Measurements of plasma potential in low-temperature magnetized plasma - comparison between Langmuir and ball-pen probe

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1. Introduction

Assuming the Maxwellian distribution of electron energies and the constant electron and positive ion saturation currents the plasma potential Φ can be calculated of the floating potential V_{fl} and the electron temperature T_e as follows, equation (1):

$$V_{fl} = \Phi - \left(\frac{k_B T_e}{e}\right)\ln(R) \qquad (1)$$

The quantities k_B and e represent the Boltzmann constant and the elementary charge, respectively. The quantity $R = I_{sat}^-/I_{sat}^+$ expresses the ratio of electron and ion saturation current, respectively. By setting ln(R)=0 we can achieve that the potential of the floating probe directly displays the plasma potential Φ.

The ball-pen probe (BPP) belongs to the category of ion-sensitive probes (ISPs). ISPs typically consist of two coaxial metallic cylinders, the outer serving as a guard and the inner as a collector. The probe is oriented perpendicularly to the magnetic field lines. The inner cylinder (collector) is retracted (distance *h*) within the outer cylinder (metallic guard tube), which shields electrons from the collector. In order to reduce the I_{sat}^- down to the level of the I_{sat}^+ proper ISP biasing is required.

The BPP construction is similar to that of an ISP: it has a collector retracted into a guard tube and positioned perpendicularly to the magnetic field lines [1]. However, the guard tube of the BPP is made of ceramic, hence it is not necessary to bias the guard, unlike in the method of plasma potential measurement by swept ISP in [2]. By sufficient retraction of the collector, magnitude of the electron saturation current is effectively reduced approaching that of the ion saturation current. As a result the BPP floats at a potential close to the plasma potential, as follows from equation (1). A scheme of the ball pen probe used is shown in Figure 1.

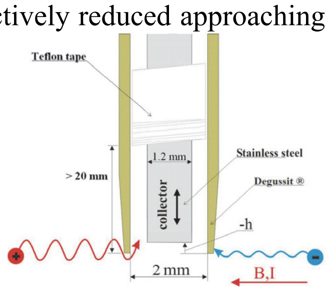

Fig.1: BPP1 cross section.

2. Experimental arrangement

The experiments were performed in the experimental system of a cylindrical magnetron that has been in detail described e.g. in [3]. The typical plasma density in dependence on the radial distance ranged from 10^{16} m^{-3} close to the anode up to 10^{17} m^{-3} close to the cathode. Tungsten Langmuir probe (LP) had a diameter of 50 µm and a length of 4 mm. The experiments described below were performed in argon within the pressure range *p*=1-20 Pa, the range of magnetic fields *B*=20-40 mT and at the discharge current I_D = 75 mA.

3. Results and discussion

The LP and BPPs with their collector retracted by *h*=-10 mm were placed 5 mm from the anode. In order to describe both the effects of pressure and magnetic field we have introduced, following the work [4], the parameter *B/p*. We performed many measurements at different *B* and *p* within several months. The difference between the plasma potential data from the BPP and the LP we normalized to the electron temperature estimated from the difference between the plasma and floating potential of the LP, see equation (2). The comparison of the plasma potential measured by ball-pen probe and Langmuir probe as a function of *B/p* is plotted in Fig. 2. It is evident from this figure that the BPP and LP data are fairly close to each other for *B/p* greater than 10 mT/Pa. That seems to be the limit of applicability of the BPP in our system and range of experimental conditions.

$$T_e = \frac{e}{k_B}\left(\Phi - V_{fl}\right)/5.19 \qquad (2)$$

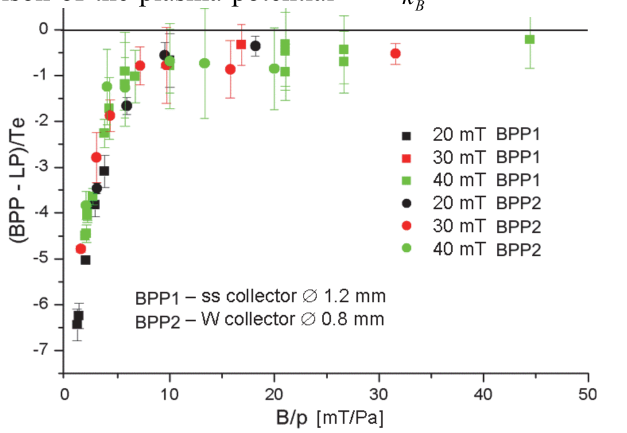

Fig. 2: *Comparison of the plasma potential measured by ball-pen probe and Langmuir probe as a function of B/p.*

References

[1] J. Adámek, et al. 2004 *Czech. J. Phys.* **54** C95
[2] R. Ochoukov, et al. 2010 *Rev. Sci. Instr.* **81** 10E111
[3] J. Adamek, et al. 2013 *Contrib. Plasma Phys.* **53** 39
[4] J.F. Behnke et al., 1999 *Czech. J. Phys.* **49** 483