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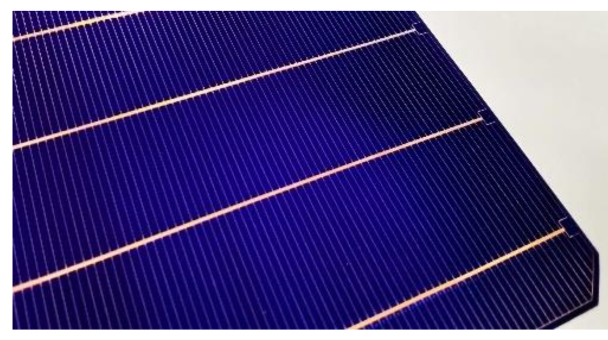
REPLACEMENT OF SILVER BY COPPER

FOR METALLIZATION OF HETEROJUNCTION SOLAR CELLS



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Too Much Silver Needed for All the PV to Come

Only a small amount of silver is required for one solar cell, around 80 mg. But for the current global solar cell production of 150 GW this adds up to more than 2000 tons per year, more than 10% of the entire annual silver supply.[1]
And the production grows rapidly. Terawatt scale volumes are postulated already for 2030! [2]

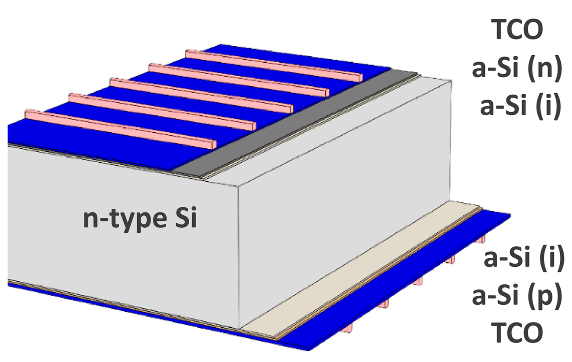
Even with strongly reduced silver consumption per cell, thousands of tons of silver would be needed for PV production in the terawatt range.
10 000 tons of silver will be required for annual production of **1.5 Terawatt** (calculated with 50 mg silver and with 7 W per cell).

2000 TONS of SILVER for 150 GW annual production

The global cumulative PV capacity has reached 600 GW. In order to reach zero CO2 emissions in 2050 altogether 70 TW solar capacity need to be installed worldwide.[3] This is about 100 times more than available now!

The silver price has increased by 50% last year. Replacement of rare and expensive materials will be mandatory to avoid material shortage and to ensure fast growing PV production at continuously decreasing cost.

Heterojunction Cells

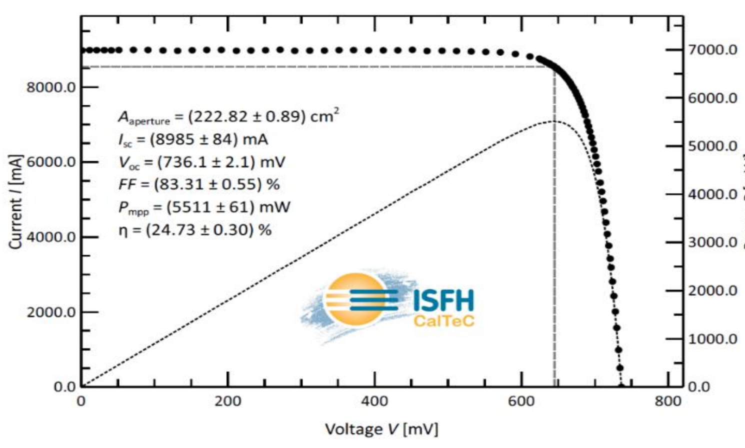


Heterojunction cells are symmetrical and intrinsically bifacial, with layers of amorphous Si and a TCO – thin conductive oxide on both sides. Beside high efficiency and a simple processing sequence, with all processes at low temperature, the structure offers an important advantage for copper metallization: TCOs are excellent barriers against copper diffusion.[4] This makes heterojunction cells resistant against copper ingress and the perfect structures for copper metallization.

Heterojunction and cells with tunnel oxide and polysilicon passivation are considered the next mainstream technologies. Since replacement of silver by copper will be crucial for growing PV production, the particular suitability of heterojunction cells for copper metallization could be an important point for the choice of the future cell technology.

