Characteristics of Recrystallized poly-Si Film Prepared by ELA of a-Si Deposited on SiO_2 / SiN / Glass Using PE-CVD Method

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In this study, we investigate the characteristic of the poly-Si film prepared by the excimer laser annealing (ELA) method of a-Si deposited using plasma enhanced chemical vapor deposition (PE-CVD) method on SiO_2 / SiN / glass substrate (SiN substrate). The crystallinity of the poly-Si film on the SiN substrate is better than that using low pressure chemical vapor deposition (LPCVD) method on the quartz glass substrate (quartz substrate). The grain size of the poly-Si on the SiN substrate is smaller than that on the quartz substrate. These phenomena are due to the difference of the crystal growth mechanism. The stress in the poly-Si film on the SiN substrate is smaller than that on the quartz substrate. For the crystal growth mechanism on the SiN substrate, it is considered that hydrogens in the poly-Si play an important role.

Key words: *ELA, poly-Si, hydrogen, SiN, stress, crystal growth mechanism*

1. Introduction

The recrystallized poly-Si film by excimer laser annealing (ELA) is attractive for thin film transistors (TFTs) [1,2]. The growth model of the poly-Si film under the high energy density of the ELA has been presented from a viewpoint of the nucleation in the super cooled liquid (SCL) [3]. From the result that the a-Si becomes poly-Si grains after a certain shot number under the low energy density, we proposed a crystal growth model based on the solid phase crystallization (SPC) which proceeds through the dislocation movement [4]. In the range from low to high energy densities, the disk shaped grain was observed [5]. The hydrogens in the a-Si film strongly affect the integrity of the recrystallized poly-Si film by ELA [6]. In this paper, we investigate the characteristics of the recrystallized poly-Si film by ELA considering the hydrogens in the film, the grain morphology and the induced stress in the film during the ELA.

2. Experimental

An a-Si film is deposited on the SiO_2(50nm) / SiN (50nm) / glass substrate (SiN substrate) by plasma enhanced chemical vapor deposition (PE-CVD). The SiN film was deposited using plasma CVD method. Some samples have the dehydrogenation process at 450 ^{o}C and for 0 to 90min prior to the ELA. The KrF multi-pulse excimer laser is irradiated on the a-Si film at 1Hz and at room temperature under approximately 10^{-4} Pa. The irradiation time is 23ns at full width at half maximum (FWHM). The energy density and shot number are 200 to 400 mJ/cm^2 and 8 to 100 shot, respectively. The poly-Si film prepared by ELA after a-Si deposition using low pressure chemical vapor deposition (LPCVD) method on the quartz glass substrate (quartz substrate) is also served to experiments for comparison. The hydrogen concentrations are 10^{20}cm^{-3} for the poly-Si on the quartz substrate and 10^{21}cm^{-3} for that on the SiN substrate, respectively. The crystallinity and surface morphology of the poly-Si film are measured by Raman spectroscopy, atomic force microscopy (AFM) and scanning electron microscopy (SEM), respectively. The stress in the poly-Si film is calculated from the Raman shift [7]. Secco etching is performed before observing the poly-Si surface by SEM to clarify the film structure and the morphology.

