Chemical mechanical polishing of CW laser recrystallized Si thin films with ethyl alcohol additive

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Abstract. The chemical mechanical polishing (CMP) on laser-crystallized poly-Si thin films was carried out. After CMP with conventional colloidal silica slurry, the surface of laser-crystallized poly-Si thin films became rougher than that of before CMP. Carbon segregation in the grain boundary was occurred by the laser crystallization. It was considered that carbon segregation hardened the grain boundary, and lowered the wettability to the slurry. For the improvement of this problem, a hydrophilic organic solution was added to conventional slurry. The surface of the poly-Si thin film was coated with the organic additive, and this coating suppressed a polishing of concave portion, and increased the wettability of convex portion in the grain boundary, and the pressure from the polishing pad was concentrated to the convex portion. In this work, ethyl alcohol was used as a hydrophilic organic solution, ethyl alcohol was soluble in the slurry and was stable in the room temperature, and planarized surface with the average roughness of 1.13 nm was obtained.

Introduction

For the enhancement of the TFT performance, laser crystallization on silicon thin films has been carried out. The laser-crystallized poly-Si thin films have a large surface roughness. The large surface roughness restricts the thickness of the gate oxide of the TFTs, and lowers the carrier mobility by the surface roughness scattering [1]. The CMP of LPCVD poly-Si thin films was reported, and the dishing was inhibited by polymer additive [2]. In this work, continuous wave (CW) laser was applied to the laser crystallization [3-4], and the CMP of the laser-crystallized poly-Si thin film was performed.

Experiments

A buffer SiO_2 film was formed on a quartz substrate by PECVD. The thickness of the buffer SiO_2 was 1 μm. After the deposition of buffer SiO_2, a non-doped amorphous silicon (a-Si) thin film was deposited by PECVD at the thickness of 150 nm. Thermal treatment on a-Si thin film was performed in N_2 ambient at 490°C for 20 minutes. After the thermal treatment, CW green laser crystallization of a-Si thin film was carried out. The wavelength of the laser was 532 nm, and laser power was 10 W. Laser spot was elliptic form and had Gaussian profile with dimensions of 20 ×90 μm^2 (FWHM). The sample wafer was placed on an X-Y linear stage, and a laser beam scanned over sample wafer. The scan speed was 30 cm/s. After the laser crystallization, the CMP on the laser-crystallized Poly-Si thin films was carried out. In the CMP process, NALCO2372 silicon slurry (Nitta-Haas Inc., average diameter of colloidal silica: 70 nm, pH: 12) and a poly-urethane polishing pad (IC1000) were used. The silicon slurry was

diluted by deionized water and the ratio of the silicon slurry was 5.0%. Ethyl alcohol (EtOH) was added to the diluted slurry. The ratio of ethyl alcohol to the diluted slurry was varied from 0 to 50%. The polishing pressure was 6.7 kPa, and the rotation of the pressurized wafer stage and platen were 15 and 10 rpm, respectively. After the CMP process, the sample wafer was cleaned by SPM (H_2SO_4:H_2O_2=4:1) for 5 min, and Buffered HF (Stella-Chemifa LAL800, NH_4HF_2: 11.4%) for 2 min.

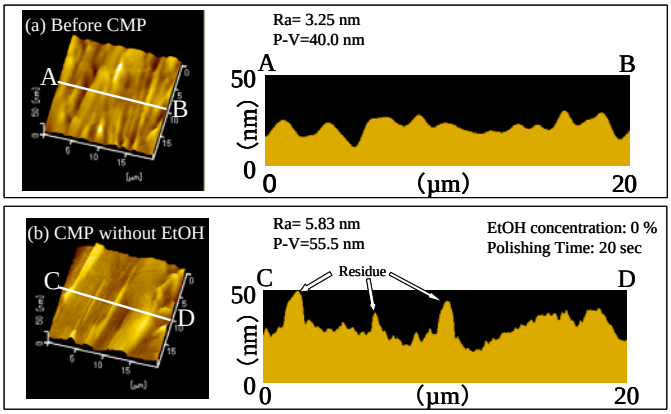

Fig.1. AFM images of laser crystallized Si thin films (a) before CMP, and (b) after CMP.

Results and Discussions

Figure 1 shows the surface morphologies of laser-crystallized poly-Si thin films before and after the CMP without ethyl alcohol additive. These surface morphologies were measured by atomic force microscopy (AFM). Before the CMP process, the laser-crystallized poly-Si thin film had a surface morphology with the average roughness (Ra) and the peak-valley (P-V) roughness of 5.83 nm and 40.0 nm, respectively. After the CMP process, the average roughness and the P-V roughness increased to 5.83 nm and 55.5 nm, respectively. Especially, anomalous residues at grain boundaries were observed as shown in Fig 1. (b). For the purpose of examination of the CMP residues, the transmission electron microscope (TEM) measurements and the energy dispersive X-ray spectrometry (EDX) were carried out. Figure 2 shows the

