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Influence of the precursor materials on the process of aluminium induced crystallisation of a-Si and a-Si:H

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Abstract

Thin films of poly-Si on low cost substrates such as glass are attractive for thin film solar cells and other large-area electronic devices. The controlled and reproducible preparation of polycrystalline silicon thin films by aluminium-induced crystallisation (AIC) needs optimization of both the process of crystallisation and the deposition conditions of the precursor silicon and aluminium layers. In this work, the influence of the hydrogen concentration in the precursor amorphous silicon layer and the deposition temperature of the aluminium layer on the structural properties of poly-Si thin films obtained by AIC of un-hydrogenated (a-Si) and hydrogenated amorphous silicon films (a-Si:H) are studied. Stacks of glass/a-Si:H/Al were prepared for performing the AIC process. The aluminium and amorphous silicon films are deposited by rf magnetron sputtering. The hydrogen concentration in the a-Si:H films is varied from 0 to 18 at.%. The substrate temperature during a-Si (a-Si:H) deposition is kept constant at 250 °C. The Al film is deposited on top of the a-Si (a-Si:H). The deposition temperature of the aluminium films (T_S^{Al}) is varied from room temperature (RT) to 500 °C. The samples are isothermally annealed in air at T_{an}=530 °C for 7 h. The structural properties of the poly-Si films are studied by Raman spectroscopy and optical microscopy. The results indicate that the hydrogen concentration in the precursor a-Si:H is a very important parameter. It is also observed that T_S^{Al} influences the structural properties of the poly-Si films. It is found that films with better crystalline structure are obtained when the a-Si:H precursor layers contain 9 at.% hydrogen and the aluminium deposition temperature is about 350 °C.

Keywords: poly-Si; AIC; a-Si:H; Hydrogen content

1. Introduction

Recently, the preparation of thin poly-Si films on cheap glass substrates is attracting a lot of attention due to its possible application in solar cells and flat panel displays. Such films can be formed by Aluminium Induced Crystallisation (AIC) of amorphous silicon [1–5]. The main parameters involved in the AIC process, i.e. the annealing temperature, duration and atmosphere, the Al/Si thickness ratio, the interfacial oxide layer, the layer sequence, the method of Al or Si deposition, the substrate pre-treatments, etc. have been intensively studied [1,2,6–12]. However, for more complete elucidation of the mechanism of the AIC process, the influence of the precursor material characteristics on the crystallisation has to be revealed. It is observed that the hydrogen content in the Si layer has an influence on the process of crystallisation, and it makes the reaction proceed faster [9,11,12]. However, it is reported that poly-Si films prepared by AIC of a-Si:H exhibit blisters on the surface and greater surface roughness, compared to those prepared from a-Si [8]. In this paper, the influence of a-Si:H films with different hydrogen content on the structural properties of poly-Si films prepared by AIC of glass/a-Si:H/Al samples is studied. For comparison, un-hydrogenated amorphous Si films are also used as precursors. The influence of the Al deposition temperature on the structure of the poly-Si films is also reported.

2. Experimental

Stacks of glass/a-Si/Al and glass/a-Si:H/Al were prepared to obtain poly-SI by AIC. Un-hydrogenated amorphous silicon (a-Si) or hydrogenated amorphous silicon (a-Si:H) layers were deposited by rf magnetron sputtering of a Cz c-Si target (p-Si, Wacker, 9–12 Ω cm) on glass substrates at T_s=250 °C in an Ar atmosphere at 0.5 Pa or in a gas mixture of Ar (0.5 Pa)+H_2 (0.1 or 0.2 Pa). These conditions result in

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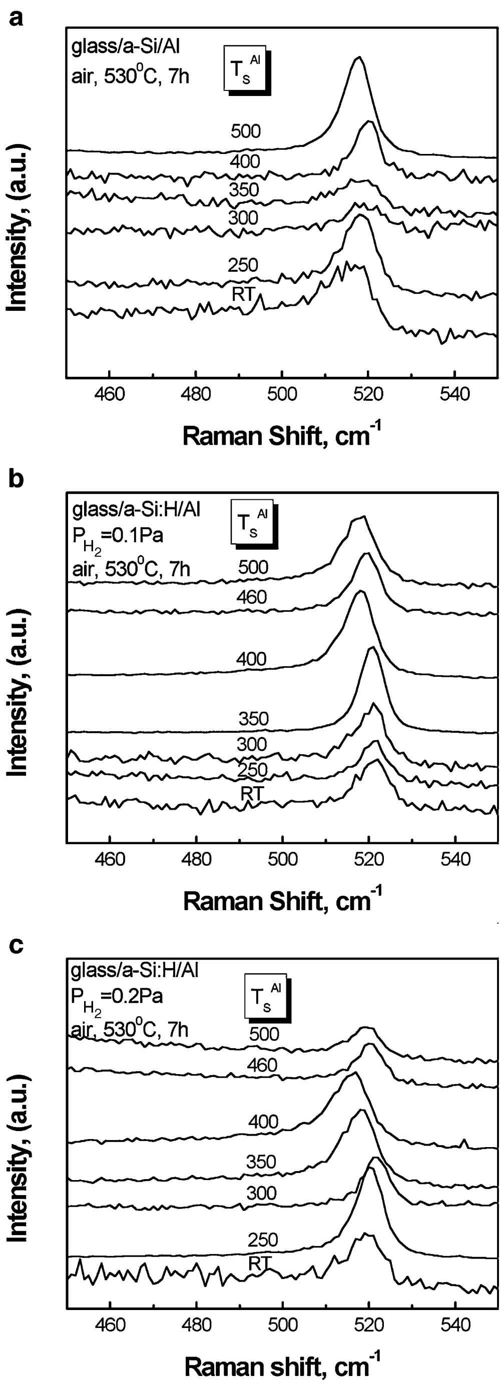

