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X-Ray Diffraction Technique to observe the Changes in Amorphous Silicon Film Solar Cells by Aluminium Induction

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ABSTRACT

The fabrication of Poly-crystalline films were done by Aluminium Induced Crystallization (AIC) of plasma Enhanced Chemical Vapour Deposited (PECVD) amorphous silicon (a-si) films. The characterizations had been done at different annealing temperatures (300 and 400C), below the eutectic temperature of the Si-Al binary system. The position of the Al layer with respect to si layer was also varied. The crystallized film-properties were analysed using X-ray diffraction, Raman Spectroscopy, Ellipsometry and many other techniques. The results showed that the process of crystallization occurred more readily when a-si was sandwiched between the substrate and the Al layer. The interfacial layer between the Al and a-si film played an important role also during annealing.

Keywords : Aluminium Induced Crystallization , Plasma Enhanced Chemical Vapour Deposited

I. INTRODUCTION

Polycrystalline Si films has been the subject of many research over the past few decades. It is a material that can increase the performance of devices like thin-film solar cells. Except normal making processes, alternate processes have been proposed, which includs laser annealing and metal-induced crystallisation (MIC). Laser annealing is a fast process but suffers from poor spatial uniformity and a narrow processing window [1]. Various metal-induced crystallisation methods have been proposed to shorten the annealing time and lower the processing temperature. Several metals, including Ni, Pd and Al, are used for this application [2–7]. Research is being conducted on Ni-induced lateral crystallisation, as Ni has a better crystallisation efficiency than other metal candidates. Aluminium-induced crystallisation (AIC) is attractive, since Al as a doping element is compatible with conventional manufacturing of integrated circuits. The efficacy of the AIC method lies in the ability of Al atoms to exchange their positions with Si atoms in the Si–Al binary system at a comparatively low annealing temperature. Thus, as a result of a layer exchange process, a grainy Si surface with improved ordering is formed and the Al atoms reach the surface of the crystallised Si-layer to form an Al-rich region. Later, this Al layer is removed by chemical etching. For application of polycrystalline silicon films in solar cells, the grain size of the material is very important and should be large for high efficiency. A way to obtain such large grains that has recently drawn a lot of attention is the use of AIC. In case of AIC, the activation energy is lowered compared to pure solid-phase crystallisation. Nast et al. [8] found that the layer exchange process starts with the formation of Si nuclei within the Al layer at the Al/a-Si interface.

After that, Si grains keep growing laterally only, until they touch adjacent grains and form a continuous polycrystalline-Si film on the glass substrate. The parameters having an influence on the overall process are, amongst others, (a) the annealing temperature, (b) the oxide layer between a-Si and Al, and (c) the Al structure, depending on the thickness.

In the work described here, polycrystalline-Si films are prepared by the AIC process at different annealing temperatures, varying the position of the Al layer with respect to the Si layer. The structural analysis of polycrystalline-Si films achieved from a-Si/Al and Al/a-Si films, done by XRD methods mainly, reveal that, besides the annealing temperature, the position of the Al layer plays an important role in the crystallisation process.

II. Experimental Details

The amorphous silicon films were deposited in a RF-PECVD system on Corning 7059 glass substrates. The radio frequency (rf) power, chamber pressure and substrate temperature during a-Si deposition were 60W, 1Torr and 240C, respectively. The thicknesses of the deposited Si films lay in the range 220–250nm. The deposition of both glass/Al/a-Si:H and glass/a-Si:H/Al systems was performed in two steps and the sample exposed to air between the two steps. For Al deposition, the samples were transferred to an electron beam gun chamber by breaking the vacuum. In one set of samples, an Al layer was deposited on the top of a-Si films and in other set of samples Si was deposited on the Al films. The thickness of the Al layer was 160–180nm. A high vacuum of 3.210^{6}mbar was maintained in the chamber during all depositions. In the case of Al deposition by an electron beam gun, 3.54kV voltage, 150mA current and 250C substrate temperature were maintained. These double-layered films were annealed under vacuum in a tube furnace at 300 and 400C, respectively for 1h. After that, the samples were etched in a standard Al etching solution (71% H_3PO_3, 8.6% HNO_3, 6.4% CH_3COOH and 14% deionised water at room temperature for 15min).

