Title

TEM STUDIES OF p+ IMPLANTED AND SUBSEQUENTLY LASER ANNEALED Si

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The present investigation is concerned with laser annealing of P^+ implanted Si. The aim of the work was to study the crystallization behavior of damage structure occurring due to high dose rate implantation using transmission electron microscopy (TEM) as the method of examination.

Experimental

P-type, 17 ohm-cm, (111) Si slices were implanted in a non-channelling direction with 120 KeV P^+ ions to a dose of 5×10^{15} ions/cm^2. This corresponded to an LSS projected range of 1510 ± 690Å. The time of implantation was fixed to 10 minutes. The implantation temperature increased to 350°C due to the high dose rate.

For the laser annealing, specimen areas in the range 6 to 10 mm across were irradiated using single pulses of ∿40 nsec from a Q switched ruby laser with wavelength ∿0.695 nm. For TEM studies, 'plan-view' (p.v.) and '90° cross-section' (c.s.) specimens were prepared in a manner described earlier.[1] The TEM examinations both for cross-section and plan view specimens were performed using the strong beam bright-field diffraction method. However, in addition, the weak beam dark field diffraction contrast method was used for plan-view specimens. Transmission electron diffraction patterns were obtained to identify the crystallinity of the damaged regions using the standard selected area method.

Results and Discussion

For the implanted but unannealed specimen, the damage consisted of a buried damage layer ∿1200Å wide comprising dense fine spotty structures in single crystal material, and was located at a mean depth of ∿2000Å (Fig. 1a). TEM plan view micrographs obtained by the weak-beam method showed that the fine structure had an average size of ∿100Å across and density of 3×10^{11}/cm^2 (Fig. 1b).

After the specimen had been laser annealed with an energy density of 0.7J/cm^2, practically no change in the damage structure or distribution occurred (Fig. 1c and 1d).

After the specimen had been laser annealed with an energy density of 1.5J/cm^2, a first damage layer comprising single crystal material containing a high density of dislocations and stacking faults extended from the surface to a depth of ∿2100Å. A second damage layer ∿700Å wide consisting of a dense fine spotty structure occurred and was in direct contact with the first damage layer (Fig. 1e). The weak beam plan view micrographs revealed the details of dislocations, stacking faults and the fine structure (Fig. 1f). The densities of dislocations and stacking faults, and fine spotting structure were $\sim 10^{10}/cm^2$ and $\sim 7 \times 10^{11}/cm^2$, respectively.

A striking feature of the specimen annealed at $1.5J/cm^2$ was the two distinctly different damage zones in contact with one another. Similar structures have already been observed by the authors[1] for P^+ implanted Si, implanted to a dose of 10^{15} ions/cm^2 and subsequently laser annealed at energies of 0.7J and $1.5J/cm^2$. There, the as implanted specimen had an amorphous layer continuous from the specimen surface to a depth of $\sim$1800Å.

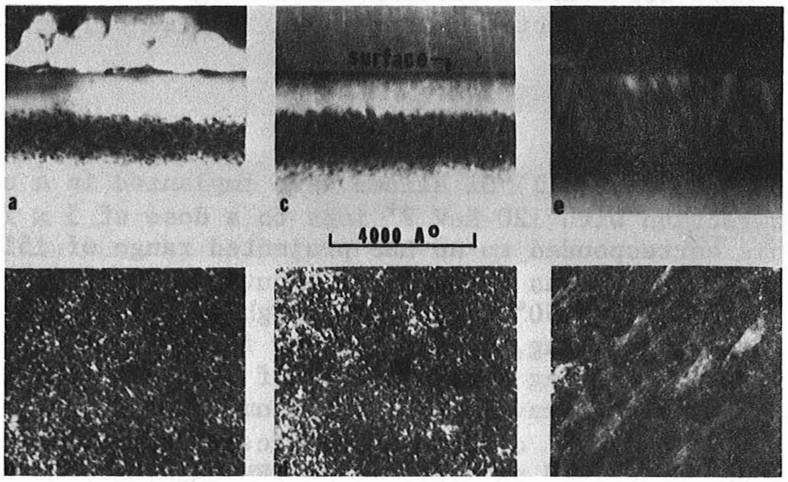

Fig. 1) - $5 \times 10^{15}/cm^2$ P^+ 120 KeV (111) Si; a) and b) unannealed c.s. and p.v., c) and d) laser annealed $0.7J/cm^2$ c.s. and p.v., e) and f) laser annealed $1.5J/cm^2$ c.s. and p.v.

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We suggest the following interpretation of the structure observed. For the $0.7J/cm^2$ specimen, the energy is distributed over a larger volume near the surface where it is single crystal, as compared to the specimen where the damage is continuous amorphous and extends to the surface. This is because of different absorption coefficients for the single crystal and amorphous material. Therefore, in the present case, the damage structure remains practically unaffected at $0.7J/cm^2$. However, for $1.5J/cm^2$, the laser energy is high enough to melt a surface layer of $\sim$2100Å thick. The remainder of the damaged region partially anneals. The molten layer then solidifies by growing on top of this partially annealed material and this produces the single crystal first damage layer containing stacking faults and dislocations.

Acknowledgments

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