Mechanisms of Decrease in Hole Concentration in Al-doped 4H-SiC by Irradiation of 200 keV Electrons

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From the temperature dependence of the hole concentration p(T) in Al-doped 4H-SiC epilayers irradiated with 4.6 MeV electrons, we reported that the density (N_{Al}) of a shallow acceptor with Ev + 0.2 eV, which is an Al atom at a Si sublattice site, was significantly reduced, while the density (N_{Deep}) of a deep acceptor with Ev + 0.35 eV was slightly decreased [1], as shown by triangles of Fig. 1. Here, Ev is the valence band maximum. In unirradiated epilayers, on the other hand, $N_{Deep} = 0.6\ N_{Al}$ in a range of N_{Al} between $8x10^{14}$ and $5x10^{16}$ cm^{-3}, as shown by open symbols of Fig. 1 [2].

Since electrons with <0.3 MeV can displace only carbon (C) atoms in SiC whereas electrons with >0.5 MeV displace all the atoms (i.e., C, Al and Si) in SiC [3], we investigate the changes of N_{Al} and N_{Deep} in a 10 um-thick Al-doped 4H-SiC epilayer by irradiation of 200 keV electrons. After the Hall-effect measurement was carried out in the epilayer irradiated with $1x10^{16}$ cm^{-2} fluence, the epilayer was irradiated with $2x10^{16}$ cm^{-2} fluence. Figure 2 shows p(T) denoted by open circles (unirradiated), solid circles (fluence: $1x10^{16}$ cm^{-2}) and solid diamonds (total fluence: $3x10^{16}$ cm^{-2}). At low temperatures, p(T) decreases with increasing fluence, whereas p(T) seems unchanged at high temperatures, indicating that by irradiation of 200 keV electrons the N_{Al} is decreased while the sum of N_{Al} and N_{Deep} is unchanged.

From the analysis of p(T), the values of N_{Al} and N_{Deep} were determined, and are shown as an open circle (unirradiated), a solid circle (fluence: $1x10^{16}$ cm^{-2}) and a solid diamond (total fluence: $3x10^{16}$ cm^{-2}) of Fig. 1. Different from the changes of N_{Al} and N_{Deep} by irradiation of 4.6 MeV electrons, N_{Al} decreases with increasing fluence of 200 keV electrons, while N_{Deep} increases. Moreover, the decrement of N_{Al} is nearly equal to the increment of N_{Deep}. Therefore, the displacement of only C atoms by irradiation of 200 keV electrons is considered to change the Al acceptor into the deep acceptor.

The changes of N_{Al} and N_{Deep} by irradiation at more fluences ($5x10^{16}$ and $7x10^{16}$ cm^{-2}) of 200 keV electrons are now investigated.

References
[1] H. Matsuura *et al.*: Appl. Phys. Lett. 83 (2003) 4981.
[2] H. Matsuura *et al.*: J. Appl. Phys. 96 (2004) 2708.
[3] H. Matsuura *et al.*: Physica B 376-377 (2006) 342.

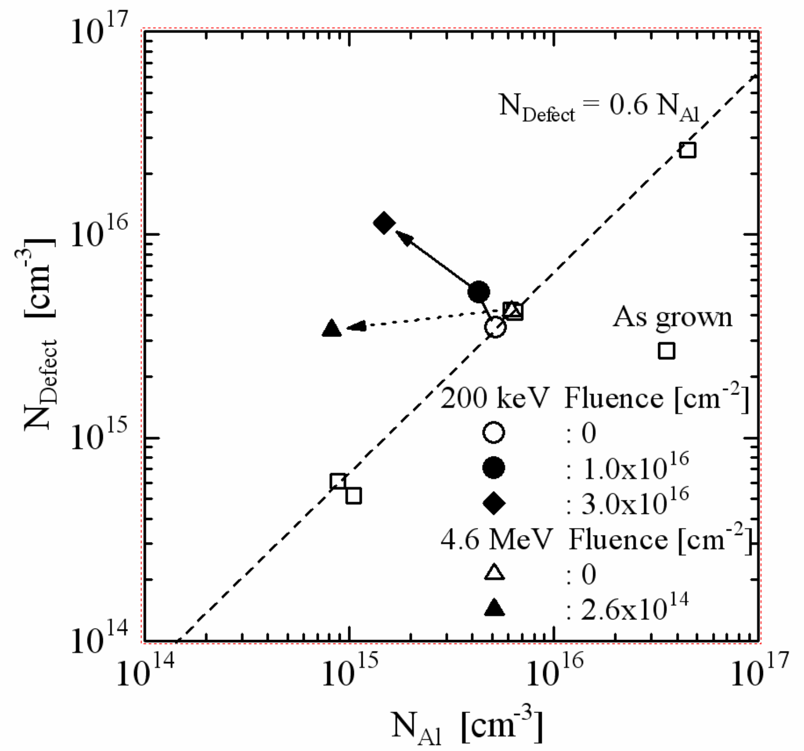

Fig. 1 Relationship between N_{Al} and N_{Deep}.

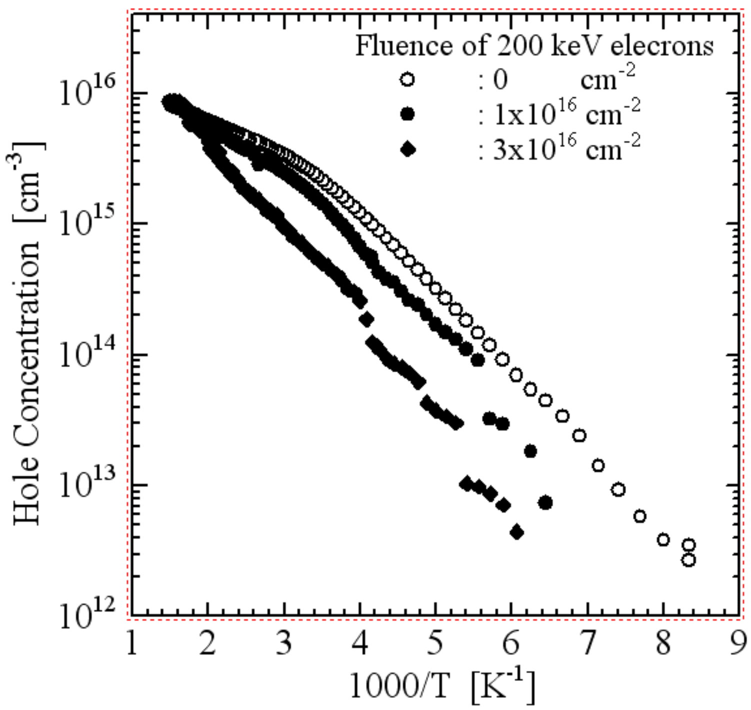

Fig. 2 Temperature dependence of hole concentration.