Ammonia production and sticking on materials relevant to fusion reactors: tungsten and 316L stainless steel

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Harnessing nuclear fusion's power is the goal of the ITER tokamak, an experimental project involving 35 nations. In the tokamak design, a magnetically confined plasma of hydrogen isotopes (deuterium and radioactive tritium) is heated to millions of Kelvin. During high-power operations in ITER, it will be necessary to seed impurities into the edge of the fusion plasma to dissipate part of the plasma exhaust power through radiation and maintain the power fluxes to the plasma-facing components within tolerable limits. Nitrogen (N) is one of the leading impurity candidates. Ammonia production has, however, been observed in the all-metal ASDEX-Upgrade and JET tokamaks during N-seeded plasma [1, 2]. The formation of large quantities of tritiated ammonia has consequences for several aspects of the ITER plant operation in terms of tritium retention, gas reprocessing and duty cycle. It is currently unclear how and where ammonia formation predominantly occurs in fusion devices, which makes it difficult to predict the ammonia formation rate in ITER.

In this contribution, we address the following questions:

- What is the dominant ammonia formation mechanism and how does the formation rate depend on the surface material?

- What is the sticking probability of ammonia molecules on ITER-relevant material (tungsten and 316L stainless steel)?

Our studies are performed in an ultra-high-vacuum environment [3] using ion beam and molecular beam exposure of polycrystalline tungsten and stainless steel (SS-316L) samples. To understand the mechanism of ammonia formation, sequential implantation of N_2^+ and D_2^+ is performed and Temperature Programmed Desorption (TPD) is used to quantify HD, D_2, N_2 and ND_3 production rates. High Resolution Electron Energy Loss Spectroscopy (HREELS) is used to gain insight into surface precursors through their vibrational signatures.

On the one hand, we show that deuterated ammonia (ND_3) is produced on both metals when bulk deuterium (D) diffusion is activated. On the other, the absolute quantity of ND_3 produced is found to be strongly dependent on the sample material. This difference in ND_3 production rate is found to be related to dissimilarities in the formation process. On polycrystalline tungsten, we demonstrate that the formation mechanism involves N atoms present at the topmost layer of the surface and bulk nitrogen is unable to participate in the production of ND_3. In stark contrast, on SS-316L, N atoms naturally contained in the bulk alloy participate significantly in the formation of ND_3. Finally, measurements of the absolute sticking probabilities of ammonia molecules on tungsten and SS-316L surfaces will be presented.

References:
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