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

James McDonough, Ph.D.
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• 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

- 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 $E_{\text{corr}}$
  - Kinetically: Reduces Co $I_{\text{corr}}$
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
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!
• 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

Normalized Cu RR vs DF Curve

- 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