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RAPID PUBLICATION

Grain Morphology of Recrystallized Polycrystalline-Si Film by Excimer Laser Annealing

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Grain morphology of recrystallized polycrystalline(poly)-Si by excimer laser annealing (ELA) was investigated for both SiO_2 (50 nm)/SiN (50 nm)/glass substrate and quartz substrate. The Raman peak of the poly-Si on the SiN substrate was shifted to the higher frequency side than that on the quartz substrate. The disk-shaped grains were observed on the quartz substrate, while they were not observed on the SiN substrate. The poly-Si grains with a uniform grain size were observed, and kept constant in a range of the present energy density and the shot number on the SiN substrate. To understand these phenomena, the crystal growth model relating to the concentration of hydrogen atoms in the film is discussed.

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1. Introduction

The characteristics of the recrystallized polycrystalline (poly)-Si film by excimer laser annealing (ELA) was investigated for the application of it to the thin film transistors (TFTs).[1–7] The hydrogen atoms in the amorphous(a)-Si film strongly affect the integrity of the recrystallized poly-Si film by ELA. The dehydrogenation process of the a-Si prior to ELA decreases the number of the dangling bonds in the recrystallized poly-Si.[8] In the particular energy densities, the disk-shaped grains are observed.[9] In this paper, we investigate the grain morphology of the poly-Si film by ELA. Relationship between the crystal growth mechanism and the stress in the poly-Si film is also discussed in terms of the concentration of the hydrogen atoms in the film and formation of the disk-shaped grains.

2. Experimental

An a-Si film was deposited on the SiO_2 (50 nm)/SiN (50 nm)/glass substrate (SiN substrate) by plasma enhanced chemical vapor deposition (PE-CVD). The SiN film was deposited using plasma CVD method. The annealing in the vacuum for dehydrogenation was performed for 60 min. The KrF multi-pulse excimer laser was irradiated on the a-Si film at 1 Hz at room temperature under approximately 10^{-4} Pa. The irradiation time is 23 ns at full width at half maximum (FWHM). The energy density and shot number were 2000 to 4000 J/m^2 and 8 to 100 shots, respectively. For comparison, an a-Si film was also deposited by the low pressure chemical vapor deposition (LPCVD) method on the quartz substrate. The peak shift and surface morphology of the poly-Si film were measured by Raman spectroscopy and scanning electron microscopy (SEM), respectively. The stress in the poly-Si film was calculated from the Raman shift.[10] Secco etching was performed before observing the poly-Si surface by SEM to clarify the film structure and the grain morphology.

3. Results and Discussion

Figure 1 shows the relationship between the Raman peak frequency and the shot number. The Raman peak of the poly-Si film on the SiN substrate is shifted to the higher frequency side than that on the quartz substrate. Although the Raman peak frequency of the poly-Si film on the quartz substrate becomes large as the shot number increases, that on the SiN substrate keeps constant. Figures 2(a) and (b) show the SEM photographs of the poly-Si surface on the SiN substrate at 4000 J/m^2 and 100 shots and that on the quartz substrate at 2500 J/m^2 and 32 shots, respectively. The poly-Si grains with a uniform grain size are observed on the SiN substrate, while the disk-shaped grains are observed on the quartz substrate. Figure 3 shows a relationship between the grain size and the shot number. The grain size of the poly-Si on the SiN substrate is approximately 70 nm in diameter, and keeps constant in a range of the present energy density and the shot number. This result indicates that the nuclei in the a-Si may dominate

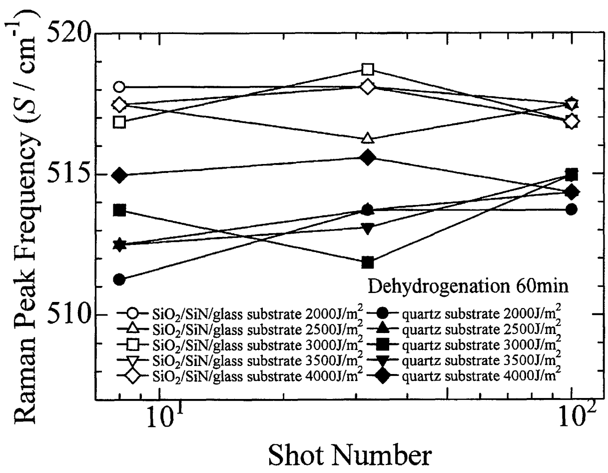

Fig. 1 Relationship between the Raman peak frequency and the shot number.

