

## Extensive Analysis of Structure-Property Relationships in Thin-Film Solar Cells Using Scanning Electron Microscopy in Combination with Focused Ion Beam

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Thin-film solar cells based on Cu(In,Ga)Se<sub>2</sub> absorber layers have shown power-conversion efficiencies of up to more than 20 %, both, on solid glass [1] and on flexible polyimide substrates [2]. These high solar-cell performances have been reached in spite of the polycrystalline nature of the Cu(In,Ga)Se<sub>2</sub> thin films with average grain sizes of about 0.5-1.5 μm. Further research and development of these solar cells needs in-depth analysis of structure-property relationships in Cu(In,Ga)Se<sub>2</sub> layers.

Scanning electron microscopy (SEM) in combination with focused ion beam (FIB) provides a toolbox for the investigation of impacts of structural defects and elemental distributions on the solar-cell performance. In the present work, FIB-sliced cross-section specimens were analyzed by means of imaging, electron backscatter diffraction (EBSD), and electron-beam-induced current (EBIC) measurements at identical positions. Moreover, energy-dispersive X-ray spectroscopy (EDX) and EBSD was performed both, in two and three dimensions, on various Cu(In,Ga)Se<sub>2</sub> solar cells and on different substrate materials.

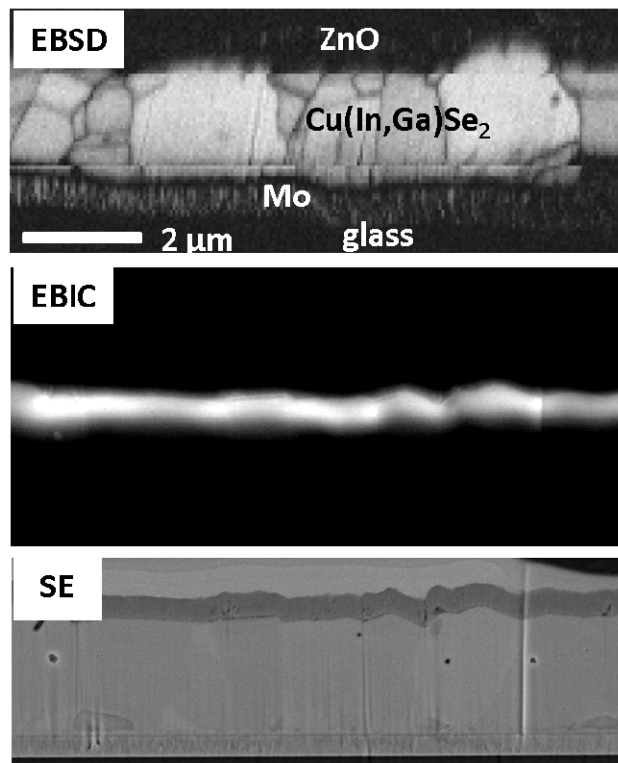
Especially when deposited on very brittle polyimide foils, cross-section specimens of the ZnO/CdS/Cu(In,Ga)Se<sub>2</sub>/Mo/polyimide solar-cell stack can be only prepared by means of FIB slicing without the effect of delamination of individual layers. Keeping the complete stack coherent is essential in order to provide decent contacts for EBIC characterization. The approaches developed in the present work can be transferred to similar optoelectronic thin-film devices on any substrate materials.

### References:

[1] P. Jackson *et al*, Prog. Photovolt.: Res. Appl. **19** (2011), p. 894.

[2] See press release at [http://www.empa.ch/plugin/template/empa/\\*/131441](http://www.empa.ch/plugin/template/empa/*/131441)

[3] The authors are grateful to B. Bunn, C. Kelch, M. Kirsch, T. Münchenberg, and J. Schniebs for solar-cell processing.



**Figure 1.** EBSD and EBIC maps as well as a secondary electron (SE) image of the identical cross-section of a ZnO/CdS/Cu(In,Ga)Se<sub>2</sub>/Mo/glass solar-cell stack.