Erosion behavior of boron-based nanostructured materials exposed to fusion-relevant deuterium plasma

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In tokamak fusion devices, Plasma-Wall Interaction (PWI) represents one of the main concerns for future reactors. Indeed, such phenomena lead to the erosion of Plasma Facing Components (PFCs), resulting in the transport of eroded particles into the plasma and their subsequent redeposition. These processes significantly affect plasma confinement performance, as well as the lifetime and operational reliability of PFCs [1]. Tungsten (W) has been chosen as the main material for the PFCs of ITER. To improve plasma confinement, boronisation is expected to be performed to generate a thin boron (B) layer on top of W surfaces [2]. Consequently, the study of PWI involving W and B is crucial for the development of future fusion reactors. In particular, the erosion behavior of B and B-W redeposits in recessed regions of the first-wall of ITER-like devices remains largely unexplored, thus requiring to be addressed. A promising way to do so is to expose laboratory produced materials relevant for tokamak redeposits in linear plasma devices.

The present work investigates the impact of ITER first-wall-relevant plasmas on B and B–W porous materials. Nanostructured samples with morphologies ranging from nanoparticles aggregate to tree-like were fabricated using femtosecond Pulse Laser Deposition (fs-PLD), which allowed control over films' properties, to systematically study their influence on erosion. In particular, B coatings with 5% to 50% of bulk density and B-W coatings with W concentration of $\approx 5\ at.\%$ were produced. Oxygen content was $< 5\ at.\%$ in all samples. Subsequently, the films were exposed to deuterium (D) plasma with ion fluences of $\Phi = 7.0 \cdot 10^{23} - 2.8 \cdot 10^{24}$ and energies in the range $E_{ion} = 43 - 223eV$, inside the GyM linear plasma device [3].

Before and after the exposure, the samples were weighted on a microbalance and characterized by means of Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDXS). These measurements enabled the estimation of morphology and composition evolution, eroded mass and effective sputtering yield for the exposed materials. In particular, the emergence of magnetic-field-oriented structures from compact disordered boron is observed in all samples, whereas elongated needle-like structures arise for compact boron films. This could be attributed to the deposition of molybdenum from the sample-holder mask and the formation of localized sputtering-resistant phases. Furthermore, the preferential sputtering of B in B-W samples is highlighted by tungsten enrichment up to 10 $at.\%$ after exposure. Then, comparing the behavior with E_{ion} of the effective sputtering yield for B samples with SDTrimSP data, it is found that the results for $E_{ion} > 43eV$ generally follow the model's trend within 20% for the more compact samples, while set to much lower values for the more porous ones, most probably caused by the presence of tree-like structures that suppress effective sputtering. Instead, values of effective

sputtering yield up to four times higher than the model were reached for $E_{ion} = 43eV$, likely due to ion-assisted chemical erosion at the samples exposure temperature of 550K.
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