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Value from Innovation

Bulk Cu CMP: Development and challenges of high removal rate, low topography slurries

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PLANAR SOLUTIONS

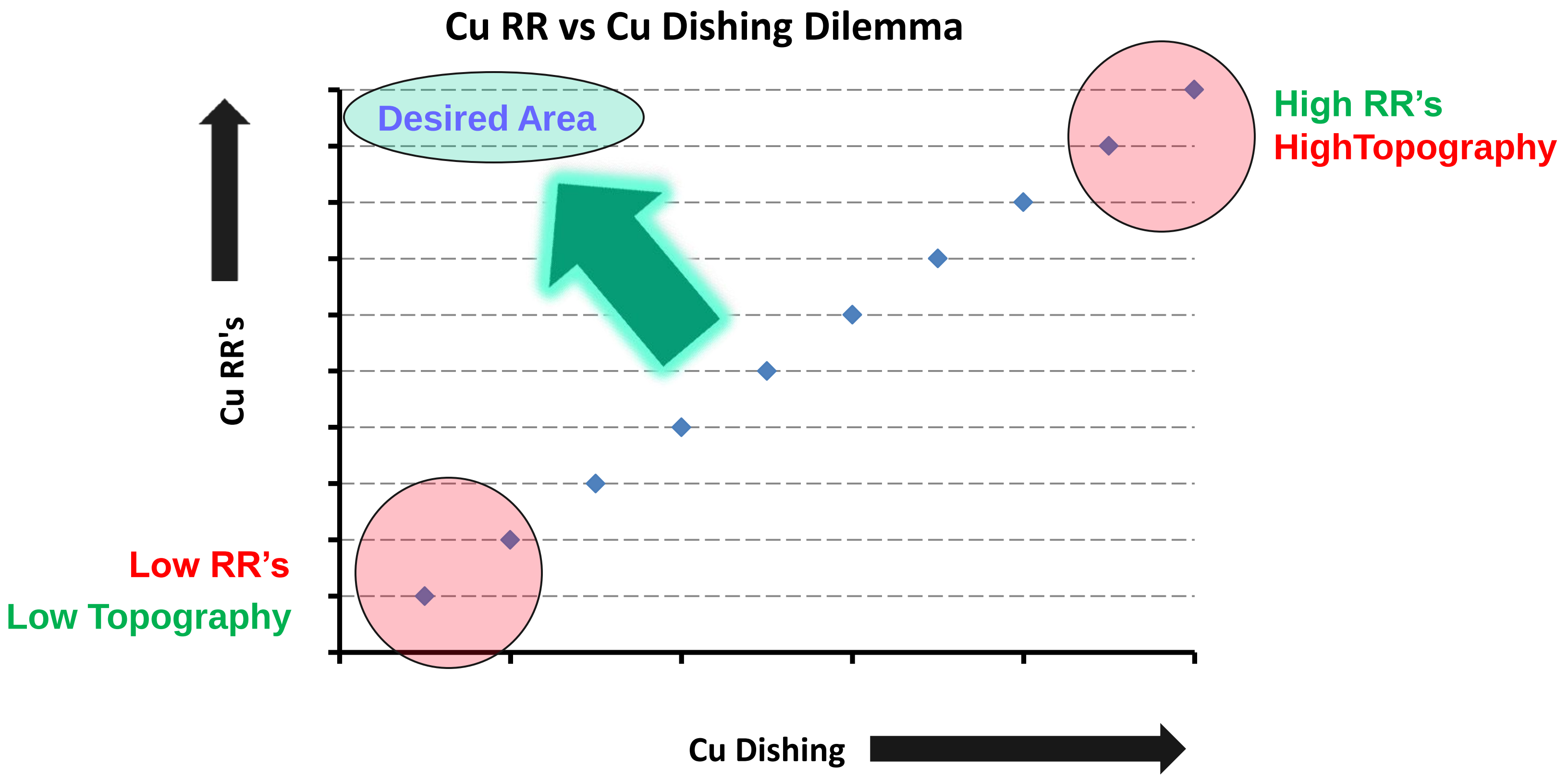
Outline

- Bulk Cu CMP evolution of challenges
  - Limitations of traditional bulk Cu CMP slurries
  - New material compatibility requirements
  - Increasing desire to use EHS friendly components

