Tribo-corrosion Mechanism for Tungsten Void in CMP in-situ Cleaning

Hong Jin Kim, Bryan Egan, Xingzhao Shi, Ja-Hyung Han

Advanced Module Engineering, GLOBALFOUNDRIES

hongjin.kim@globalfoundries.com

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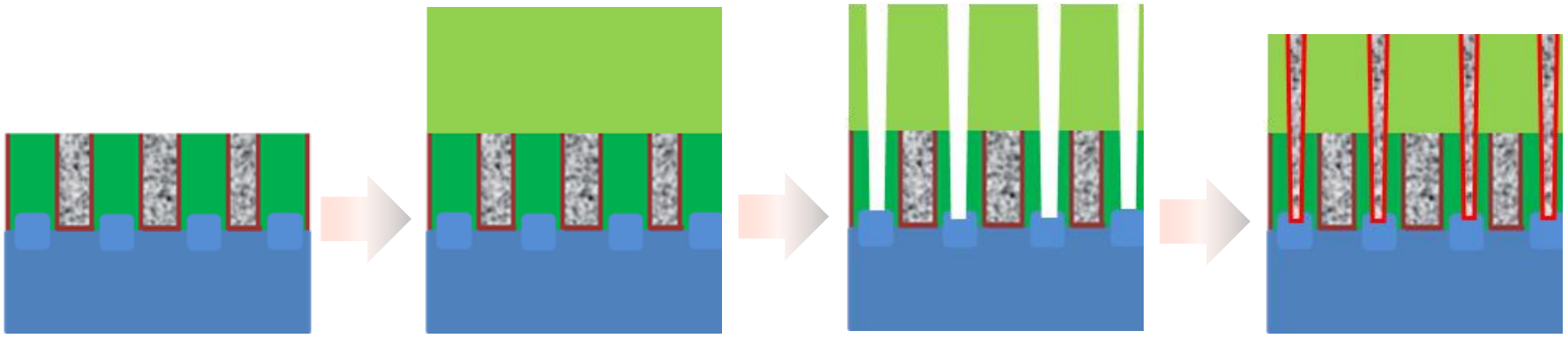
Tungsten Metal Interconnection for Sub-14nm

Tungsten Interconnect Formation: Process Flow

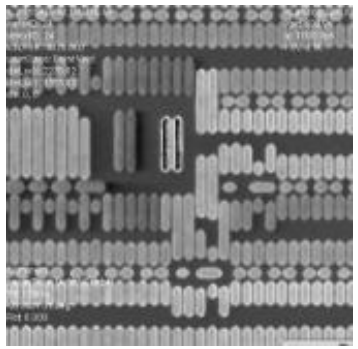
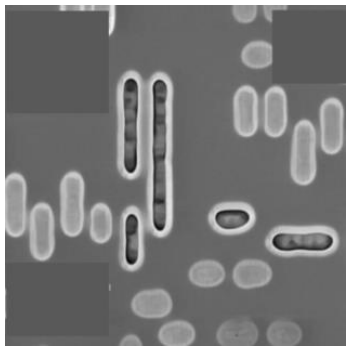
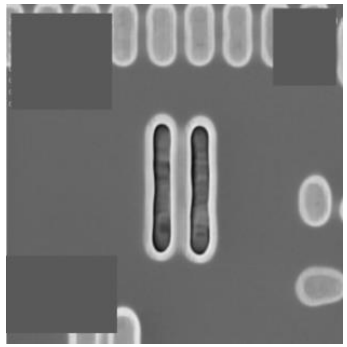
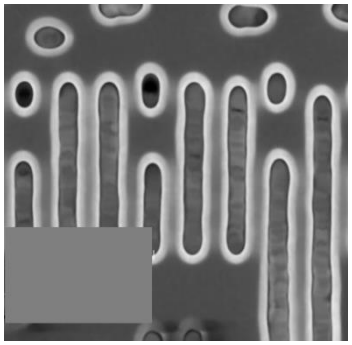


