Platform for High-efficiency Silicon Heterojunction Solar Cells

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CSEM has set up a complete platform for the production and the characterization of monofacial and bifacial both-side contacted silicon heterojunction solar cells, as well as for advanced back-side contacted devices. Innovative and industry-relevant solutions are continuously developed for the improvement of all cell processing steps, aiming for high conversion efficiencies at competitive costs. The technological topics covered at CSEM include wafer bulk quality improvements, wafer texturing and cleaning by wet-chemistry, PECVD depositions of ultra-thin passivating and contact layers, PVD depositions of low-cost and/or high-mobility transparent conductive oxides, advanced cell metallization and cell interconnection processes and various cell characterization techniques. Efficiencies up to 22.8% on industrial full-size 6", screen-printed, both-side contacted cells are demonstrated, as well as, in collaboration with EPFL, 22% back-side contacted cells (European record for such devices to date).

The silicon heterojunction (SHJ) technology is one of the most promising technologies for driving the costs of photovoltaic electricity lower. Compared to standard crystalline silicon solar cells, this type of cells is able to reach higher conversion efficiencies, while being fabricated with fewer fabrication steps at the same time. In addition, thanks to their symmetric structure, SHJ solar cells can easily be integrated in bifacial modules, leading to increased energy yield. Calculations show that, with SHJ solar cells, the average levelized costs of energy could be below 4 €cts/kWh in sunny countries. These costs are comparable with base-load electricity produced from non-renewable resources.

Since 2013, a strong effort was put to establish a complete, performant and flexible platform at CSEM covering all aspects of production and characterization of such SHJ solar cells, from as-cut wafers to finished devices. This technological platform allows CSEM conducting advanced R&D projects on specific processing steps, to develop new processes, materials and cell concepts, and also to provide services and small batch production for its customers.

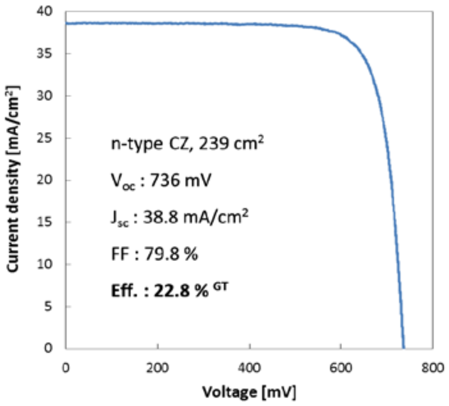

Figure 1: I-V curve of the best full-area 6" CSEM SHJ solar cell (busbar-less, screen-printed metallization, high-mobility TCO, measured with GridTouch).

Concerning the wafer preparation by wet-chemistry, special additives for the texturing baths are developed in-house, and simplification of the wafer cleaning process is also actively pursued. Depositions of advanced functional ultra-thin films by PECVD and ALD are investigated, in order to improve the wafer surface passivation and the carrier transport properties within the cell. The implementation of new high-mobility transparent conductive oxides (TCO) layers in the cells allows improving their general optical properties. Finally, ultra-fine front metallization applied by screen-printing, stencil-printing, inkjet-printing or plating helps to minimize shadowing and thus improves the generated current. Applying all these developments, a 22.8% efficient large-area SHJ solar cell was fabricated, using industry-compatible processes (Figure 1) [1].

In addition to classical both-side contacted devices, advanced interdigitated back-contacted (IBC) SHJ solar cells are also being developed, in collaboration with EPFL. In this configuration, the electrical contacts of both polarities are placed at the back side of the cell (Figures 2 and 3), permitting a gain in performance thanks to the complete removal of the front metallization shadowing. Nevertheless, the patterning of the rear contacts induces additional technical challenges. The approach developed at CSEM relies on mechanical hard masking during PECVD for the patterning of a-Si:H layers, and on hot-melt resist inkjet printing followed by wet etching for the patterning of TCO/metal stacks. Being completely photo-lithography free, this process flow permits to limit the fabrication costs of IBC SHJ cells, and represents a first step towards mass production. The best efficiency obtained so far is 22% on 9 cm² devices[2], which represents the European record for IBC SHJ solar cells to date.

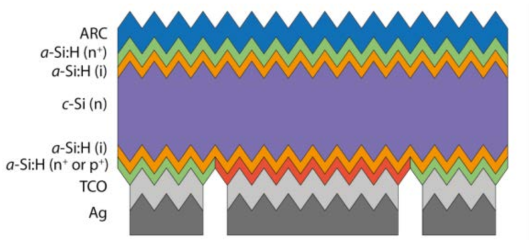

Figure 2: Schematic structure of an IBC SHJ solar cell.

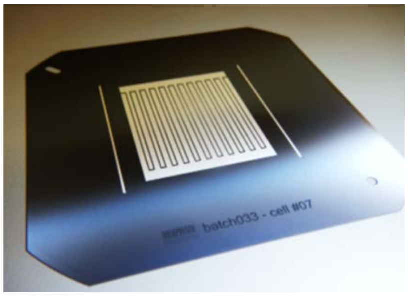

Figure 3: View of the back side of a 3 x 3 cm² IBC SHJ solar cell fabricated at CSEM-EPFL. The interdigitated pattern of the p and n contacts is clearly visible.

[1] A. Descoeudres, *et al.*, Energy Procedia, 77, 508 (2015)

[2] B. Paviet-Salomon, *et al.*, IEEE J. Photovoltaics, 5, 1293 (2015)