Quality Improvement of SIMOX Wafers by Utilizing Nitrogen-doped Cz Si Crystal

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Recently, thin film Si-on-insulator (SOI) technologies have been recognized as an essential solution to improve the performance of CMOS LSIs. Among them the separation by implanted oxygen (SIMOX) method with the internal thermal oxidation (ITOX) technique [1], so-called ITOX-SIMOX, has been one of the most promising candidates for commercial use. Along with the LSI technology trend, a defect-free SOI surface is required nowadays. It was reported, however, that there were square-like pits on a conventional high-dose SIMOX [2] and we also found similar surface pits on an ITOX-SIMOX [3]. We verified that the surface pits on ITOX-SIMOX arose from the crystal originated particles (COPs) in the starting Cz Si wafer and were successfully eliminated by utilizing COP-free wafers [3] including nitrogen (N) -highly-doped Cz Si wafers [4]. In this study, we addressed the influence of the surface pits on ITOX-SIMOX wafers on the GOI performance. The positive effect of ITOX on GOI improvement was discussed in terms of pit shape deformation. Finally, superior GOI performance of ITOX-SIMOX using N-doped Cz Si wafers was also shown.

Various 200 mm Si wafers were prepared as starting materials of ITOX-SIMOX, including conventional Cz Si and N-doped Cz Si wafers. Oxygen ions were implanted at 180 keV into the wafers with a dose around 4 x 10^{17} cm^{-2}. The wafers were then annealed to form SOI structure at 1350 ^{o}C in Ar + O_2 and some of them were additionally oxidized to grow an ITOX layer. After the removal of top oxide, the layer thickness was evaluated by spectroscopic ellipsometry and the resulting structure was in the range of 60 - 340 nm with SOI layer and 85 - 120 nm with buried oxide. The wafer surface was then observed with atomic force microscope (AFM) to evaluate surface pit formation. In order to investigate the GOI, lateral type MOS capacitors, properly designed for SOI [5], were fabricated on the wafers and the charge to breakdown (Q_{BD}) characteristics were measured.

Fig.1 shows typical AFM view of the surface pits on ITOX-SIMOX fabricated on the conventional Cz Si together with that of a COP on the unprocessed Cz Si wafer as comparison. As can be seen, the depth of the surface pit is quite shallow compared to its lateral size, whereas the COP has almost the same dimension with its depth and lateral size.

Fig.2 shows the Weibull plotted Q_{BD}s of 9-nm gate oxide on ITOX-SIMOX using conventional Cz Si. Though these ITOX-SIMOX wafers have surface pits, they exhibit dramatically better Q_{BD} characteristics than that of conventional Cz Si itself, the GOI degradation of which is mainly attributed to COPs, suggesting that the shallow shape of the surface pits on SIMOX prevents the GOI from degradation.

It was also confirmed the GOI performance of ITOX-SIMOX can be improved by using N-doped Cz Si which can eliminate the surface pits by controlling COP generation. Fig.3 shows the relation between the probability of Q_{BD} failure (initial + random) on ITOX-SIMOX and the N-concentration in the starting material. In this figure, the Q_{BD} characteristics of SIMOX without surface pits exhibit considerable improvement compared to those with pits, the mechanism of which will be discussed hereafter.

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[2] H. Naruoka et al. IEEE Int. SOI Conf. (1997) 182.
[3] I. Hamaguchi et al., IEEE Int. SOI Conf. (2000) 18.
[4] A. Ikari et al. , Solid State Phenomena, 69/70(1999) 161.
[5] K. Kawamura et al., IEEE Trans. Electron Devices 48 (2001) 307.

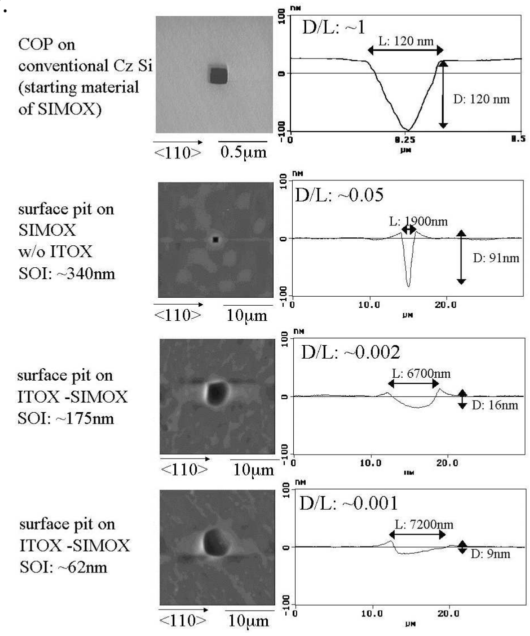

Fig.1 Typical AFM view of surface pits on ITOX-SIMOX fabricated on the conventional Cz Si together with that of COP on the unprocessed Cz Si wafer as comparison.

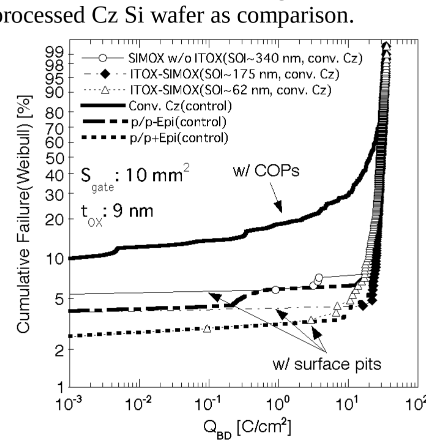

Fig.2 Weibull plot of Q_{BD} characteristics of 9-nm gate oxide on ITOX-SIMOX wafers fabricated on conventional Cz Si wafers.

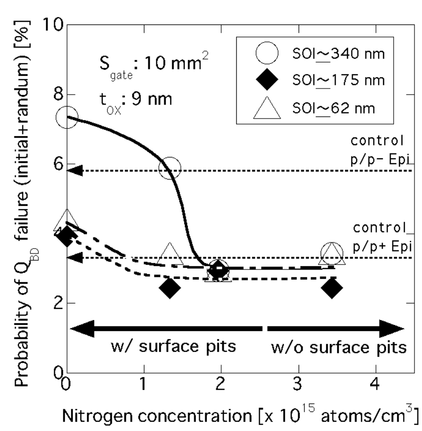

Fig.3 Relation between probability of Q_{BD} failure (initial + random) on ITOX-SIMOX and nitrogen concentration in the starting material.