- Challenges associated with high RR, low topography bulk Cu CMP slurries
  - Non-Prestonian RR vs downforce performance
  - Cu residue, uniformity, and process window concerns

- The future of bulk Cu CMP

Limitations of traditional bulk Cu CMP Slurries

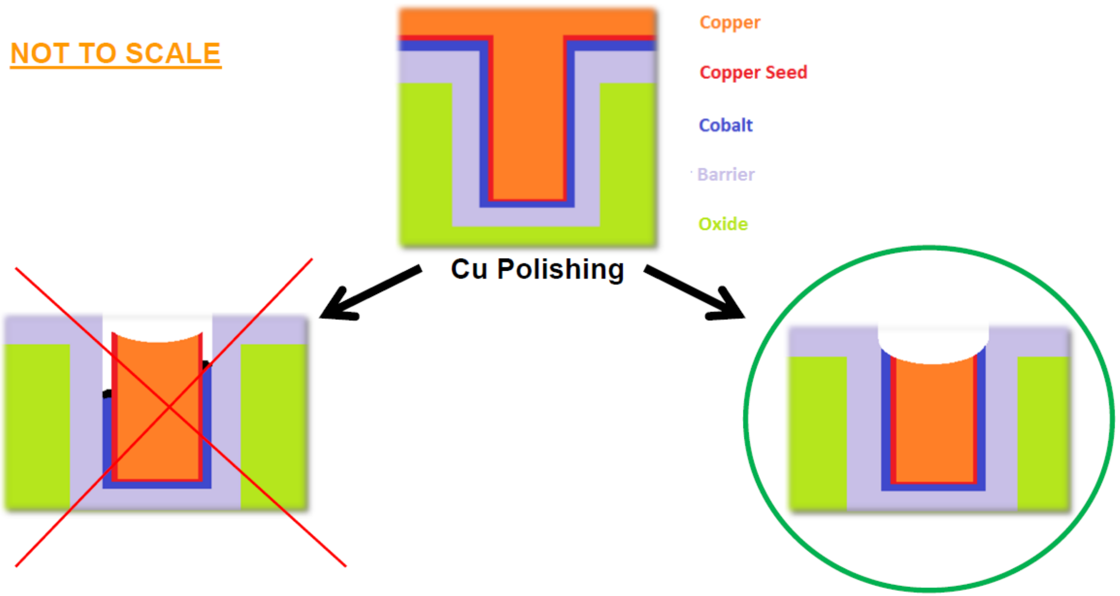


- Traditional Cu CMP slurries often constrained by RR vs dishing balance. Cannot have both high RR's and low topography simultaneously

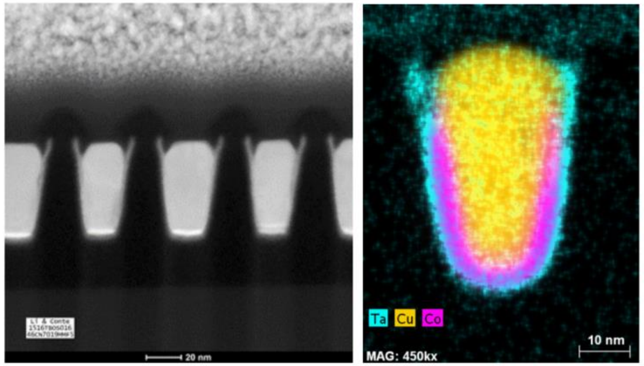
Material Compatibility and EHS Concerns

- As nodes become smaller and smaller, new materials have been incorporated or tested as alternatives to the traditional Cu/Ta/TaN stack
    - Examples include cobalt and ruthenium
- Traditional CMP slurries may not be compatible with these newer materials
    - With new stackings, new galvanic corrosion concerns may arise
    - Traditional slurry pH, components, etc. may be incompatible with new materials (e.g. acidic slurry with Co liner)
- Cu slurries utilizing nitrogen-rich compounds are facing increasing EHS scrutiny and pressure for safer alternatives

