Thad Druffel, Ruvini Dharmadasa, Kevin Elmer, Dustin Williams, Apolo Nambo, Vanessa Williams
Bert Thin Films, Inc.

LECO Processing of Copper Pastes

Metallization Workshop
21 October 2025
Berlin, Germany

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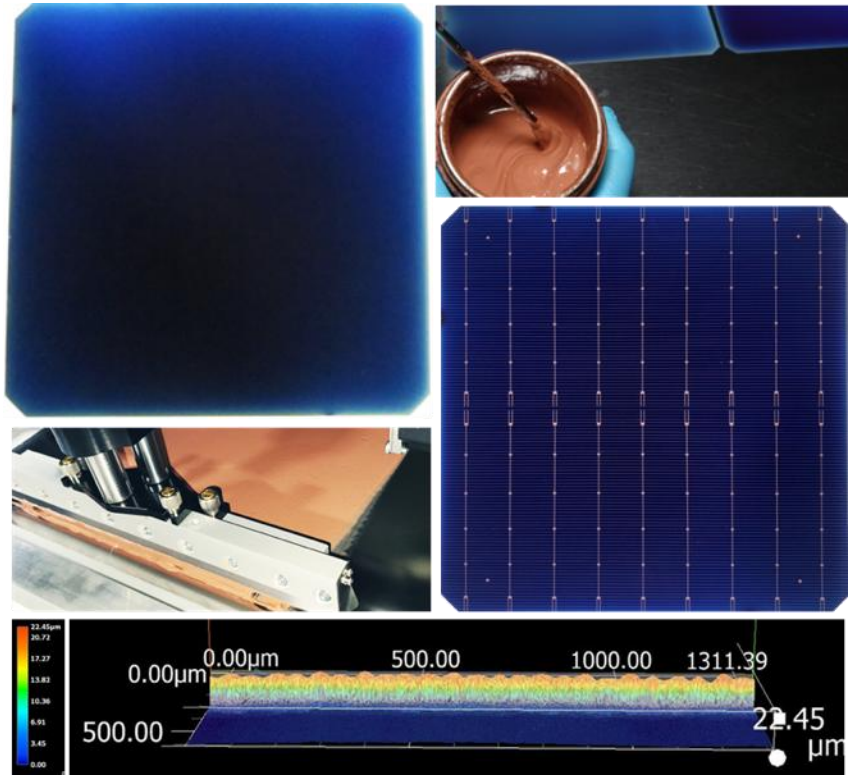

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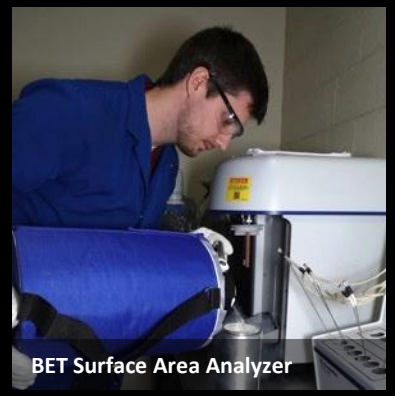
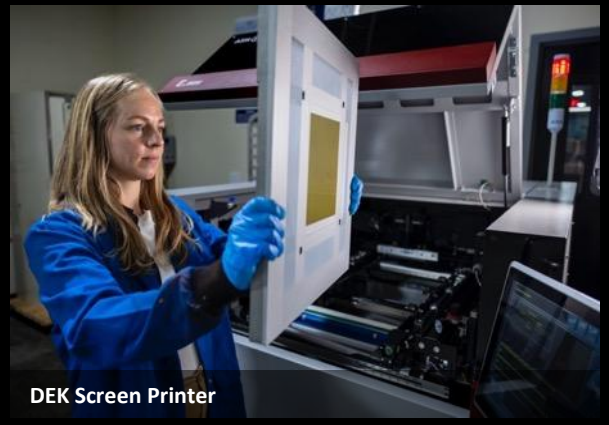

