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Thermal desorption of silicon oxide layer on Si(100) investigated by Si 2p core-level photoemission

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Introduction

Thermal desorption of silicon oxide layer on Si(100) has been investigated by Si 2p core-level photoemission with synchrotron radiation. Tromp et al. reported that 100 Å-thickness SiO_2 layer is thermally removed from the Si surface by the formation and lateral growth of voids in the oxide, exposing regions of atomically clean Si, while the surrounding oxide retains its initial thickness [1]. The same desorption behaviors were also observed for thinner oxide layer [2]. We here demonstrate the formation of the same kind of void by a comparison of the suboxide Si-2p components for thermal oxide layers with and without the process of the thermal desorption.

Experimental

The photon energy was set at 135eV, where the escape depth of photoelectrons from the Si 2p core level in silicon has a minimum. A B-doped Si(100) wafer used as the silicon substrate was chemically treated with the RCA method and then annealed by resistive heating at 1000ºC in the UHV chamber. The 99.99% oxygen gas was used to form the oxide. The overall instrumental energy resolution was estimated at about 0.2eV. The Si 2p core-level spectra are deconvoluted by a least-square fitting procedure using the spin-orbit split Voigt functions.

Results and Discussion

Figure 1 shows a Si 2p core-level spectrum of the oxide at the oxidation temperature of 750ºC and the oxygen pressure of 10^{-4}Torr for 30s. From the measured ratio of Si^{4+} intensity to Si^0 intensity, the oxide thickness is estimated at 3.3Å. Three suboxide components between Si^0 and Si^{4+} also exist at the SiO_2/Si interface. Figure 2 shows the spectrum of the oxide, which is made by two reaction processes: oxidation at 800ºC and 1Torr for 10m, and then annealing at 1000ºC for 30s in vacuum. A 15Å-thickness oxide is formed by the oxidation process. By the annealing process, a part of the oxide is desorbed from the surface, and the thickness in Fig. 2 is estimated at 3.7Å if the oxide layer is uniformly decreased. However, the suboxide intensities in Fig. 2 are much less than those in Fig. 1 in spite of the identical ratio of Si^{4+} to Si^0. Moreover, new components S1 and S2, which can be associated with bare Si surface, appear at around Si^0. These results can be explained by nonuniform void formation on the surface as shown in Fig. 3. The surface ratio covered with the SiO_2 layer in Fig. 3(b) is estimated at about 0.38 by quantitative analysis with the escape depth theory.

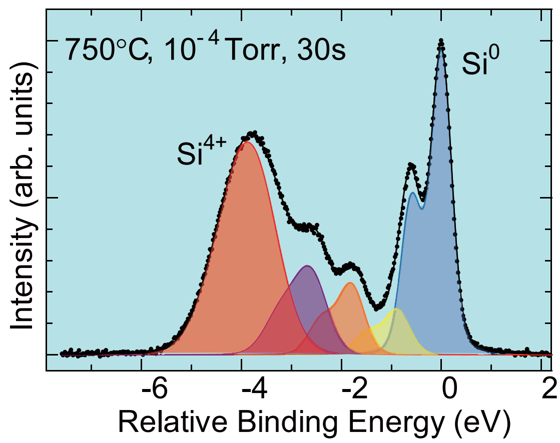

Fig. 1 Si 2p core-level spectrum of the oxide at 750ºC and 10^{-4}Torr for 30s.

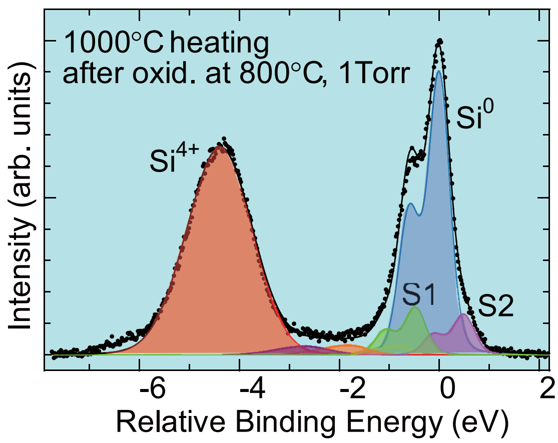

Fig. 2 Si 2p core-level spectrum of the oxide by two reaction processes.

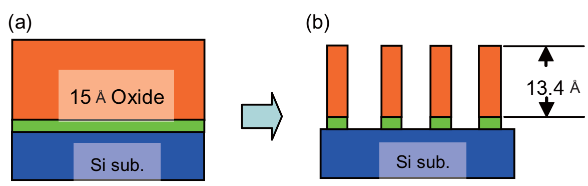

Fig. 3 Schematic of surface structures for SiO_2 layers before (a) and after (b) 1000ºC annealing.

References

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