Material Compatibility Concern: Co compatibility



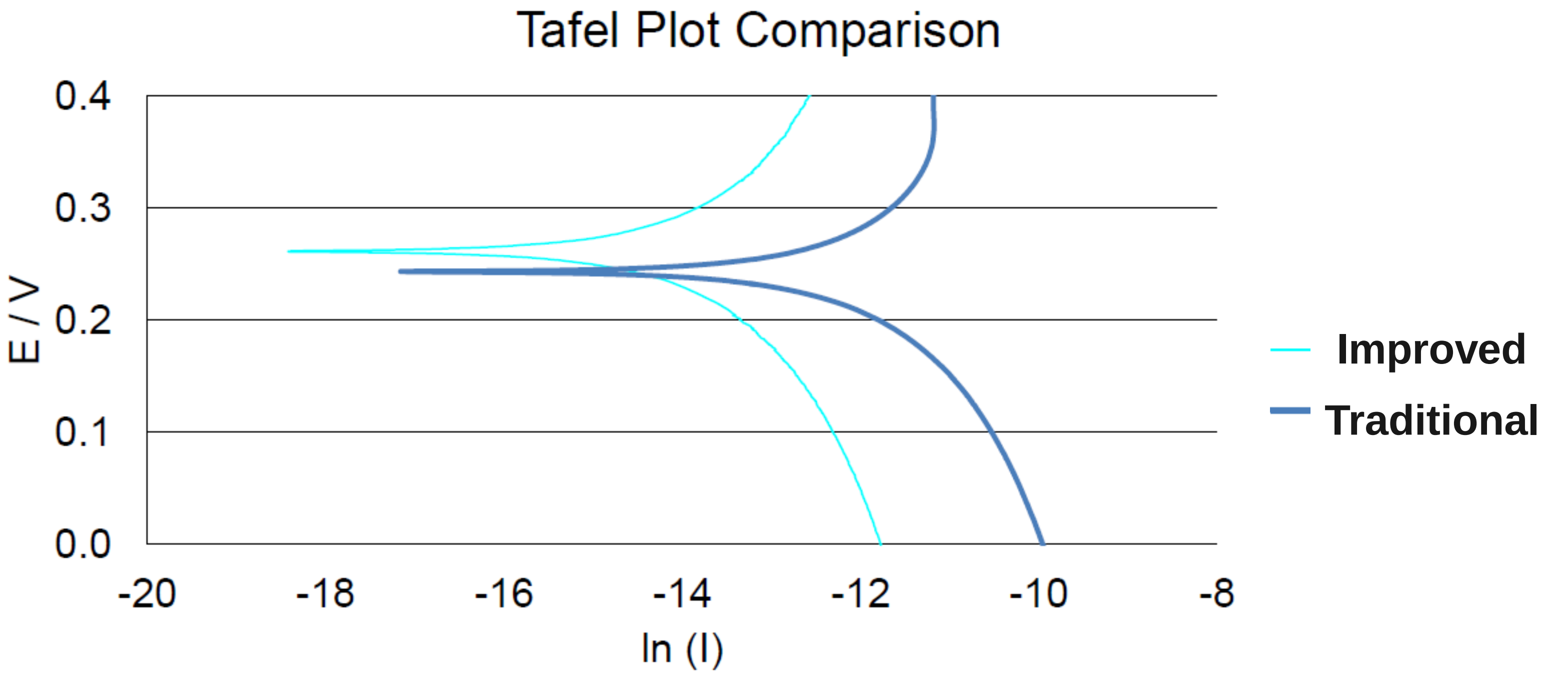
Co CMP Divot



T. Nogami IITC 2013 IBM

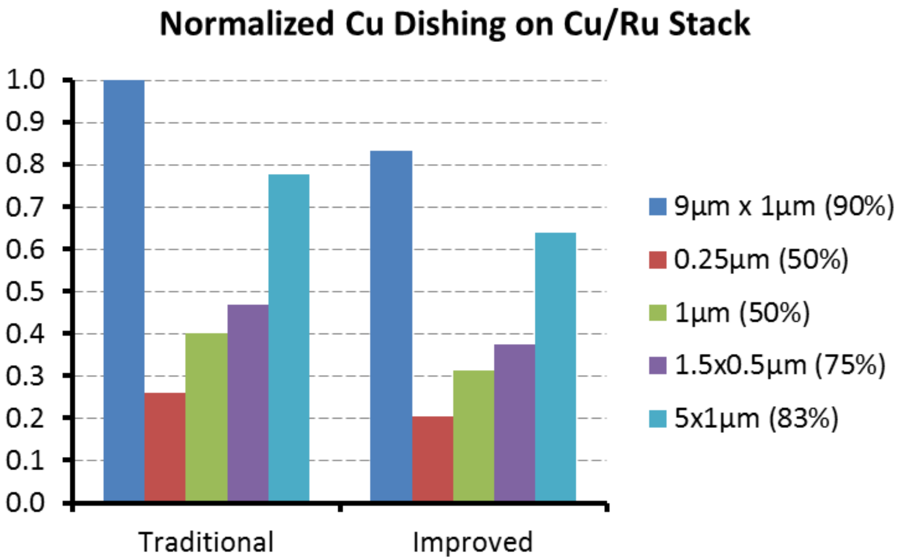
- Unlike Ta, Co does not self passivate during polishing and is largely at the mercy of the POU slurry properties

Material Compatibility Concern: Co compatibility



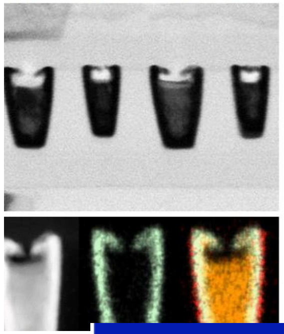
- Co Tafel plots shown for Traditional and Improved Cu slurries
- Improved version enhances Co compatibility 2-fold:
  - Thermodynamically: Raises Co E_{corr}
  - Kinetically: Reduces Co I_{corr}

Material Compatibility Concern: Ru compatibility



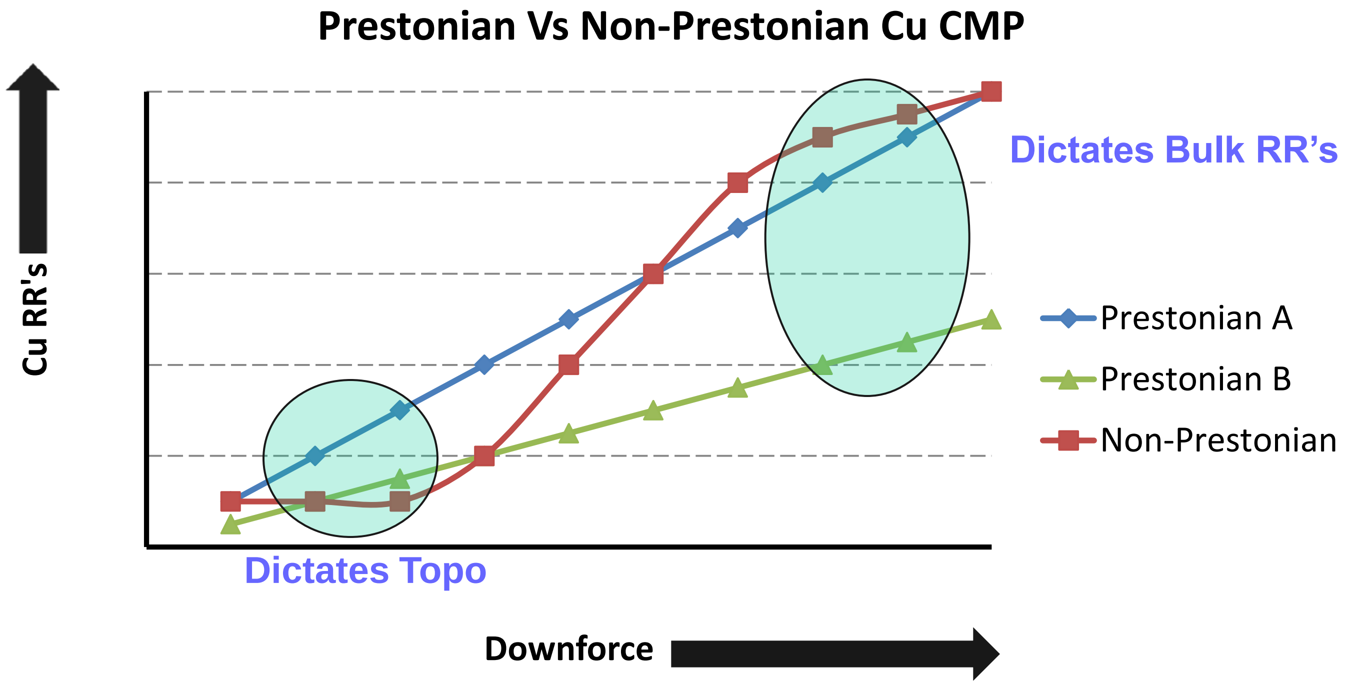
- Slurries which perform on Cu/Ta/TaN may not necessarily translate to Cu/Ru stacking
  - Galvanic corrosion a concern, a symptom of which is increased dishing
  - Thin Ru layers also at risk of mechanical destruction/delamination as Ru is consumed locally in galvanic corrosion spots

