

Cu Cleaning Mechanisms: Will an Undercut and Lift-Off Mechanism Continue to Dominate?

by

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The answer is:

NO!



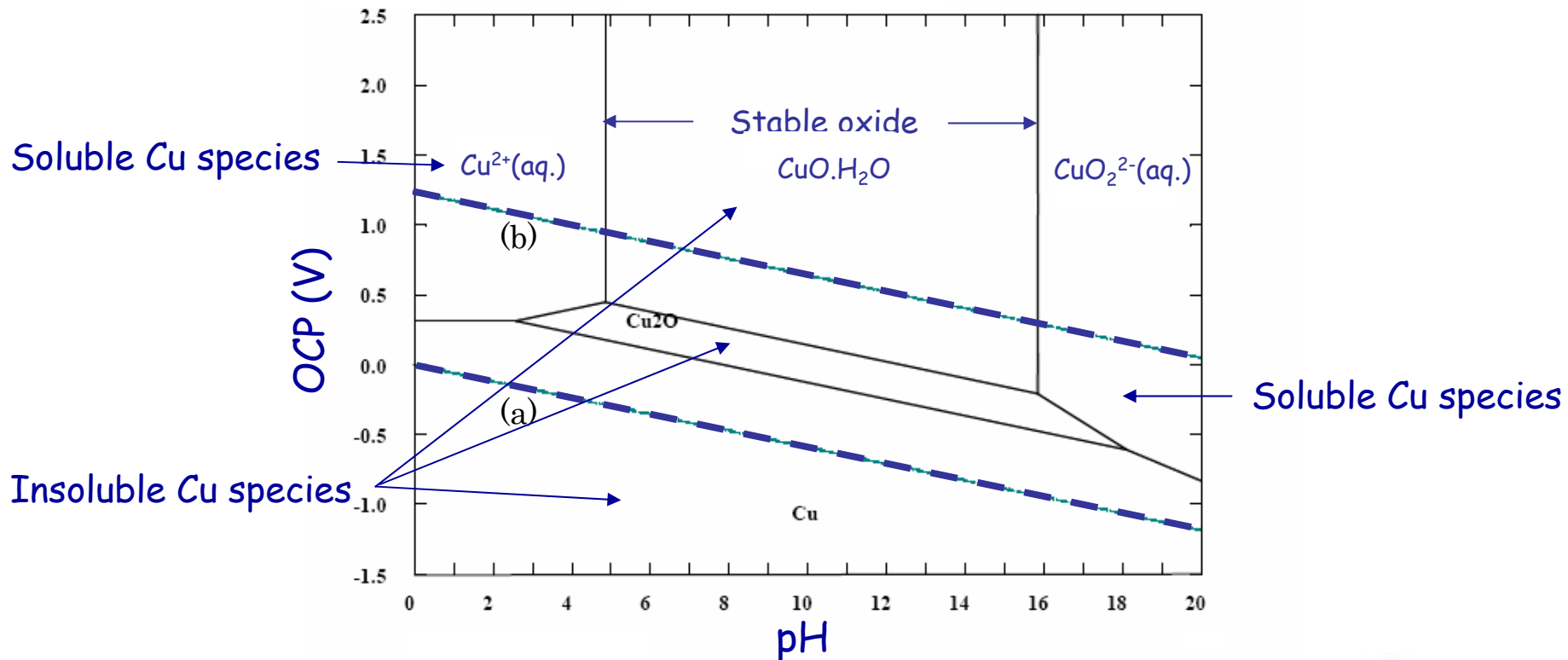
Outline

- Introduction
 - Cu Pourbaix diagram
 - Typical Cu post-CMP cleaner composition
- Cu post-CMP cleaning mechanisms
 - Undercut and lift-off
 - Non-selective
 - Selective
 - Etching
 - Dissolution
 - Conversion
 - Displacement
- Summary



Stability of Cu Species

Pourbaix Diagram for Cu



Pourbaix diagrams only apply for aqueous formulations



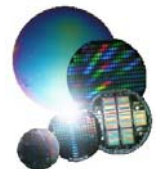
Typical Post-CMP Cu Cleaner

- Diluted with DI water at time of use
- Composition
 - Water, Cu complexing agent, water miscible organic solvent, pH adjuster; optional corrosion inhibitor and/or open circuit potential (OCP) adjuster
 - Use pH and OCP to control Cu etch rate, Cu oxide removal selectivity, and particle removal efficiency



