Formation of Epitaxially Ordered SiO_2 in Oxygen-implanted Silicon during Thermal Annealing

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Introduction

The separation by implanted oxygen (SIMOX) wafer is one of the most promising silicon on insulator (SOI) materials, which is a key material for the low power and high speed Si based-electric devices. The SIMOX wafer has the buried oxide layer between the top Si layer and the Si substrate, which is made by O^+ ion implantation at a dose of 10^{17}~10^{18}/cm^2 and subsequent annealing at 1350ºC. The buried oxide layer is generally believed to have an amorphous structure on the analogy of the thermal oxide layer on the Si substrate.

However we have found the extra streak at 0.5 0.5 L (L~1.0) in the reciprocal space of the Si substrate in the X-ray diffraction pattern from the SIMOX wafer. This streak did not change even after the removal of the top Si layer, but the intensity gradually decreased with etching off the buried oxide layer. This indicates the existence of the epitaxially ordered SiO_2 all over the buried oxide layer. The higher order reflections of the extra streak were also found at the middle of the reciprocal lattice points of the Si substrate, such as 1.5 0.5 L (L=0.4~1.4) and 1.5 1.5 L (L=0.2~1.8). From these results the ordered oxide was estimated to have the epitaxial relation of 2x2, using the notation of surface structure, but the poor periodicity perpendicular to the interfaces [1-3].

In this paper the formation process of the epitaxially ordered SiO_2 in oxygen-implanted silicon during the thermal annealing was investigated.

Experimental

The implantation into Si substrates was carried out at an energy of ~180 keV at a dose of 4x10^{17} O^+ /cm^2. The samples were annealed for 1, 10, 30, 60, 120, and 240min at the 1350^{o}C. The ramping and cooling rate are 20^{o}C/min. The Ar/O_2 flow rate in the annealing atmosphere was 100/0.5.

X-ray diffraction patterns using an imaging plate (IP) detector were obtained with a Weissenberg camera at BL-18B. X-rays with the wavelength of 0.1nm were employed. For quantitative measurements, the four-circle diffractometers installed on BL-4C were used. The measurements were carried out at the symmetric condition using X-rays with the wavelength of 0.152 nm.

Results

The X-ray diffraction patterns around the 111 Bragg point and the origin of the reciprocal space were observed in oscillation photographs for the samples. We can clearly see the extra diffraction streak at the position of 0.5 0.5 L (L~1) in the photograph for the samples of 240-min. Even in the photograph of the 1 min-annealing sample, the very faint streak was observed at the same position, which shows that the ordering of the oxide began at the initial stage of the annealing process.

The intensity distributions of the extra streaks observed by the four-circle diffractometers are shown in Fig.1. We can see that the intensity of the streak increased as the annealing time. This means that the ordered SiO_2 of the 2x2 symmetry gradually grew through the thermal annealing.

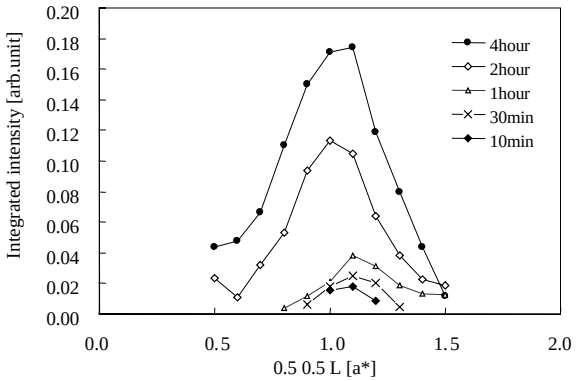

Fig.1 Intensity distributions along the extra diffraction streak of 0.5 0.5 L (L=0.5~1.5).

References

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