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Observation of Lattice Defects in Ion-Implanted Si Wafer by A Double Crystals Spectrometer Method

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Ion-implanted Si wafers were investigated by an X-ray diffraction technique in which a parallel arrangement of a double crystals spectrometer was used.[1] In this study were measured changes of a lattice parameter and a radius of curvature of the ion-implanted wafer after isochronal anneal-ing in the range of $450^\circ \sim 1200^\circ$ C. From these results the location of the ion-implanted atom within the unit cell of the crystal was studied.
Prior to observation was taken a special precaution about X-ray beams and diffraction conditions used. If the usual conditions about X-ray beams and diffraction, in which penetration depth of the incident X-ray beams (several microns) is deeper than the ion-implanted layer ($\sim$0.1 micron), were used, we cannot obtain any information about the ion-implanted layer. From the reason described above the following experimental conditions were used : (1) a low energy X-ray beams such as CrK α_1 and (2) an asymmetric diffraction condition in which the incident and the exit angles of the X-ray beams were nearly $2\theta_B$ and zero (actually a few minutes of arc) respectively was used because the penetration depth of X-ray beams was made to be shallow. Moreover, was used an anomalous transmission effect in the Bragg case,[2] which occurred extensively in the asymmetric diffraction condition, in order to measure the radius of curvature of the wafer. Then the measurements were carried rapidly and simply.

The surface of the ion-implanted Si wafers were $\{111\}$ and species of ion were B, P, and Si. The process of ion-implantation was carried with the use of the conventional method at room temperature at the dose of 1×10^{16}, 1×10^{16}, and 1×10^{15} atoms/cm^2 for B, P, and Si respectively. Annealing process was carried under the following conditions : temperature range was $450^\circ \sim 1200^\circ$ C, N_2 gas was flowed at 0.3 l/min, and each annealing lasted 10 min. After each annealing radius of curvature and sheet resistance were measured as shown Figs. 1 and 2, respectively. Directions of radius of curvature were determined to be plus or minus on the condition that they were convex or concave configurations as viewed from the ion-implanted surface. It is evident from Fig. 1 that all wafers bend in the direction of the ion-implanted surface in an "as-implanted" condition irrelevant to implanted species and that radii of curvature change into the reverse of those in an "as-implanted" condition after passing through infinity except the wafer on which Si was implanted as annealing temperature increases. The variation of radius of curvature and sheet resistance are in fairly good agreement with each other, if the lattice location is considered. That is, it is reasonable to think that the curve of the wafer changes from convex to concave as viewed from the ion-implanted surface when Si atoms which were displaced by ion-implantation process[3,4] and the implanted atoms on interstitial sites occupy the substitutional sites, if the atomic radii of the implanted atoms were smaller than that of the host crystal.

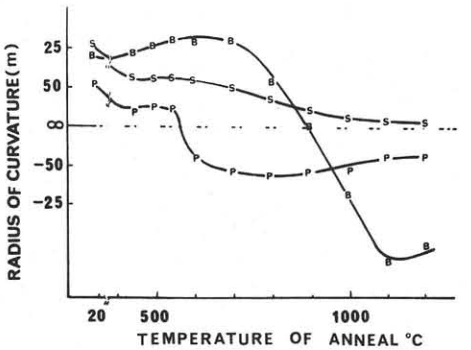

Fig. 1. The effect of annealing temperature on radius of curvature developed by changes of lattice location. B, P, and S show the experimental results from the wafers on which B, P, and Si atoms are implanted, respectively.

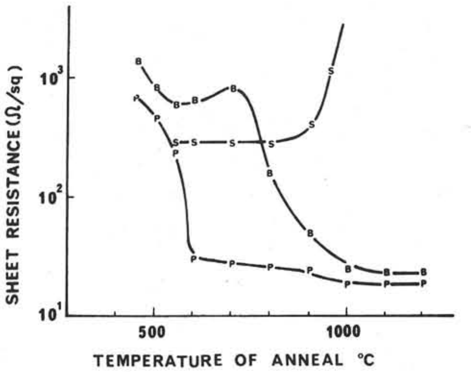

Fig. 2. Isochronal annealing of ion-implanted layers at various temperatures. Each annealing lasted 10 min. Signs B, P, and S are similar to those in Fig. 1.

The variations of lattice parameter and diffracted intensity, at which the lattice parameter were measured, were also observed after each annealing process.

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