

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

by

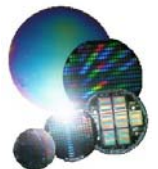
Darryl W. Peters, Ph. D.  
Paragon Consultants, LLC  
111 Kennedy Mill Road  
Stewartsville, NJ 08886  
484-515-7186

[paragonc@gmail.com](mailto:paragonc@gmail.com)



The answer is:

NO!



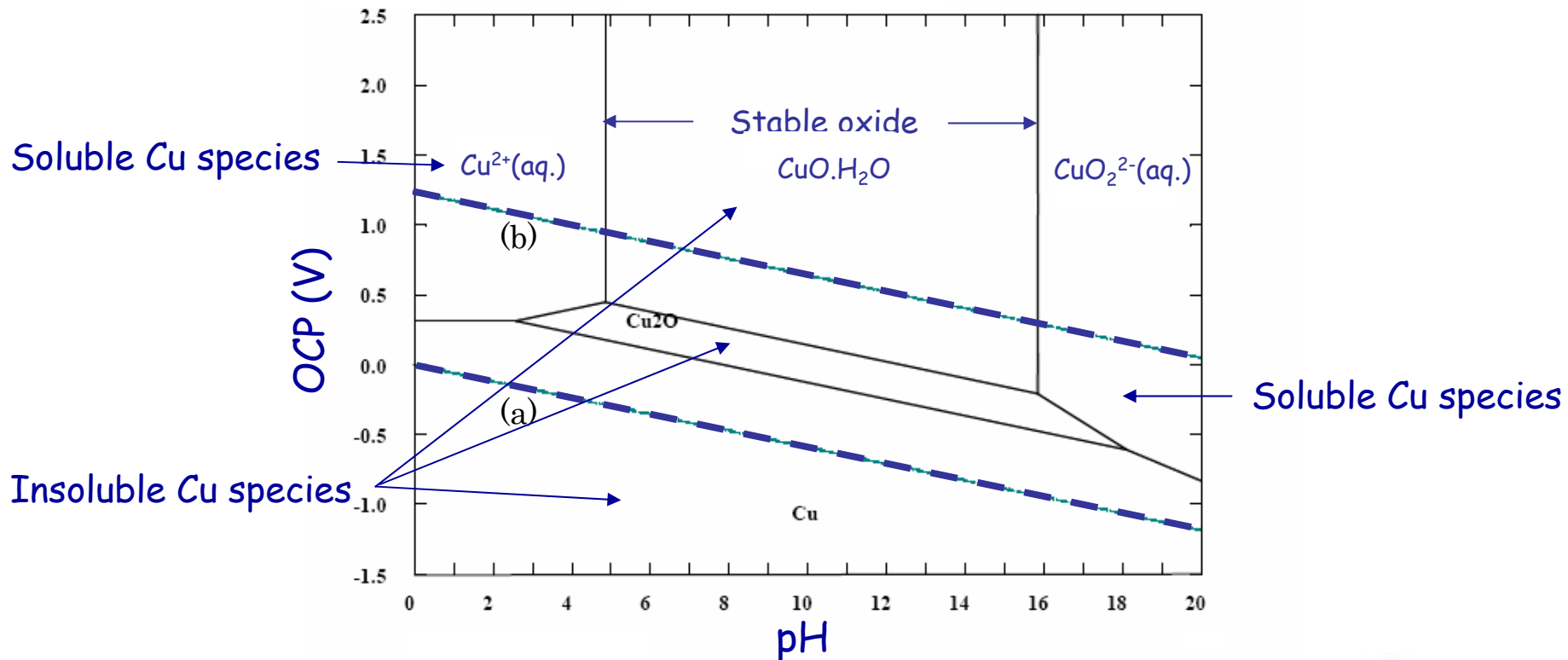