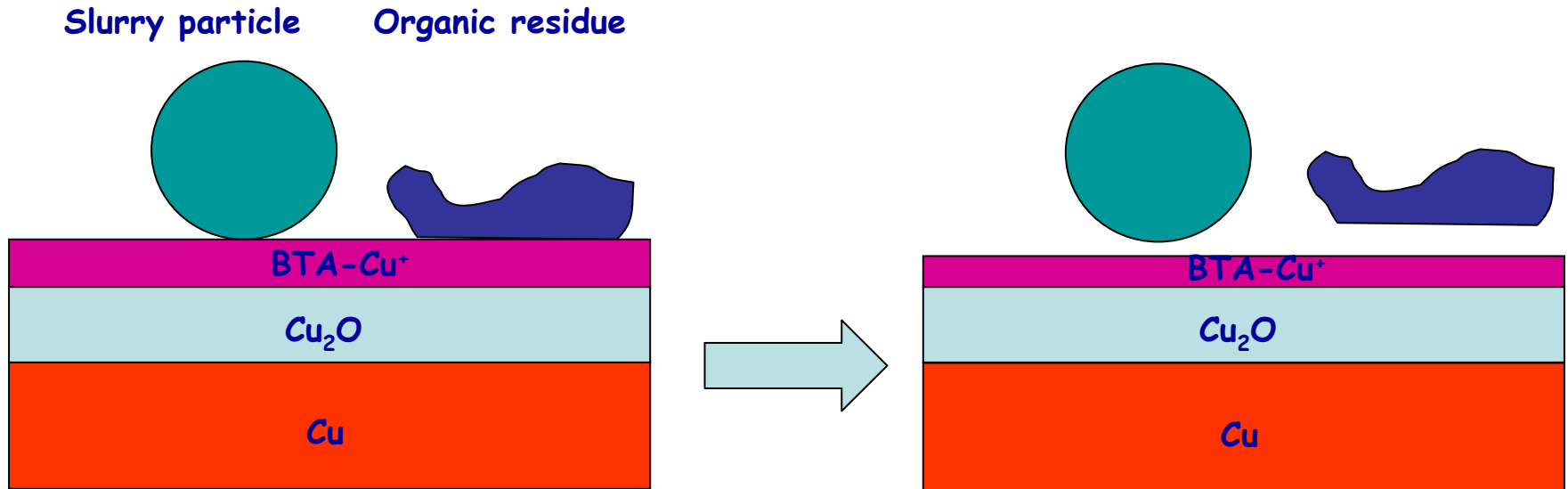
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Cleaning Mechanisms

Undercut and lift-off (non-selective)



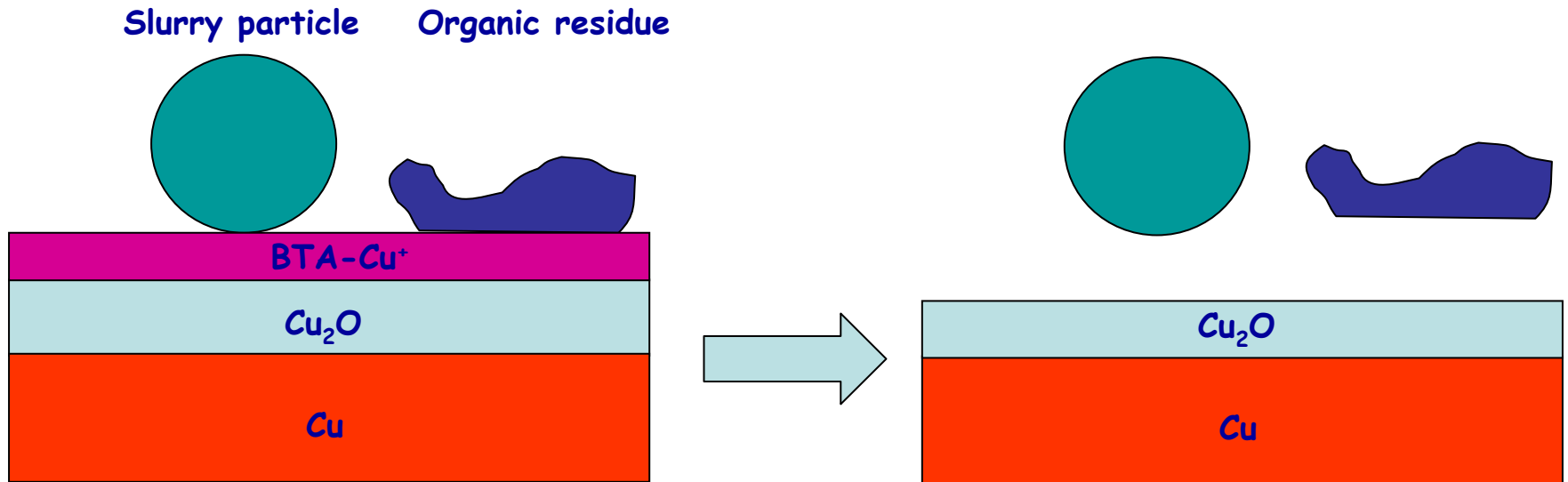
Typical products (acidic): CP-70/72

Citrate solutions do not remove BTA; hence the Cu surface is hydrophobic and prone to watermarks



