

New Metallization Concept for High Efficiency/Low Cost c-Si Photovoltaic Solar Cells



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● Agenda

New Concepts for High Efficiency and Low (material) Cost

□ Firing Ag Paste for Higher Efficiency

Low J_{01} → improved V_{oc} loss

Low surface concentration capability

□ Ag replacement to Cu

Low silver consumption

Low Sn diffusivity

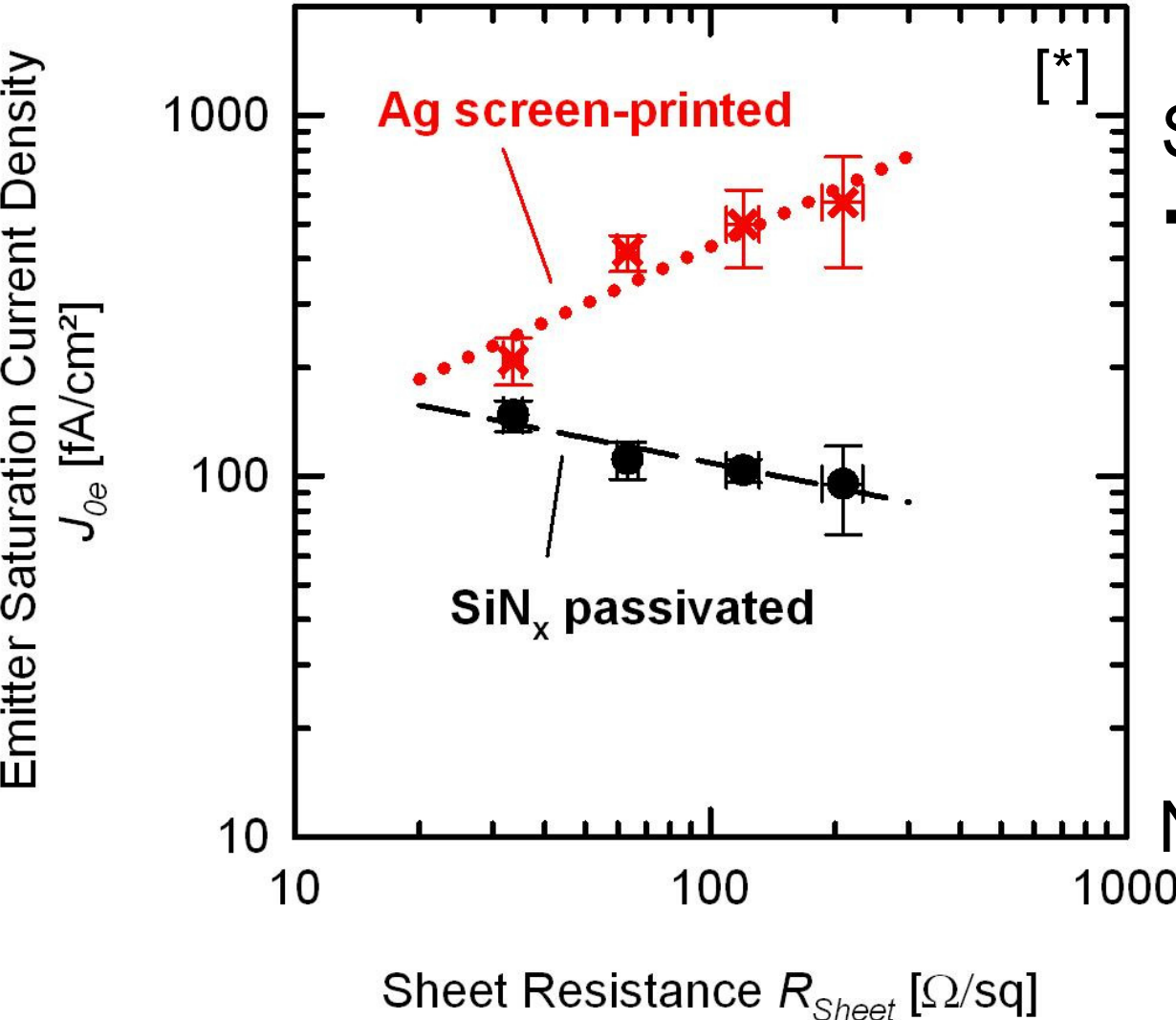


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Firing Silver Paste for High Efficiency

● Problem of Metallization



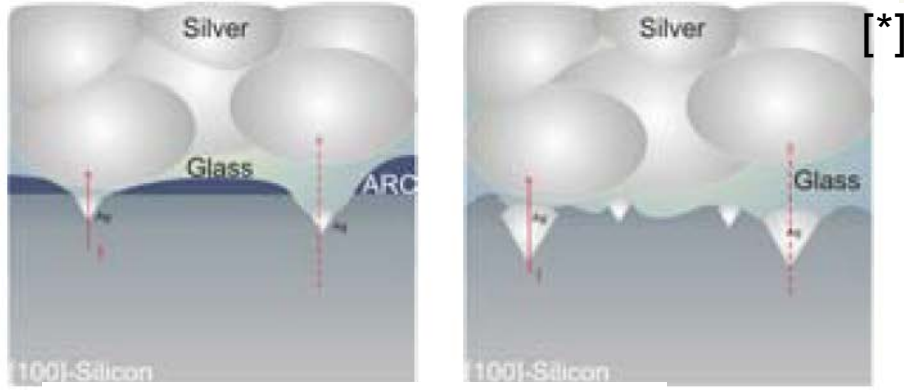
Sophisticated wafer
 → Low J_{0e}
 = High V_{oc}

Metallization
 → inc. J_{0e}
 = high V_{oc} loss

NOT sophisticated!!

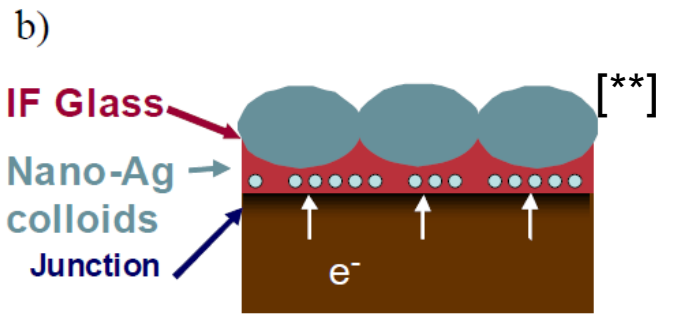
[*] H. Hannebauer et al.,
 Proceedings of 27th EU-PVSEC, 2012

● Contact Formation



- ❑ Etching SiN_x:H layer
- ❑ Forming Ag crystallites on emitter
- ❑ Thin glass frit layer
- ❑ Colloidal Ag in glass


 Contribute to contact



- ✓ Emitter surface exposed to glass layer
- ✓ NO passivation underneath the fingers

[*]G. Schbert, Doctral Thesis, University of Konstanz, Germany, 2006

[**]L. K. Cheng et al., DuPont Technical Paper

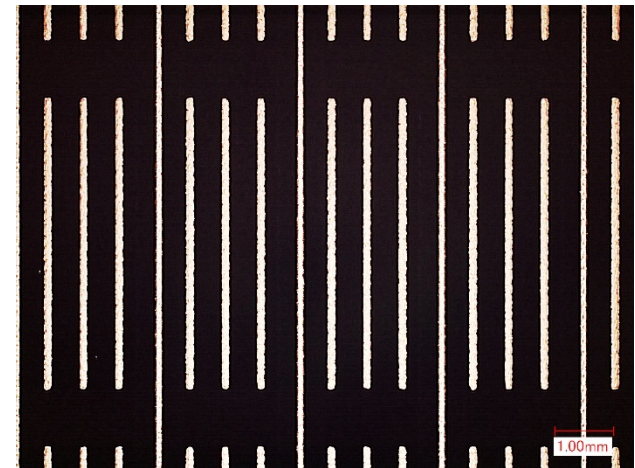
● Concept

Indirect contact formation by Screen Printed Thick Film Technology

- Low J_{01} = Higher V_{oc}
- Enough low ρ_c = Same FF
- Make electrical contact with
low surface concentration
(ex. N_D : 10^{19} cm^{-3} order)