# Outline

- 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



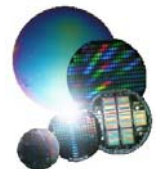
# Typical Post-CMP Cu Cleaner

- 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



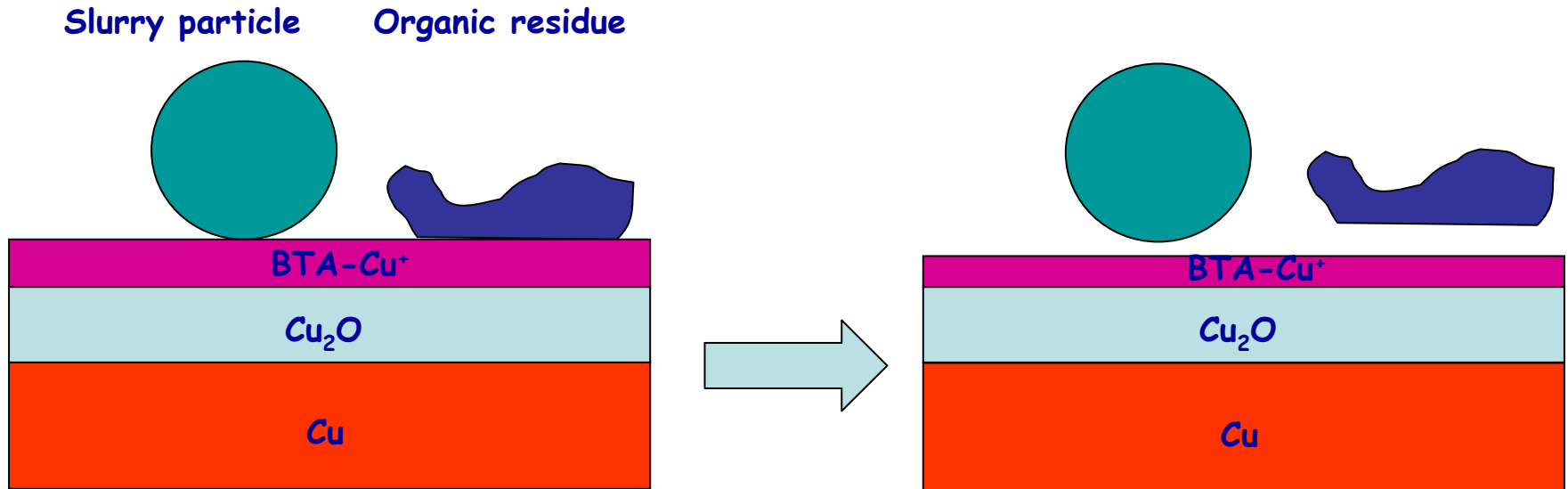
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# Cleaning Mechanisms

Undercut and lift-off (non-selective)



