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Metallization: Cost Reduction and Performance Optimization for the Key Consumable of Solar Cell Production

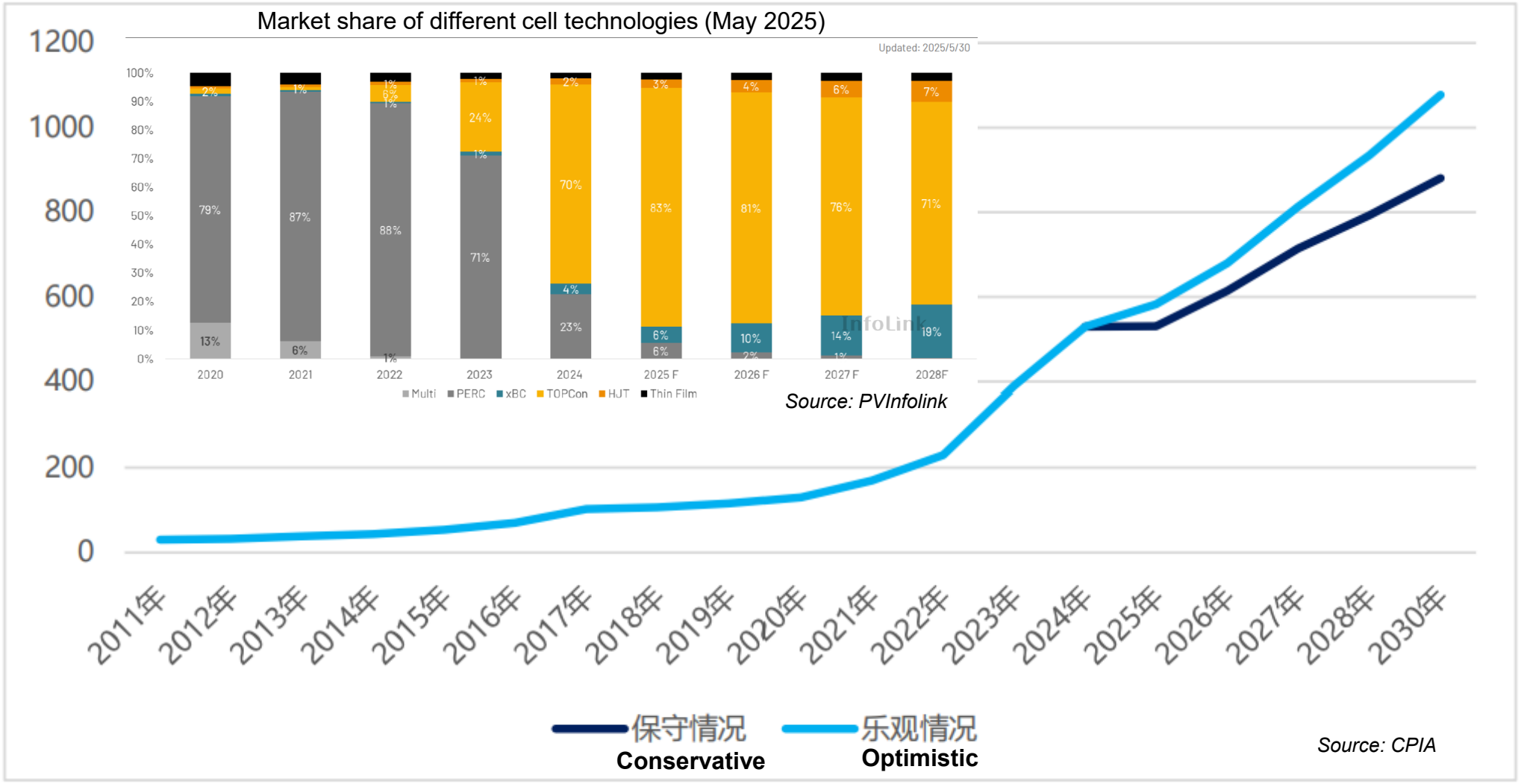
Solamet Electronic Materials

Dr. QJ Guo, CTO

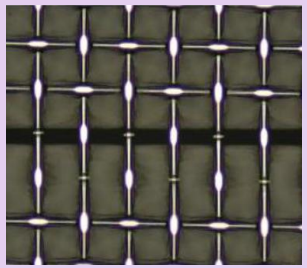
2025-09-08

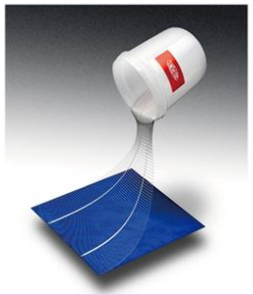
Overview of the PV market and solar cell technologies

