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Investigation of Behavior of Nanovoids in Electroless Cu Layer of 1st via Bottom of 3-Layer Stacked Micro-via Integrated in Substrate under Thermal Shock Test

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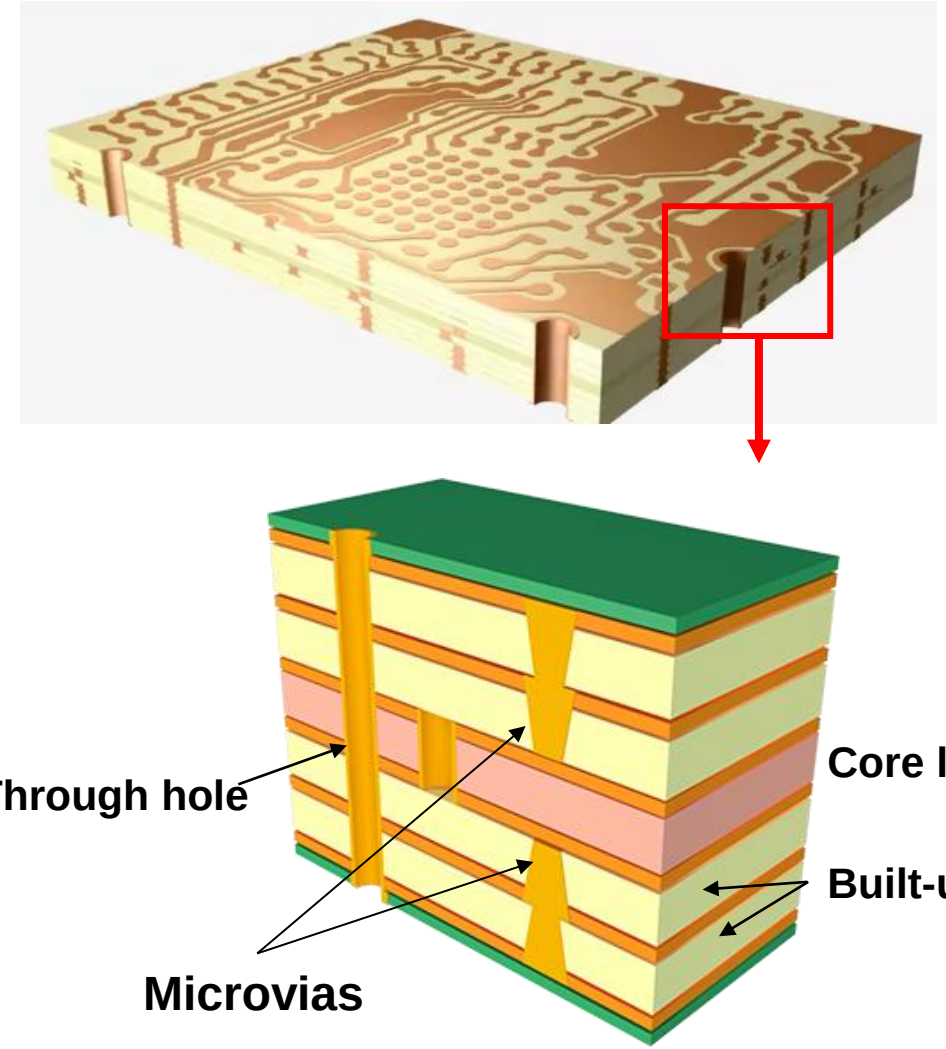
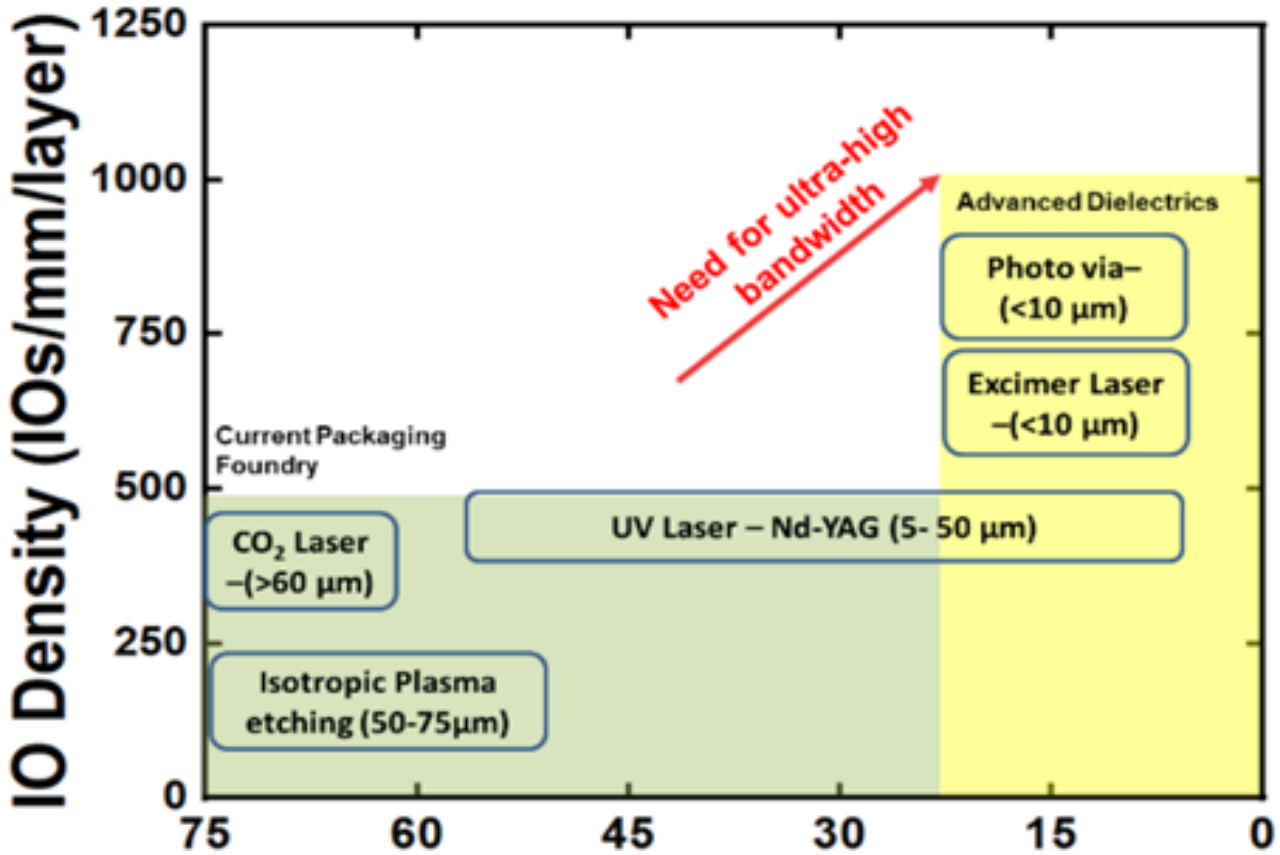
Outline

1. Introduction
2. FEM simulation for three-layer stacked micro-vias
3. STEM/Atom probe analysis on nanovoids in e-less Cu
4. ToF-SIMS for e-less-Cu layer
5. Summary