● Evaluation

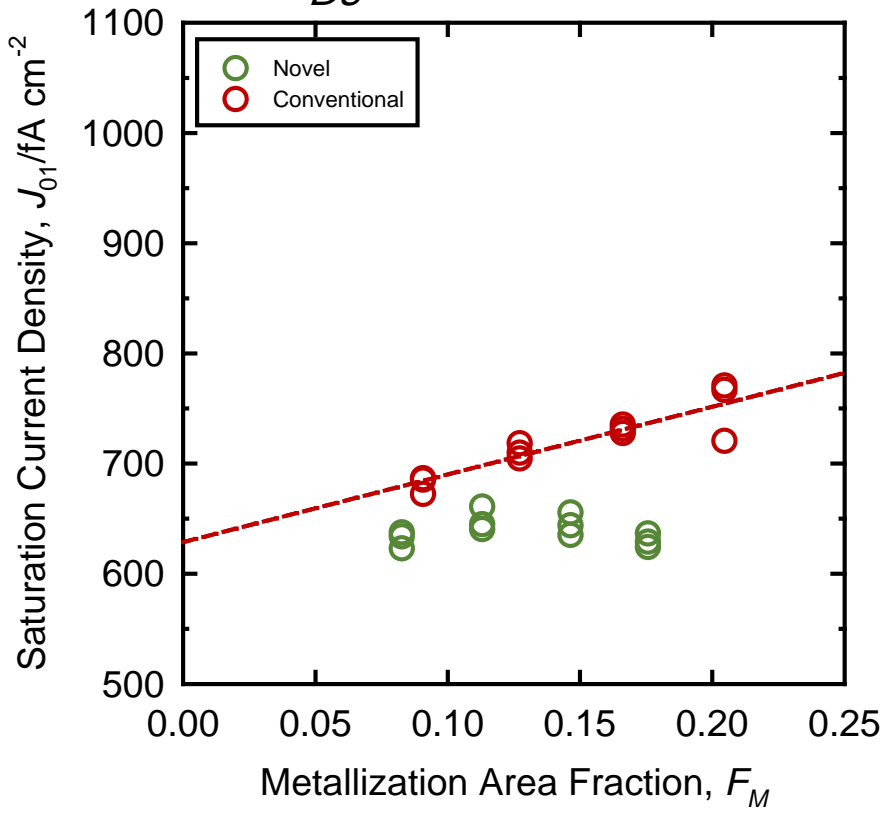
- ❑ Low J_{01} → improved V_{oc} loss
- ❑ Low surface concentration capability
 - ✓ $8 \times 10^{19} \text{ cm}^{-3}$ & $2 \times 10^{20} \text{ cm}^{-3}$ @ surface
(tex. wafer, $156 \times 156 \text{ mm}$)
 - ✓ Metallization fraction, F_M vs J_{01} [*]
 - ✓ $100 \mu\text{m}$, 64 fingers (for H pattern)
 - ✓ $100 \mu\text{m}$, 5 mm intermediate fingers
 - ✓ Full area Al-BSF
 - ✓ Firing at $800 \text{ }^\circ\text{C}$ peak



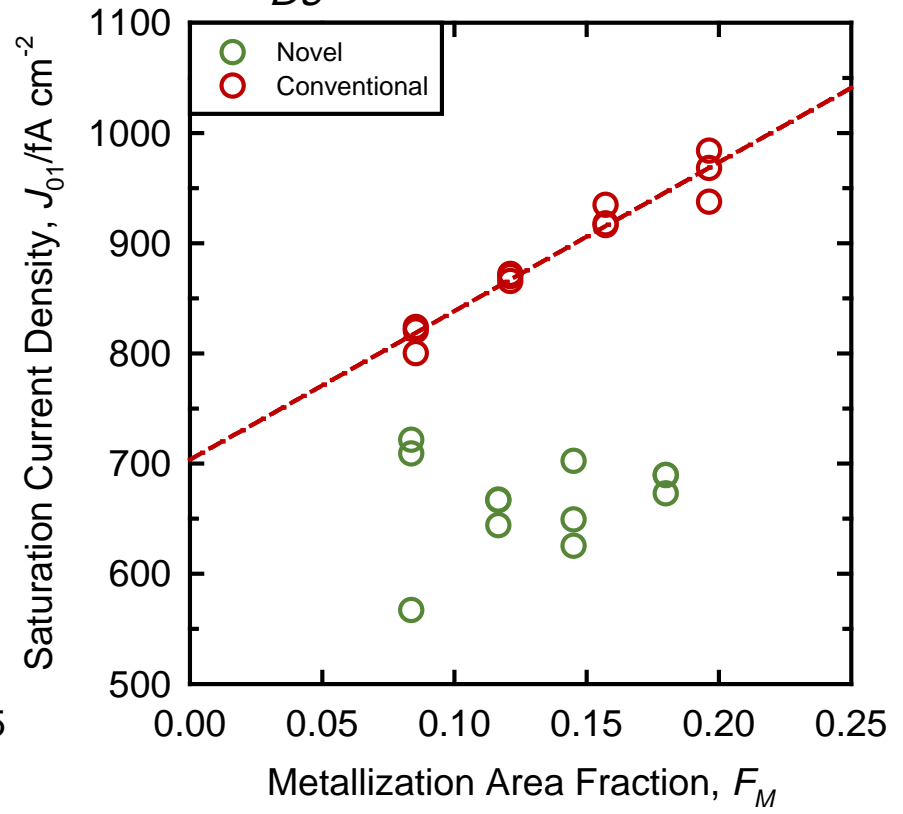
[*] T. Fellmeth et al., Energy Procedia, 8 (2011) 115-121

F_M vs j_{01} - R_{sheet} dependence-

Wafer 95 $\Omega/sq.$
 $N_{Ds} \approx 2 \times 10^{20} \text{ cm}^{-3}$



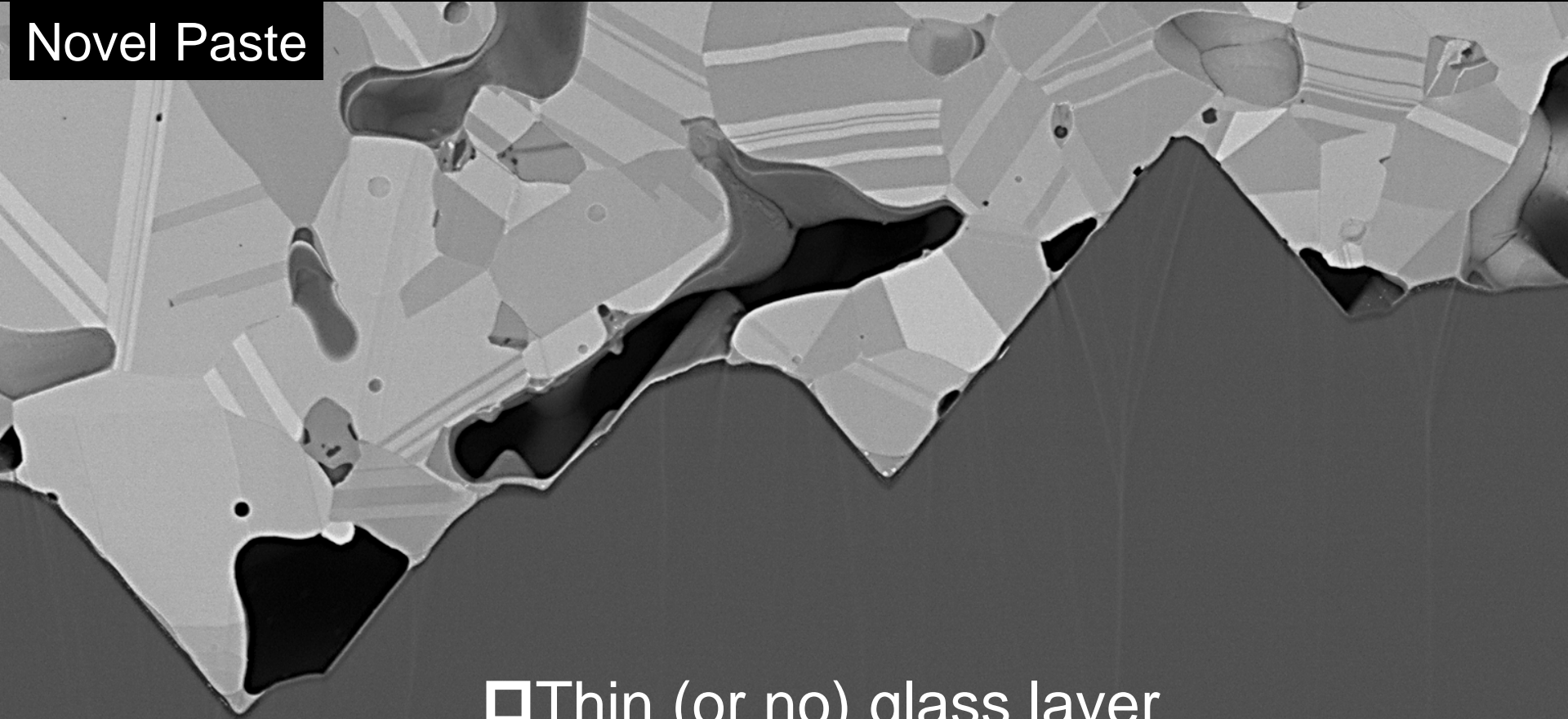
Wafer 130 $\Omega/sq.$
 $N_{Ds} \approx 8 \times 10^{19} \text{ cm}^{-3}$