BET Surface Area Analyzer

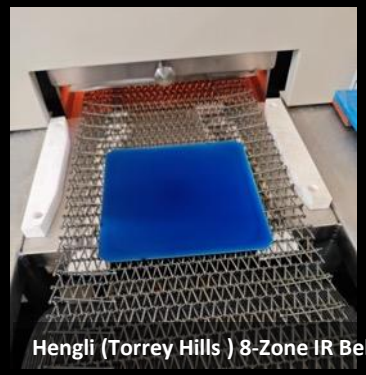

Humidity Chamber


Exakt 80S 3-Roll Mill


DEK Screen Printer

CURRENT FACILITIES


Cell Engineering LECO Tool


Hengli (Torrey Hills) 8-Zone IR Belt Furnace


P Energy Laminator

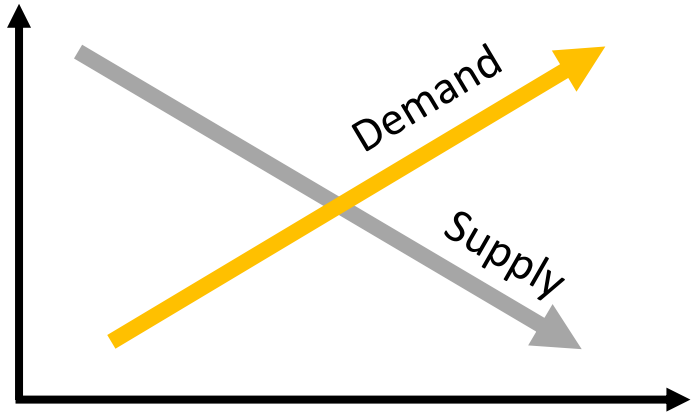

Sinton FCT-650 Flash Tester and EL Imager

Unique Capability in US

BERT THIN FILMS INC

Introduction

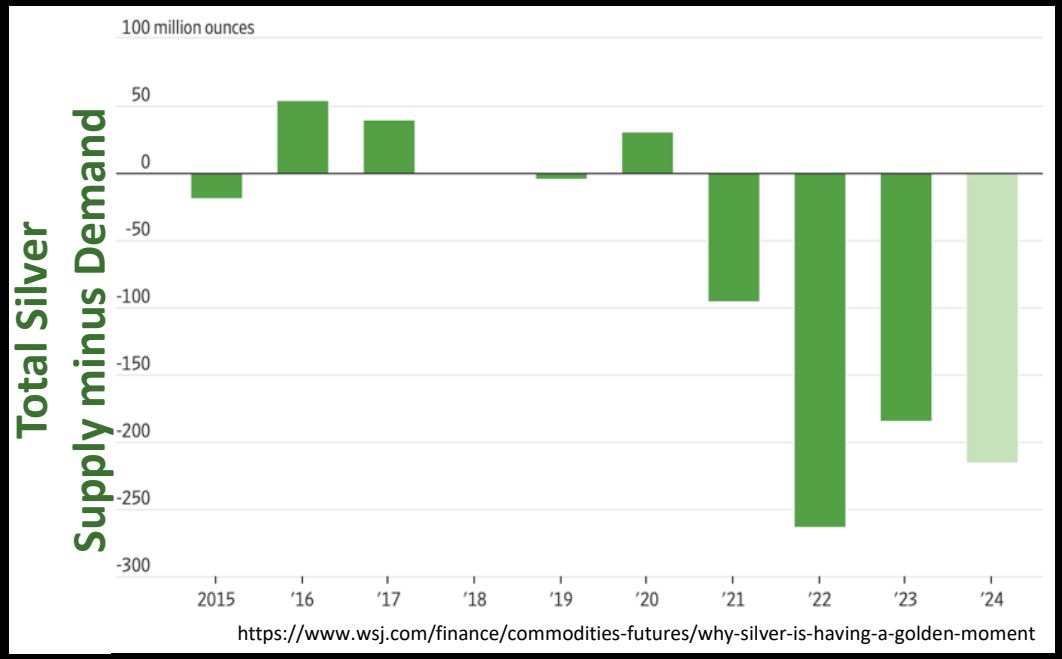
The Imminent Problem



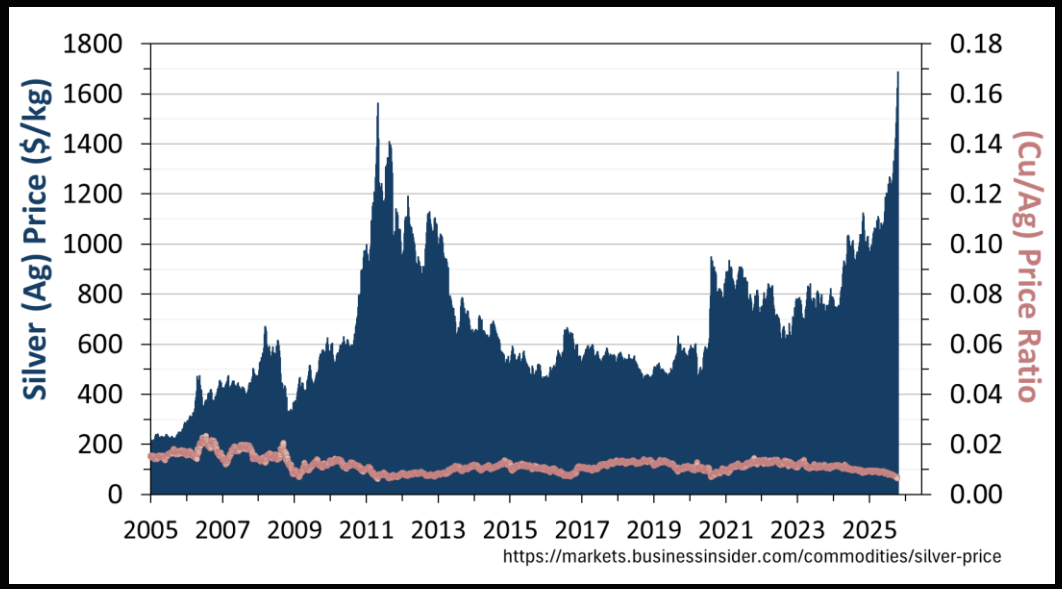
Solar demands too much silver.

We remove high priced volatile material.

Major impact on cost and sustainability.



https://www.wsj.com/finance/commodities-futures/why-silver-is-having-a-golden-moment



https://markets.businessinsider.com/commodities/silver-price

Copper Pastes

The Solution: CuBert™

Drop-in Replacement for Silver Paste.

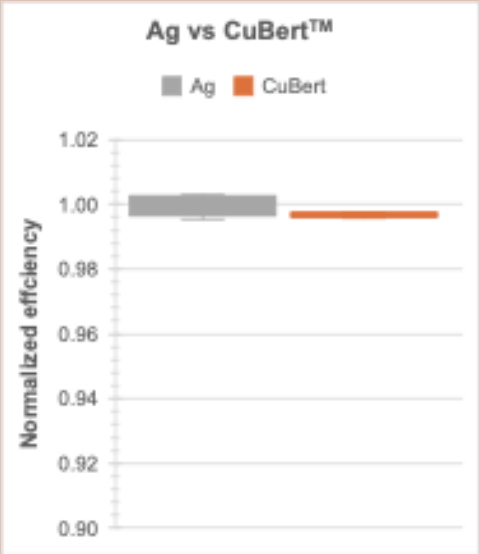
Screen Printable and Air Fired Copper pastes.

No changes to processing.
No new equipment.

Demonstrated Results:

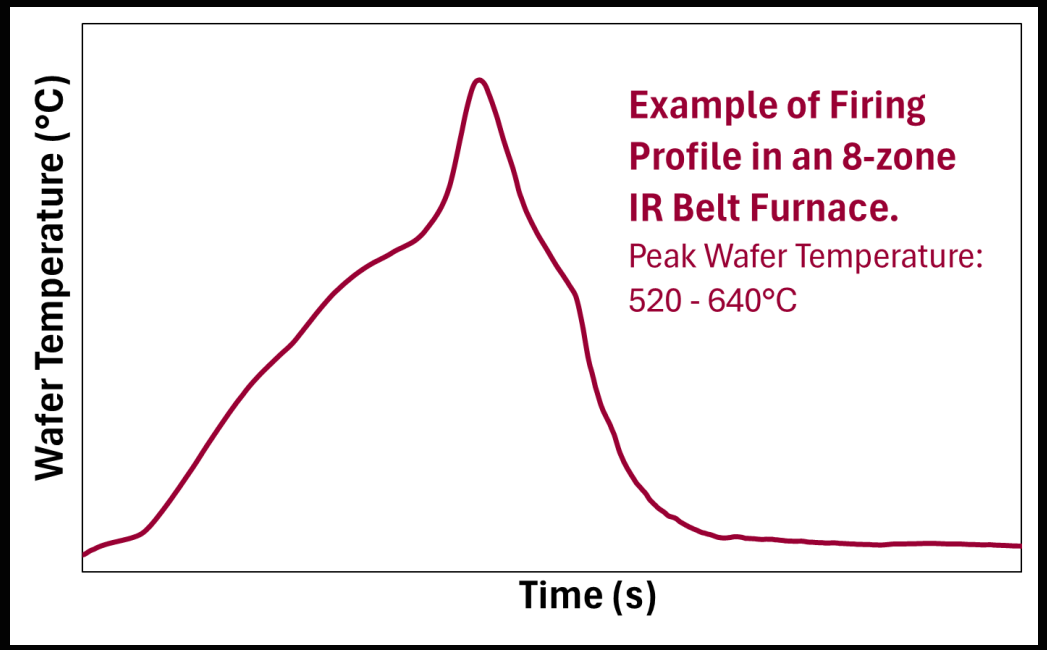
- >24% η
- LECO Compatible
- Durable

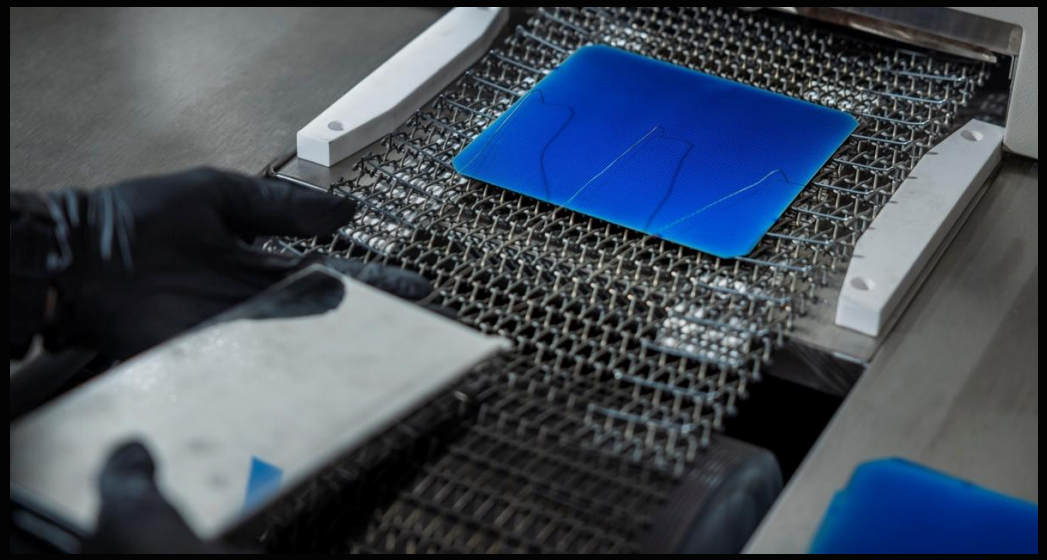
Comparable Efficiency



UNIQUE IN THE INDUSTRY

Firing





Cells are Fired in Air.

TOPCon

- **Utilizes passivation layers.**

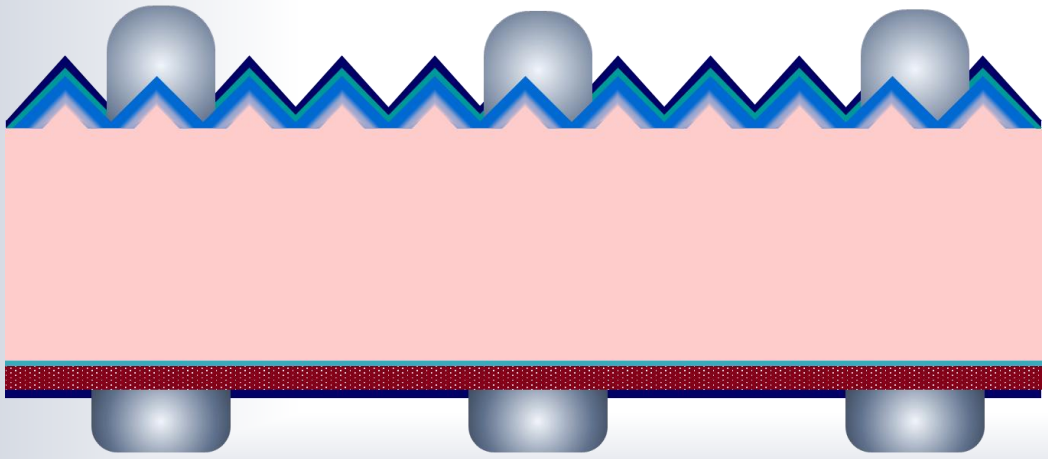
→ Leading to a higher theoretical efficiency, η > 28%.

- **TOPCon has rapidly overtaken PERC's market share.**

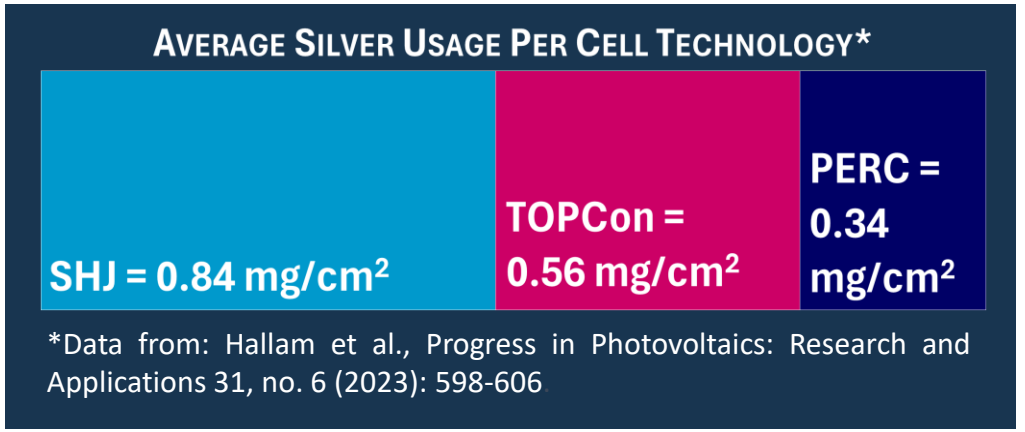
→ ~49% share in 2024 (ITRPV, 15th Edition).

- **Uses screen printed silver, Ag contacts on both sides.**

→ Nearly doubles the amount of Ag.



Front Metal Contacts
Silicon Nitride, SiN_x Anti-Reflective Coating
Passivation Layer
p^+ Emitter
n-type Wafer
Tunnel Oxide Passivation Layer
n^+ Poly-Silicon
Silicon Nitride, SiN_x Anti-Reflective Coating
Rear Metal Contacts



*Data from: Hallam et al., Progress in Photovoltaics: Research and Applications 31, no. 6 (2023): 598-606