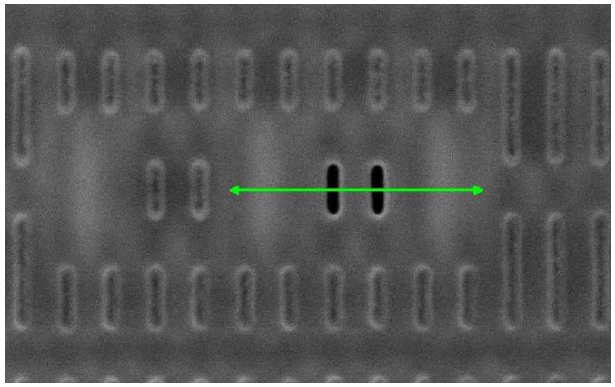
BEOL Cu Process

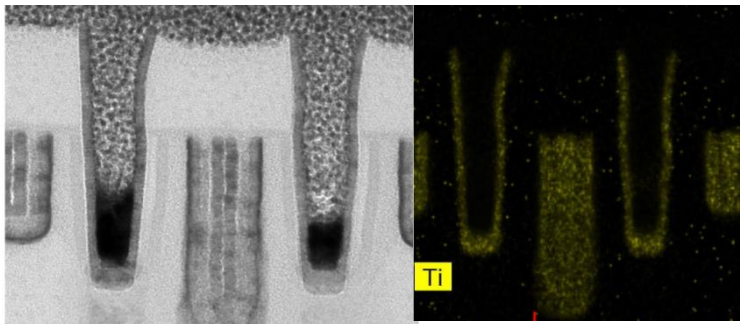
MOL process optimization → reliability, yield, M1 capacitance, M1 resistance, contact resistance, contact open

Tungsten Void Defects

Tungsten Void Defects

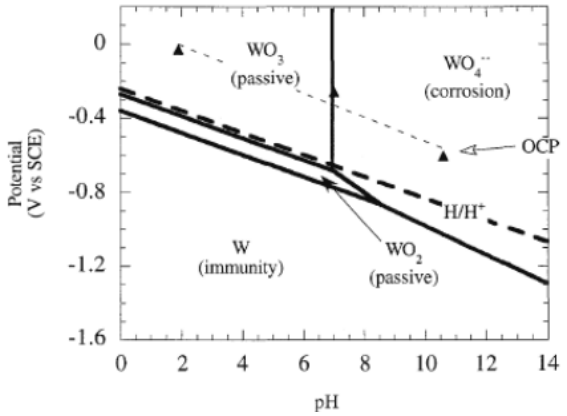




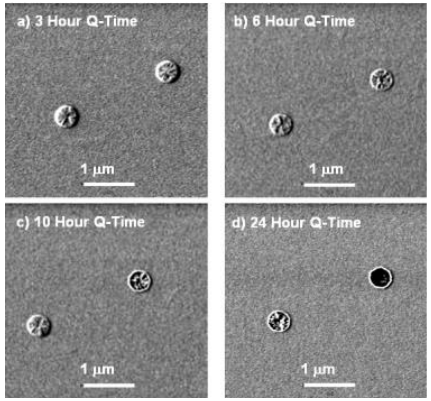
Tungsten Void Defect: Missing Tungsten (barrier metal survived)

Tungsten Void Defect: Literature Review

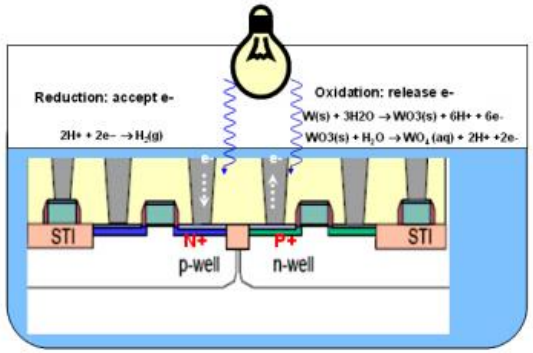
Chemical Dissolution and Electrochemical Corrosion



