# "How You Polish Determines How You Clean": The Need for Holistic Approach to Post CMP Clean"

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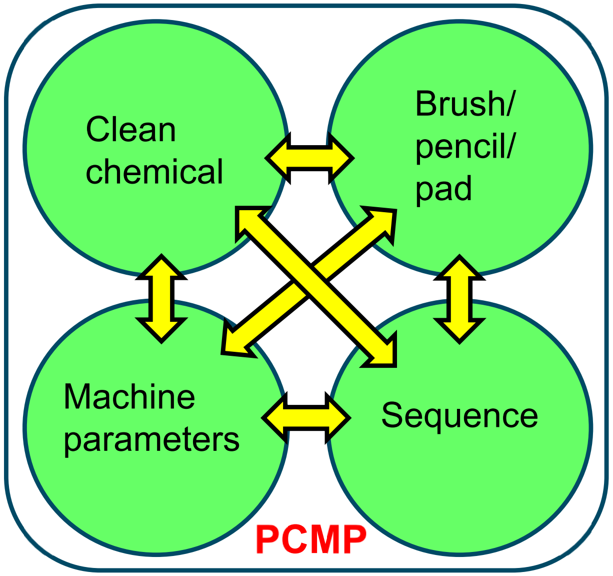
2024 CMPUG Symposium on Advances in CMP and Post-CMP Cleans:
***CMP + P-CMP Cleans: The Marriage, The Challenges, The Future***
Dec. 4 ~ 5, 2024

# The conventional views of post CMP cleaning…



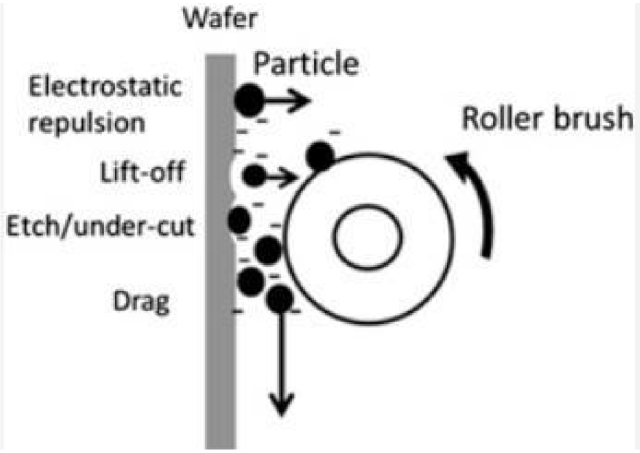
Clean chemical

Brush/ pencil/ pad

Machine parameters

Sequence

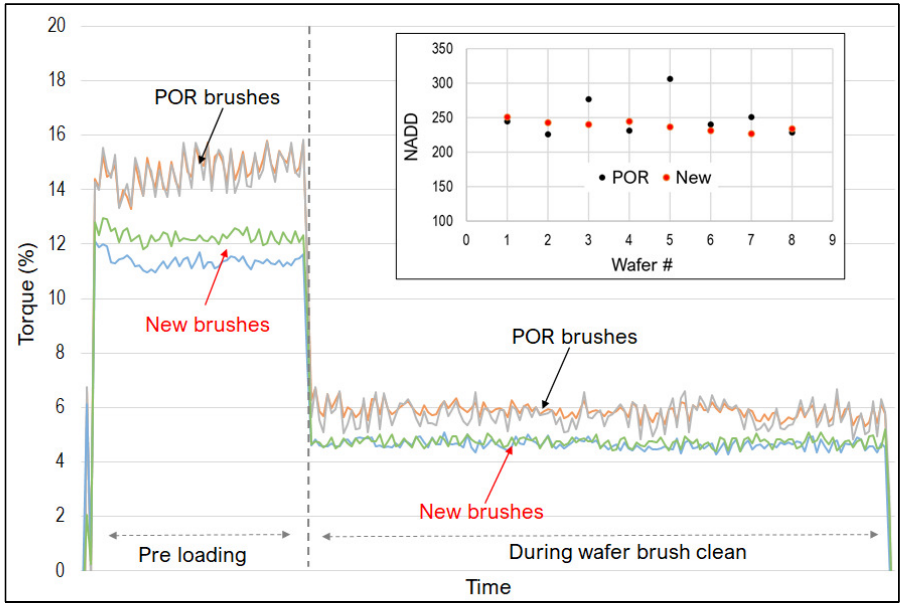
**PCMP**



Y. Chen *et al.*, *Chap 5, Handbook of Silicon Wafer Cleaning Technology, 3rd Ed.*, pp. 253~301 (2018)

- Chemical forces to break bonds/weaken absorption and frictional force to dislodge & remove particles.
- Surfactant/additive to prevent re-dep; corrosion inhibitor to passivate metal surface.
- Increasing # of cleaning steps (pre-clean + up to 3 brush/pencil stations).

