Deuterium interaction with helium induced defects in Tungsten and in RAFM steel

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Helium is a product of DT-fusion reaction and will be a natural impurity in DT plasma in future fusion devices. The accumulation of He in the surface layer of plasma facing components (PFCs) can drastically change the surface morphology and influence hydrogen isotope transport into the bulk of PFCs [1]. Tungsten is one of most attractive materials for PFCs in fusion devices. Reduced-activation ferritic/martensitic (RAFM) steels are considered as a structural material, but there some proposals to use it as plasma facing material in some parts of the wall [2].

In this work, we investigate D trapping in He pre-irradiated W and EUROFER using thermal desorption spectroscopy (TDS). All ion irradiations and TDS measurements have been performed in the UHV setup MEDION with two beam lines for He^+ and D_3^+ implantation. The energy of He ions was 3 keV, and the energy of D_3^+ ions was 2 keV (670eV/D). Helium pre-irradiation was done at RT with the fluence in the range of 10^{19}-10^{22} He/m^2. The results of measuring the TDS of deuterium demonstrated the effect of a sharp decrease in the efficiency of retention of deuterium ions into the surface layer of W and Eurofer when the limiting saturation of ion-implanted helium is reached. It was shown that He irradiation at a low fluence (10^{19}-10^{20} He/m^2) produces a high concentration of trapping sites, which increase the D trapping efficiency in W and EUROFER.

We also estimated the de-trapping energy for W, which made it possible to determine the kinds of traps. TMAP 7 modelling for determination of de-trapping energies was shown that the increase of the He fluence leads to growth of the V_nH_m complexes and the increase of the D de-trapping energy from 1.16-1.48 eV at 10^{19} He/m^2 up to 2.08-2.27 eV at 10^{21} He/m^2. Presence of He in defects leads to decrease of the D de-trapping energy. The highest energies were attributed to non-overfilled vacancy clusters and bubbles. At the highest He fluences (above 10^{21} He/m^2), the D retention drastically dropped down, that was attributed to nearly full occupation of all trapping centers by He atoms [3].

An additional series of experiments was performed with fuzz. The presence of nanostructured ‘fuzz’ on the surface of tungsten affects the reduction of the reflection coefficient, thereby increasing the deuterium flux penetrating into the tungsten and providing the trapping sites for D (D trapping by He bubbles). Both factors lead to an increase in the D accumulation at low fluences. On the other hand, open porosity, which provides enhanced desorption of D from the sample, together with the strain field induced by He bubbles, which interrupt the D diffusion towards to the bulk, lead to a decrease in the D accumulation. Removal of the W ‘fuzz’ is accompanied by a decrease in the He concentration which, in turn, leads to an increase in the D retention due to healing of open porosity and providing trapping sites for D which were previously occupied by helium atoms [4].

[1] Y. Ueda et al., J. Nucl. Mater., 442 (2013) S267.

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[4] O.V. Ogorodnikova, et. al, J. Nucl. Mater. 548 (2021) 152873.