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CHANGE IN STRUCTURAL PROPERTIES OF THIN CRYSTALS OF Si UNDER ELECTRON IRRADIATION

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The action of electron irradiation on the structural properties of silicon was studied.

Single crystal silicon is convenient for investigations involving channeling of light ions. Further, it is a material used for studies of radiation occurring during the passage of accelerated electrons and ions.[1] Therefore the influence of accelerated e^- on the structure of Si is a matter of both scientific and practical interest.

Single crystalline silicon films of (111) orientation were prepared using the technique suggested in Ref. 2. Silicon films of thickness $t = 2$, 5, 10, 20 and 190 μm have been irradiated by electrons of energy $E = 4.5$ MeV at rates ranging from 10^{14} e^-/cm^2 sec to 16×10^{16} e^-/cm^2 sec. Radiation doses in the interval from 1×10^{16} to 4×10^{19} cm^{-2} were used. The damage-dose behaviour of electron irradiated Si was measured by the channeling technique using 430 keV protons. Yield and energy of the backscattered particles were measured with a surface barrier detector at 164° scattering angle. The energy resolution was ~25 keV at fwhm.

The dechanneling fraction of aligned hydrogen beam X_{ch} as well as the critical angle of channeling $\psi_{1/2}$ near the (111) axis of the Si crystals have been monitored because these characteristics of channeling are dependent on defects, elastic strain in the lattice and surface state of the irradiated crystals.

Normalized axial spectra of protons scattered from a virgin 5 μm film of Si (curve 1) and irradiated crystals of the same thickness with electrons at dose 3.3×10^{16} cm^{-2} (curve 2), and 3.3×10^{18} cm^{-2} (curve 3) are depicted in Figure 1. One can clearly see that after irradiation of the 5 μm Si crystal at a dose of 3.3×10^{16} cm^{-2}, the aligned yield of the backscattered particles decreases over the whole depth analysed. The effect of the reduction in dechanneling of hydrogen ions is larger near the surface and achieves ~50% at a depth of about 0.4 μm. When the dose of e^- radiation is increased a subsequent increase of the yield of aligned spectra is revealed. It is found that the amount of the relative increase in aligned yield up to doses of ~3–5×10^{17} e^-/cm^2 is different from the Si films investigated. For example, if the thickness of

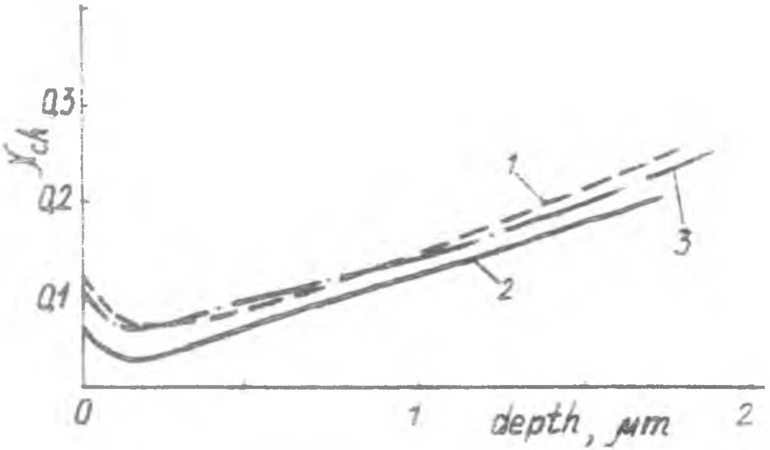

FIGURE 1 Normalized (111)-axis spectra of RBS protons from the thin Si films (5 µm): virgin (1), after e^- irradiation ($E_{e^-}=4.5$ MeV) with doses 3.3×10^{16} cm^{-2} (2), 3.3×10^{18} cm^{-2} (3).

the Si film is 5 µm, χ_{ch} increases up to a few percent only, instead of a 30–50% increase in the aligned yield for a 20 µm film.[3] A further increase in the dose of e^- radiation up to 2×10^{19} cm^{-2} does not lead to a substantial change in the aligned spectra of the Si thin films. It appears that a stabilization of the dechanneling property of the Si structure for hydrogen ions takes place. In particular, for a 5 µm film the normalized axial emission is reduced, reaching, in some cases, χ_{ch} for a virgin crystal; curves 1 and 3 in Figure 1.

In the last case the decrease in dechanneling rate seems to be at least partly due to the increase in the critical angle $\psi_{1/2}$ with dose. Among other contributions can be envisaged the positive influence of the radiation on imperfections in the grown films. It is important to note that the quality of the thin films is not as high as the quality of bulk crystals.

The nature of the physical processes which promote improvement in structural perfection of the Si thin films is not presently understood, but known effects for low doses of γ-rays and e^--radiation used for annealing of point defects in semiconductors[4] correlates with the present results and may generate some ideas for an explanation of them.

It should also be pointed out that the effect of improving channeling of hydrogen ions in thin films is greater if the electron current density increases. The last effect can be envisaged as a result of increasing the film temperature. Our estimates show that the temperature of thin crystals irradiated with a high density electron beam can reach up to 600–800°C.

This study has shown that thin silicon crystals preserve their structural perfection even after extensive e^--radiation with high fluences of particles. The investigation of the defect types in irradiated crystals provides new information about processes which lead to changes in the silicon thin film structure.

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