Area 1: Crystalline and Thin Film Silicon PV

METAL PRECIPITATE DISTRIBUTIONS IN HIGH-PERFORMANCE AND CONVENTIONAL MULTICRYSTALLINE SILICON

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Multicrystalline silicon (mc-Si) is a promising material substrate to enable sustainable growth of the photovoltaic industry. This material is characterized by lower capital intensity requirements and lower operating costs compared with single crystalline alternatives such as Czochralski crystal growth. In recent years, conventional casting methods for mc-Si have been modified to engineer wafers with much smaller grain sizes. This modified material is termed high-performance multicrystalline silicon (HP mc-Si).

HP mc-Si is known for lower dislocation densities and higher solar cell efficiencies than conventional mc-Si. The current world record mc-Si solar cell uses *n*-type HP mc-Si as a substrate to produce 21.9% efficiency. The root-cause of the higher cell efficiencies is said to be due to the lower dislocation density throughout the wafer, which results in higher overall minority carrier lifetimes. It is further possible that HP mc-Si wafers also benefit from a larger number of uniformly-distributed heterogeneous nucleation sites, yielding smaller, more getterable metal-rich precipitates than conventional mc-Si.

In this contribution, we investigate the hypothesis that metal-rich precipitates in HP mc-Si wafers are smaller and present in higher densities than those in conventional mc-Si. Two ingots, one seeded for conventional mc-Si growth and one seeded for HP mc-Si growth, are prepared under similar conditions. Wafers are selected from each ingot from similar ingot heights, and electron back scatter diffraction is used to characterize grain boundary orientations throughout the wafer. We employ synchrotron-based micro-X-ray fluorescence microscopy (µ-XRF) to multiple grain boundary types in each wafer to characterize metal-rich precipitate distributions. Studied grain boundary types include random angle, Σ3, and Σ9. We find that the precipitation behavior with grain boundary orientation is similar between the two growth methods, and that larger precipitates are present in conventional *vs.* HP mc-Si. For example, Figure 1 shows a comparison of µ-XRF maps of copper concentration at random angle grain boundaries with 18.6° and 18.3° misorientation in conventional and HP mc-Si, respectively. Quantified µ-XRF maps, including precipitate size and density, from each studied grain boundary will be presented at the conference.

This work provides essential insight for design of growth processes as well as post-growth high temperature processes, including phosphorous diffusion gettering and contact metallization firing. These results may also have impacts for light- and elevated temperature-induced degradation in mc-Si, which is thought to be related to precipitate dissolution during firing.

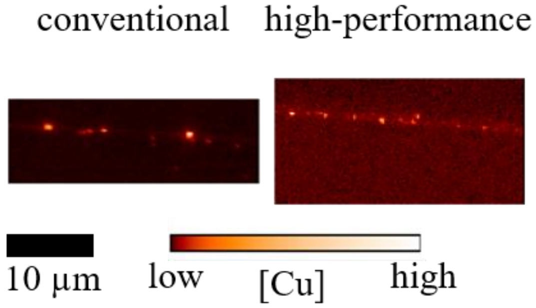

Figure 1: Synchrotron µ-XRF maps of copper concentration at grain boundaries with 18.6° and 18.3° misorientation in conventional and high-performance multicrystalline silicon, respectively. Maps are 30 µm wide, with 200 nm full-width at half-maximum beam diameter and 220 nm pixel size.