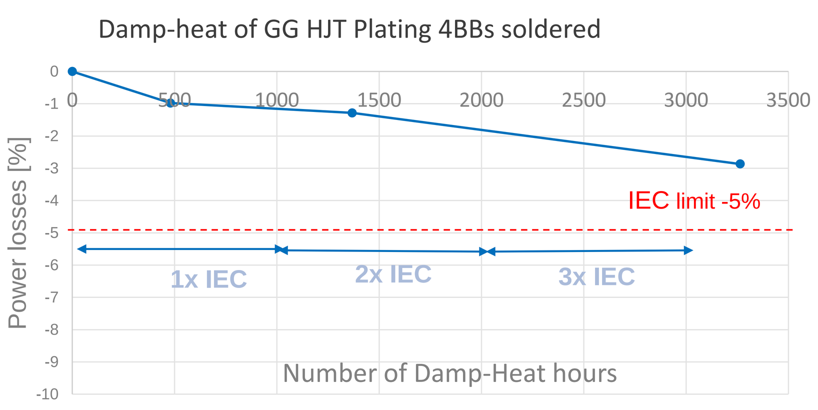
Reference Copper Plating Process at CSEM

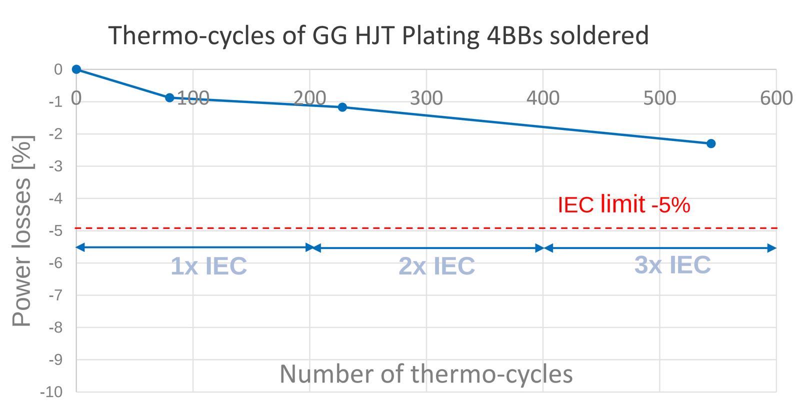
Process with a sputtered metal seed layer and patterning by inkjet printing of an organic mask. High efficiency >24.7% achieved on industrial heterojunction cell precursors.
The process offers cost advantage over silver screen printing and has been tested on industrial equipment for implementation in production by a cell manufacturer.



EXCELLENT MODULE STABILITY > 3x IEC NORM

1-cell modules tested with SmartWire Interconnection and cells with pure copper seed layer, sputtered directly on TCO. The excellent module stability confirms the resistance of heterojunction cells against copper ingress. For interconnection with soldered ribbons cells with an additional adhesion layer have been used, because of higher requirements on adhesion.