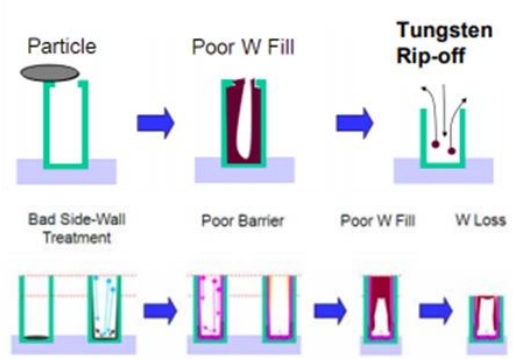
Q-Time



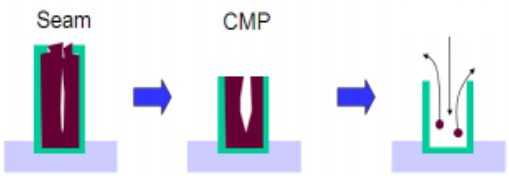
Optical Light



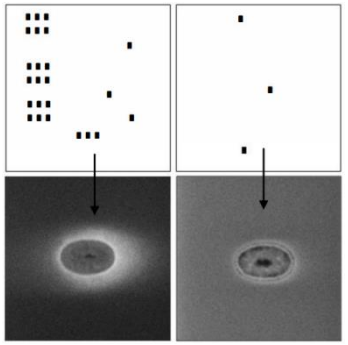
Block Fill



Seam Open

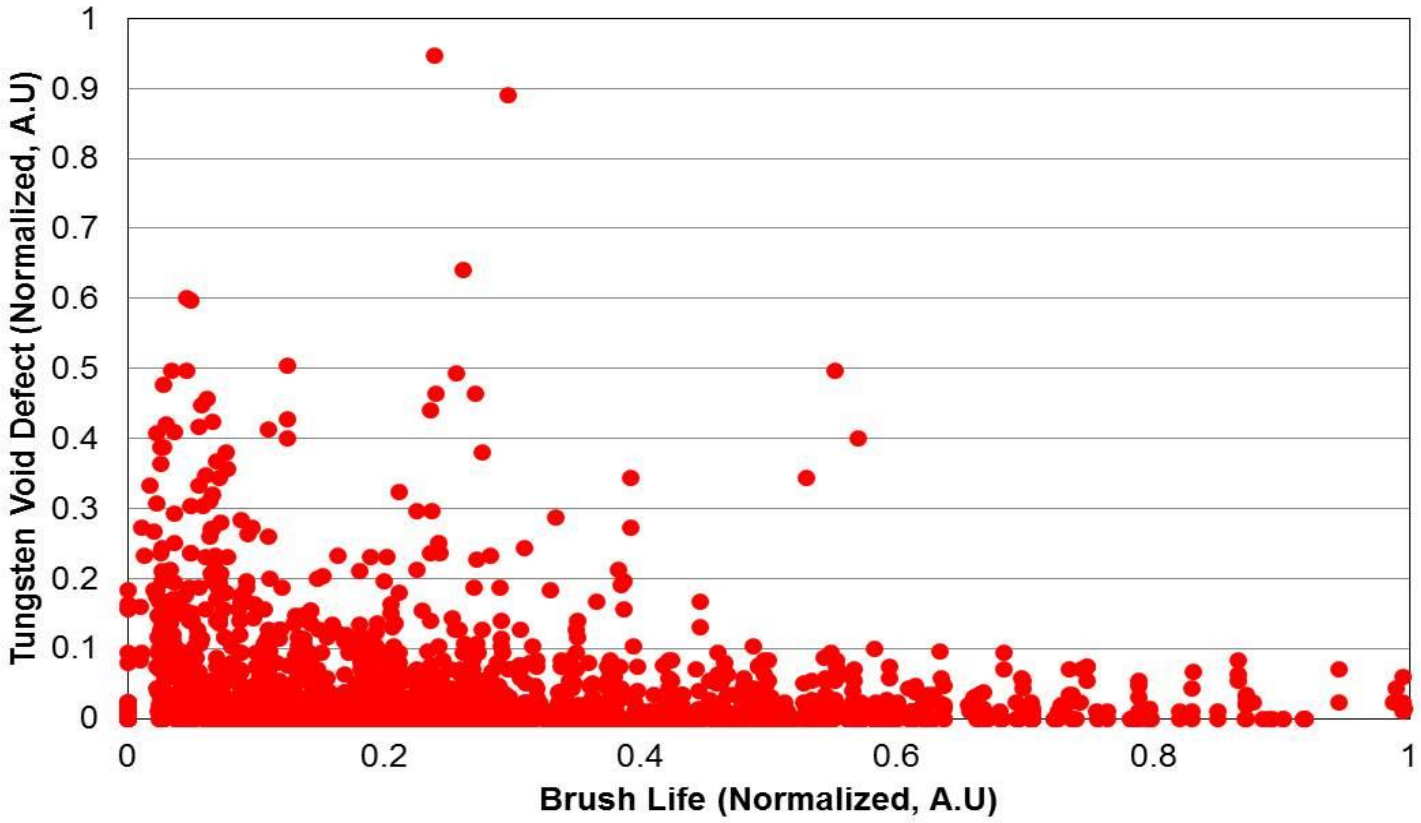


Integration & Contact Design



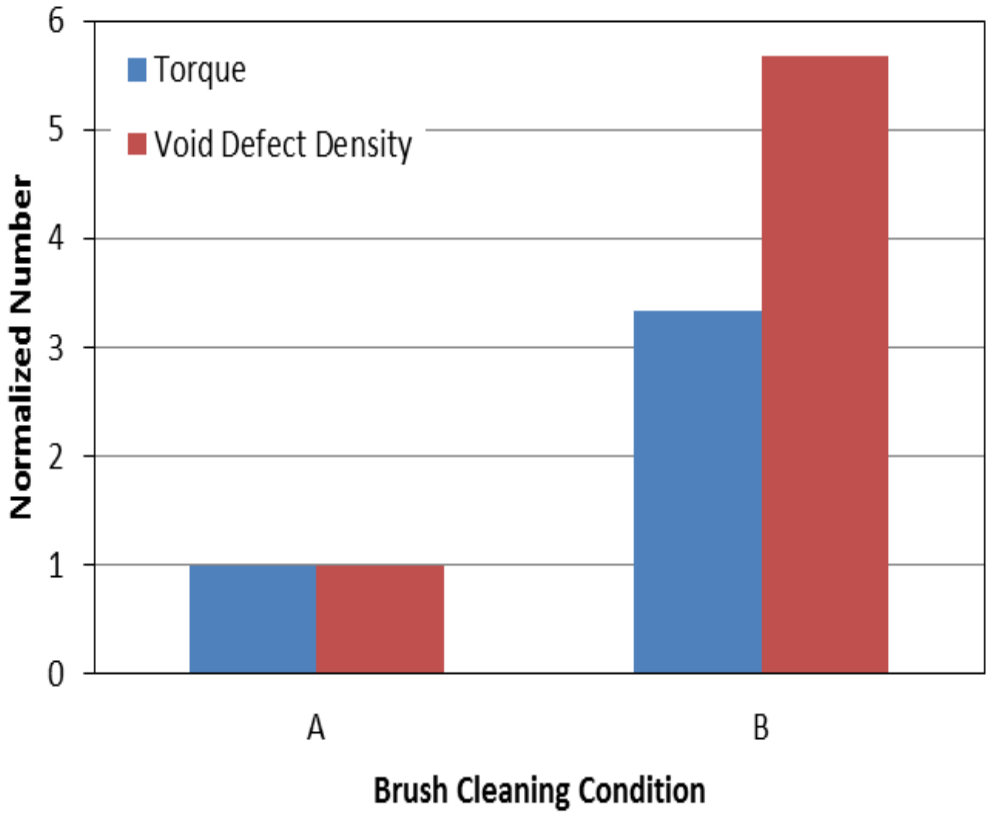
*) Reference: 1)Re-Long Chiu, et al.,17th IEEE International Symposium on the Physical and Failure Analysis of Integrated Circuits (IPFA), July 2010, 2) Polly