Sticking, isotopic exchange and production of ammonia on materials relevant to fusion reactors: tungsten and 316L stainless steel

M. Minissale\textsuperscript{a}, A. Dunand\textsuperscript{a}, F. Ghiorghiu\textsuperscript{a}, T. Aissou\textsuperscript{a}, T. Angot\textsuperscript{a}, G. De Temmerman\textsuperscript{b}, R. Bisson\textsuperscript{a}

\textsuperscript{a} Aix-Marseille Université, CNRS, PIIM, Marseille, France
\textsuperscript{b} ITER Organization, Route de Vinon-sur-Verdon, CS-90046, 13067 St. Paul Lez Durance Cedex, France

thierry.angot@univ-amu.fr

For high-power operations in ITER, it is foreseen to inject extrinsic impurities into the edge 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 \cite{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 sticking probability of NH\textsubscript{3} molecules on ITER-relevant material (tungsten and 316L stainless steel)?
- What is the isotope exchange efficiency of NH\textsubscript{3} molecules with deuterated surfaces?
- What is the dominant ammonia formation mechanism and how does the formation rate depend on the surface material?

Our studies are performed in ultra-high-vacuum using ion beam and molecular beam exposure of polycrystalline tungsten (W) and stainless steel (SS316L) samples. The absolute sticking probabilities of NH\textsubscript{3} molecules on W and SS316L surfaces have been measured as a function of surface temperature and NH\textsubscript{3} kinetic energy revealing a molecular adsorption on both surfaces. NH\textsubscript{3} dissociation is found to be negligible below 450 K as seen by \textit{in situ} Auger electron spectroscopy. A kinetic model is able to reproduce the evolution of sticking probabilities with NH\textsubscript{3} surface coverage and the material temperature.

The isotope exchange of NH\textsubscript{3} molecules with deuterated surfaces, forming NH\textsubscript{3-x}D\textsubscript{x} molecules, has been measured as a function of surface temperature and NH\textsubscript{3} kinetic energy. A kinetic model is being constructed to reproduce the observed production rate as a function of deuterium coverage.

To understand the mechanism of ND\textsubscript{3} formation from elements implanted in the material bulk sequential implantation of N\textsubscript{2}\textsuperscript{+} and D\textsubscript{2}\textsuperscript{+} at 300 K is performed and Temperature Programmed Desorption (TPD) is used to quantify HD, D\textsubscript{2}, N\textsubscript{2} and ND\textsubscript{3} production rates. On the one hand, we show that deuterated ammonia (ND\textsubscript{3}) is produced on both metals when bulk deuterium (D) diffusion is activated. On the other hand, the absolute quantity of ND\textsubscript{3} produced is found to be strongly dependent on the sample material. This difference in ND\textsubscript{3} production rate between W and SS316L is related to a difference of nitrogen bulk mobility.

\cite{1} D. Neuwirth et al., Plasma Phys. Control. Fusion 54, 085008 (2012)
\cite{2} M. Oberkofler et al., J. Nucl. Mater. 438, S258 (2013)