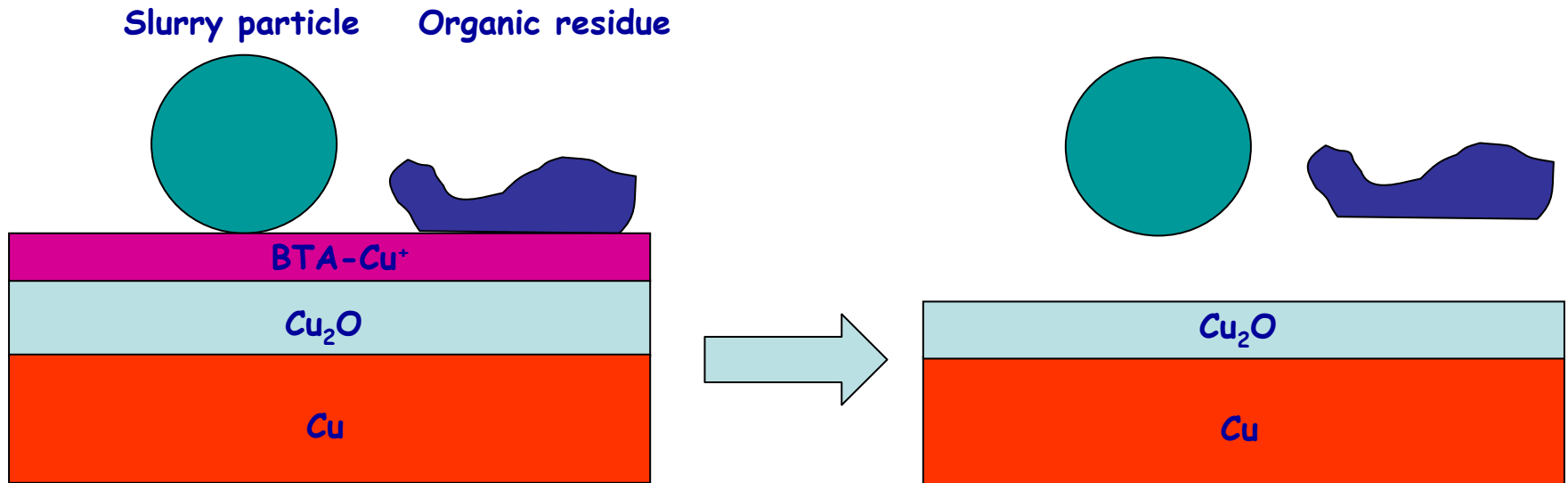
Typical products (acidic): CP-70/72

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

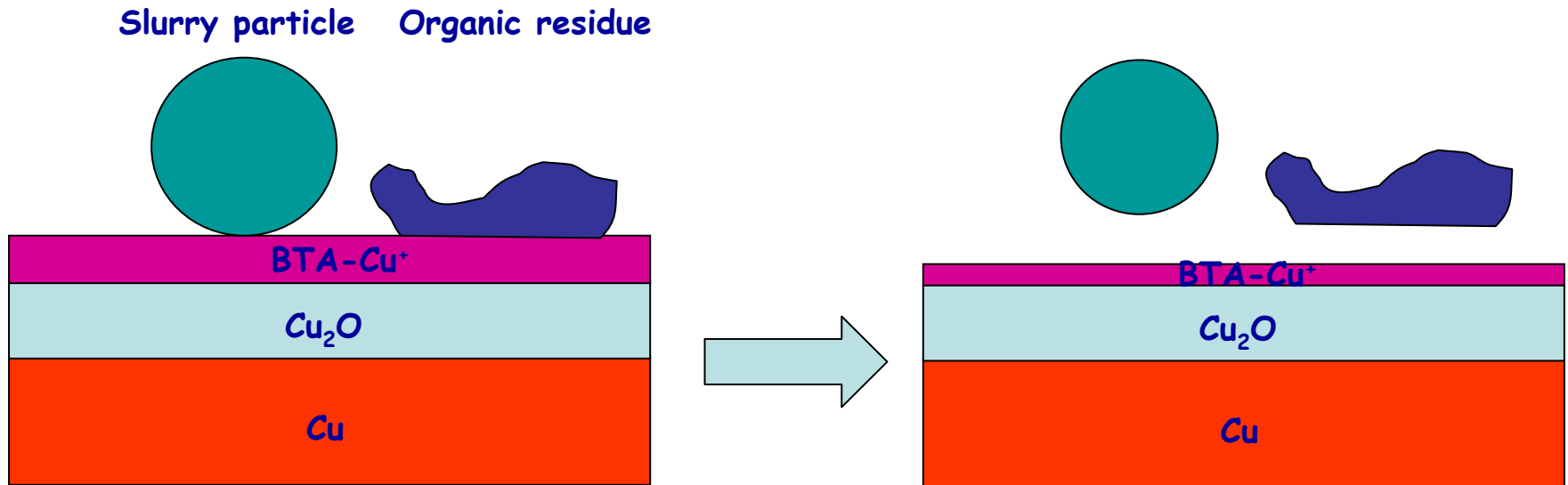
BTA is removed and cuprous oxide protects Cu from corrosion, easing wafer staging requirements





