Formation of Large-grain polycrystalline Si Layer on Quartz by Al-induced Crystallization for Thin-Film Solar Cells

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Aluminum-induced crystallization (AIC) have been intensively investigated as one of the alternative for low temperature post-crystallization Si [1]. Several groups have already reported the fabrication of AIC-based Si thin film solar cells. However, the efficiency is much lower than that for conventional wafer Si solar cells. Therefore, the intrinsic crystalline qualities of AIC poly-Si such as grain size and crystal-orientations have to be optimized. In this study, we optimized the growth parameters of poly-Si seed layer formation on quartz substrates. Furthermore, solid phase epitaxy (SPE) on AIC seed layer was investigated to form thicker crystalline Si layer.

The a-Si/Al/quartz sample stack was annealed to induce the crystallization. The Al and a-Si layer (Al/a-Si ratio 1:1.25) were deposited by sputtering. The Al layer was exposed to air for 48 hours prior to a-Si deposition. The optimization was done by changing the initial sample thickness and annealing temperatures. The sample crystallinity was characterized by electron backscatter diffraction (EBSD). Then, a-Si layer with 1µm was deposited on AIC poly-Si. The thicker epitaxial layer was formed by rapid thermal annealing (RTA) via SPE process. The Si SPE film was characterized by UV-Vis measurement. The crystalline quality Q was estimated by equation:
where, R_{e1} and R_{e2} are the reflectance of two

$$Q = \frac{1}{2}\left[\frac{R_{e1}}{R_{e1,cSi}} + \frac{R_{e2}}{R_{e2,cSi}}\right] x100\%$$

prominent maxima of crystalline associated peaks about 367 nm (e1) and 274 nm (e2)[2].

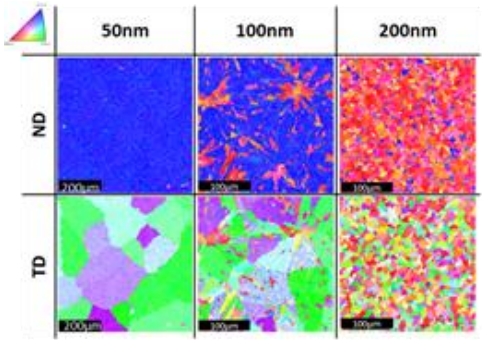

Figure 1. EBSD of poly-Si by varied Al-thickness and annealed at 425°C for 100h

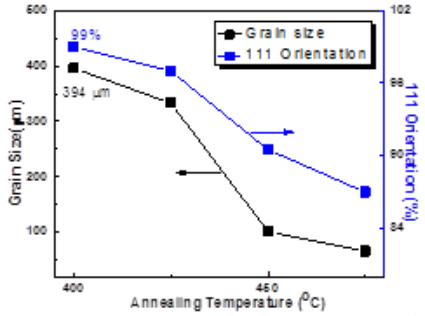

Figure 2. EBSD of 50nm AIC poly-Si annealed at various temperature

The effect of Al thickness to poly-Si formation was shown in Figure 1. These results indicated the thinner Al layer sample had larger grain size and higher (111)-orientation fractions. The best AIC sample was obtained for a 50 nm Al thick sample with preferential (111)-orientations 97% and grain diameter up to ~333µm. The 50nm, 100nm and 200nm Al thick layer had different roughness RMS by ~ 2.6nm, 3 nm and 5 nm respectively. Rough interface lead to rapid Si diffusion and make the nucleation occurs at AlOx/Al interface, while the smooth interface cause slow Si diffusion and hence the nucleation taking place at the Al/quartz interface for thin Al samples, produced the low energy surface Si crystal in (111)-direction [3].

The effect of annealing temperature was summarized in Fig. 2. The grain size significantly increased with decreasing the annealing temperature followed by slightly changing the (111)-orientation fraction. The AIC poly-Si crystalline properties was transferred into thick Si layer by SPE process. The data of UV-reflectance measurement showed higher Q of ~82 %, when 50nm AIC poly-Si used as seed layer (Figure 3).

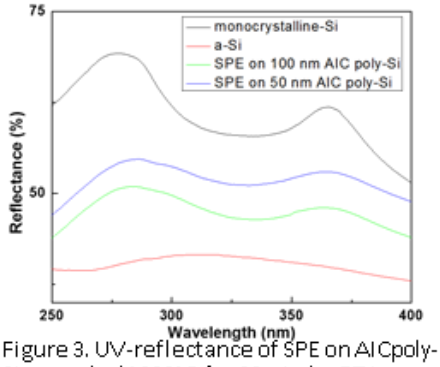

Figure 3. UV-reflectance of SPE on AICpoly-Si annealed 1000°C for 30min by RTA

Refs: [1] O. Nast, et al., J. App. Phys. 88 (2000)124; [2] P.I. Widenborg et al. J. of Cryst. Grow. 276(2005)20; [3] M. Kurosawa, et al., J. App. Phys. 116, (2014)