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Deuterium Retention of Boron Powder from Deuterium Gas or Ion Exposure to Estimate Tritium Inventory in Advanced Fusion Reactors

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We report retention of deuterium (D), as a proxy of tritium (T), from D_2 neutral gas and D^+ ion exposures on commercial boron (B) powder, as a proxy of B dust potentially formed in fusion reactors. D removal behavior from B powder is reported to estimate a potential T inventory in B dust in advanced fusion reactors, ITER, SPARC, etc., which plan to employ B wall conditioning, either by glow discharge boronization [1] or B powder injection [2]. B wall conditioning forms surface coatings of chemical compounds on tungsten (W) plasma-facing components (PFCs), thus suppressing plasma contamination by impurities such as oxygen, carbon, and tungsten. However, B-based slag/dust particle formation is expected, as reported for carbon-based dust formation in fusion devices [3]. Although such B dust particles can retain hydrogen species and thus cause a tritium (T) inventory issue, there are no reports on hydrogen isotope retention of B dust for hydrogen neutral gas or hydrogen ion exposures. The talk will discuss the implications on total T inventory in fusion reactors and T removal scenarios based on research results.

In this work, we investigated D retention of commercially available B powder (BeanTown, -325 mesh) in an upgraded ultrahigh vacuum chamber, Sample Exposure Station (SES) [4]. Elemental composition analysis on the B powder by energy dispersive spectroscopy and X-ray photoelectron spectroscopy characterized the oxidation level of the powder surface. Scanning electron microscopy characterized the shape and size of the powder. The B powder was exposed to D_2 neutral gas (gas temperature of 300 K) or D^+ ions (incident energy of 170-530 eV), and analyzed by temperature programmed desorption to quantify the D retention and desorption temperature. The D exposure configurations varied for the B powder temperature up to 760 K, B powder surface oxidation level, D_2 gas pressure up to 5 mTorr, D_2 exposure time up to 40 minutes, or D^+ ion fluence up to 1×10^{18} D cm^{-2}.

A strong D_2 desorption peak at 700 K, corresponding to B-D bonding [5], was observed for all D exposure cases. For D_2 gas exposures, the D retention was significantly enhanced when the B powder temperature was 500-550 K. B powder bakeout under vacuum at 600 K for several hours after D_2 exposure exhibited D removal. On the contrary, the B powder bakeout at 420 K did not contribute to removing D even after one day. However, we found that D removal was enhanced under backfilled H_2 or O_2 gas at 5×10^{-5} Torr, even for 420 K bakeout.

D retention yields were also determined for D^+ ion exposure on the B powder. A maximum threefold D retention yield enhancement was observed for D^+ ion exposure when the surface oxygen level decreased, which agrees with a previous report [5].

References

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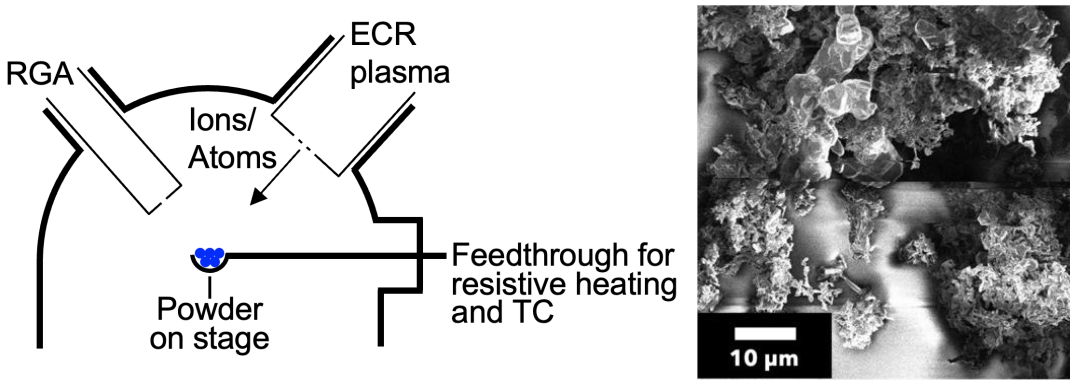

Figure 1. Schematic of the SES chamber, upgraded to investigate D retention in powder samples (left), and SEM image of the B powder used for this research (right).