Direct Measurement of the Plasma Potential and Electron Temperature using the Ball-pen Probe in Linear Magnetized Plasma

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The direct measurement of plasma potential (ϕ_s) and electron temperature (T_e) is very important for studying the plasma turbulence driven transport quantitatively. The ball-pen probe (BPP) is an innovative method for direct measurements of the ϕ_s and the T_e in magnetized plasmas [1]. Furthermore, the BPP has many advantages in terms of simple and robust design, and the high temporal resolution of the signals. Hence, the BPP has been implemented on Plasma Assembly for Non-linear Turbulence Analysis (PANTA) device to study the turbulence dynamical characteristic.

The usual relation between the ϕ_s and the floating potential ϕ_f of a Langmuir probe is given by

$$\phi_s = \phi_f + \alpha T_e \ \ with\ \alpha = \ln(R) = \ln(I_{sat}^-/I_{sat}^+) \quad (1)$$

where $R = I_{sat}^-/I_{sat}^+$ represents the ratio between the electron and the ion saturation currents (in argon plasma $\alpha \approx 4\sim5$ [2]). The principle of the BPP is to reduce the electron saturation current I_{sat}^- until it reaches the ion saturation current I_{sat}^+ by retracting the conducting pin of the Langmuir probe inside an insulating tube perpendicular to the magnetic field line. Ideally, the ratio of the ion to electron current of the BPP should be approximately one so that the probe floats at the plasma potential.

The PANTA device has the vacuum vessel with axial length (z) of 4 m and diameter of 0.45 m. In order to generate the plasmas, 3 kW RF (7.0 MHz) power and 0.5 Pa argon gas pressure (P_{Ar}) are set as the operation conditions, and the helicon plasma is confined by a homogeneous axial magnetic field of B = 1500 G. A radially movable BPP is installed at z = 1100 mm from the plasma source, which is made of stainless-steel collector with diameters of 3.2 mm and ceramic shielding with an inner diameter of 4 mm as can be seen in Fig. 1 (a). The collector can move inside the ceramic tube for precisely step by approximately 0.01 mm resolution. In addition, the collector is a conical-shaped, which is placed perpendicular to magnetic field lines. The collector depth (h) is generally adjusted to the value of the ion Larmor radius or deeper to screen off the electron of plasmas by the ceramic shield. Figure 1(b) shows a typical BPP I-V characteristic, which is normalized to its ion saturation current I_{sat}^+. The I_{sat}^- is significantly decreased by moving the collector inside the shielding tube. Measurement of the I-V characteristic confirmed that the electron saturation current I_{sat}^- at h = -1 mm is markedly decreased approximately 3 times in comparison with the I_{sat}^- at h = 3 mm. In addition, ln(R) attains a minimum (i.e., ln(R) = 0.8), when the tip of the collector is at $h \approx$ -1.0 mm. In this situation, it is considered that the probe potential is close to the plasma potential.

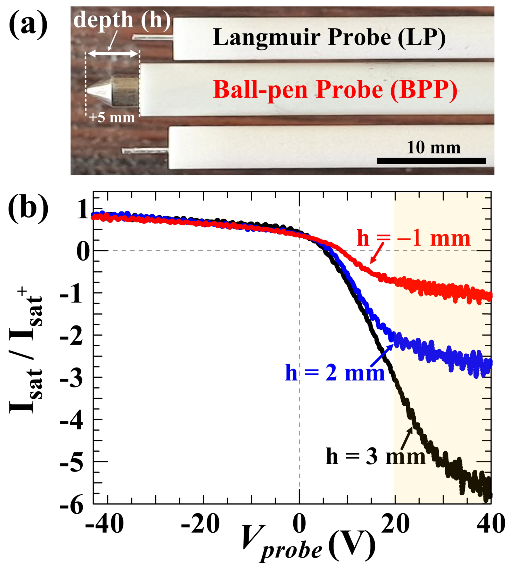

Fig.1 (a) Photography of the probe array with BPP and Langmuir probes. (b) Normalized current-voltage (I-V) characteristic at three different depths of the BPP collector.

In this presentation, we will introduce the first measurement results of the BPP in the linear magnetized plasma PANTA, which is successfully measuring the ϕ_s and the T_e.

References

[1] J. Adámek *et al.*, Contrib. Plasma Phys. **53** 39 (2013).
[2] F. F. Chen, Lecture notes on IEEE-ICOPS meeting (2003).