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Nucleation-Control in Solid-Phase-Crystallization of a-Si/SiO_2 by Local Ge Insertion

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1. Introduction

Formation of high quality polycrystalline Si (poly-Si) on insulating substrates has been widely investigated for the fabrication of thin film transistors (TFT) and poly-Si gate-electrodes. A melt-grown process such as laser annealing does not ensure sufficient reliability, due to the energy fluctuation of laser. Therefore, low-temperature (~550 ^oC) solid-phase crystallization (SPC) is strongly required. The SPC of a-Si on SiO_2 is initiated by the crystal nucleation. Due to large activation energy (3.7 eV) for this process, SPC technique at a low temperature has not been established [1]. In addition, nucleation occurred randomly in the whole region of a-Si films and at the a-Si/SiO_2 interface. This forced oriented crystal growth impossible. Consequently, low temperature nucleation at the controlled position becomes essential for high performance TFT.

Our main idea to solve this problem is the local doping of Ge atoms into a-Si films in order to stimulate crystal nucleation. In the present study, the local Ge insertion method has been investigated to control nucleation in SPC of a-Si/SiO_2.

2. Experimental Procedures

In the experiment, a-Ge and a-Si films (Ge thickness: 5-15 nm, total thickness: 50 nm) were deposited on SiO_2 (thickness: 160 nm) grown on Si wafers. The deposition was performed at a room temperature by using MBE system in a vacuum about 10^{-10} Torr. Three types of multi-layered structures, i.e., (a) a-Si/a-Ge/a-Si/SiO_2, (b) a-Si/a-Ge/SiO_2, and (c) SiO_2/a-Ge/a-Si/SiO_2 were fabricated, where the top SiO_2 layer shown in (c) was deposited by using TEOS-CVD method (300 ^oC). They were shown in Fig. 1. In addition, a-$Si_{1-x}Ge_x$ single layer ($0 \leq x \leq 1$, thickness: 90 nm) were also deposited on SiO_2 for the reference. These samples were annealed at 600 ^oC in dry N_2 ambient. The grown layers were characterized by using the spectroscopic ellipsometry, Auger electron spectroscopy (AES), and X-ray diffraction method.

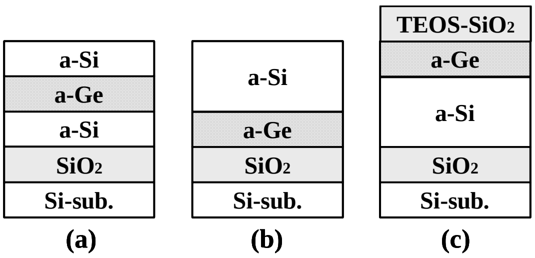

Fig. 1 Schematic cross section of sample structures: (a) a-Si/a-Ge/a-Si/SiO_2, (b) a-Si/a-Ge/SiO_2, and (c) SiO_2/a-Ge/a-Si/SiO_2.

3. Results and Discussion

First, effects of Ge fraction on the SPC of a-$Si_{1-x}Ge_x$ on SiO_2 were examined. Isochronal annealing (20 min) characteristics are shown in Fig. 2(a), where crystallinity (normalized to 100 % for crystal Si and 0 % for a-Si) was evaluated by using the spectroscopic ellipsometry measurement [2]. The nucleation temperature was estimated as the temperature where SPC initiated, and they are summarized in Fig. 2(b). This clearly indicates that the nucleation temperature was decreased significantly with