High efficiency n-TOPCon solar cells is mainstream



Metallization is key to industrialization of higher efficiency solar cells





Advancements in paste and screen technologies have been able to continuously enable improvements in cell efficiency and production cost

A Richter et al, Nature Energy, 2021, 6: 429-438
R Peibst, et al. Prog Photovolt Res Appl. 2022: 1–14
F Haase et al. Sol. Energy Mater. Sol. Cells, 2018, 186: 184-193

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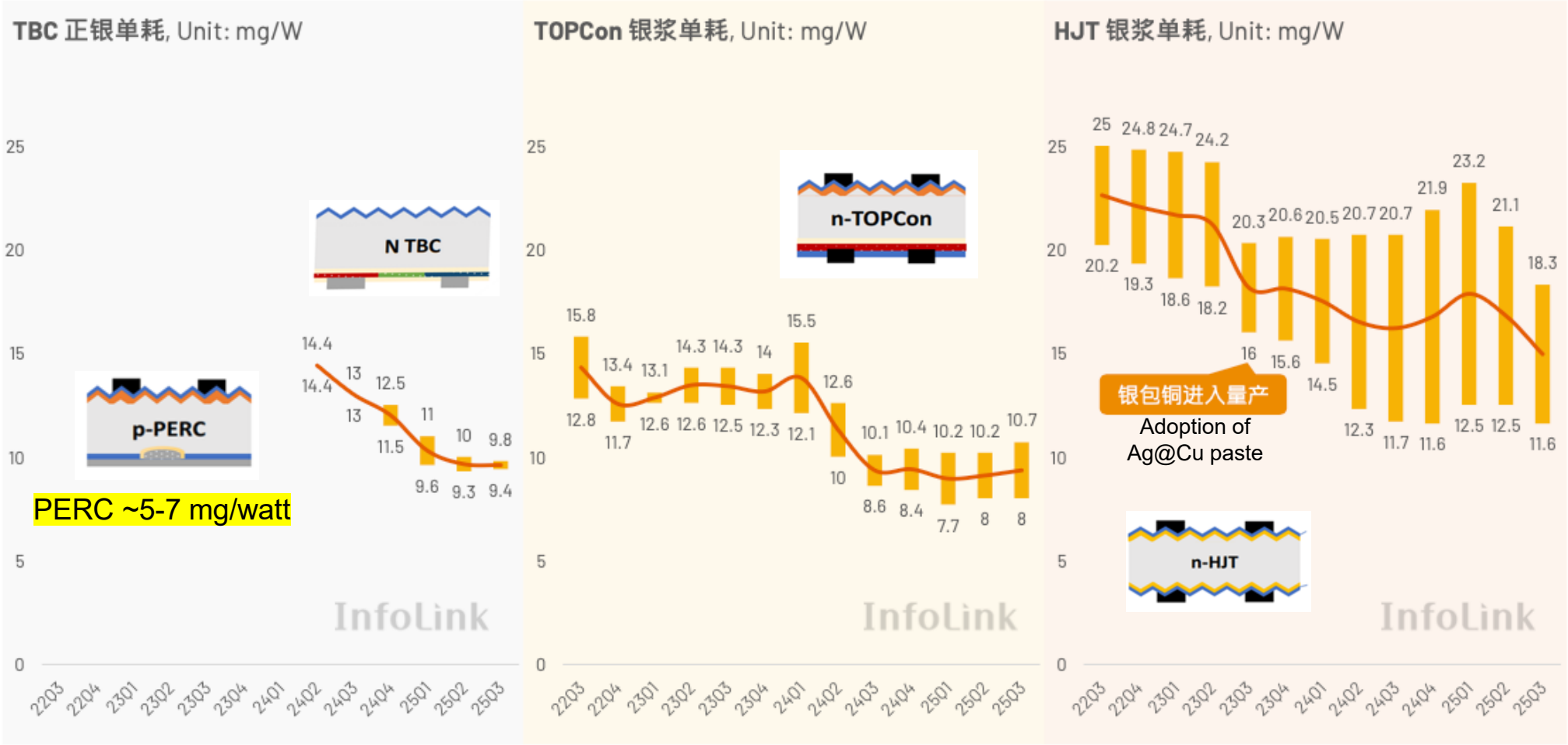
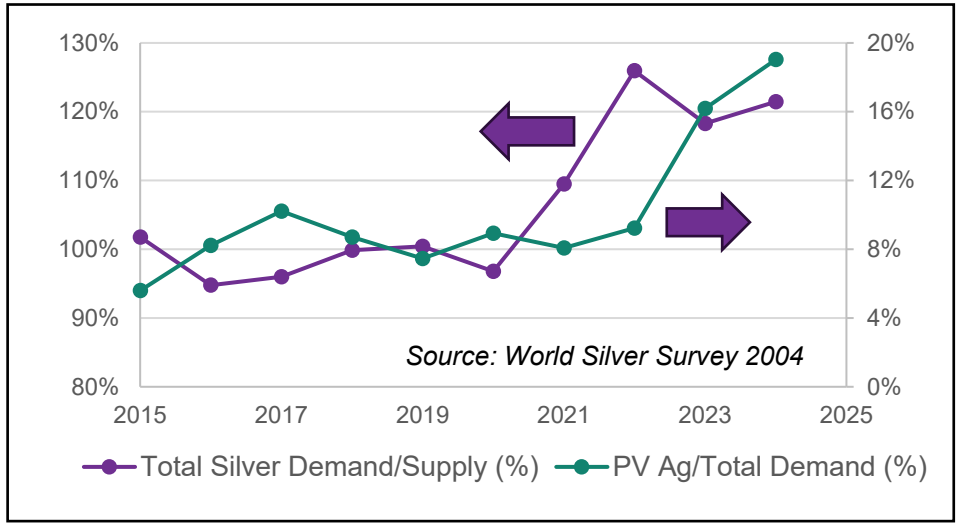
Ag consumption nearly doubles with high efficiency cell technologies