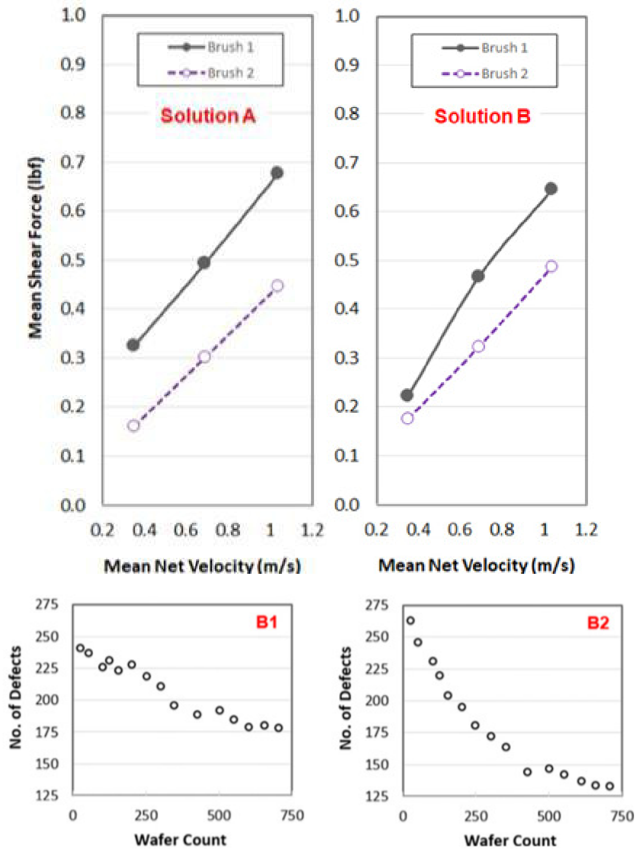
# Post CMP cleaning: complicated nature that is not well understood yet



W.-T. Tseng, *ASMC* 2021

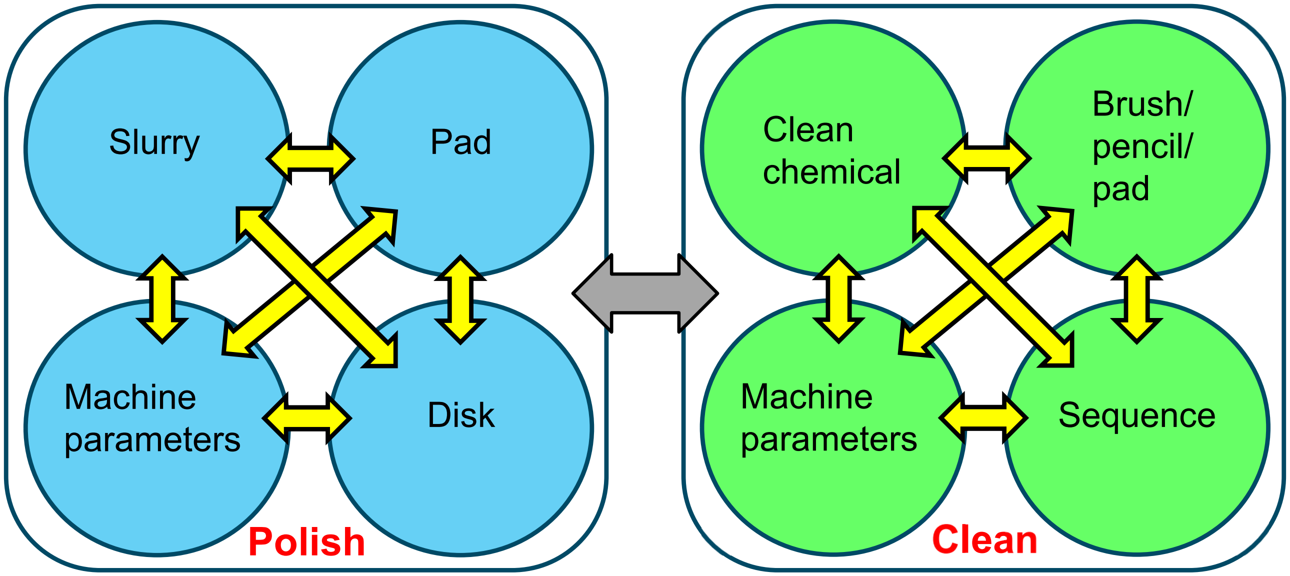
- Clear interactions between clean chemical and brushes → each clean chemical and brush type seems to exhibit its own characteristic torques and mean shear force footprints.