Lan, et al., Advanced Semiconductor Manufacturing Conference (ASMC), 2014 25th Annual SEMI, 3) K Hwang et al, Planarization/CMP Technology (ICPT), 2015 International Conference on

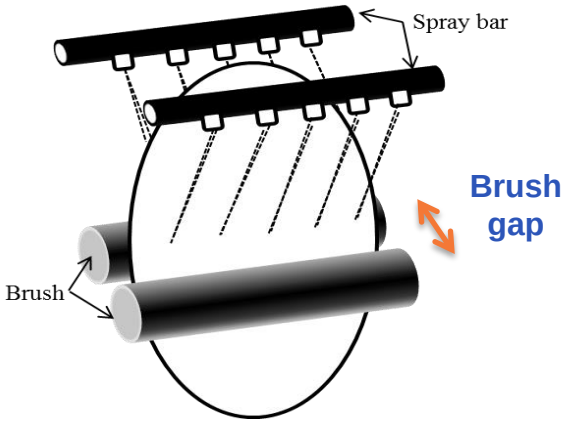
Effect of Brush Lifetime



- W void defect → known as "electro-chemical corrosion": underlayer material (N or P), pH, chemical, temperature, light,..
- MOL W CMP void has correlation with brush lifetime → *"early brush life effect"*

