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# Microscopy study of contact formation of Si photovoltaic

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Si photovoltaic is the most active commercial products for solar cells. Nevertheless, the current conversion efficiency is still low and the optimization of microstructure for the best efficiency is still underway. However, the understanding of the microstructure is very limited probably due to thick electrode layers involved in preparing a thin cross sectional TEM sample [1-4]. In this report, we first demonstrate a method for TEM sample preparation and then through TEM characterization, we show several new features that will degrade conversion efficiency. The main issue concerns what layered structures are really formed in the front and back-side of the contacts, including phases, morphology and composition across all the interfaces.

Fig. 1(a) and (b) show bright-field cross-sectional TEM images of front contact formation on textured surface for different areas. Fig. 1(a) shows that the Ag crystallites embedded in the Si substrate are distributed non-uniformly, which degrade the contact quality and result in a high contact resistivity. This is because the Ag crystallites are indispensable for providing a current path from the Si substrate into Ag grid bulk. In Fig. 1(b), a thick glass layer between Ag grid bulk and the Si substrate is observed and some small Ag crystallites precipitate in the glass layer. This indicates that the sample is over-fired for the front contact and the firing condition has to be optimized [4].

Fig. 2(a) shows low-magnification bright-field cross-sectional TEM image of back contact formation on textured surface. From TEM image, besides the Al-Si eutectic layer and Si substrate are clearly observed, the image shows an extrusion of about 3~4 μm in size into the Al-Si alloy at the Al-Si alloy/Si interface and a necking phenomenon at the bottom of the extrusion. The top of the extrusion has pyramidal-like morphology and is about 4 μm in size which looks like the remaining portion of the original Si texture without alloying with Al. EDS results show that the extrusion is Si-rich in composition (not shown), implying that the extrusion should result from un-melt Si pyramidal texture. Fig. 2(b) shows a TEM close-up image of a Si-rich extrusion with the corresponding electron diffraction pattern. The lattice spacing and the spot pattern are in agreement with a Si single crystal in [110]-projection. The Si-rich extrusion/Al-Si alloy interface presents faceting along

{111} planes of Si with the presence of defects in the extrusion. This is because the textures are characterized by (111) faceted planes which are close-packed and provide a greater obstacle for atoms to interdiffuse.

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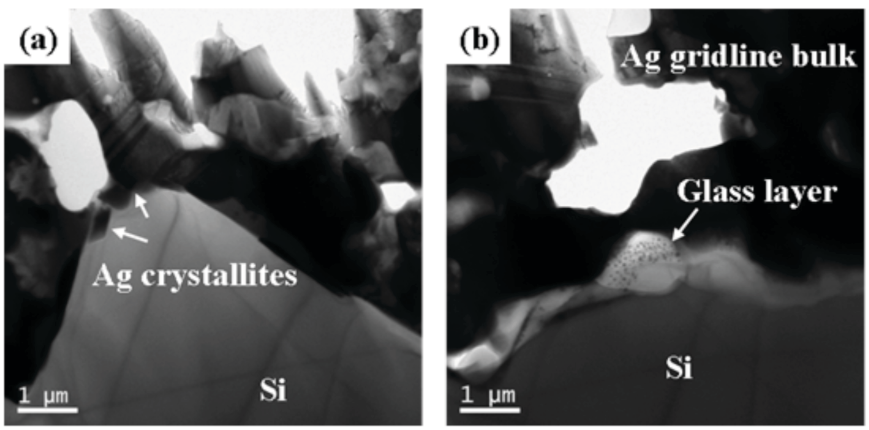


FIG. 1. Bright-field cross-sectional TEM images of front contact formation on textured surface for different areas.

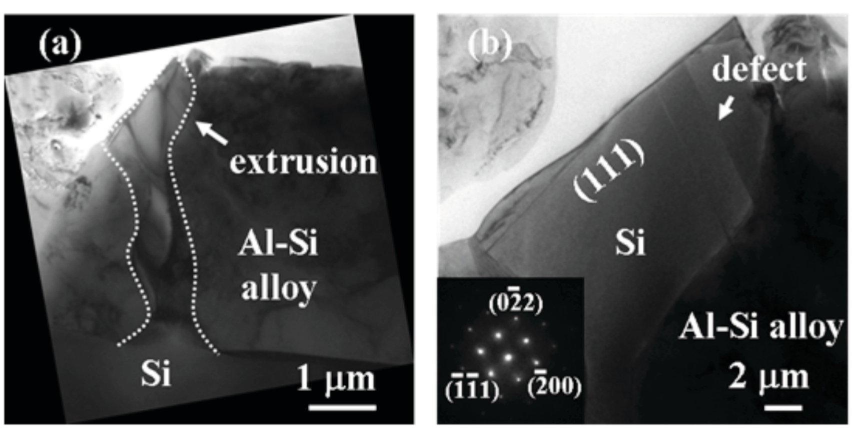


FIG. 2. (a) Low-magnification bright-field cross-sectional TEM images of back contact formation; and (b) TEM close-up image of a Si-rich extrusion with the corresponding electron diffraction pattern.

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