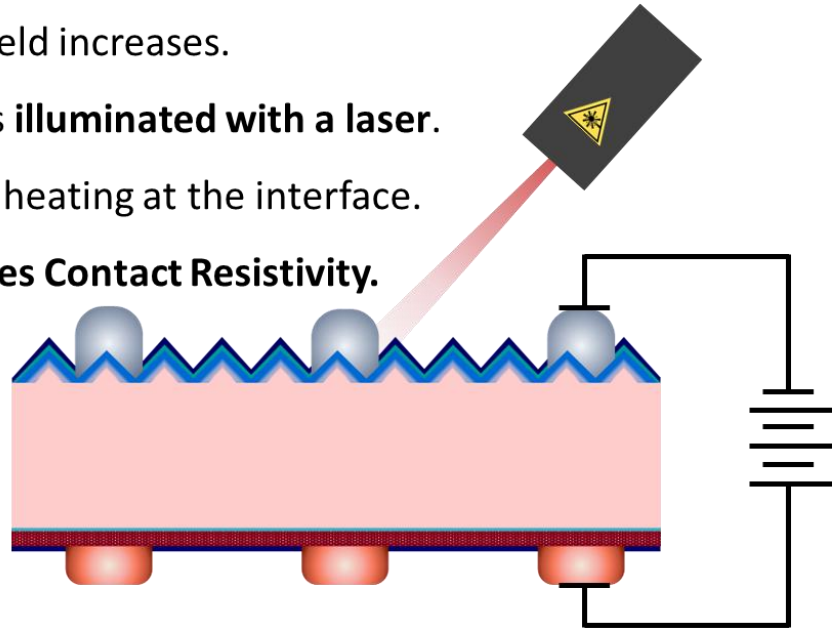
TOPCon

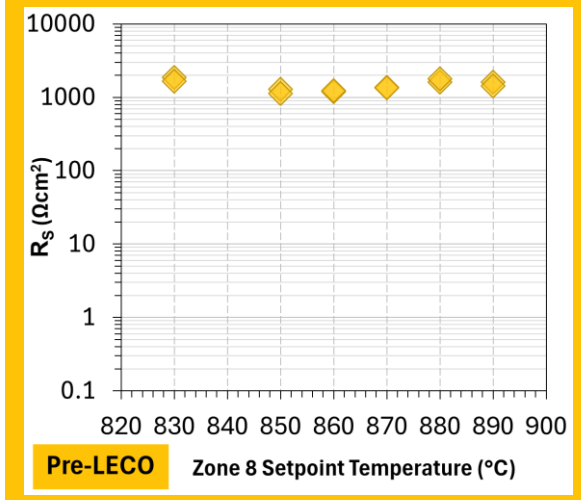
Laser Enhanced Contact Optimization (LECO)

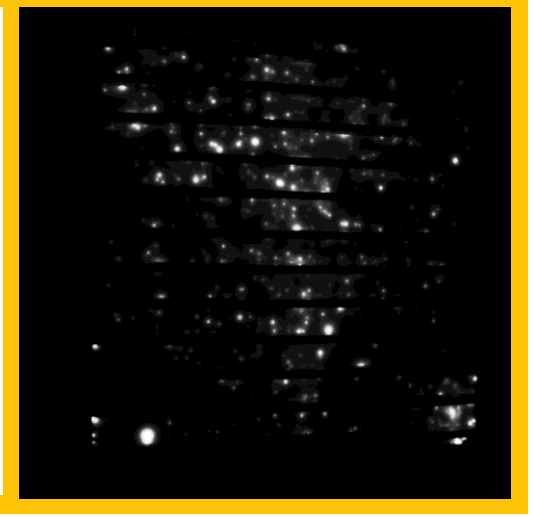
- **Narrows efficiency distribution range.**
- **Increases production yield.**
- **Aids with the contacting of shallow emitters.**

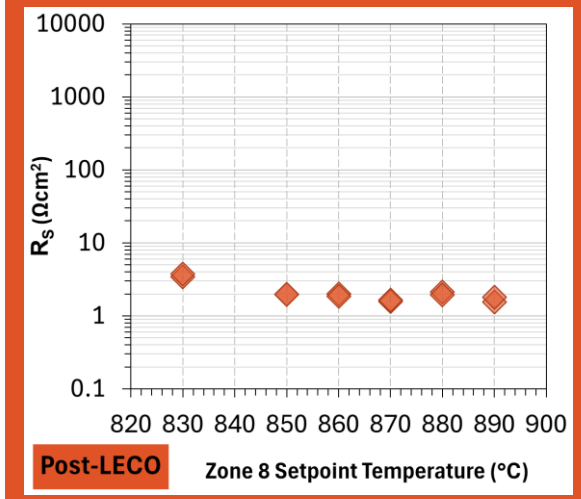
- The cell is fired, creating shallow pin-point contacts.
- The cell is placed under **Reverse Bias**.
- Electric field increases.
- The cell is **illuminated with a laser**.
- Localized heating at the interface.

→ **Decreases Contact Resistivity.**









TOPCon

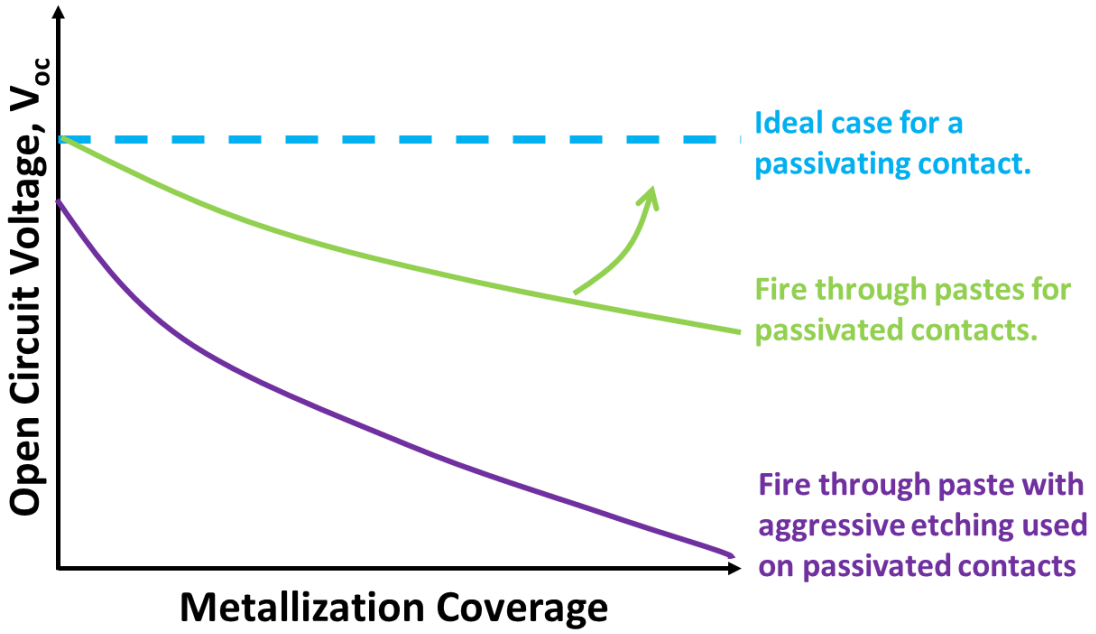
Metallization Requirements.

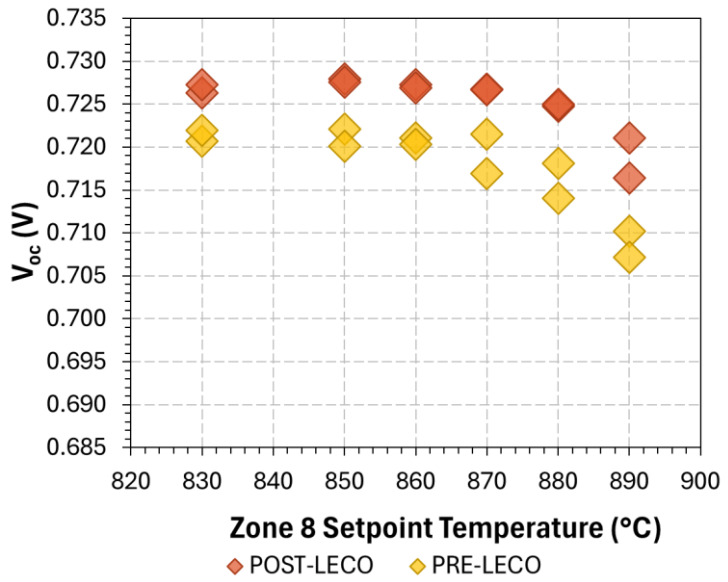
The Open Circuit Contact, V_{oc} is impacted by:

- The etchants in the paste.
- Metallization pattern coverage.
- Firing temperature.

