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Buried Oxide Formation in Low-Dose Low-Energy SIMOX

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Low-dose, low-energy SIMOX (Separation by IMplanted OXygen) materials can reduce the production cost and also provide thinner top silicon and buried oxide (BOX) layers for smaller dimension electronic devices. However, it is more challenging to control the processing conditions since these layers are much thinner than those of conventional wafers. Several studies have shown that the defects in the top Si layer as well as in the BOX layer are influenced by the growth of the oxide precipitates during the implantation and the annealing processes [1-3]. The structural transformation of BOX layer including the Si-O bonding information is necessary to be investigated in order to understand and be able to control the quality of SIMOX structure. This study focuses on the investigation of the relationship between the structural transformation and the characteristics of the Si-O bonds in the as-implanted and annealed SIMOX samples. The effect of implanted oxygen doses and annealing condition on the structural transformation of the BOX layers was investigated using Transmission Electron Microscopy (TEM). In addition, the Si-O bonding in these SIMOX materials was evaluated based on their infrared absorption characteristics using Fourier Transform Infrared Spectroscopy (FTIR).

SIMOX wafers were prepared using the Ibis 1000 high-current oxygen implanter. The oxygen doses ranging from 2.0 to 8.0×10^{17} O^+/cm^2 were implanted into p-type <100> Si wafers at 65 keV and 100 keV. During implantation, the wafer temperature was kept at about 560 ^oC and beam current was adjusted to 40 mA. After the implantation, samples were annealed at different annealing temperatures (1100^{o}C – 1350^{o}C) and time (0 and 4 hours) in the furnace containing 0.5% O_2 in Ar atmosphere. The microstructures of these SIMOX samples were investigated using Hitachi 8100 TEM operating at 200 keV. After removing the native SiO_2 from the SIMOX wafers, the FTIR measurements were performed at the room temperature using a Perkin Elmer 1725X FTIR.

Fig. 1 illustrates the cross-sectional TEM micrographs of as-implanted SIMOX samples at 65 keV with doses of (a) 2.0, (b) 3.5, and (c) 5.0×10^{17} O^+/cm^2, respectively. It is observed that the microstructures of SIMOX wafers changes with increasing oxygen doses. At the doses of 2.0×10^{17} O^+/cm^2 at 65 keV, no well-defined BOX layer is observed. However, a number of small SiO_2 precipitates are observed around the projection range. With increasing oxygen doses to 3.5×10^{17} O^+/cm^2 for the 65 keV sample, the laminar structures of silicon in BOX layers are observed.

Fig. 2 shows the relationship between the Si-O stretching peak positions and the oxygen doses with implantation energy of 65 keV and 100 keV. The Si-O stretching peak position in the as-implanted samples toward lower frequencies compared to a typical thermal oxide (≈ 1080 cm^{-1}) and also shifts toward lower frequencies at lower doses. The increasing of compressive stress of the BOX layers and the substochiometry of the oxide were proposed to describe these peak position shifts [4,5]. It was suggested that the peak position increase due to the increasing of stoichiometry in the oxide layer. However, the higher the oxygen dose, the more the compressive stress built up in the BOX layer resulting in the insensitivity of the peak shift. The least shift position of the 65 keV samples corresponds to the samples implanted with 3.5×10^{17} O^+/cm^2 which has microstructure shown in

Fig. 1(b). In addition, we have observed that the microstructure of SIMOX sample implanted at 100 keV with the dose of 6.0×10^{17} O^+/cm^2 is similar to the sample implanted at 65 keV with the dose of 3.5×10^{17} O^+/cm^2.

Therefore, we can indicate the optimum dose at a certain implantation energy, below which the substoichiometry of SiO_x plays a dominant role and above which the compressive stress in BOX layer is critical. Moreover, these results suggest that the compressive stress plays an important role to control the peak shift when the implanted oxygen starts forming striations in a BOX layer. Therefore, the least shift as shown in Fig. 2 move toward a higher dose with increasing of implantation energy.

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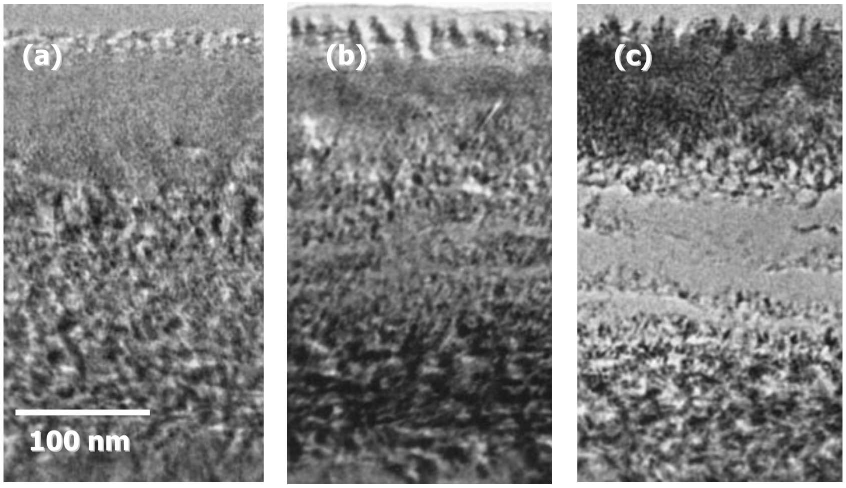

FIG. 1.

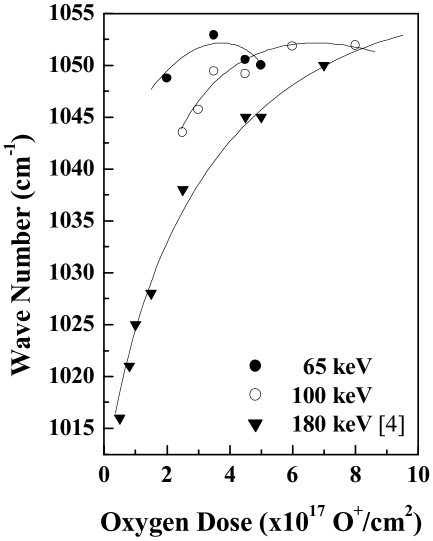

FIG. 2.

FIG. 1. TEM micrographs of as-implanted SIMOX wafers implanted at 65 keV with doses of (a) 2.0×10^{17} O^+/cm^2, (b) 3.5×10^{17} O^+/cm^2, and (c) 5.0×10^{17} O^+/cm^2, respectively.

FIG. 2. The relationship between the peak positions in wave number (cm^{-1}) of Si-O stretching in as-implanted SIMOX wafers and the oxygen doses at different implantation energy of 65 keV, 100 keV, and 180 keV [4].