Ru CMP Cu-recess



R. Patlolla et al., ICPT 2015 IBM

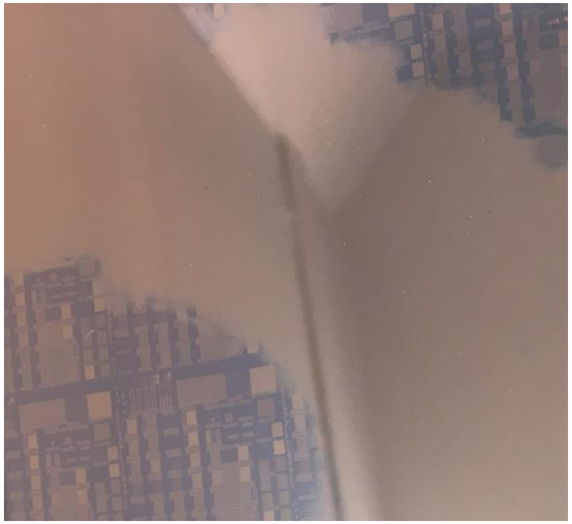
Prestonian vs Non-Prestonian Cu CMP

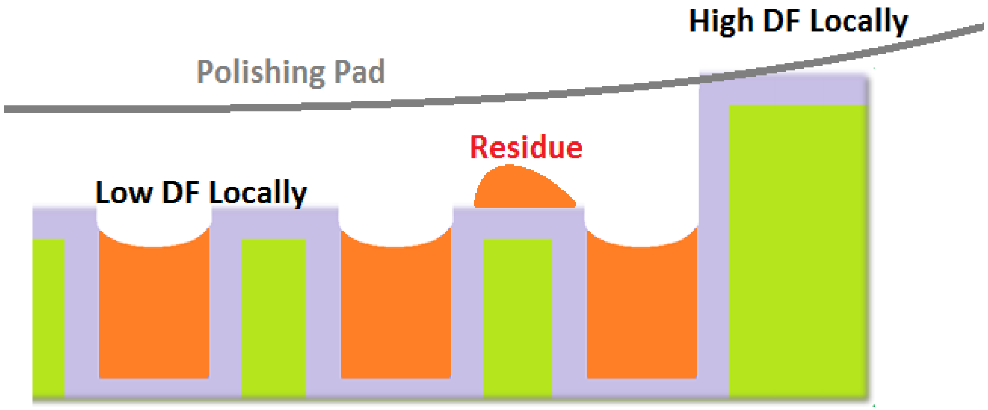


- Non-Prestonian behavior can simultaneously achieve:
  - High RR's of high topography Prestonian slurry A
  - Low topography of low RR Prestonian slurry B
  - This non-Prestonian slurry can be a single-platen slurry, as it serves the needs of P1 (high RR's) and P2 (low topography)

