Direct Interconnection of plated Silicon Heterojunction Solar Cells

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Copper electroplating is investigated as an alternative metallization technique for silicon heterojunction solar cells which suppresses entirely the use of silver and creates highly conductive metallic fingers. This process has been successfully implemented for bifacial solar cells in a R&D pilot line at CSEM. This metallization technique is particularly adapted for the direct cells interconnection method where conductive fingers are to maximize performance and minimize costs. This work was conducted in the frame of the SFOE pilot and demonstration Swiss-Inno-HJT project.

Copper electroplating is a promising next generation metallization technique for silicon solar cells, and in particular for silicon heterojunction solar cells (SHJ). Indeed, this method enables to suppress expensive silver in the SHJ cells manufacturing and furthermore allows the fabrication of more conductive and narrower finger geometries with respect to state-of-the-art printing of low temperature (~ 200ºC) cured Ag pastes [1]. In this prospect, a R&D plating pilot line was developed and ramped-up at CSEM for the production of copper plated SHJ solar cells. The established process starts with a low-cost hot-melt inkjet patterning technique in order to form an insulating mask with typically 30 µm-wide openings on a metallic seed-layer. Next, the seed-layer is locally thickened in those opened areas to form the metallic finger. This process takes place in vertical plating tools where both sides of the cells are plated simultaneously enabling a fast and simple manufacturing of bifacial cells metallization grids. Finally, both the insulating mask and the seed-layer are removed. Currently, these processes are further developed at CSEM to reduce the cost of patterning and of electrodeposition while increasing the conversion efficiency of SHJ devices.

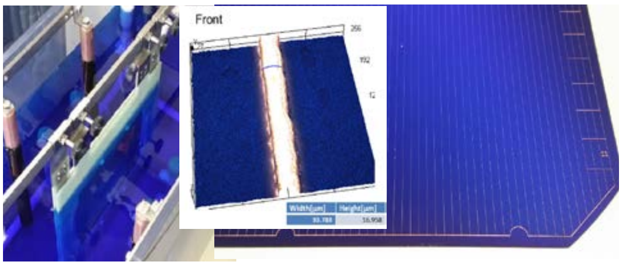

Figure 1: (left) Vertical plating bath for bifacial SHJ cells, (middle) 3-D reconstruction of a 35-µm-wide and ~16-µm-thick electrodeposited copper finger; (right) plated metallization grid on SHJ solar cell.

With the developed materials and processes, highly conductive copper fingers typically ~35 µm-wide and ~16 µm-thick can be fabricated in CSEM R&D pilot line on full 6" bifacial cells, as shown in the 3-D reconstruction of Figure 1. This leads to line resistance of 0.3 Ω cm^{-1}, more than 3 times more conductive than a screen-printed silver counterpart, while significantly reducing the optical shadowing. The achieved performance is key for improving the performance of standard H-patterned silicon heterojunction solar cells interconnected by state-of-the-art ribbon soldering or gluing.

In parallel, alternative solar cell interconnection technologies and modules designs are being developed to improve performance, aesthetics and reliability. Among the developed approaches, CSEM focuses on the multi-wire technology, relaxing the constraint on the metallization grid, and on the direct interconnection of segmented SHJ cells. The latter technique, also referred as "shingling", is presented in Figure 2, where the cells are cut in smaller sub-cells and stacked as roof-tiles with electrically conductive adhesive (ECA) to ensure a reliable electrical contact.

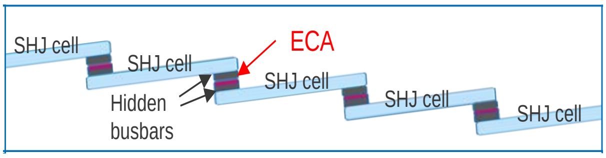

Figure 2: Schematic of the shingle cell interconnection approach.

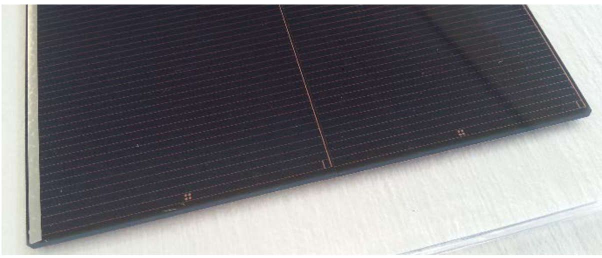

Figure 3: Test module with 2 sub-cells featuring an electrodeposited copper metallization assembled with the shingle cell interconnection approach.

This direct interconnection method presents the advantages to suppress the optical and electrical losses related to the interconnecting ribbons present in state-of-the-art modules, to increase the power density and to yield improved aesthetics of the solar panel. This technique is currently investigated at CSEM with promising module efficiency of 20.6% achieved with screen-printed SHJ cells. In such advanced module configuration, the more resistive silver fingers implies to laser cut 4 to 6 sub-cells per 6" wafer cell, leading to damages potentially reducing electrical performance. These losses as well as the ECA consumption can significantly be mitigated by using copper plated SHJ cells where the highly conductive fingers enable to cut in only 3 or even 2 sub-cells reducing the area affected by the laser process, lowering the ECA amount required for the contact and the number of sub-cells to handle. An example of a test module with 2 copper plated cells is shown in Figure 3. With respect to state-of-the-art glued ribbon interconnection, the amount of ECA is reduced with such interconnection configuration, and power density increased. For the SHJ cells case, low damage segmentation must therefore be achieved to guarantee the high performance of such direct interconnected modules.

[1] J. Geissbühler, *et al*. IEEE J. Photovoltaics 4, 4 (2014).