3. Results and Discussion

Fig.1 shows the relationship between the Raman peak intensity and the shot number. The Raman intensity of the poly-Si film on the SiN substrate is higher than that on the quartz substrate. The dehydrogenation is carried out for 60min prior to the ELA. All the samples shown in Figs.2-7 are also served to the dehydrogenation for 60 min. Fig.2 shows the relationship between the Raman peak shift and the shot number. The Raman peak shift of poly-Si film on the SiN substrate is larger than that on the quartz substrate. Although the Raman peak shift of poly-Si film on the quartz substrate becomes large as increasing the shot number, that on the SiN substrate keeps constant. Fig.3 shows the relationship between the FWHM of the Raman peak and the shot number. The same phenomenon as that for the peak shift is observed except for the data of 200 or 250mJ/cm^2 on the quartz substrate. The reason of this is due to the difference of the crystal growth mechanism. Fig.4 shows the SEM photograph of poly-Si surface for the condition of 400mJ/cm^2, 100 shots and on the SiN substrate. For the SiN substrate, the disk-shaped grain is not observed. Fig.5 shows the relationship between the grain size and the shot number. The grain size of the poly-Si on the SiN substrate is approximately 70nm, and keeps constant in the present energy densities and the shot numbers. This is because the nuclei in the a-Si by PE-CVD may dominate the nucleation process. The defects which are formed by the hydrogen burst during the ELA and the microcrystals in the a-Si [8] are thought to be serve as the origin of the nucleus generation. Fig.6 shows the relationship between the average roughness (Ra) of the poly-Si surface and the shot number. The Ra of poly-Si on the SiN substrate is larger than that on the quartz substrete. Fig.7 shows the relationship between the stress of the poly-Si and the shot number. The stress of the poly-Si film on the SiN substrate is smaller than that on the quartz substrate. Although the stress of poly-Si film on the quartz substrate becomes small as increasing the shot number, that on the SiN substrate keeps constant. The stress relaxation of the film with the shot number on the quartz substrate is though to be related to the disk-shaped grain formation [5]. The small induced stress in the film on the SiN substrate may be related to the nucleus generation under the high concentration of the hydrogens [9]. For examination of the origin of the hydrogens in the film, the stress of the poly-Si film with or without dehydrogenation

