Hydrogen Interaction With Tungsten Surface

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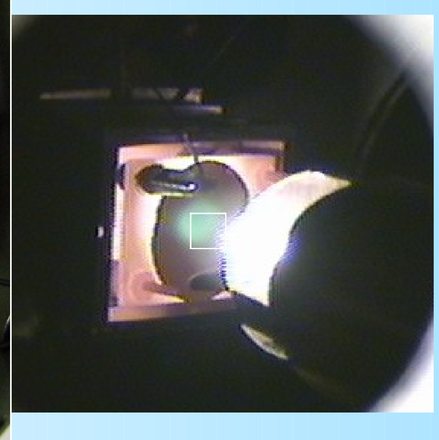
Abstract: Tungsten is the material for high heat load PFC in both current and future fusion devices, such as AUG,JET-ILW and ITER. The interaction of hydrogen with tungsten is important in order to understand the retention and recycling of hydrogen on the walls of reactor. We are studying the processes occurring on tungsten surface, which is exposed to neutral hydrogen atoms and molecules.

Introduction:

Retention in PFM is an important subject, due to the tritium problem. In the past years there were numerous studies on retention in tungsten with energetic ions up to few hundred eV, where ions directly penetrate into the bulk. Here we will concentrate on the interaction of low energy (< eV) neutral atoms and molecules with tungsten, where reactions on the surface are dominant. These kind of studies are important for modelling of the retention and TDS experiments. Namely, when atoms diffuse on the surface the molecule desorption rate is dependent on the recombination rate of two atoms on the surface. Beside this the mean ion energy in the divertor region is 15 eV [1], and these ions behave very much like low energy neural atoms, since they neutralize on the surface and their penetration depth is very small.

Experiment:

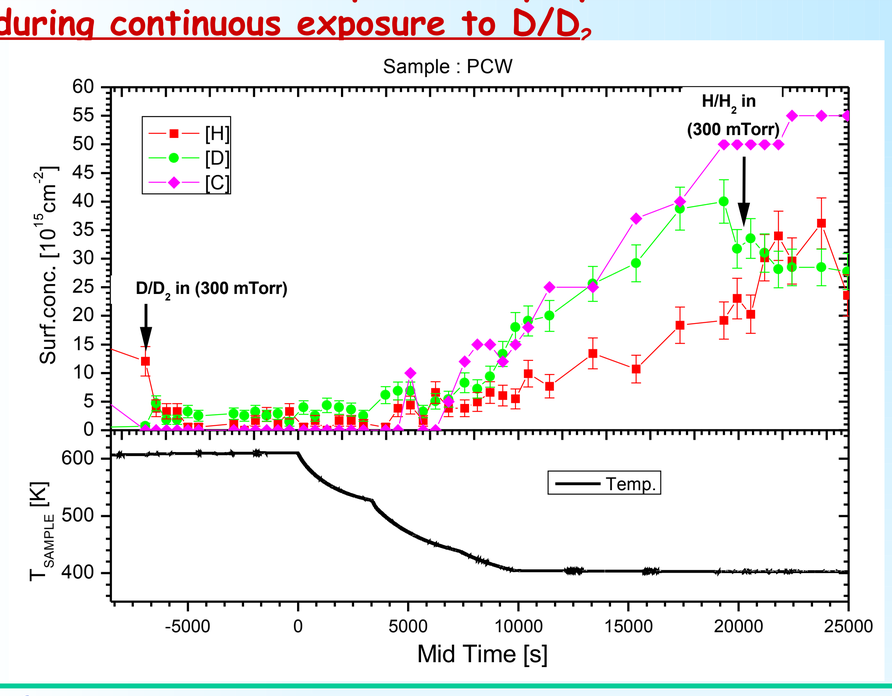
We have studied the interaction of hydrogen atoms and molecules by ion beam methods ERDA and RBS. A polycrystalline tungsten sample (Plansee - ITER grad, 99.99% purity) was exposed to hydrogen atom beam [3] and the surface was monitored by ERDA and RBS in real time. The sample was initially cleaned by hydrogen atom beam at high temperature (300°C), where it is known that atoms erode the hydrocarbon [2] and also oxygen impurities [3]. Sample was mounted on a holder whose temperature can be varied from 10°C to 400°C (second holder temp. up to 1200°C).



