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 Ω/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, ~30 µm large Ag fingers for ~6 Ω/cm line resistance and ~60 µm large fingers for 1 Ω/cm line resistance could be achieved. Pushing to the limits, ultra-fine-line printing of only 16 µm large fingers could be achieved through a mask opening of 12 µm and a mesh to opening orientation of 90°. 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 µm large printed fingers for a line resistance of ~ 4.5 Ω/cm using such material.

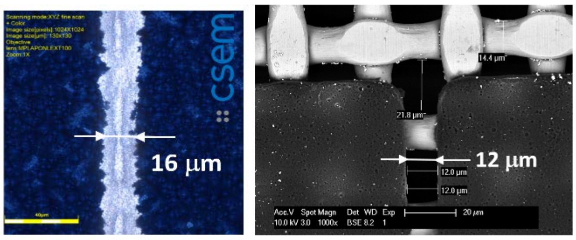

Figure 2: (left) Optical image of silver screen-printed finger, and (right) SEM image of the screen opening.

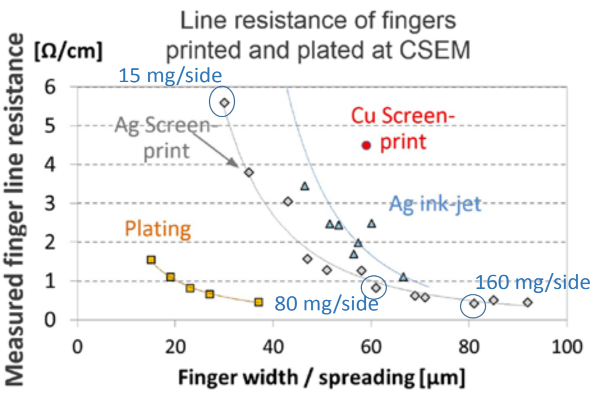

Figure 2: Measured finger line resistance vs. finger width for varying metallization techniques and materials.

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 µm wide) or lines with high aspect ratio (up to 0.7, enabling for a line resistance of 1 Ω/cm for ~65 µm large fingers). Finally, the lowest line resistance for fine line metallization was achieved by copper electroplating, with down to 20 µm large fingers still with a line resistance of 1 Ω/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 Ω/cm to ensure minimum electrical losses in the cell metal grid. Considering Figure 2, down to 20 µm large Copper plated fingers and down to 60 µm 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 Ω/cm still ensuring minimum electrical losses.

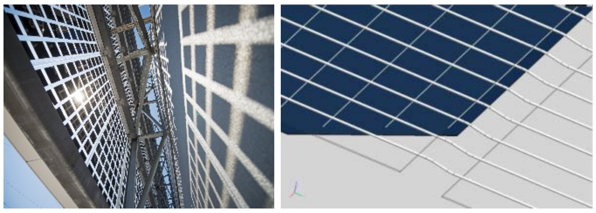

Figure 3: (left) Picture of the CSEM's façade from the backside of the solar modules (right) scheme of SmartWire interconnection of two busbar-less cells.

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 Ω/cm only are obtained. While this ensures enhanced performance via reduced shadowing (~0.5-1% 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 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.