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Smart tungsten alloys as first wall material for a future fusion power plant

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Due to its low sputtering yield, excellent thermal conductivity and low tritium uptake tungsten is currently deemed as most promising plasma facing material (PFM) for future power plant DEMO. However, in case of an accident the coolant supply may be damaged. The air can get into contact with PFMs during the air ingress. According to modeling, the temperature of PFMs can rise up to 1200oC due to nuclear decay heat. At this temperature neutron-activated tungsten forms the volatile radioactive oxide which can be mobilized into the atmosphere. Therefore, oxidation of tungsten must be avoided.
Self-passivating "smart"alloys are being developed to suppress tungsten oxidation. Smart alloys can adjust their properties to the environment. During plasma operation the preferential sputtering of lighter alloying elements will leave a pure tungsten surface facing the plasma. During an accident the alloying elements in the bulk are forming stable oxides thus protecting tungsten from mobilization.
The isothermal oxidation of thin film alloys produced by magnetron sputtering was carried out at 1000C in the atmosphere containing 80 at.% of Ar and 20% of O2. Oxidation resulted in the dramatic 6.4×106 fold reduction of the oxidation rate as compared to that of pure tungsten.
Manufacture of bulk materials based on experience gained from the thin films is crucial. Bulk W-Cr-Ti samples were produced at CEIT (Spain) from mechanically alloyed powders treated by hot isostatic pressing at 1200C at the pressure of 150 MPa.
Smart alloys and pure tungsten samples were exposed to the steady-state deuterium plasma under identical conditions in the linear plasma device PSI 2 at FZJ. The temperature of the samples was ˜700C, the energy of impinging ions was 210 eV matching well the conditions expected at the first wall of DEMO. The total fluence was 1.3×1026 ion/m2. Weight loss measurements demonstrated similar mass decrease of smart alloys and of pure tungsten samples after exposure implying that the sputtering rate of smart alloy is mostly defined by sputtering of its tungsten matrix. Investigations confirmed the preferential sputtering of alloying elements leaving almost pure tungsten facing the plasma as predicted with TRYDIN code. Plasma tests are followed by the oxidation of exposed samples comprising the first complete performance test of smart alloys in DEMO-relevant conditions.

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