Trends in high density interconnect of substrates

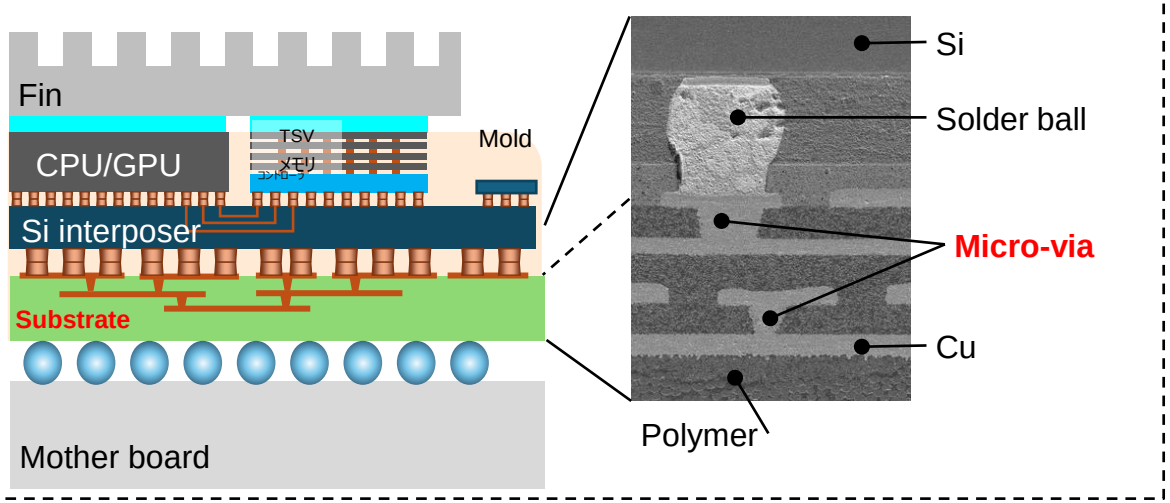




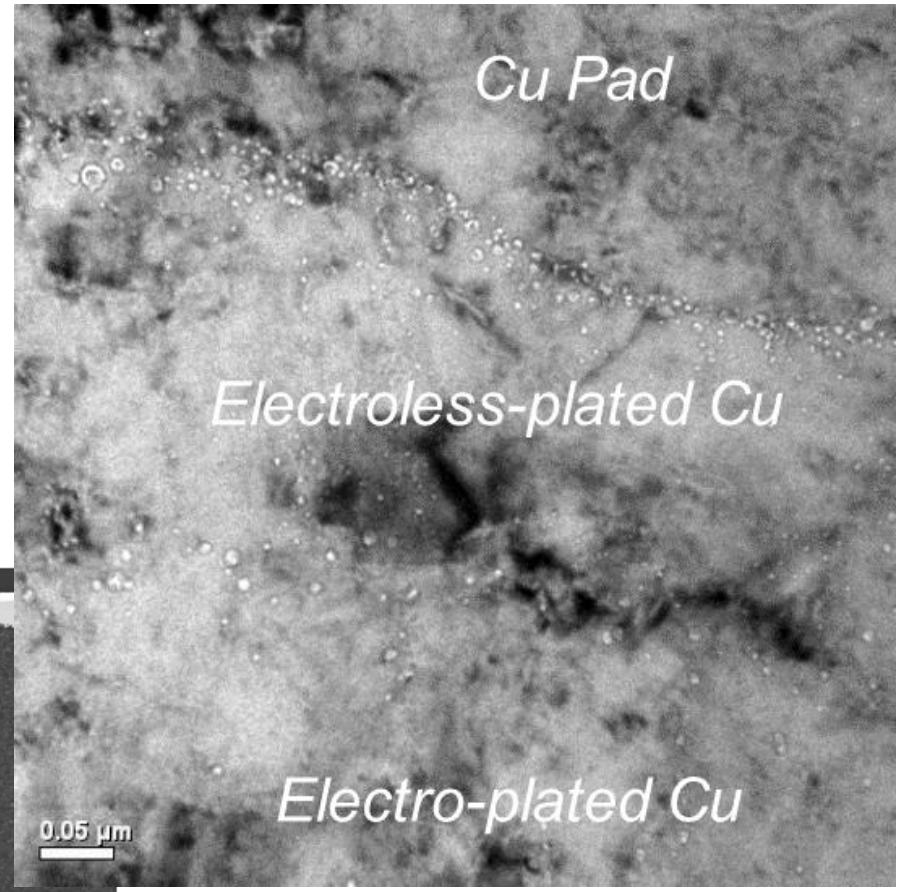
Shreya Dwarakanath May 2020

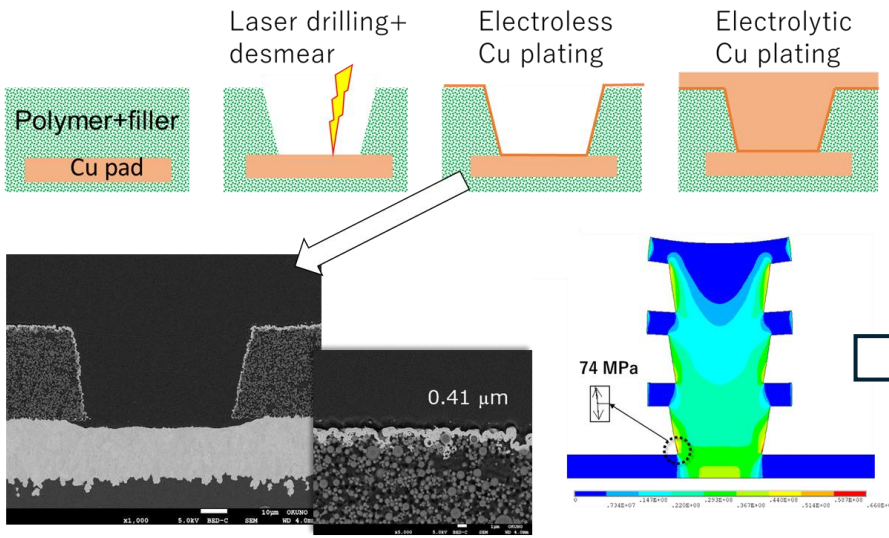
Weak Micro-Via Concern of Substrates

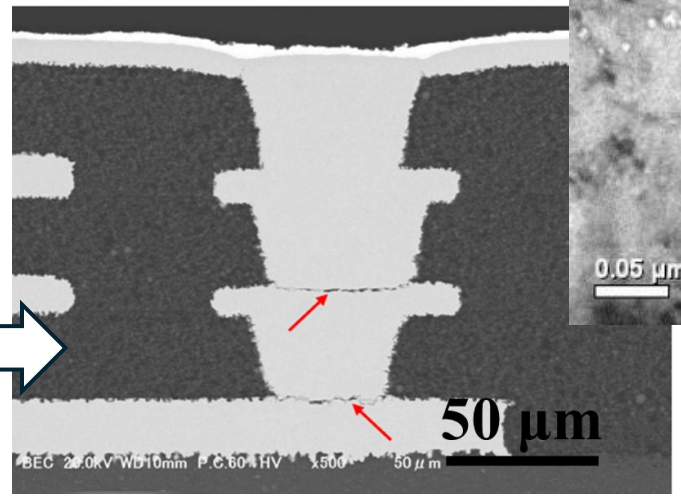
Packaging of advanced semiconductors



Nano voids in e-less Cu







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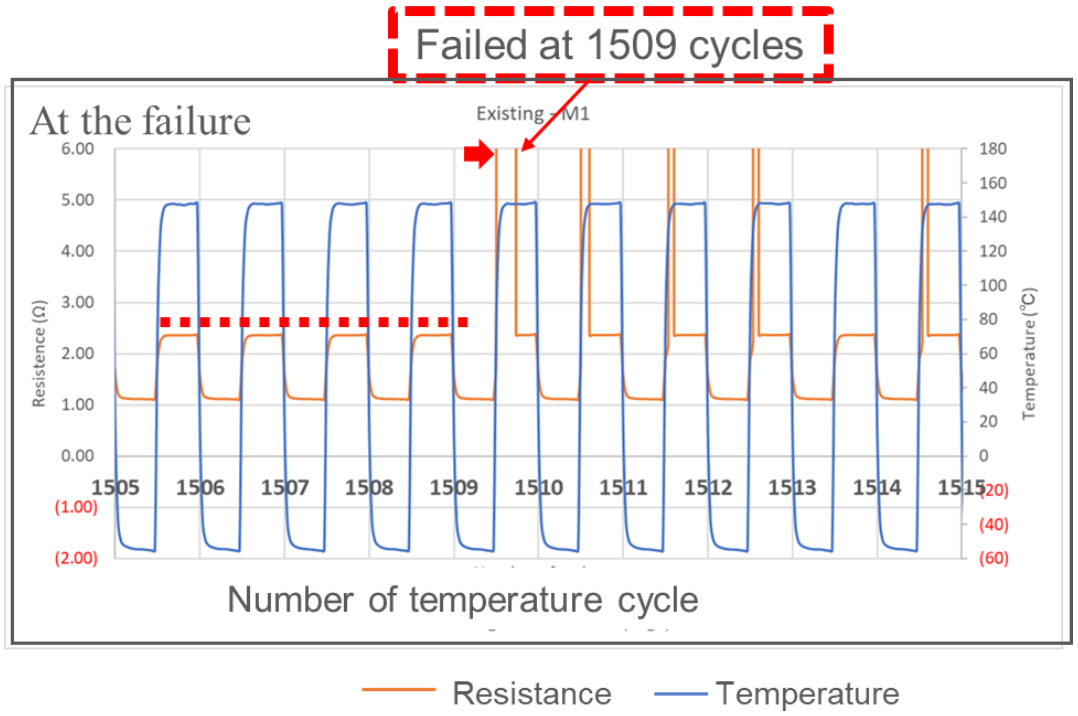
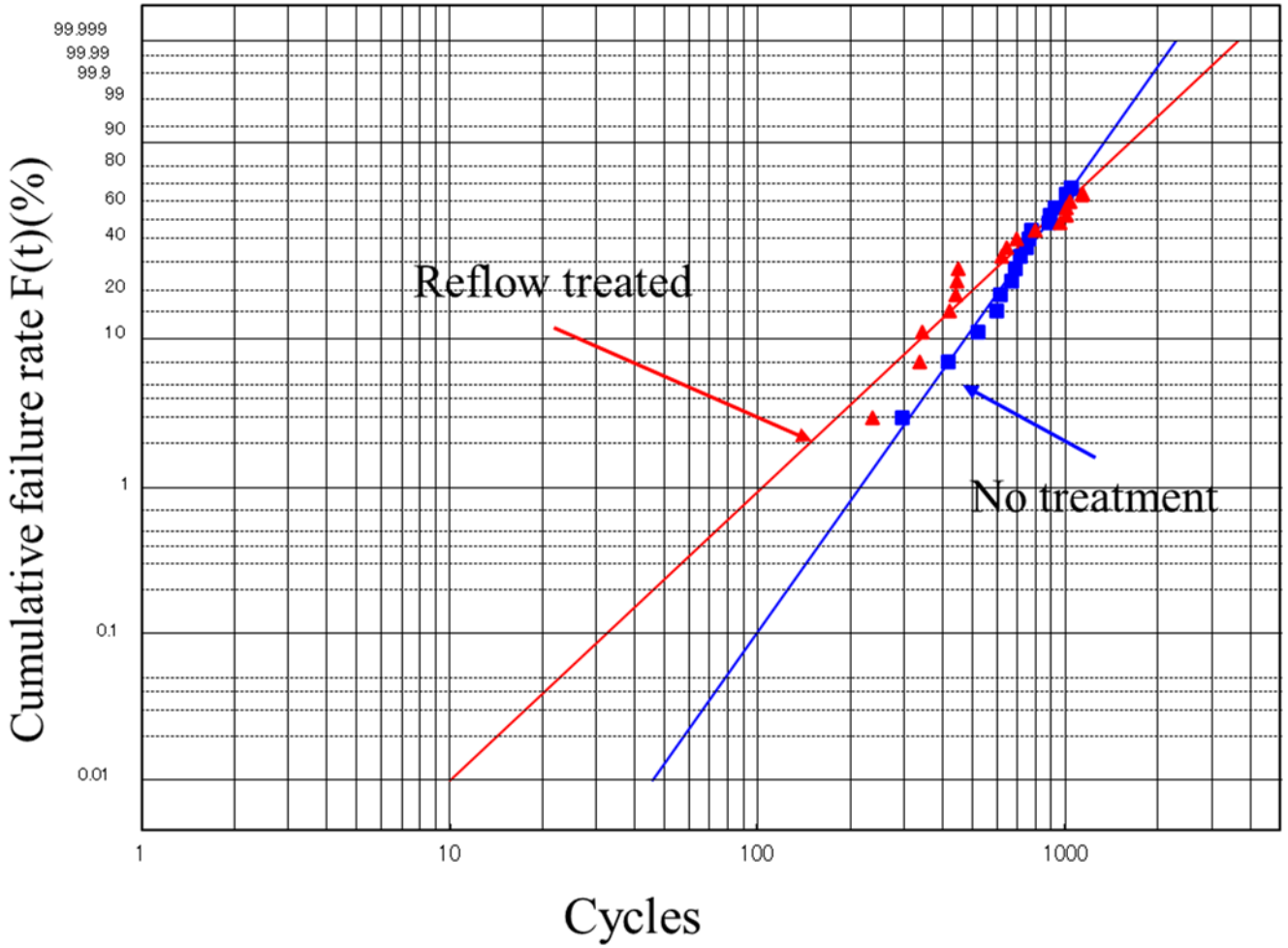
Thermal shock failure



-55ºC~150ºC



Reflow treatment enhances degradation

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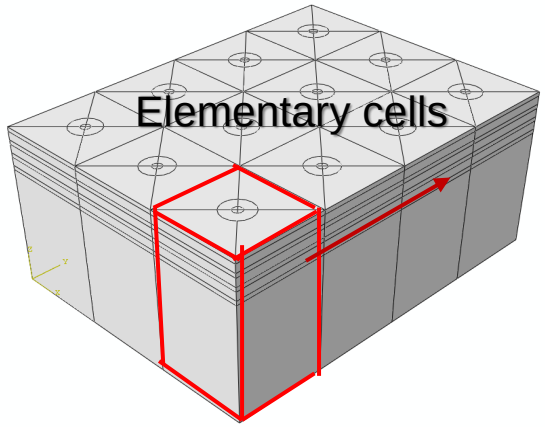
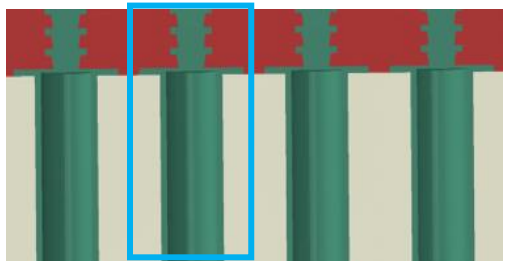
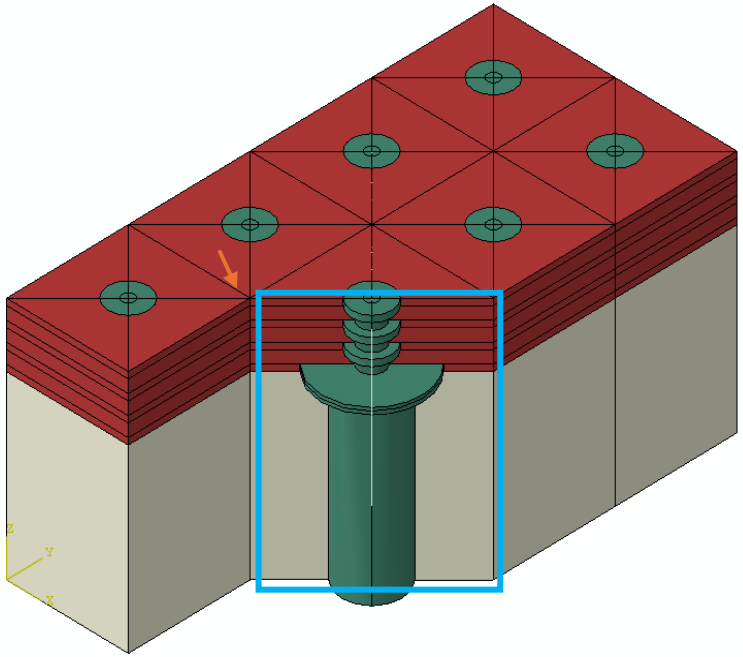
FEM 3D Model of HDI substrate



