Sticking probability of ammonia on polycrystalline tungsten and 316L stainless steel

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Abstract

Ammonia production has been observed in thermonuclear fusion reactors when nitrogen is injected at the edge of fusion plasma to maintain power fluxes to plasma-facing components within tolerable limits. The international experimental reactor ITER, under construction in France, will use a deuterium-tritium mix to obtain an energy gain from the fusion plasma. **Tritium is radioactive and nuclear safety regulation imposes a stringent control of tritiated species within the reactor. It is thus necessary to understand where tritiated ammonia will stick on the reactor vessel, which is made of tungsten and stainless steel.** We exposed tungsten and 316-L stainless steel samples to a supersonic molecular beam of ammonia. Using the King & Wells method, we measured the evolution of the sticking probability with the ammonia surface coverage, the samples temperature and the ammonia kinetic energy. We observe similar sticking features on both surfaces, consistent with a non-dissociative adsorption mediated by two precursors. We derive **a generalized and separable Kisliuk model that is able to reproduce quantitatively these experiments thanks to intrinsic and extrinsic precursors having different trapping probabilities.**

ITER wall conditions

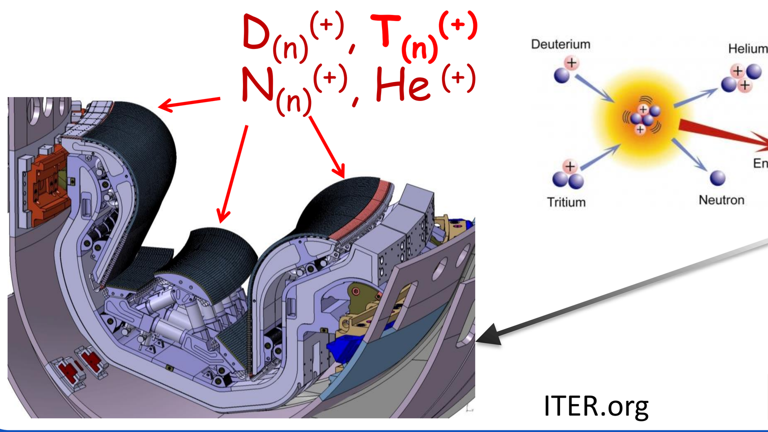
SS316L vacuum vessel (60 m²)

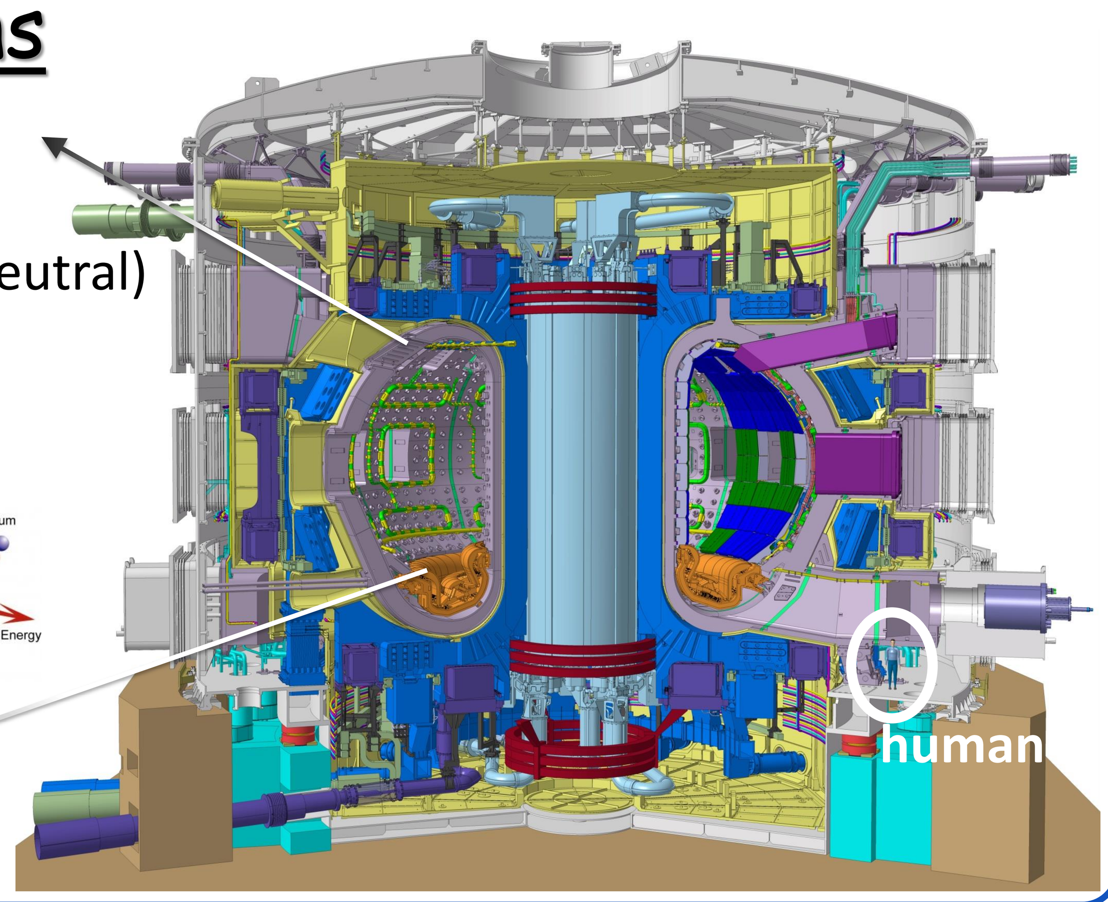
background gases (H_2, NH_3…)