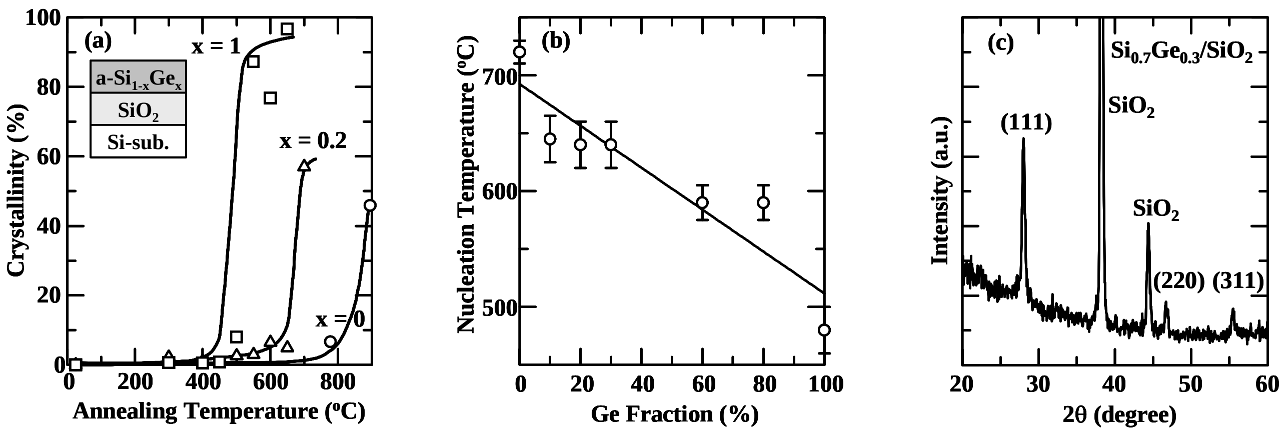

Fig. 2 Crystallinity change of a-$Si_{1-x}Ge_x$($0 \leq x \leq 1$) on SiO_2 during isochronal annealing (20 min) (a), nucleation temperature as a function of Ge fraction (b), and XRD spectra of poly-$Si_{0.7}Ge_{0.3}$ on SiO_2 after annealing at 600 ºC for 20 min.

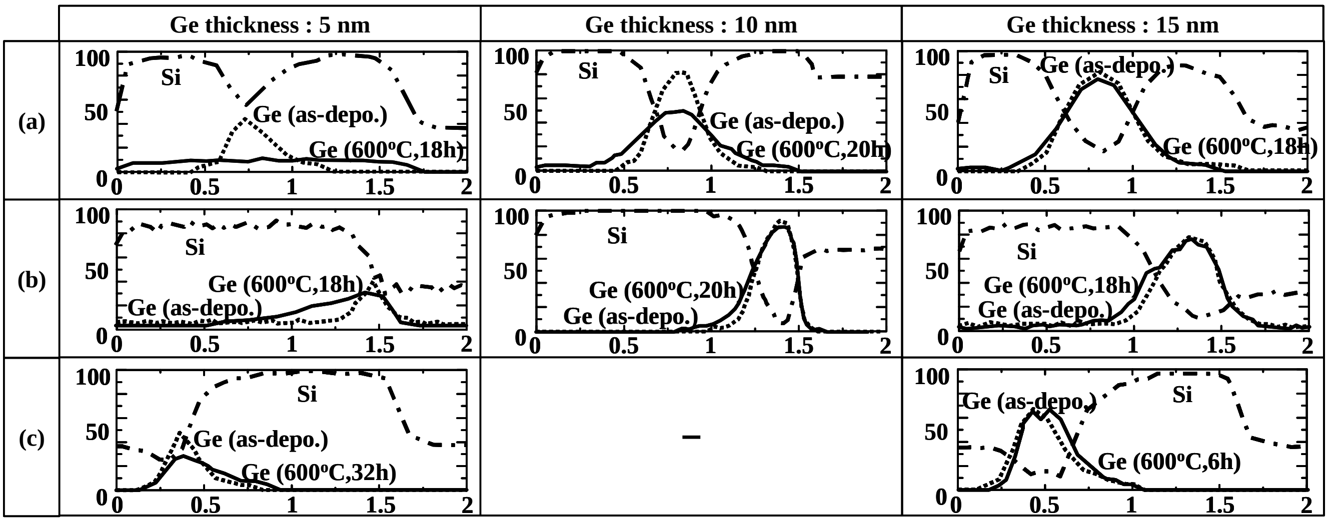

Fig. 3 Concentration profiles of Si and Ge before and after annealing obtained by AES for (a), (b), and (c) samples with different Ge thickness. Sample structures are shown in Fig. 1. X-axis is sputtering time (min), corresponding to the depth from the samples surface, and Y-axis is atomic concentration.