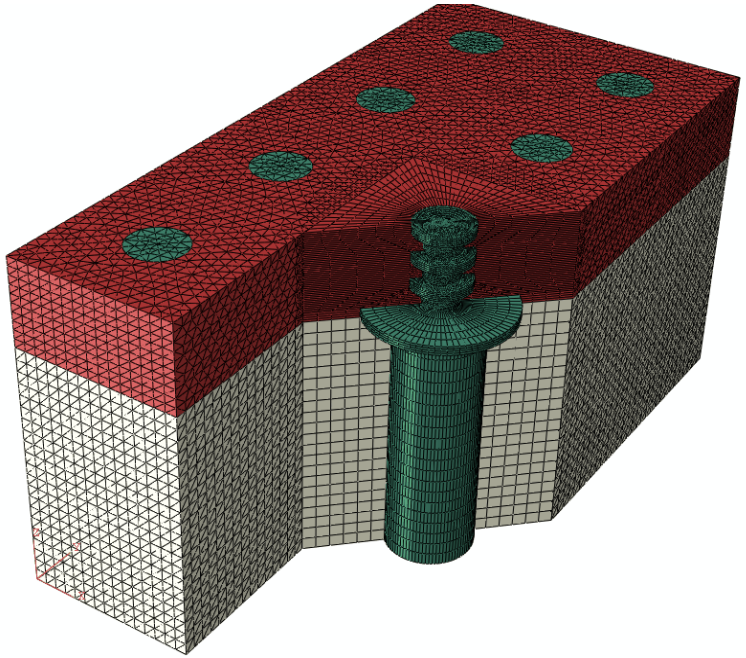
Sketch



Cross section view



Internal view

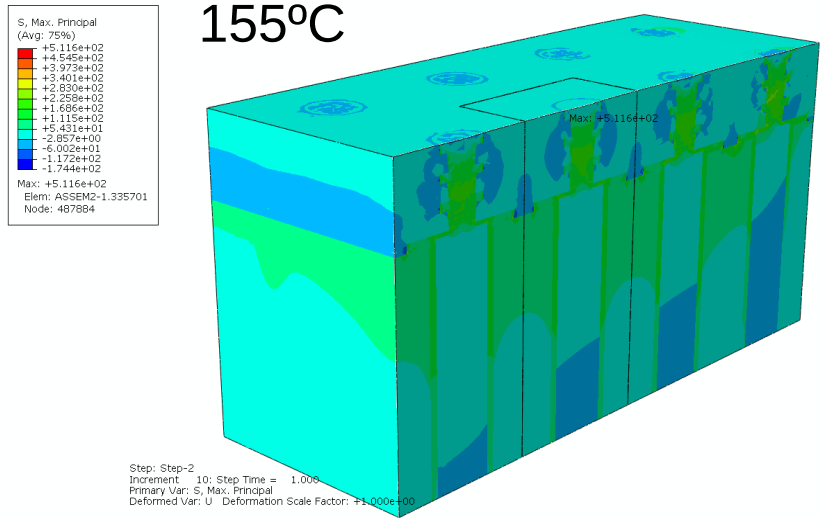


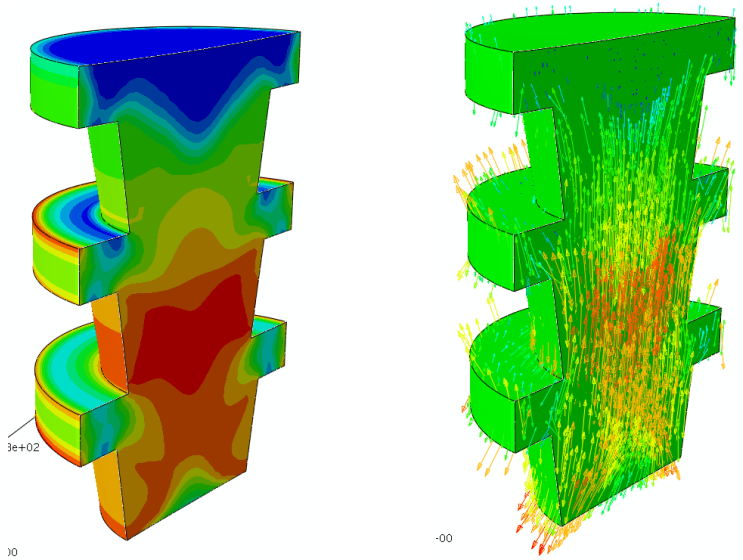
Mesh

-55ºC ~ 150ºC

Stresses in substrate at low and at high temperature

155ºC

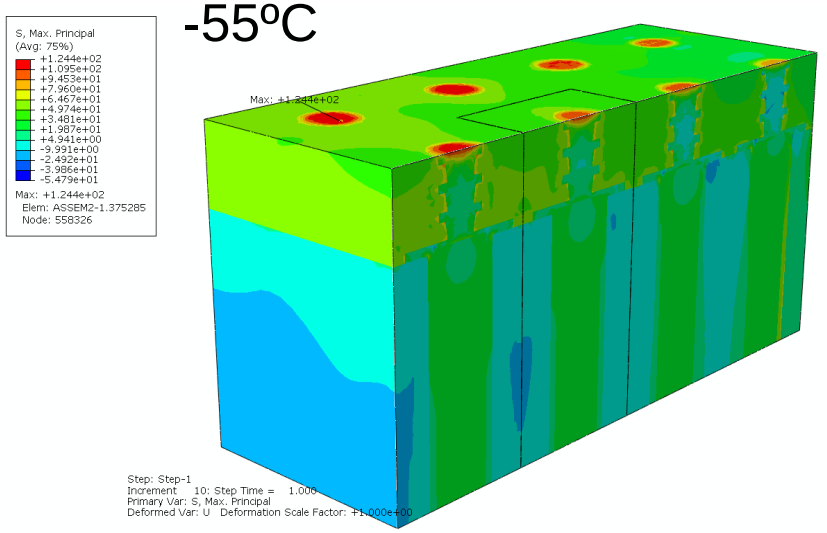


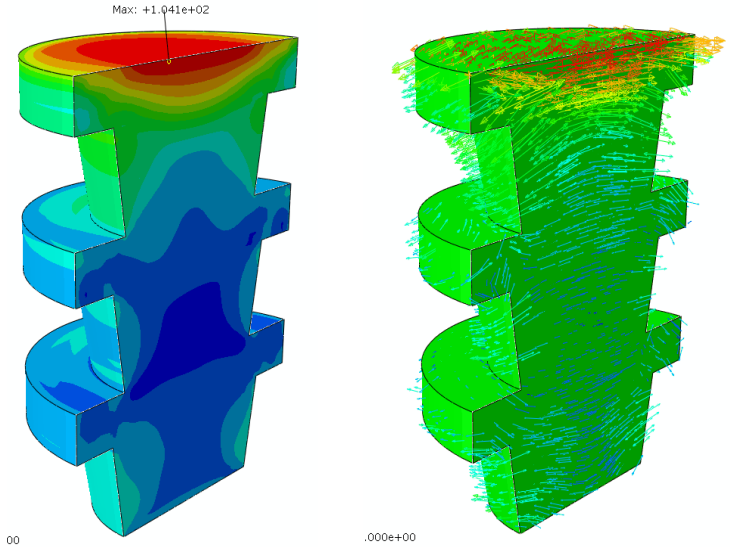


Stress distribution

Stress direction

-55ºC





Stress distribution

Stress direction

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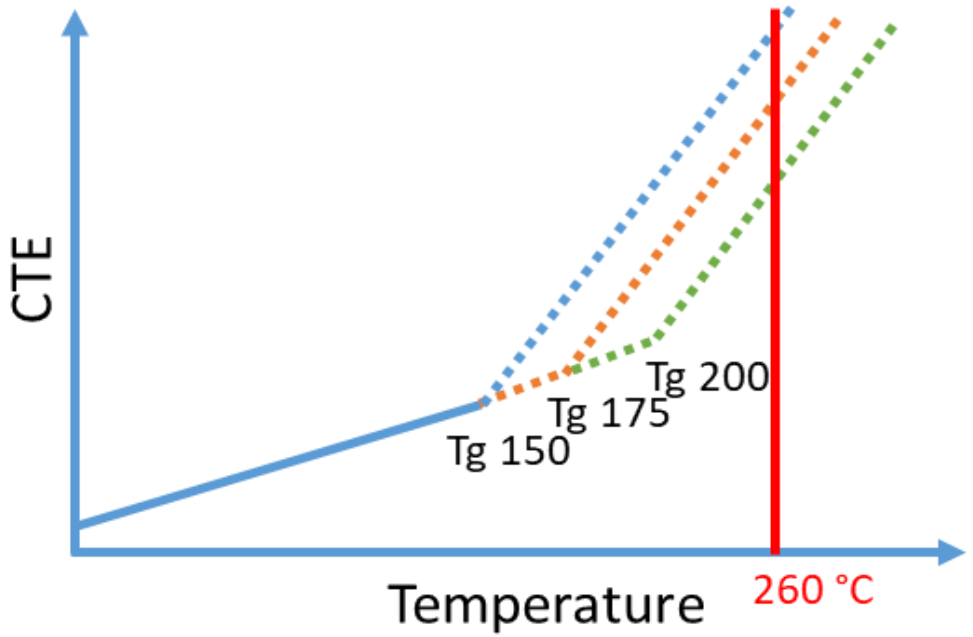
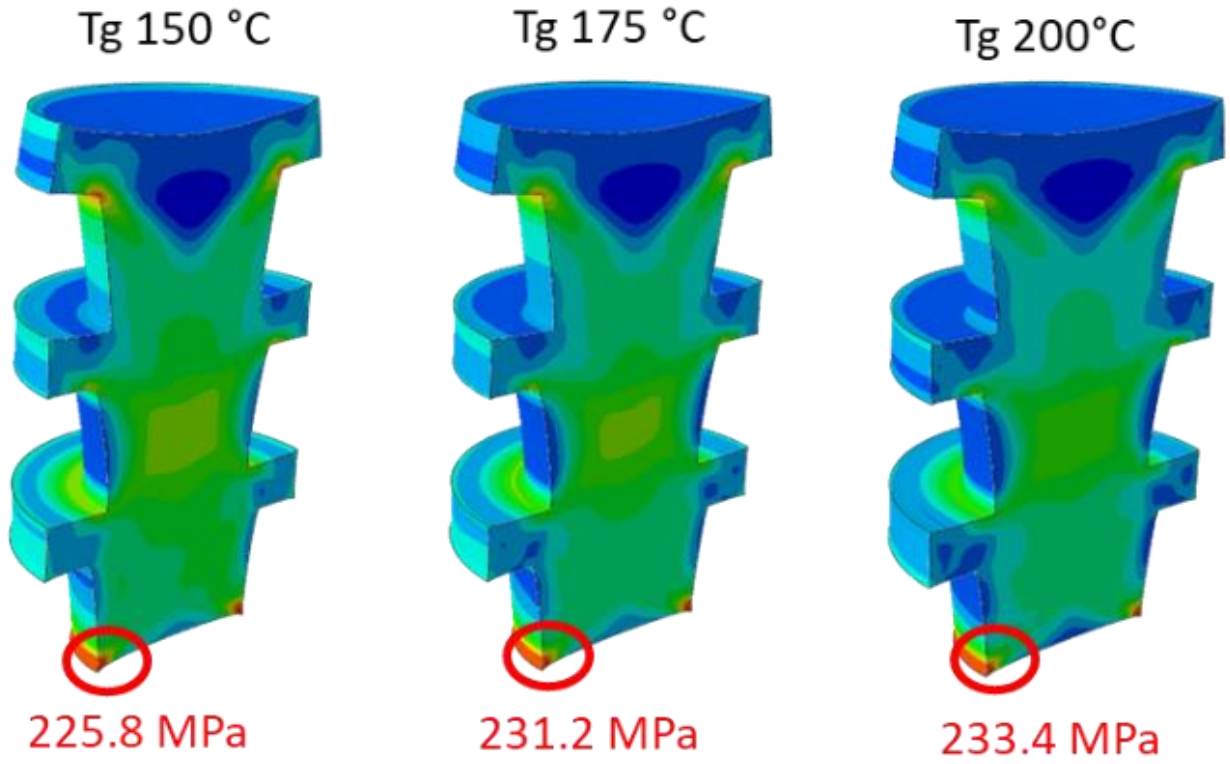
Stresses in substrate with different Tg temperature

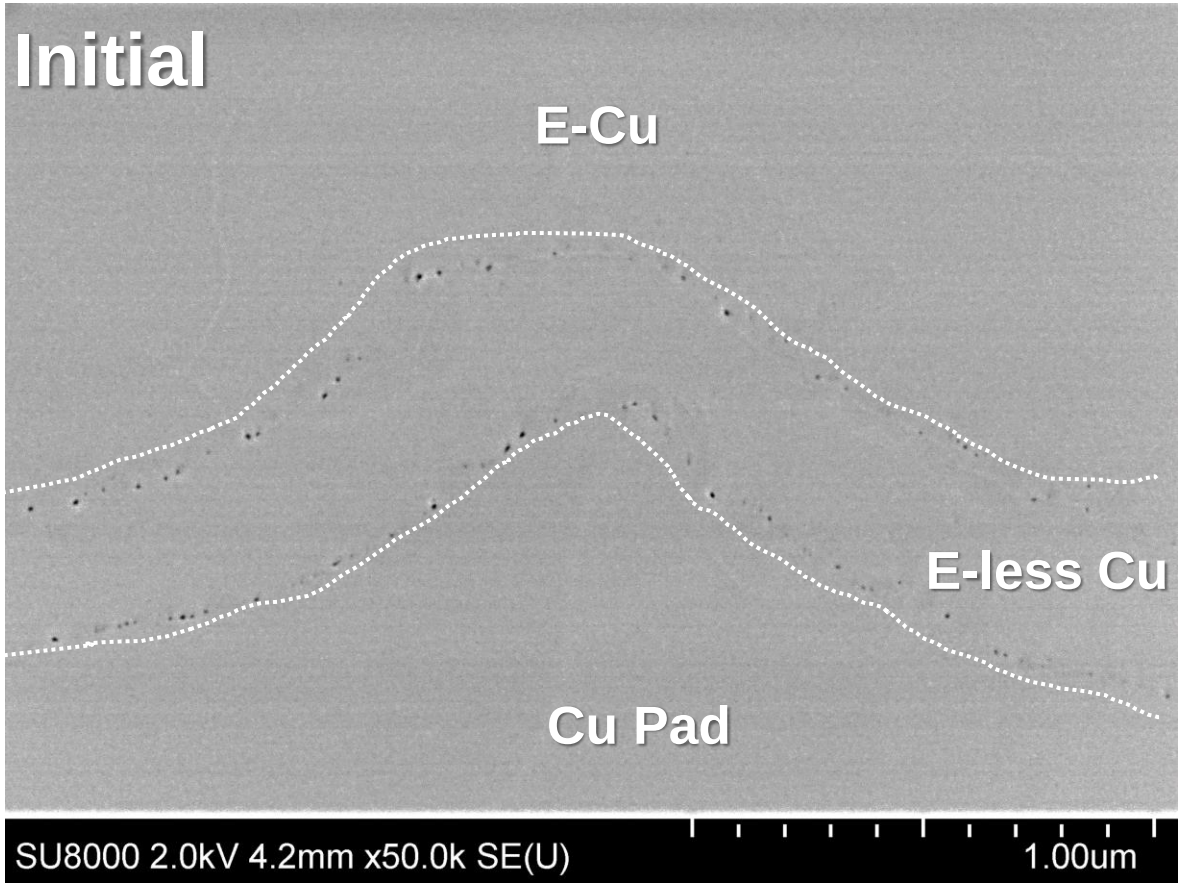


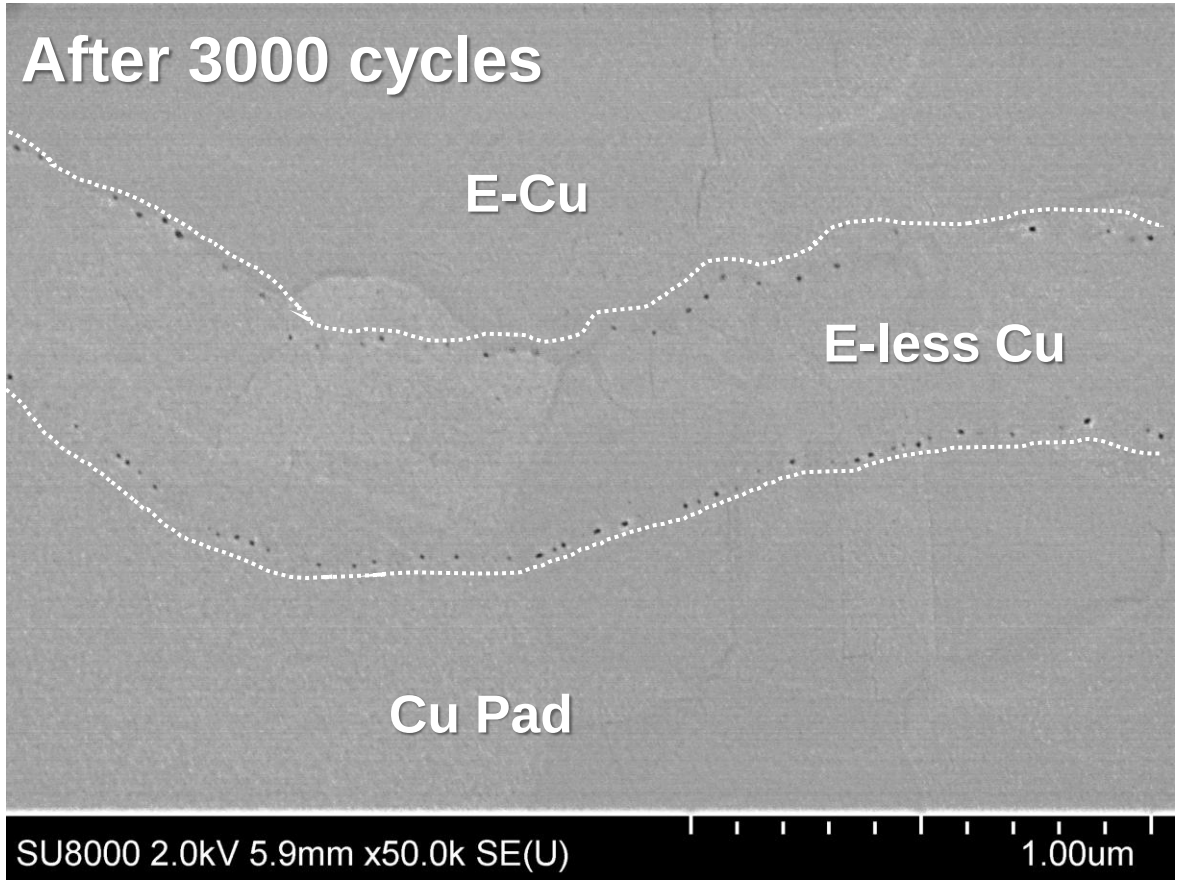
*CTE(@260C)=0.3489*Tg+22.67+1.3283*(260-Tg)



At higher temperature above T_g of Resin materials, stress becomes stronger at the edge corner of the bottom of the 3-layer stacked micro-via.
Stress sometimes induced and causes the destruction of micro-via.

