High Performance Back-contacted Silicon Heterojunction Solar Cells

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CSEM is developing the next generation of back-contacted silicon heterojunction solar cells, aiming at demonstrating top-level conversion efficiencies with a cost-effective process flow based on CSEM "Tunnel-IBC" approach.

Crystalline silicon solar cells implementing passivating contacts based on hydrogenated amorphous silicon and transparent conductive oxide layers feature the key advantage of increased operating voltages, as demonstrated in CSEM silicon heterojunction solar cell (SHJ) platform. In addition, maximum optical performance can be achieved using an all back-contacted solar cell architecture, providing no metallization shadowing at the cell sunny-side. The back-contacted silicon heterojunction (BC-SHJ) architecture therefore represents one of the silicon solar cell approaches with the highest efficiency potential, combining optimum electrical and optical performances. This was demonstrated by Kaneka, Japan, with the world-record conversion efficiency of 26.7% for a silicon solar cell using such a BC-SHJ architecture. However, the successful industrial spread of BC-SHJ devices is impeded by their complex and delicate process flow, usually involving several costly photolithography steps, to realize the patterned rear contacts. In the frame of the European project "NextBase", CSEM, in close collaboration with EPFL and Meyer Burger Research, has been developing the next generation of BC-SHJ devices, targeting high conversion efficiency along with a cost-effective process flow.

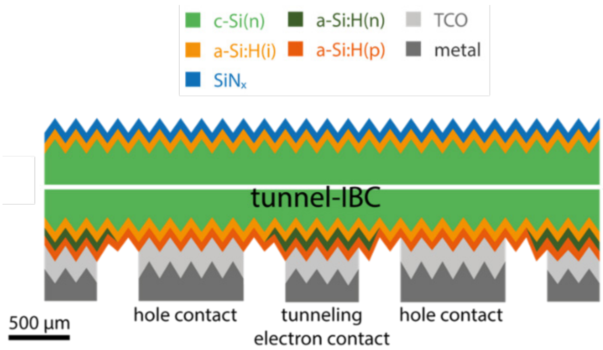

Figure 1: Schematic cross-section of the tunnel-IBC concept developed at CSEM.

CSEM developed and patented a novel BC-SHJ architecture, named "tunnel-IBC", featuring an interband silicon tunnel junction at the electron-collecting regions. In contrast to conventional BC-SHJ devices, where both the electron- and the hole-collecting fingers have to be patterned and aligned, in the tunnel-IBC concept only the electron collector is patterned. An overlaying full-area hole collector is then deposited. As a consequence, a tunnel junction is formed at the electron-collecting regions. Therefore, to work efficiently, the tunnel-IBC device requires an efficient carrier transport through the tunnel junction, and a low lateral conductance within the hole collector in order to avoid shunts between the electron- and hole-collecting regions. The key enablers of the tunnel-IBC technology are nanocrystalline silicon layers featuring anisotropic crystalline growth, hence simultaneously fulfilling the two above-mentioned contrasting requirements. Our innovative tunnel-IBC architecture dramatically simplifies the process flow of BC-SHJ devices as it eliminates the hole collector patterning as well as its alignment to the electron collector. This novel design is thus a major step towards cost-effective processing of BC-SHJ devices.

As a major achievement, CSEM fabricated in 2019 a first record lab-scale tunnel-IBC solar cell (25 cm²) reaching an efficiency of 25%, certified at Fraunhofer ISE Callab. Recently, CSEM further improved its materials and processes to reach a 25.4% efficient tunnel-IBC device (internal measurement calibrated using the certified record cell). The current-voltage curve of these record devices are plotted in Figure 2. Numerical simulations show that efficiency above 26% are reachable with the tunnel-IBC concept. These results demonstrate the high-efficiency potential of the tunnel-IBC technology developed at CSEM.

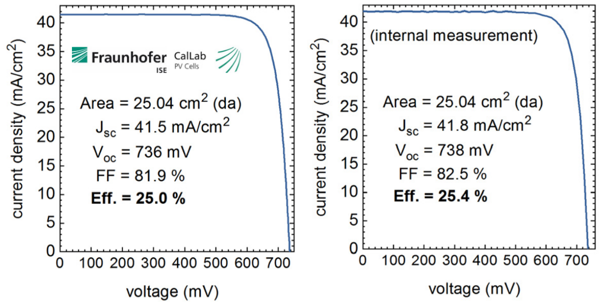

Figure 2: Current-voltage curves of the certified 25% (left) and newly manufactured 25.4%-efficient (right) record BC-HJT device developed by CSEM.

Remarkably, the manufacturing cost structure of the tunnel-IBC device proposed by CSEM was analyzed by the Nextbase EU project partners (CEA). By implementing individual tunnel-IBC devices at 25% efficiency, the CoO of the tunnel-IBC technology was estimated at 0.26 €/Wpeak at medium size production volume, with potential to go lower for multi-gigawatts factory. This convincingly demonstrates that back-contacted devices must not be considered as too expensive per se, and that the tunnel-IBC concept is an interesting option to provide high-efficiency modules at competitive CoO.

This work was funded by the European Union's Horizon2020 Programme for research, technological development and demonstration under Grant Agreement no 727523.