3 - 12 Recrystallization of He-ion Implanted 6H-SiC upon Annealing

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SiC is a wide band-gap semiconductor material with high breakdown voltage, large electron saturation migration rate, small dielectric coefficient and good chemical stability which is of great interest for high-speed communication and high-power control devices. For SiC microelectronics devices, ion-implantation is a kind of great ways to dope impurities. However, high dose energetic ions could create radiation damages which may cause amorphization at RT. Thermally annealing could cause recrystallization of SiC amorphous layers which significantly affects electric and optical properties of SiC material. Recrystallization of amorphous SiC occurs in a wide window of annealing temperature. A partial recrystallization of amorphous SiC occurs upon annealing at a low temperature, whereas complete recrystallization of amorphous SiC occurs upon annealing at a high temperature. He implantation-induced damage in SiC has been extensively investigated. However, the complete recrystallization threshold temperature of keV He-ion implantation has not been systematically studied.

6H-SiC samples oriented < 0001 > surface supplied by the MIT company, were implanted by 15 keV He ions to doses of 1.5×10^{16}, 5×10^{16} and 1×10^{17} cm^{-2} at RT. According to the Monte-Carlo code SRIM2008, the implantation doses correspond to the peak damage varying from 0.4 to 2.7 dpa (displacement per atom), and to the peak helium concentration varying from 1.2 to 8 at.%. The implantation experiment was performed in the 320 kV Multi-discipline Research Platform for Highly Charged Ions of the Institute of Modern Physics, Chinese Academy of Sciences (CAS). Post-implantation, wafers were isochronally annealed in a tube furnace ranging from 600 to 900 °C or 30 min in vacuum ($\leq1\times10^{-3}$ Pa) .

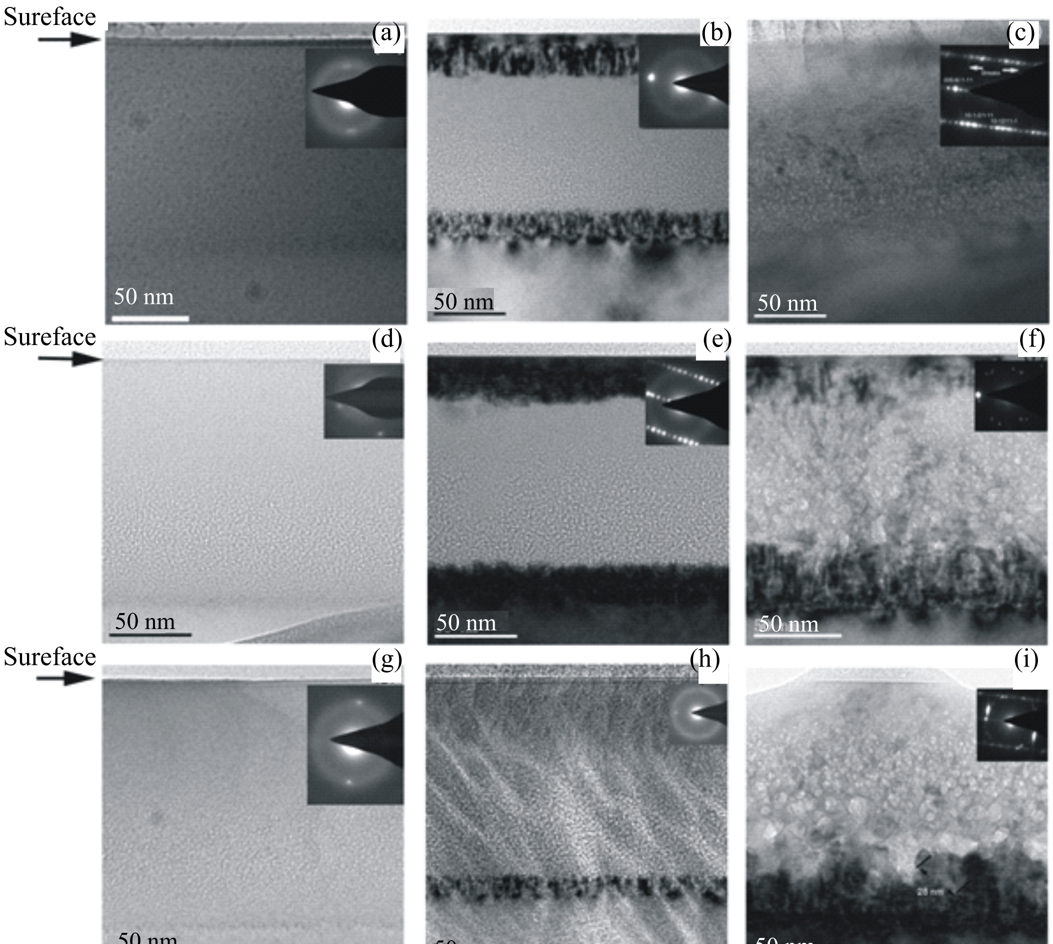

Fig. 1 Under-focused XTEM bright field micrographs of 15 keV He-implanted 6H-SiC to doses of [(a)-(c)] 1.5×10^{16}, [(d)-(f)] 5×10^{16} and [(g)-(i)] 1×10^{17} cm^{-2}, [(a), (d) and (g)] as-implantation; [(b), (e) an (h)] at 800 °C; [(c), (f) and (i)] at 900 °C. The sample surfaces were indicated by arrows.