# 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



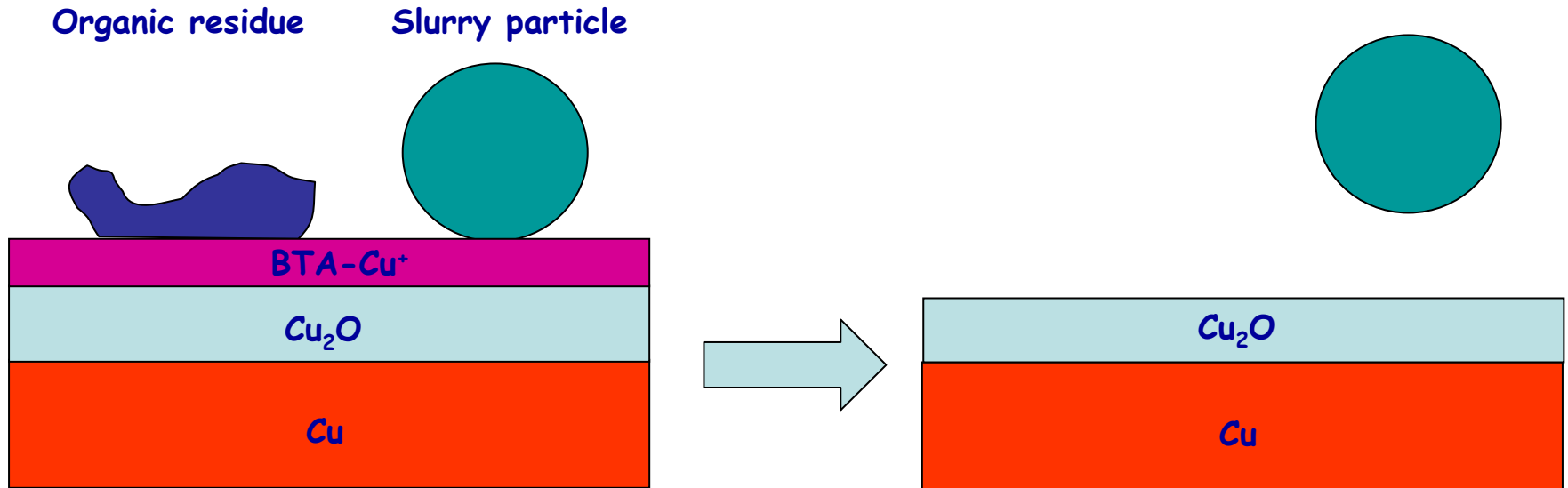
# Undercut Cleaning

- 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



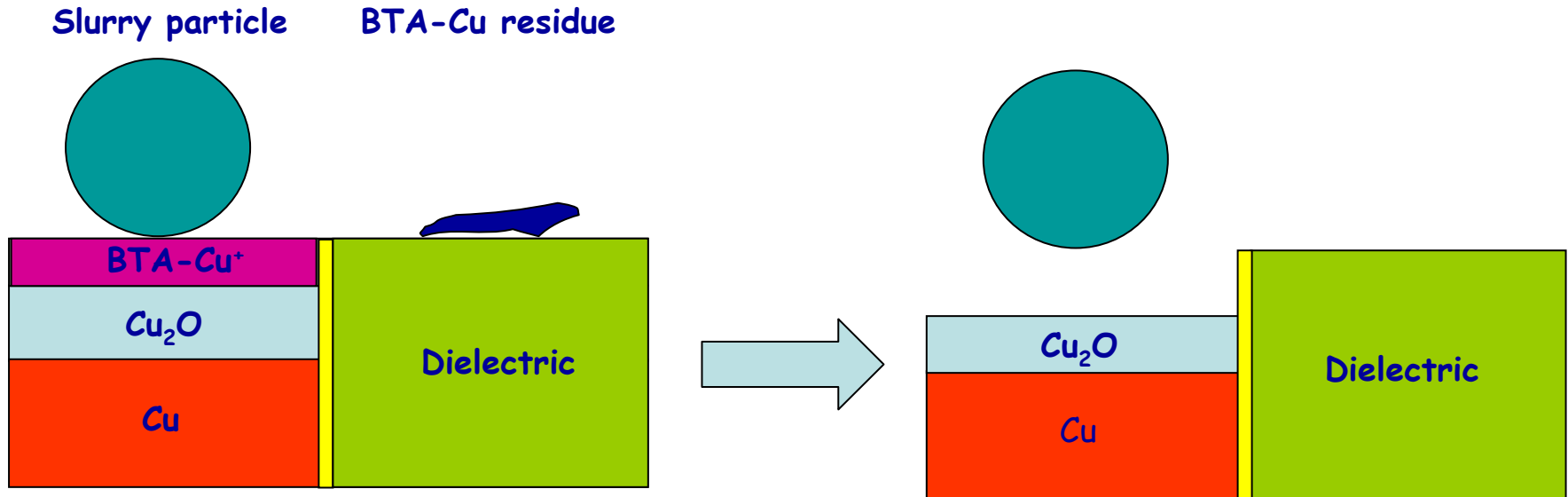
# Dissolution Cleaning

- 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