Front Contact requirements to work with LECO:

- Finer line printing on shallower emitters.
- Small point contacts.
- An initial high contact resistivity.





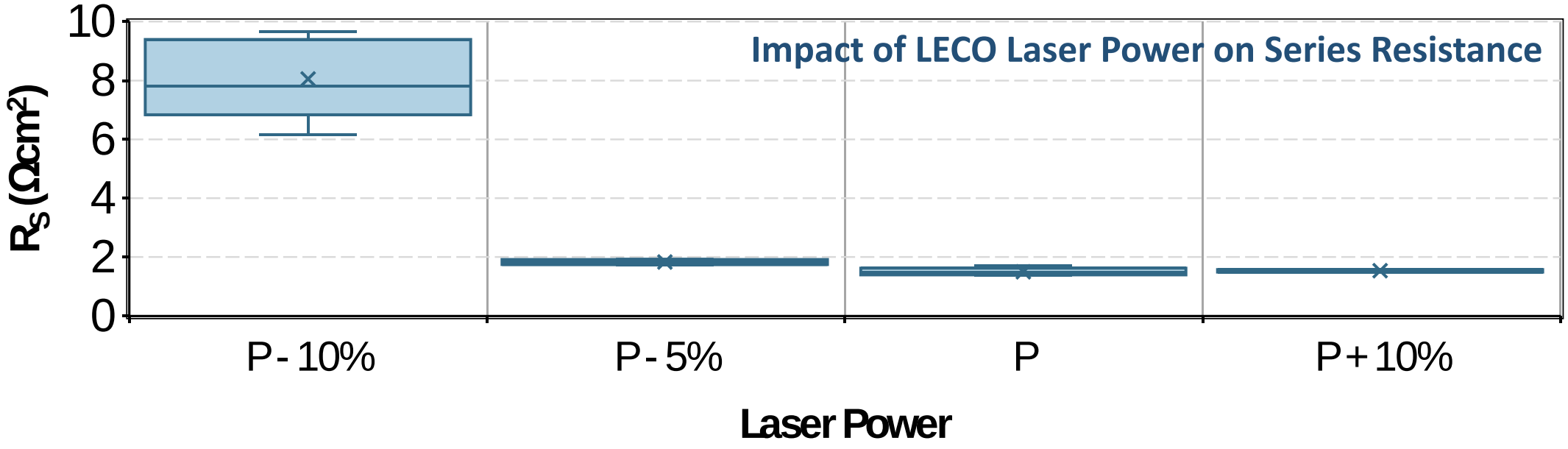
Etching rate increases with temperature.

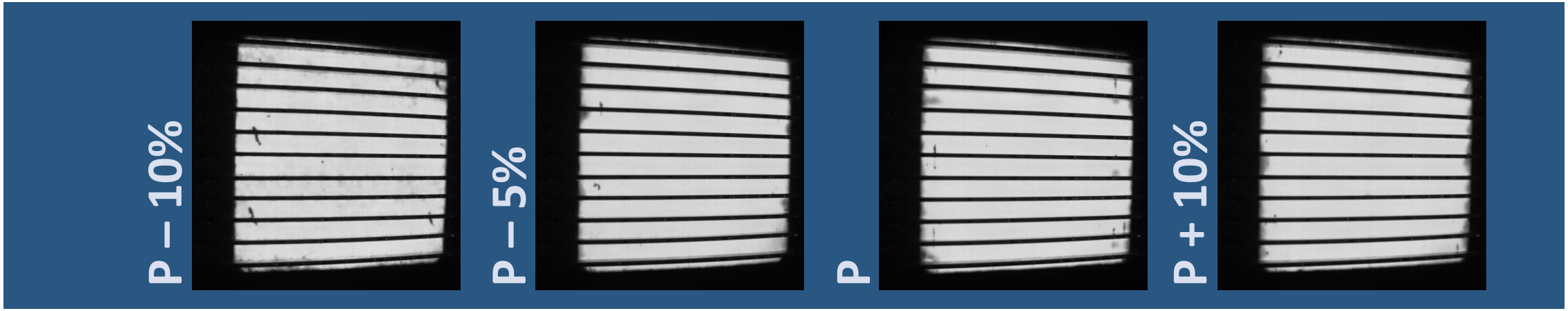
Damages the rear passivation layer.

→ Lowers V_{oc}.

TOPCon

Results.

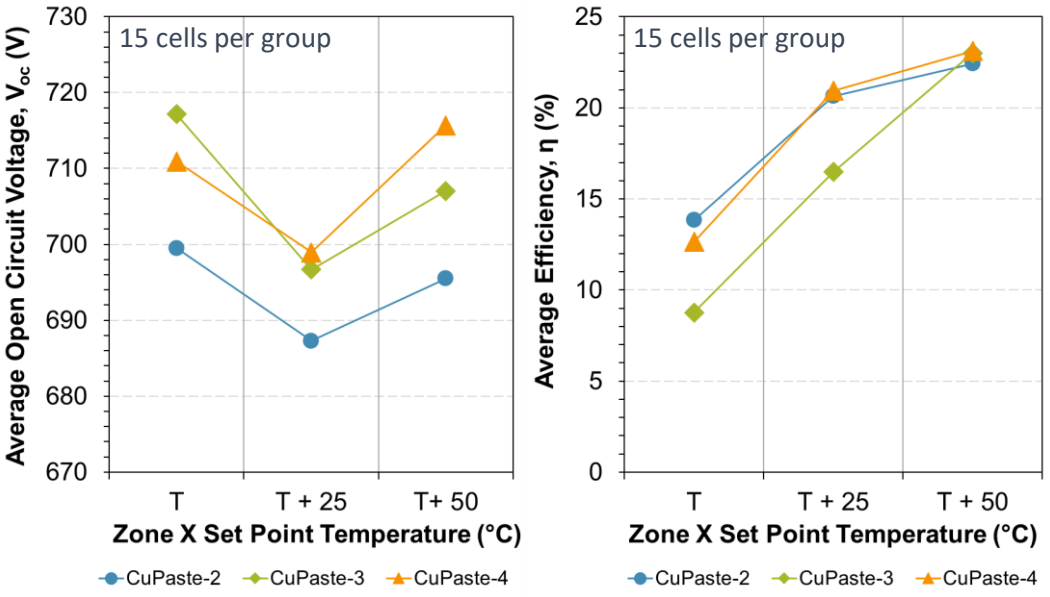




TOPCon

Results.

Firing, Processing and Measurement at a Third-Party Site.

