Deep level defects E_1/E_2 in n-type 6H silicon carbide induced by electron radiation and He-implantation

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Abstract. 6H-SiC samples subjected to He-implantation and e^--irradiation (E_e=0.2MeV-1.7MeV) were investigated by deep level transient spectroscopy (DLTS). E_1/E_2 were identified in the He-implanted and the e^--irradiated samples with $E_e \geq 0.3$MeV. Considering the minimum e^- energy required to displace the atoms in the lattice, the E_1/E_2 creation was related to the C-atom displacement. Similar to previous reports, the peak intensity and the capture cross sections of E_1/E_2 anomalously varies from samples to samples. It was shown that these anomalies were due to the presence of a DLTS peak overlapping with the E_1/E_2 signals.

INTRODUCTION

E_1/E_2 are the deep level defects commonly found in particle irradiated or ion implanted n-type 6H SiC but their microstructures are controversial.[1-5] As E_1 and E_2 are regarded as the same defect occupying the hexagonal and the cubic sites, the E_1 and the E_2 should have fixed peak intensity ratio and capture cross section. However, the E_1:E_2 ratio and their capture cross sections were found to vary from samples to samples.[2,3,6] In the present study, we have investigated the E_1/E_2 defects in n-type 6H-SiC induced by e^--irradiation and He-implantation.

EXPERIMENTAL

Samples were from the n-type 6H-SiC (0001) epi layer (5μm, $n=1\times10^{16}$cm^{-2}) grown on the n^+-type 6H-SiC substrate ($n=8\times10^{17}$cm^{-2}). E_1/E_2 defects induced by He-implantation and e^--irradiation with different energies were studied. Electron irradiations were performed with E_e=0.2MeV, 0.3MeV and 1.7MeV. For the He-implantation, He ions were implanted with energies of 55keV, 210keV, 430keV, 665keV and 840keV (each with 2×10^{11}cm^{-2}) to create a 2μm box-shaped defected region.

RESULTS AND ANALYSIS

The E_1/E_2 peaks were clearly identified and were the dominant peaks in the e^--irradiated samples with electron energies $E_e \geq 0.3$MeV but could not be detected with E_e=0.2MeV. As the C atom has a lighter mass as compared to the Si atom, for a given e^- energy, the maximum energy transferred from the electron to the C-atom is larger than that to the S-atom. This implies the minimum e^- irradiation energy required to displace the C-atom is less than that for the Si-atom. It was thus pointed out that the creation of the E_1/E_2 by the electron irradiation was due to the displacement of the C-atom.[1] For the as-He-implanted sample, the E_1/E_2 were not the most intense peaks, but their intensities grew with increasing annealing temperature before they annealed out.

The ratios of peak intensity E_1:E_2 for the He-implanted, the 0.3MeV and the 1.7MeV e^-- irradiated samples as a function of the annealing temperature are shown in figure 1. The E_1:E_2 ratio was constant at

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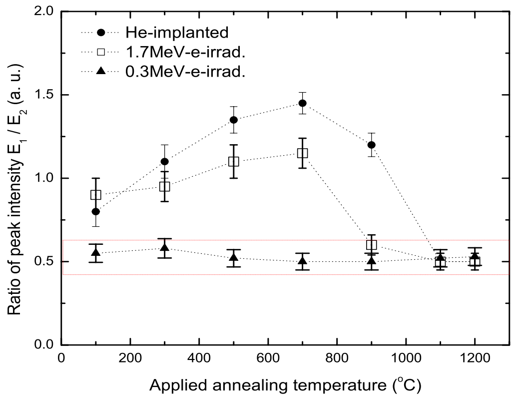

FIGURE 2. E_1:E_2 ratio as a function of the annealing temperature.

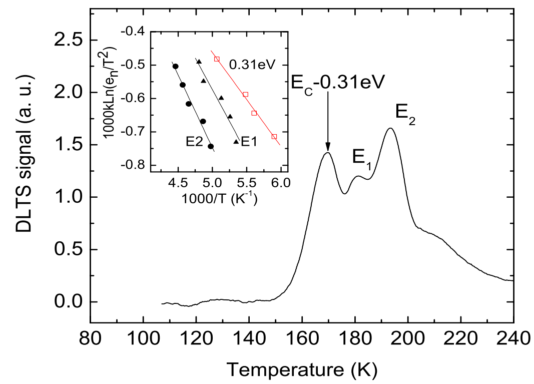

FIGURE 2. DLTS spectrum for the 900°C annealed He-implanted sample.

about 0.5 for the 0.3MeV e^--irradiated sample. In contrast, for the 1.7MeV e^--irradiated and the He-implanted samples, the E_1:E_2 ratio depends on the samples and on the annealing treatment. However, after the 1000°C annealing, the E_1:E_2 ratio became constant at ~0.5, which is the similar value of the 0.3MeV e^--irradiated sample.

$\sigma[E_1]$ and $\sigma[E_2]$ were calculated by monitoring the increase of the peaks intensities as a function of the filling pulse width t_p, i.e. $\Delta C \sim 1 - \exp(-\sigma n v / t_p)$. For the 1.7MeV and the He-implanted samples, the E_2 intensity increases with t_p at a faster rate than the E_1. The E_1 defect thus has significantly larger value of σ than the E_2 ($\sigma[E_1]=8\times10^{14}$cm^2 and $\sigma[E_2]=5\times10^{-15}$cm^2 for the 1.7MeV e^--irradiated sample). For the 0.3MeV e^--irradiated sample, the E_1 and the E_2 intensities increase with t_p at similar rates, and this results in similar values of σ ($\sigma[E_1]=3\times10^{15}$cm^2 and $\sigma[E_2]=5\times10^{-15}$cm^2). Moreover, after the 1000°C annealing, the discrepancy in values of $\sigma[E_1]$ and $\sigma[E_2]$ for the 1.7MeV e^--irradiated and the He-implanted samples disappeared (with σ~5×10^{-15}cm^2).

To conclude our anomalous observation, the E_1:E_2 peak ratio and the capture cross sections vary from samples to samples for the 1.7MeV e^--irradiated and the He-implanted samples. However, these anomalies disappeared after the 1000°C annealing. For the 0.3MeV e^--irradiated sample, these anomalies were never observed. One of the explanations is that there exists a defect peak overlapping with the E_1/E_2 signals. This defect is only induced with 1.7MeV e^--irradiation or He-implantation, but not with the 0.3MeV electron irradiation, and it anneals at 1000°C. The most direct evidence for the existence of such defect is shown in figure 2, for which this peak is separated from the E_1/E_2 signals with V_r=-2V, rate window=136ms and t_p=100µs. The defect was found to be at E_C-0.31eV and $\sigma=8\times10^{-14}$cm^2.

CONCLUSION

E_1/E_2 in e^--irradiated and He-implanted 6H n-type SiC were studied by DLTS technique.. The E_1/E_2 induction was related to the C-atom displacement in the lattice. Another defect peak (E_C-0.31eV) was found to overlap with the E_1/E_2 signals and this is possibly the cause of the peak intensity ratio and the capture cross section anomalies of the E_1/E_2.

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REFERENCES

1. Chen *et al*, Phys. Rev. Lett. **92**, 125504 (2004).
2. Hemmingsson *et al*, J. Appl. Phys. **84**, 704 (1998).
3. Kawasuso *et al*, J. Appl. Phys. **90**, 3377 (2001).
4. Aboelfotoh and Doyle, Phys. Rev. B **59**, 10823 (1999).
5. Pensl and Choyke, Physica B **185**, 264 (1993).
6. Gong *el al*, J. Appl. Phys. **85**, 7604 (1999).