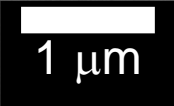
Cross Section View [FE-SEM]

- Commercial Emitter Wafer Test -

Novel Paste



- Thin (or no) glass layer
- No silver crystallite
- Remain the passivation?



● Interface Analysis



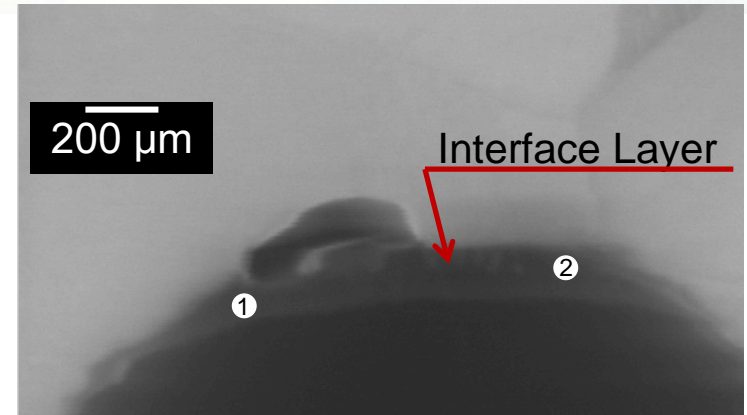
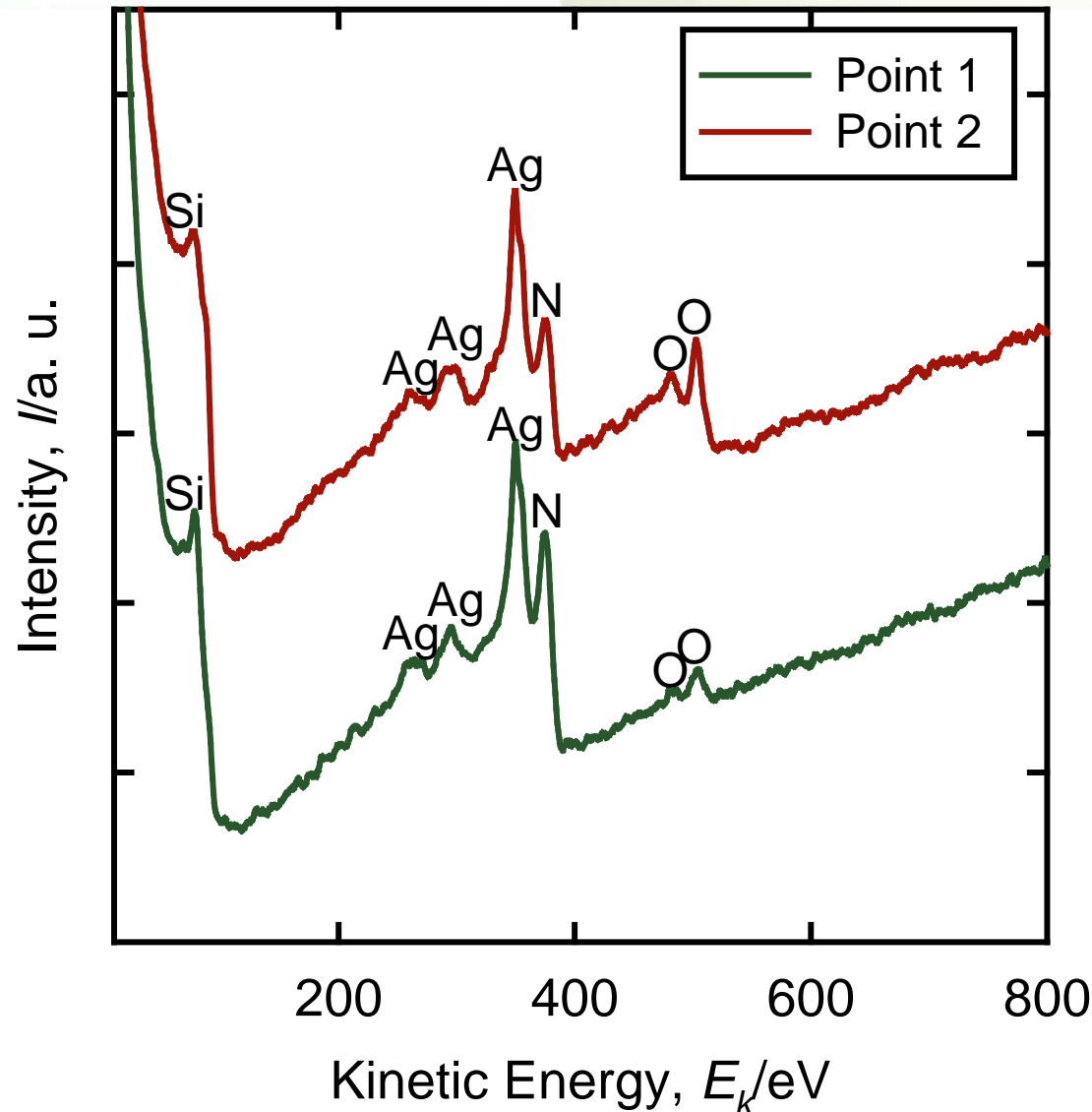
Ag

- Colloidal particle
 - Ag side (O rich region)
- Not visible metal (Ag)
 - Si side (N rich region)?

