Correlative microscopy approaches for optoelectronic semiconductor devices at the example of thin-film solar cells

Abou-Ras, D.[1]

[1] Helmholtz-Zentrum Berlin, Germany

The correlation of various microscopy techniques on identical specimen areas provides essential information for the analysis of structure-property relationships in optoelectronic semiconductor devices. The present contribution gives an overview of such research work employing scanning electron and scanning probe microscopy as well as light microscopy methods, using thin-film solar cells based on polycrystalline Cu(In,Ga)Se_2 absorber layers as examples [1]. It will be shown that electron backscatter diffraction (EBSD), electron-beam-induced current and cathodoluminescence measurements on the identical sample region on Cu(In,Ga)Se_2 thin films provide access to recombination velocities at grain boundaries in these films [2]. Together with potential barriers for charge carriers measured by scanning probe microscopy, these analyses provide important input parameters for two-dimensional device simulations, which indicate that enhanced recombination at Cu(In,Ga)Se_2 grain boundaries is one origin for the limited open-circuit voltage in the corresponding solar cells [3]. Furthermore, when combining EBSD and Raman microspectroscopy on identical sample regions, it will be demonstrate how to extract orientation-distribution maps from Raman intensity distributions, which are confirmed by the EBSD orientation-distribution maps [4].

The author is grateful for financial support by the Helmholtz Virtual Institute "Microstructure Control for Thin-Film Solar Cells" (VH-VI-520) and by the BMWi project EFFCIS (No. 03240768).

[1] D. Abou-Ras, Correlative microscopy analyses of thin-film solar cells at multiple scales, Mater. Sci. Semicond. Proc. **65** (2017) 35-43, doi: 10.1016/j.mssp.2016.07.009.

[2] D. Abou-Ras, N. Schäfer, T. Rissom, M.N. Kelly, J. Haarstrich, C. Ronning, G.S. Rohrer, A.D. Rollett, Grain-boundary character distribution and correlations with electrical and optoelectronic properties of $CuInSe_2$ thin films, Acta Mater. **118** (2016) 244-252, doi: 10.1016/j.actamat.2016.07.042.

[3] D. Abou-Ras, S.S. Schmidt, N. Schäfer, J. Kavalakkatt, T. Rissom, T. Unold, R. Mainz, A. Weber, T. Kirchartz, E. Simsek Sanli, P.A. van Aken, Q.M. Ramasse, H.-J. Kleebe, D. Azulay, I. Balberg, O. Millo, O. Cojocaru-Mirédin, D. Barragan-Yani, K. Albe, J. Haarstrich, C. Ronning, Compositional and electrical properties of line and planar defects in Cu(In,Ga)Se2 thin films for solar cells - a review, Phys. Stat. Sol. (RRL) 10 (2016) 363-375, doi: 10.1002/pssr.201510440.

[4] T. Schmid, N. Schäfer, S. Levcenco, T. Rissom, D. Abou-Ras, Orientation-distribution mapping of polycrystalline materials by Raman microspectroscopy, Nature Sci. Rep. **5** (2015) 18410-1-7.