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§36. Study on Dynamics Radiation-induced Effects of Silicon Carbides under Hydrogen Isotope Ion Irradiations

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Silicon carbides (SiCs) are potential candidates as separators between tritium breeding and neutron multiplier materials composing Li-Pb blanket modules. Therefore, it is significantly important to understand the thermal behaviors of hydrogen isotopes (H^+, D^+, and T^+) and helium (He^+) ions retained in SiCs.

In present study, silicon carbide (CVD-SiC) materials with high purity and density, synthesized by the chemical vapor deposition technique, have been used. The depth profiles of deuterium as well as hydrogen atoms near the surface of CVD-SiC were analyzed by means of high-energy ERD, combined with RBS, using 2.8 MeV He^{2+} ion probe beams from Tandem accelerator, installed at Institute for Materials Research, Tohoku University [1]. The CVD-SiC was placed on a manipulator in contact with a tungsten-ceramics heater in a vacuum chamber evacuated to pressure of 1.3×10^{-5} Pa and heated at a temperature of 973 K using the tungsten-ceramics heater to remove small amounts of residual hydrogen. The temperature of CVD-SiC was measured with an alumel–chromel thermocouple in contact with the surface. Implantation of deuterium atoms into the specimens was made up to fluences of 1.0×10^{18} D/cm^2 with 10 keV D_2^+ ions at room temperature. The projected range of 5 keV D^+ ions to the SiC materials is approximately 75 nm [2]. Subsequently, in order to determine the decomposition temperature of H and D from as-prepared and D^+ ion-implanted CVD-SiC, the depth distribution of hydrogen and deuterium atoms, retained in the whole the CVD-SiC after isochronal annealing for 10 min at the various temperatures of 297 to 973 K, was in-situ measured in vacuum at room temperature by simultaneous high-energy ERD and RBS measurements.

Figure 1 shows typical ERD spectra of recoiled H^+ and D^+ ions from 5 keV D^+ ion-implanted CVD-SiC after annealing at each temperature of 297-973 K for 10 min, measured using 2.8 MeV He^{2+} ion probe beams. The horizontal axis (Channel Number) corresponds to several energies of recoiled H^+ and D^+ ions and represents the distance from the surface. The vertical axis (Counts) corresponds to the hydrogen and deuterium concentration. Each small and big peak near 200 and 360 channel numbers are associated with recoiled H^+ and D^+ ions from the CVD-SiC, indicating the residual hydrogen and implanted deuterium at approximately 75 nm in depth. From the ERD spectrum, measured after the implantation at the fluence of 1.0×10^{18} D/cm^2, the saturation concentration (D/SiC: D per the SiC diamond-type unit cell) of deuterium atoms trapped in the near surface of approximately 75 nm in depth for the SiC specimens was estimated to be approximately 2.2.

Figure 2 shows changes in the whole H and D concentrations in as-prepared and D^+ ion-implanted CVD-SiC after isochronal annealing at various temperatures for 10 min, obtained by normalizing the H and D concentrations at several temperatures with the initial H and D concentrations at 297 K. The D concentration in D^+ ion-implanted CVD-SiC starts to reduce at 373 K which is different from graphite and subsequently rapidly reduces at 673 K. There exist two kinds of release processes at critical temperature of 673 K. The rapid and gradual decreases of the D concentration in the CVD-SiC are caused by thermal desorption of D atoms from several sites due to Si and C atoms, respectively. The decrease of the D concentration is similar to that of the H concentration in as-prepared CVD-SiC, although the critical temperature is different (473 K). The isotope difference may depend on significantly

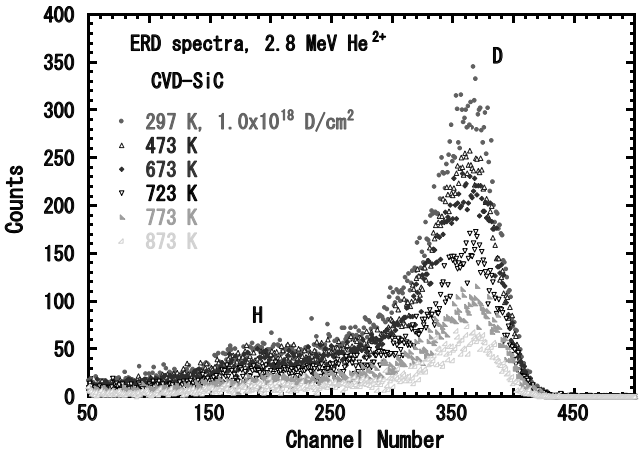

Fig. 1. Typical ERD spectra of H and D recoiled from CVD-SiC samples after isochronal annealing.

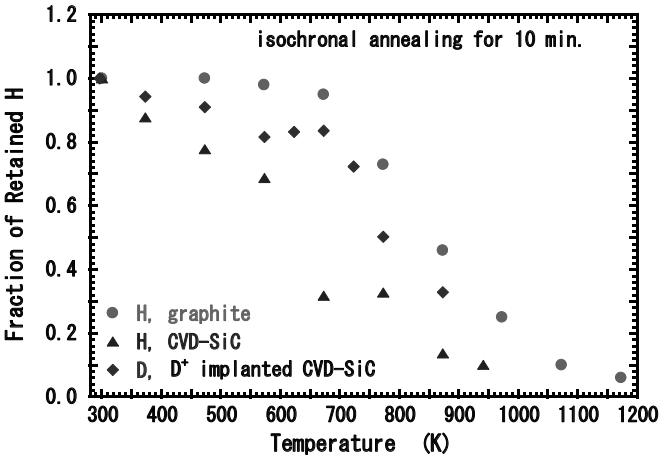

Fig. 2. Change in the retained H and D in CVD-SiC samples as a function of temperature.

1) Tsuchiya B., Nagata S., Toh K., Shikama T.: Nucl. Instr. and Meth. in Phys. Res. **B 249** (2006) 370.
2) Ziegler J.F., Biersack J.P., Littmark U.: The Stopping and Range of Ions in Solids, Pergamon Press, New York, (1985).