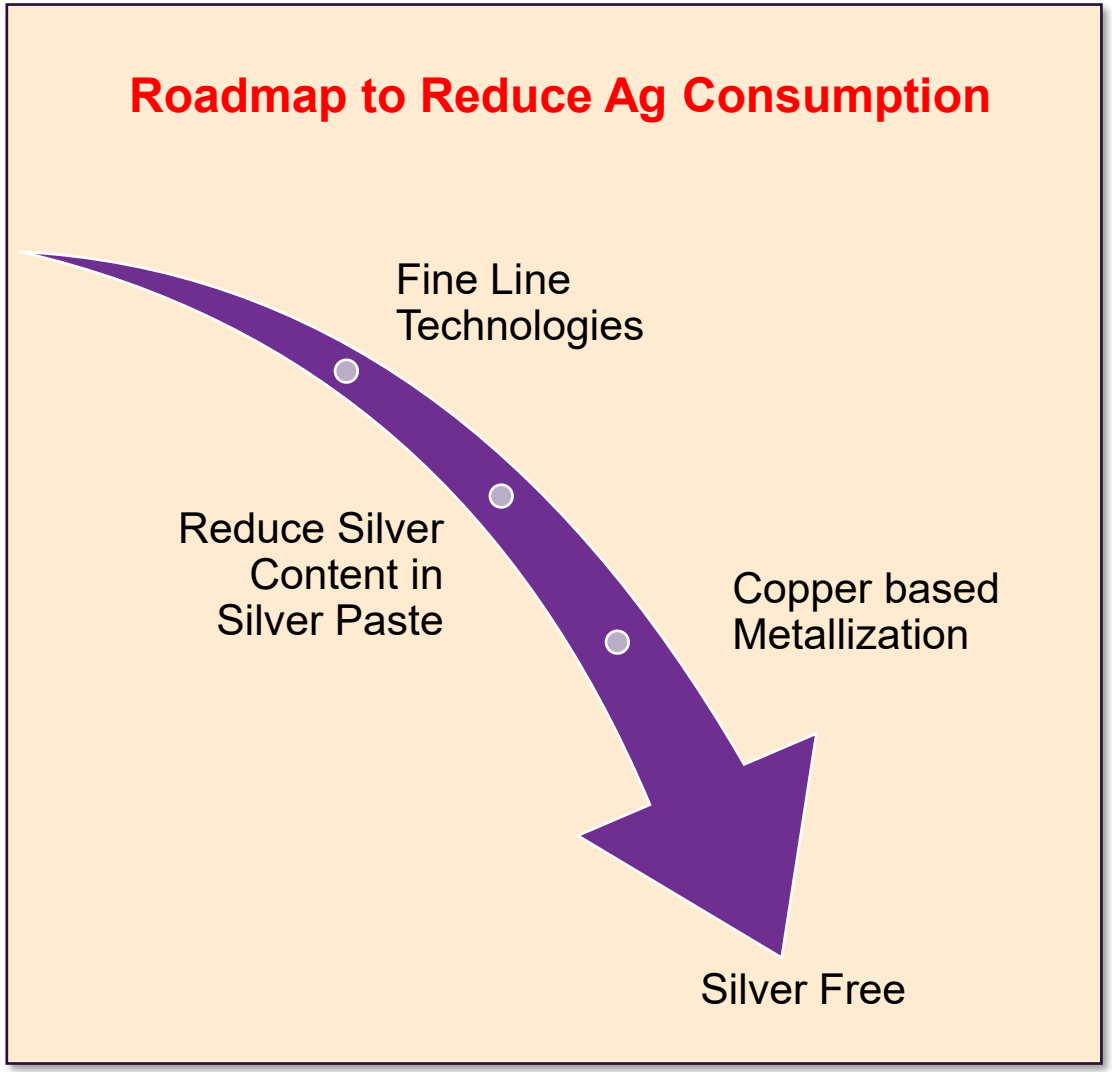
Trends in metallization silver consumption