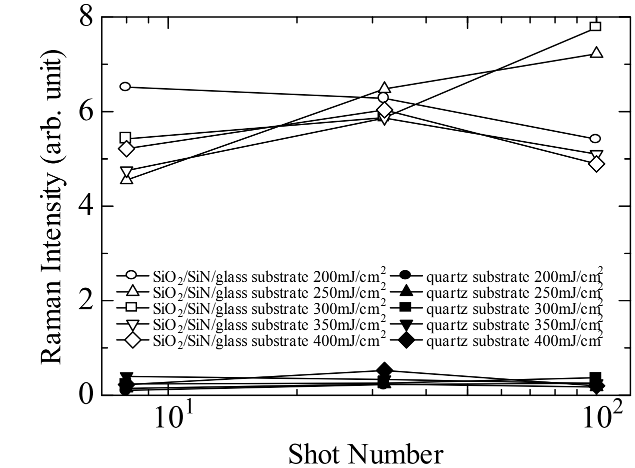

Fig.1 Relationship between the Raman peak intensity and the shot number

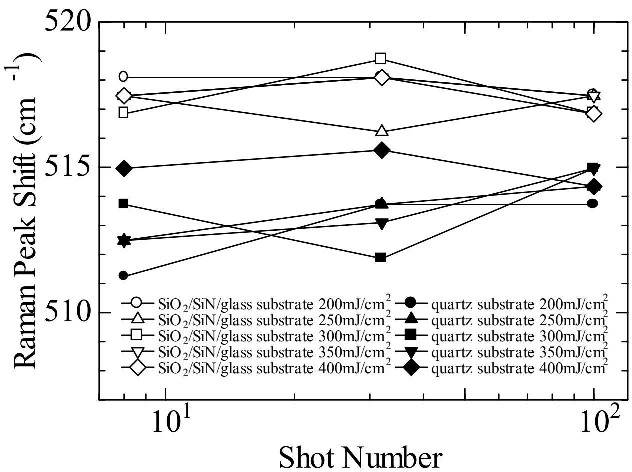

Fig.2 Relationship between the Raman peak shift and the shot number

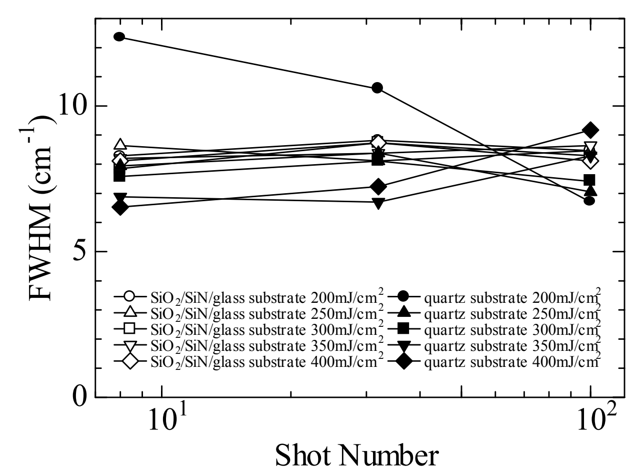

Fig.3 Relationship between FWHM of the Raman peak and shot number

is measured. Fig.8 shows the relationship between the stress of the poly-Si on the SiN substrate and the shot number. The difference of the induced stress of the poly-Si between with the dehydogenation and without it is not observed. It is also found that the stress of the poly-Si film on the SiN keeps constant as increasing the shot number. The reason why the stresses of the samples for 400mJ/cm^2 without the dehydrogenation are smaller than those with another laser conditions is that only the crystal growth mechanism of 400mJ/cm^2 is the nucleation in the SCL. The diffusion length of H_2 molecular in the SiO_2 film during the dehydrogenation annealing is estimated approximately 250nm [10]. It is found that the hydrogens are sufficiently supplied to a-Si by the diffusion from the SiN to the a-Si film. For the crystal growth mechanism on the SiN substrate, it is inferred that hydrogens in the SiN film play an important role. It is also important to consider the influences of both the hydrogen in a-Si deposited by the PE-CVD method and the difference of the thermal conductivity between the both substrates on the crystallinity of the poly-Si film.

4. Conclusions

The characteristic of the poly-Si film prepared by ELA method of a-Si deposited on SiO_2 / SiN / glass substrate using PE-CVD method was examined. The crystallinity of the poly-Si film on the SiN substrete is better than that on the quartz substrate. Raman peak shift and FWHM keep constant in the range from 200 to 400mJ/cm^2 or from 8 to 100 shots, respectively. The grain size is estimated approximately 70nm, and it keeps constant for the present energy densities and the shot numbers. For the SiN substrate, the disk-shaped poly-Si grain is not observed. The roughness of poly-Si surface is larger than that on the quartz substrate. The induced stress in the poly-Si film on the SiN substrate is smaller than that on the quartz substrate. These phenomena are thought to be due to the hydrogens included in the poly-Si film with a high concentration. From the present experiment, the origin of the hydrogen is thought to be the diffusion of those from the SiN to the a-Si via the inter SiO_2 layer.

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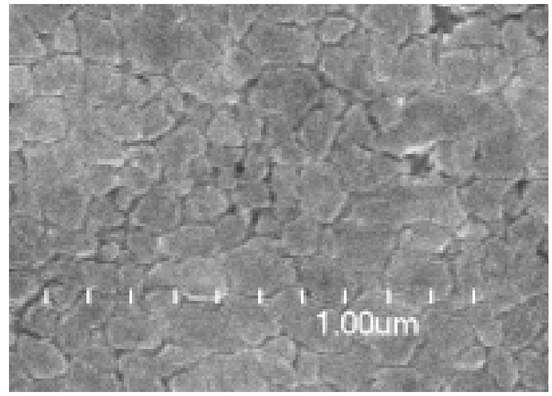

Fig.4 SEM photograph of poly-Si surface for the condition of 400mJ/cm^2 and 100 shots

