Cryo-FIB TEM Sample Preparation for $Cu_2ZnSn(S,Se)_4$ Solar Cell

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Thin-film chalcogenide photovoltaic (PV) technology is one of the leading candidates for beyond terawatt production capacity. Presently, CdTe and $Cu(In,Ga)(S,Se)_2$ (CIGSSe) thin-film PV have surpassed 1 gigawatt (GW) commercial production capacity. By replacing indium and gallium in CIGSSe with the more abundant and lower cost zinc and tin, it should be possible to boost production to the 100GW level to impact the world-wide electricity demand. Researchers at IBM TJ Watson Research Center currently hold the world record efficiency for CZTSSe solar cells beyond 11%. Transmission electron microscope (TEM) characterization is critical to CZTSSe development but TEM sample preparation is challenging, because the CZTSSe material is soft and mechanical polishing (especially tri-pod polishing) has not been a successful approach. Focus Ion Beam (FIB) was the primary TEM sample preparation technique but artifacts such as particle formation on the sample surface and Cu enrichment in the CdS buffer layer can be created when a sample is prepared by FIB at room-temperature (RT). The interface between the CdS buffer layer and the CZTSSe absorber is critical for PV performance and Cu poisoning in CdS is inconsistent with good electrical performance. To mitigate FIB artifacts, cryogenic (cryo) FIB was used to prepare PV TEM samples. In this study, we compared TEM samples prepared by RT-FIB and cryo-FIB from the same CZTSSe solar cells. Cyro-FIB samples had almost no particle formation during sample preparation, and the TEM sample showed no Cu diffusion/enrichment in the CdS layer by EDX.