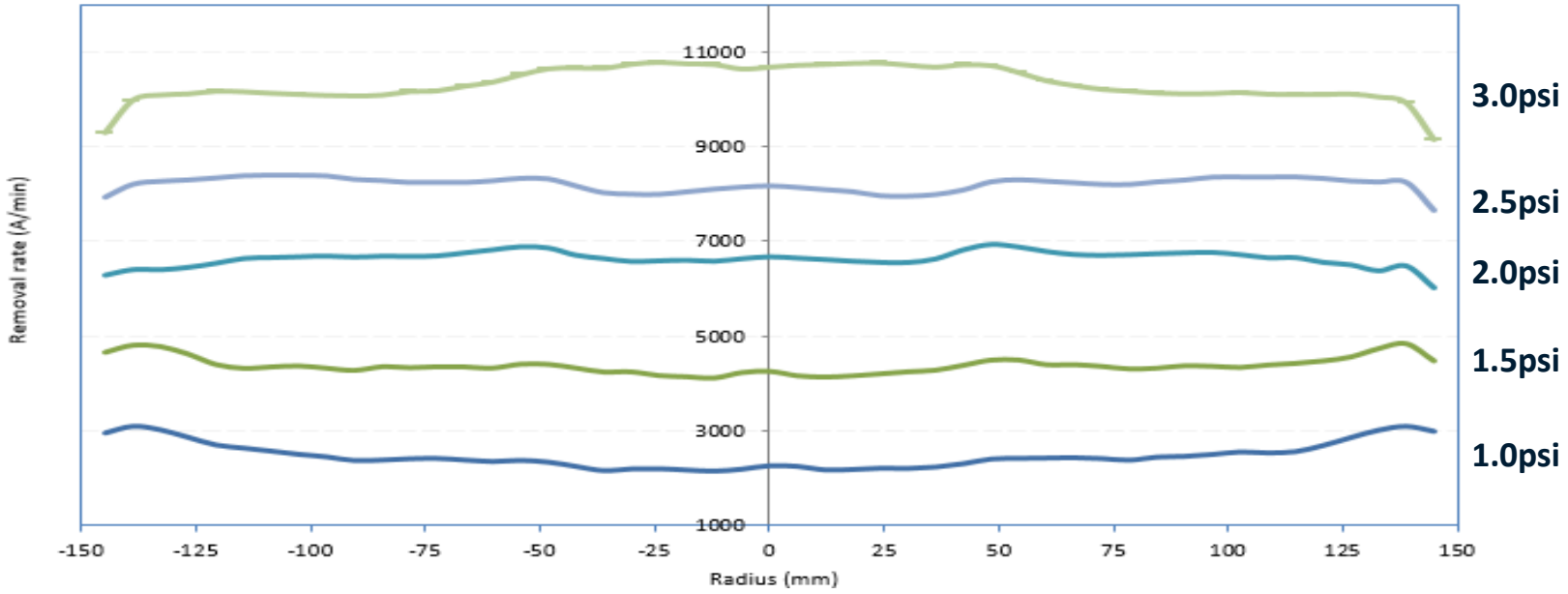
Cu RRs comparison, Dow hard pad, 3M's Conditioning Disk



