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Erosion of thin boron films at the linear plasma device PSI-2 during deuterium discharges: atomic and molecular spectroscopy of boron

Marc Sackers, Oleksandr Marchuk, Anne Houben, Eduard Warkentin, Marcin Rasinski, Sebastijan Brezinsek, Arkadi Kreter

Forschungszentrum Jülich GmbH, Germany

Boronization of tungsten is one of the solutions providing successful ignition of the deuterium plasma in ITER, but the erosion behavior in deuterium plasmas of thin B layers (˜100 nm thickness) requires detailed investigation. In this case, both chemical and physical sputtering significantly contribute to the erosion of the boron layers.
To address the lack of experimental data, we deposited ˜130 nm boron layer thickness onto polished tungsten samples via magnetron sputtering and exposed these to deuterium plasmas in the linear plasma device PSI-2. A reciprocating probe estimated the peak flux of deuterium ions onto the sample as 4e21 m^{-2} s^{-1}. Biasing the target to 43 V (floating), 60 V, 80 V, and 100 V allowed for controlling the impact energy of the deuterons. Complete removal of the boron layers occurred after roughly 150 s to 170 s at floating potential and 80 V bias. For partial erosion (70 s of the plasma exposure), focused ion beam/scanning electron microscopy (FIB/SEM) provided post-mortem layer thickness measurements to estimate erosion rates and compare them with theoretical data.
We used optical emission spectroscopy (OES) to monitor time-resolved physical and chemical erosion. An Acton 750 imaging spectrometer tracked physical erosion by capturing two resonant B I lines at 250 nm with a time resolution of 10 s. Simultaneously, two Littrow spectrometers observed chemical erosion by measuring the 432.8 nm BD Q-branch of the AΠ-XΣ+ system in the spectral orders m=2 and m=56 with a temporal resolution of 10 s and 60 s, respectively. Due to the strong oxygen-gettering properties of boron, a four-channel Avantes spectrometer (298 nm to 889 nm, integration time of 0.2 s) detected the prominent O I lines at 777 nm and 844 nm, with their 1/e decay times around 9 s.
Our findings demonstrate that OES is a reliable operando diagnostic for studying the erosion of thin boron layers under controlled conditions in PSI-2. During the deuterium discharges in the linear plasma device, we observed a clear transition from the deposited boron layer (˜130 nm) to the underlying polished tungsten substrate. These measurements will contribute to refining modeling predictions for the lifetime of boron coatings in ITER.