Cleaning Mechanisms

Undercut and lift-off (selective)



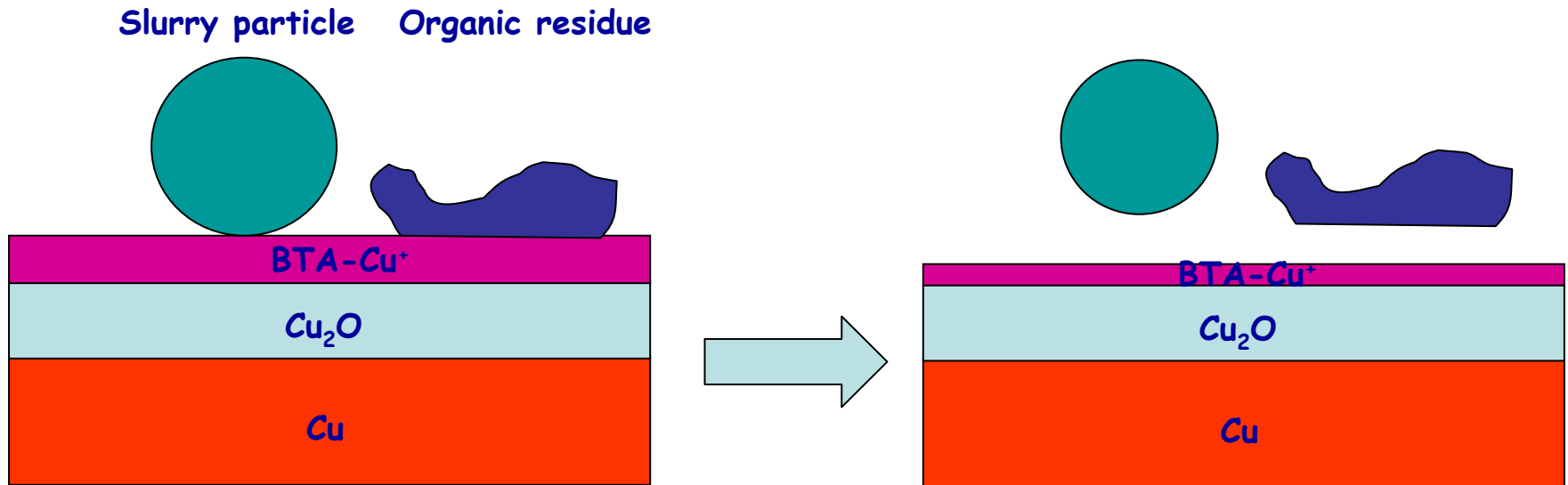
Typical products (basic): ESC774/784/797, Orion-1

BTA is removed and cuprous oxide protects Cu from corrosion, easing wafer staging requirements



Cleaning Mechanisms

Undercut and lift-off (etching)



Typical product (acidic): Electroclean (EC)

Citrate solutions do not remove BTA, HF etches silica, Cu surface is hydrophobic due to presence of BTA and prone to watermarks