+ E_k > 50 eV (charge exchange neutral)

Tungsten divertor (200 m²)

+ E_k < 50 eV (ion and neutral)



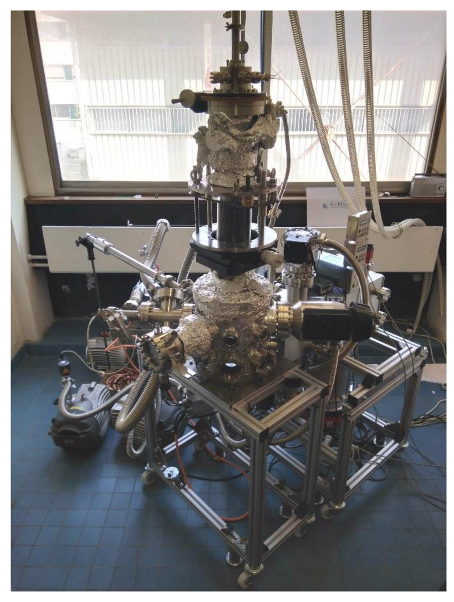


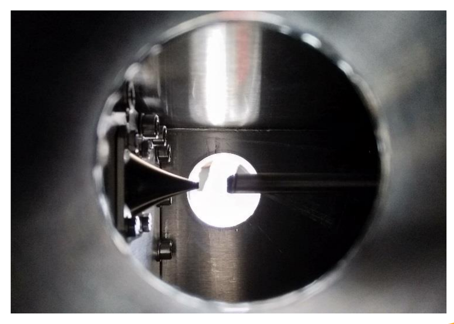
Experimental methods

- Poly-W: ALMT, 99,99%, native oxide
- 316L steel: Goodfellow, Fe > 60%, Cr 18%, Ni 10%, Mo 3%, Mn <2%, Si <1%, N <0.1%, P <0.045%, C <0.03%, S <0.03%

- W: 1000 K anneal (native oxide is left)
- SS316L: 800 K anneal (avoid sublimation)

