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XPS study of the initial oxidation stage on HF-treated Si(100) surfaces

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Introduction

The initial oxidation stage on Si(100) surfaces has been extensively studied to achieve highly-qualified metal-oxide-semiconductor(MOS) transistors. Most of the previous works have been concerned with the well-defined Si(100) 2×1 surfaces[1]. In the practical fabrication process of LSIs, however, the HF-treatment is utilized prior to the gate oxidation. In this report, the initial oxidation process on the HF-treated Si(100) surfaces has been studied. We present our recent investigations by using synchrotron radiation XPS.

Experimental

The XPS measurements were performed at Beam Line 11D. Photoelectrons were collected by an electron energy analyzer of the 180 degrees hemispherical-sector type with an acceptance angle of ±1 degree. The photon energy of primary X-ray is 150eV. The base pressure of the ultrahigh vacuum system was 2×10^{-10} Torr. Measurements were carried out at room temperature.

Result and Discussion

Fig.1 shows Si2p spectra of XPS obtained from HF-treated Si(100) surfaces. The oxidation was made by leaving the sample in air. The humidity and the temperature of the air were 70% and 24°C, respectively. It can be seen clearly that the Si oxidation progresses with the oxidation time. In Fig.2, we show the variations of the effective oxide thickness (EOT) as a function of the oxidation time. The EOT appears immediately after the beginning of the oxidation, then increases gradually until 6 days. It is understood that the mechanism of the initial oxidation is different from that in the latter duration.

To understand the difference, we have conducted angle-resolved XPS(Fig.3). For 1-h oxide, we can see that the photoelectron intensities of Si 2p 0+ and 4+ are almost independent of the escape angle of the photoelectrons. This implies that the initial oxidation progresses quite non uniformly forming piles into the Si substrate. Presence of highly active sites, such as defect sites can be suggested. In sharp contrast, the 6-day sample exhibits the angle dependence of the photoelectrons, suggesting formation of the uniform oxides. We relate these non uniform oxides with the electrical characteristics of the MOS gate transistors.

Reference

[1] Y.Harada et al., Jpn J. Appl. Phys. 39(2000)560.

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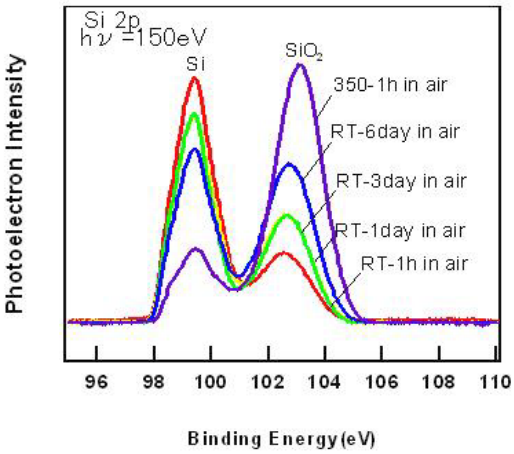

Fig.1 Si 2p spectra of SR-XPS obtained from HF treated Si(100)

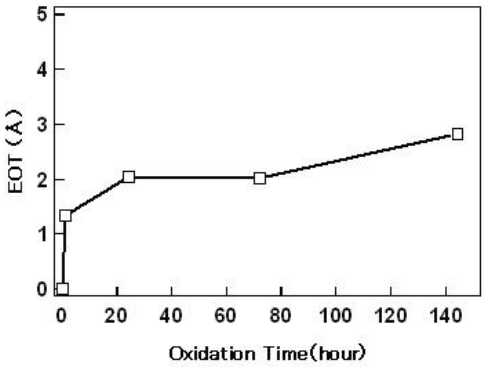

Fig.2 Effective oxidation thickness (EOT) variations as a function of oxidation time.

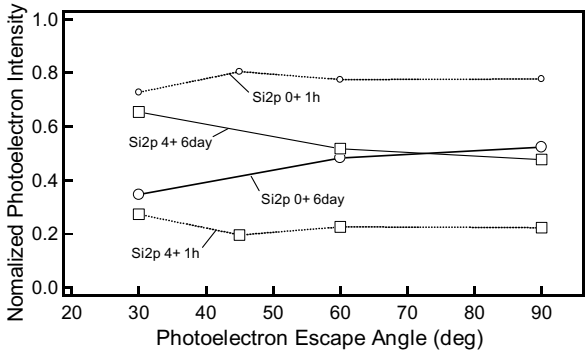

Fig.3 Escape-angle dependence of the Si2p 0+ and 4+ photoelectrons.