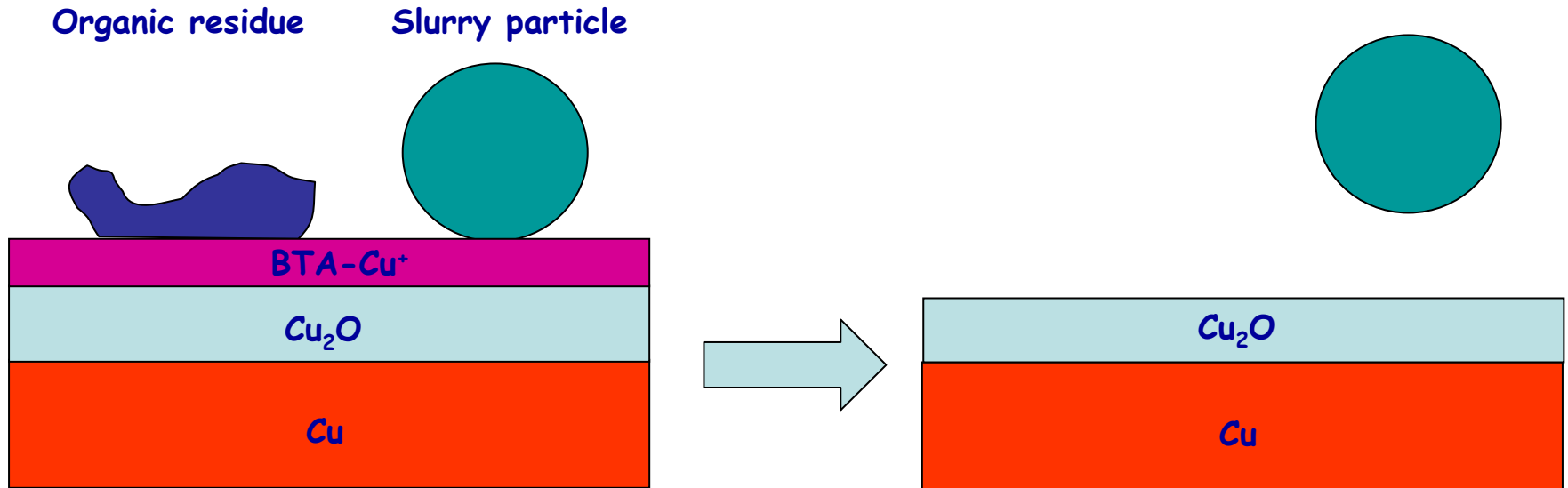
Undercut Cleaning

- A large number of post-CMP cleaners use an undercut and lift-off cleaning mechanism
 - They range from total removal of Cu oxides to selective removal of cupric oxide or BTA
- Some post-CMP cleaners contain HF to etch silica particles and aid in their release
 - Most substrates are damaged by HF
 - The wafer surface is hydrophobic due to fluoride termination on dielectric and residual BTA on Cu
 - Results in water marks
 - Surfactants cause damage to low-k dielectrics



Cleaning Mechanisms

Dissolution



Typical products (basic): ESC774/784/797, Orion-1

Products contain organic solvents to dissolve organic residues, cuprous oxide protects Cu from corrosion



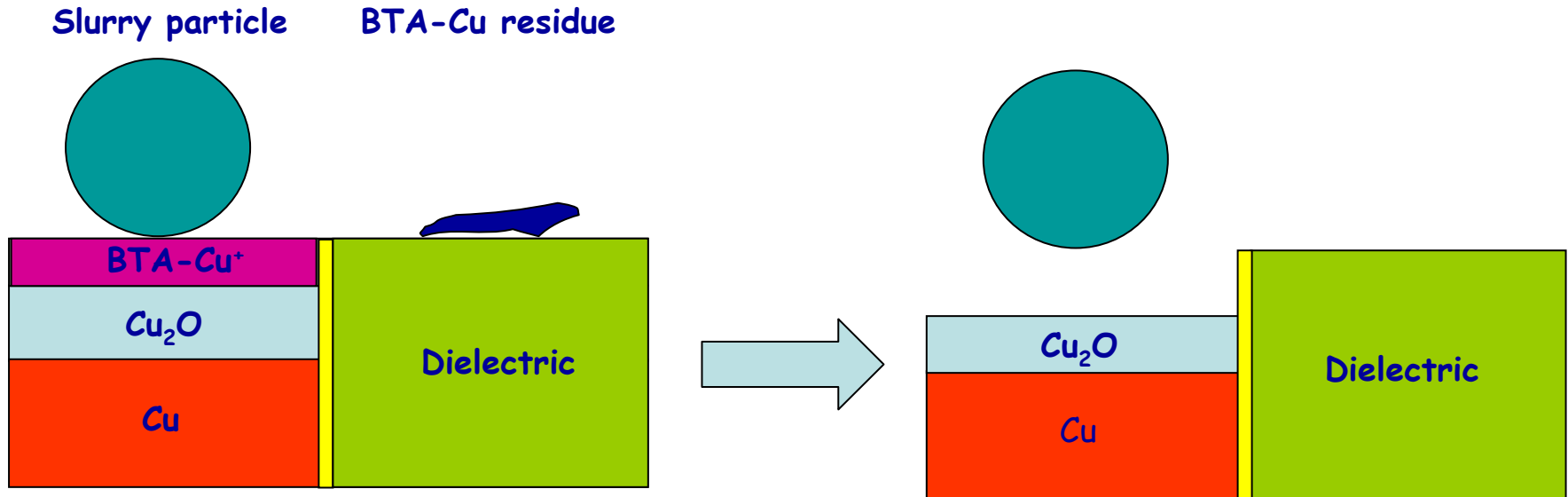
Dissolution Cleaning

- Newer post-CMP cleaners contain water miscible organic solvents to dissolve organic contaminants
- There are many water miscible organic solvents to choose from
 - Alkanolamines, amides, etc