Si

100 nm

Interface Analysis



$\text{SiN}_x\text{:H}$

→ partially oxidized

Ag side

→ higher O content

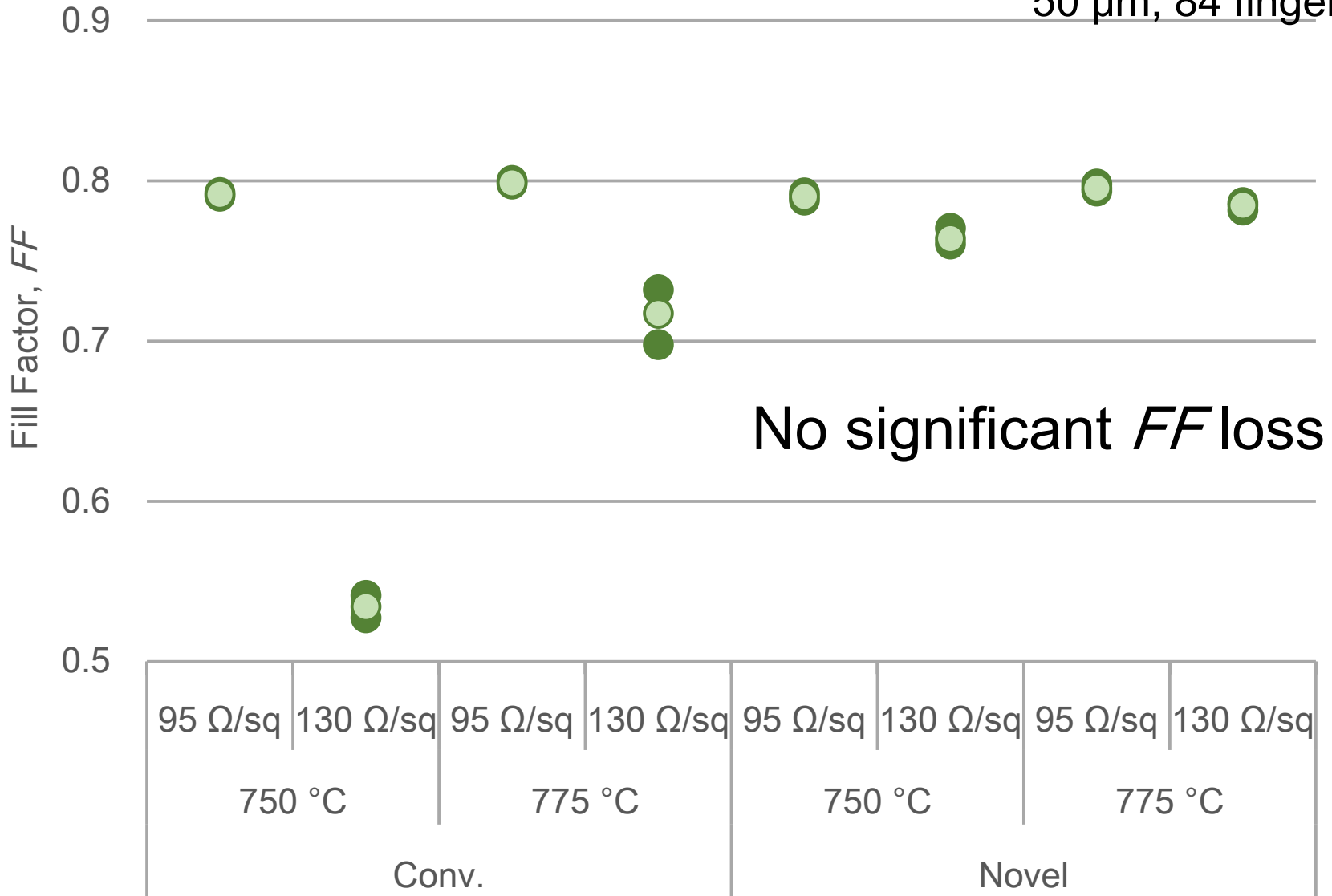
Si side

→ lower O content

Cell Level Test

- Fill Factor, *FF* -

50 μm , 84 fingers

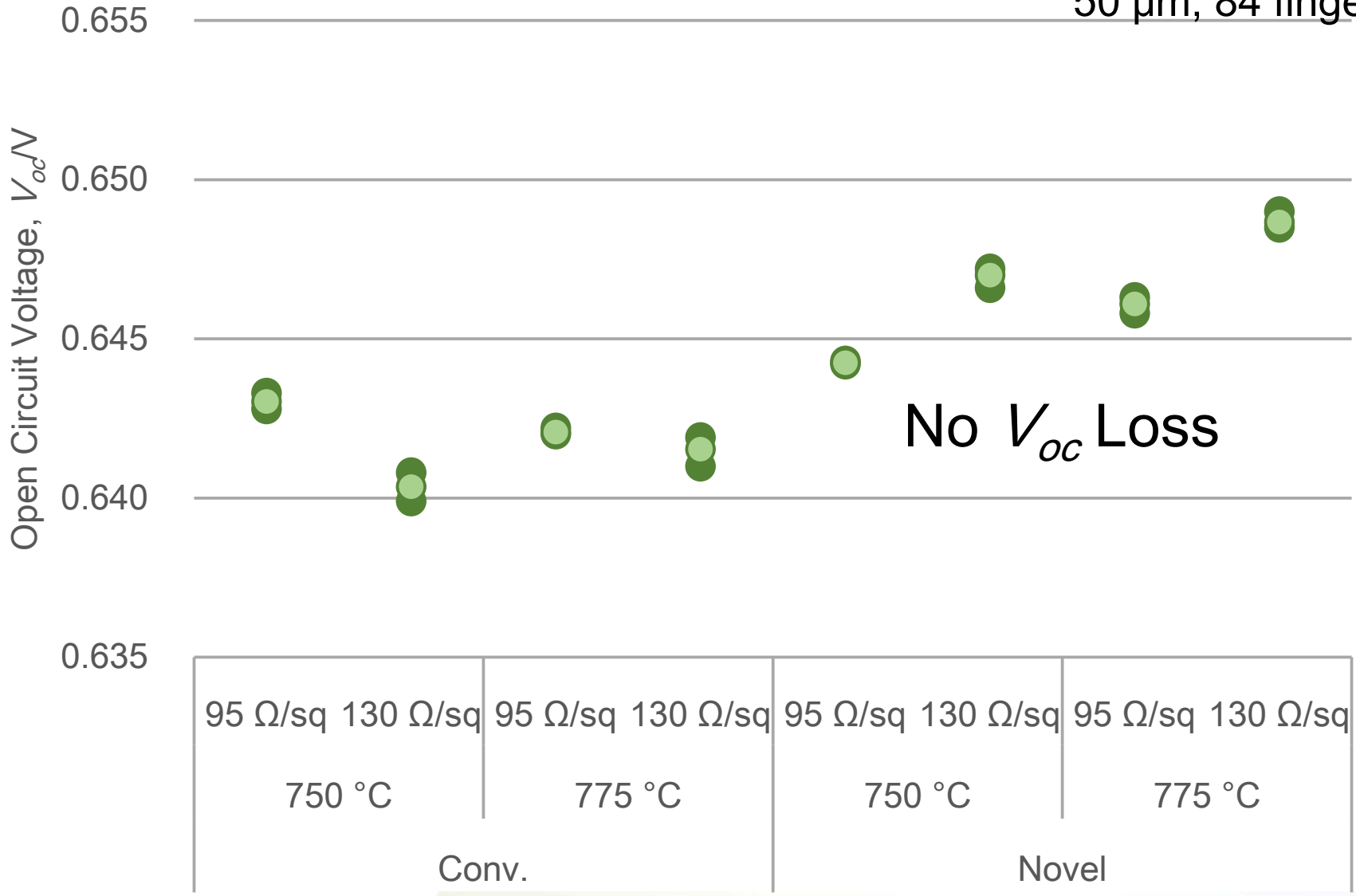


No significant *FF* loss

Cell Level Test

- Fill Factor, *FF* -

50 μm , 84 fingers



● Summary of Silver Paste

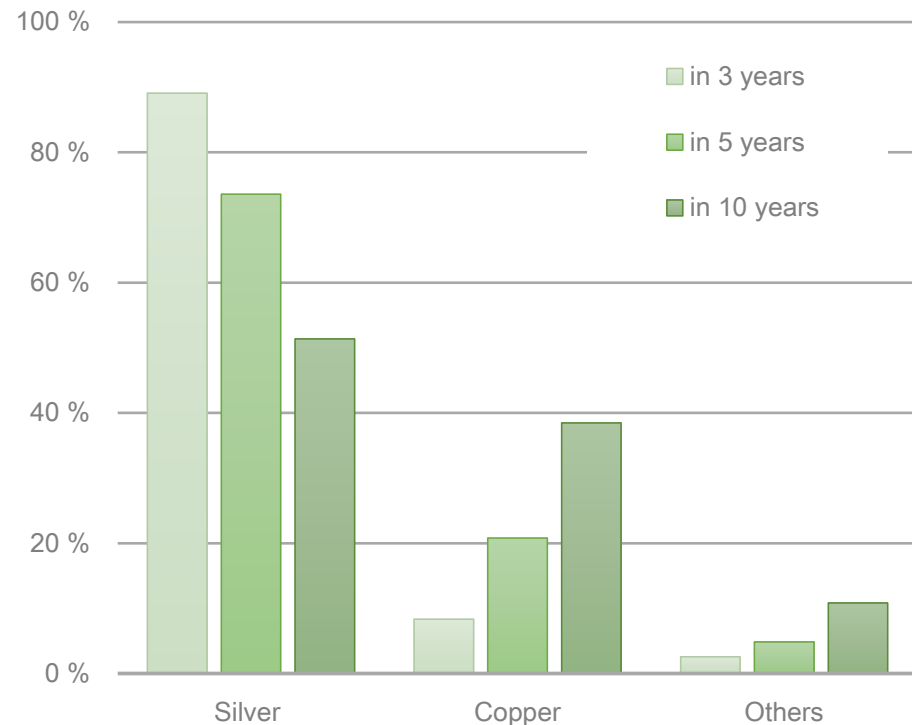
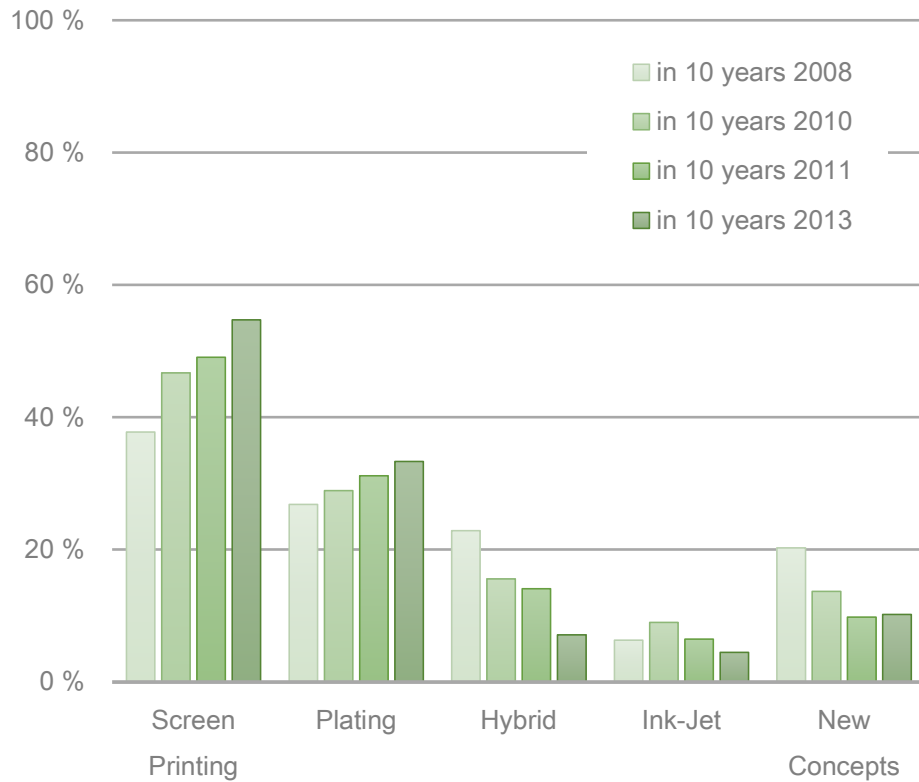
