Development of reflective back contacts for high-efficiency ultra-thin CIGS solar cells

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$Cu(In,Ga)Se_2$-based (CIGS) solar cells with an ultra-thin absorber layer (<500 nm) allow manufacturing cost reduction but exhibit low efficiencies due to poor light absorption and back contact recombination. To achieve high-efficiency ultra-thin CIGS solar cells, it is necessary to develop reflective back contacts that enhance CIGS absorption. In this work we present the first ultra-thin CIGS solar cells prepared directly on top of an ohmic and reflective back contact.

First, numerical electromagnetic simulations of complete solar cells with different CIGS thicknesses and various mirror materials have been performed. We demonstrated the possibility to reach a short-circuit current of J_{SC} = 36.3 mA/cm² for a 150-nm-thick CIGS absorber with a silver nanostructured mirror[1].

In this work, we first fabricated flat reflectors consisting of a silver mirror covered with an ITO back contact in order to replace the conventional Mo back contact. The thermal stability as well as the high reflectivity and conductivity of these reflectors have been confirmed based on TEM/EDX analysis, optical and electrical measurements.

We demonstrate the direct fabrication of complete ultra-thin solar cells (500-nm-thick CIGS) on top of reflective back contacts with a 13.4%-efficiency. The CIGS thin films were deposited by co-evaporation with a three stage process. I(V) and EQE measurements are displayed in figure 1 and evidence the EQE improvement in the infrared region thanks to enhanced back reflection. The back-reflector results in a J_{SC} gain of 2.3 mA/cm² as compared to a Mo back contact (from 26.2 to 28.5 mA/cm²). Using GD-OES and TEM investigations, we show that a decreased CIGS deposition temperature from 550°C to 500°C limits the formation of a detrimental gallium oxide layer at the CIGS/ITO interface, and leads to a higher V_{OC} attributed to the steeper GGI grading in ultra-thin CIGS layers. Further improvements are expected with an additional ARC and a patterning of the reflective back contact. Preliminary results of nanostructured back contacts fabricated by nanoimprint lithography will be also presented.

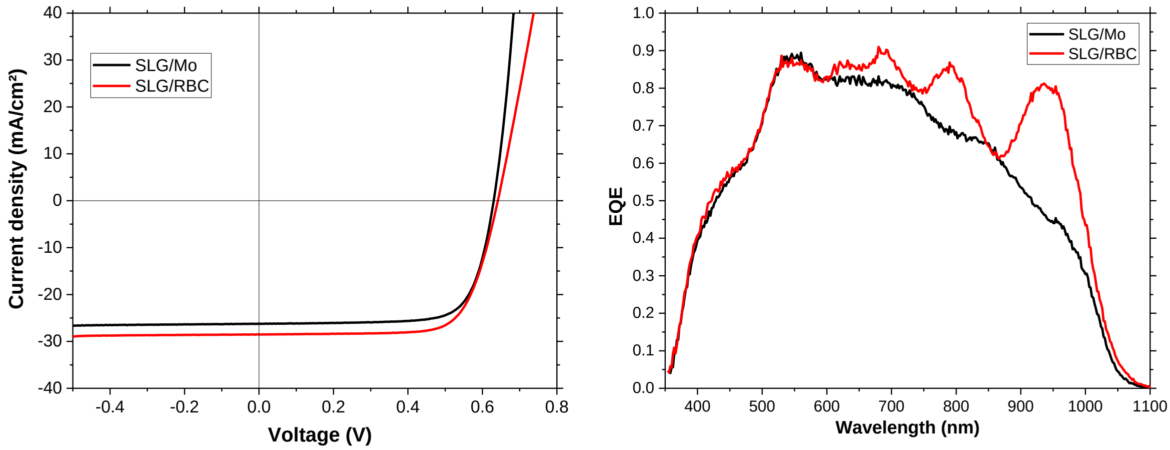

Fig. 1 Experimental I(V) and External Quantum Efficiency (EQE) curves for ultra-thin CIGS solar cells on molybdenum (black) and reflective (red) back contacts.

[1] J. Goffard et al., 'Light Trapping in Ultrathin CIGS Solar Cells with Nanostructured Back Mirrors', IEEE Journal of Photovoltaics, vol. 7, no. 5, pp. 1433–1441, (2017).