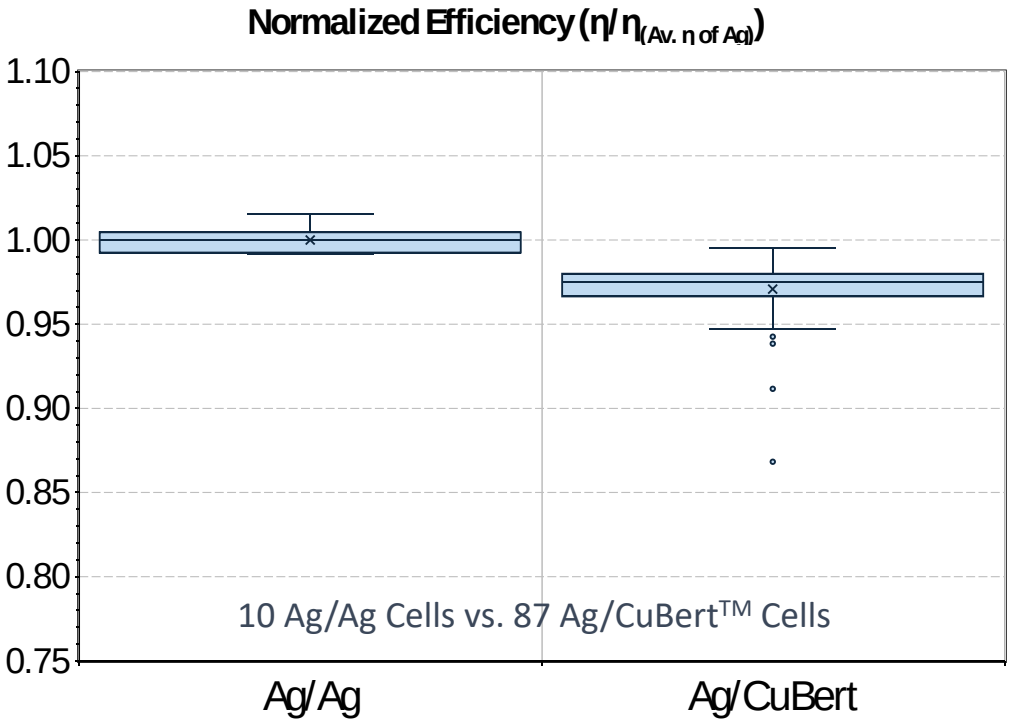


Paste Etching Rate = CuPaste-2 > CuPaste-3 > CuPaste-4

Firing and Processing trials with CuBert™ have been carried out at multiple 3rd party sites.

Next steps: (1) Improve performance at Bert Thin Films.
(2) Conduct further trials with Industry Partners.

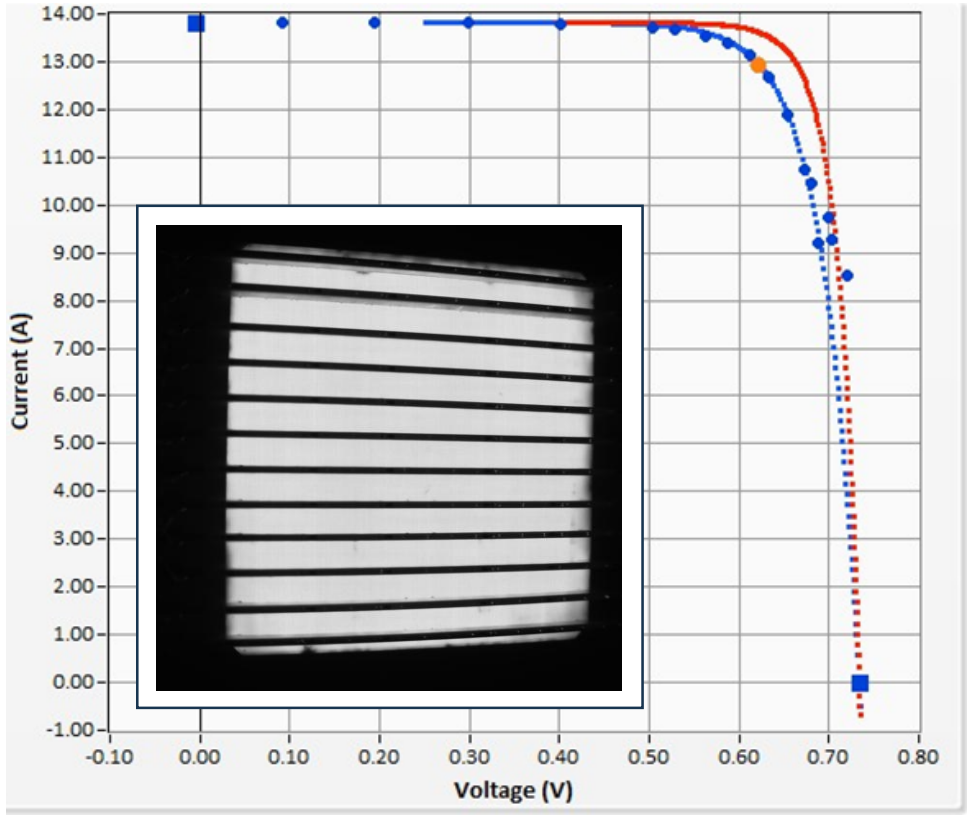
Printing, Firing, Processing and Measurement at Bert Thin Films.



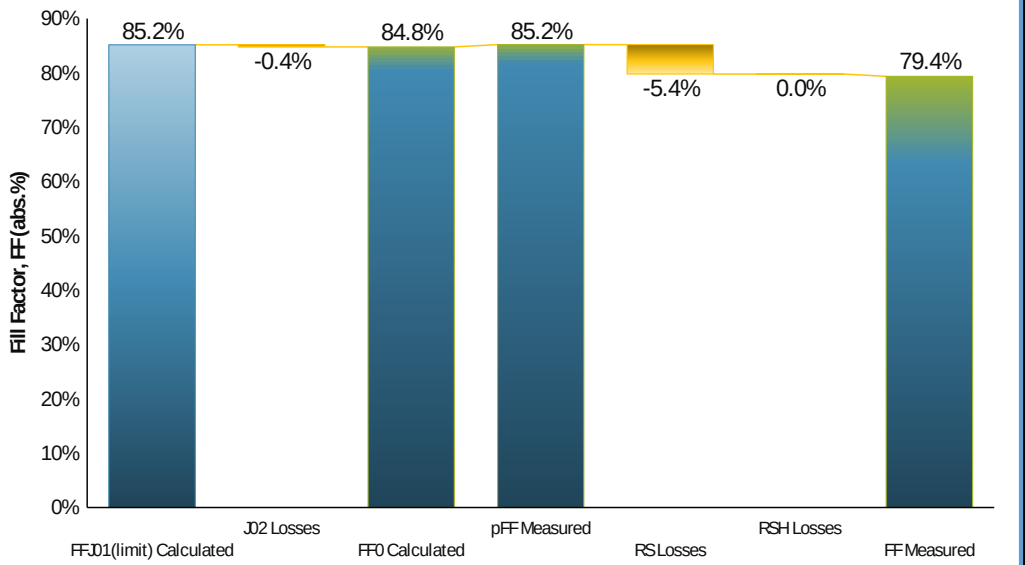
Changes to the metallization pattern help lower R_S.

Next steps: (1) Change the rear finger pitch.
(2) Optimize pastes for bus bars and fingers.

