4-3 Study on Three-Dimensional Distribution of Implanted Ions by $He^+$ Backscattering Technique

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## 1. Introduction

In application of ion implantation technique to semiconductor industry, it is important to know exact three-dimensional ion distributions. Especially, experimental studies on depth distribution of ions in a double-layer target and lateral distribution of ions in a mono-layer target are important as well as the theoretical studies.[1),2)] In the present work, it has been tried to obtain the net distribution of implanted ions (In this case, Ar is used.) by 1.5 MeV $He^+$ backscattering technique. And the following conclusions are derived; (1) The spatial distribution of heavily doped impurity atoms can be quantatively measured using this technique and (2) the experimental distributions have shown qualitative and quantative agreement with the theoretical predictions.

## 2. Ion Distribution Implanted into a Double-Layer ($SiO_2$-Si) Target

Float-zoned >10Ωcm n-type Si wafers cut in the <111> orientation have been oxidized anodically. Ar ion implantation has been done at room temperature, at an energy of 50 keV and to a dose of $1 \times 10^{16} cm^{-2}$. To determine the specific energy loss of He in the anodically oxidized $SiO_2$, the energy spectrum from an unimplanted $SiO_2$-Si target has been measured. The spectrum of He scattered from Si and O in $SiO_2$[3)] is shown in Fig.1, in which energy per channel is 2.57 keV/ch. Using Fig.1 and the thickness of $SiO_2$ (335Å) measured by the ellipsometry, the energy loss in the $SiO_2$ is concluded to be 330 keV/μm, under this experimental condition. For the energy loss in Si, the reported values[4)] are used. Then, the depth-to-channel-number conversions become 48Å/ch. and 68Å/ch. for He scattered from Ar in $SiO_2$ and in Si, respectively.

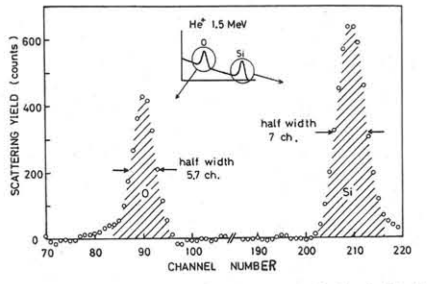



Fig.1 Energy spectrum of 1.5 MeV He scattered from $SiO_2$.

Energy spectra scattered from Ar in a $SiO_2$(335Å)-Si and in a Si target are shown in Fig.2. The calculated interface between $SiO_2$ and Si is 264-265 ch. and the scattering yield from Ar in the

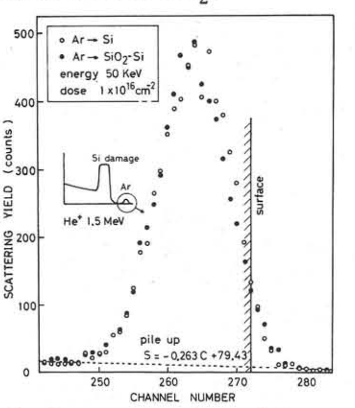



Fig.2 Energy spectra of He scattered from Ar. The incident beam direction is chosen to a <111> axis to avoid "Pile Up".

$SiO_2$-Si target shows a discontinuity between these channels. Theoretical and experimental depth distributions of 50 keV Ar in $SiO_2$-Si and in Si are shown in Fig.3, in which the theoretical one in the $SiO_2$-Si target is calculated using the energy distribution of ions.[1] The discontinuity in ion concentration is shown at the interface between $SiO_2$ and Si as predicted by this theory. The ion distribution could be determined more precisely by taking account of detector resolution.

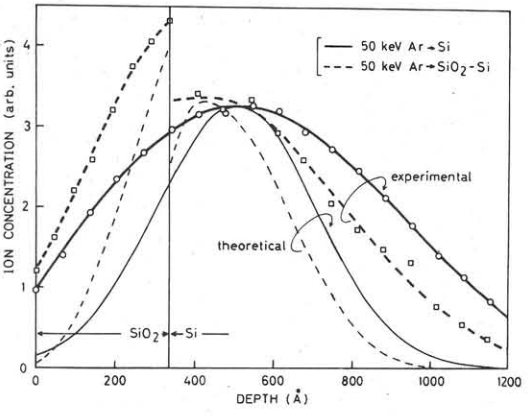
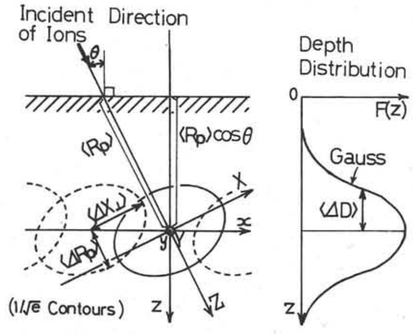



Fig.3 Depth distribution of Ar implanted into a $SiO_2$-Si target and into a Si target.

## 3. Lateral Distribution of Implanted Ions

Informations on the lateral spread of implanted ions can be put into the depth distribution, when a target is tilted to the ion-beam direction. If it is assumed that the probability distribution of the rest point of one ion is three-dimensionally Gaussian, the standard deviation of the lateral spread $\langle \Delta X_\perp \rangle$ can be evaluated from other deviation values such as $\langle \Delta R_p \rangle$ and $\langle \Delta D \rangle$ (see the equation in Fig.4). Ar ions have been implanted into two Si targets normal and 60° tilted to the incident beam, at an energy of 100 keV and to a dose of $4\times10^{15}$ ions/cm$^2$. Our experimental data show that the above assumption is reasonable. By taking account of errors arising from "Pile Up" effect and not negligible energy resolution, the values of $\langle \Delta R_p \rangle$ and $\langle \Delta X_\perp \rangle$ are obtained from the above samples; $\langle \Delta R_p \rangle$ = 480∿700 (Å), $\langle \Delta X_\perp \rangle$ =100∿550 (Å). From these results, it is concluded that the lateral spread clearly detectable by this technique. Discrepancy in $\langle \Delta R_p \rangle$ with the theoretical value ( $\langle \Delta R_p \rangle$ = 368 (Å), $\langle \Delta X_\perp \rangle$ = 303 (Å)) can be explained by the carbon contamination on the samples during measurement.




$$\langle \Delta D \rangle^2 = \langle \Delta R_p \rangle^2 \cos^2\theta + \langle \Delta X_\perp \rangle^2 \cdot \sin^2\theta$$

Fig.4 Illustration of implantation into tilted target and depth distribution.

## 4. Conclusion

Depth distribution of ions in a double-layer target and lateral distribution of ions are presented.

## References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