Back contact interfacial engineering for ultrathin CIGS solar cells

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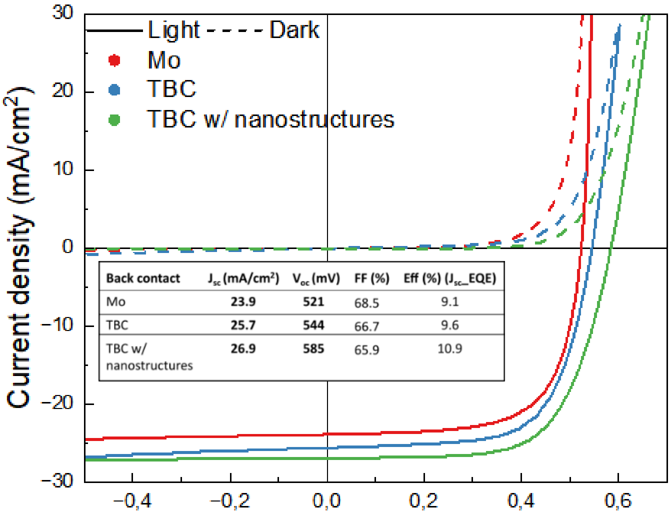
The Horizon Europe HIBITS project aims to develop high-efficiency $Cu(In,Ga)Se_2$ (CIGS) solar cells with reduced absorber thickness and innovative back contacts, targeting conversion efficiencies up to 25%. While reducing CIGS layer thickness typically decreases photon collection at long wavelengths, achieving high efficiencies necessitates highly reflective back contacts, precise control over CIGS composition, deposition conditions, and strategic interface engineering.

In this frame, our research focuses on optimizing ultrathin CIGS solar cells by replacing traditional Mo back contacts with transparent and reflective back contacts. We first optimized a transparent conducting back contact combining good optical and electrical properties as well as stability under the high-temperature conditions typical of CIGS deposition. A Silver mirror encapsulated with such optimized conductive oxide exhibits reflectance up to 90%, which can significantly enhance long-wavelength photon collection in the full cell. To further improve photon collection, we have developed the fabrication of scattering nanostructures out of dielectric material by nano-imprint lithography. Those strategies enable to improve the overall efficiency of solar cells with reduced CIGS thickness.

The replacement of Mo back contact and reduced thickness arise new challenges regarding CIGS growth, for which we use a specifically tuned multi-stage process. Initial device results for 500 to 700nm thick CIGS layers show improvement of both open-circuit voltage (V_{oc}) and short-circuit current density (J_{sc}) with those novel back contacts as compared to Mo (*Figure 1*). The addition of interlayers such as Al_2O_3 on Ag mirrors showed improved passivation, thereby increasing both the V_{oc} and the J_{sc}.



Back contact	J_{sc} (mA/cm²)	V_{oc} (mV)	FF (%)	Eff (%) (J_{sc}_EQE)
Mo	**23.9**	**521**	68.5	9.1
TBC	**25.7**	**544**	66.7	9.6
TBC w/ nanostructures	**26.9**	**585**	65.9	10.9

Figure 1 : I-V measurements for 0.5µm CIGS cells on Mo and Transparent Back Contact (TBC) without and with nanostructures

To gain a better understanding of the interfacial phenomena between the CIGS and the back contact, enabling us to develop strategies for achieving conversion efficiencies over 20%, we will present a multi-faceted approach that combines advanced optical simulations with in-depth characterizations. These include reflectance measurements, photoluminescence studies, current-voltage characteristics, external quantum efficiency (EQE), and Glow Discharge Optical Emission Spectroscopy (GD-OES) analysis of material composition.