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Fuel Retention and Erosion of Metallic Plasma-Facing Materials under the Influence of Plasma Impurities

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The fuel retention and the lifetime of plasma-facing components are critical factors potentially limiting the availability of a magnetic fusion reactor. It is necessary to test how plasma-facing materials perform with respect to hydrogen retention and erosion under the realistic mixed species plasma conditions including impurities like helium and argon. This contribution summarizes the experimental studies on the linear plasma devices PSI-2, Magnum-PSI and PISCES-B. Both plasma-facing materials foreseeing for ITER, tungsten and beryllium, were investigated. Aluminium was tested as a potential surrogate for toxic beryllium for plasma-material interaction studies. The fraction of helium or argon added to deuterium plasma was in a range of ˜1-10%. Typical exposure parameters were an electron density of ˜10ˆ18-10ˆ19 mˆ-3 for PSI-2 and PISCES-B and ˜10ˆ19-10ˆ20 mˆ-3 for Magnum-PSI, an electron temperature of ˜10 eV, an ion flux to the target of ˜10ˆ22-10ˆ23 mˆ-2sˆ-1 for PSI-2 and PISCES-B and ˜10ˆ23-10ˆ24 mˆ-2sˆ-1 for Magnum-PSI, an incident ion energy of ˜10-100 eV and a sample temperature of 400-1000 K. In pure deuterium plasmas the deuterium retention was higher at the lower flux for sample temperatures of 530 and 630 K. At 870 K, the deuterium retention was found to be higher at the high flux. Blisters of about 40 – 50 nm size were formed in the high flux exposures, while no blistering was observed at the low flux. The influence of helium and argon on the deuterium retention in tungsten was investigated in PSI-2. For a sample temperature of 380 K and a fluence of 10ˆ26 mˆ-2, the retention dropped by a factor of three to 1x10ˆ20 mˆ-2 when 5% helium was added to deuterium plasma. The addition of argon did not significantly affect the total deuterium retention. A comparison of beryllium and aluminium with respect to the deuterium retention and erosion properties was performed in PISCES-B and PSI-2. In general, aluminium exhibited similar phenomena to beryllium with respect to the evolution of the surface morphology and sputtering when exposed to deuterium and mixed deuterium-argon and deuterium-helium plasmas. However, the TDS characteristics of the aluminium targets indicated different deuterium retention mechanisms than in beryllium.

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