Source: PV InfoLink

Reducing silver consumption is key to sustainability and growth





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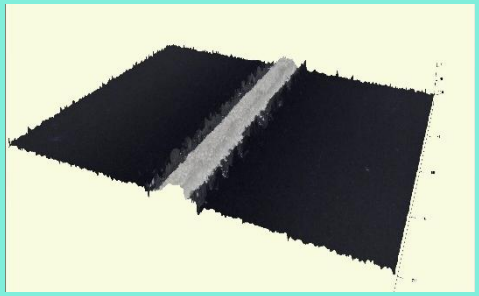
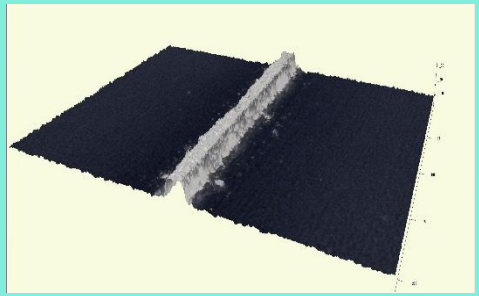
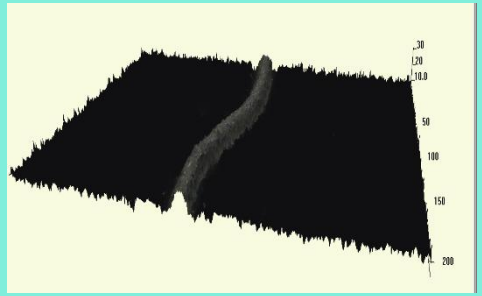
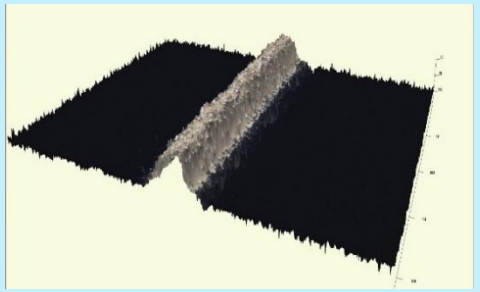
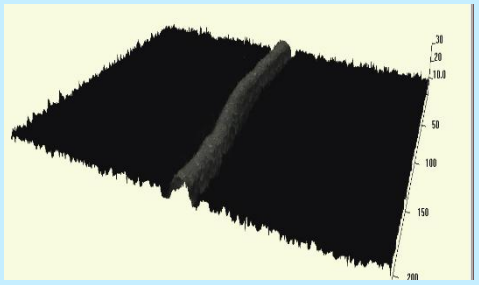
Fine line is the mainstream solution to high efficiency and lower cost

