Testing high-Z refractory coatings in PISCES-A for helicon source impurity mitigation for MPEX

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Materials Plasma Exposure eXperiment (MPEX) is a steady-state linear plasma device designed to experimentally simulate fusion reactor-relevant plasma conditions to test divertor materials. The physical and technical basis for MPEX was tested on Proto-MPEX, which has demonstrated high-density (1×10^{20} m^{-3}) plasma operation at 100 kW of helicon source power [1,2]. However, during the operation of Proto-MPEX, rectified sheath-induced helicon window erosion was observed, posing a significant deposition of impurities on the downstream target surface. During the operation of the helicon plasma source, the rectified sheath voltage forms on the plasma-facing surface of the helicon window. This sheath voltage exceeds the energy threshold for sputtering (~ 1000 V) of the window material, such as silicon nitride (Si_3N_4), causing its erosion.

This work will discuss the strategies planned to mitigate impurity generation by (i) coating the window surface with a high-Z refractory coating and (ii) applying an electrostatic shield to the outer surface of the window to lower impurity generation. Our hypothesis is that (i) the high-Z refractory material will reduce window erosion due to its higher energy threshold for sputtering by deuterium ions (~ 250 eV), and (ii) application of an electrostatic shield will minimize the window erosion by reducing the rectified sheath potential (< 300 V) formed on the window surface.

The results of the measured sputtering yields of tantalum oxide (Ta_2O_5) and hafnium oxide (HfO_2) coated Si_3N_4 coupons exposed to a low-energy D-ion flux (ion fluence ~ 10^{26} m^{-2}) in PISCES-A linear plasma device under different RF bias conditions (≤ 200 $V_{RF(peak)}$) [3] will be presented. Preferential erosion of the oxygen present in the refractory coating and the effect of the plasma impurities due to poor vacuum conditions were analyzed. Surface composition analysis confirms no surface enrichment of the high-Z components after plasma exposure. The existence of plasma impurity ions and a spread in ion energies due to the applied RF bias voltage likely results in increased sputtering yields for the refractory coating.

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