Effect of Brush Torque



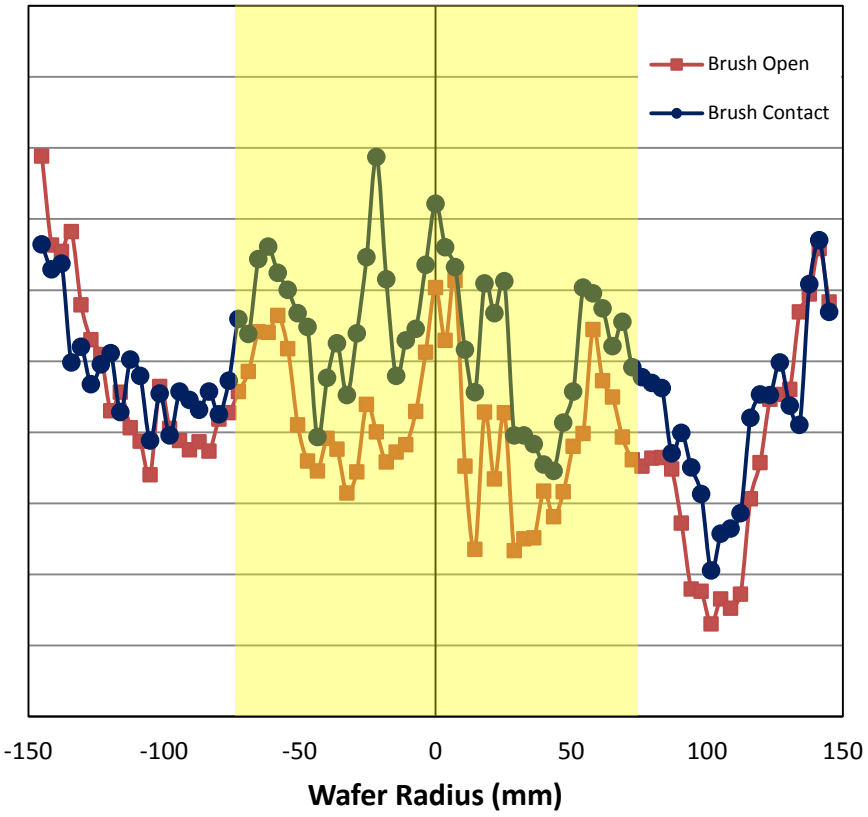


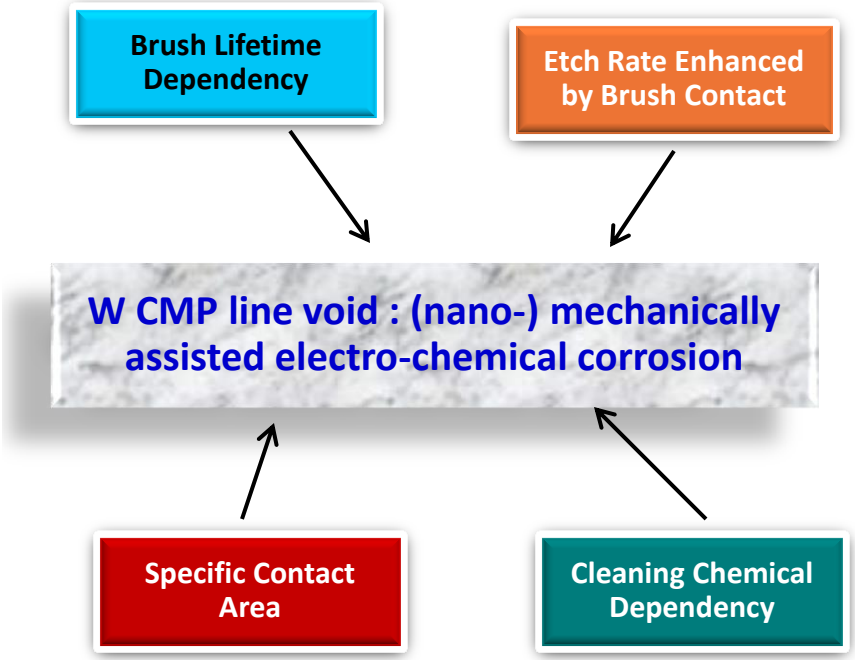
- **Brush torque can be controlled by brush gap**
- **Smaller brush gap applies higher force to the wafer**
- **Higher torque condition results in more void defects**