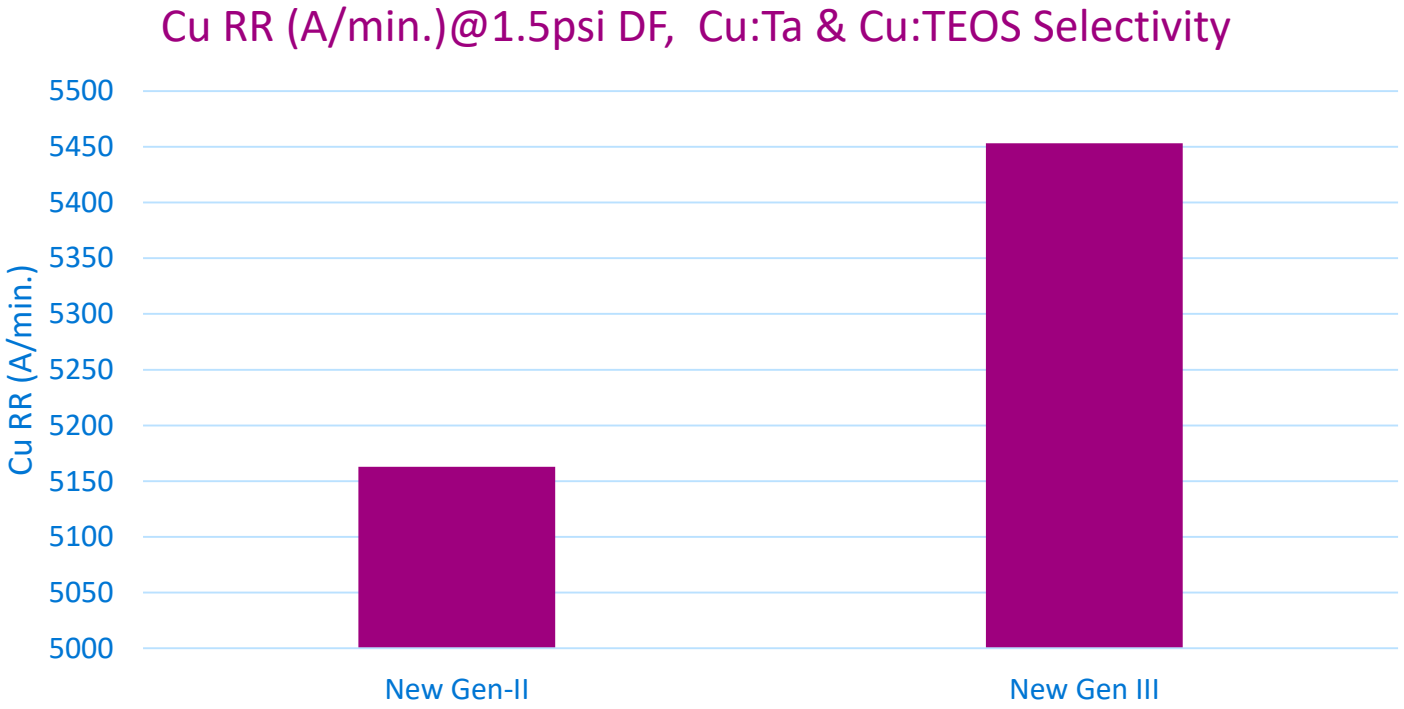


RR LINEAR TO GO UP BY INCREASING DFs, BUT DEFECT COUNT REMAINS AT THE SAMPLE LEVEL





NEW GEN. CU SLURRY SELECTIVITY PERFORMANCE



Versum's New Gen-II and Gen-III advanced Cu slurries showed higher selectivity performances of Cu:Ta, and Cu:TEOS. The selectivity of Cu:Ta is >300:1 and Cu:TEOS is 800:1 in New Gen-II Advanced Cu Slurry and >600:1 and 1000:1 in New Gen-III Advanced Cu Slurry.