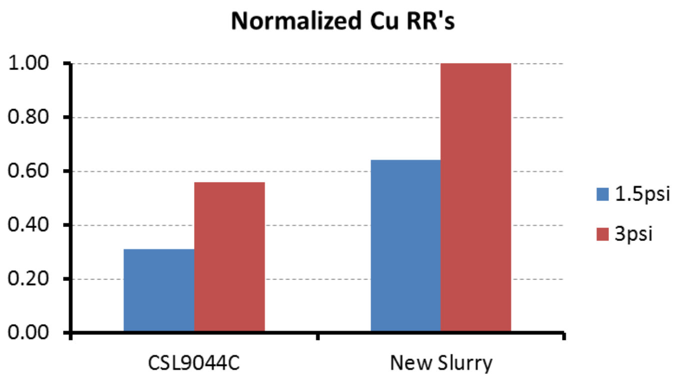
Prestonian vs Non-Prestonian Cu CMP

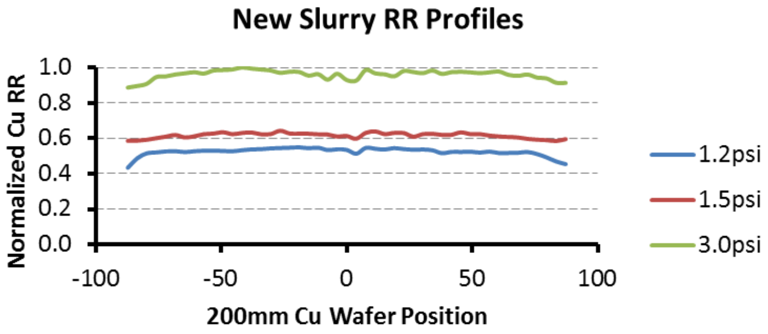
- Additive to slurry could protect Cu surface especially strongly at low DF
  - Attraction between additive and Cu surfaces >> Mechanical action from polishing
- Non-Prestonian behavior carries risks during polishing, particularly at low DF
  - Recessed areas such as dished Cu lines subjected to low DF (good)
    - Very low overpolish rate, low dishing
  - Cu residue spots may also be protected/passivated by additive (bad)

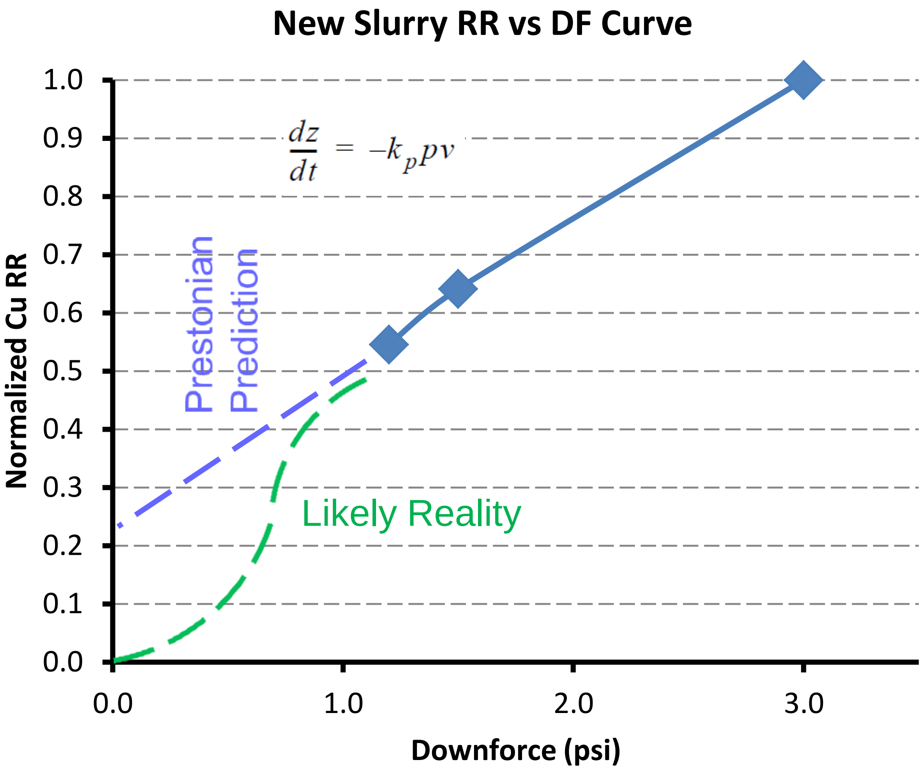




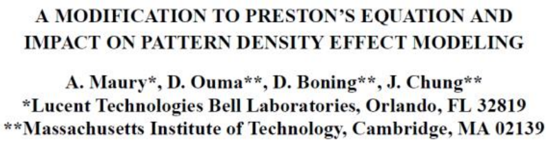
New High RR, Low Topography Bulk Cu Slurry







- Extrapolation of RR vs DF data would predict significant Cu RR at 0 psi
  - Reference to right describes why Preston's Eq may require correction to have Y intercept
- Empirical work with this slurry suggests Cu RR's → 0 A/min as DF → 0!