TOPCon



J_{sc} ($mAcm^{-2}$)	V_{oc} (V)	FF (%)	η (%)	R_S (Ωcm^2)	R_{SH} (Ωcm^2)
41.8	734	79.4	24.4	1.08	418×10^3



Fill factor loss analysis*, shows losses are predominately due to series resistance.

*Khanna, Ankit, Thomas Mueller, Rolf A. Stangl, Bram Hoex, Prabir K. Basu, and Armin G. Aberle. "A fill factor loss analysis method for silicon wafer solar cells." IEEE Journal of Photovoltaics 3, no. 4 (2013): 1170-1177.

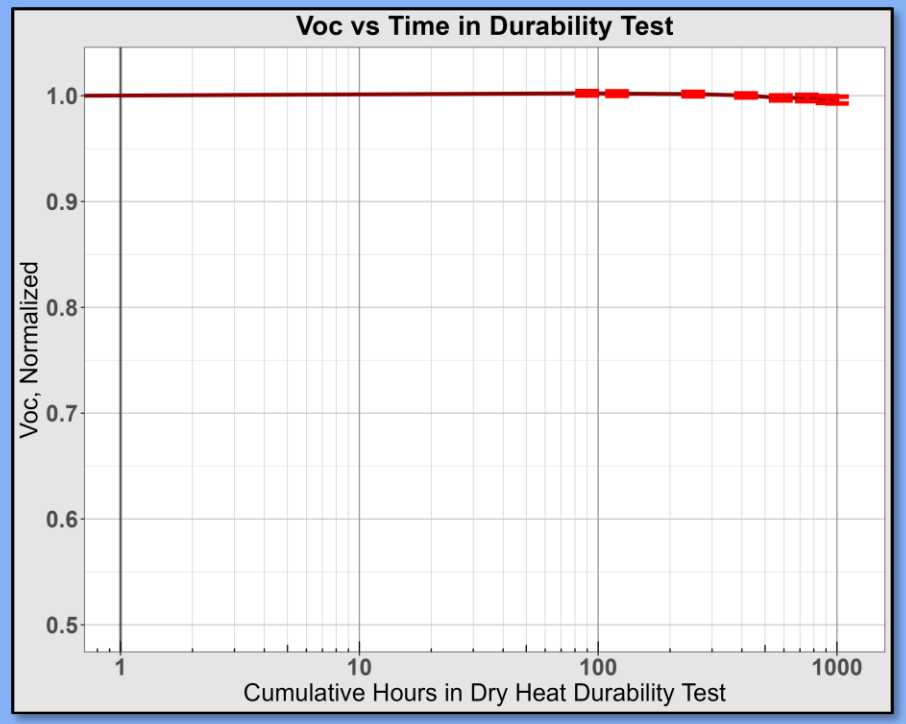
Next Steps

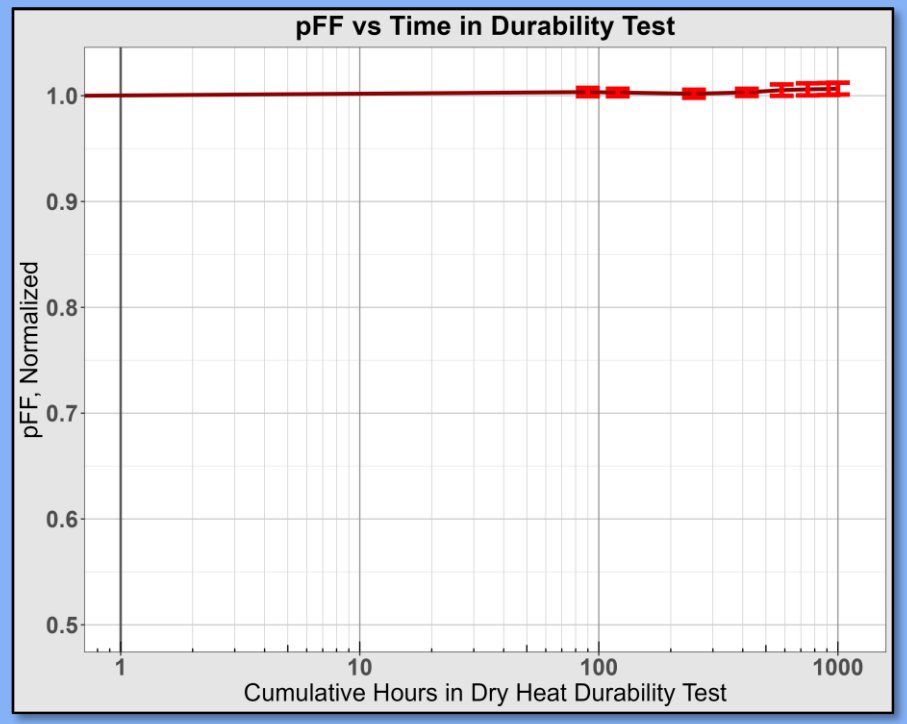
- Narrow performance distribution.
- Change the metallization pattern to lower series resistance.
- Reduce the finger and bus bar dimensions.

→ **Increase Efficiency.**

❖ Develop CuBert™ for the front contact.