Low acceleration voltage SEM observation of e-less Cu layer





SEM V_{acc} = 1-2 kV

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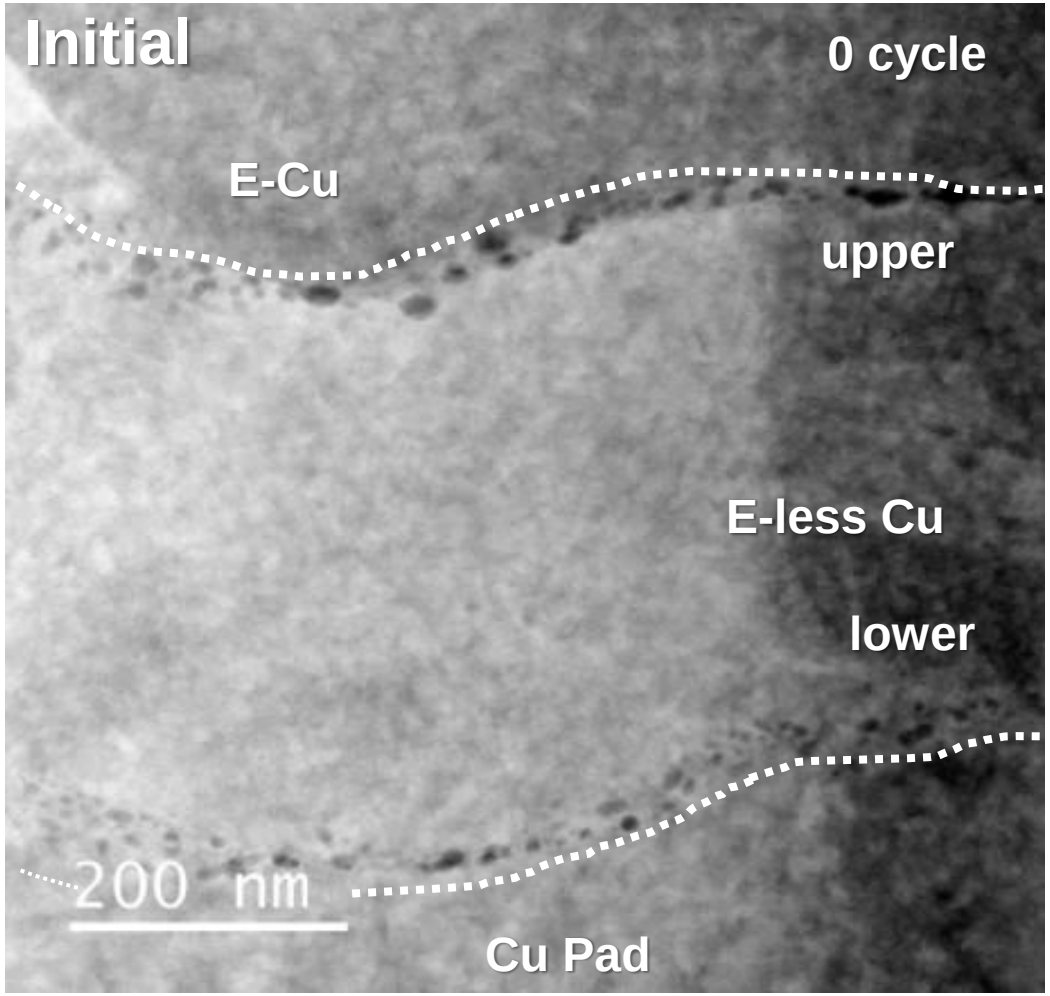
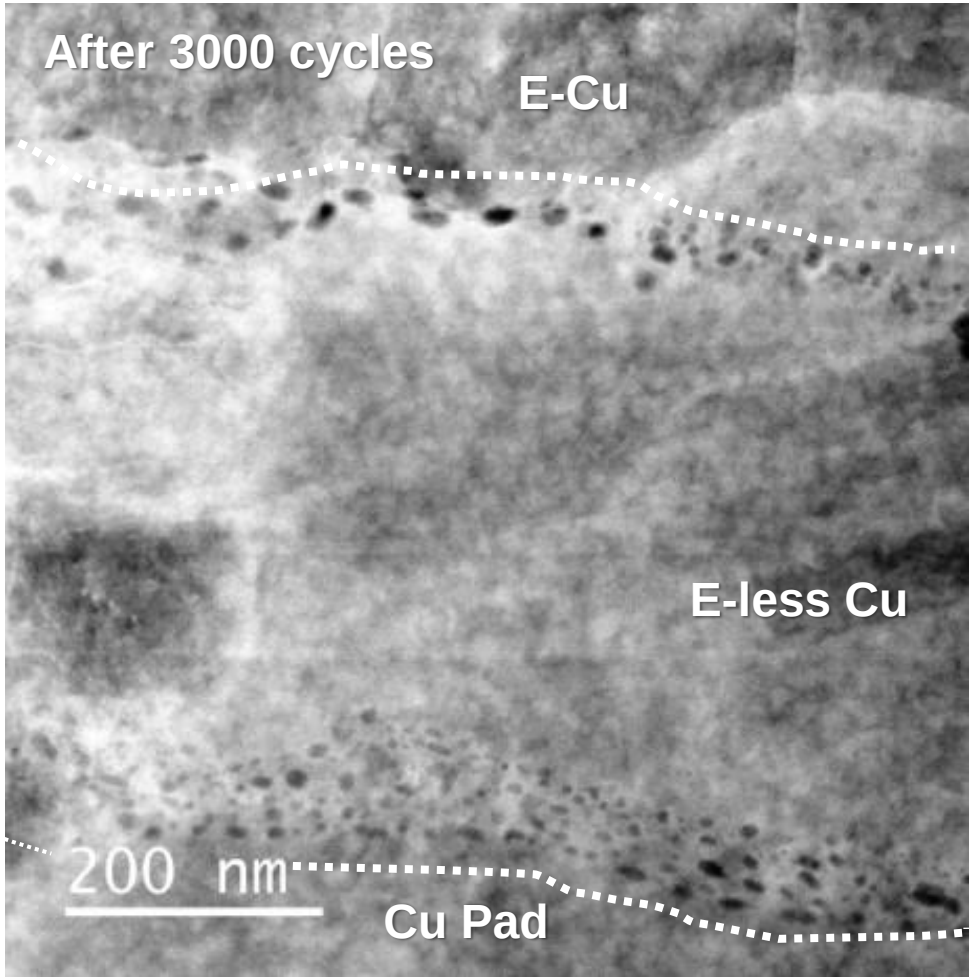
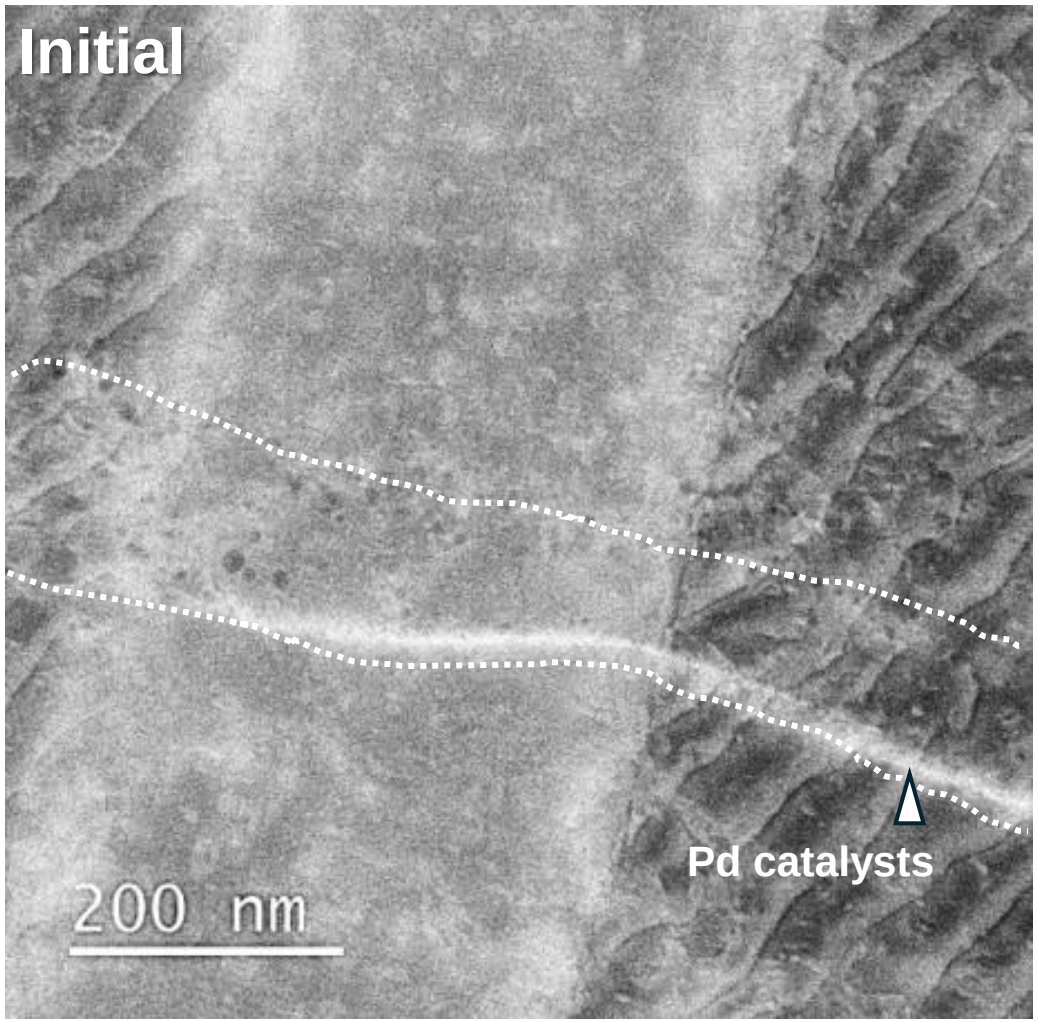
HAADF-STEM Observation of e-less Cu layer