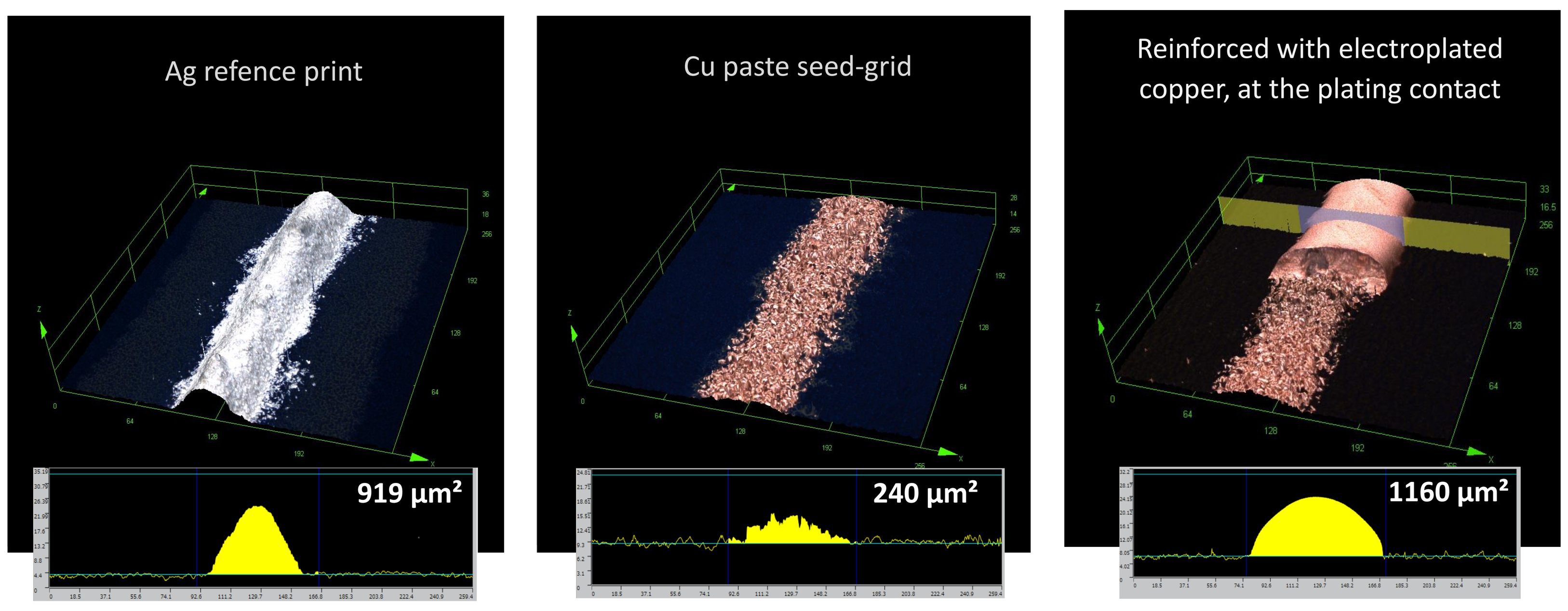




Replacing Silver by Copper

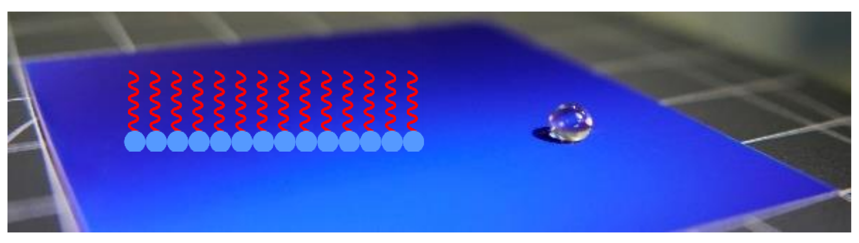
The standard method for the formation of metallization grid lines on crystalline silicon solar cells is screen printing of a silver particle paste.

Simply replacing the silver paste by copper paste leads to low cell efficiency. The resistivity of printed copper paste is too high. The lines are therefore reinforced with an electrodeposited copper layer.



	Ag paste	Cu paste	Cu plated	
Specific resistivity	5.3	**27**	**2.0**	**[µΩ·cm]**
Line resistance per length unit (40 µm screen opening)	1.5	**95**	**0.3**	**[Ω/cm]**

The surface of heterojunction cells is conductive and after seed-grid printing an insulating plating mask is deposited. It is either an inorganic dielectric layer, like Al_2O_3 or SiO_xN_y, or so called self-assembling molecules (SAMs). The mask enables copper deposition selectively only on grid positions.



C18-PA

Phosphonic acids like octadecyl phosphonic acid (C18-PA) form a covalent bond to ITO and the hydrocarbon chains form a well-ordered monolayer. This monolayer is highly hydrophobic and protects the wafer surface against strongly acidic copper electrolyte solutions.

