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Comparison of Techniques for Strain Measurements in $CuInSe_2$ Absorber Layers of Thin-film Solar Cells

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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. The analysis of the microstructure of the Cu(In,Ga)Se_2 absorber layer is essential for further improvement of the photovoltaic performance. Cu(In,Ga)Se_2 thin films produced by co-evaporation are subject to strain due to recrystallization processes during growth. Since quaternary Cu(In,Ga)Se_2 absorber layers exhibit substantial chemical gradients and grain sizes depending on the final chemical composition [1,2], ternary $CuInSe_2$ thin films were used for a comparative study of different techniques for macrostrain and microstrain analyses. A further favorable feature of these thin films is the average grain sizes of more than 1 µm, which is suitable with respect to the spatial resolutions of the techniques applied.

For the investigation of the macrostrain and microstrain in polycrystalline CuInSe2 thin films, electron backscatter diffraction (EBSD), X-ray diffraction (XRD) and Raman spectroscopy measurements were employed. While macroscopic XRD experiments were performed on a five-circle ETA diffractometer, microdiffraction within individual grains was conducted at the ID01 Microdiffraction Imaging beamline at the European Synchrotron Radiation Facility, Grenoble, France. In addition, information on microstrain was extracted by the Williamson-Hall method from XRD data acquired under grazing incidence using a PANalytical X'pert Pro diffractometer. Raman spectra were collected using a Horiba Jobin Yvon LabRam HR spectrometer coupled to an Olympus BX41 microscope. EBSD maps were measured using a Zeiss Ultra Plus scanning electron microscope equipped with a NordlysNano EBSD detector as well as using the Oxford Instruments AZtec acquisition and evaluation software. The recorded EBSD patterns were evaluated by means of the software CrossCourt (BLG Productions). Shifts in EBSD patterns can directly be correlated with strain distributions within individual grains (see Figure 1). Based on a specific reference pattern, strain distributions can be calculated within individual grains with a spatial resolution of about 50 nm [3].

The results on the strain distributions obtained by the different diffraction techniques were compared, also with respect to the relationships between macrostrain and microstrain. It is the aim to correlate the local strain distributions in $CuInSe_2$ thin films to the optoelectronic properties of the corresponding solar cells obtained by means of electron-beam-induced current and cathodoluminescence measurements.

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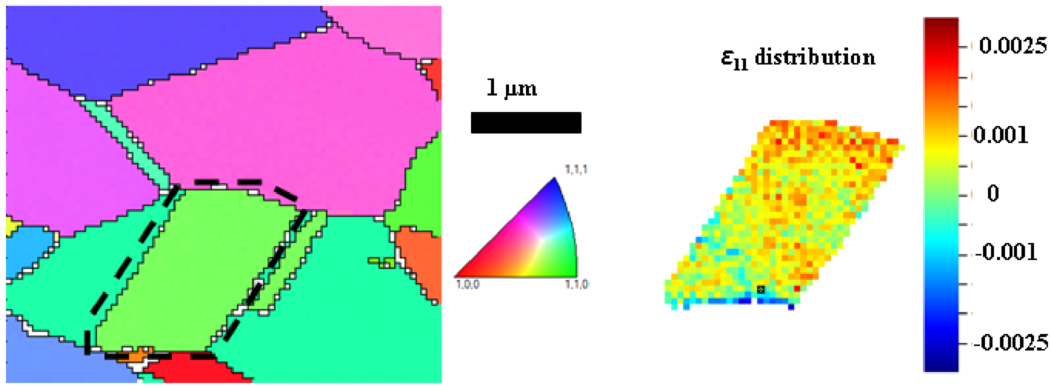

Figure 1: Orientation distribution map of $CuInSe_2$ absorber layer (left). Calculated strain distribution map within individual grain (right).