☞ *How can we exploit such signals to improve clean efficiency?*



Y. Sampurno *et al.*, *ECS J. Solid State Sci. Technol.* 10, 064011 (2021)

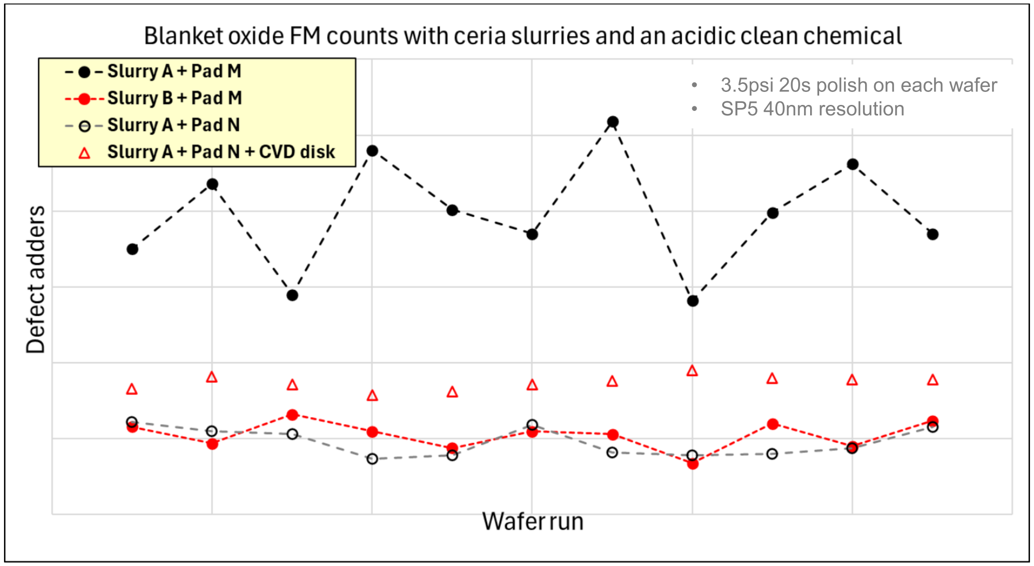
# The interplay between polish and post clean...



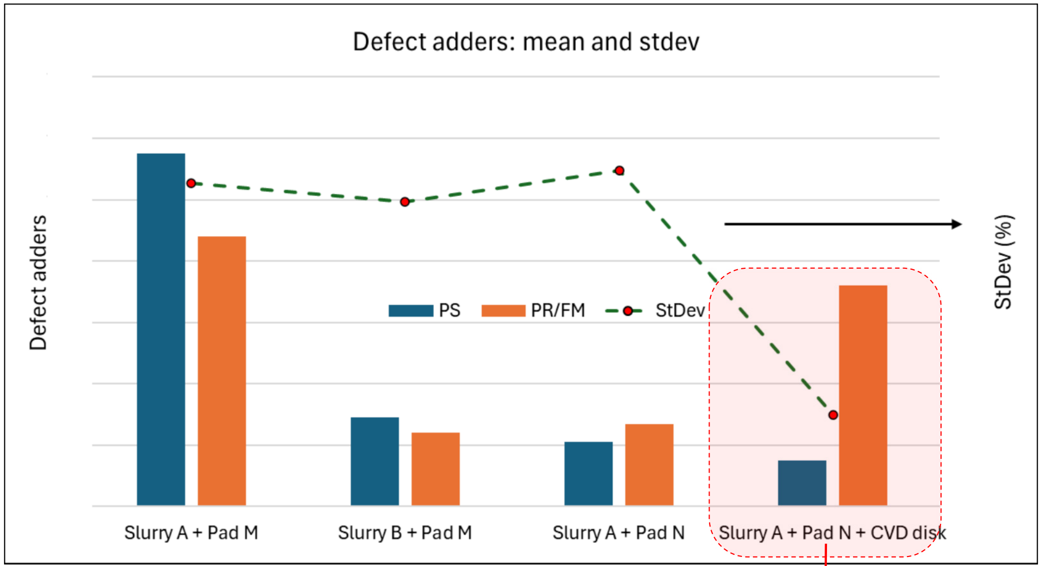
Is there any problem with the following statements?