A MODIFICATION TO PRESTON'S EQUATION AND IMPACT ON PATTERN DENSITY EFFECT MODELING

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*Lucent Technologies Bell Laboratories, Orlando, FL 32819
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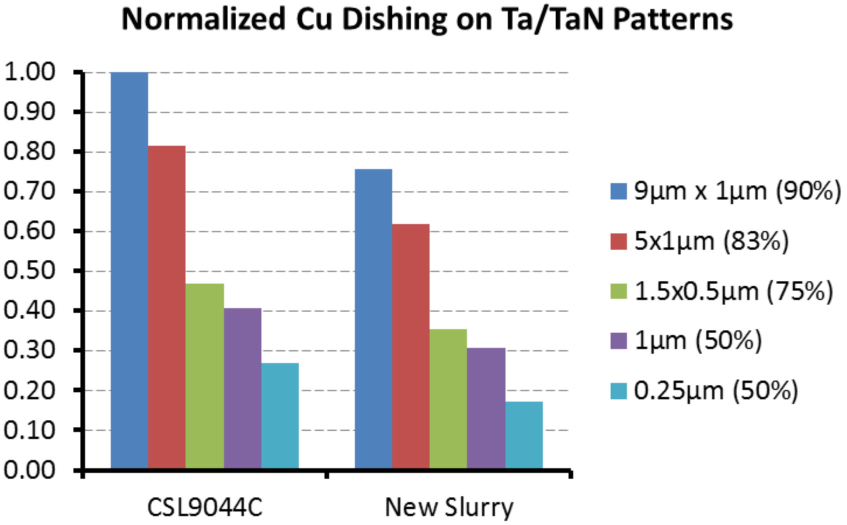
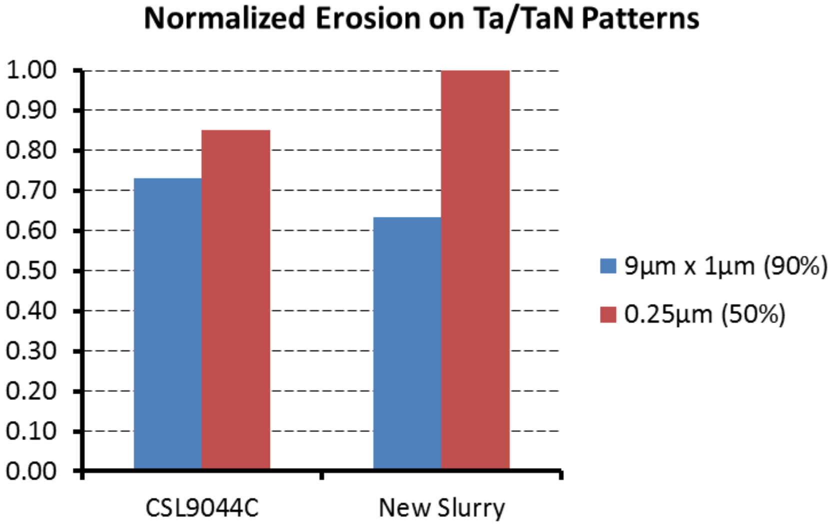
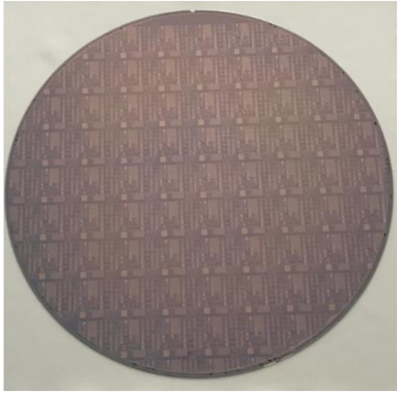
New High RR, Low Topography Bulk Cu Slurry