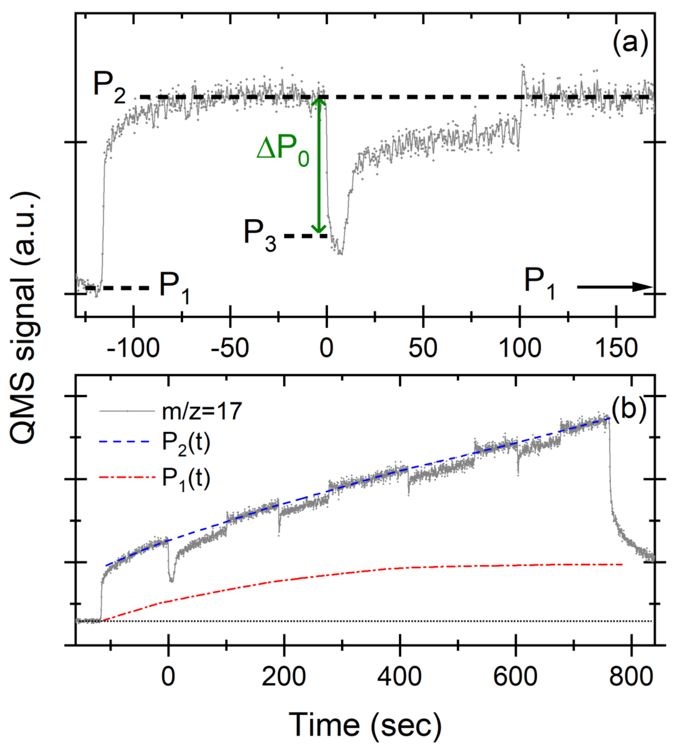
- 50 micron nozzle hole; 1,2 bar at 295 K
- 2% NH_3 in He (55 meV) or N_2 (260 meV)





King & Wells experiments

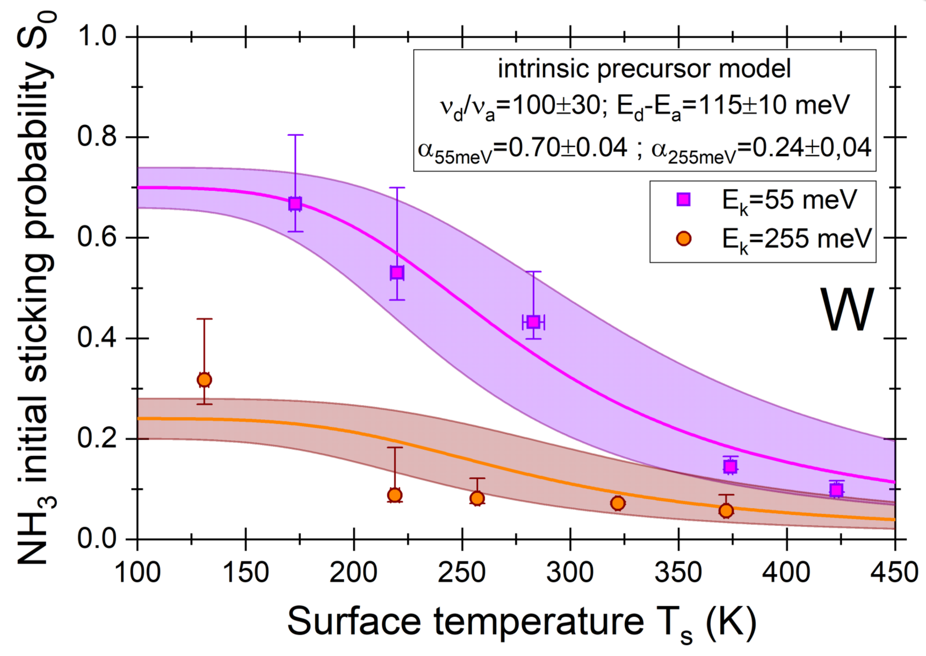
- Difficult for NH_3 because it is a sticky molecule on the vacuum chamber walls (see results on SS316L)
- Background subtraction is not straightforward, especially for surface temperature below 300 K