Cleaning Mechanisms

Conversion



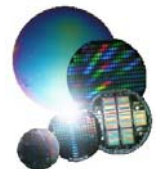
Typical products (basic): ESC774/784/797, Orion-1

Water insoluble residue is converted to a water soluble complex



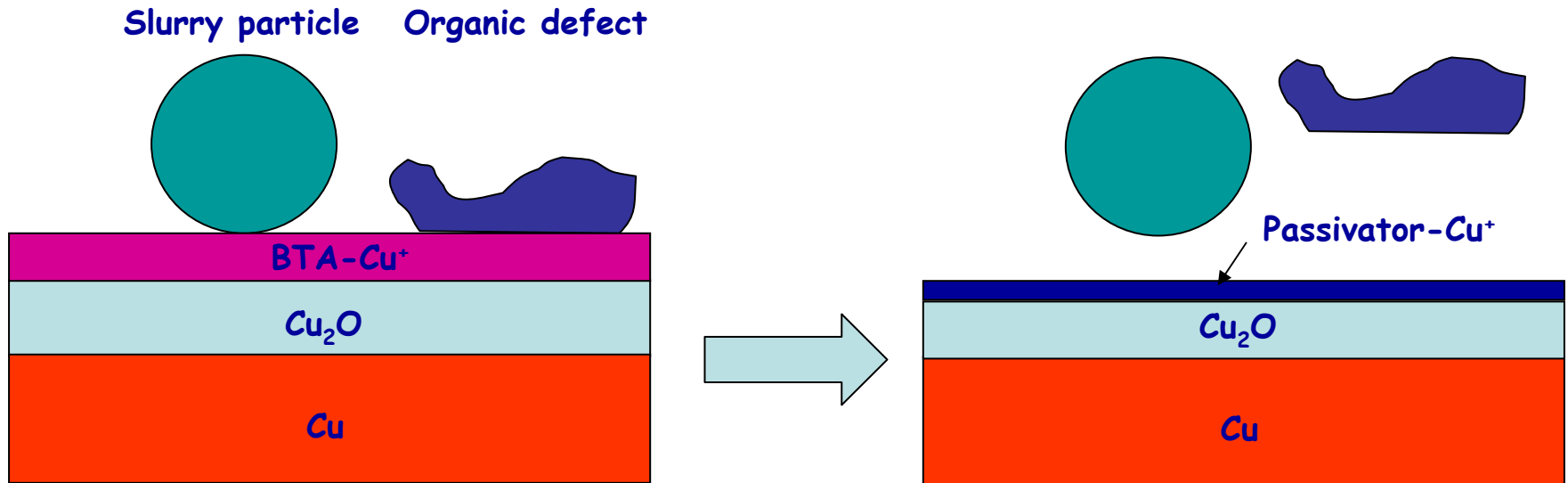
Conversion Cleaning

- Newer post-CMP cleaners contain complexing agents that form water soluble Cu complexes
 - Aids removal of Cu ions on dielectric
 - Can result in an improvement in TDDB
 - Aids in selective dissolution of oxide



Cleaning Mechanisms

Displacement



Typical product (basic): SP-28

Passivator protects Cu from corrosion, yields a hydrophilic surface to prevent water marks

Ref.: D. Peters, et al, "Displacement Cleaning: A New Mechanism for Copper Post-CMP Cleaning", Pac Rim-CMP 2005; D. Peters, "Cu Post-CMP Displacement Cleaning: A Mechanistic Product Development Approach Based on Selected Thermodynamic and Kinetic Data", MRS (2007).



Displacement Cleaning

- Fast cleaning method
- No etching of substrate
- Leaves exposed Cu protected
 - Relaxes queuing requirements after clean
- Results in lowest organic defect counts
- Effective for low or high pH slurries
- Results in low Cu surface roughness
- Eliminates water marks on Cu



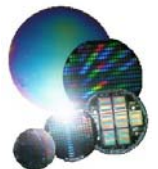
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Summary

- Post-CMP wet cleans are here to stay
 - They yield the highest particle removal efficiency of any technique to date
- It is not necessary to match the pH of the cleaner with the pH of the slurry
- Undercut and lift-off cleaning will likely not be acceptable on technology nodes below 65nm



Summary

- Relaxing wafer staging constraints can lower the process cost of ownership
 - Throughput requirements are relaxed
- Cu post-CMP cleaners which utilize displacement cleaning are presently used in IC manufacture for 65nm technology



Thank you very
much for your
attention!

