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Analysis of Boron-Hydrogen Interactions and Deuterium Retention for Fusion Applications

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Plasma-facing component boronization reduces the impurities coming from the walls of the tokamak and improves the performance of plasma experiments. Understanding how boron interacts with fusion fuels (deuterium and tritium) is important for nuclear safety and plasma detachment requirements, given the radioactivity of tritium, the possible production of diborane and potential impurity effects on recycling. The present work provides new experimental data for a better understanding of the boron-hydrogen interaction.

An amorphous boron sample (99.9 wt.% purity) was exposed to a beam of deuterium ions (D2+) with 250 eV/D at room temperature. Deuterium retention was evaluated using temperature-programmed desorption (TPD) with a temperature ramp of 1 K/s and a maximum temperature of 1350 K. The TPD spectra were measured for various deuterium-containing molecules, including possible products of diborane ionization. The sample surface composition was additionally characterized by X-ray photoelectron spectroscopy (XPS).

Implanted deuterium ions desorb mainly as D2 and HD (73% of D) and partly as D2O and HDO (27% of D). Given the line-of-sight geometry of our TPD setup, the branching ratio for diborane products was estimated to be 0.04% relative to the main products of desorption. We conclude the absence of diborane production under the present experimental conditions.

TPD measurements show two desorption components. The first one is a low-temperature broad peak (400-600 K), similar to previous observations on boron polycrystals [1]. The second component appears at a much higher temperature (>1220 K). It is narrower, has a higher intensity and interestingly, the position of its maximum depends on the absolute amount of deuterium retained.

XPS measurements were performed after heating the sample to 1023 K to remove most of the impurities, after irradiation by the 250 eV/D ions at room temperature, and again after heating to 1023 K to remove deuterium. The B1s and O1s peaks show identical behaviour: D2 irradiation shifted energy levels by 1.2 eV towards higher binding energy. Heating the sample after irradiation shifted back the peak energy by 0.4 eV towards lower binding energy, likely due to the remaining presence of deuterium in the sample given the high-temperature desorption peak of ~1200 K.

[1] Y. Oya et al., J. Nucl. Mater. 329–333, 870–873 (2004)