- Novel “Fire-Through” silver paste showed quite positive effect for J_{01} at low surface concentration.
- Colloidal silver dispersed interface layer might be assist electron conduction.
- Interface layer might prevent the defect formation on Si surface and prevent surface recombination.



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Silver Replacement

Demand

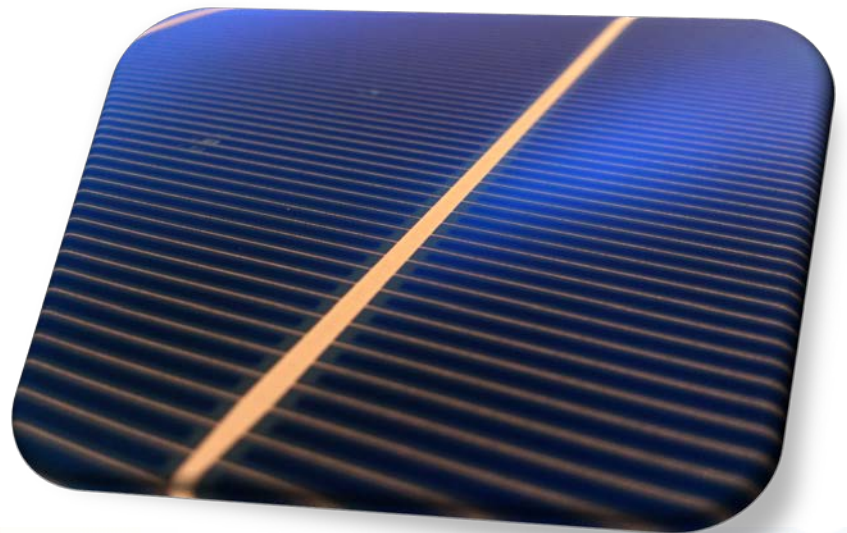
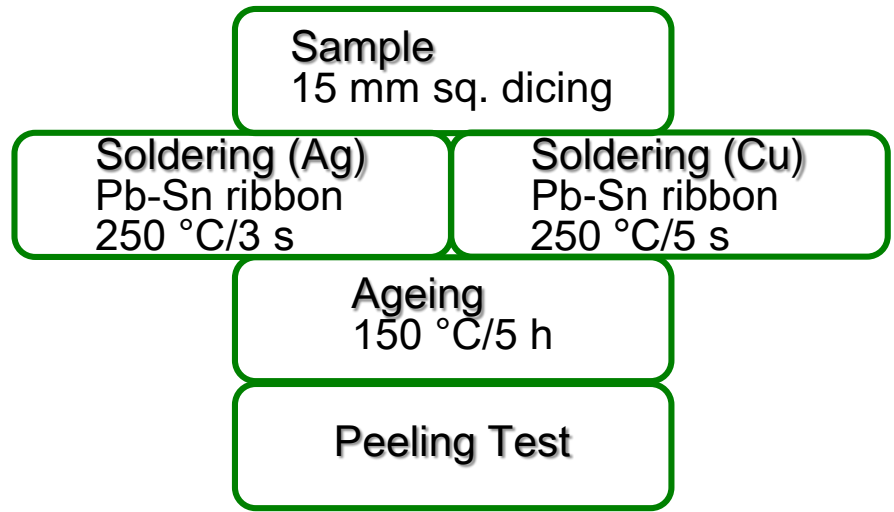
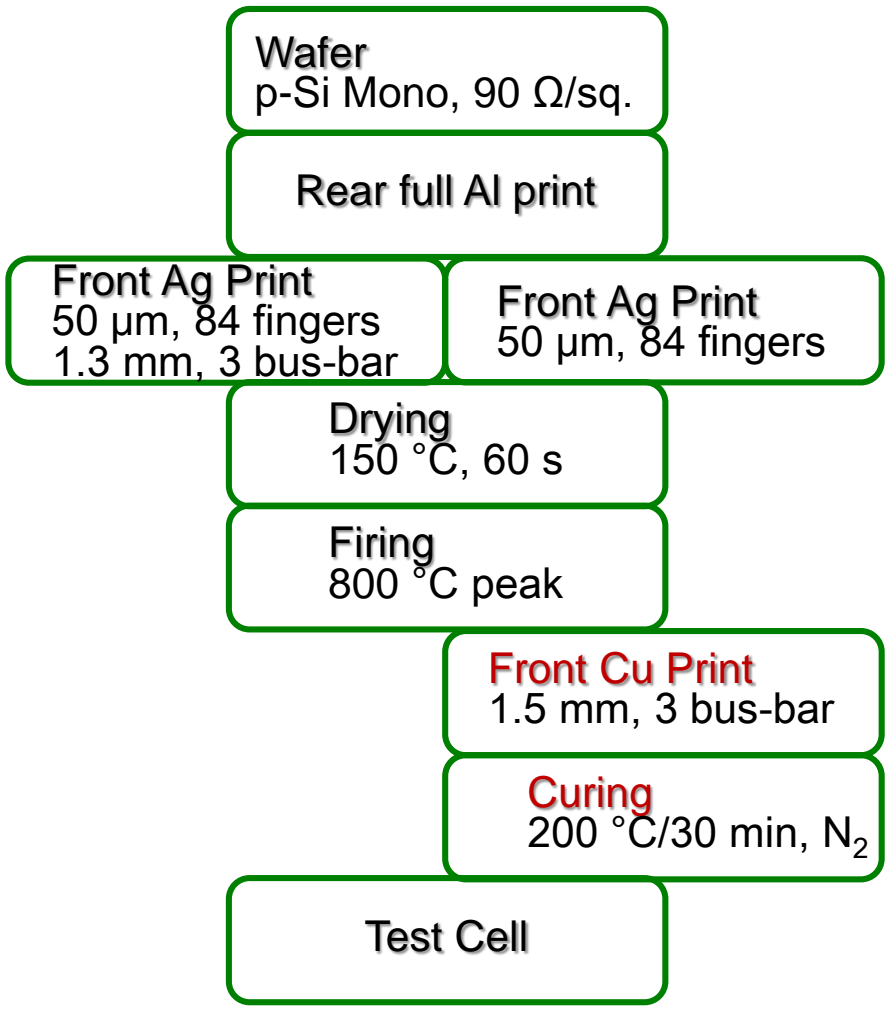


Screen Printing Technology with Silver Replacement !