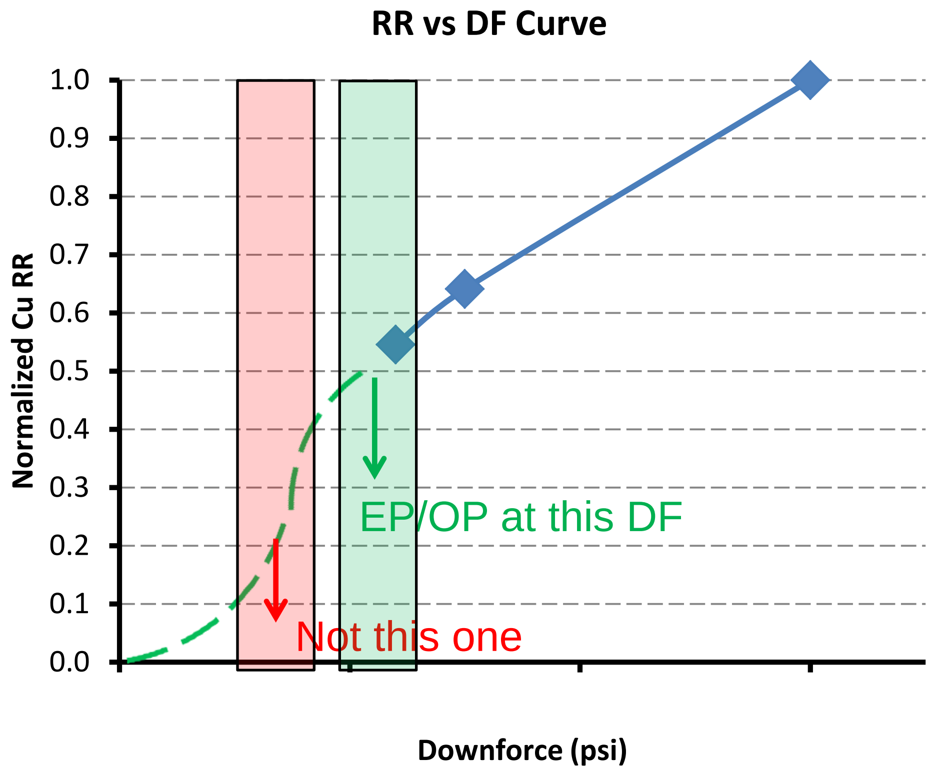

Normalized Cu Dishing on Ta/TaN Patterns


Normalized Erosion on Ta/TaN Patterns

- Due to very low RR's at low DF in dished Cu lines, dishing can remain low despite high Cu bulk/high DF RR's
- 10s OP leaves no Cu residue with this Non-Prestonian slurry



Process Windows of High RR, Low Topo Cu CMP



- Clearing Cu at a downforce in steep RR vs DF slope area risks Cu residue

Significant factors with Non-Prestonian slurry:

- Pad type and grooving
- Platen/head RPMs
- Slurry flow rate
- Downforce
- Sensitivity of slurry to these factors could be higher than traditional slurry!

However, there are advantages…

- OP rates extremely low, so extra OP time to clear away Cu residue will not increase Cu line dishing
- Planarization efficiency could be improved, as features at highest Z are exposed to highest DF/RR’s, low Z protected strongly
- Higher RR’s, faster clearing, less exposure time for sensitive materials such as Co and Ru

Future of Bulk Cu CMP

- Advanced nodes
  - High RR's not necessarily a key driving force
  - Compatibility with new materials critical
  - Topography requirements increasingly stringent
  - Defectivity improvements, especially scratch performance, particularly critical
  - EHS component/slurry concerns may prohibit evaluation

- Legacy nodes
  - Cost, cost, cost! Reduce slurry usage and maximize yield.
    - Increased dilutability
    - Increased RR's without topography sacrifice
    - Revised formulations to decrease cost
    - Reduced defectivity to increase yields
  - EHS unfriendly formulations which may have been grandfathered in as companies tightened EHS restrictions risk being replaced by safe alternatives

http://www.motherjones.com/kevin-drum/2016/04/donald-trump-skinflint

Summary

- New nodes bring new challenges
  - New material compatibilities required
  - More narrow tolerances for scratching, topography, RR fluctuations, etc.

- Push from fabs and foundries toward EHS friendly components

- Achieving low topography while avoiding Cu residue critical

- Performance drivers at advanced nodes, cost drivers at legacy nodes

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