Atom flux density was measured by exposure of a-C:H layer [4] to atoms at elevated sample temperature (distance 79 mm, angle 24°):

- 1.6×10^{15} H s^{-1} cm^{-2} at 175 W HABS heating power,124 mTorr driving pressure – 0.038 sccm.
- 1.0×10^{15} D s^{-1} cm^{-2} at 175 W HABS heating power, 144 mTorr driving pressure – 0.03 sccm.
- These flux densities are higher than given by the manufacturer (atoms in background?).

Reverse thermodesorption study by in-situ ion beam analysis during continuous exposure to D/D_2

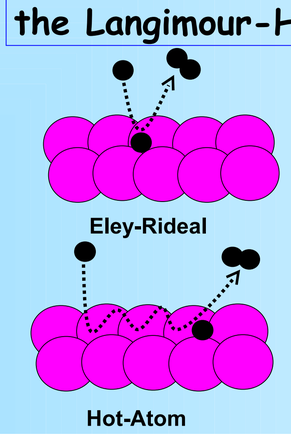


Tungsten:

The binding energy of hydrogen atom on tungsten is usually taken to be 2.9-3 eV. Still tungsten exhibits high hydrogen saturation concentration above 1 ML (1 ML - one hydrogen atom per one tungsten atom) and hydrogen atoms are adsorbed in several binding sites having different desorption energy. Polycrystalline tungsten is characterized by a mixture of the binding sites observed for the single-crystal surfaces [2].

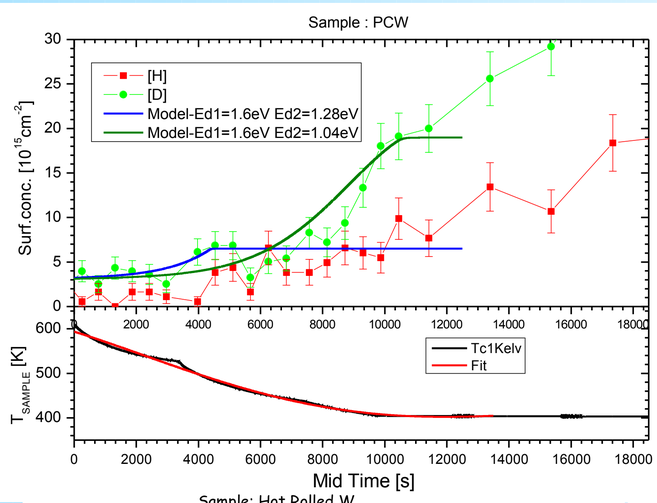
Modelling

Kinematic model developed by Jackson et al. [5] for Eley-Rideal and hot atom recombination mechanism (RM) extended by including the Langimour-Hinshelwood RM.