- *Oxide RR of slurry A is higher than that of slurry B.*
- *Pad C shows higher planarization efficiency than pad D.*
- *Chemical E exhibits higher particle removal efficiency than chemical F.*

# Interactions among slurries, pads, and disk…


Blanket oxide FM counts with ceria slurries and an acidic clean chemical

- 3.5psi 20s polish on each wafer
- SP5 40nm resolution

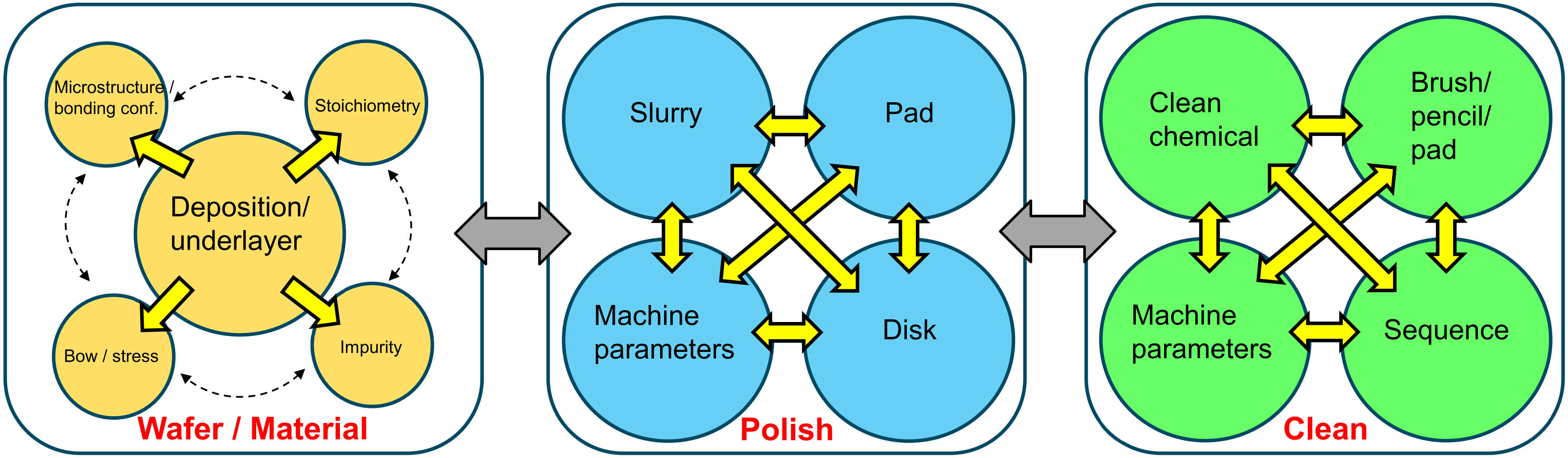

Defect adders: mean and stdev

- 12% higher RR.
- Higher PR/FM but more consistent performance.

- Without modifying anything in the post clean modules, defects can be reduced by changing the slurry or pad alone.
- *And let's NOT ignore the potential role of conditioner…!*

