Analytical approach for description of temperature dependence of hydrogen-metal co-deposition

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Co-deposition of hydrogen with sputtered particles is expected to be the main channel of hydrogen isotope accumulation in ITER. The hydrogen content in co-deposits depends on many factors, including the substrate temperature and energy/flux of particles coming to the deposition area [1]. The hydrogen concentration in co-deposits can be very high, up to tens of percent, even for materials with very low hydrogen solubility [1-3]. This can be explained by the presence of a high concentration of defects in the deposited films. The difference in the concentration of defects and their binding energies along with the difference in the hydrogen diffusivity can give different temperature dependencies of hydrogen concentration. This was demonstrated in experiments studying the co-deposition of D with W, Al, and Mo in [2,3]. Different stepwise temperature dependencies measured through 25 K intervals were observed in a wide temperature range from RT to 800 K.

A one-dimensional model of hydrogen diffusion in presence of several types of defects co-existing during co-deposition was developed in [2,3]. Assuming the zero concentration of mobile particles on the surface (that an infinite recombination rate) and local equilibrium between mobile and trapped hydrogen, a simple analytical formula was obtained for the temperature dependence of the H content in co-deposits, which fitted well experimental data from [2,3].

In this work, we extend this approach by taking into account the finite rate of the movement of the interface between the film and vacuum due to film growth. With the assumption that the mobile D concentration is much smaller than the concentration of available traps, an analytical formula for D content has been obtained. This new formula is compared with the experimental data on D co-deposition with Be from [1], including the temperature dependence and the dependence on the incident flux and energy of D particles.