EFFECTS OF Si, Ge PRE-IMPLANT INDUCED DEFECTS ON ELECTRICAL PROPERTIES OF P^+-N JUNCTIONS DURING RAPID THERMAL ANNEALING

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ABSTRACT

Defects introduced by Si, Ge preamorphization and their effects on the dopant diffusion and electrical characteristics. Good crystalline quality are obtained after the annealing of Ge ion double implanted samples. The defect clusters under the a/c interface are expected to extend up to the deep in the Si ion implanted samples. The dislocation loops near the junction absorb the interstitial Si atoms resolving from the defect cluster and result in the prevention of enhanced boron diffusion near the tail region of boron profile and show good reverse current charactristics.

1. INTRODUCTION

Recent developments in the downscaling of microelectronic devices have resulted in the adoption of Si,Ge ion implantation prior to shallow dopant implantation[1,2]. The amorphous layer induced by these heavy and electrically neutral ions has been shown to eliminate dopant channeling in the tail region during shallow junction formation. However, ion implantation has serious disadvantage of creating a large amount of defects. All the defects introduced during the ion implantation and the subsequent processing considerably influence the electrical properties of device characteristics[3,4].

Therefore, it is worthwhile to elucidate the structure and the natuer of defects introduced by Si, Ge Preamorphization and their effects on electrical characteristics. In this study, the annealing behaviors of Si, Ge pre-implant induced defects and their effects on the electrical properties of p^+-n shallow junctions during RTA are investigated.

2. EXPERIMENTAL

Single-crystal, 5-10Ω · cm, phosphorus-doped (100) Cz Si wafers were implanted at three different conditions for surface amoprhous layer formations : (a) by Si ions with dose of $1X10^{15}$ions/cm^2 at 50keV ; (b) by Ge ions with a dose of $1X10^{15}$ions/cm^2 at 50keV ; (c) by Ge ions with a dose of $2X10^{15}$ions/cm^2 at 150keV plus $1X10^{15}$ions/cm^2, 50keV. Boron was implanted at 20keV with a dose of $1X10^{15}$ions/cm^2 at room temperature. After implantation, these wafers were subjected to RTA(Rapid Thermal Annealing) for 10s at temperatures ranging from 550 to 1100℃ in a nitrogen ambient. Boron profiles were obtained by PERKIN ELMER ATOMIKA 6500 secondary ion mass spectroscopy (SIMS) with C_s^+ beam. The structural analyses were preformed by using JEOL JEM 200CM scanning transmission microscope(TEM) with 200KV acceleration voltage. The annealing behaviors of the residual lattice defects during RTA evidenced by TEM were directly related to boron enhanced diffusion recorded by SIMS techniques. For annealed samples, measurements of leakage currents were also carried out to analysize the electrical characteristics of p^+/n junctions.

3. RESULTS AND DISCUSSION

Fig. 1 shows the continuous amorphous layer formed by (a) Si ion, (b) Ge ion and (c) Ge ion double implantations followed by boron implantation with a dose of $1X10^{15}$ions/cm^2 at 20keV at room temperature. The thickness of surface amorphous layers were (a) 100nm by Si ion (b) 70nm by Ge ion, and (c) 180nm by Ge ion double implantations. Point defect clusters are also formed just below the amorphous/crystalline (a/c) interface due to the implanted ion range straggling. The defect clusters under the a/c interface are almost the same in degree in the samples. However, Ge ion implantation produce sharper interface between the amorphous and the crystalline regions. This may be that the heavier Ge ions lose most of their energy through nuclear collisions and make more disorder, which results in sharper a/c interface.

Fig. 2 shows the comparision of boron depth profiles in Si samples formed by various preamorphization conditions. The thicker the surface layer, the more effective for the elimination of boron ion channeling in Ge ion implanted samples. On the other hand, Si ion implanted sample shows the effectiveness to prevent the channeling compared to the Ge iòn double implanted samples with thicker surface amorphous layer. From this, in the case of Si ion implanted samples, the defect clusters under the a/c interface are expected to extend up to the deep in the substrate.