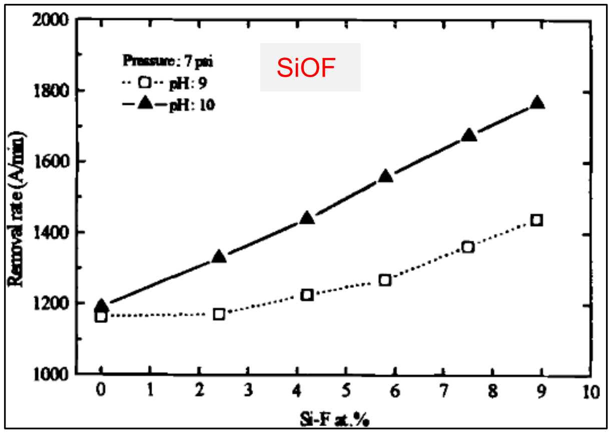
**Are we still missing something???** 🤔

# The reality: comprehensive view of CMP



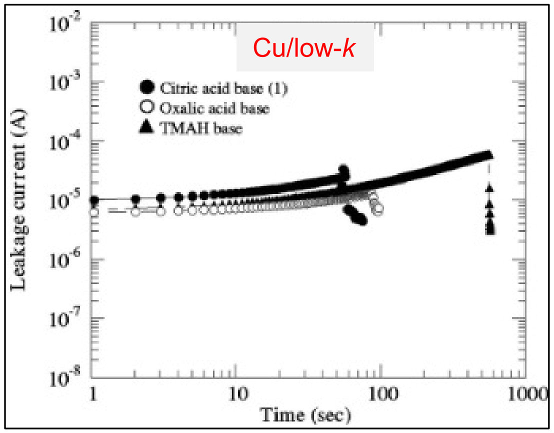
➔ Incoming materials matter, and they matter A LOT!

# Interactions between wafer material and CMP



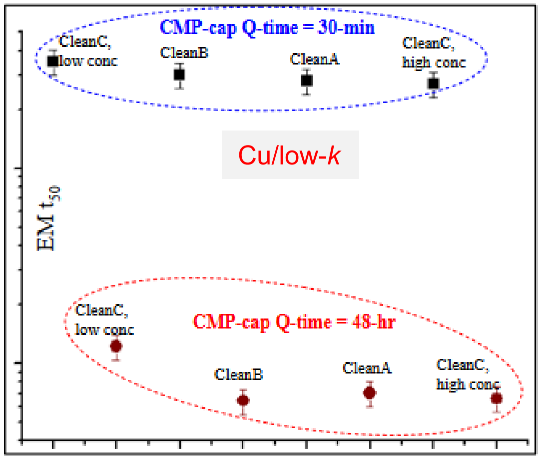
SiOF

W.-T. Tseng *et al*., *J. Electrochem. Soc.*, 144, 1100-1106 (1997)



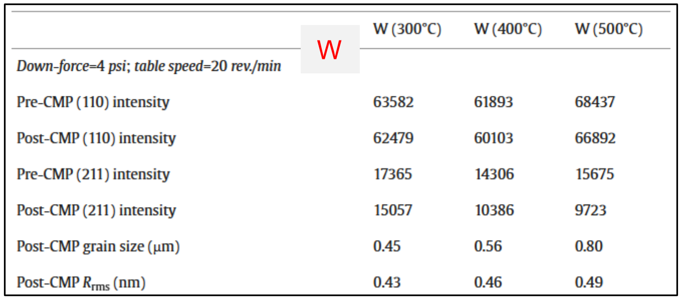
Cu/low-*k*

Y. Yamada *et al*., *J. Electrochem. Soc.* **155, H485-H490** (2008)



Cu/low-*k*

W.-T. Tseng *et al*.., *Proc. ASMC* pp. 57-62 (2012).