Friction force enhances tungsten void defects (or tungsten corrosion)

W Etch Rate Investigation

Tungsten Etch Rate at Brush Cleaner (dHF)

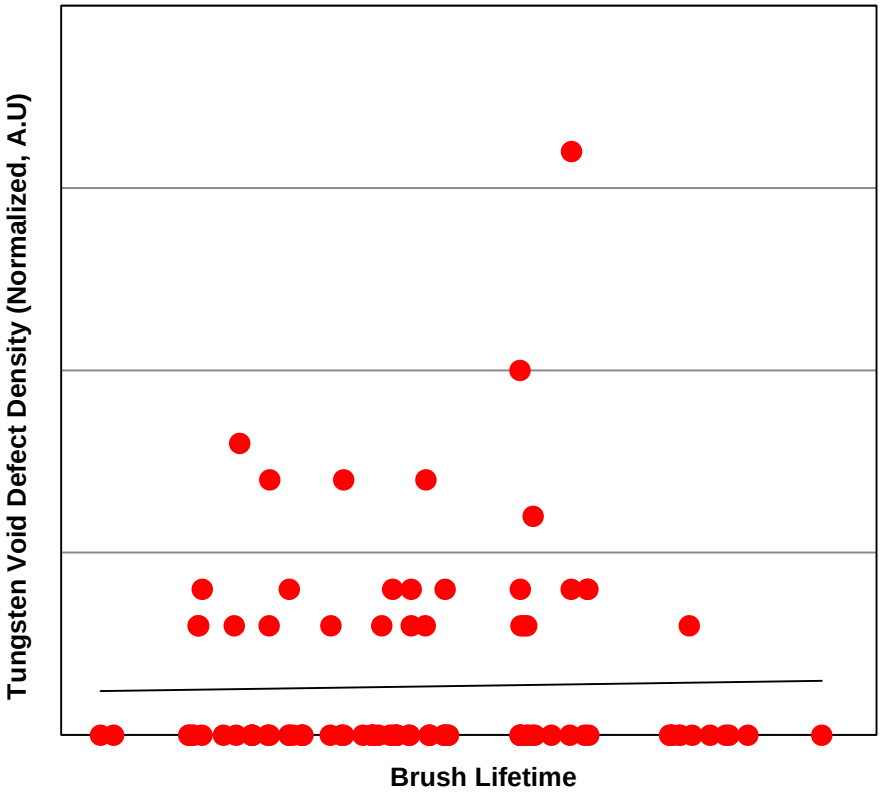




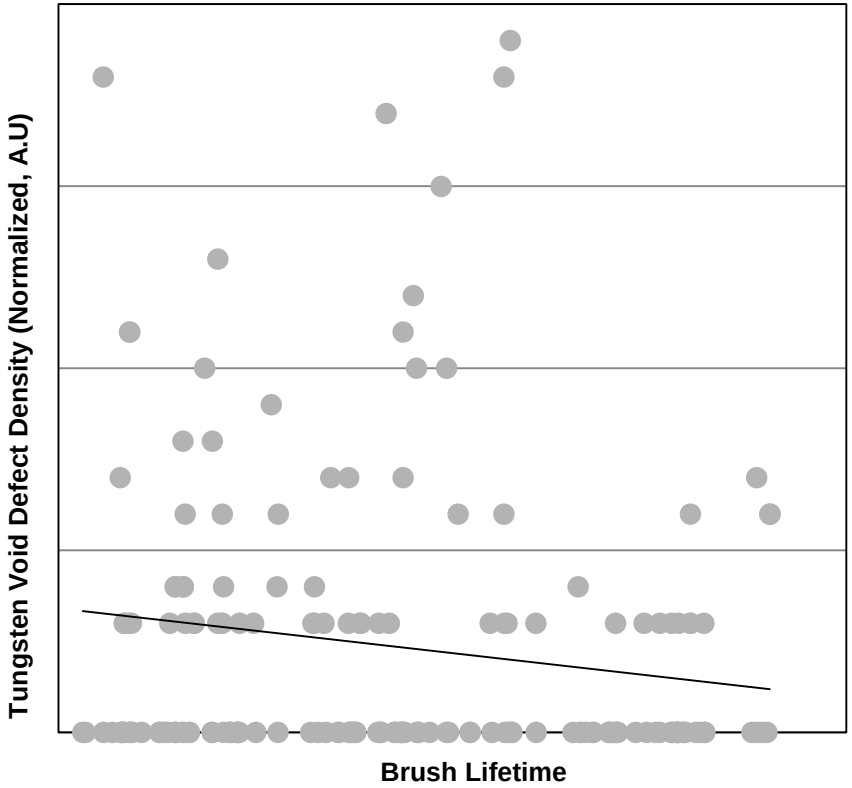
Tungsten void is not just 'electrochemical corrosion' → It needs more experiments, characterization and deeper understanding…