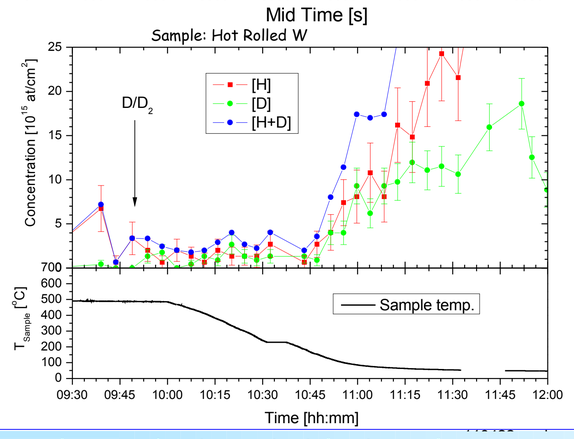


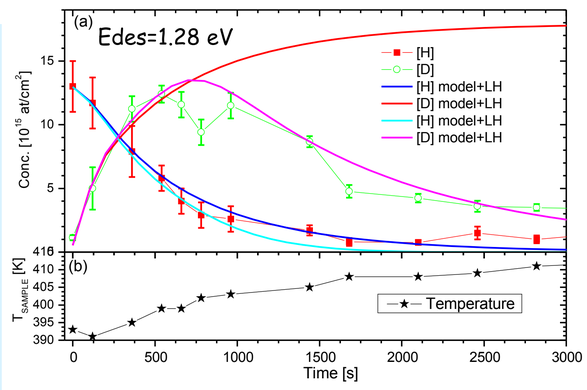
$$\frac{d[H]/N}{dt} = \frac{dx}{dt} = -\phi_x c_{xx} x(t) + \phi_x b_y y(t)(1 - P_{yx}) + \phi_x (S_x - P_{xx})(1 - P_r - c_{xx}x(t) - c_{xy}y(t) - b_y y(t)) - 2k'_d x(t)^2 - k'_d x(t) y(t)$$

$$\frac{d[D]/N}{dt} = \frac{dy}{dt} = -\phi_x c_{xy} y(t) - (1 + P_{yy} - S_y)\phi_x b_y y(t) - \phi_x P_{xy}(1 - P_r - c_{xx}x(t) - c_{xy}y(t) - b_y y(t)) - 2k'_d y(t)^2 - k'_d x(t) y(t).$$

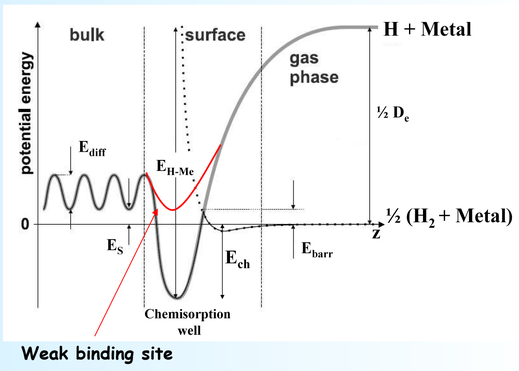


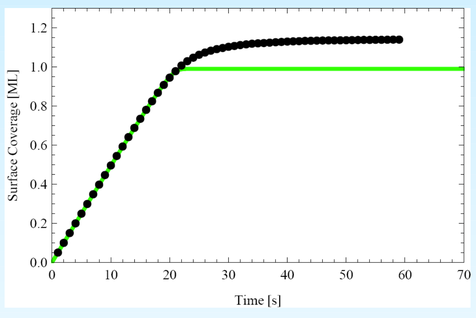
D flux 0.9×10^{15} at.cm^{-2}s^{-1}
Strongest binding state:
- Sat. Conc 3×10^{15} at/cm^2
- Edes > 1.6 eV
Middle binding state:
- Sat. Conc 3.5×10^{15} at/cm^2
- Edes=1.28 eV
Weak binding state?:
- Sat. Conc 16x1015 at/cm2
-Edes=1.04 eV

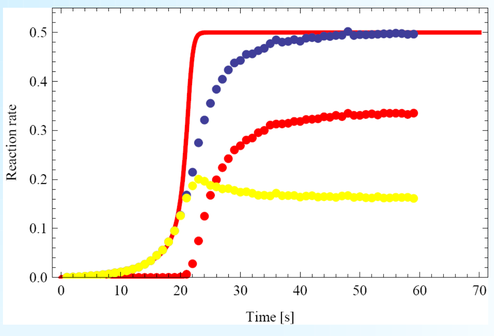




In order to obtain an insight into the recombination mechanism with more than one binding site per unit cell, a Monte-Carlo simulation was performed [6,7]. We have simulated hydrogen atom recombination with hydrogen atoms assuming two different binding sites. The weak binding sites have lower chemisorption energy (higher energy of produced molecule) and when these states become occupied the atom recombination goes mainly through these states. This leads to the increased vibrational excitation of released molecules [7].







Conclusions:

Saturation concentrations and energies of desorption energies were obtained for different binding sites on tungsten. The obtained desorption energies are in agreement with [2]. The saturation concentration for second binding site is different for PCW and hot-rolled tungsten, but similar for the first-strong binding site.

References:
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