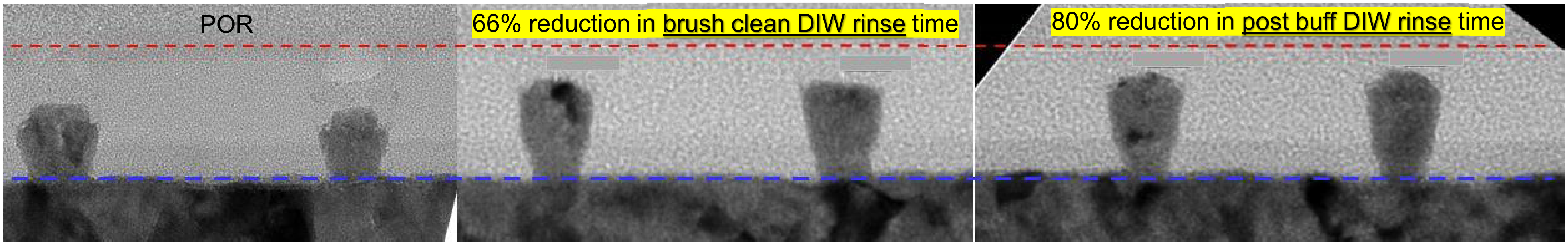
W

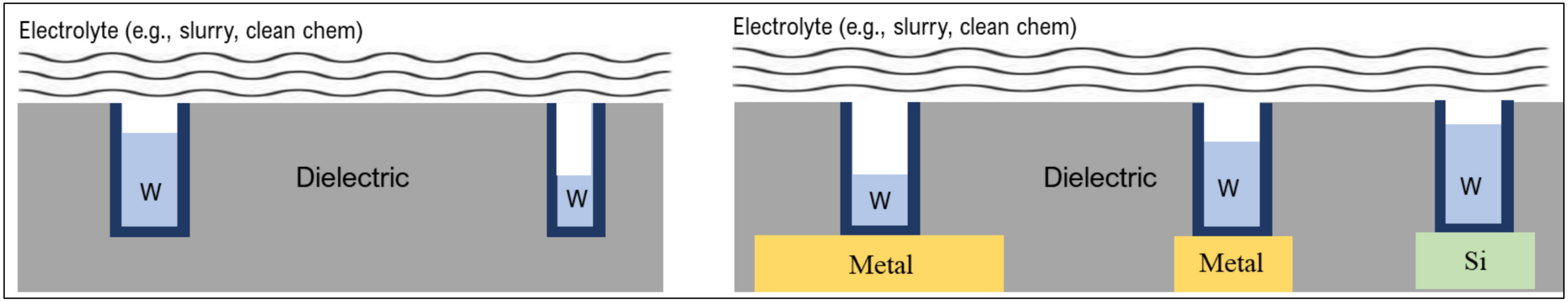
| | W (300°C) | W (400°C) | W (500°C) |
|---|---|---|---|
| *Down-force=4 psi; table speed=20 rev./min* | | | |
| Pre-CMP (110) intensity | 63582 | 61893 | 68437 |
| Post-CMP (110) intensity | 62479 | 60103 | 66892 |
| Pre-CMP (211) intensity | 17365 | 14306 | 15675 |
| Post-CMP (211) intensity | 15057 | 10386 | 9723 |
| Post-CMP grain size (μm) | 0.45 | 0.56 | 0.80 |
| Post-CMP $R_{rms}$ (nm) | 0.43 | 0.46 | 0.49 |

W.-T. Tseng *et al*., *Thin Solid Films*., 370, 96-100 (2000)

- Bonding configuration (of dielectrics) and microstructure + impurity (of metal) can affect CMP performance.
- Interactions between incoming material and slurry/clean chemical can modulate electrical yield and reliability!
- Much less study on this important subject over last 10+ years…😔

# Nano-scale corrosion during metal CMP





W.-T. Tseng *et al., ECS J. Solid State Sci. Technol.* 13 114004 (2024).

- Reduction of DIW usage post polish rinse and/or during brush clean helps decrease the amount of W loss ➔ impacts on defects/cleaning?

# Multipaths to metal CMP corrosion control

**Bulk polish**

EP + OP + on-platen DIW rinse → no impact on integrity of final metal patterns.

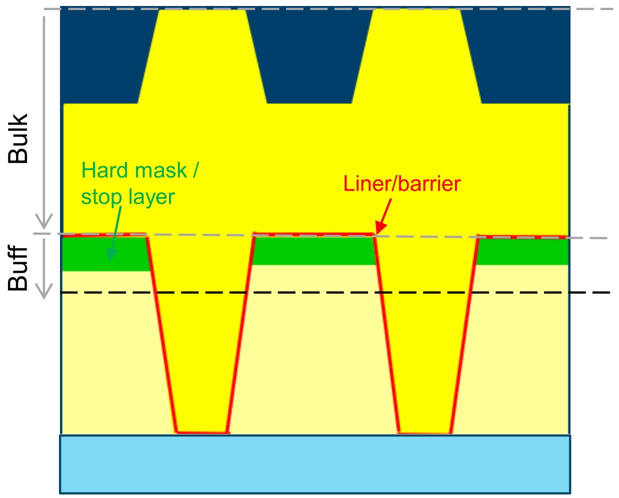
**Buff polish**

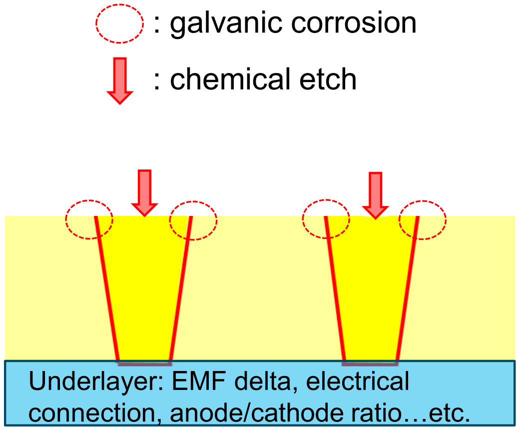
Timed polish + on-platen DIW rinse → pH shock, DIW + residual slurry attack on metal.

