Deuterium retention in TiC and TaC doped tungsten at high temperatures

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Tungsten is proposed for use as a plasma facing-material in the divertor region in ITER and future fusion devices. However, the use of pure tungsten is problematic due to its poor thermo-mechanical properties. Toughened, fine-grained, recrystallized (TFGR) tungsten-based materials doped either with 1.1 wt.% titanium carbide (W-1.1TiC) or 3.3 wt.% tantalum carbide (W-3.3TaC) are promising for use as plasma-facing or structural materials because of their improved ductility at low temperatures, high resistance against radiation damages, and good resistance to crack formation [1]. However, these materials have shown a tendency to retain higher amounts of deuterium than pure as-received W [2, 3]. As the divertor plates in fusion reactors will be operated at high temperatures, detailed investigation of deuterium behavior in these materials at high temperatures is of great importance.

In the first series of experiments, the samples made of W-1.1TiC, W-3.3TaC, and pure as-received W were irradiated by deuterium ions (mainly D_3^+) with a mean energy of 38 eV/D extracted from an electron-cyclotron resonance plasma in the PlaQ installation at a temperature of 800 K to the fluences of 1×10^{24} D/m^2–1.8×10^{25} D/m^2. In the second series of experiments, the samples were exposed to D_2 gas at a pressure of 100 kPa at 800 K, 873 K, and 963 K for 24 hours. The deuterium inventory in the samples was studied by means of nuclear reaction analysis (using the D(^{3}He,p)α reaction) and thermal desorption spectroscopy.

It was found that in the case of irradiation at 800 K deuterium retention in W-3.3TaC was comparable to that in pure as-received W, while in W-1.1TiC it was several times higher. Deuterium depth distributions in the samples indicated several times higher bulk concentration of retained deuterium in W-1.1TiC than that in W-3.3TaC and in as-received W. Such significant difference in hydrogen behavior between W-1.1TiC and W-3.3TaC was not observed in the case of irradiation at lower temperatures [2, 3]. The TDS spectra from the samples consisted of a single broad peak with maxima at T > 950 K. A shift of the peak position towards higher temperatures and its broadening with increasing fluence were observed.

In the case of exposure of the samples to D_2 gas, at all used temperatures the bulk deuterium concentration in W-1.1TiC was more than one order of magnitude higher than that in W-3.3TaC and pure tungsten. The highest deuterium bulk concentration in W-1.1TiC was observed in the case of exposure at 800 K and was about an order of magnitude higher than that after irradiation at 800 K. These observations may indicate that at high temperatures deuterium diffusion and trapping inside the carbide precipitates becomes essential.

[1] H. Kurishita et al., Material. Trans. **54** (2013) 456
[2] M. Zibrov et al., Phys. Scr. (2014), in press (Proceedings of PFMC14)
[3] M. Oya et al., Phys. Scr. (2014), in press (Proceedings of PFMC14)