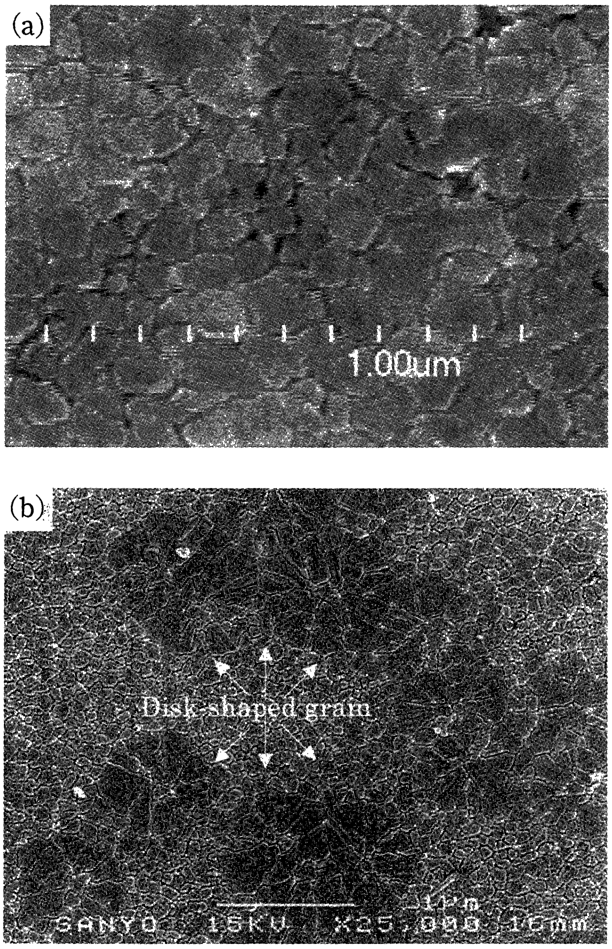

Fig. 2 SEM photographs of the poly-Si surface on the SiN substrate for the conditions of 4000 J/m^2 and 100 shots (a) and that on quartz substrate for the conditions of 2500 J/m^2 and 32 shots (b), respectively.

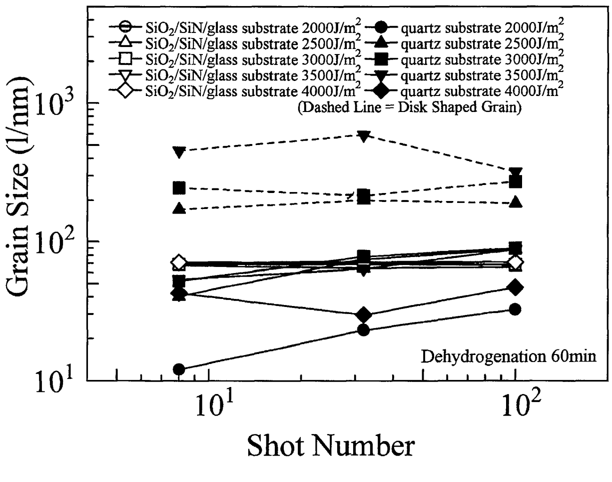

Fig. 3 Relationship between grain size and shot number.

the nucleation process for the poly-Si film on the SiN substrate. The grain size of the poly-Si on the quartz substrate becomes large as the shot number or the energy density increases except for 4000 J/m^2.[11] Because the hydrogen atoms with a concentration of 10^{21} cm^{-3} are included in the a-Si by PE-CVD, the hydrogen atoms or molecules burst out of the a-Si during the ELA. This phenomenon may generate the nucleation site in the a-Si. Another source of the hydrogen atoms is thought to be in the SiN film. They are introduced

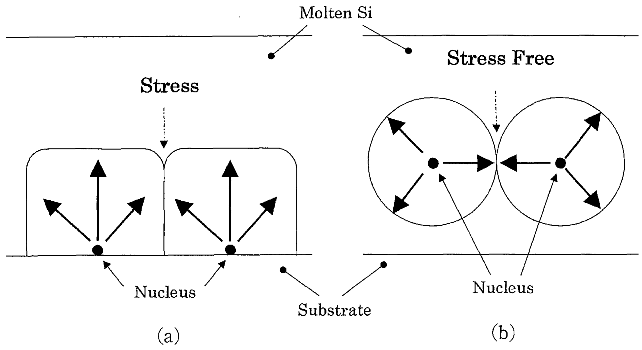

Fig. 4 Schematic models for crystallization on the quartz substrate (a) and on the SiN substrate (b).

into the SiN film during the formation by plasma CVD.[12] The stress of the poly-Si film on the SiN substrate is smaller than that on the quartz substrate. The stress of the poly-Si film on the quartz substrate becomes small as the shot number increases, while that on the SiN substrate keeps constant. It is found that the crystallinity of the poly-Si on the SiN substrate is better than that on the quartz substrate. To understand this phenomenon, the crystal growth model relating to the concentration of the hydrogen atoms in the film is proposed. Figures 4(a) and (b) show the schematic models for crystallization on the quartz substrate and on the SiN substrate. When the nucleation sites are located at the interface between the a-Si and the quartz substrate, the stress generated between the neighboring grains becomes large as the grain growth proceeds as shown in Fig. 4(a). The formation of the disk-shaped grains will relax the induced stress. On the other hand, when the nucleation sites are located in the silicon liquid by the laser irradiation to the a-Si deposited by the PE-CVD, the stress generated between the neighboring grains becomes smaller because the nucleation sites are not fixed in the silicon liquid as shown in Fig. 4(b).

4. Conclusions

The measured results for Raman peak showed that the peak frequency of the poly-Si on the SiN substrate was shifted to the higher frequency side than that on the quartz substrate. The disk-shaped grains were observed on the quartz substrate, while they were not observed on the SiN substrate. The poly-Si grains with a uniform grain size, which was approximately 70 nm in diameter, were observed, and kept constant in a range of the present energy density and the shot number. To understand these phenomena, a crystal growth model relating to the hydrogen atoms in the film was discussed. For the poly-Si on the quartz substrate, the nucleation sites are thought to be located at the interface between the a-Si and the quartz substrate and the stress generated between the neighboring grains becomes large as the grain growth proceeds. The formation of the disk-shaped grains will relax the induced stress. For the poly-Si on the SiN substrate, the nucleation sites are thought to be located in the liquid silicon caused by the hydrogen burst and the stress between the neighboring grains becomes small because the nucleation sites are not fixed.

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