**Transient**

Wafer constantly exposed to DIW → need to reduce transient time

Tool ambient control (e.g., displacing $O_2$ with $N_2$?




◌ : galvanic corrosion

⇩ : chemical etch

Underlayer: EMF delta, electrical connection, anode/cathode ratio…etc.

Pre-clean: DIW / clean chem

Clean 1: cyclic spread of DIW & clean chem

Clean 2: cyclic spread of DIW & clean chem

IPA drying: wet → dry

Time-dependent dendrite formation (Cu)

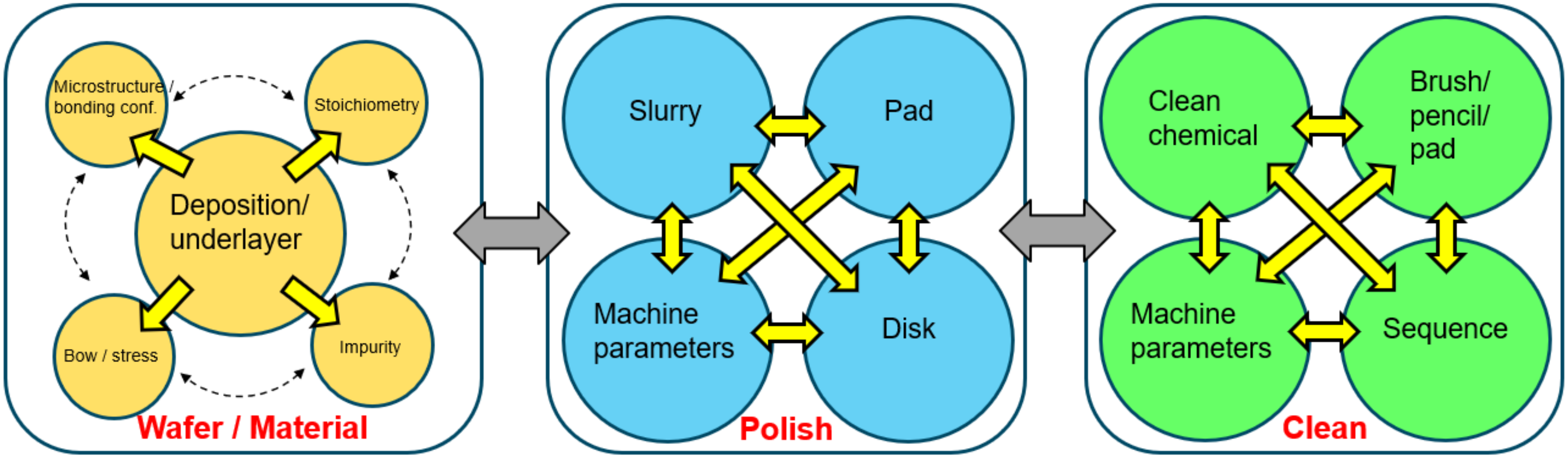
Reducing of DIW may compromise cleaning performance?

More effective corrosion inhibitor?

Functional water?

More effective drying?

# The call for holistic approach to CMP R&D…



- PVD *vs*. CVD *vs*. ALD.
- Impacts on polish and PCMP cleaning.
- New materials:
  - Mo w/ or w/o liners
  - Ru & Ru-based liners
  - SiCN/SiCNO
  - Polyimide
  - AlN$_x$
  - etc.

- Slurry-pad-disk co-optimization.
- Nano abrasives? Selectivity engineering.
- Engineered asperity pads & its “conditioning”.
- On-board, in-situ metrology.
- Bevel & backside polish + clean.
- Ambient/mini-environment control?
- ML/AI based control and optimization.

- PCMP for hydrophobic wafer.
- Metal passivation *vs*. cleaning.
- Functional water? Oxygen & DIW management?
- Innovation in brushes and drying?
- Revisit sonication? Other physical forces to assist cleaning?
- Cleaning process monitor?