Multi-Modal Characterization of a CIGS Solar Cell System

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Worldwide materials science innovations are driving thin film solar cell technology developments. Three specific thin film technologies, copper indium gallium selenide (CIGS), cadmium telluride and amorphous silicon are competing to achieve the highest efficiency. Today, CIGS technology achieves 22% efficiency [1], matching the performance of modern polycrystalline solar cells.

Microscopy and microanalysis techniques focused on observing and understanding the materials' micro- and nanostructure help drive this efficiency [2, 3]. Traditional cleaving or tearing of the samples for further analysis cannot guarantee access to the cell's specific layers of interest. FIB-SEM cross sectioning, on the other hand, allows the researcher to target specific sample areas and material layers. Figure 1 shows FIB-prepared cross-sections of three CIGS cells on three separate substrates. In each of the three images, a preparation artifact is observed in the CIGS layer. To reduce this artifact, several techniques were employed on the FIB-SEM, including sub-30 kV ion beam milling energies and low temperature milling. In addition, helium and neon imaging were performed for comparison to SEM imaging.

Analysis with scanning transmission electron microscopy (STEM) on lamellas was also performed on the front, zinc oxide (ZnO), and back, molybdenum (Mo), electrodes. STEM reveals different grain morphology between intrinsically doped ZnO (i:ZnO) and Al-doped ZnO. STEM also reveals the extent of unwanted $MoSe_2$ formation during the CIGS coating process in the Mo layer. Further, the STEM geometry also enables energy dispersive spectroscopy (EDS) measurements with a spatial resolution below 10 nm.

Another analytical technique, secondary ion mass spectrometry (SIMS), was performed to detect Na and K in the CIGS active material. These alkali materials diffuse into the CIGS layer during growth and are known to improve cell performance. Figure 2 compares SIMS depth profiles measured on CIGS thin films on two different substrates. Na and K signals are strong on the glass substrate up to the ZnO layer, as glass contains these elements.

References:

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[3] P. Gratia, et al., J. Am. Chem. Soc. (2016), 138, p15821-15824.

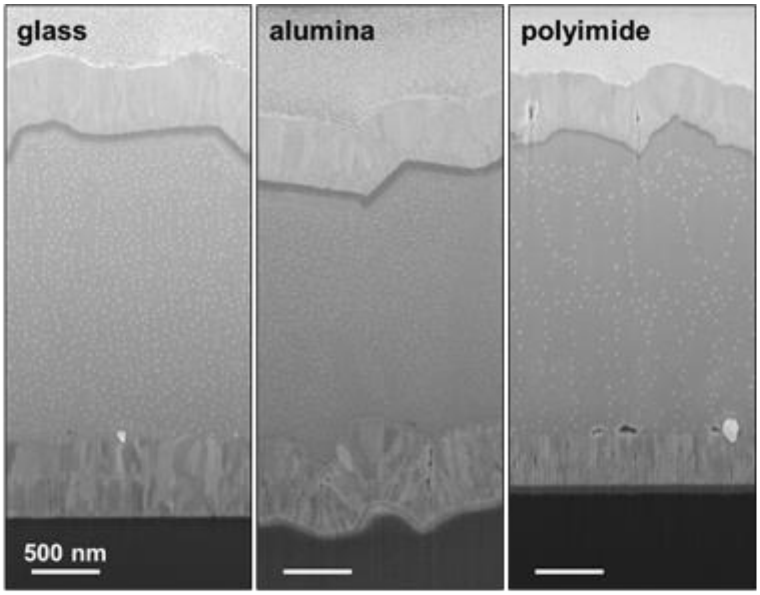

Figure 1. Cross sections of CIGS solar cells on glass, alumina and polyimide.

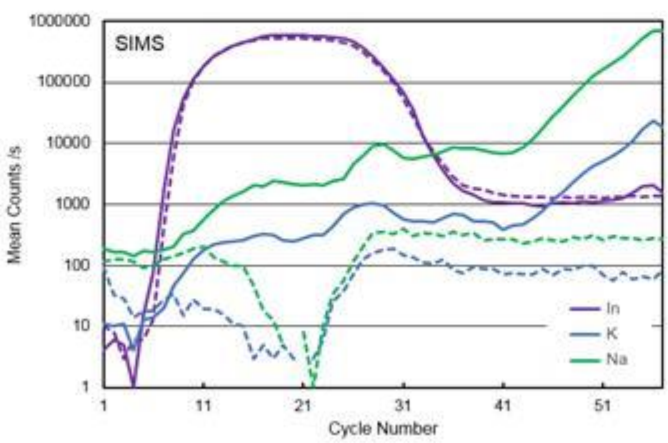

Figure 2. SIMS depth profiles for In, K, and Na for two CIGS solar cells with glass (solid lines) and alumina (dashed lines) substrates.