Ultrathin CIGS Solar Cells Using Metallic back Reflectors and TCO Stack

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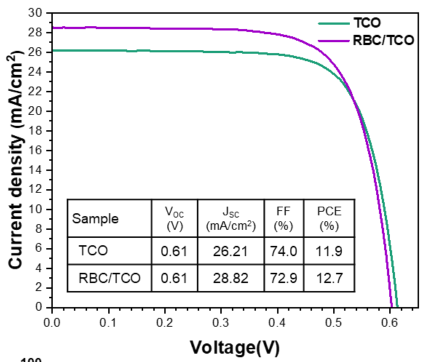
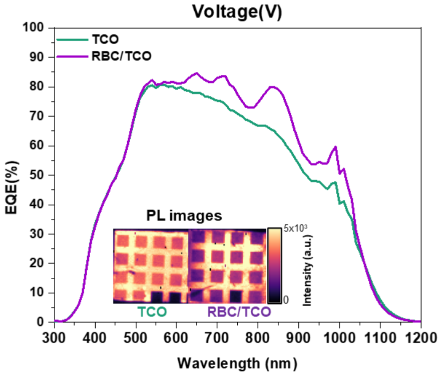
$Cu(In,Ga)Se_2$ (CIGS) solar cells are among the most promising thin-film photovoltaic technologies, achieving record efficiencies of up to 23.6% with absorber layers typically 2-3 µm thick. However, the limited availability and high cost of indium present significant challenges for the large-scale production of cost-effective modules. Reducing the CIGS absorber thickness to below 500 nm offers a viable pathway to lower material consumption and deposition time, thereby decreasing manufacturing costs. [1,2]

Nevertheless, ultrathin CIGS (UCIGS) absorbers suffer from reduced light absorption, leading to lower charge carrier generation, diminished short-circuit current density (J_{SC}), and consequently, lower power conversion efficiency (PCE). One promising strategy to address this issue is the replacement of the conventional molybdenum (Mo) back contact with a reflective metallic back contact (RBC) to enhance optical confinement and boost J_{SC}. However, direct integration of metals can result in undesirable metal diffusion into the UCIGS layer, causing device shunting and instability. To mitigate these effects, a diffusion barrier is required, ideally a material that is both transparent and electrically conductive. [3,4]





In this study, we demonstrate the optimization of a metallic RBC with a stack of transparent conductive oxides (TCOs) as a diffusion barrier and optical spacer to improve the performance of UCIGS solar cells. The impact of different metals and spacers will be discussed. Devices fabricated with this architecture and a 500 nm-thick absorber layer exhibit an increase in PCE from 11.9% (TCO reference) to 12.7%, despite similar open-circuit voltages (V_{OC}) of 0.61 V. This improvement is primarily attributed to an enhanced J_{SC}, which increases from 24.12 mA/cm^2 to 28.82 mA/cm^2. These results are further supported by photoluminescence (PL) and external quantum efficiency (EQE) measurements. Our findings offer a promising route toward the design and scalable fabrication of cost-effective, high-performance ultrathin CIGS solar cells.

1. Gouillart, Louis, et al. *Thin Solid Films* 672 (2019): 1-6.
2. National Renewable Energy Laboratory (NREL). *Best Research-Cell Efficiency Chart*.
3. Gouillart, Louis, et al. *Thin Solid Films* 672 (2019): 1-6.
4. Mollica, Fabien, et al. *Progress in Photovoltaics: Research and Applications* (2025).