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SYNCHROTRON AND X-RAY STUDIES OF SPONGY-LIKE BURIED LAYERS PRODUCED IN SILICON BY HELIUM IMPLANTATION

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Helium implantation into silicon produced bubbles and other defects; in effect of heat treatment He out-diffusions partially creating spongy-like buried layer and leaving voids [1]. Such voids are of considerable interest as their properties find numerous applications in semiconductor devices. The formation and morphology of defects, induced by He^+ implantation in silicon followed by temperature and pressure treatments, have been studied using X-ray reciprocal space mapping and grazing incidence small angle X-ray scattering (GISAXS). GISAXS is a powerful, non-destructive technique, useful for analysing structures with 1-150 nm dimensions. The goal of this work was to show how the high temperature and high pressure treatments influence the creation of voids (gas-empty cavities) formed from gas-filled cavities in Si:He.

The X-ray reciprocal space maps for the 004 reflection were recorded at room temperature on high resolution diffractometer using CuKα radiation. The GISAXS experiments were carried out on the SAXS beamline at synchrotron facility of Electra, Trieste, using radiation with wavelength λ = 0.07 nm and photon energy 16 keV. Two-dimensional CCD detector positioned perpendicularly to the incident beam was used to record the SAXS intensity.

Numerous interference fringes were observed on the X-ray 004 reciprocal space maps for the as-implanted sample confirming the layered structure, composed of the relatively perfect top Si layer of about 1 μm thickness and of the disturbed buried layer containing implanted helium. After processing at 720 K, the X-ray diffuse scattering, related to the presence of point defects as well as the thickness fringes originating from the less disturbed top Si layer, remained to practically unchange. Processing at 1270 K resulted in increasing diffuse scattering. However, the diffuse scattering intensity from Si:He treated under pressure at 1270 K was lower in comparison to that for the Si:He sample annealed under enhanced pressure.

The 2D GISAXS pattern representing map of the scattered intensity for the as-implanted Si:He sample is presented in Fig 1. The 2D GISAXS pattern exhibits isotropic scattering, whose iso-intensity contour plots are circles, showing a random distribution of spherical objects in average. To get quantitative information about He bubbles created by ion implantation and subsequent processing, Guinier's approximation has been used. When Guinier's approximation is applied for the experimental results, the radius of gyration for the bubbles in as-implanted Si:He are estimated to be around 1 nm. That gives us the value for the average radius of the bubbles at around 1.3 nm. This value is the same as the value estimated for the sample annealed at 720 K. To get information about the transformation from bubbles to the voids, and about the structure of the voids, the samples were annealed under enhanced pressure. Most interesting results were obtained upon annealing of the Si:He sample at 1270 K under 0.6 GPa. It has been shown that enhanced pressure strongly affects the formation of voids and/or large cavities in the spongy-like buried Si layer. After high temperature and high-pressure treatments, the {111} facets on the cavities in spongy-like buried Si have been observed. It means that high-pressure treatment suppresses the creation of interstitial-related defects.

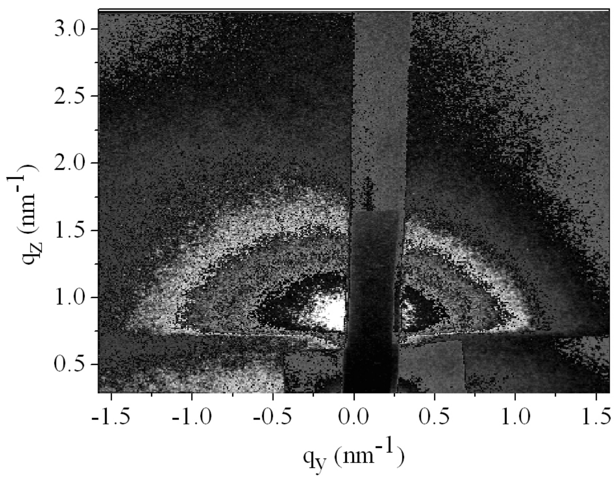

Figure 1. 2D GISAXS pattern for as implanted Si:He sample.

References

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