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RAPID PUBLICATION

Recovery Stage of Polycrystalline-Si Prepared by Excimer Laser Annealing

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By irradiating the multi-pulse excimer laser with the energy density smaller than 200 mJ/cm^2 on the amorphous silicon (a-Si), the crystallinity of the Si increases, as increasing the number of the pulse. During the first laser irradiation some part of the melted a-Si becomes the polycrystalline (poly)-Si which corresponds to the nucleus, and after the second irradiation the poly-Si does not melt and the remaining a-Si becomes the poly-Si. The crystal growth of the poly-Si proceeds by the solid phase crystallization (SPC). Crystal growth of poly-Si by excimer laser annealing (ELA) is discussed by considering the recovery stage. This stage is examined from the relationship between the amorphous Si area and the total irradiation time. The fact that the measured data coincides with the theoretical data indicates that the recovery proceeds during the ELA at the low energy density.

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1. Introduction

The characteristics of the recrystallized polycrystalline (poly)-Si film prepared by excimer laser annealing (ELA) and that of the thin film transistors (TFTs) on the poly-Si film have been reported.[1,2)] The growth model of the poly-Si related to the nucleation from the super cooled liquid (SCL) has been presented.[3)] However, the growth model does not clarify the phenomenon that the crystallinity of poly-Si increases as the number of shot becomes large. We have examined the crystal growth of low-temperature processed poly-Si from a viewpoint of the solid phase crystallization (SPC) considering the dislocation theory.[4)] It is wellknown that the recovery occurs by annealing the metal in which the strain is introduced.[5)] Recovery stage is concerned with both the disappearance of the point defects and the rearrangement of the dislocations. This stage is discussed theoretically.[6)] It is very important to examine if the recovery occurs or not during the laser irradiation on the amorphous Si (a-Si).

This paper discusses the recovery stage by considering the relationship between the a-Si area and the total irradiation time. The analysis is pursued by the reproduction of the measured data through the theoretical formulas.[6)]

2. Solid Phase Crystallization at Low Energy Density

The energy densities at the present experiment are 1750 and 2000 J/m^2. Considering the analytical data of the recrystallized film annealed at those low energy densities[4], it is found that the crystallization of Si is consisted of two stages. During the first stage with the small shot numbers of ELA, the solidification from the melted Si to the poly-Si during the laser irradiation on the a-Si surface occurs. This process corresponds to the recovery stage which is discussed precisely later. In the second stage with the larger shot number than the critical one at which a-Si is completely transferred to poly-Si, SPC occurs during the laser irradiation and the grain size enlargement is observed with the progress of the recrystallization.

3. Recovery Stage from a-Si to poly-Si

Because the number of the defects in the poly-Si is smaller than that in the a-Si, the deformation from a-Si to poly-Si via the melting process of Si is thought to be the recovery stage. The relationship between the progress of recovery stage x and the annealing time t is shown by the eq. (1).[6)]

$$\ln x = -kt + C \tag{1}$$

In the present research, x is the a-Si area, because it is proportional to the number of the lattice defect such as the point defects or the dislocations. k is the probability of the disappearance of the lattice defect. C is a constant. The annealing time t corresponds to the total irradiation time, and it is defined as the value of the full width at half maximum (FWHM) of one laser pulse (23 ns) multiplied by the number of shot.

4. Growth and Analysis Methods

An a-Si film with the H_2 concentration of 4E20 cm^{-3} is deposited on the quartz substrate by the low pressure chemical vapour deposition (LPCVD) method using Si_2H_6. The film thickness is 50 nm. The KrF excimer laser is irradiated after the a-Si deposition at RT. The energy density and the shot number are 1750, 2000 J/m^2 and 3–200, respectively. The a-Si area is measured by the scanning electron microscopy (SEM) after the Secco etching.

5. Results and Discussion

Figure 1 shows the relationship between the Raman intensity and the number of shot for 1750 and 2000 J/m^2. From the results that the peak intensity becomes large as the number of shots is increased, it is found that the crystallinity of the recrystallized poly-Si film increases as the number of shots becomes large. From the previous report·[4], it is clarified that the average grain size of the poly-Si keeps constant and the area ratio of the crystallization increases as increasing the shot numbers. This phenomenon means that the a-Si is trans-

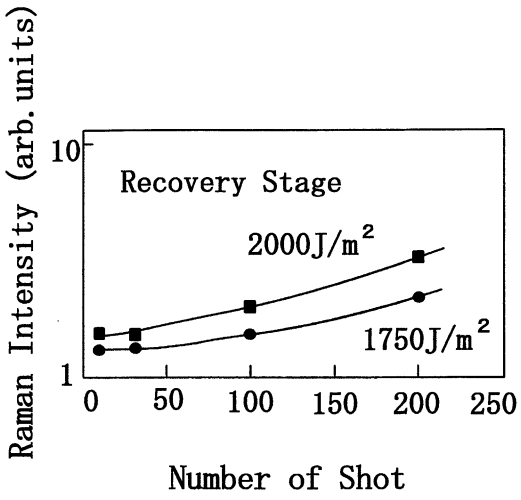

Fig. 1 Relationship between the Raman intensity and the number of shot.

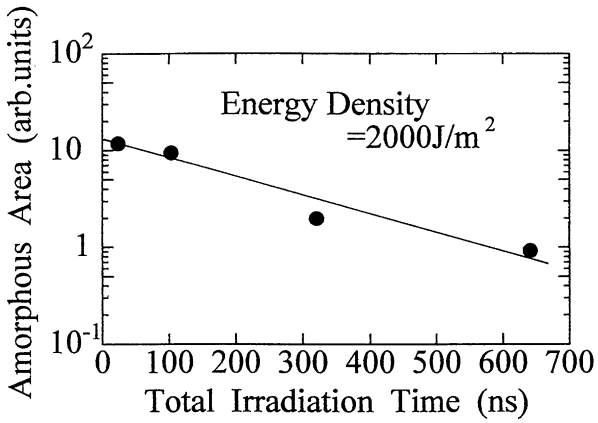

Fig. 2 Relationship between the a-Si area and the total irradiation time.

formed to the poly-Si grains which have a constant radius, as increasing the shot numbers. The fact that the disappearance of point defects occurs indicates that the crystallization process corresponds to the recovery stage. However, it is difficult to identify the recovery and the primary recrystallization. Figure 2 shows the relationship between the a-Si area and the total irradiation time. The phenomenon that the a-Si area decreases as increasing the total irradiation time agrees with the result that the crystallinity increases as increasing the shot number as shown in Fig. 1. The experimental data agree with the calculated solid line by eq. (1). This result shows that the recovery progresses for 2000 J/m^2 as the number of shot increases. These results indicate that the recovery progresses during the laser annealing at the present condition.

6. Conclusions

It was shown for the first time that recovery occurs during pulsed-laser irradiation at the energy density of 2000 J/m^2. This result strongly indicates that recrystallization mechanism of poly-Si by pulsed-laser irradiation at the low energy densities smaller than 2000 J/m^2 is the SPC.

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