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Structure-property relationships in thin-film solar cells by scanning electron microscopy in combination with focused ion beam

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Chalcopyrite-type solar cells based on $Cu(In,Ga)Se_2$ absorber layers have shown power-conversion efficiencies of more than 20 % on glass and polyimide substrates [1,2]. The analysis of the microstructure of the $Cu(In,Ga)Se_2$ absorber layer and of the corresponding structure-property relationships is essential for further improvement of the photovoltaic performance.

Scanning electron microscopy (SEM) offers several techniques for investigating the microstructure of the $Cu(In,Ga)Se_2$ absorber layers. The investigated layers showed average grain sizes of 0.5-1.5 µm, depending on their compositions [3], which allowed us to perform electron backscatter diffraction (EBSD), electron-beam-induced current (EBIC) and energy-dispersive X-ray spectroscopy measurements on identical positions of the specimens, in order to correlate microstructural and electrical properties as well as elemental distributions to the performances of the solar cells. Focused ion beam (FIB) was used to prepare the cross-sectional specimens for SEM imaging and analysis by slicing and polishing of the $ZnO/CdS/Cu(In,Ga)Se_2/Mo$/glass solar-cell stacks without delamination of the individual layers. Evaluation of microstrain within individual grains from EBSD data was performed for the first time on $Cu(In,Ga)Se_2$ layers using CrossCourt3 analysis software (see Fig. 1 for an example). Small shifts of features within the measured EBSD patterns can be related to variations in microstrain, which were found to be of the order of 10^{-3}.Advanced EBSD analysis of $Cu(In,Ga)Se_2$ solar cells by extraction of strain distributions in combination with EBIC measurements at identical specimen positions gives information on structure-property relationships in thin-film solar cells that complements state-of-the-art grain-boundary analysis [4,5]. First insights on the effect of strain on the charge-carrier collection influencing the EBIC signal (see Fig. 2) will be presented.

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2. See press release at http://www.empa.ch/plugin/template/empa/*/131441
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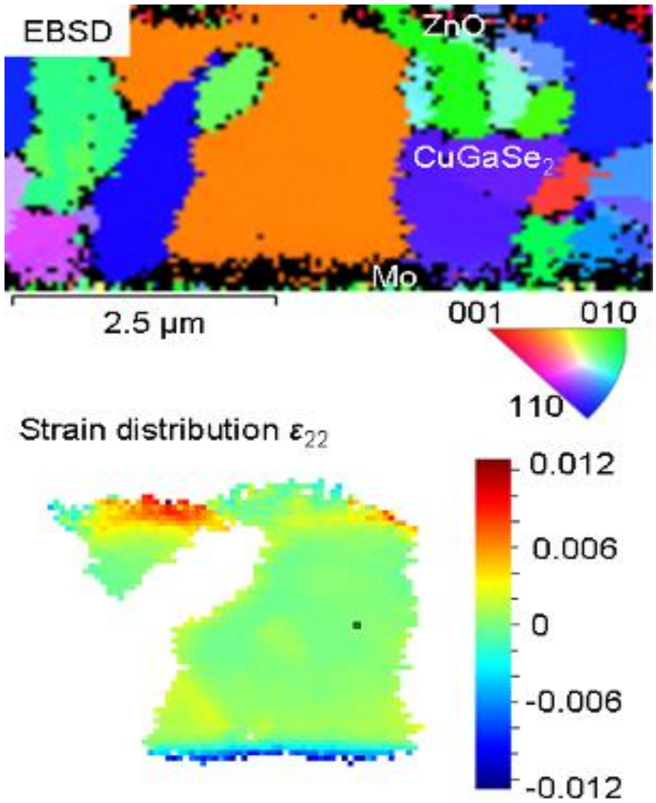

Figure 1. Cross-sectional EBSD orientation distribution map of a $ZnO/CdS/CuGaSe_2/Mo$/glass solar-cell stack (top), and calculated strain distribution within one grain using the software CrossCourt3 (bottom).

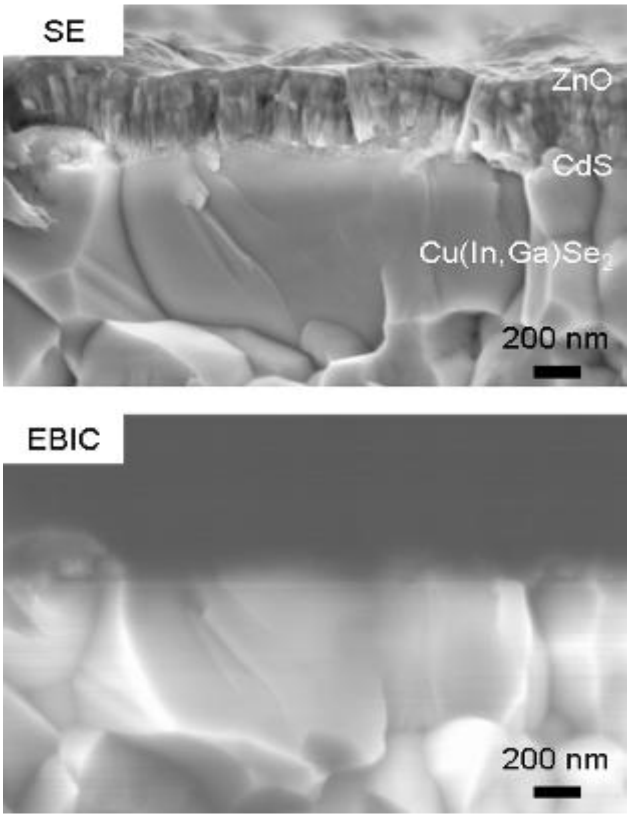

Figure 2. Secondary electron (SE) and EBIC images of the cross-section of a $ZnO/CdS/Cu(In,Ga)Se_2/Mo$/glass solar-cell stack.