Brush Cleaning Optimization

Brush Cleaning Condition A



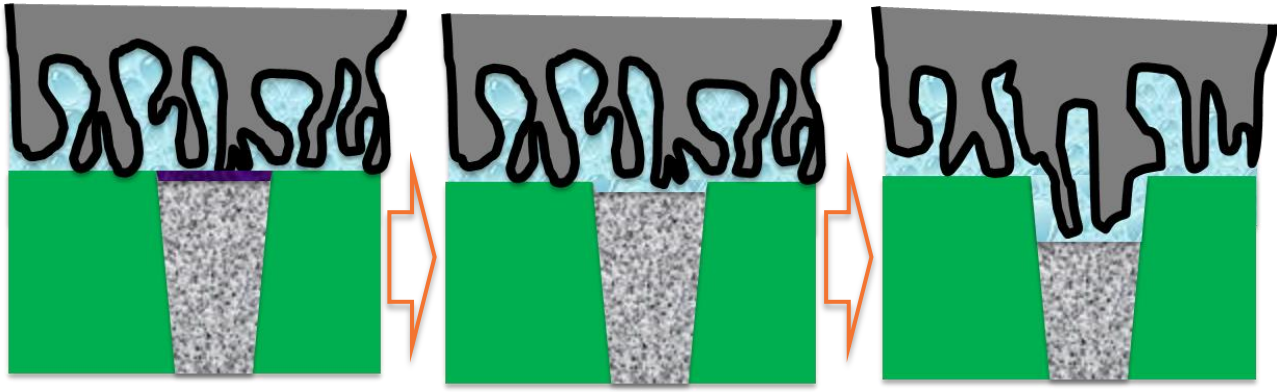
Brush Cleaning Condition B



Brush cleaner module → key knob to control tungsten void defect

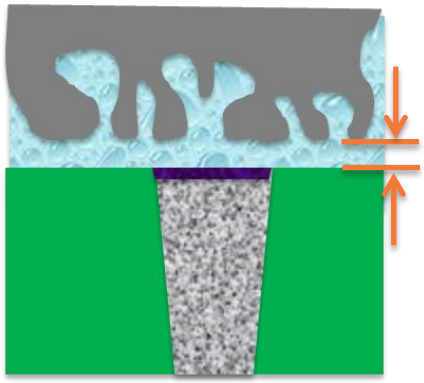
Brush-Induced Tribo-corrsion Mechanism

Early Brush Life



- Skin layer: hard surface
- Direct contact → oxidized W removed by brush asperity
- CMP-like process → removal of oxidized W
- Chemical attack to bare W → either chemical dissolution or electrochemical corrosion of W

Mid-End Brush Life



- Skin layer worn out
- Fully soaked
- Hydrodynamic lubrication → oxidized W protect bare W from corrosion

Summary

In this presentation a new mechanism of tungsten void defect formation during the CMP process is suggested. Different from known tungsten corrosion mechanism, experimental data highlights the importance of the CMP in-situ cleaner. Tungsten void defect density strongly depends on cleaner brush and a cleaner module enhances the formation of tungsten void defect. This presentation supports friction force during brush cleaning as accelerating tungsten corrosion. This phenomenon is considered as mechanically assisted corrosion (tribo-corrosion) and it is a dominant mechanism for tungsten void defect at advanced node semiconductor manufacturing. The experimental results in this paper will provide new insight on semiconductor manufacturing process and defect improvement strategy for tungsten contact CMP.