

Materials Science & Engineering Doctoral Defense

Multi-Scale Characterization of the Roles of Alkali Post-Deposition Treatments and Ag-Alloying in Cu(In,Ga)Se₂ Solar Cells

School for Engineering of Matter, Transport and Energy

Tara Nietzold

Advisor: Dr. Mariana Bertoni

Abstract

Thin film solar cells are based on polycrystalline materials that contain a high concentration of intrinsic and extrinsic defects. Improving the device efficiency in such systems relies on understanding the nature of defects - whether they are positive, negative, or neutral in their influence - and their sources in order to engineer optimized absorbers. Oftentimes, these are studied individually, as characterization techniques are limited in their ability to directly relate material properties in individual layers to their impact on the actual device performance. Expanding the tools available for increased understanding of materials and devices has been critical for reducing the translation time of laboratory-scale research to changes in commercial module manufacturing lines.

The use of synchrotron X-ray fluorescence (XRF) paired with X-ray beam induced current and voltage (XBIC, XBIV respectively) has proven to be an effective technique for understanding the impact of material composition and inhomogeneity on solar cell device functioning. The combination of large penetration depth, small spot size, and high flux allows for the measurement of entire solar cell stacks with high spatial resolution and chemical sensitivity. In this work, I combine correlative XRF/XBIC/XBIV with other characterization approaches across varying length scales, such as micro-Raman spectroscopy and photoluminescence, to understand how composition influences device performance in thin films.

The work described here is broken into three sections. Firstly, understanding the influence of KF post-deposition treatment (PDT) and the use of Ag-alloying to reduce defect density in the Ga-free material system, CuInSe₂ (CIS). Next, applying a similar characterization workflow to industrially relevant Ga-containing CIGS modules with Ag and KF-PDT. The influence of light soaking and dark heat exposure on the modules are also studied in detail. Results show that Ag used with KF-PDT in CIS causes undesirable cation ordering at the CdS interface and affects the device through increased potential fluctuations. The results also demonstrate the importance of tuning the concentration of KF-PDT used when intended to be used in Ag-alloyed devices. Commercially-processed modules with optimized Ag and KF concentrations are shown to have the device performance instead be dominated by variations in the CIGS composition itself. In particular, changes in Cu and Se concentrations are found to be most influential on the device response to accelerated stressors such as dark heat exposure and light soaking.



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Zoom Link: <https://asu.zoom.us/j/82783767793>