The structural properties were investigated by X-ray diffraction mainly. For X-ray diffraction, CuK (35kV/20mA) radiation with wavelength 1.54A˚ was used to investigate the crystalline orientations of the films, the measurement being undertaken in Bragg–Brentano geometry. The thicknesses of the films were measured by a Dektak profilometer. The Raman spectra were taken using a 514.5-nm Ar ion laser. Raman spectra in the range 400–560cm^{1} for each film were deconvoluted into three Gaussian peaks corresponding to crystalline silicon (520cm^{1}), an intermediate grain boundary (510cm^{1}) and an amorphous phase (480cm^{1}). The crystalline volume fraction (X_c) was calculated from X_c ¼ [(I_cþI_g)/(I_cþI_gþI_a)]100%, where, I_c, I_g and I_a are the integrated intensities of the crystalline, grain boundary and amorphous components, respectively.

III. Results and Discussions

The conversion of a-Si layer into polycrystalline silicon by the AIC process was confirmed by XRD. Figure 1a shows the XRD spectra of polycrystalline Si films obtained from a-Si/Al films annealed at 300 and 400C for more than one hour. A sharp peak observed around 2¼28 in Figure 1a corresponds to crystalline Si(111). Other c-Si(220) and (311) peaks at around 47 and 57 can also be noticed. The presence of these peaks indicates the possible formation of a crystalline film by the AIC process. If we increase the annealing temperature (T_a) to 400C, the intensities of the Si(111) and (220) peaks increase. At a higher value of T_a, more nucleation centres induced by Al are created, possibly leading to larger amounts of silicon being crystallised. However, no peak corresponding to Al appeared in the annealed and etched films. Figure 1b shows XRD spectra of c-Si films obtained by annealing Al/a-Si films at 300 and 400C. For the film annealed at 300C, a peak at 2¼38.6 corresponding to the (111) orientation of Al is observed. In this case, the absence of crystalline Si peaks shows that the present film is still mostly amorphous. Comparing Figure 1a and b, it is clear that, even at higher T_a, Al cannot be removed totally in the case of an AIC-processed Al/a-Si film. The probable reason is that, with AIC, the sensitive crystallisation depends on the interfacial layer between the Al and the Si or vice-versa layer. The existence of Al_2O_3 between the Al and a-Si layers lowers the crystallisation process, as can be shown by further experimentation.

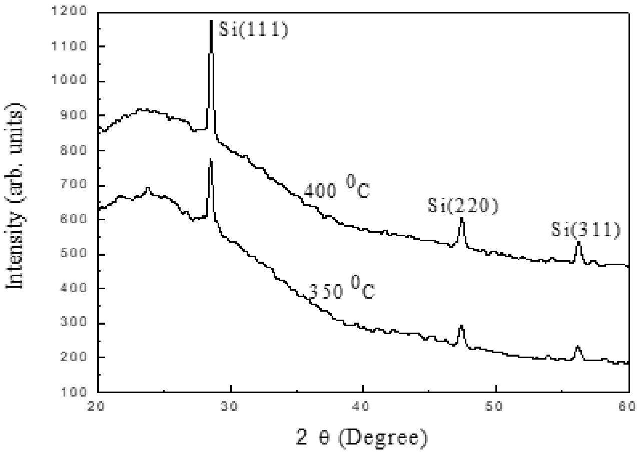

Figure-1a

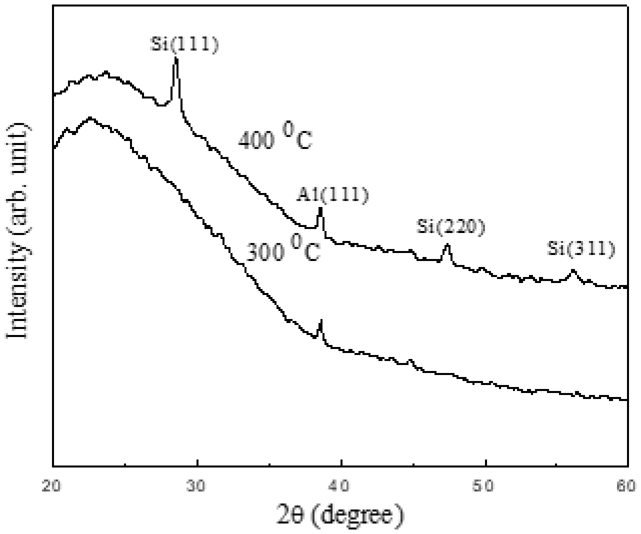

Figure-1b

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