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Annihilation Effect of High Concentration Oxygen Atoms on Secondary Defects in As^+-Implanted Si

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For source and drain formation in MOS devices, high dose As^+ ion implantation through SiO_2 films has generally been employed. During this implantation process, knoked-on oxygen atoms into Si subtrates strongly interact with the defects introduced by As^+ implantation. This interaction increases with increasing As^+ ion dose or increasing screen oxide films under device fabrication conditions. Eventually, the disorders after annealing through-oxide As^+-implanted samples severely remain in implanted layers for conventional source and drain formation process[1]. However, in the present experiment, it was found that, under certain conditions, a high concentration of oxygen atoms has an annihilation effect on secondary defects in high dose As^+-implanted (100) Si.

When high dose As^+-implanted (100) Si is annealed at temperatures between 600 and 900°C, secondary defects remain at two different depths as shown in Fig. 1. One type of defect (type 1) exists at the As^+ ion range, R_p, and arises as a result of the precipitates due to the high concentration As atoms at R_p. The other type (type 2) remains at the interface between the original amorphous layer formed by As^+-implantation and the underlying Si substrates. Table 1 summarizes the results of such secondary defect formation and the characteristic change in the defect type by annealing under the present experimental conditions. It is noteworthy that in through-oxide samples implanted with 2×10^{16} As^+/cm^2, type 1 defects are annihilated and completely disappear after annealing at 1000°C. SIMS measurements revealed that high concentration oxygen atoms above $1 \times 10^{20}/cm^3$ are introduced into the region from the SiO_2/Si interface to the As^+ion range depth. Therefore, it can be expected that the formation of As-rich precipitation will be retarded by As-O bonding as recently suggested by Celler et al.[2] and stable defects will not be formed in the As^+ ion range after annealing.

In order to verify this defect annihilation result, a double implantation experiment was performed using As^+ and O^+ ions. First, As^+ ions were implanted with a dose of 2×10^{16} As^+/cm^2 into bare Si at 80 keV ($R_p \sim 480$Å), followed by 22 keV oxygen ($R_p \sim 480$Å) ion implantation with doses between 5×10^{13} and 5×10^{15} O^+/cm^2. Typical cross sectional TEM (XTEM) and plan view TEM results are shown in Fig. 2 after annealing for 15 min at 950°C. As clearly seen from the figure, the residual defect structures and depth distributions vary depending on oxygen dose. At a dose of 5×10^{15} O^+/cm^2, only type 2 defects remain. This suggests again that the existence of high concentration oxygen atoms effectively acts to annihilate type 1 defects by saturating the arsenic bonds with oxygen. Moreover, high temperature heat treatment resulted in complete elimination of all defects in doubly 2×10^{16} As^+/cm^2 and 5×10^{15} O^+/cm^2 implanted layers as shown in Fig. 3, although the defects did not disappear for the 2×10^{16} As^+/cm^2 implanted samples with lower oxygen doses.

References

1) For example; W. K. Chu, N. Muller, J. W. Mayer and T. W. Sigmon, Appl. Phys. Lett. 25 (1974) 297.

2) G. K. Celler, L. E. Trimble, K. W. West, L. Pfeiffer and T. T. Sheng; Appl. Phys. Lett. 50 (1987) 664.

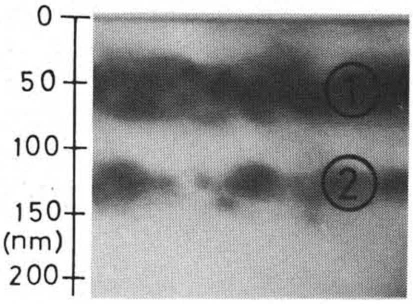

Fig. 1 XTEM micrograph showing two different defect types remained in 80 keV, 5 x 10^{15} As^+/cm^2 implanted (100) bare Si followed by 800°C, 15 min annealing.

Table 1 Summary of the characteristic change of residual defect types by annealing under the present implantation and annealing conditions. 1 and 2 correspond to the defect type in Fig. 1, respectively. All the implantation was carried out at 80 keV.

Impl. Dose (/cm^2) / Anne. Temp. (°C)	5 x 10^{15}	2 x 10^{16}	5 x 10^{15}	2 x 10^{16}
	bare		180 Å SiO_2 through	
800	1 2	1 2	1 2	2
950	2	1 2	1	2
1000	no	1	1	no

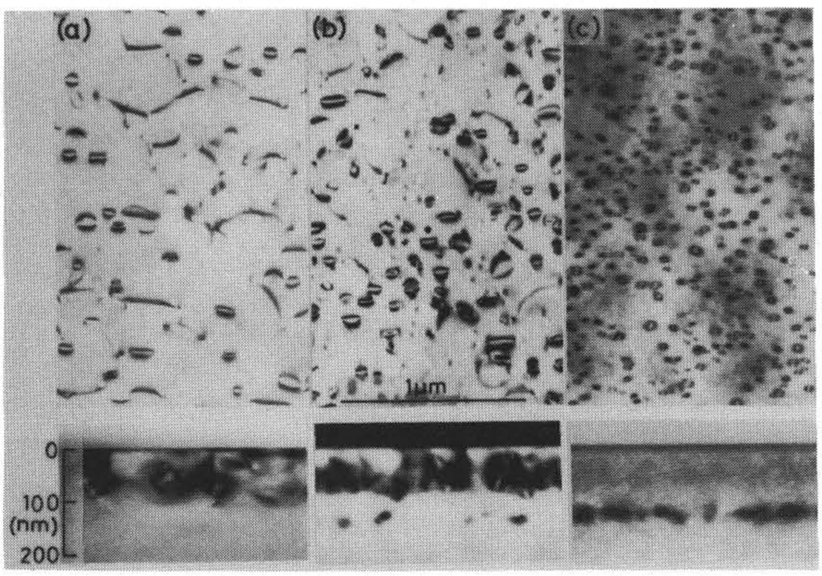

Fig. 2 Plan view TEM (upper part) and corresponding XTEM (lower part) micrographs showing defect structure variations with 22 keV, implanted oxygen doses in 80 keV, 2 x 10^{16} As^+/cm^2 implanted (100) bare Si followed by 950°C, 15 min annealing. (a) 5 x 10^{13} O^+/cm^2, (b) 5 x 10^{14} O^+/cm^2 and (c) 5 x 10^{15} O^+/cm^2 implantation.

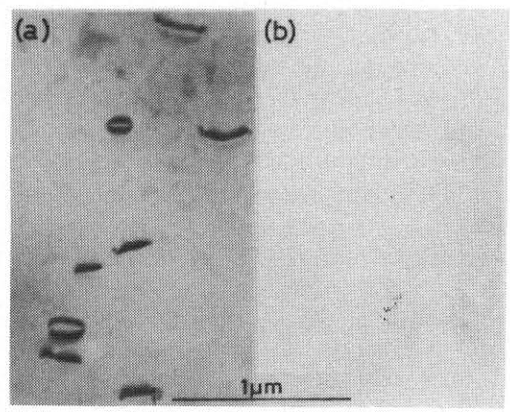

Fig. 3 Plan view TEM micrographs of defect remaining and disappearance after 1000°C, 15 min annealing of Fig. 2(b) and (c) samples. (a) Fig. 2(b) sample and (b) Fig. 2(c) sample.