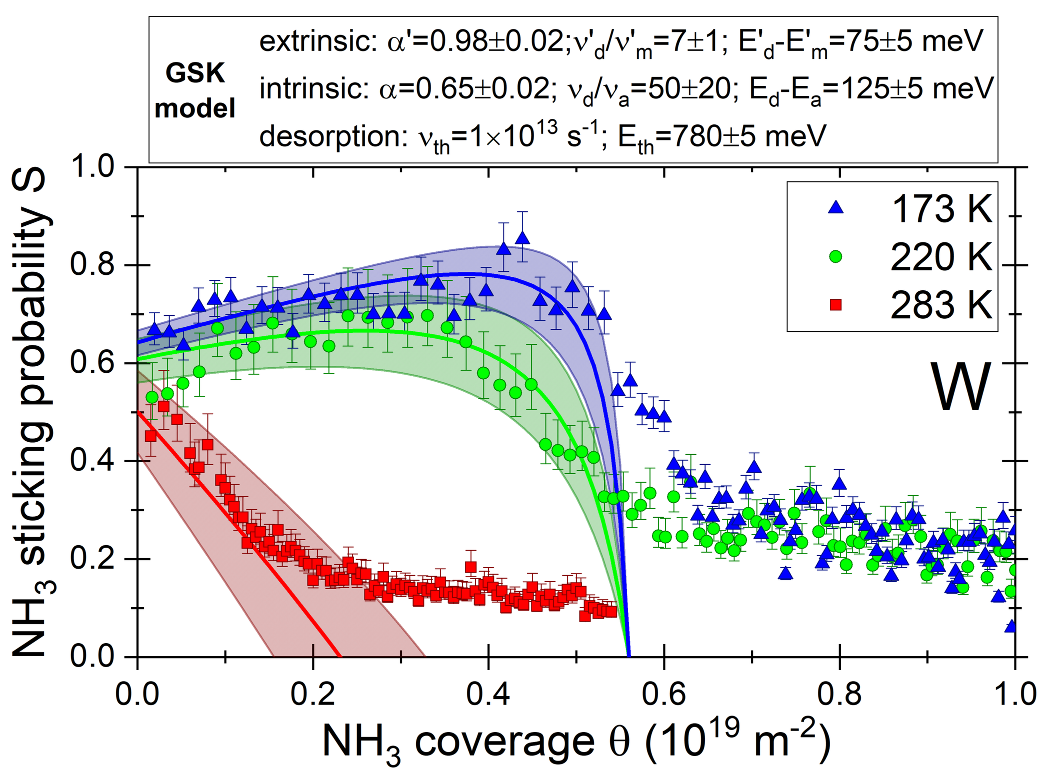
Poly-W sticking probabilities as a function of T_s

- S_0 decreases with increasing surface T_s
- S_0 decreases with increasing ammonia E_k