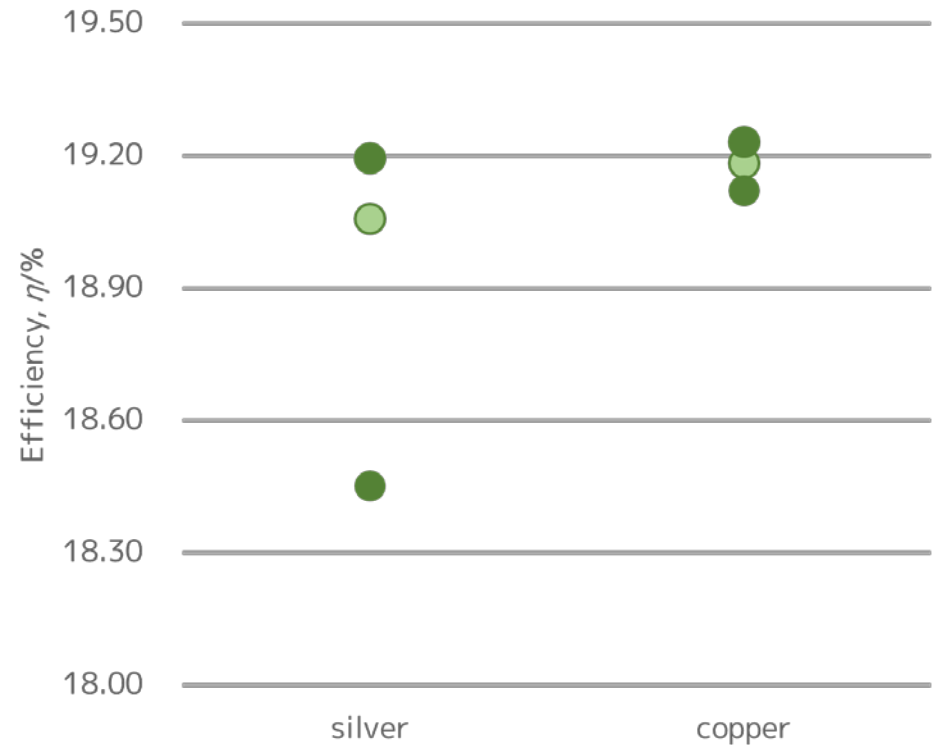
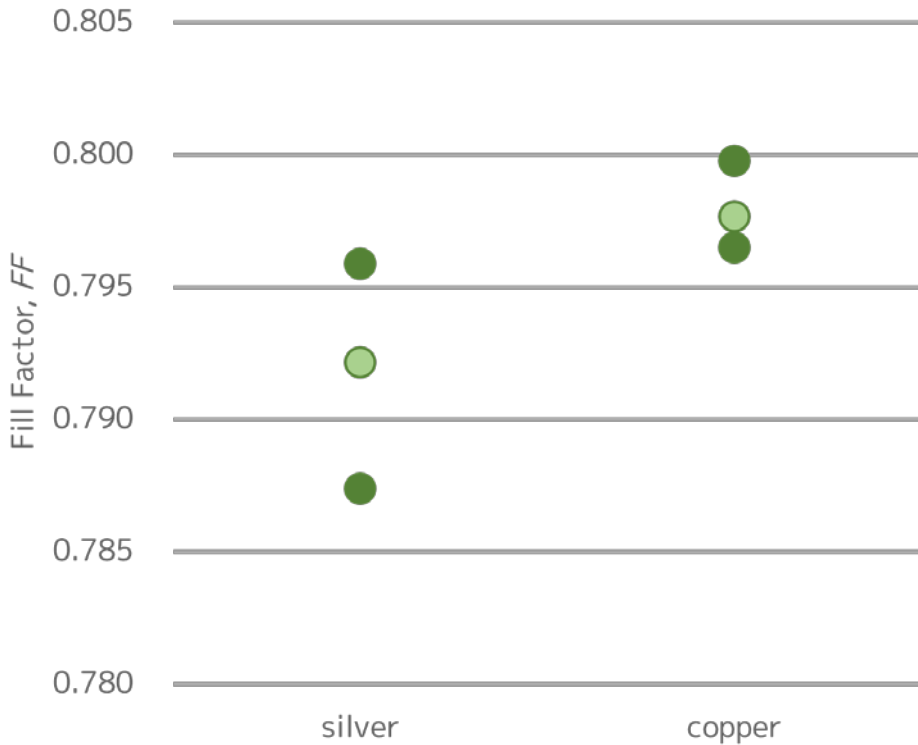
1st step → Copper Bus Bar

[*]G. Schubert et al., Energy Procedia, 43 (2013) 12-17

● Test Process

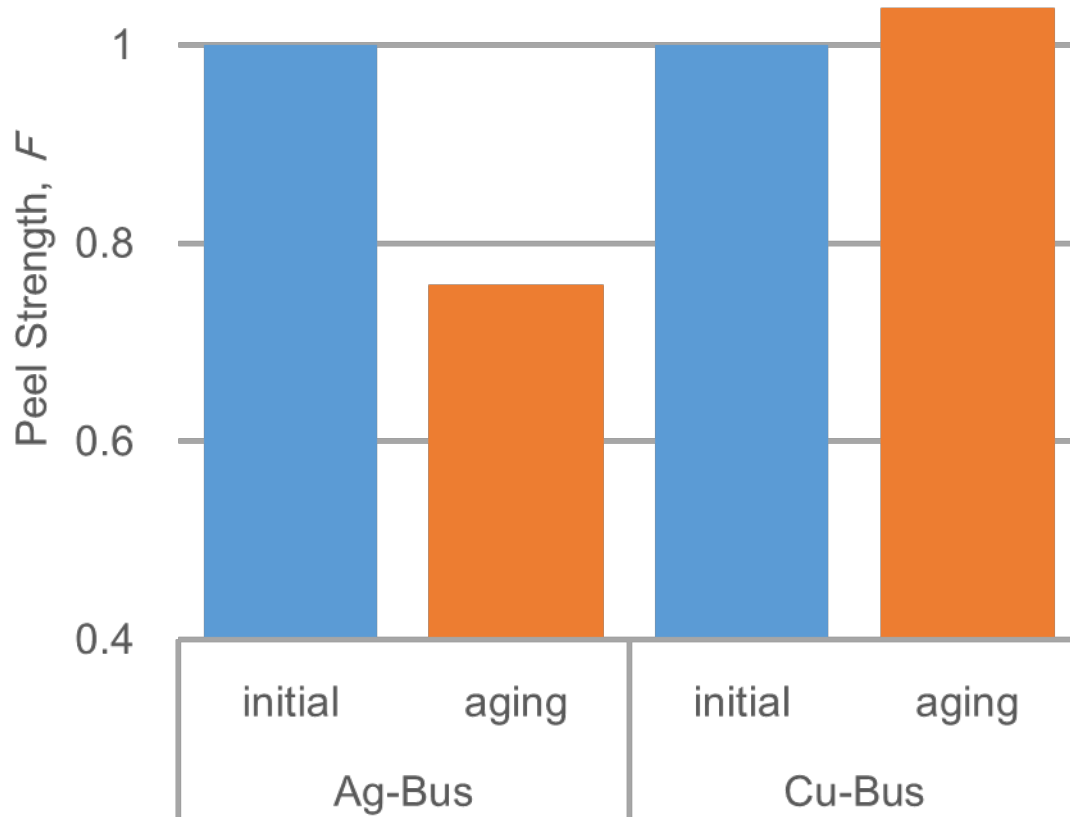


● IV Results



No negative effects on cell level !!

