IGNITION CONTROL OF THE EXPLOSIVE CRYSTALLIZATION OF AMORPHOUS SILICON FILMS BY FLASH LAMP ANNEALING

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Thin-film polycrystalline silicon (poly-Si) solar cells formed on low-cost substrates have been attempted to next-generation solar cells because of low material usage and high stability against light soaking. One of the methods of forming poly-Si films is the crystallization of precursor amorphous Si (a-Si) by post-annealing. Flash lamp annealing (FLA) is a millisecond order annealing technique of using pulse emission from Xe lamp array, and can crystallize μm-order-thickness a-Si films with suppressing thermal damage to underlying substrates. We have confirmed that FLA can crystallize a-Si films with a thickness of >4 μm[1]. The crystallization of a-Si films by FLA progresses laterally, which is referred to as explosive crystallization (EC)[2, 3]. EC is considered to start from high temperature parts; however, the position of its ignition has not been controlled thus far. The control of the ignition of EC is essential particularly for the formation of large-area poly-Si films. The reaching temperature of thick a-Si films is higher than that of thinner ones[3], and the ignition of EC is expected by using a-Si films with partially thick parts. In this work, we prepared a-Si films with partially stacked a-Si parts to form poly-Si films by FLA, aiming at the ignition control of EC.

We used flat glass substrates (Corning Eagle XG) with a size of 19.8 × 19.8 × 0.4 mm³. After the ultrasonic cleaning of the glass substrates, Cr films with a thickness of 200 nm were deposited on them by sputtering. a-Si films with a thickness of ~2 μm were deposited on the Cr films along the sides of the substrates by sputtering by masking most of the Cr films with glass plates. a-Si films were then deposited on the entire surfaces by catalytic chemical vapor deposition (Cat-CVD) at a catalyzer temperature of 1800±50 °C and a substrate temperature of 200 °C. A single shot of 7-ms-duration flash lamp pulse with a fluence of ~12 J/cm² was supplied for each sample pre-heated at 500 °C in Ar atmosphere. We evaluated the crystallization of Si films by Raman spectroscopy.

Figures 1(a) and (b) show the surface images of Si films after FLA for the samples with and without partially thick a-Si. Gray-colored regions are observed only in Fig. 1(a), particularly on and near the thick a-Si region. On the other hand, no color change is seen in Fig. 1(b). Figure 2 shows the Raman spectra of the regions (1)–(3) corresponding to the parts shown in Figs. 1(a) and (b). The Raman spectra of regions (1) and (2) have a peak at around 520.5 cm⁻¹ originating from crystalline Si (c-Si) phase, while the spectrum of region (3) consists of a weak, broad peak at ~480 cm⁻¹, corresponding to a-Si phase. These facts indicate that only the a-Si films with the partially thick a-Si are crystallized by FLA. From the calculation results of Raman Spectra, regions (1) and (2) have high crystalline fractions of >70%, and full-width at half maximums (FWHMs) of ~7 cm⁻¹. This indicates the existence of a number of nm-sized fine grains in the poly-Si. For the above results, the EC of Cat-CVD a-Si films (region 1) is ignited on the thick a-Si parts (region 2), and the thick a-Si parts on the substrate along edges may be effective to ignite the EC of a-Si films.

Stacked a-Si

Figure 1: Surface images of Si films after FLA for the samples (a) with and (b) without stacked a-Si.

Figure 2: Raman spectra of Si films after FLA obtained from the parts shown in Figs. 1(a) and 1(b).