Fig. 3 shows XTEM micrograph of samples annealed at the temperature of 1100℃ of the continuous amorphous layers induced by (a) Si ion, (b) Ge ion and (c) Ge ion double implantations, respectively. The band of disolcation loops are observed at the depth of 100nm in Si ion implanted sample. However, its difficult to remove the dislocation loops in this sample with compared to the Ge ion double implanted samples with dislocation loops at the deeper 200nm. The dislocation loops clearly disappear during the repid thermal annealing in the Ge double implanted samples. This implies that the defects induced Ge double implantation recover during solid phase epitaxial regrowth. And good crystal quality is obtained in the Ge ion double implanted samples.

Fig. 4 shows the boron depth profile with respect to the annealing temperatures in Si ion implanted sample. After 900 and 1000℃ anneaing, boron profile shows enhanced diffusion below the boron concentration of about $1X10^{18}$ions/cm^3. This may be induced by the interstitial Si atom resolving from the defect clusters under the a/c interface. However, in the case of Ge ion double implanted samples, the enhanced diffusion of boron ions is not observed to the temperature of 1000℃ (Fig. 5). Results from the SIMS and XTEM observations strongly indicate that the dislocation loops near the junction absorb the interstitial Si atoms resolving from the defect clusters and result in the prevention of enhanced boron diffusion near the tail region of boron profile.

4. CONCLUSIONS

The annealing behaviors of Si, Ge pre-implant induced defects and their effects on the diffusion of boron ions and electrical properties of p^+-n shallow junctions during RTA are investigated.

The defect clusters under the a/c interface are expected to extend up to the deep in the Si ion implanted samples. Defects induced by Ge ion double implantation recover during solid phase epitaxial regrowth, and shows good crystalline quality. The dislocation loops near the junction absorb the interstitial Si atoms resolving from the defect clusters and result in the prevention of enhanced boron diffusion near the tail region of boron profile and show good reverse current charactristics.

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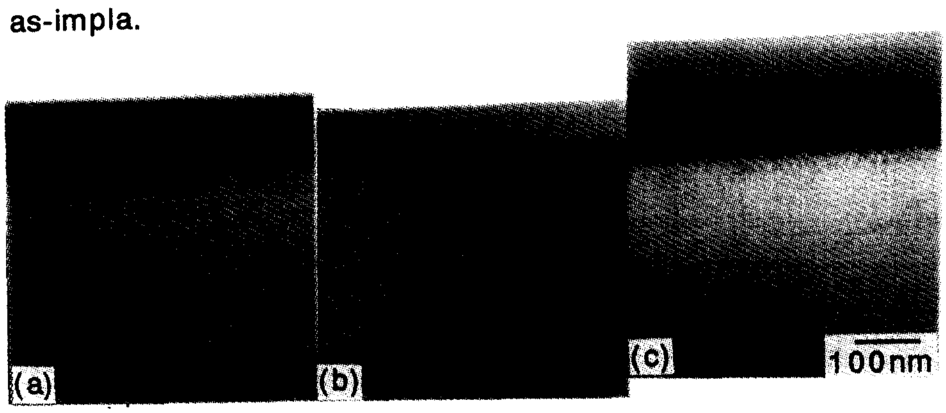

Fig. 1 XTEM micrograph of the continuous amorphous layer formed by (a)Si ion, (b)Ge ion and (c) Ge ion double implantations followed by boron implantation with a dose of $1X10^{15}$ions/cm^2 at 20keV at room temperature.

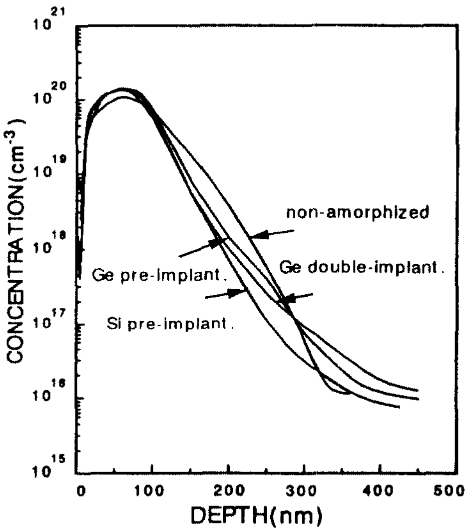

Fig.2 Boron depth profiles at various preamorphization conditions.

