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Report:

Nanocrystalline materials have attracted considerable interest, then the reduced size of the crystallites causes changes in their optical, mechanical and thermodynamic properties with respect to the bulk material. In the case of silicon carbide, which is one of the most promising semiconductor materials for high temperature, high-freqency, and high-power electronic devices, it has been shown recently that ion implantation can stimulate the processes of nucleation and grain growth [1]. Therefore, in this investigation the crystallization process in dependence on the implantation parameters was studied in detail.

Single-crystalline (c) 6H-SiC wafers with 3.5° off-axis (0001) orientation were used as substrate material. An 1.8 µm thick amorphous surface layer was generated by a 5 MeV Si^+ implantation at room temperature. By 300 keV Al-implantation the recrystallization was stimulated in a 400 nm thick surface layer. The implantation parameters were varied in a dose range from 3×10^{15} to 3×10^{17} Al/cm^2 at temperatures from 300 to 700 °C. Synchrotron x-ray diffraction was used to ascertain the morphology and grain size of the recrystallized surface layers. Due to the low divergence of the synchrotron beam it was possible to restrict the penetration depth of the x-rays to less than 0.5 µm by grazing incidence. In this case, only reflections from the polycrystalline surface layer contribute to the diffraction signal.

In Fig. 1 the diffraction patterns (dotted curve) of samples as-amorphized and implanted with 3 × 10^{17} Al/cm^2 at 300 °C are shown. After Al-implantation the shape of the diffraction curve changes and diffraction peaks typical for polycrystalline material appear. Obviously, recrystallization occurs already at an implantation temperature of 300 °C, well below the SiC thermal recrystallization temperature of about 800 °C [2]. This clearly demonstrates that ion beam irradiation strongly enhances the kinetics of the amorphous to polycrystalline phase transition in SiC. The measured diffraction curve shows a very good correspondence with the 3C-powder diffraction data. In particular, nearly identical intensity ratios of the diffraction peaks are observed. Therefore, it can be assumed that randomly oriented grains of 3C-SiC polytype are formed during Al-implantation. From width of the diffraction peaks an average grain size of 9 nm was determined. Furthermore, 3C-SiC crystals with an expanded lattice ($\Delta a/a=0.014$) were observed (see shoulders at smaller diffraction angles). This may be caused by lattice defects due to the recrystallizing implantation process.

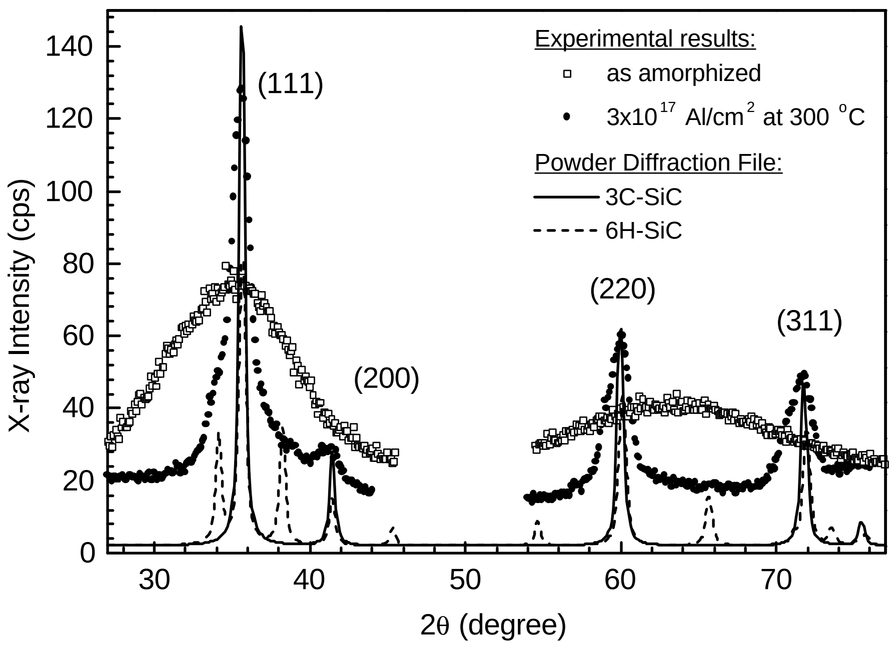

Fig. 1

x-ray (λ=0.154 nm) diffraction patterns for grazing incidence (0.35°) of samples as-amorphized and implanted with 3 × 10^{17} Al/cm^2 at 300°C. The theoretical powder diffraction patterns of 3C-SiC and 6H-SiC are plotted for comparison.

References

[1] V. Heera, J. Stoemenos, R. Kögler, and W. Skorupa, J. Appl. Phys. 77, 2999 (1994).

[2] A. Höfgen, V. Heera, F. Eichhorn, and W. Skorupa, J. Appl. Phys. 84, 4769 (1998).