Protecting B_4C coating for ITER divertor tiles. Deposition, operation, removal of erosion products

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Summary

Recent investigations revealed a number of problems of tungsten application in ITER. It was shown [1] that in situ renewable protecting crystalline boron carbide(B_4C) coating can protect tungsten tiles from plasma irradiation, and by this means prevent tungsten redeposited films and dust formation and tritium accumulation. Non-toxic, non-explosive, and non-hazardous carborane ($C_2B_{10}H_{12}$) was used as the initial substance for (B_4C) coating deposition.

The paper presents the new device constructed for B_4C coating deposition in ITER relevant conditions and for testing of materials and coatings, first results of coating deposition and of thermal cycling of deposited layers of B_4C and tungsten, results of irradiation of B_4C coating deposited on MPG-8 graphite in quasi stationary plasma accelerator QSPA-T and of graphite and boron-carbon layers exposition in ozone-oxygen mixture.

In the constructed device B_4C coating is formed from boron and carbon atoms sputtered by plasma ions from corresponding targets. Deposition rate approaches several tens of microns per hour. The materials and coatings can be thermally cycled and tested under ion and electron continuous or pulse irradiation with power density up to 40 MW/m^2.

The B_4C coating on the tungsten substrate demonstrated perfect adhesion and successfully underwent thermal cycling tests in the range RT – 1100°C. Deuterium concentration in coating deposited in D_2+Ar atmosphere at 700°C was $D/(B+C)\leq 0.01$.

Tungsten layer of 200 nm was deposited on the tungsten surface and subjected to 60 thermal cycles (300-1200°C). The processes of deposited tungsten layer separation from the bulk tungsten through formation of practically continuous layer of blisters between the deposited layer and bulk tungsten was precisely investigated. It was suggested that the blisters formation was provided by the stresses appeared due to coating crystallization during thermal cycling.

B_4C coating deposited on fine grain graphite MPG-8 was subjected to QSPA-T plasma pulses with 1 GWatt/m^2 power density. The coating remained continuous and protected graphite against destruction even after 100 QSPA-T pulses.

The experiments devoted to carbon and boron-carbon layer gasification with help of ozone-oxygen mixture were made. At 10% ozone concentration and 1 bar total pressure erosion rate of 5 μm/h of a flat carbon film was measured when the film temperature was 250^{0}C.The walls and bottom of 1mm wide and 5mm deep gap eroded almost at the same rate. Erosion rate of boron-carbon layer at 6% ozone concentration at 250^{0}C decreased along with the increase of boron concentration. It was 30 nm/h for B:C=0,8:1 and dropped down to 3 nm/h for B:C=2:1.

[1] O.I.Buzhinskij, V.G.Otroschenko, D.G.Whyte et al., J. of Nucl. Mater. 313-316 (2003) 214.