

## Multiple Metallization Schemes enabled by Multi-wire Interconnection.

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The SmartWire Contacting Technology provided by Meyer Burger consists in busbar-less cells interconnected using copper wires coated with a low melting point alloy, replacing the standard busbars and ribbons soldering. This multiple-wire approach permits using typically 18 wires instead of 3 to 5 ribbons, limiting the transport length in the cell metallization, therefore reducing the power losses in the metallization grid. This enables for the implementation of metallization lines with a line resistance up to  $10 \Omega/\text{cm}$  without impacting the module electrical performance, providing opportunities for a great flexibility in the metallization techniques and materials for solar cells.

A variety of materials and techniques have been tested at CSEM for the fabrication of the metallization grids in silicon heterojunction solar cells. A first focus was set on fine-line screen-printing of low temperature cured Ag pastes. Following dedicated optimization,  $\sim 30 \mu\text{m}$  large Ag fingers for  $\sim 6 \Omega/\text{cm}$  line resistance and  $\sim 60 \mu\text{m}$  large fingers for  $1 \Omega/\text{cm}$  line resistance could be achieved. Pushing to the limits, ultra-fine-line printing of only  $16 \mu\text{m}$  large fingers could be achieved through a mask opening of  $12 \mu\text{m}$  and a mesh to opening orientation of  $90^\circ$ . In order to potentially lower metallization costs, not only a reduction of laydown material was studied, but also alternative materials such as copper-based low temperature cured pastes. First experiments demonstrated about  $60 \mu\text{m}$  large printed fingers for a line resistance of  $\sim 4.5 \Omega/\text{cm}$  using such material.

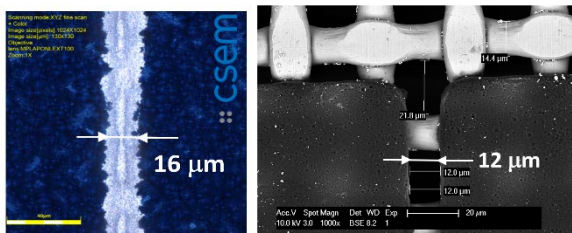


Figure 2: (left) Optical image of silver screen-printed finger, and (right) SEM image of the screen opening.

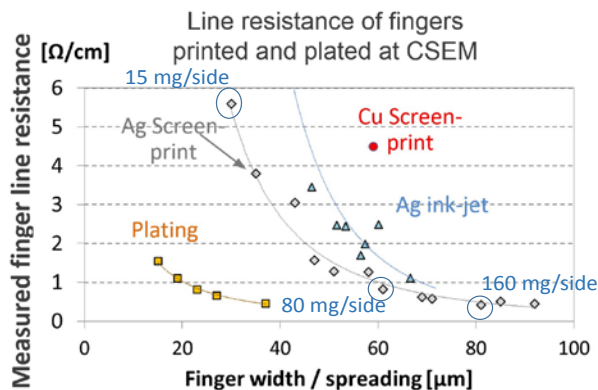


Figure 2: Measured finger line resistance vs. finger width for varying metallization techniques and materials.

A second focus was then set on alternative metallization techniques. Direct inkjet-printing of Ag was evaluated and different printing strategies were developed targeting either fine lines (minimum of  $35 \mu\text{m}$  wide) or lines with high aspect ratio (up to 0.7, enabling for a line resistance of  $1 \Omega/\text{cm}$  for  $\sim 65 \mu\text{m}$  large fingers). Finally, the lowest line resistance for fine line metallization was achieved by copper electroplating, with down to  $20 \mu\text{m}$  large fingers still with a line resistance of  $1 \Omega/\text{cm}$ , as produced in CSEM R&D plating pilot line.

In standard modules, cells are interconnected using 3 to 5 ribbons, imposing a line resistance below respectively 0.5 to

$1 \Omega/\text{cm}$  to ensure minimum electrical losses in the cell metal grid. Considering Figure 2, down to  $20 \mu\text{m}$  large Copper plated fingers and down to  $60 \mu\text{m}$  large printed Ag fingers can be implemented (the latter corresponding to a minimum laydown mass of about 80 mg of Ag per side without counting busbars). Alternatively, CSEM puts a strong focus in developing with Meyer Burger the SmartWire Contacting Technology (SWCT), which consists in interconnecting the cells via 18 wires instead of 3 to 5 ribbons: this strongly relaxes the constraint on the metallization grid to line resistances below  $10 \Omega/\text{cm}$  still ensuring minimum electrical losses.

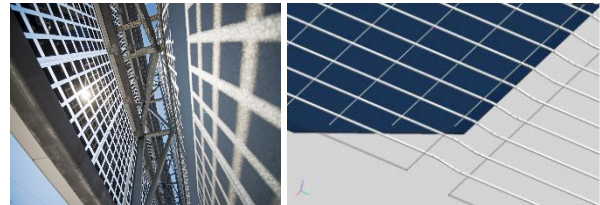


Figure 3: (left) Picture of the CSEM's façade from the backside of the solar modules (right) scheme of SmartWire interconnection of two busbar-less cells.

Considering Figure 2, all the developed metallization techniques and materials can now be employed: the multi-wire approach widens the possibilities offered for the metallization process and materials. Importantly, this first gives access to the implementation of fine-line printing even though line resistance of 2 to  $6 \Omega/\text{cm}$  only are obtained. While this ensures enhanced performance via reduced shadowing ( $\sim 0.5\text{-}1\%$  current generation increase), it can reduce Ag usage by up to a factor 5. Fine-line printing enabling for only 60 mg of Ag for both sides of bifacial SHJ cells ( $30 \text{ mg/side}$ ) was demonstrated at pilot level with 1000 cells processing, compatible with high performance multi-wire modules. Prototype modules were fabricated with silicon heterojunction busbarless cells produced with metallization grids based on fine-line screen printed Ag, screen-printed Cu based fingers, inkjet-printed Ag, as well as copper plated fingers. Each prototype module used 18 wires interconnection scheme, and was then tested for accelerated degradation under damp heat and thermo-cycling. All modules demonstrated  $<5\%$  degradation after IEC testing standards, confirming the potential implementation of larger variety of metallization technologies and materials via the use of multiple-wire interconnection.

The new CSEM's solar powered façade implements such heterojunction cells interconnected by SWCT, further demonstrating improved aesthetics of this module concept for building integration.