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Deuterium retention in sputter-deposited W-B layers: Implantation and in-situ ion beam analysis during annealing

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Tungsten (W) is one of the main materials considered for Plasma Facing Components (PFC) in magnetic confinement fusion devices, due to its comparably low sputter yield and low retention of deuterium (D) and tritium (T), among other favorable properties [1]. It may be necessary to coat the W wall with boron (B) in a process known as boronization, to reduce the partial pressure of low-Z impurities like oxygen and water [2]. However, this procedure may result in the formation of W-B mixtures due to continuous redeposition steps from plasma wall interactions.
Properties such as fuel retention and oxygen gettering might differ between the W-B mixtures and W. To better understand the behavior of these materials and consequences of their presence in fusion devices, we investigated D retention in W-B films with different stoichiometries. The films were grown on silicon substrates by means of magnetron sputter deposition. Thin-films of unmixed W and B were also grown for comparison. After pre-characterization, the layers were subjected to deuterium implantation (1 keV D2+) followed by in-situ analysis. Specifically, the compositions of the films were determined with Time-of-Flight Elastic Recoil Detection Analysis (ToF-ERDA) and depth profiles were obtained in-situ by simultaneous Elastic Recoil Detection Analysis (ERDA) and Rutherford Backscattering (RBS) measurements using a primary beam of 2 MeV He+ ions.
The samples were annealed to 600°C and in-situ ion beam analysis measurements were performed on all samples before, during and after the annealing process. The concentration of B in the films led to significant differences in D retention. After annealing, the lowest amount of retained D was seen for a W-to-B ratio of 2:1, with an areal density of 8×10^{13} D/cm^2, having close to three times lower retention than unmixed W. The bare B film showed the highest retention with an areal density of around 1×10^{17} D/cm^2, after annealing to 600°C. Ex-situ analysis was performed to characterize the changes in surface structure of the films before and after implantation/annealing. Significant morphological modifications due to implantation/annealing steps were observed, such as W surface enrichment (B-rich films), and crack formation (W-rich films).

[1] V. Philipps, J. Nucl. Mater. 415 (2011)
[2] K. Schmid, T. Wauters, Nucl. Mater. Energy 41 (2024)