Fine line = Reduce Shading Loss + Lower Silver Paste Laydown

	Screen Printing	Stencil Printing	Pattern Transfer
High Temperature Air Firing	 Current: 15~19um @ 8~11um FO Prospect: 13~17um @ 6~9um FO	 Current: 12~15um @ 6~11um FO Prospect: 9~11um @ 4~6um FO	 Current: 10~12um @ 8~10um FO Prospect: 7~10um @6~8um FO
Low Temperature Curing	 Current: 28~34um @ 16~17um FO Prospect: 24~30um @ 14~17um FO	 Current: 22~28um @ 12~14um FO Prospect: 18~24um @ 10~12um FO	 Current: 17~19um @ 15~17um FO Prospect: 13~17um @ 12~15um FO

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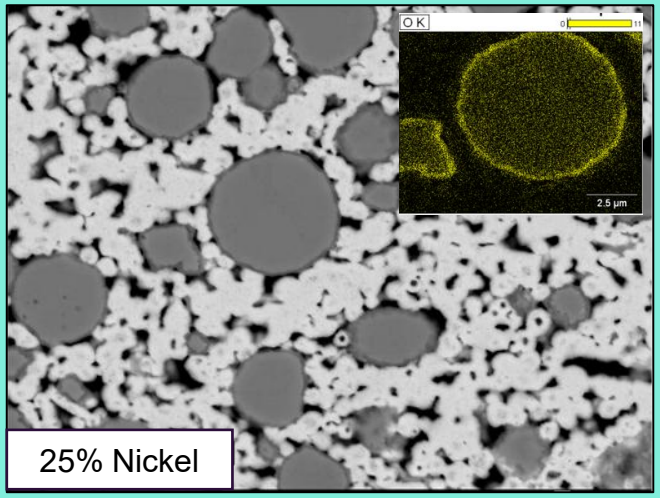
Reduce silver content using base metals

High Temperature Air Firing

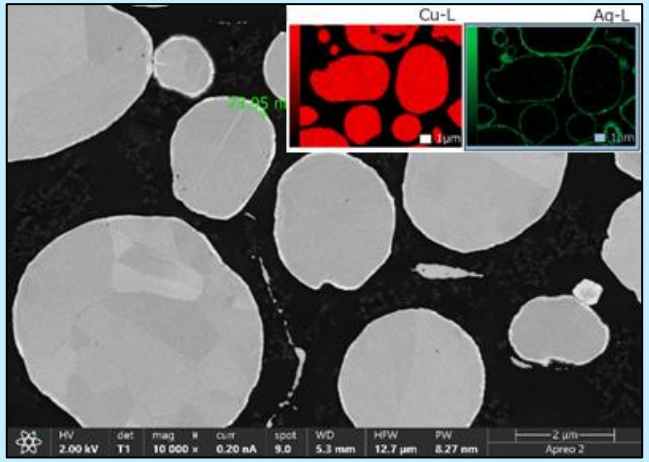


Customer Trials vs Silver Paste on TOPCon Rear Side

Sample	ΔVoc (mV)	ΔFF (%)	ΔIsc (mA)	ΔEff (%)	Laydown (mg)
Customer A 5% Ni	+0.1	+0.1	-6	+0.02%	=
Customer B 10% Ni	-0.6	+0.14	-10	+0.01%	=

Combining nickel powder with customized glass frit design able to demonstrate competitive performance with significant silver saving

Low Temperature Curing



Solamet® PV43A Volume Resistivity with Different Ag Content

Product	Ag content	Resistivity μΩ·cm
PV43A-T6	40-50% Ag	5.5 – 6.0
PV43A-T7	30-40% Ag	6.0 - 6.5
PV43A-T8	20-30% Ag	6.5 – 8.0
PV43A-T9	10-20% Ag	8.0 – 13.0
PV43A-T9+	< 10% Ag	12.0-25.0

