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An impurity powder dropper for boron wall conditioning and a material sampling probe for conditioning evaluation in the SMART tokamak

S. Abe[1], A. Luby[1,2], F. Nespoli[1], R. Lunsford[1], J.W. Berkery[1], A. Rodriguez-Gonzalez[3], D.J. Cruz-Zabala[3], J. Salas-Suarez-Barcena[3], M. Garcia-Munoz[3], and E. Viezzer[3]
[1] Princeton Plasma Physics Laboratory, [2] Drexel University,
[3] University of Seville
e-mail (speaker): sabe@pppl.gov

We report the design and installation of an impurity powder dropper (IPD) and a sampling probe (SP) for the Small Aspect Ratio Tokamak (SMART) at the Plasma Science and Fusion Technology Laboratory of the University of Seville, Spain. SMART explores the performance of positive and negative triangularity plasmas in a low aspect plasma ratio range of $1.4 < R/a < 3$ with the major radius of $R = 0.40–0.60$ m and the minor radius of $a = 0.20–0.33$ m [1]. The IPD gravitationally delivers boron (B) powder to plasmas [2] so that SMART's stainless steel vacuum vessel walls can be coated with B to reduce the influx of intrinsic impurities from the wall (oxygen, carbon, nitrogen, and iron) in the plasma during operation, which radiate power and cool the plasmas [3], as well as gas fueling/recycling from the wall. The designed IPD will be installed at the top of the SMART vessel to inject B powder with 1-10 mg/s near the core and divertor plasmas for positive and negative triangularity operations, respectively. The B coatings from the SMART IPD will be evaluated by material analysis using the new SP and optical emission spectroscopy (OES) utilizing a broad-range spectrometer (OceanOptics, HR-6XR500-10), which will be an important input for IPD applications in current and advanced fusion reactors.

The SP introduces target substrates into the SMART vessel near the divertor plasma region of the negative triangularity operation to sample the B coating deposited on the substrate surface during IPD operations. Target substrates can be made of stainless steel, tungsten, silicon crystal, etc. The SP consists of a linear translator to introduce and retract the target substrates, gate valves to separate the SP from the SMART vessel and ambient air, a port to vent and pump down the SP, and a target-substrate mount head on an arm. The target-substrate mount head is equipped with a thermocouple thermometer to measure the substrate temperature, which affects chemical compositions and bonds of B deposition films. The SP can be detached from the SMART vessel after plasma exposures, but is still separated from ambient air using a gate valve to work as a vacuum suitcase. The SP unit containing the sampled B film will then be transferred to an argon-filled glove box to retrieve and store the sample in an argon-filled sample container, preventing contamination by ambient air. The samples will be analyzed by material analysis techniques such as X-ray photoelectron spectroscopy, focused ion beam, scanning electron microscopy, and temperature desorption spectroscopy at the University of Seville and Princeton Plasma Physics Laboratory for chemical composition and bonds, thickness, morphology, and hydrogen isotope retention [4].

References

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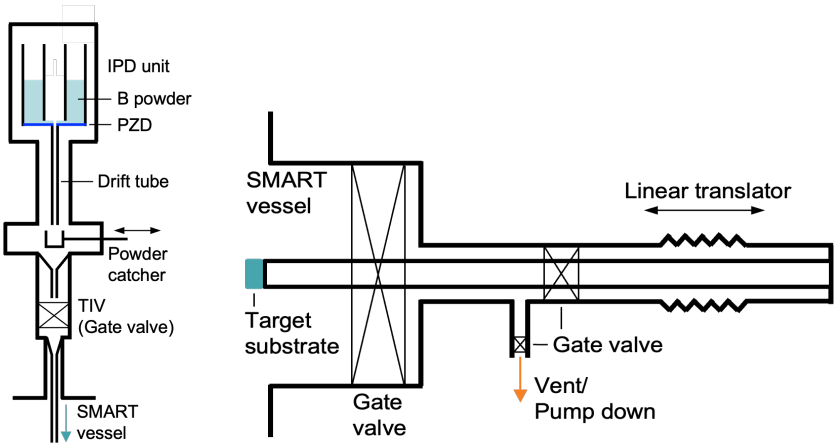

Figure 1. Schematics of the IPD (left) and SP (right) designed for the SMART tokamak. (PZD: Vibrating piezoelectric disk, TIV: Torus interface valve)