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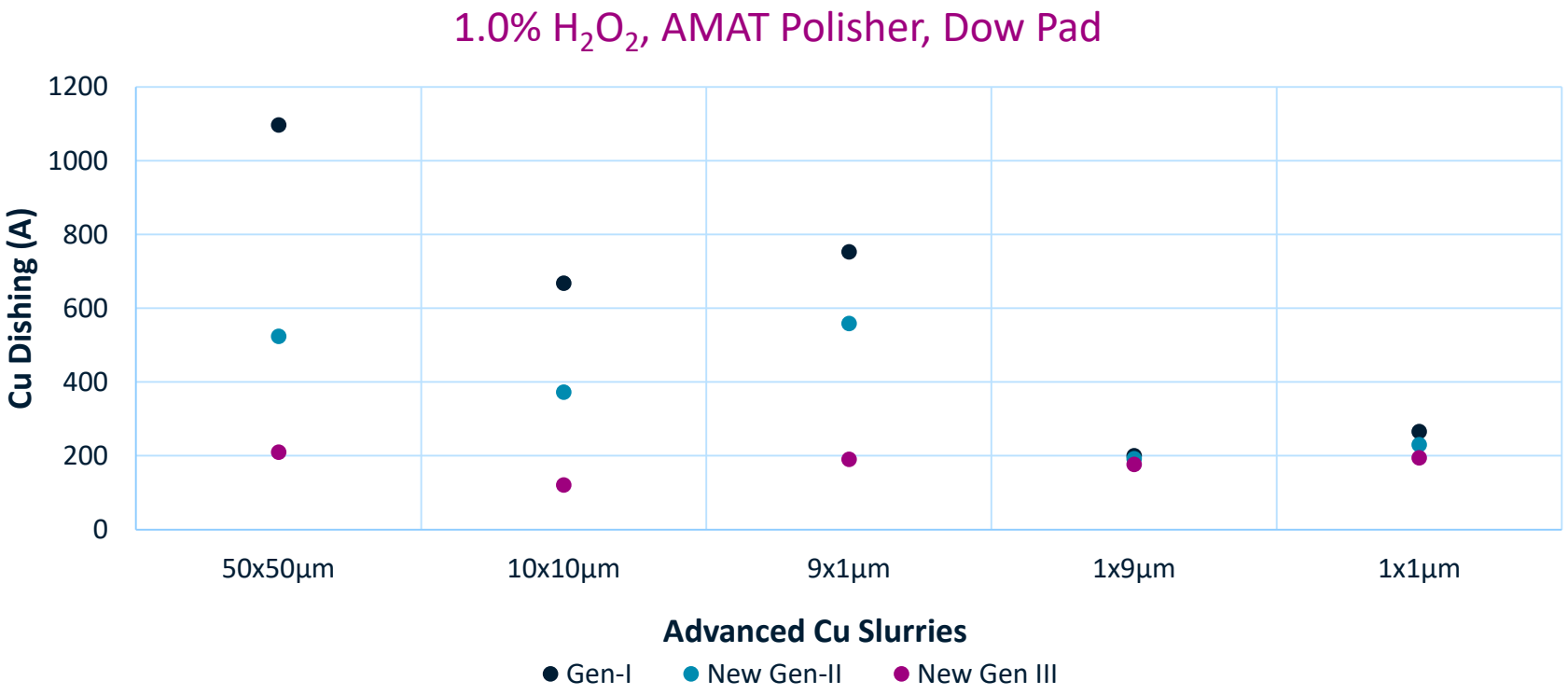
ADVANCED COPPER SLURRIES

CU DISHING COMPARISON



VM's New Gen-II and GEN-III advanced Cu slurries showed significantly improved Cu dishing performances and more uniform loading effects across various sized and density Cu line features than GEN-I Cu slurry which due to the novel Cu dishing reducing chemistry being developed and used in VM's new advanced Cu CMP slurries.

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SUMMARY

- Versum Material's New Gen. advanced Cu CMP slurries use the unique chelating agents to have achieved more uniform reactions with copper oxide surface during Cu CMP process, thus providing higher Cu removal rates than prior Gen. Cu slurry.
- New Gen. advanced Cu CMP slurries also use the well-screened high purity colloidal silica as abrasives and novel chemical additive(s) as Cu dishing reducer, which led to the much improved and more uniformed Cu dishing performances with very low trace metal contents.
- New Gen. advanced Cu CMP slurries provide >10 day stable pot Life & >1yr. stable shelf life and high selectivity towards barrier and dielectric films.
- New Gen. advanced Cu slurries are offered at 12x concentrations for low CoO.

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THANK YOU!

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