Cell Durability

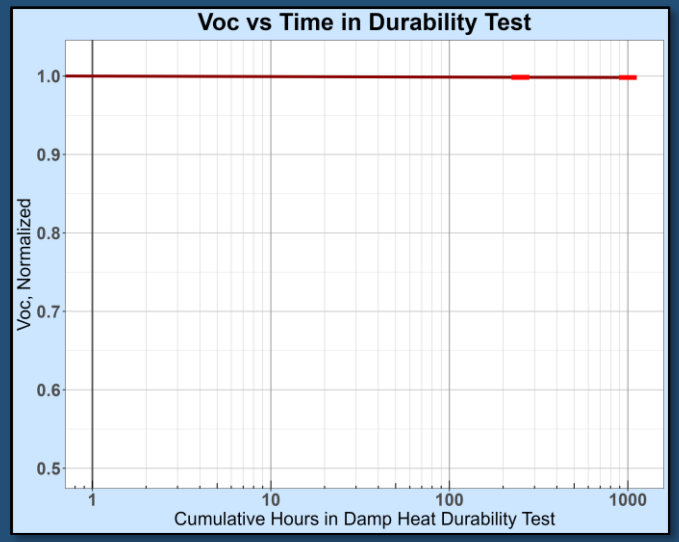


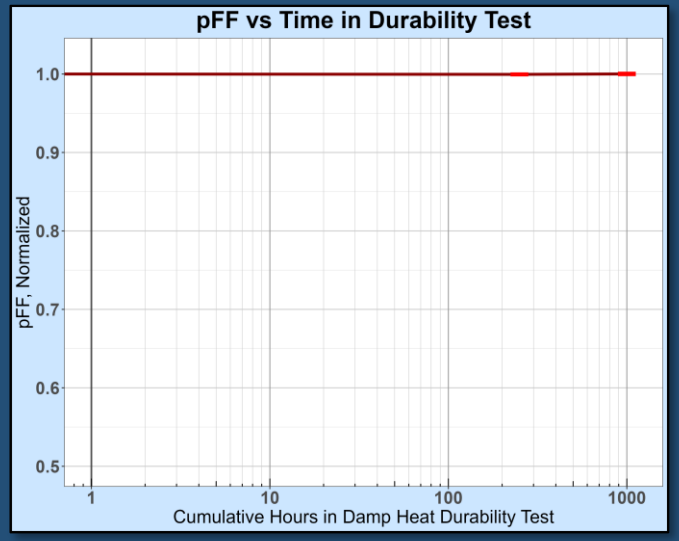


200°C in N_2 environment

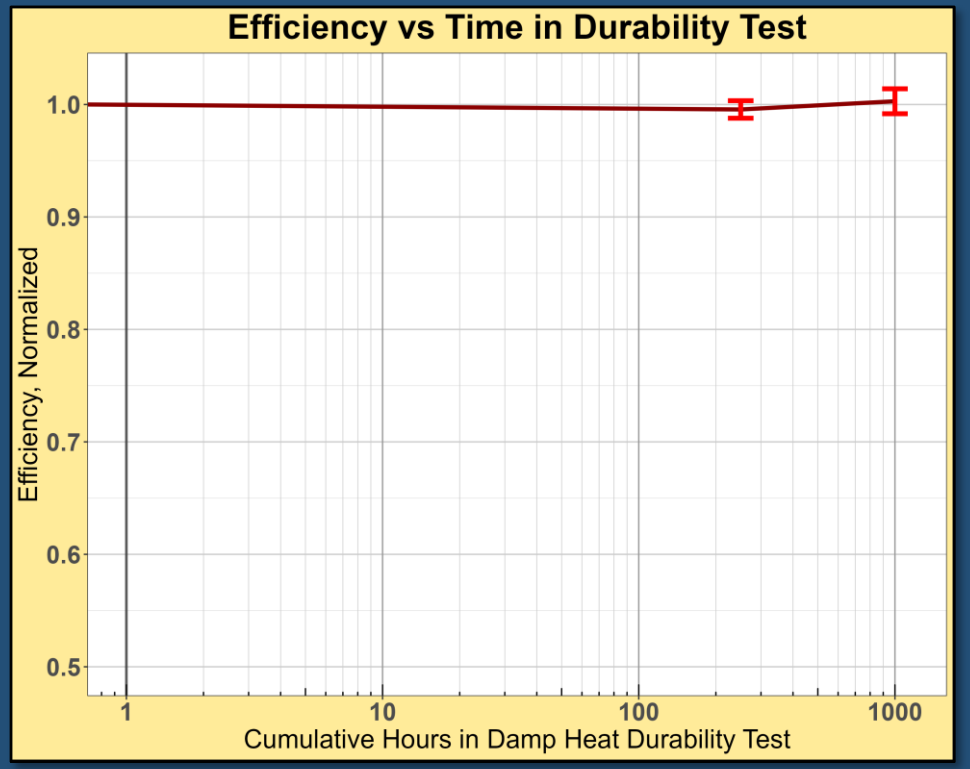
Dry heat study shows effectiveness of inherent diffusion barrier.

Mini-Module Durability





Time-series metrics of single-cell Ag/Cu mini-modules



Sample size: 5 mini-modules

Damp heat study shows successful maintenance of:

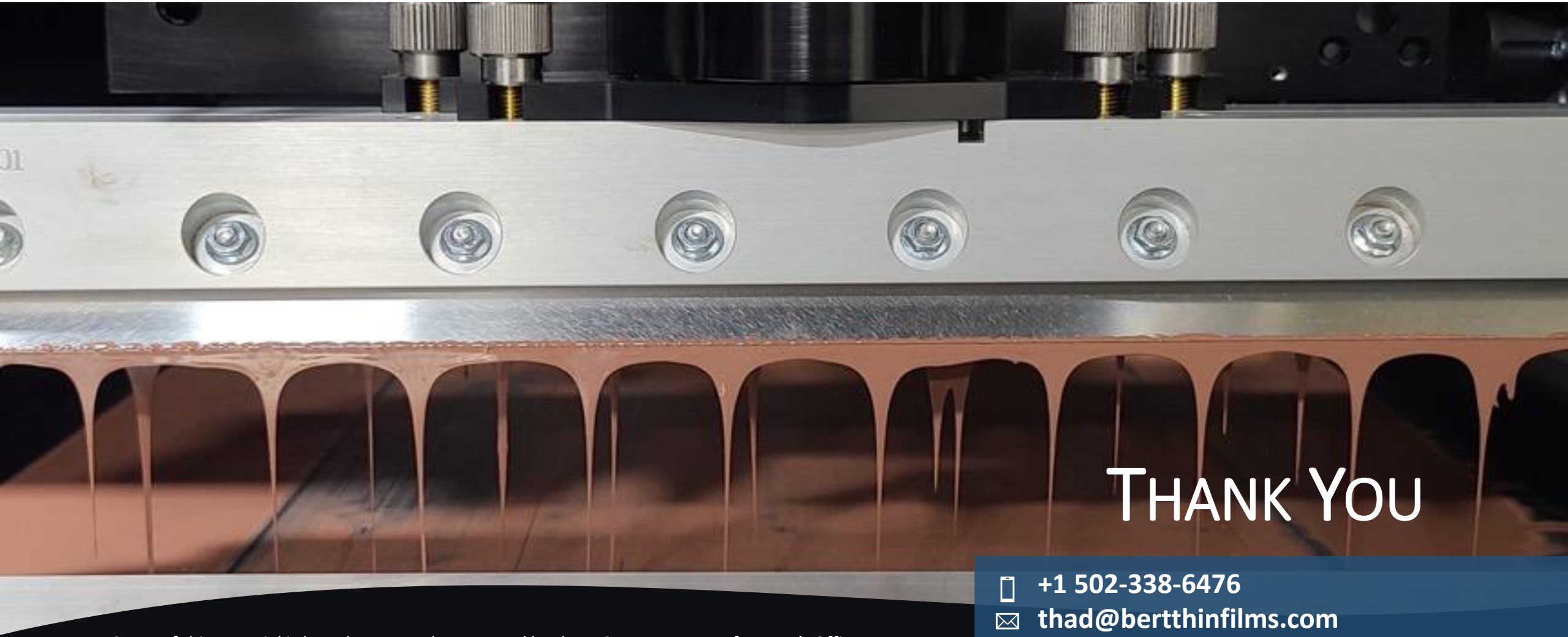
- ☑ **Cell Health**
- ☑ **Module Efficiency**

Summary

Screen Printable Air Fired Copper Paste

Industry needs to move on from Silver	▪ 20% consumption in 2024 ▪ ~10% cost of module
Copper pastes are most cost-effective	▪ No changes to equipment ▪ Scalable at both paste and cell manufacturing levels
Demonstrated firing in Air in belt furnace	▪ PERC and TOPCon ▪ Efficiencies 24%
Demonstrated durability	▪ Cell ▪ Module

BERT THIN FILMS INC



THANK YOU

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