# Development of High Mobility TCOs for Heterojunction Solar Cells

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*In the framework of the European Horizon 2020 AMPERE project (Automated photovoltaic cell and Module industrial Production to regain and secure European Renewable Energy market), CSEM develops transparent conductive oxide films with a twofold goal: improve the solar cell efficiency by improving the TCO's electron mobility and reduce the cost of manufacturing of the solar cell by developing non-indium-based TCO.*

Silicon heterojunction technology (HJT) solar cells hold the power conversion efficiency record (>25%), 1-2% higher than conventional silicon technologies[1]. It has shown a large potential to address the challenges of efficiency, cost, reliability and durability of photovoltaic cells and modules production. The AMPERE project[2] focuses on the industrialization and automation of demonstrated innovative technologies to manufacture HJT solar cells and bi-facial modules in Europe. CSEM is notably working on fulfilling the goals of improving cell performance by developing high-mobility TCOs and reducing cell production cost by developing cheaper TCOs. High mobility TCOs are typically hydrogenated impurity-doped indium oxide based. Their high electron mobility enables high conductivity for low carrier concentration, hence low parasitic absorption and high photocurrent in cells; cheaper TCO are typically based on the earth-abundant tin or zinc oxides. The main candidate materials evaluated in AMPERE are high-mobility tungsten-doped indium oxide (IWO) and In-free aluminum-doped zinc oxide (AZO). Both materials are obtained at CSEM by RF-sputtering in a research-scale tool from planar targets. At this stage in the project material quality is investigated and optimized with respect to the performance obtained when integrated in project partner CEA-INES pilot-line rear emitter mono-facial cells. Figure 1 shows that the cells with AZO exhibit identical performances than the ones with CSEM indium tin oxide (ITO) reference process.

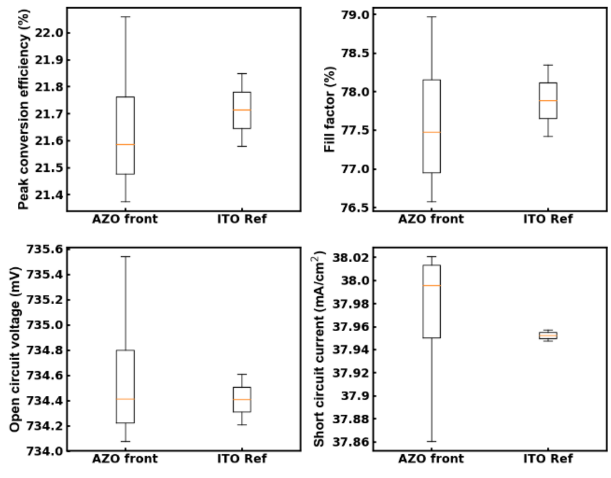


*Figure 1: Light IV measurements of HJT cells having an AZO front electrode and comparison with ITO CSEM reference process.*

This confirms the high potential of AZO as indium-free alternative to ITO.

IWO is processed at CSEM using solely residual water present in the chamber as a sufficient source for H incorporation and high mobility. IWO was tested as front and back electrode in solar cell precursors fabricated at CEA-INES, and compared to CSEM ITO reference process. Figure 2 shows that IWO front electrode leads to a very significant current gain of 0.4 mA/cm$^2$, while back IWO on the other hand leads to a more modest gain of 0.1 mA/cm$^2$. Altogether a full IWO cell leads to a total current gain of 0.5-0.6 mA/cm$^2$.

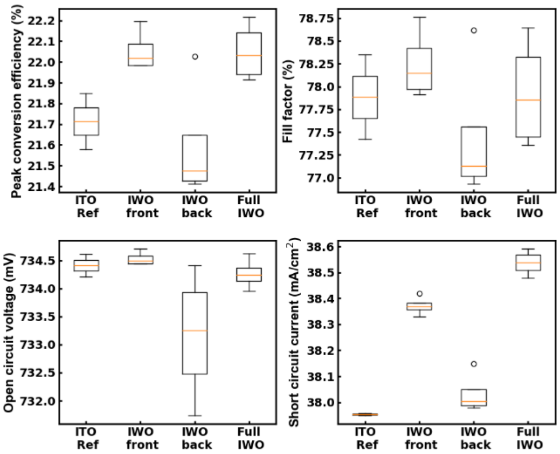


*Figure 2: Light IV measurements of cells having an IWO front electrode, an IWO back electrode, and both, and comparison with CSEM ITO reference process.*

Overall the best device with IWO front leads to an efficiency gain of 0.3-0.4% compared to full ITO. These results highlight the great potential of IWO as high mobility high transparency TCO for use in heterojunction solar cells.

The project continues with further optimization of the TCO processes for pilot-line HJT cell precursors; later TCOs' reliability will be investigated and deposition process itself will be optimized.

[1] NREL, "NREL Efficiency Chart," 7 July 2018. [Online]. Available: https://www.nrel.gov/pv/assets/pdfs/pv-efficiencies-07-17-2018.pdf

[2] www.ampere-h2020.eu