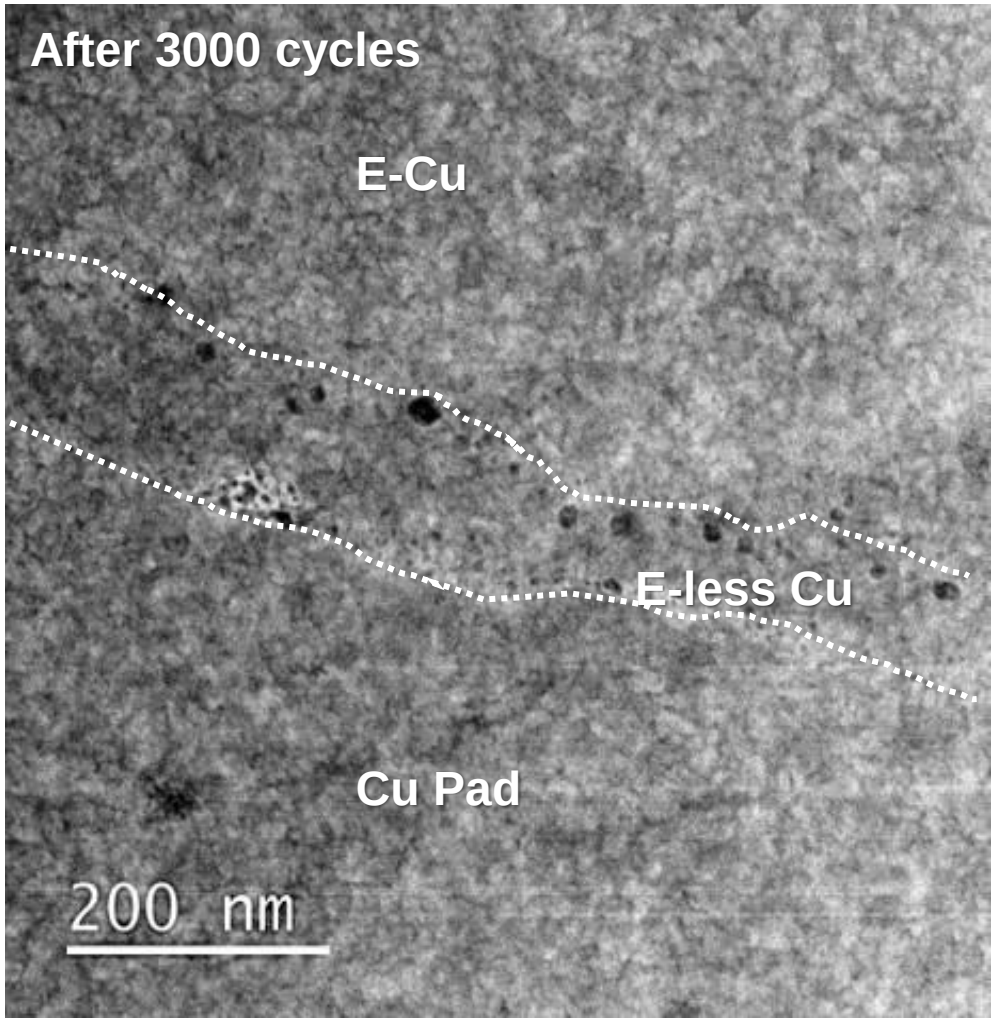




STEM V_{acc} = 200 kV

HAADF-STEM Observation of e-less Cu layer for FLET





STEM V_{acc} = 200 kV

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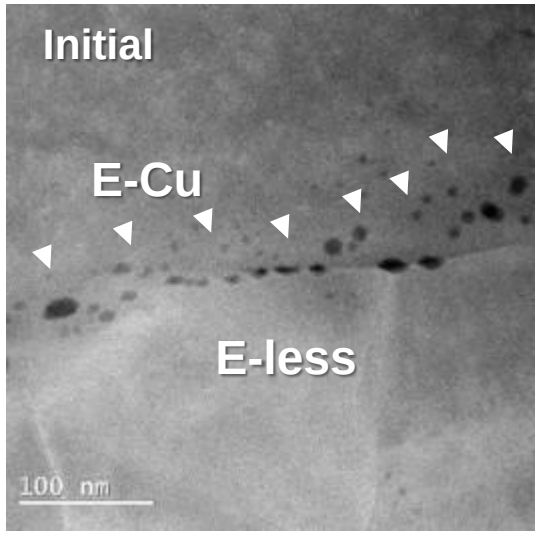
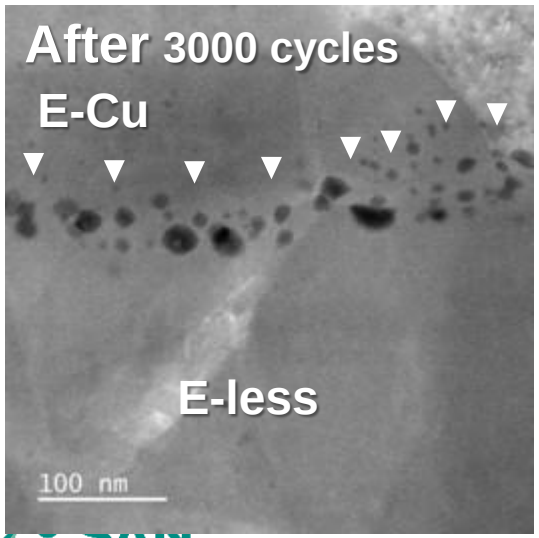
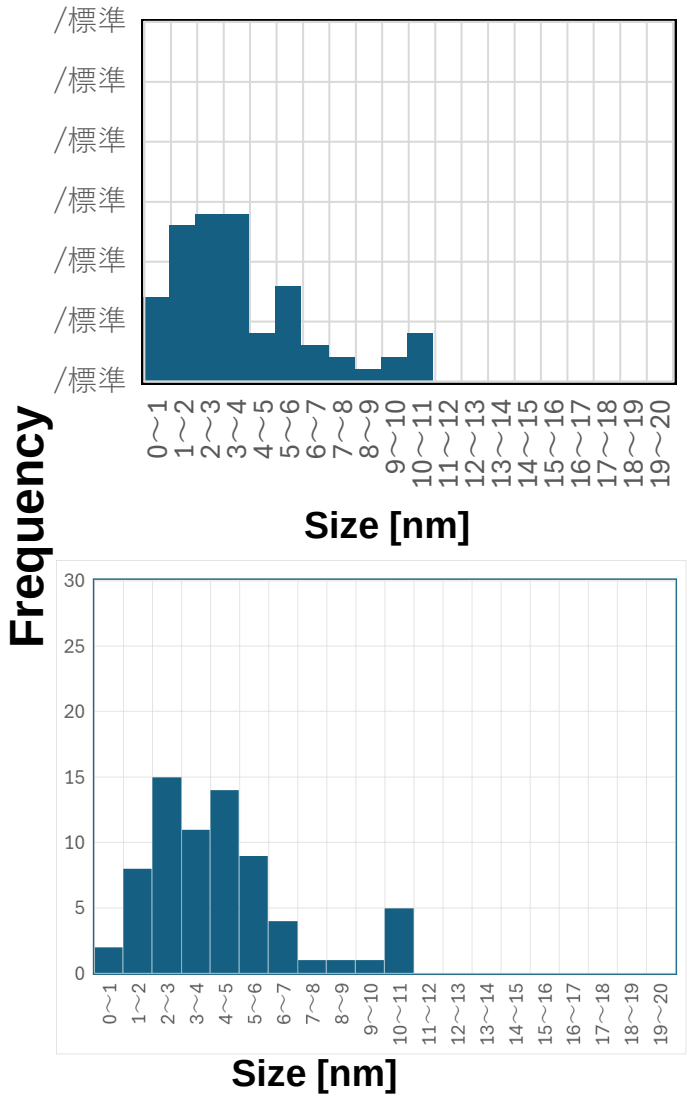
Distribution of nanovoids

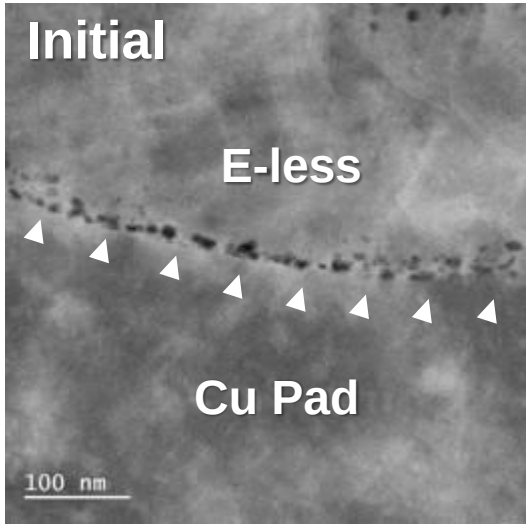
Upper

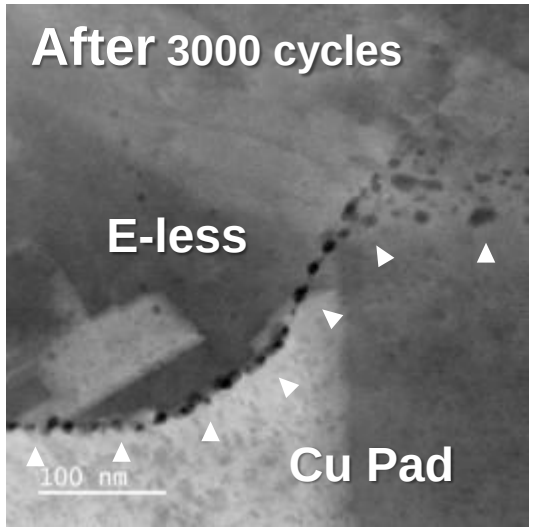


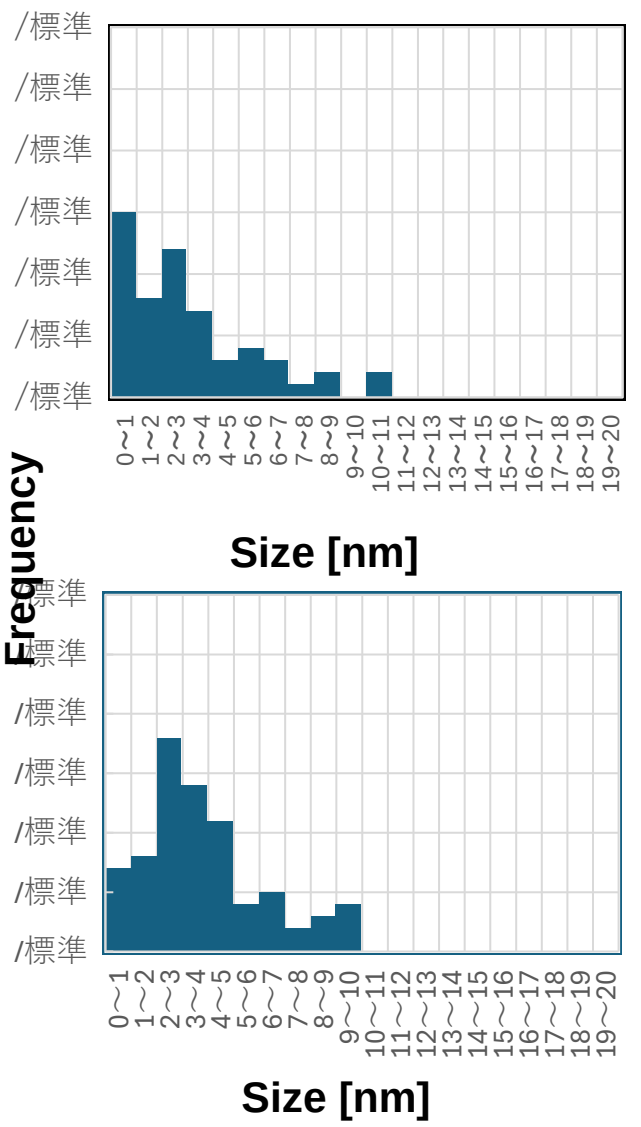




Lower







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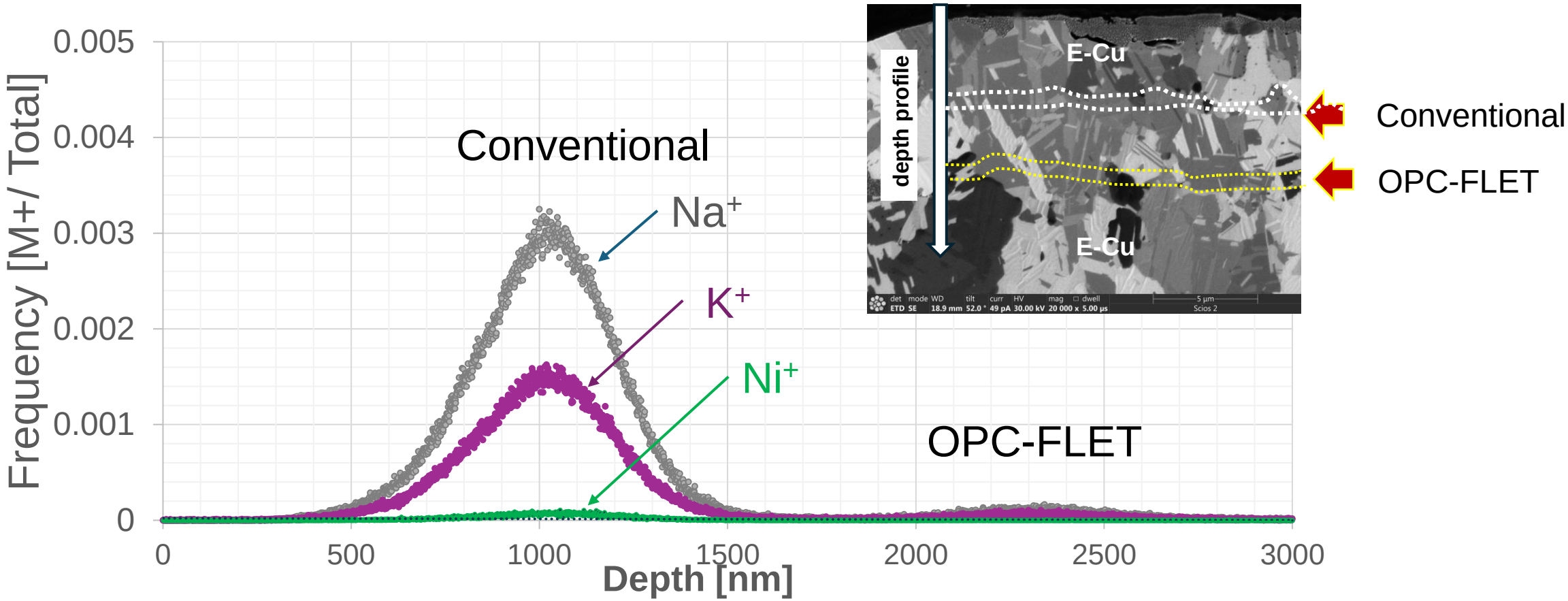
SIMS measurement across electro/electroless plated layers