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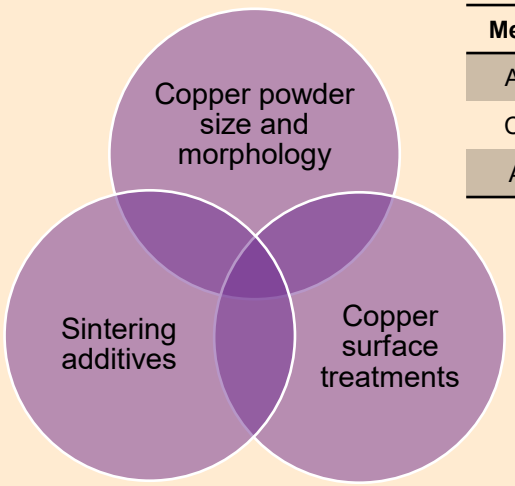
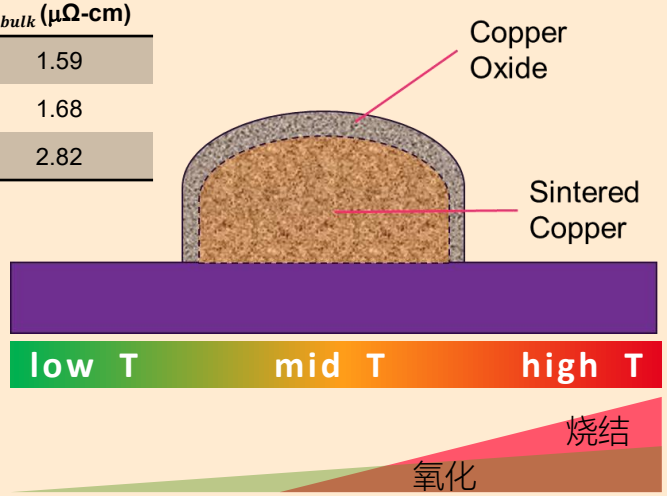
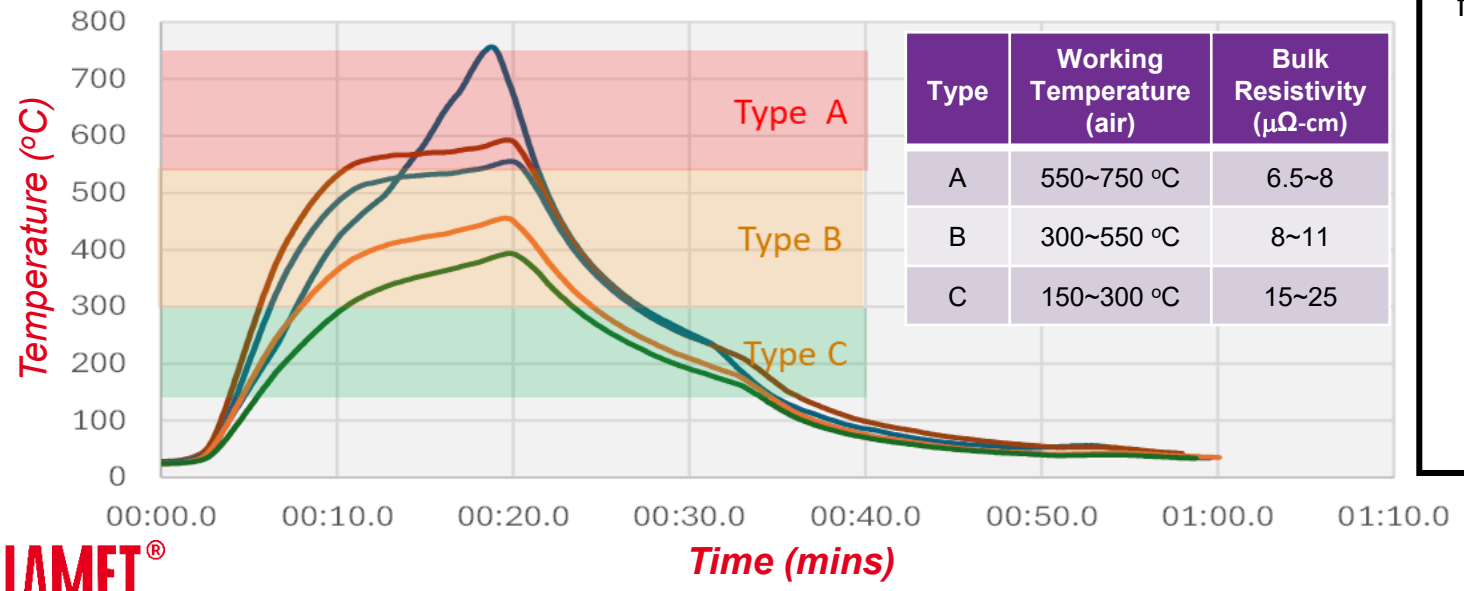
Feasibility of silver-free copper metallization solutions