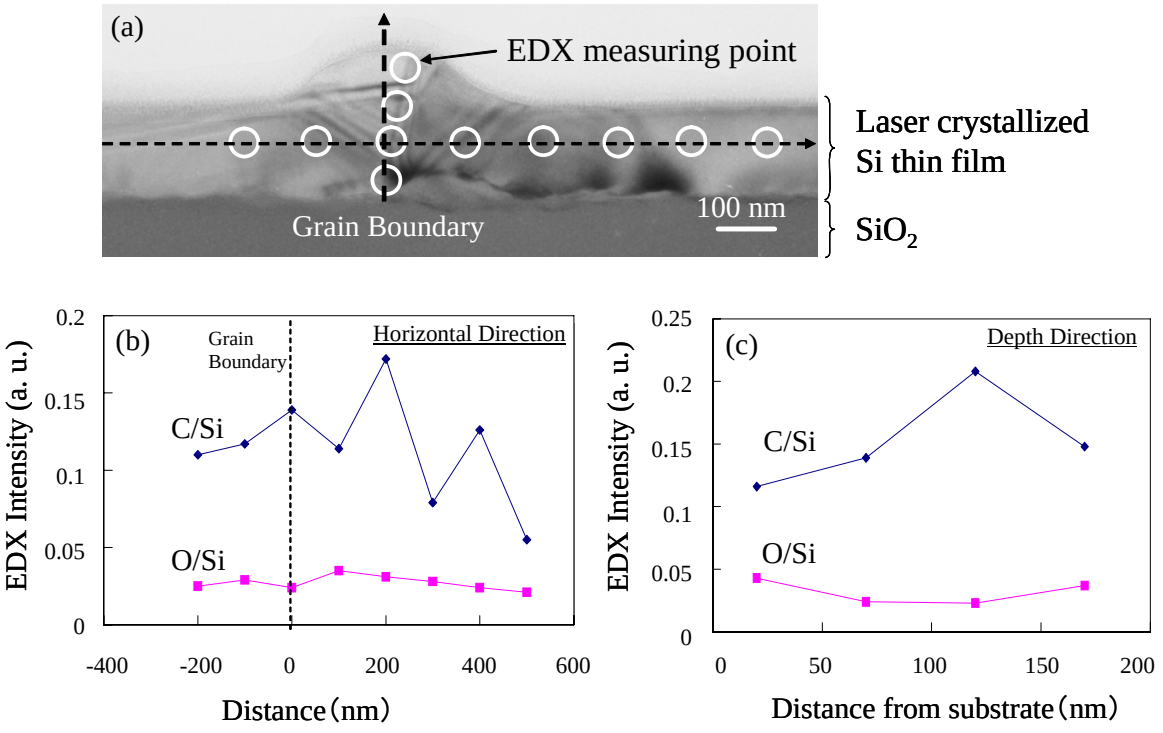

Fig.2. EDX measurement of laser crystallized Si thin films: (a) cross-sectional TEM of laser crystallized Si thin films, (b) EDX distribution in the horizontal direction and (c) in the depth direction.

results of the TEM-EDX measurements. Figure 2 (a) shows the TEM micrographs and the measuring points of the EDX. Figure 2 (b) and (c) show carbon and oxygen distributions in the horizontal and depth direction in the laser-crystallized poly-Si film, respectively. In Fig. 2 (b) and (c), the background noise level was 0.02. In this measurement, carbon was observed near the grain boundary. This result shows the carbon segregation in the grain boundary was occurred. It was considered that carbon segregation hardened the grain boundary, and lowered the wettability to the slurry.

Ethyl alcohol was added to the slurry. It was considered that the surface of the poly-Si thin film was coated with ethyl alcohol, and this coating suppressed a polishing of concave portion, and increased the wettability of convex portion in the grain boundary, and the pressure from the polishing pad was concentrated to the convex portion. The ratio of ethyl alcohol to the diluted slurry was varied from 0 to 50%. Figure 3 shows the average roughness of the laser-crystallized poly-Si thin films after the CMP with ethyl alcohol. As increasing ethyl alcohol additive, the average roughness became smaller, and at the polishing time of 80 and 120 s average roughnesses had minimal values at ethyl alcohol concentration of 25 and 35%, respectively.