- Na^+ and K^+ ions are increasing around the electroless Cu layer

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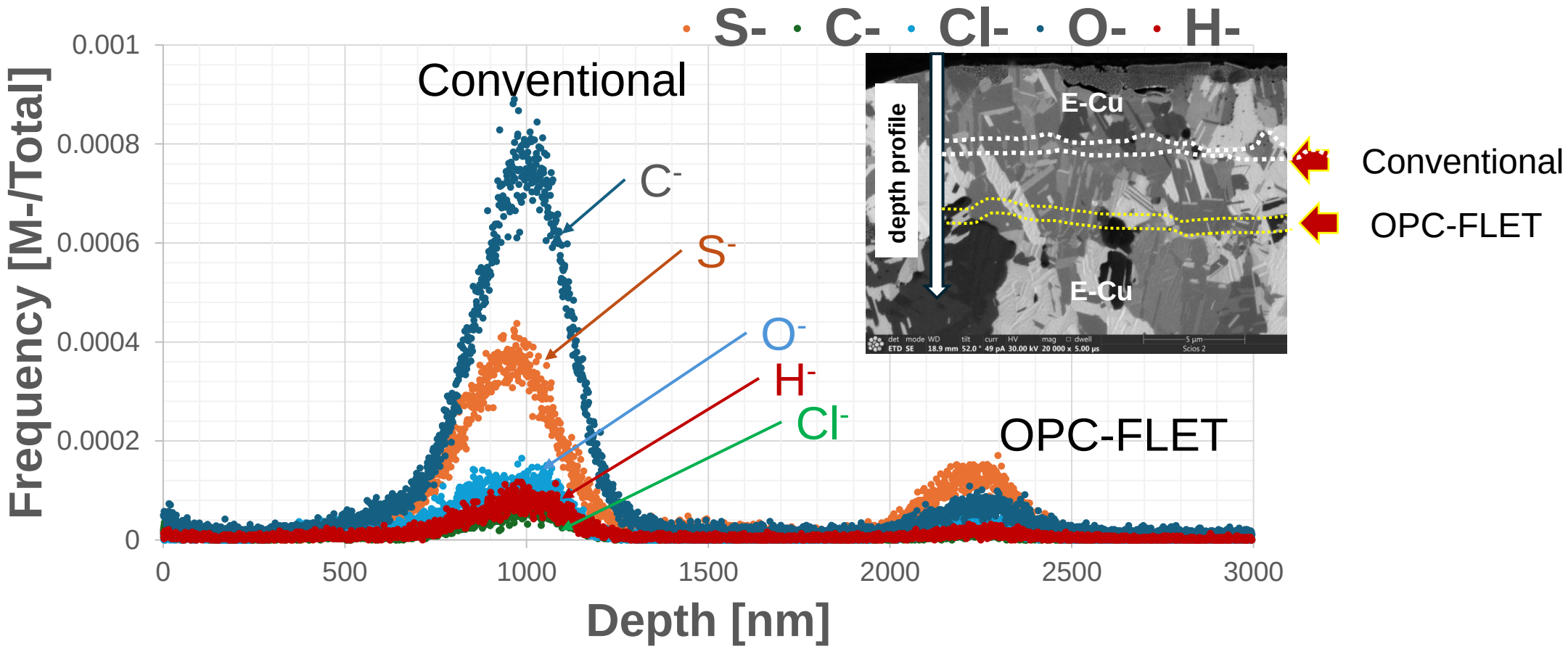
SIMS measurement across electro/electroless plated layers



- S- , C- , Cl-, O- and H- ions are high in the electroless Cu layer

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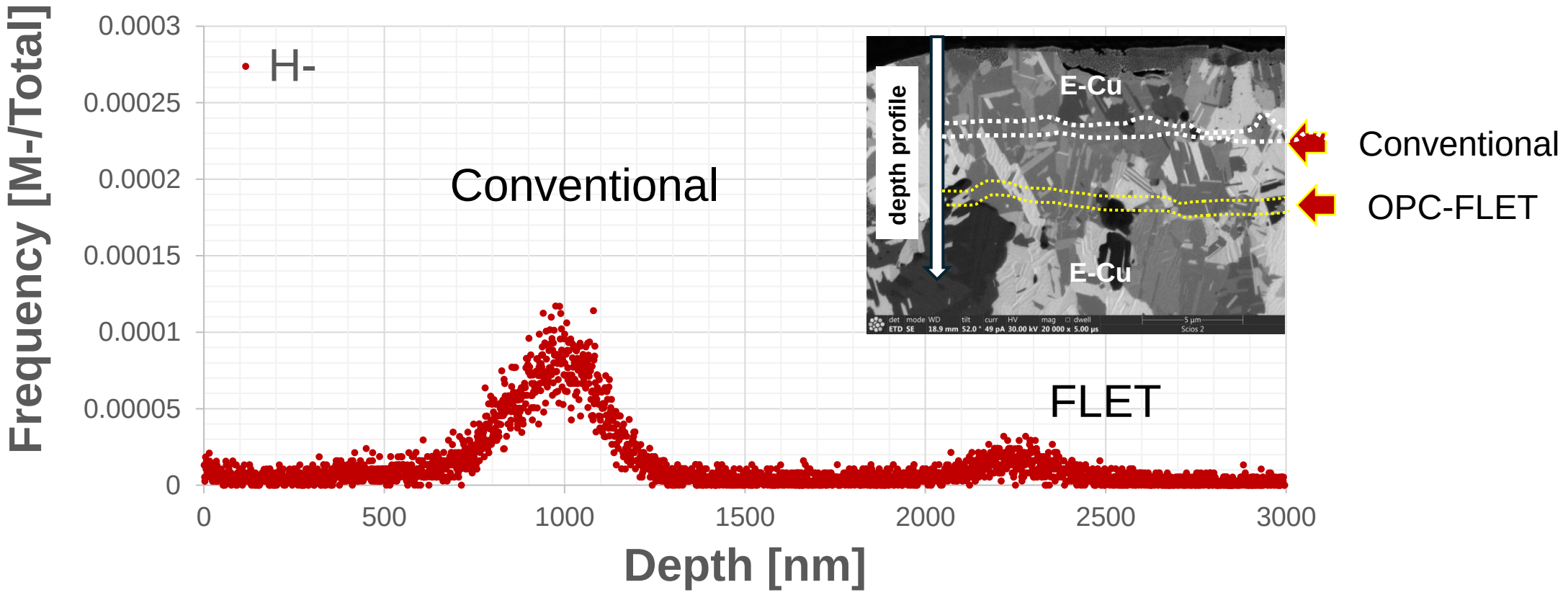
H^- profile across e-less cu layers



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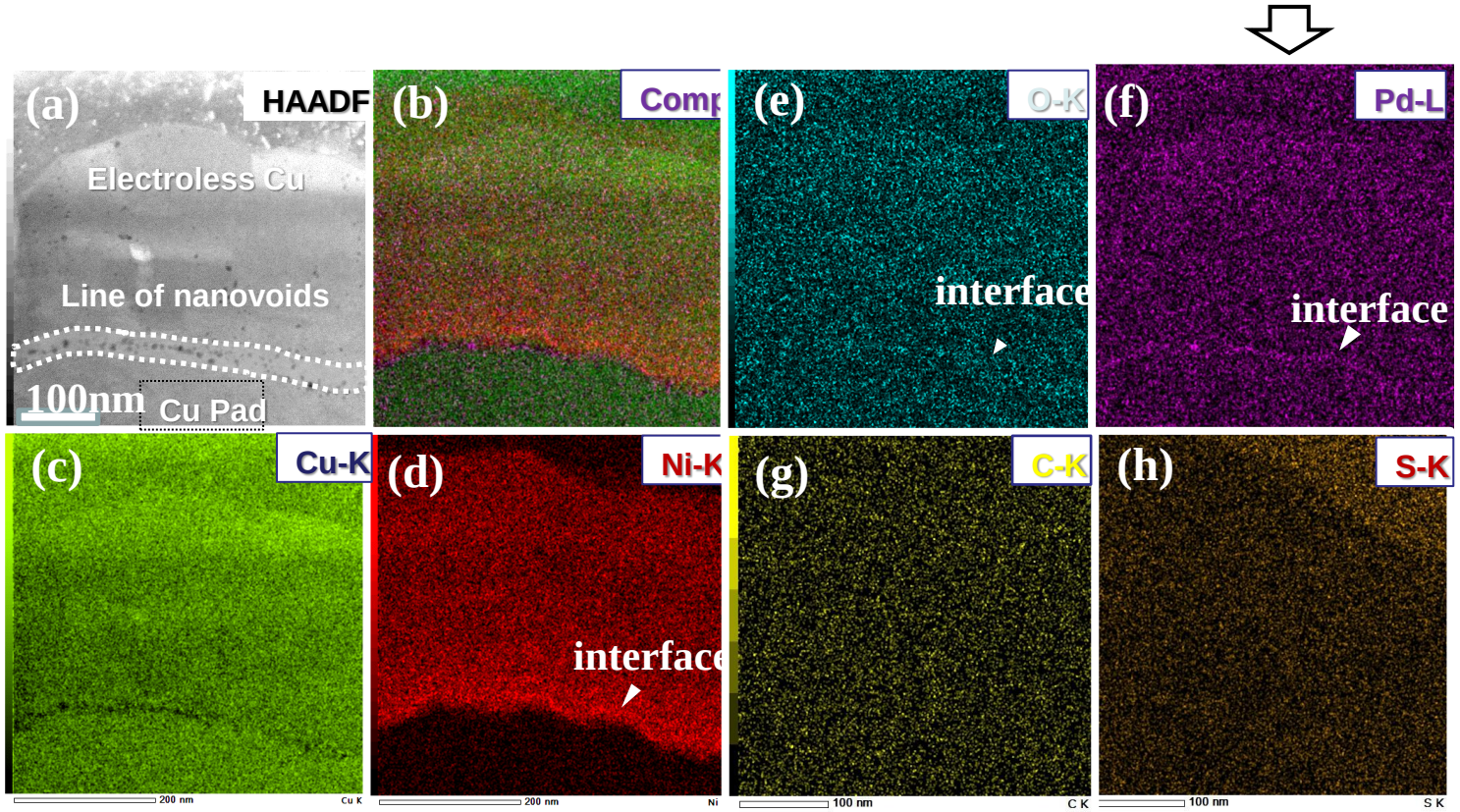
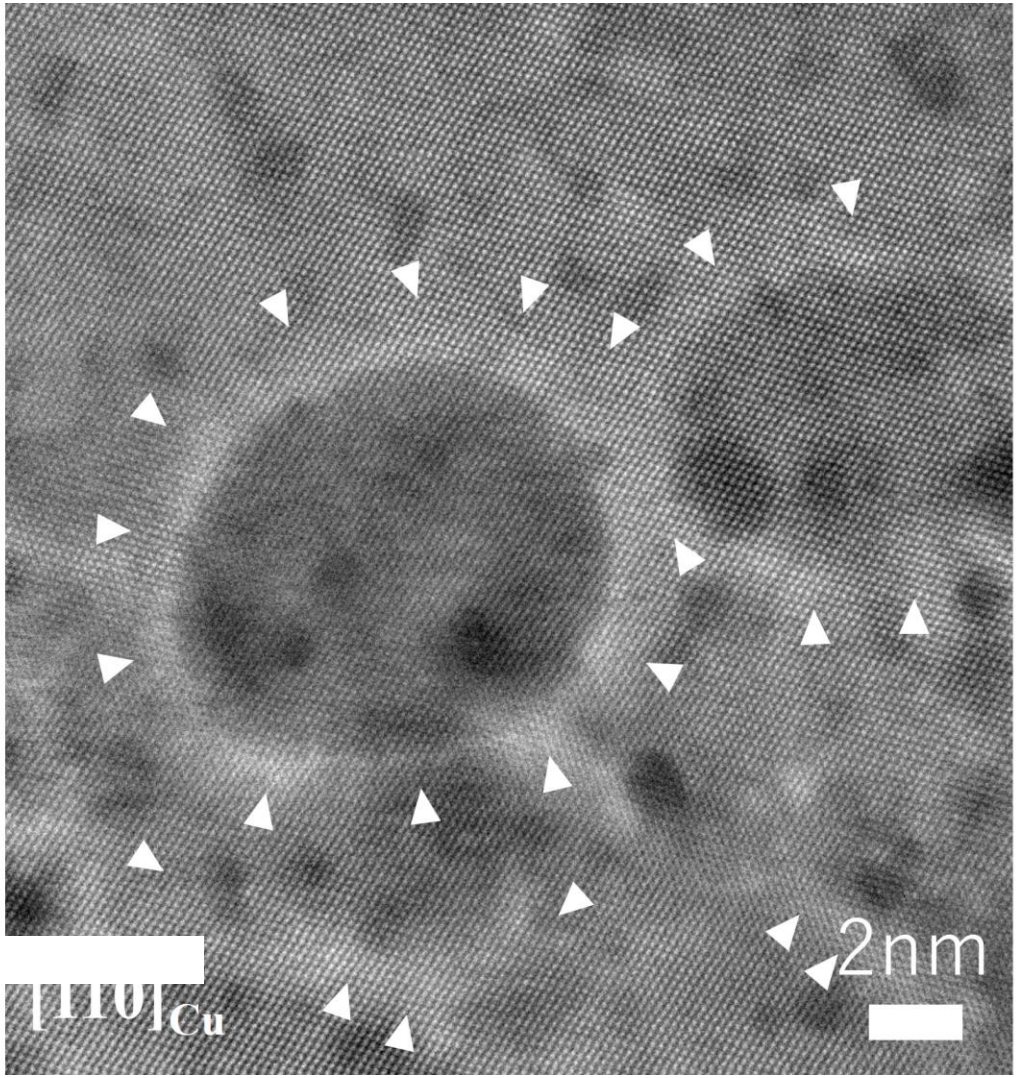
STEM-EDS maps of traditionally processed E-less Cu layer