Metal	ρ_{bulk} (μΩ-cm)
Ag	1.59
Cu	1.68
Al	2.82

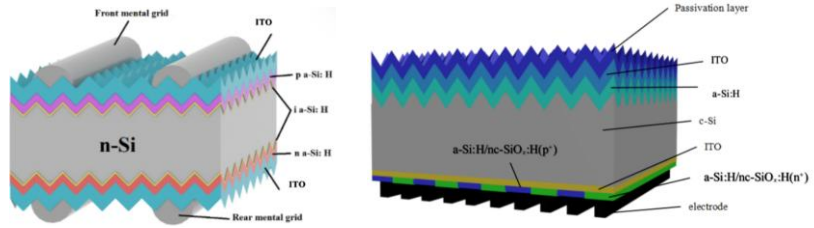




Type	Working Temperature (air)	Bulk Resistivity (μΩ-cm)
A	550~750 °C	6.5~8
B	300~550 °C	8~11
C	150~300 °C	15~25

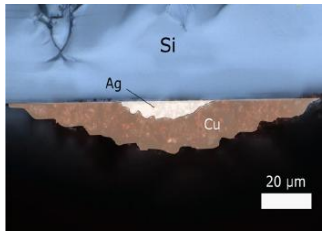
Applications in high efficiency cell structures

1. Replace current Ag@Cu pastes for HJT and HBC cells

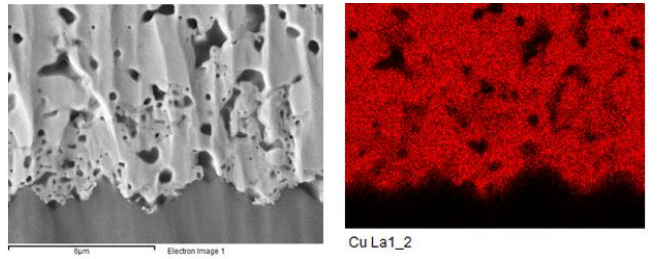


2. Two step using seed layer + low T copper paste for n-TOPCon and n-TBC

Chen et al, Sol. RRL 2023



3. One step co-firing using seed layer + copper paste for n-TOPCon and n-TBC



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DuPont™ Solamet® → SOLAMET® 索特

- July 1, 2021, Jiangsu Solamet Electronic Materials Co., Ltd. acquired DuPont Solamet® metallization business, including all products, personnel, intellectual property, and assets worldwide
- Solamet is the industry innovation leader and holds the broadest portfolio and access to metallization paste intellectual properties

- Headquarters:
  - Huzhou-Zhejiang (CN)
  - Shanghai (CN)
- R&D and Technology Centers:
  - Shanghai (CN)
  - Taoyuan (TW)
- Manufacturing Sites:
  - Dongguan (CN) t/yr
  - Taoyuan (TW) → support customers with Taiwan made certification for US end market since 2023

1983
- Launched first photovoltaic conductive paste product

1999
- PV145 the world's first commercial fire-through PV metallization paste

2009
- PV41x new low-temperature conductive paste for thin film PV

2011
- Revolutionary PV17x silver paste products based on patented Pb-Te-O frit Technology
- Launched PV3N1 - world's first commercial Ag-Al paste for N-type Solar Cell

2015
- PV76x/PV56x/PV36x complete commercial metallization solution for PREC

2016
- PV3Nx/PV6Nx/PVD2x world's earliest commercial complete n-TOPCon metallization package

2018
- ACS Heroes of Chemistry Award for the enormous contribution of Pb-Te-O frit technology to the PV industry

ACS Awards Heroes of Chemistry
Pb-Te-O frit chemistry

2021
- **Established Solamet as an independent operating business, opened a new chapter**

2023
- **Launched revolutionary PV3NL TOPCon LECO metallization solution**

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Closing Remarks

- High efficiency n-type solar cells have become mainstream in the market, however demand for silver paste already surpasses supply
- Reduction in mg Ag/watt is critical for sustainability and growth, requiring new breakthroughs in metallization technology
  - Ultra fine line technology for improving efficiency and reducing silver paste laydown
  - Reduced silver content metallization paste delivering at least comparable performances
  - Pure copper paste metallization paste towards a "silver free" future
- Solamet is committed to continue to invest and deliver innovations in metallization technology to drive higher efficiency and lower cost

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