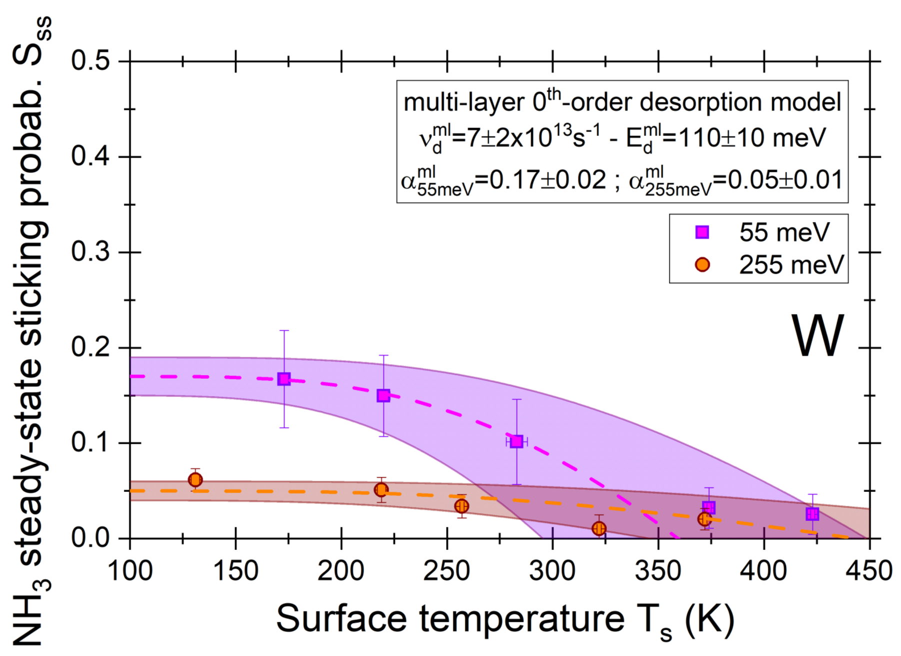
➢ Trapping-mediated chemisorption model

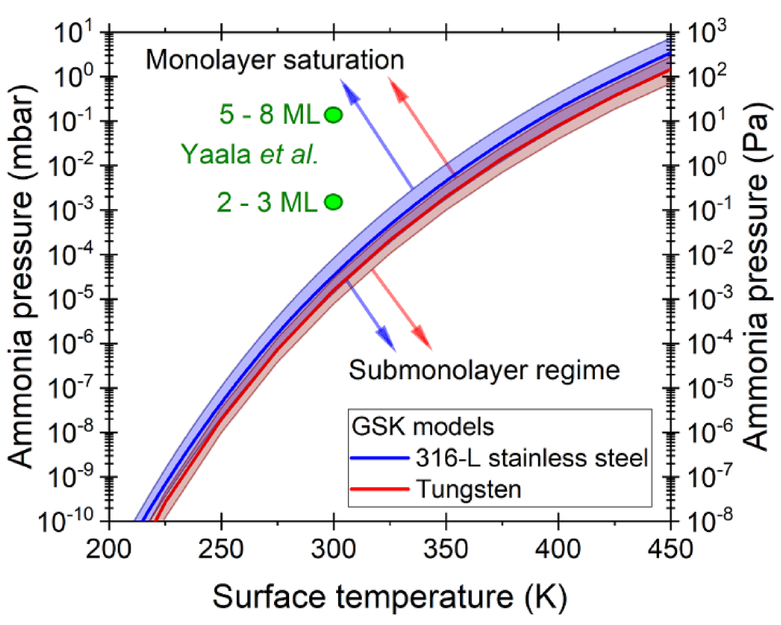


Sticking probability as a function of materials temperature and NH_3 coverage



A two precursors adsorption model & an island-based multi-layers adsorption model are able to reproduce all our sticking results and are consistent with Yaala *et al.* (Nuc. Fusion **58** (2018) 106012) experiments