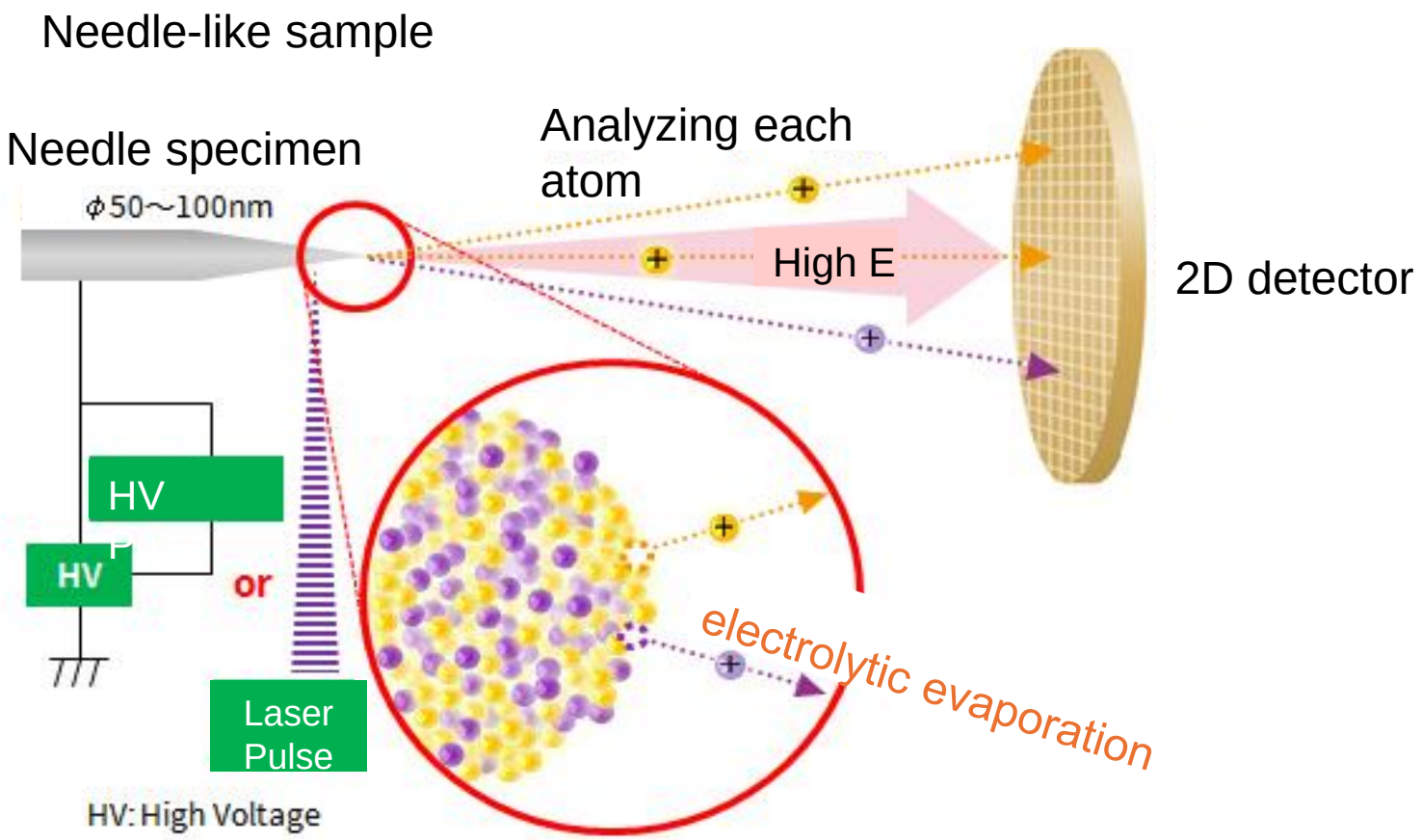


Nishijima et als, ECTC(2023)

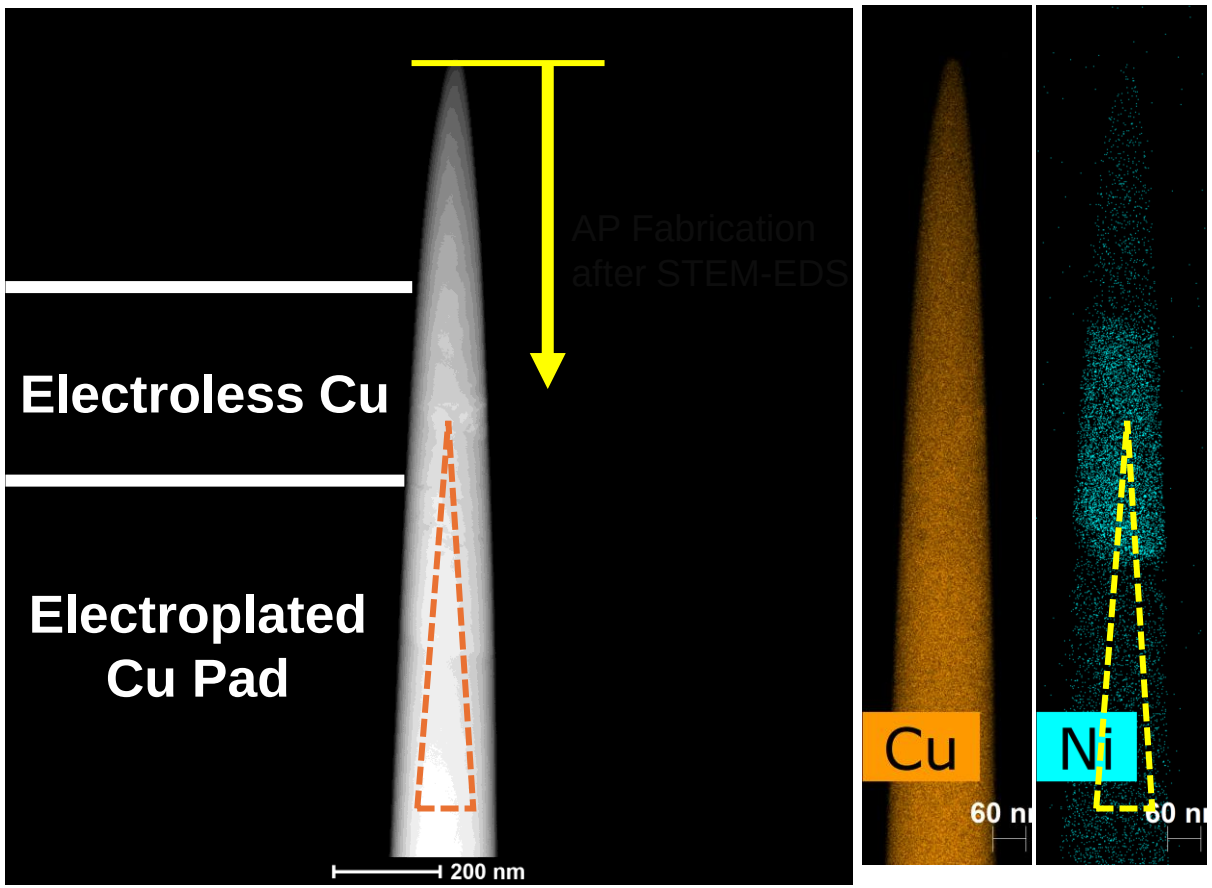
Atom Probe Tomography

1. HV is applied to a needle-like sample, a high Electric Field is generated at the tip of it, causing the field evaporation
2. The atomic arrangement of the field-evaporated ions is determined by a 2D detector.
3. The ion species is also identified based on the flight time.
4. 3D atomic distribution can be obtained and 3D arrangement reconstructed.

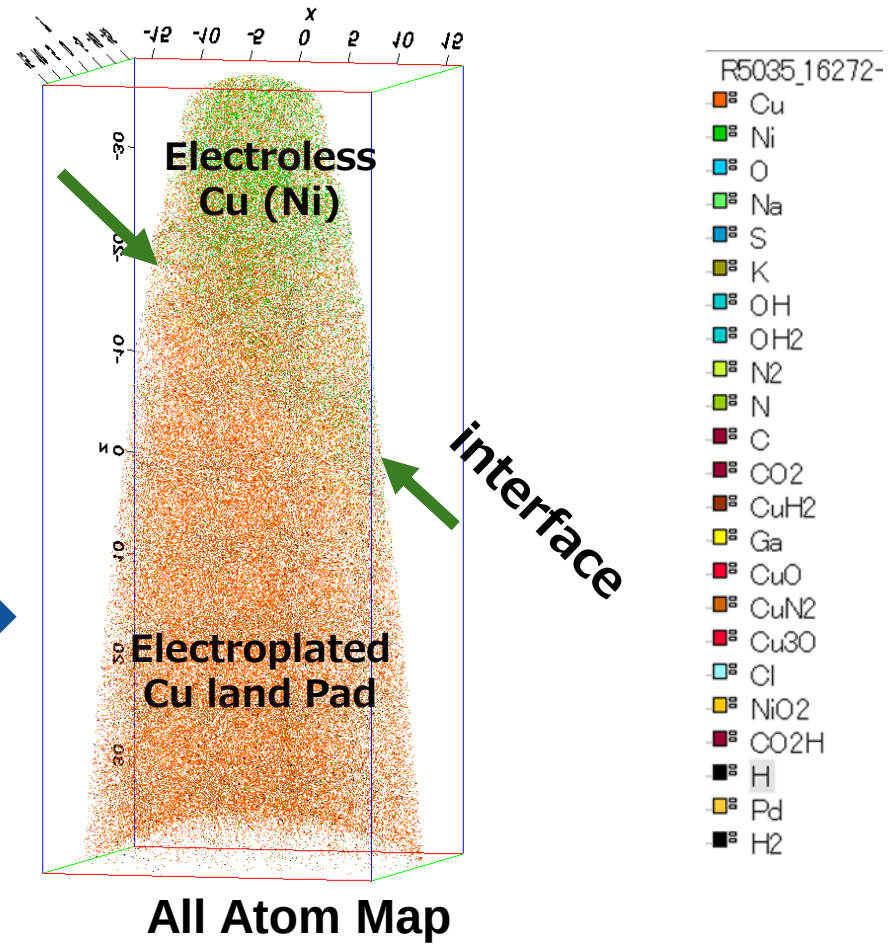
Schematic of 3DAP



Analysis for nanovoids in lower electroless layer



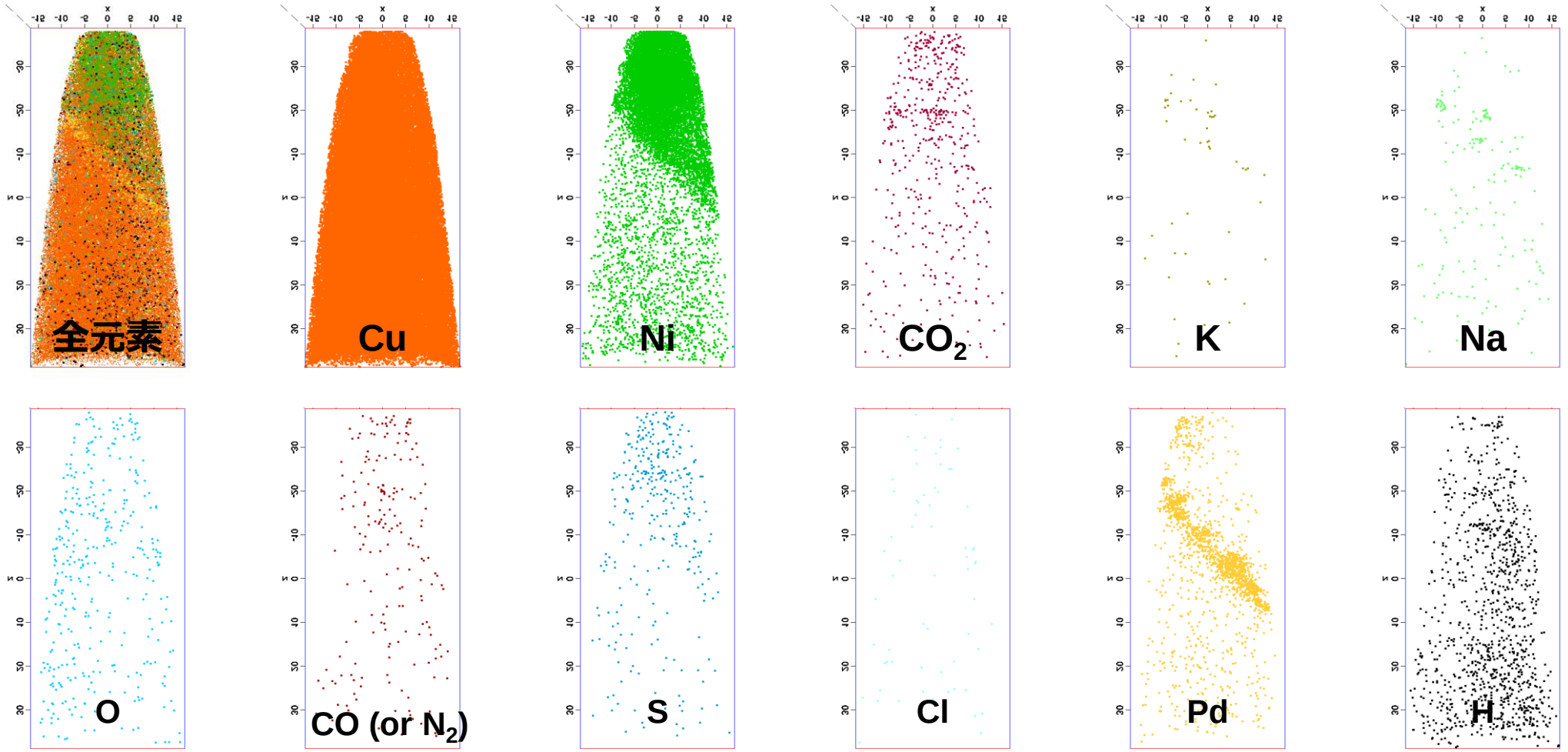
STEM Map



All Atom Map

Check the electroless layer which contains Ni element by STEM-EDS measurement and prepare needle like Atom Probe sample at the △ position by using FIB