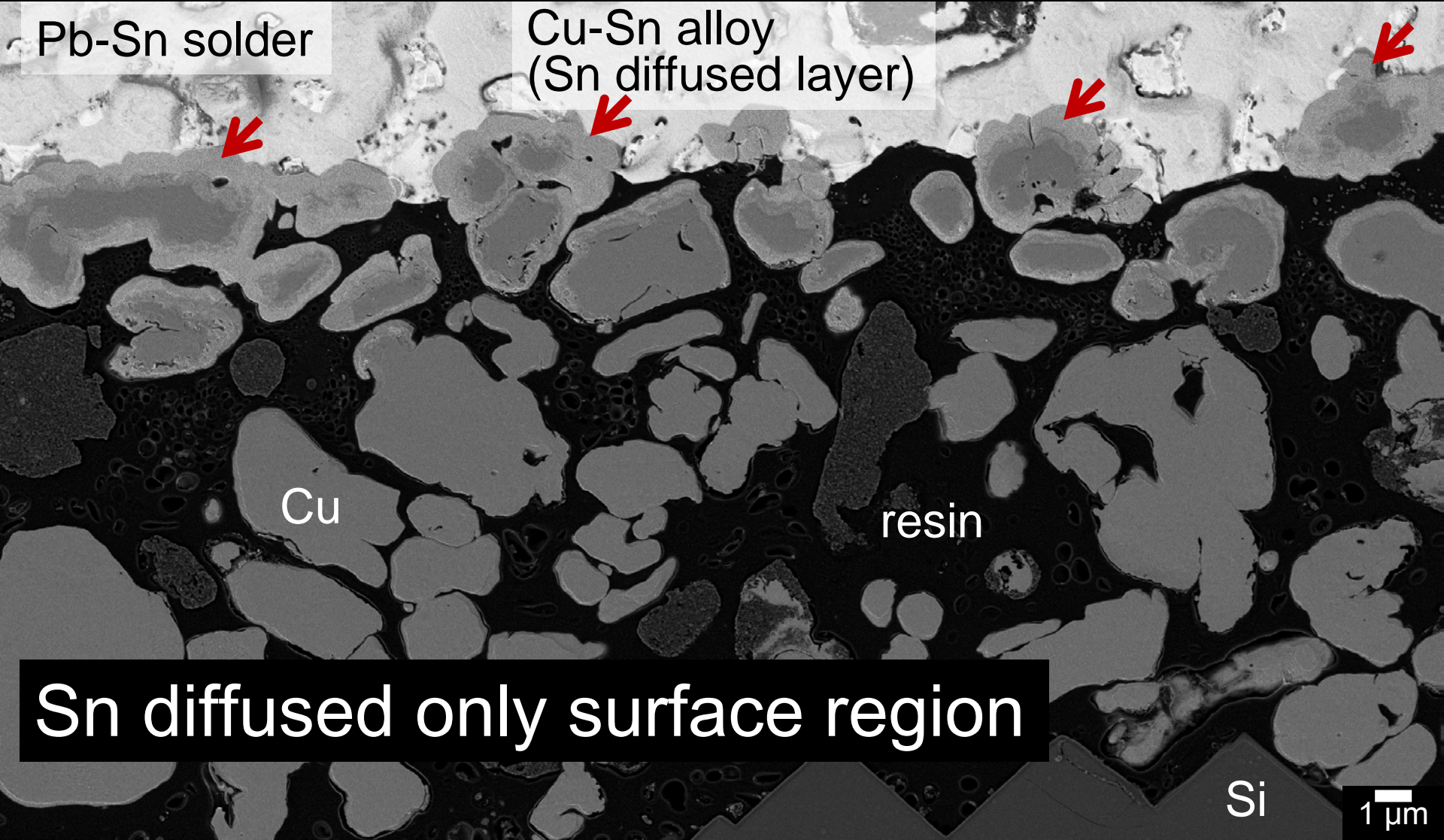
● Peeling Strength



Peeling strength
@ after ageing
No negative impact

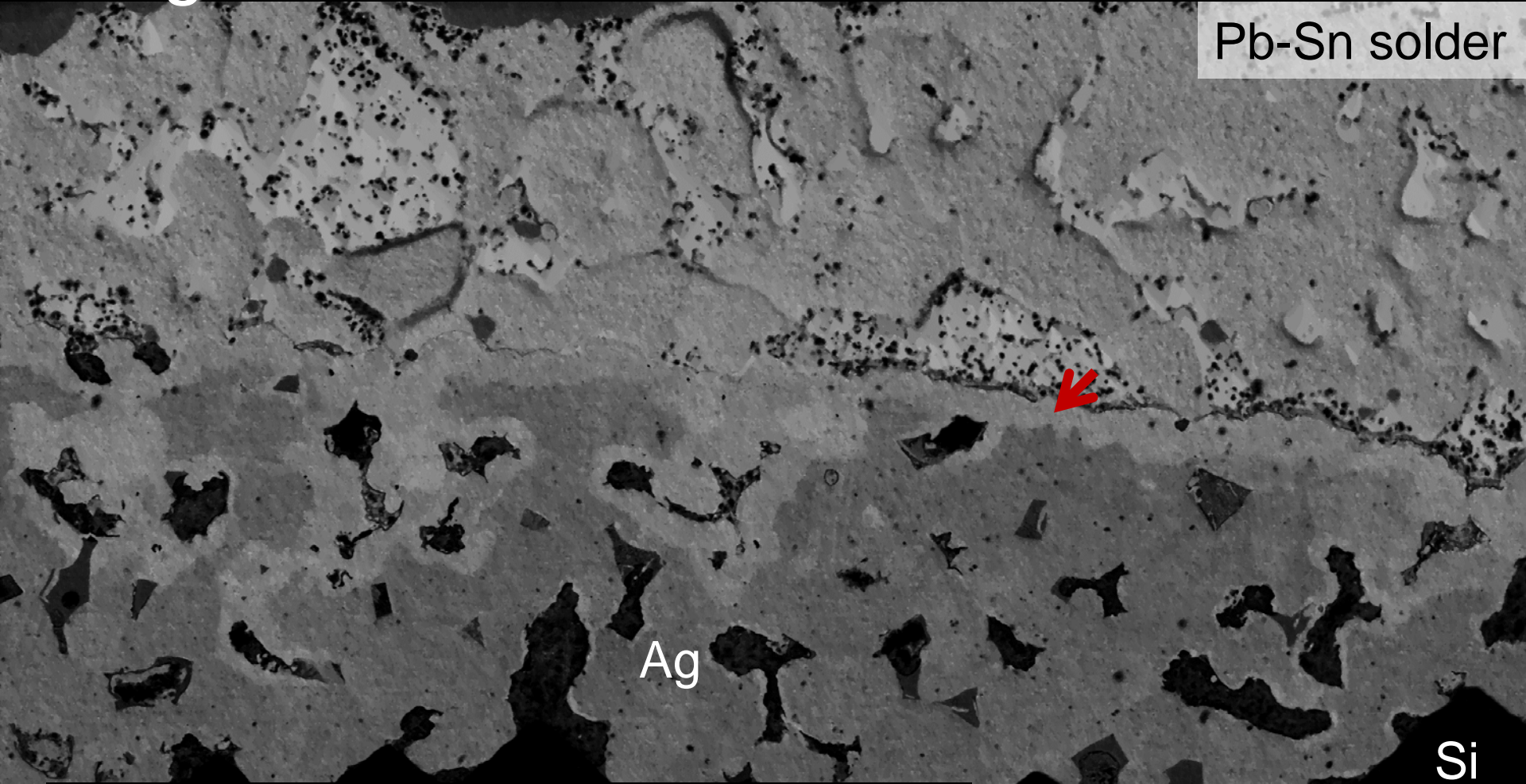
After ageing cross section

-Cu bus-



Sn diffused only surface region

After ageing cross section -Ag bus-



Pb-Sn solder

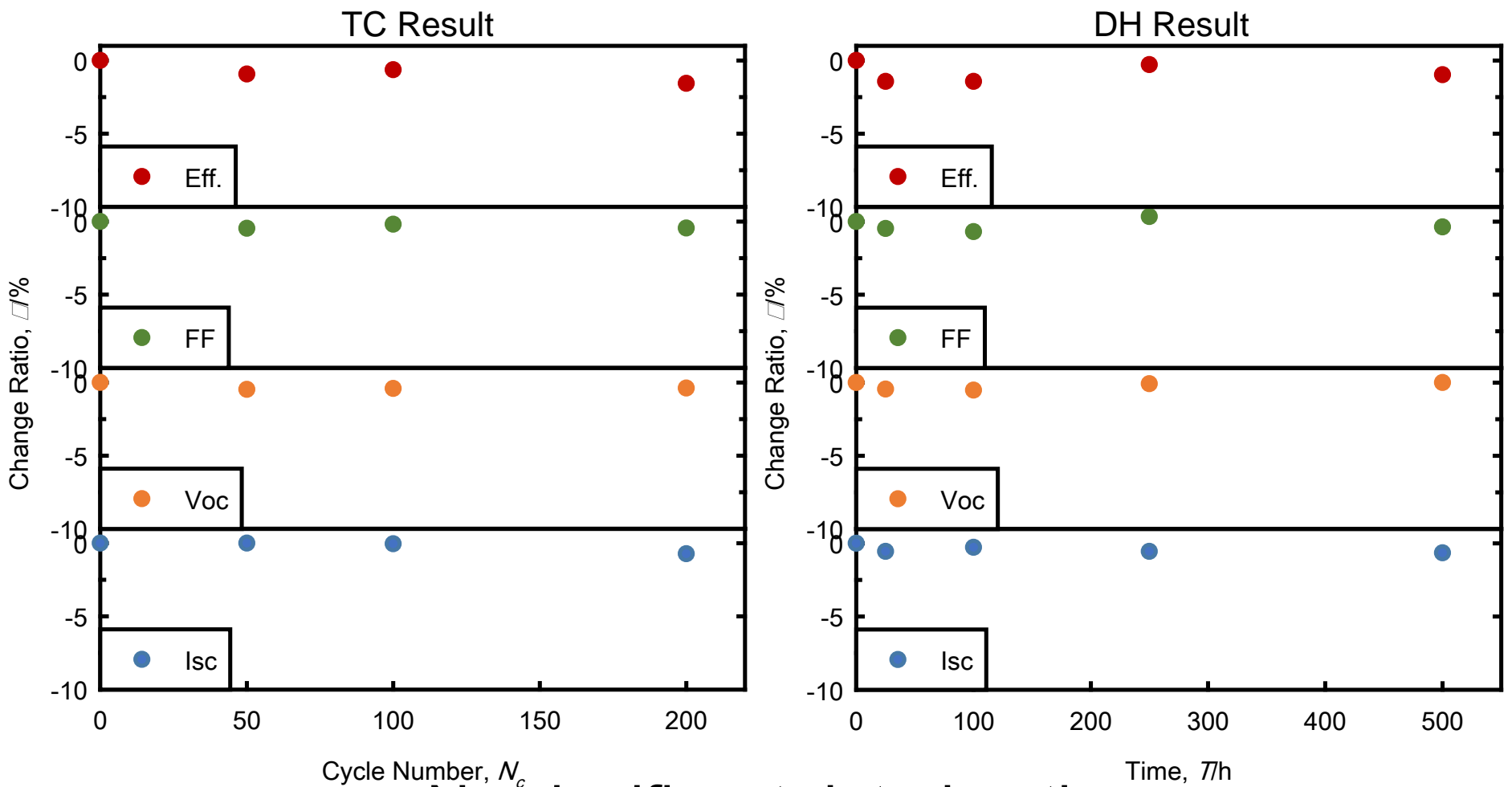
Ag

Si

Sn diffused into Ag deeply

1 μm

One Cell Module Test



No significant deterioration
(test still continue)

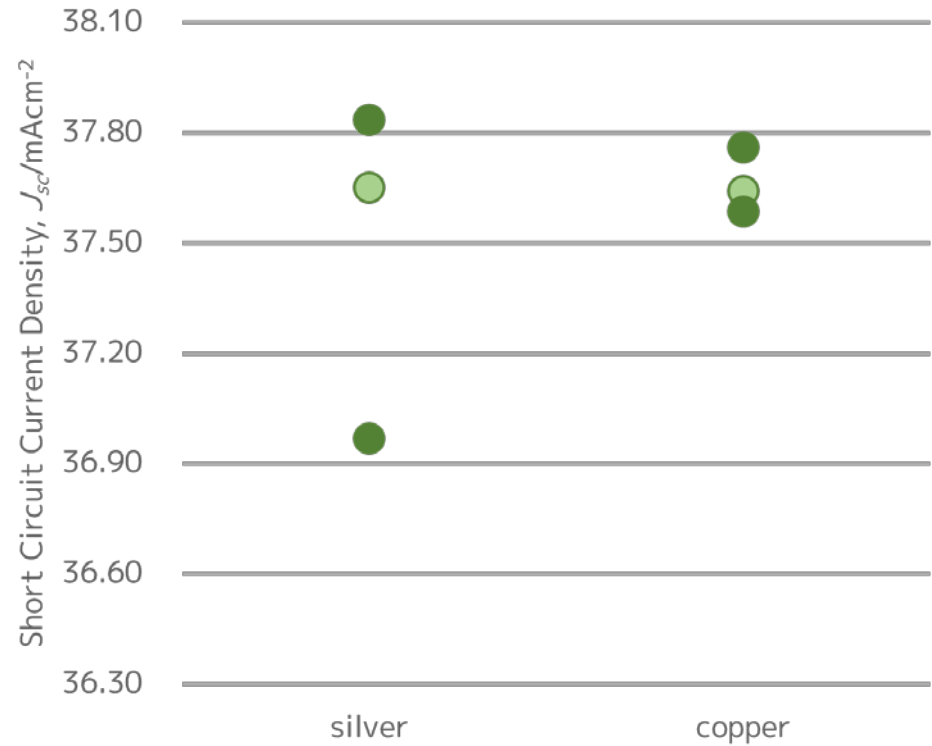
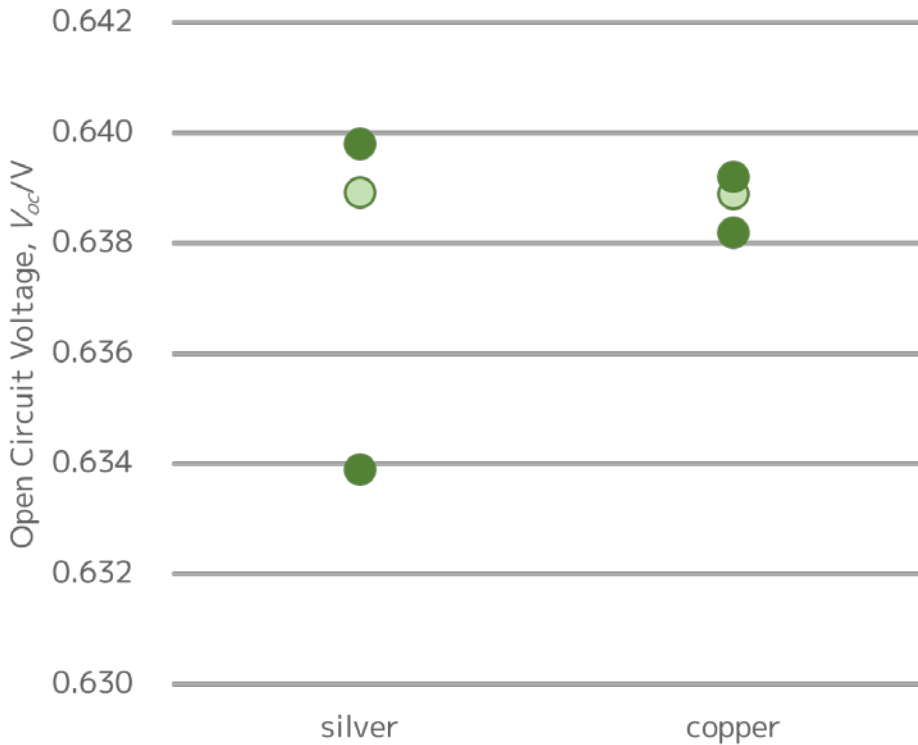
● Summary of Copper Paste

- Copper bus bar successfully worked at cell level.
- No disadvantage was observed at mini-module test.

● Acknowledgements

- This work was partly supported by the New Energy and Industrial Technology Development Organization (NEDO) under the Ministry of Economy, Trade and Industry (METI).
- We would like to thank Dr. Tomihisa Tachibana, Mari Aoki and Prof. Yoshio Ohshita (Toyota Technological Institute) for useful discussion.
- We also would like to thank Hideo Tokuhisa and Satoko Morita (Advanced Industrial Science and Technology) for Cu-bus mini module test.

IV Results



No negative effects on cell level !!