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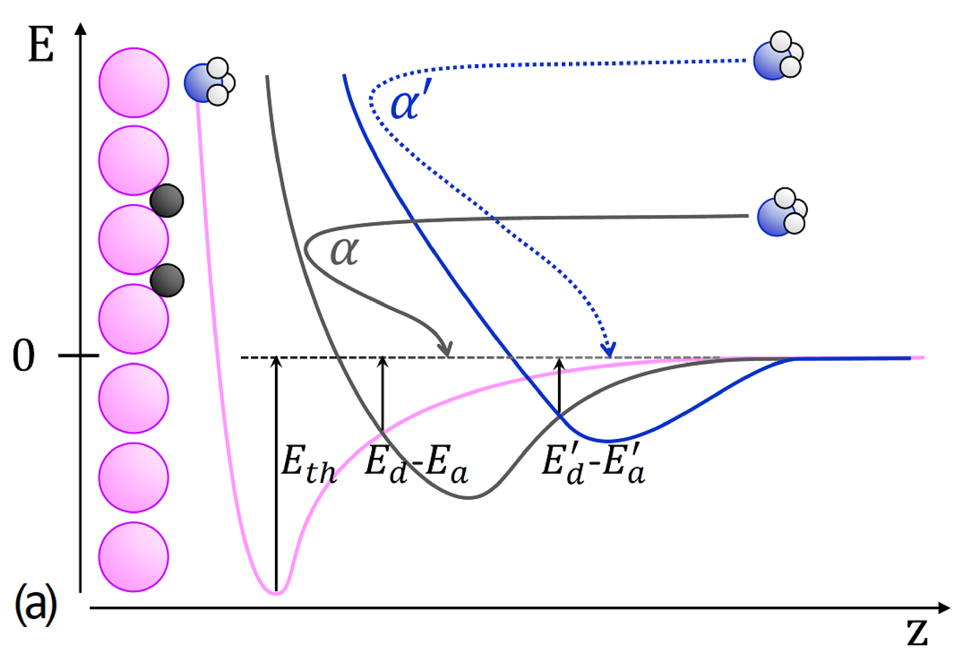
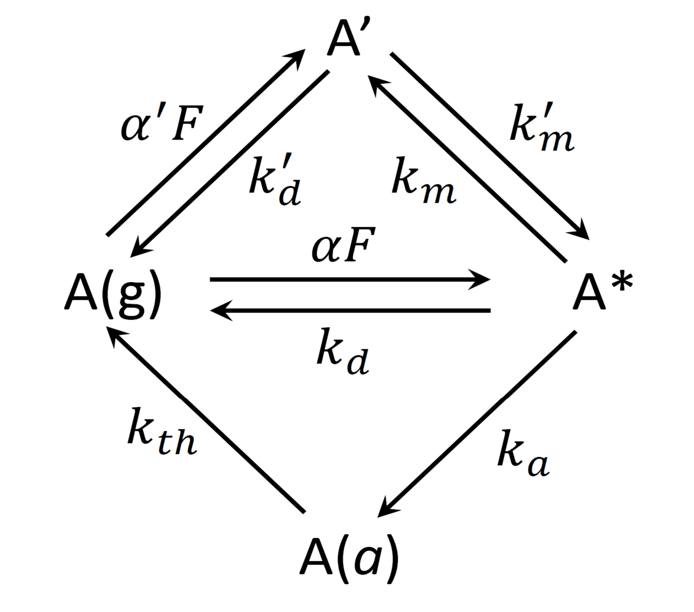
Trapping-mediated chemisorption model

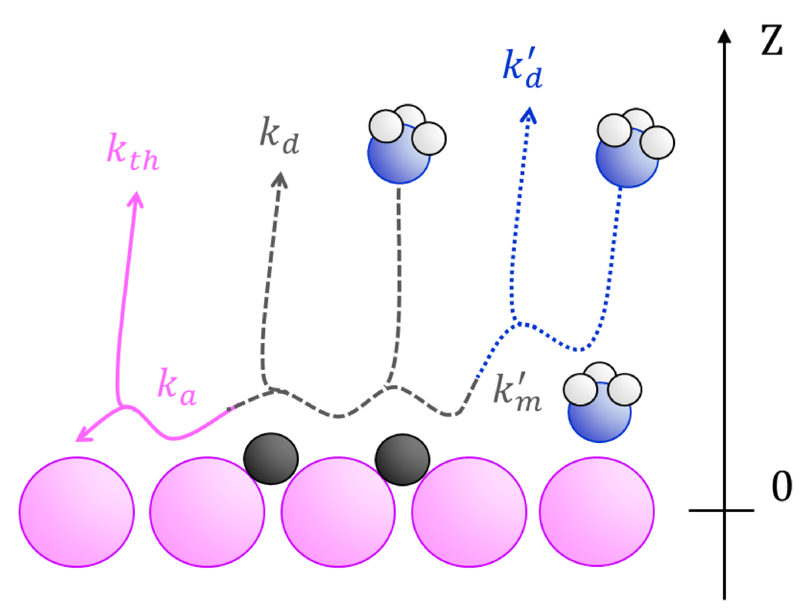




Generalized Kisliuk (GK) model

$k_m \approx 0$ → GSK model

The GSK model assumes a negligible transfer from the intrinsic precursor to the extrinsic precursor, which allows one to extract precursors kinetic parameters in a two-step analysis. The GSK analysis indicates that the trapping probability is lower on the bare surface (intrinsic precursor) than on the NH_3-covered surface (extrinsic precursor).



Conclusion

Ammonia sticking on tungsten and 316L stainless steel is non-dissociative and mediated by two precursors. Transient and steady-state surface coverage depend on NH_3 pressure and materials temperature and are described by the present models.

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