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Development of high heat and particle load test facility to study plasma-surface interactions

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I. Introduction

In order to study plasma-surface interactions (PSI) occurring in fusion boundaries and low temperature plasmas, we have constructed a laboratory experiment that can provide high heat and particle loads to a target. We adopted an Applied-Field MagnetoPlasmaDynamic (AF-MPD) thruster [1,2] as a plasma source because it is operated in continuous mode at the relatively low pressure and high input power. In addition, the AF-MPD thruster can have high exhaust speed (20 km/s) and high plasma density (10^{14} cm^{-3}).

II. Setup

Figure 1 shows a sketch of our plasma source consisting of a copper anode, a thoriated tungsten cathode, and 3 alumina insulators. A ring-shaped NdFeB permanent magnet is placed just outside the plasma source and provides an axial B-field of 0.17 T.

The plasma ignition was successfully achieved in 2018 and the plasma is now routinely obtained. Figure 2 shows a photo of the Ar plasma when the plasma current is 150 A.

To measure the heat flux generated by our plasma, we developed a heat flux sensor consisting of a 20 x 20 x 38 mm^3 copper block and a copper circular tube having a diameter of 12.7 mm.

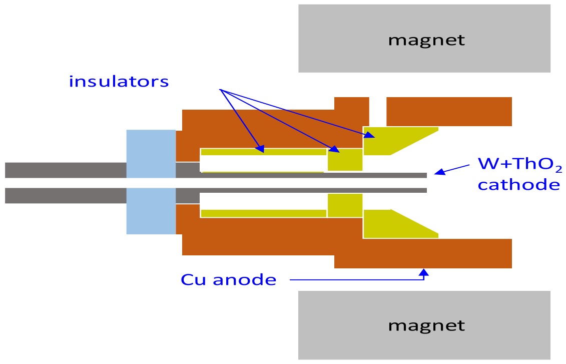

Figure 1. Sketch of our plasma source

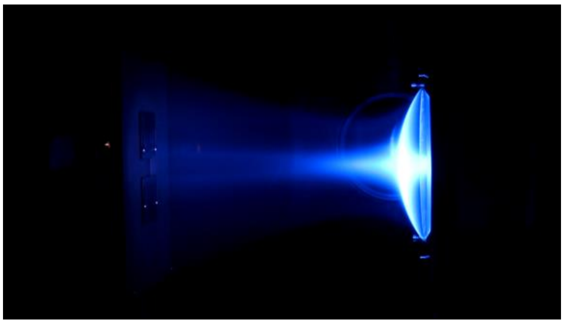

Figure 2. Photo of our plasma

III. Experiment

The heat flux provided by our plasma source is derived from the measurement using the conduction equation and the heat transfer equation. It is found that both methods give similar values (difference is less than 10%) and the measured heat flux is 4.0 MW·m^{-2} when the plasma current is 300 A [3]. The ion particle flux is measured by a Langmuir probe with a negative bias of -200 V to obtain the ion saturation current. The ion flux is then deduced from the relation $\Gamma_i = I_{is}/e/A_p$ where A_p is the probe tip area. The measured particle flux is 4×10^{22} m^{-2}·s^{-1} when the plasma current is 300 A [3]. The electron temperature and electron densities are measured by optical emission spectroscopy based on the Ar collisional-radiative model [4]. It is revealed that the electron temperature is around 2 eV while the electron density is 10^{13} cm^{-3}.

IV. Concluding remarks

We are now upgrading our experiment including optimizing the plasma source design and enhancing the strength of B-field using a solenoid coil (up to 0.4 T). After we complete the upgrade, we will study PSI under high heat and particle load conditions [5,6]. We are particularly interested in blister and fuzz formations on the tungsten surface when the high H/D/He ion fluence is introduced.

References

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