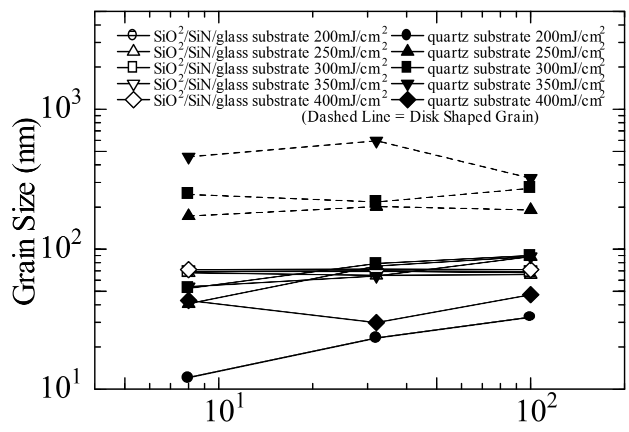

Fig.5 Relationship between the grin size and the shot number

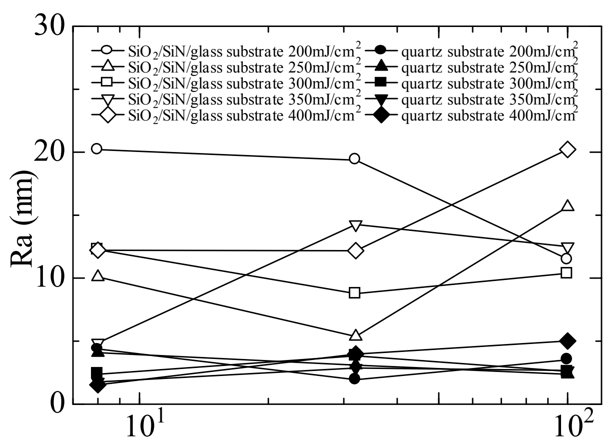

Fig.6 Relationship between Ra and shot

the collaboration research.

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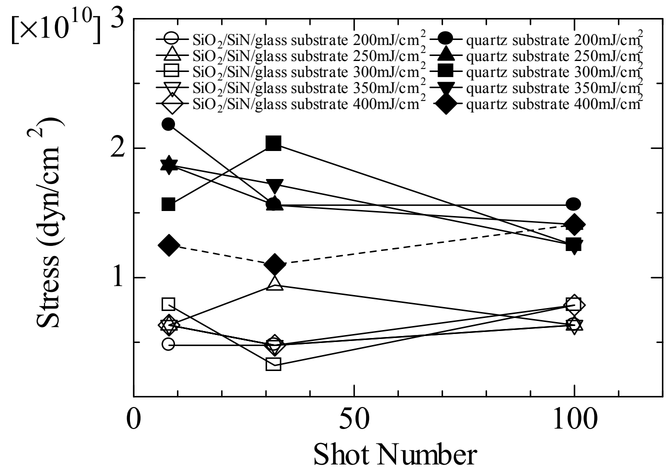

Fig.7 Relationship between the stress of the poly-Si and the shot number

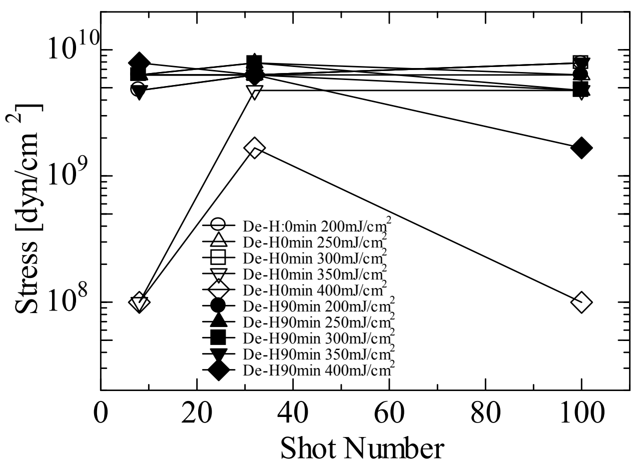

Fig.8 Relationship between the stress of poly-Si on the SiN substrate and the shot number