Analysis for nanovoids in lower electroless layer



- Ni, K, Na, and Pd show characteristic distribution compared to other elements

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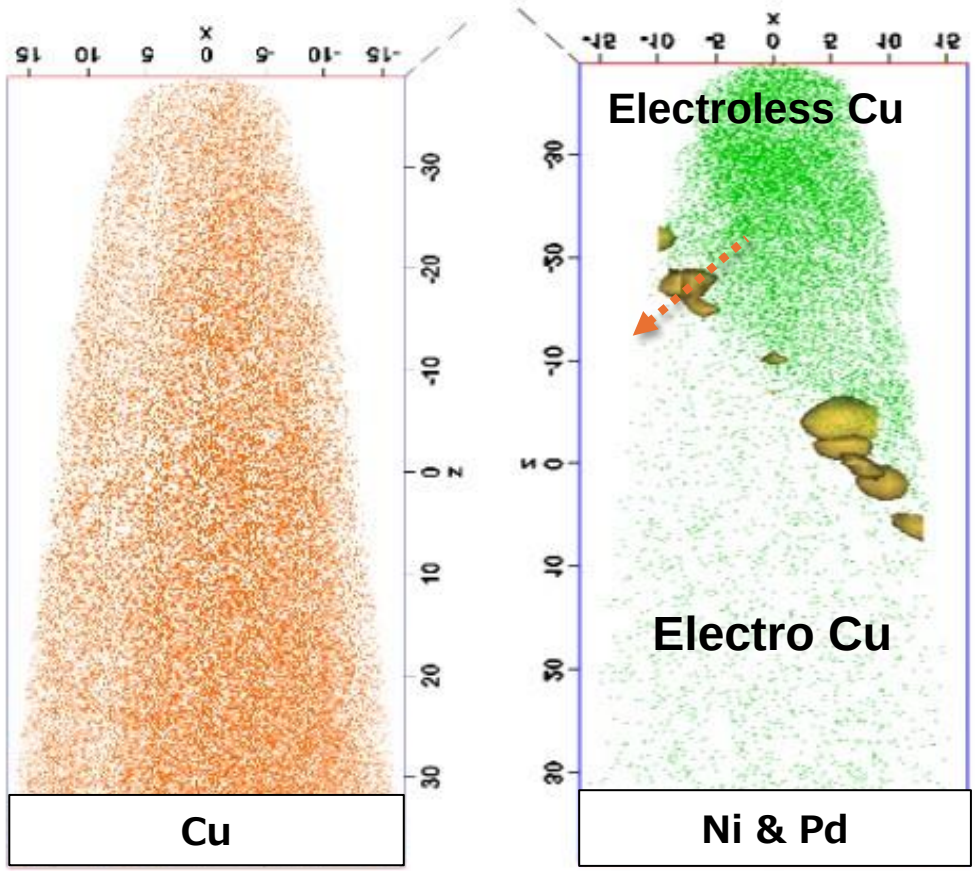
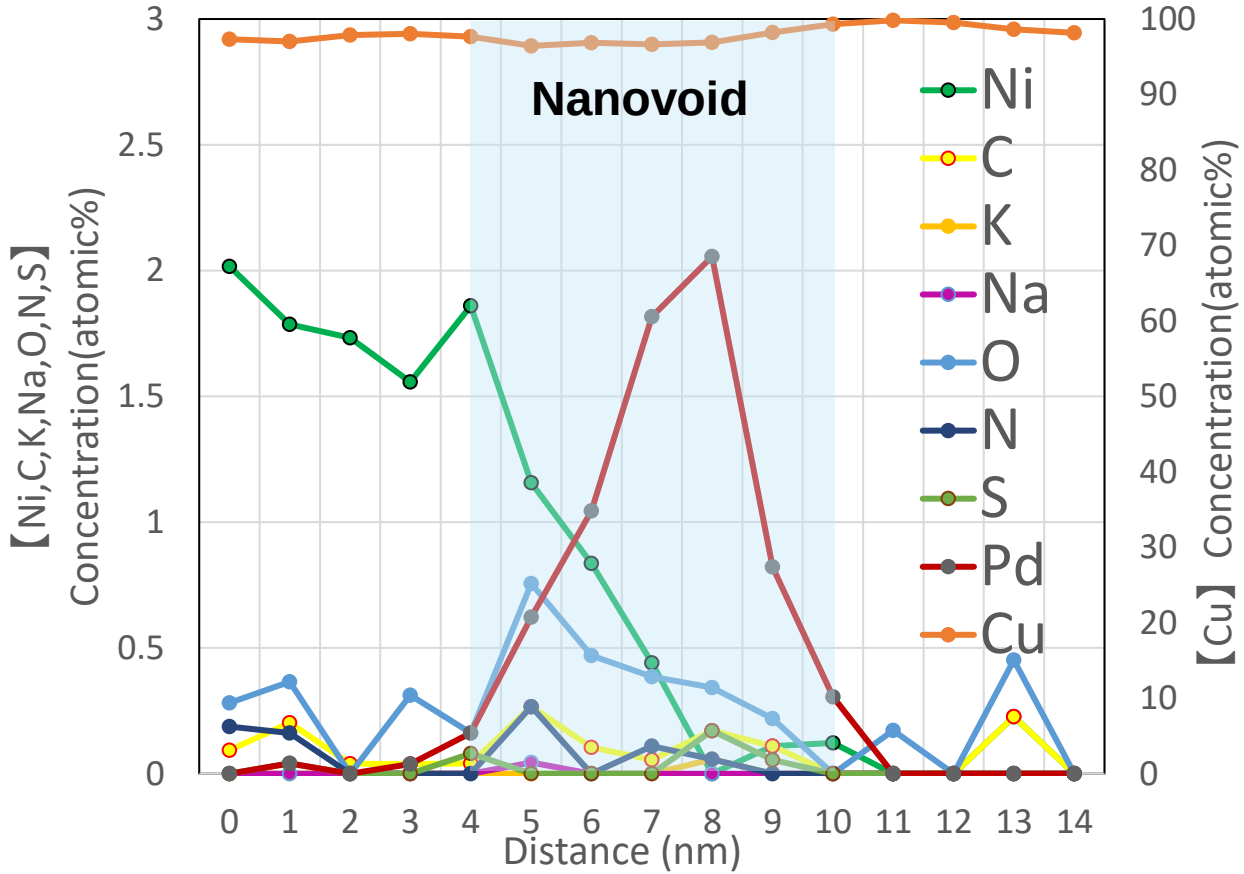
Pd across the nanovoid





atom maps of Cu, Ni and Pd by Atom Probe Tomography (APT).

Cu (Orange) and Ni (Green) elemental Maps

Iso-concentration surface of Pd (yellow ocher)

Elemental distribution of Pd-covered nanovoid

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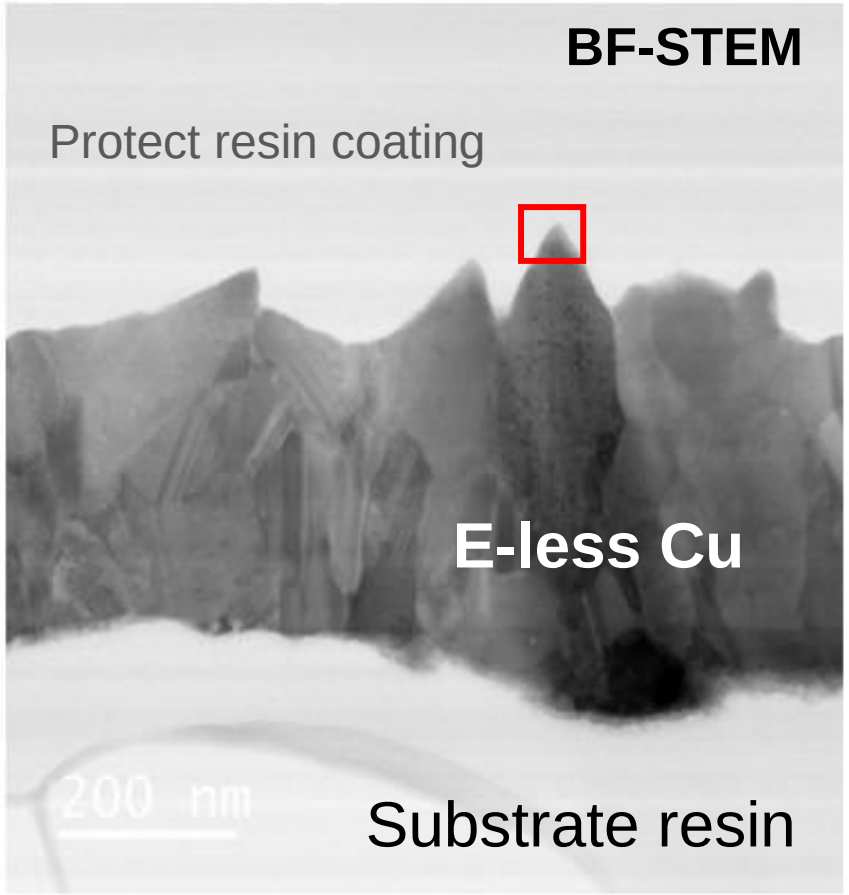
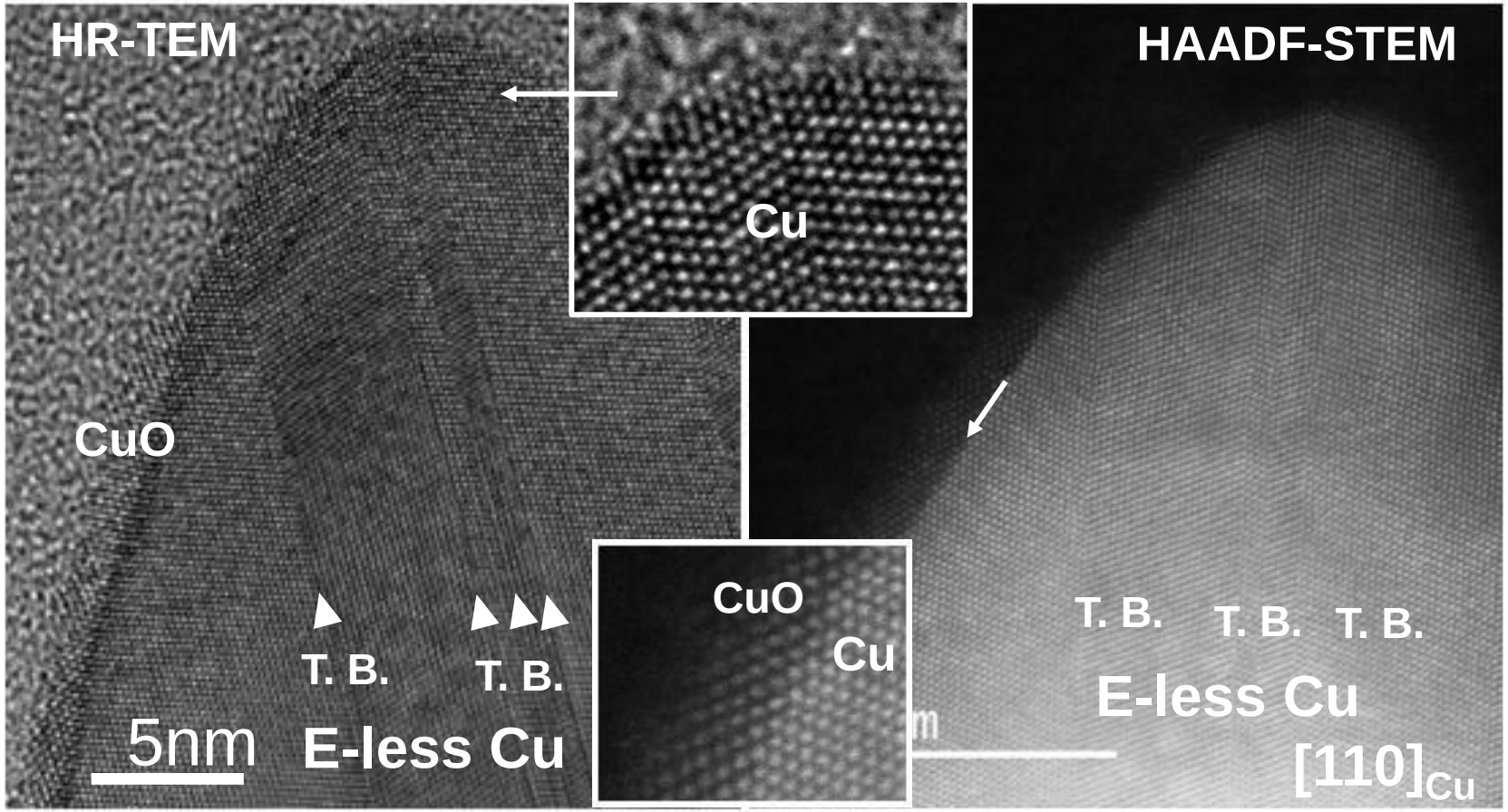
Microstructure of electroless Cu layer surface





- CuO cannot be completely removed in cleaning processes
- Residues in desmear process are not completely removed

→ Nanovoid formation

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Summary

1. FEM simulation of microvias show stress concentration at the bottom of microvia during thermal cycle test. The bottom interface corner shows highest tensile at high temperature.
2. Nanovoids at the lower interface (Pd-covered nanovoids) that are unavoidable with traditional methods also arise and co-exist. However, Pd-covered nanovoids, which can be suppressed effectively in FLET plating.
3. Atom probe tomography and ToF-SIMS show exhibit clear image of residues across electroless Cu plating. Electroless Cu layer contains trace elements, impurities. Conventional electroless Cu plating contains a lot of impurities compared to the FLET.

Thank you for your attention !

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