Fig. 1 shows low-magnification under-focus XTEM bright images of He-implanted 6H-SiC. In the present study, 1.5×10^{16}, 5×10^{16} and 1×10^{17} $cm^{-2}$are termed as "low dose", "moderate dose" and "high dose", respectively. In the TEM image, the dark contrasts exhibiting dark spots located in the upper and lower interface of the damage band were observed. This dark contrast originates from a high density of stacking faults and lattice strain caused by implantation-induced damage. In the middle of the damage band, no diffraction contrast was observed after annealing at temperatures $\leq$ 800 °C. Besides, the selected-area diffraction patterns taken from the implantation area over ~200 nm of the corresponding samples are shown as insets (see Fig. 1). It can be seen that a ring pattern is exhibited in this area. These results suggest that complete amorphization occurred in the middle of the damage band. In the as-implantation, the images show that the thickness of amorphous layers corresponds to 125 nm in Fig. 1(a), 140 nm in Fig. 1(d) and 167 nm in Fig. 1(g). Through under-focus and over-focus transformation, nanoscale helium bubbles with 1~2 nm in diameter were observed in the deeper zone of the damage band for the moderate and high dose implanted samples. After annealing up to 800 °C, no significantly structural evolution was found in these samples. Only a small zone of recrystallization occurred near the amorphous/crystalline (a/c) interface, and most of the amorphous layer remained. The density and size of helium bubbles observed in the damage band did not change. After annealing at 900 °C, substantial microstructural features changed compared to the cases of the lower annealing temperature. In the insets of Figs. 1 (c), (f) and (i), the selected-area diffraction patterns taken from the damage band exhibit strong Bragg reflections, suggesting a full epitaxial recrystallization of the amorphized layer at annealing temperature 900 °C. It should be noted that besides the diffraction spots corresponding to the (11-20) diffraction pattern from 6H-SiC, the extra spots due to the (011) diffraction pattern from 3C-SiC (marked in the inset, note that the 111 reflections of 3C-SiC are equivalent to the 10-12 and 0006 reflections of 6H-SiC) were superimposed, suggesting that the polycrystalline structures were formed in the damage band. It is consistent with the report of Harada et al.[1]. Besides, helium bubbles grown significantly for the moderate and high dose implanted samples. In parallel, helium bubbles were found in the damage band of the low dose implanted sample.

Reference

[1] S. Harada, M. Ishimaru, T. Motooka, et al., Appl. Phys. Lett, 69(1996)3534.

3 - 13 HRXRD Study of 6H-SiC Implanted With 300 keV He Ions

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In this paper, samples used are oriented 6H-SiC < 0001 > surface supplied by the MIT company. They were cut into 10 mm×10 mm×10 mm in size. The 6H-SiC wafers were implanted with 300 keV He ions to a fluence of 1×10^{17} cm^{-2} at 600°C. The implantation experiment was performed at the 320 kV Multi-discipline Research Platform for Highly Charged Ions of the Institute of Modern Physics, Chinese Academy of Sciences (CAS). The 300 keV He ions were implanted into 6H-SiC in vacuum ($\leq 2\times10^{-4}$ Pa) and the current density was approximately 0.8 $\mu A/cm^2$. After He implantation, the samples were isochronally annealed at 750 and 1 200 °C for 30 min, respectively, with the GSL1700X high-temperature vacuum sintering furnace in Ar atmosphere.

The HRXRD is a powerful tool for analyzing strains of the near surface caused by ion implantation. The HRXRD measurements were carried out with the D8 Discover HRXRD of BRUKER in the Suzhou Institute of Nano-Tech and Nano-Bionics, CAS. The ω-2θ scanning mode was used near the (0004) Bragg reflection plane with resolution of 0.0001°. A 2 kW sealed X-ray tube was used with pure Cu Kα1 line of wavelength λ=0.154 056 nm and the sample table was equipped with X, Y and Z translational axis and ω, 2θ, ϕ and χ rotational axis.

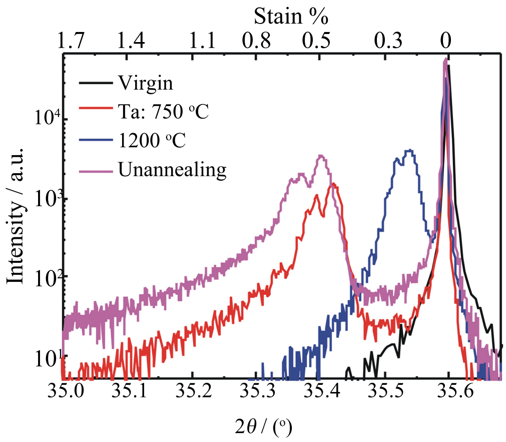

Fig. 1 (color online) Experimental ω-2θ scanning on the (0004) Bragg planes of un-implanted SiC and He-implanted SiC at 600 °C to the fluence of 1×10^{17} cm^2 and subsequently annealed samples at 750 and 1 200 °C for 30 min respectively. The quantity on the top-axis indicates the elastic-strain level. Ta in the figure denotes the annealing temperature.

Fig. 1 shows experimental ω-2θ scanning results. The black curve shows only one main sharp Bragg peak indicating that there is nearly no dilatation of lattice parameter in the direction perpendicular to the material