X-ray methods for solar cell studies

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I am professor in X-ray methods for materials science at DTU Energy and hold an ERC Consolidator Grant, SEEWHI – Solar Energy Enabled for World by High resolution Imaging. My group works with a large set of diverse X-ray methods to characterize and improve 3rd generation solar cells.

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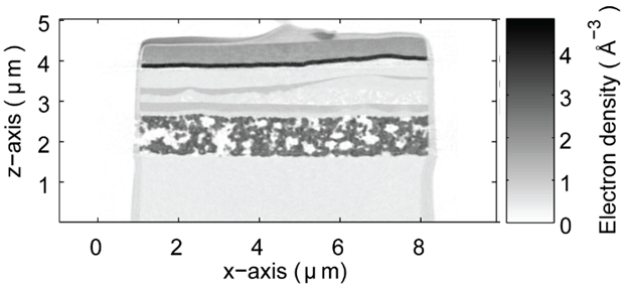
The transition to 100% renewable energy will require several complementary technologies, of which solar energy is one of the most important. This requires a huge scale-up of solar cell production, with a considerable energy input, given the current dominating silicon-based technology. In the SEEWHI project, we are applying a broad spectrum of X-ray techniques for the characterization and optimization of 3rd generation solar cells, primarily based on two broad groups of materials: organic and metal chalcogenides. The techniques that we use cover size scales from ångstrøm to micrometers and provide both structural and chemical information about materials and devices. In many cases, we apply several techniques in parallel for multimodal and multiscale correlation of physical parameters, and often *in situ*, to follow a manufacturing process or degradation as it happens.



Axial slice through a polymer tandem solar cell, partially coated from aqueous dispersion, obtained by ptychographic X-ray Tomography [1]

We will present results of

- Ultra-high resolution ptychographic tomography [1]
- …combined with X-ray Fluorescence (XRF) and X-ray Beam Induced Current (XBIC) (data from MAX IV)
- Scanning Transmission X-ray Microscopy (STXM) [2]
- 3D X-ray Diffraction Microscopy (3DXRD)
- Small Angle X-ray Scattering (SAXS, data from MAXLAB) [3]
- *In situ* Grazing Incidence Small and Wide Angle X-ray Scattering (GISAXS/GIWAXS) [4]
- Ultrafast time-resolved X-ray absorption spectroscopy.

The results apply to studies of both polymer solar cells and Cu_2ZnSnS_4 with the kesterite structure (CZTS), but can equally well find application for other materials systems, e.g. perovskites or other thin film technologies, or even the classical silicon solar cells. Almost all techniques (with the possible exception of ultrafast XAS) may eventually be available at MAX IV.

[1] Dam, H.F. et al. Adv. Energy Mat., 2015, 5, 1400736

[2] Pedersen, E.B.L. et al. J. Mat. Chem. C, 2014, 2, 5176-5182

[3] Pedersen, E.B.L. et al. J. Mat. Chem. A, 2015, 3, 17022-17031

[4] Rossander, L.H. et al. Energy Environ. Sci., 2017,10, 2411-2419