increasing Ge fraction. As a result, nucleation at 500 °C becomes possible by using a-Ge films. Crystal orientations of grown layer evaluated by using XRD method is shown in Fig. 2(c), which showed multi-peaks of (111), (220), and (311). This is because nucleation occurred randomly in the whole region of a-Si films and at a-Si/SiO_2 interface.

The result shown in Fig. 2(b) triggers off the following idea of nucleation-positioning: When we insert thin Ge layers into a-Si/SiO_2 structures, crystal nucleation should be initiated in the Ge region. This will enable the position control of the nucleation.

To examine this idea, experiments were performed by using the samples shown in Fig. 1. Figure 3 shows concentration profiles of Si and Ge obtained by AES for (a), (b) and (c) samples with different Ge thickness (5, 10 and 15 nm). For (a) sample with thin Ge-thickness (5 nm), Ge atoms were completely diffused into both sides of a-Si regions because of its high diffusion constant (6.3×10^{-20} m^2/s @600 °C) [3]. This fact indicates that our idea is difficult to realize. However, abnormal localization of Ge is found for (a) samples with thick Ge films (15 nm). Such phenomena become significant by using (b) and (c) samples, where Ge localized even for samples with thin Ge films (5, 10 nm).

To understand such phenomena, annealing characteristics of the crystallinity for (a) and (b) samples was examined, which were summarized in Fig.4. For (a) sample with thin Ge-thickness (5 nm), crystallization occurred after annealing for 1000 min, which is close to that of the a-Si/SiO_2 structure. However, for all samples which showed abnormal Ge-localization, SPC was significantly enhanced, i.e., the incubation time was about 50 min. Consequently, the inserted Ge layers successfully acted as preferential nucleation sites.

These results suggest that two-dimensional nucleation at a-Si/SiO_2 interface can be possible by using (b) and (c) sample structures with thin Ge films (5 nm). Preliminary results indicated the preferential SPC with (111) orientation. Such SPC driven by interface nucleation will be a useful tool to achieve high quality poly-Si on SiO_2.

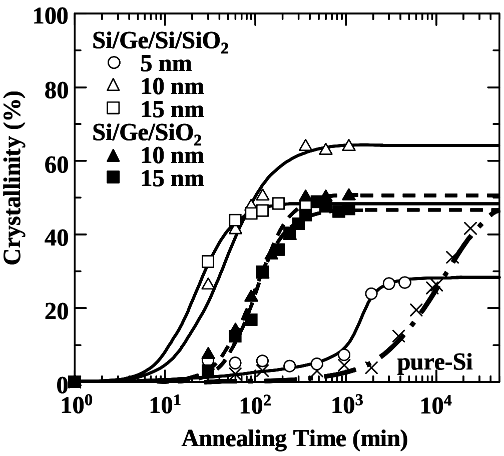

Fig. 4 Crystallinity change for (a) and (b) samples during isothermal annealing (600 °C). The result obtained for a-Si/SiO_2 is also shown for reference.

4. Conclusion

Local insertion effects of thin Ge layers into a-Si/SiO_2 structures were examined from the view point of SPC control. Abnormal retardation of Ge diffusion during SPC was found for all samples where Ge layers were inserted between a-Si and SiO_2. This enabled the positioning of nucleation by preferential nucleation at Ge regions. In addition, possibility of oriented crystal growth driven by the interface nucleation was presented.

Reference

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