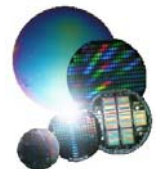
Typical products (basic): ESC774/784/797, Orion-1

Water insoluble residue is converted to a water soluble complex



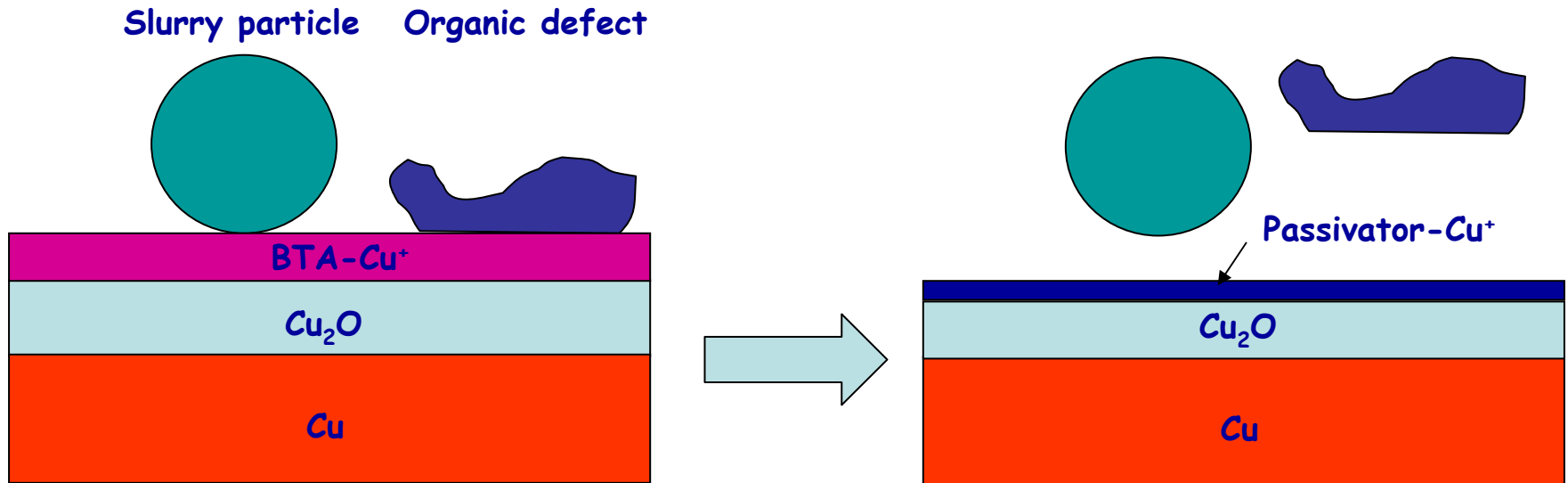
# Conversion Cleaning

- 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!