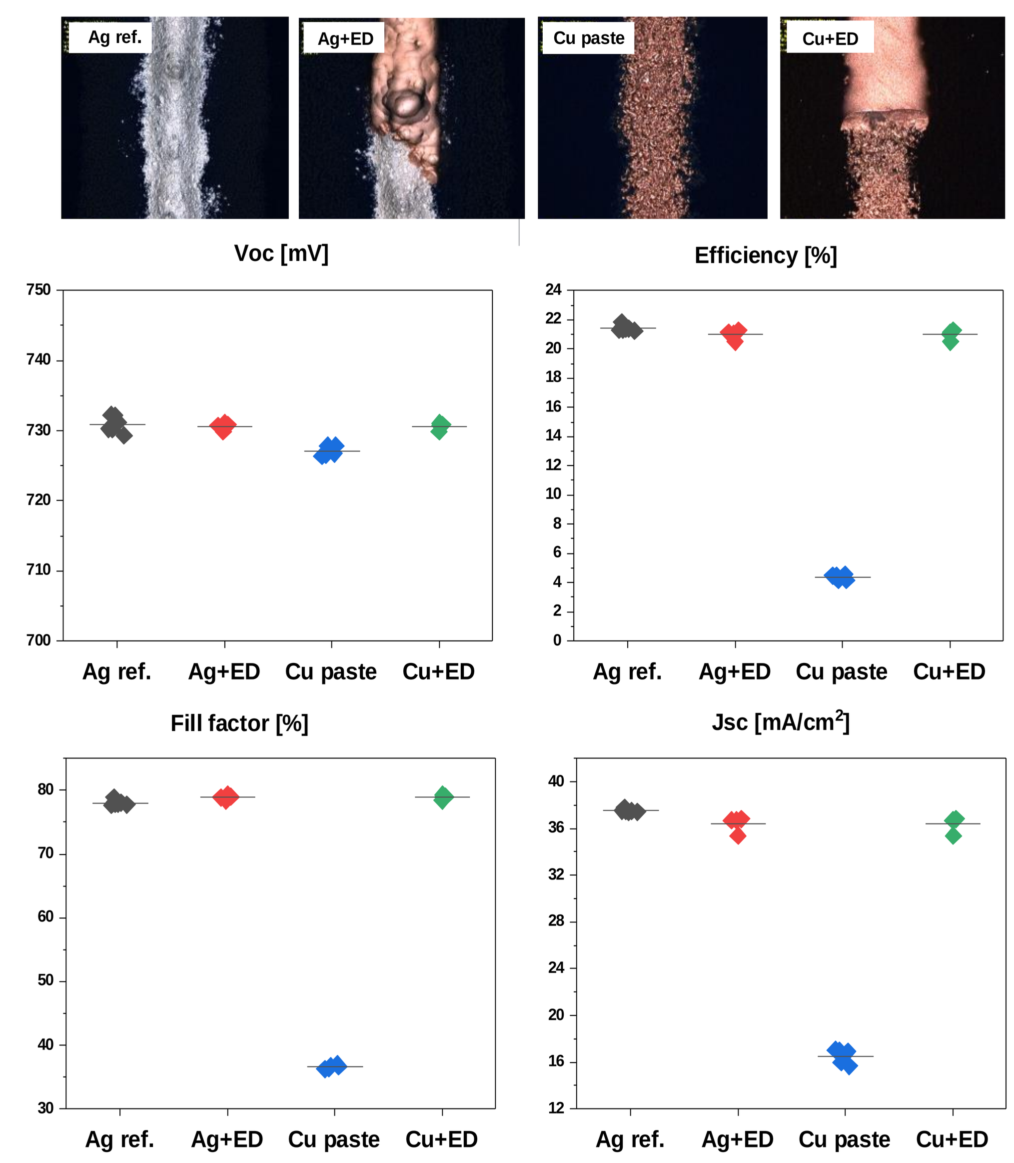
Inorganic dielectric layers are 10-100 nm thick, a SAM layer is only 2 nm thick. The SAM consumption per wafer is ~5 mg. These layers enable enormous material savings for high volume production compared to standard technology: a standard organic mask is 20-25 µm thick and the consumption per wafer is in the range of 1 g.

CELL EFFICIENCY COMPARISON

With copper paste alone the efficiency drops to below 5% (4-busbar-layout on M2 wafers). But after reinforcement with electrodeposited copper all cell parameters reach the same level as the silver reference.

Printing and annealing of copper paste directly on TCO (ITO) does not impair the cell performance.

The process is short and simple: screen printing, mask depositon and electroplating. Additional equipment would be necessary only for mask deposition and for plating. Beside the lower material consumption also the upfront investment is lower compared to the reference process.



ED = electrodeposited copper

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