Figure 4 shows the average roughness of laser-crystallized poly-Si thin films as a function of polishing time at the ethyl alcohol concentration of 35%. As increasing polishing time, an average roughness decreased, and took a minimal value of 1.13 nm at 160 s. Figure 5 shows the P-V roughness as a function of polishing time. As increasing polishing time, a P-V roughness also decreased, and took values of 19.9 nm and 12.4 nm at 160 and 200 s, respectively. Figure 6 shows the surface morphology of the laser-crystallized poly-Si thin film after CMP with ethyl alcohol additive. Figure 7 shows the TEM micrograph of the laser-crystallized poly-Si thin film after CMP with ethyl alcohol additive. The TEM micrograph of the poly-Si thin film shows the surface was planarized by the CMP with ethyl alcohol additive, and the thickness of the poly-Si thin film varied only slightly. It was considered that

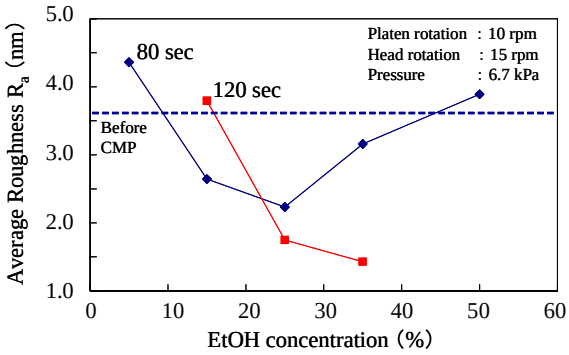

Fig.3. Average Roughness as a function of ethyl alcohol concentration.

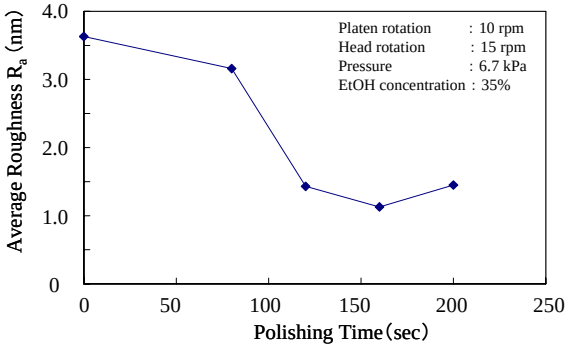

Fig.4. Average Roughness (Ra) as a function of polishing time.

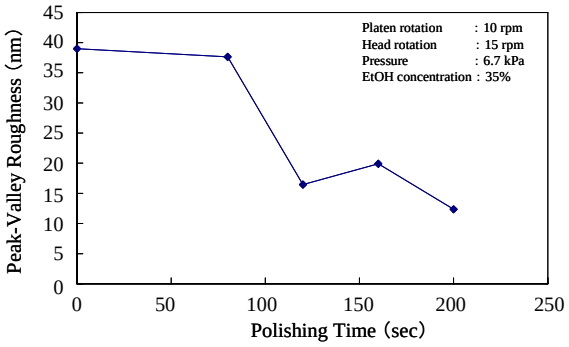

Fig.5. Peak-valley roughness as a function of polishing time.

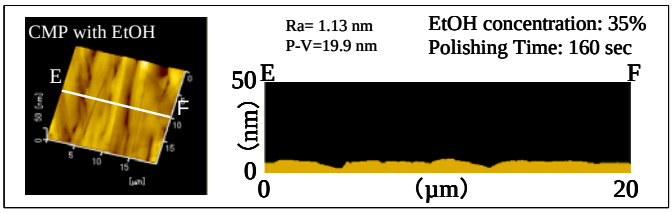

Fig.6. AFM image of laser crystallized Si thin film after the CMP with ethyl alcohol additive.

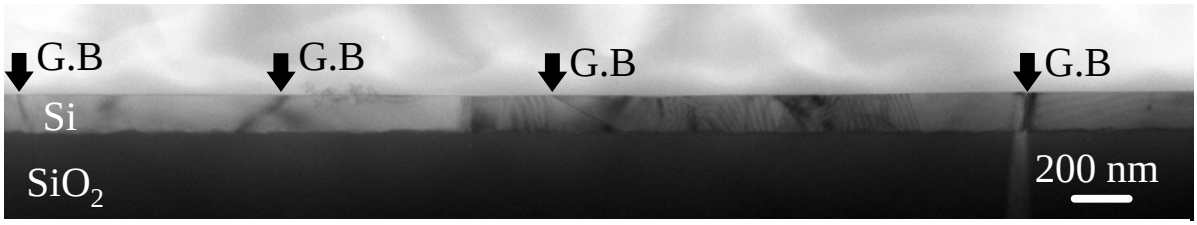

Fig.7. Cross-sectional TEM image of laser crystallized Si thin film after the CMP with ethyl alcohol additive.

ethyl alcohol was adsorbed at the surface of the poly-Si thin films, and the adsorbed layer inhibited alkali etching of the poly-Si thin films. In the convex portion at the grain boundaries, the ethyl alcohol adsorbed layer was removed by the colloidal silica, and the CMP was performed.

Summary

The CMP of the CW laser-crystallized poly-Si thin films was carried out. Before the CMP, the laser-crystallized poly-Si thin film had the average and P-V roughness of 3.25 nm and 40.0 nm, respectively. After the CMP with ethyl alcohol additive, the laser-crystallized poly-Si thin films were planarized, and the average and P-V roughness were 1.13 nm and 19.9 nm, respectively. It was considered that the ethyl alcohol was adsorbed at the surface of the poly-Si thin films, and in the convex portion at the grain boundaries the CMP was selectively performed.

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