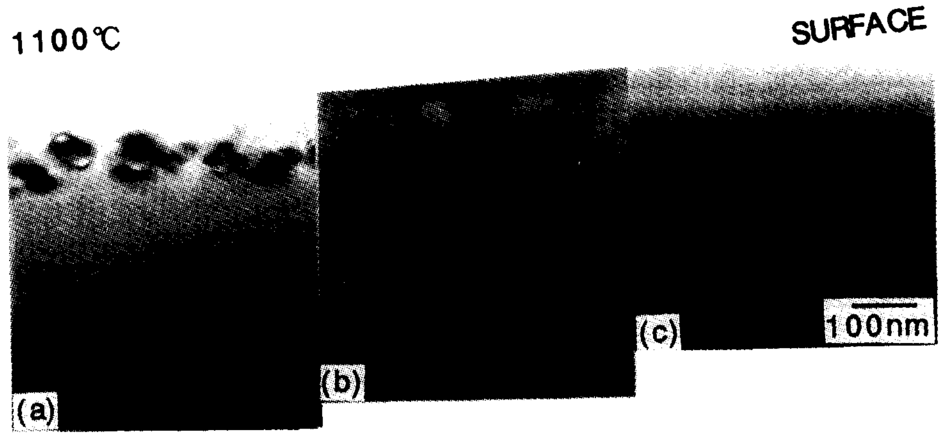

Fig.3 XTEM micrograph of samples annealed at the temperature of 1100℃ of the continuous amorphous layers induced by (a) Si ion, (b) Ge ion and (c) Ge ion double implantations, respectively.

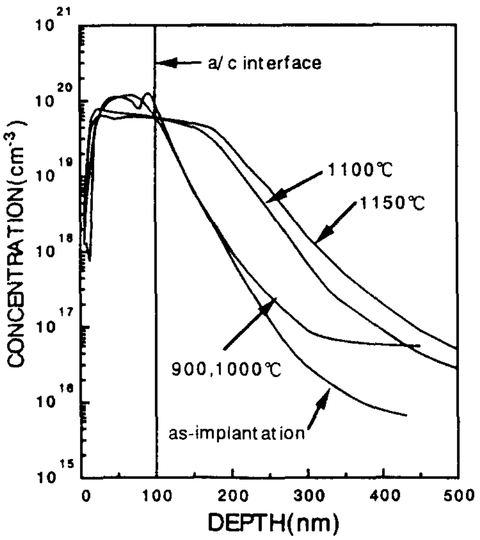

Fig. 4 Boron depth profiles in Si ion implanted sample.

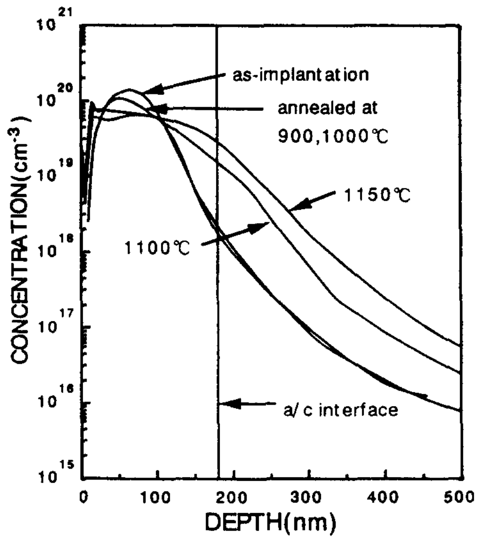

Fig. 5 Boron depth profiles in Ge ion double implanted sample.