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セラミックス中におけるトリチウムの拡散と捕捉
Tritium diffusion and trapping in various ceramics

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Ceramics have many advantages for the usage as component materials in fusion devices. One of critical issues for the assessment of utilization of ceramics for fusion devices is the evaluation of tritium retention and its trapping characteristics. In our previous studies, the deuterium retention behaviors for SiC and SiO_2 were studied and it was found that the deuterium trapping process was quite different among these samples. However, systematic understanding for hydrogen isotope retention and trapping behaviors is not enough. The nature of bond in ceramics, which can be categorized into covalent bond and ionic bond, would be one of the key parameters for controlling the retention and desorption behaviors of hydrogen isotope in/from ceramics. In this study, the correlation between the hydrogen isotope retention and desorption behaviors and the nature of bond of ceramics was discussed.

The plate or disk types of SiC, Si_3N_4 and SiO_2 were used as samples. The sizes of plate samples were 10×10 mm and 0.5 mm thickness for Si_3N_4, and SiO_2, although that for SiC was 10 mm diameter and 0.5 mm thickness disk. The differences of electronegativity of constituent elements for SiC, Si_3N_4 and SiO_2 were 0.7, 1.2 and 1.7, respectively. These samples were preheated at 1173 K for 1 hour under vacuum with the pressure of less than 10^{-5} Pa. Then, the 0.2 keV deuterium ion (D_2^+) implantation and TDS measurement were performed to elucidate the deuterium retention and desorption behaviors. The D^+ flux and fluence were set to be 1.0×10^{17} D^+ m^{-2} s^{-1} and 1.0×10^{22} D^+ m^{-2}, respectively. The TDS measurements were carried out from room temperature to 1173 K with a heating rate of 0.5 K s^{-1}. In addition, the chemical states of constituent atoms before and after D_2^+ implantation were evaluated by XPS to clarify the deuterium trapping characteristics.

Figure shows D_2 TDS spectra for the D_2^+ implanted SiC, Si_3N_4 and SiO_2 samples. These TDS specta consisted of four desorption stages at 450 K, 650 K, 800 K and 1000 K, attributing to the desoprtion of deuterium trapped on surface, retained in the interstitial site, trapped as Si-D bond and trapped as C/N/O-bonds, respectively. The deuterium retentions by surface adsorption and Si-D bond were increased in the orders of $SiO_2>Si_3N_4>SiC$ and $SiC>Si_3N_4>SiO_2$, respectively, showing that the retention of deuterium bound to Si as Si-D bond was increased with the increase of covalent characteristics of the ceramics. The XPS analyses showed that the positive peak shift of Si-2p was observed for SiC after deuterium implantation, indicating the formation of Si-D bond for covalent ceramics. However, the amount of deuterium adsorbed on the surface was opposite trend, leading to the ionic characteristics would control the deuterium adsorption. It can be said that electrostatic interaction with deuterium on the surface would have a large contribution on the amount of deuterium adsorbed on the surface and the adsorption on the surface would be major trapping site of hydrogen isotope for the ionic ceramics.
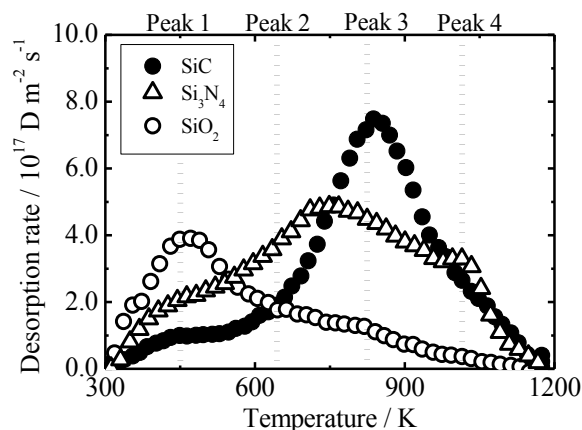

Fig. TDS spectra for each D_2^+ implanted ceramics