4C, 18B/2002G062

Comparison of ordered structure in buried oxide layers in high-dose, low-dose, and ITOX SIMOX wafers

Takayoshi SHIMURA*[1], Kazunori FUKUDA[1], Takuji Hosoi[1], Kiyoshi YASUTAKE[1], and Masataka UMENO[2]
[1]Department of Material and Life Science, Graduate School of Engineering, Osaka University, 2-1 Yamadaoka, Suita, Osaka 565-0871, Japan
[2]Department of Management Science, Faculty of Engineering, Fukui University of Technology, 3-6-1 Gakuen, Fukui, Fukui 910-8585, Japan

Introduction

The silicon-on-insulator (SOI) wafer composed of a top Si layer, a buried oxide (BOX) layer and a Si substrate has an ideal structure for complementary metal oxide semiconductor (CMOS) devices. A separation-by-implanted-oxygen (SIMOX) wafer, that is fabricated by O+ ion implantation and subsequent high-temperature annealing, is one of the most promising SOI wafers, because of its brief fabrication process and the thickness uniformity of the top Si and BOX layers.

When a SIMOX wafer was investigated by X-ray diffraction, diffraction streaks perpendicular to the wafer surface were observed at the middle of the reciprocal lattice points of Si, such as 0.5 0.5 L ($0.6<L<1.6$) and 1.5 0.5 L ($0.4<L<1.4$), where the diffraction of bulk Si is forbidden. These streaks did not change even after the removal of the top Si layer, but the intensity gradually decreased with a successive thinning of the BOX layer. This indicates that epitaxially ordered SiO_2, which has a different atomic arrangement from that in the thermal oxide layer, exists throughout the BOX layer.

The SIMOX wafers fabricated by O^+ ion implantation at doses of ~$2x10^{18}$ and ~$4x10^{17}$ cm^{-2} are commonly called high-dose and low-dose SIMOX wafers, respectively. The low-dose SIMOX process is followed by an internal-thermal-oxidation (ITOX) process. In the ITOX process, the wafer is oxidized at about 1350ºC in an oxidizing environment, so that the BOX layer increases at the interface between the top Si layer and the BOX layer. The additional BOX layer is called an ITOX layer.

In this paper, we show the results of X-ray diffraction experiments for the ordered SiO_2 in the BOX layers of the high-dose, low-dose, and ITOX SIMOX wafers. It was found that the SiO_2 molecules in the BOX layers of the low-dose and ITOX SIMOX wafers are better ordered than those in the high-dose SIMOX wafer, and that the ordered structure of the ITOX layer is different from that of the originally formed BOX layer, suggesting that the ITOX layer has a structure similar to that of the thermal oxide layer.

Experimental

X-ray diffraction experiments were performed using four circle diffractometers installed on BL-4C at the Photon Factory (PF), KEK, Tsukuba. The intensity distributions of the extra streaks were measured under a symmetric condition, in which the incident and outgoing angles to the wafer surface are equal to each other. Each intensity distribution represents the series of the integrated intensities obtained by rotating the samples at each measurement point, and the background intensities were subtracted. The wavelength was chosen to be 0.1542 nm.

Results

The intensity distributions of the extra streaks of 0.5 0.5 L ($0.3<L<2$) for the high-dose, low-dose, and ITOX SIMOX wafers were observed. We see that the intensities of the streaks are roughly the same for all three kinds of wafers. The linear absorption coefficient of Si is 147 cm^{-1} for X-rays of the wavelength of 0.1542 nm and the incident angle of X-rays to the wafer surfaces is 8.4 deg at 0.5 0.5 1.1, so that the absorption effect of the top Si layers is less than 2 %. Thus, the intensity distributions represent the intensities of X-rays scattered by the ordered SiO_2 in the BOX layers. It should be noted that the BOX layer of the high-dose SIMOX wafer is about 4 times as thick as those of low-dose and ITOX SIMOX wafers. This indicates that the atoms in the BOX layer of the low-dose and ITOX SIMOX wafers are better ordered than those of the high-dose SIMOX wafers, or that the amounts of the ordered SiO_2 per unit volume for the low-dose and ITOX SIMOX wafers are larger than that of the high-dose SIMOX wafer.

The intensity profiles of the higher order reflections of the streaks of 1.5 0.5 L ($0.4<L<1.5$) and 1.5 1.5 L ($0.2<L<1.8$) were also observed. It is apparent that the intensities of the streaks of the high-dose SIMOX wafer are lower than those of the low-dose and ITOX wafers. This means that the ordering of SiO_2 in the high-dose SIMOX wafer is poorer than that in the low-dose and ITOX SIMOX wafers, because atomic displacements from the lattice points reduce the intensity of the higher order reflections by the static Debye-Waller factor.

* shimura@mls.eng.osaka-u.ac.jp