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Quasi-amorphous structure in the thermal oxide layer on an Si(113) substrate

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Introduction

In the X-ray diffraction patterns from thermal oxide thin films on Si(001), (111), and (110) wafers, very weak diffraction peaks are observed on the low angle side of the crystal truncation rod (CTR) scattering around the 111 Bragg points. The intensity of the extra peak depends on the thickness of the oxide layer and is not observed from the sample when the oxide layer is removed by etching in HF solution. The intensity profile along the CTR scattering shows the Laue-function-like oscillation pattern near the extra peak, of which period corresponds to the inverse of the film thickness. The angular width of the peak perpendicular to the CTR scattering is the same order of magnitude as that of the CTR scattering from the substrate. From these results we speculated that the thermal oxide layer has quasi-amorphous structure, in which the atoms were displaced from the average positions, but the average lattice has epitaxial relation with the substrate [1-5].

In this study we examined the existence of the ordered structure in the thermal oxide layer on a Si(113) wafer, which may be a competitive substrate material for Si integrated circuits [6].

Experimental

A Si(113) wafer was oxidized in dry O_2 ambient at 850 °C. The thickness of the oxide layer is about 23nm.

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 diffractometer with a Si(111) crystal analyzer installed on BL-4C was used. The measurements were carried out at the symmetric condition using X-rays with the wavelength of 0.1542 nm.

Results

The intensity distribution of the CTR scattering elongated from the 111 Bragg point is shown in Fig.1(a). The horizontal axis indicates the distance from the 111 Bragg point. We clearly see the extra peak at q=-0.74. The extra peak was observed at 0.78 0.78 0.33 of the Si substrate. In Fig.1(b) the enlargement of (a) around the extra peak is shown. The intensity oscillation is observed, of which period is about 0.22a*. The inverse of this period is roughly equal to the thickness of the oxide layer.

The extra peaks were also observed on the CTR scatterings from the 11-1 and –111 Bragg points. The intensity distributions of the extra peaks along the CTR scatterings have similar oscillation, of which period corresponds to the inverse of the thickness of the oxide layer. These results indicate that the thermal oxide layer on the Si(113) substrate has the quasi-amorphous structure.

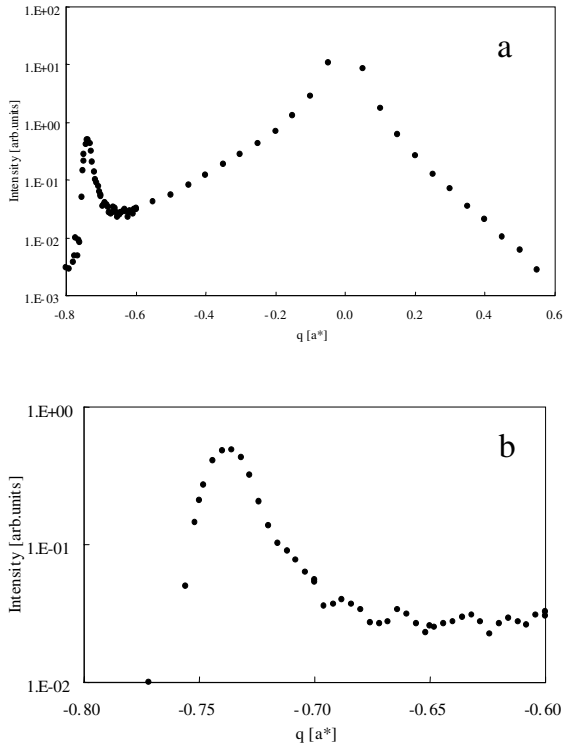

Fig.1 a) Intensity distribution of the CTR scattering from the 111 Bragg point . b) Enlargement of (a) around the extra peak.

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