Fig. 1. Raman spectra of AIC poly-Si prepared from un-hydrogenated precursor Si material (a), and from hydrogenated precursor Si material – 9 at.% hydrogen concentration (b), and 18 at.% hydrogen concentration (c), depending on the Al deposition temperature (T_S^{Al}).

hydrogen concentrations (measured by ERDA) in the a-Si:H of 9 and 18 at.%, respectively. The base pressure in the chamber was 1.10^{-4} Pa. The Al layers were deposited on top of the a-Si (a-Si:H) films by rf magnetron sputtering at various temperatures from room temperature (RT) to 500 °C with deposition rate of 30 nm/min. The heating duration for Al layer deposition was from 6 to 28 min for the range of the aluminium deposition temperature (T_S^{Al}). The time for native oxide formation at the interface was about 15 min. The thickness of the Al and a-Si (a-Si:H) were equal — 150 nm. The prepared glass/a-Si/Al and glass/a-Si:H/Al stacks were isothermally annealed at 530 °C for 7 h in air. The annealing under atmospheric pressure was done in a horizontal quartz tube furnace. After annealing, the surface was treated with a wet polishing etch (HNO_3, HF, DI water) before the investigations of the films. The structure of the poly-Si films was studied by Raman spectroscopy and optical microscopy. Raman spectra were excited by the 488 nm line of an Ar^+ laser. The peak positions and the Full Width at Half Maximum (FWHM) of the Raman bands were measured with a mean error of 0.5 cm^{-1}. All Raman spectra presented in this work were measured under the same conditions.

3. Results and discussion

RBS analysis shows that Al content in the annealed films is about 10% and increases as a function of the depth. The poly-Si films contain 60% Si and 30% O. The presence of the O can be explained by an annealing in the ambient atmosphere. It is reasonable to suppose that the oxygen is mainly bound to Al, because of its higher affinity to oxygen compared to Si [13]. However, the presence of SiO_x can not be excluded. More detailed analysis of the elemental composition is in progress.

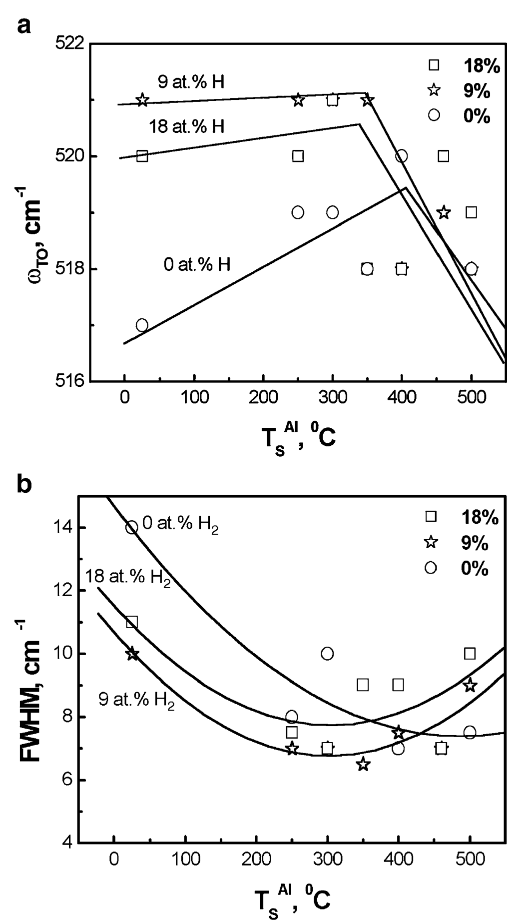

Fig. 2. Dependence of the Si–Si TO-like peak position (a) and of the FWHM of the Si–Si TO-like peak (b) on the Al deposition temperature (T_S^{Al}) for different hydrogen concentrations in the a-Si:H precursors. The curves are guides to the eye.