Metallization and Interconnection for Competitive Silicon Heterojunction Solar Cells

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The SwissInno-HJT Pilot and Demonstration project, funded by the Swiss Federal Office for Energy, focuses on the implementation of a R&D pilot production-line of silicon heterojunction (HJT) solar cell, and on the demonstration of the high performance of the developed technologies. In the frame of this project, CSEM develops advanced cell metallization technologies targeting both production cost reduction and module efficiency increase. Advanced materials, processes and concepts are developed on the semi-automatic high precision printer and on the electroplating R&D pilot-line acquired and installed at CSEM. Screen-printed cells with below 30 mg of silver per side were systematically demonstrated in combination with SmartWire interconnection, as well as industrial-size copper-plated cell with up to 22.8% (GridTouch) conversion efficiency.

Today's standard metallization process for silicon heterojunction (HJT) solar cells relies on screen-printing of low curing temperature silver paste. The 3 to 5 times higher resistivity of this paste as compared to high temperature silver paste demand larger volume of printed material to reach good line conductivity, therefore resulting into increased metallization costs. An important challenge for competitive HJT cell production is therefore the reduction of the metallization costs. Two routes are being followed at CSEM to reduce the silver laydown: combining fine-line printing with multiple wires interconnection, or switching to copper plating.

The use of multiple wires interconnection of HJT cells enables to reinvent the cell metallization, by relaxing the constraint onto finger conductivity by more than a factor 10. Fine-fingers can be used, enabling for increased current density (reduced shadowing) and reduced silver laydown without compromising on electrical performance. A production of 1'000 cells with an average of 30 mg of silver for the front side metallization was successfully done at CSEM (see Figure 1) for module integration, yielding no finger interruption and no impact on electrical performance, demonstrating that this approach enables to save up to 85 % of Ag with respect to busbar/ribbon interconnection (with typically 180 mg for front side). Pushing to the limits, bifacial HJT cells with as low as 15 mg silver per side were demonstrated, and ultra-fine fingers with 16 µm printed width and 10 µm height could be printed through ultimate screens with 12 µm openings (see Figure 1). Initial evaluation of copper paste for screen-printing shows further interesting results, with sufficient line resistance achieved for utilization with wire interconnection (see Figure 2). Modules done with such Copper paste metallization could demonstrate < 5 % degradation after 1000 hours of damp-heat and 200 thermo-cycling.

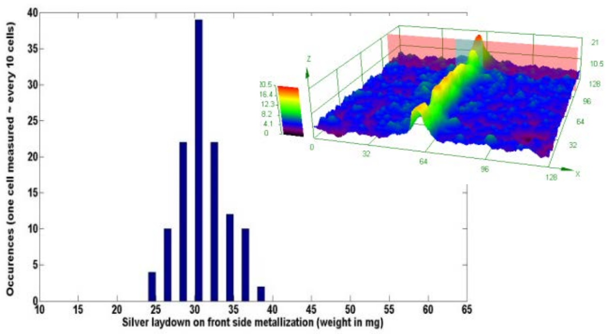

Figure 1: Distribution of silver laydown on front side of 1000 HJT cells (left). Printed silver finger of 20 µm width and 10 µm height (top-right).

The second approach takes advantage of copper electroplating to form the electrical grid; suppressing completely the use of silver while improving the finger conductivity (see Figure 2) and reducing the optical shadowing, as copper-electroplating can enable the fabrication of finer line (down to 8 µm width done at CSEM). Typical width and resistance of copper lines using the developed patterning and plating processes are shown in Figure 2. This metallization enabled performance gain with respect to standard screen printing thanks to reduced shadowing as shown in Table 2 with the increased current generation for busbar-less cells. Implementation in modules was done and long term reliability demonstrated with less than 5 % degradation after 2000 hours of damp heat and 400 thermo-cycles. Thanks to a low finger resistance of plated fingers, the use of 3 busbars design is possible without power losses increase; so that this developed metallization scheme is compatible with standard interconnection technology.

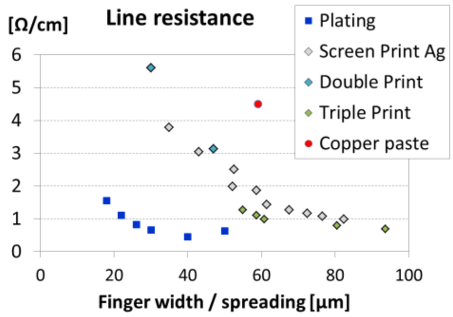

Figure 2: Line resistance versus line width of different metallization.

Table 1: Best cells performance for silver screen-printed and copper-plated cells in busbar-less (Grid Touch) metallization design [1].

HJT CELL	Voc mV	FF %	Jsc mA/cm²	Eff %
Screen-Printed	735	79.3	38.7	22.6
PLATED NiCu	733	79.2	39.2	22.8

Alternative approaches for metallization and interconnection of HJT cells have been successfully developed in CSEM, with two competitive approaches set up demonstrating performance and reliability: fine-line printing and wire interconnection, and copper electroplating. Further developments on the reduction of indium in the wire for the first approach, and on the reduction of the patterning cost on the second approach are the next steps for further reducing HJT cells metallization and interconnection costs.

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[1] A. Lachowicz, *et al.*, Contact Resistance on Plated Silicon Heterojunction Solar Cells, 5th Metallization Workshop, 2014