The effect of grain size on the transport of deuterium in tungsten

Matic Pečovnik[1], Sabina Markelj[1], Anže Založnik[1] and Thomas Schwarz-Selinger[2]

[1] *Jozef Stefan Institute, Jamova cesta 39, 1000 Ljubljana, Slovenia*
[2]*Max-Planck-Institut für Plasmaphysik, Boltzmannstrasse 2, D-85748 Garching, Germany*

In this work we studied the effect of grain size on retention and transport of deuterium in tungsten. Tungsten consists of grains with distinct crystal structure that are separated by grain boundaries. These grain boundaries can act as weak trapping sites for hydrogen isotopes and also act as a faster way for deuterium diffusion into the bulk of the material [1]. From the results of this study we can extrapolate the influence of grain size on tritium retention and transport in the walls of future fusion reactors made of tungsten.

We carried out the experiment on three polycrystalline samples of tungsten that have different average grain sizes and a monocrystalline sample with surface orientation (100). In tungsten, native defects in the crystal mesh are present which act as strong trapping sites for hydrogen isotopes. Additional defects are created when the material is bombarded by particles from the hydrogen plasma and by neutron bombardment. In experiments samples were bombarded by high energy W ions as a substitute for neutron bombardment. We have structurally damaged the tungsten samples by irradiation with 20 MeV W^{6+} ions [2], creating defects to a depth of $2.3\,\mu$m. These samples with different grain sizes were then exposed to a flux of deuterium atoms at a temperature of 600 K for 70 hours. During the exposure we monitored the amount of retained deuterium in the material and its depth profile using Nuclear Reaction Analysis (NRA) by ^{3}He ion beam, explicitly using the reaction $D(^3He,p)\alpha$. The samples were also analysed with Thermal Desorption Spectroscopy (TDS), which provided us with the energies and densities of the hydrogen traps in the material.

The time dependence of retention of deuterium, which we acquired with the *in situ* NRA measurement, clearly shows a dependence on grain size in damaged tungsten, while the TDS spectra show no difference between different tungsten samples. This gives our method of exposure to atomic hydrogen and *in situ* NRA analysis a significant place in the research field of hydrogen transport in materials. Our experimental set-up also allows the quantification of the acquired experimental data.

We have described the complex process of hydrogen transport in tungsten, where grain boundaries play a significant role, on the macroscopic level by changing the height of the potential barrier for entrance of deuterium atoms into the bulk. For this purpose, we used the model within the TESSIM code [3]. As it turns out, we could describe the transport of deuterium in the bulk of the tungsten by reducing the potential barrier for samples with smaller grain sizes. Meanwhile the barrier for samples with large grain size approaches the value for the damaged single crystal sample.

[1] T. Oda, Fusion Engineering and Design **112**, 102-116 (2016).
[2] T. Schwarz-Selinger, Nuclear Materials and Energy **0**, 1-6 (2017).
[3] K. Schmid *et al.*, Journal of Nuclear Materials **426**, 247-253 (2011).