Use of electron emissive probe in plasma with negative ions

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Emissive probes have been a part of standard diagnostic set in many laboratory plasmas. Due to the possibility of obtaining plasma potential directly from the floating potential of a highly emissive probe it has in the last few years again emerged itself as a possible diagnostics tool in tokamaks and stellarators [ref]. Also, the recent findings of [1] showing the agreement between the plasma potential measurements using a ball-pen probe and a self-emissive Langmuir probe have spurred further interest in this area. With laser heated emissive probe, also the ability to measure high frequency oscillations was demonstrated [2], which is important in measurements of fluctuations in SOL. However, there is still a dispute regarding the actual position of the floating potential of a highly emissive probe relative to the plasma potential. The theory had since [3] persistently suggested, that the floating potential saturates more than 1.5 T_e below the plasma potential with increasing heating due to space-charge build-up by the low-energy emitted electrons, however measurement results have been ambiguous. Since also the various Langmuir probe methods also provide a variety of results. Previously, we have made several theoretical models and simulations regarding the position of the point of critical emission (transition between temperature limited and space-charge limited regime) e.g. [4], the saturation potential and the potential dip with regards to temperature and density ratios of involved particle species [5]. It was recently shown, that the ratio between the temperatures of the emitted electron and the bulk electrons is very important in the formation of the potential dip in front of the emitting electrode. While for low temperature ratio the floating potential indeed saturates below the plasma potential, simulations show, that for higher temperature ratios the floating potential tends to surpass the plasma potential. The potential structure in front of the electrode however still remains.

Our goal in the present work was to make measurements in plasma with a higher temperature ratio . Since the temperature of the emitted electrons depends solely on the temperature of the emitting electrode, the temperature of emitted electrons is always close to 0.2 eV. Therefore, the only parameter, that could be altered, was the temperature of the bulk electrons. We opted to take a different approach, by virtually lowering the temperature of electrons, i.e. by introducing negative ions into the mix.

The experiment was performed in Linear Magnetized Plasma Device (LMPD) at the Jozef Stefan Institute in Ljubljana. The scheme of the experiment is presented in Figure 1.

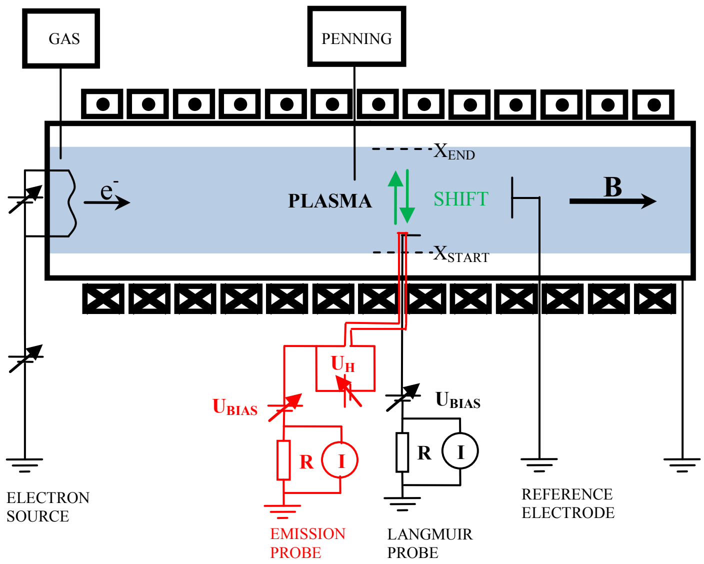

Figure 1: Scheme of the LMPD

The discharge is made through the hot tungsten cathode biased negatively with respect to the vacuum chamber. The chamber is approximately 1m long, and has inner diameter of 19cm with two gas inlets, which allows mixing of various gases. Axial magnetic field can be varied from 0.007T to 0.4T.

We have built a probe head with two probes, one made from tungsten and one made from platinum, Figure 2. The latter was used as a cylindrical Langmuir probe with diameter 125 microns and 10mm in length. Platinum was used to avoid formation of oxides on the probe surface. The tungsten probe formed a current loop to be used for heating. The heating of the probe prevented deposition of oxides on the probe surface during high emission. The probes were parallel to each other with a separation at least 5 mm. We have checked the perturbations of the neighbouring floating probes and found it negligible. The probes were put on the same head to speed up the process of measurement, since we wanted to measure in the same radial position. The probes could be oriented parallel or perpendicular to the magnetic field.

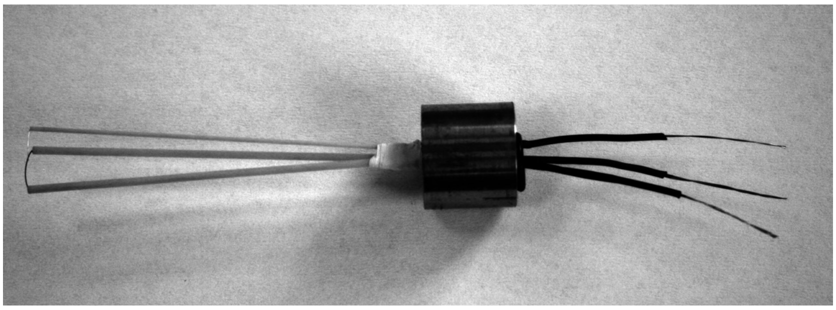

Figure 2: Probe head with 1 tungsten emissive probe (front) and 1 platinum Langmuir probe (back)

We have made several series of measurements in different radial positions, with different mixtures of gases. Main three gas setups were: Ar only with pressure p_{Ar} =0.01 Pa, Ar with relative pressure p_{Ar}=0.01Pa (buffer gas) and O with relative pressure p_O=0.2Pa and O only with pressure p_O =0.2Pa. The magnetic field was either B=0.007T, B=0.015T or B=0.025T. The discharge voltage was U_d=50V and the discharge current was kept constant at I_d=500mA. During the measurements we often had to change the tungsten filaments of the hot cathode due to rapid wear in oxygen plasma.

Argon and oxygen were used for comparing due to the natural abundance of negative ions O^- in oxygen plasma and a normal positive plasma column formed in argon plasma. Different radial positions were used due to the increasing ratio of negative ion density to bulk electron density when closing the chamber walls. We wanted to achieve conditions, when only a negligible part of electrons would be present, so only cold positive and negative ions and emitted electrons would be present.

As a method of comparison of the highly emissive probe results, we used either First derivative probe technique (FDPT) [6] or classical second derivative method. The former can be used in extended gas pressures or with higher magnetic field and we have already applied it successfully in our machine to measure negative ion density [7].

In Figure 3 and Figure 4 we present results for the floating potential of the emissive probe in two different radial positions and dependent on the heating current. As expected, in pure oxygen plasma, the floating potential of the emissive probe is close to or even above the plasma potential of the emissive probe. However, since there can be quite some arbitrariness in the designation of the plasma potential from the cold Langmuir probe characteristics, these results have to be confirmed in a more comprehensive analysis.

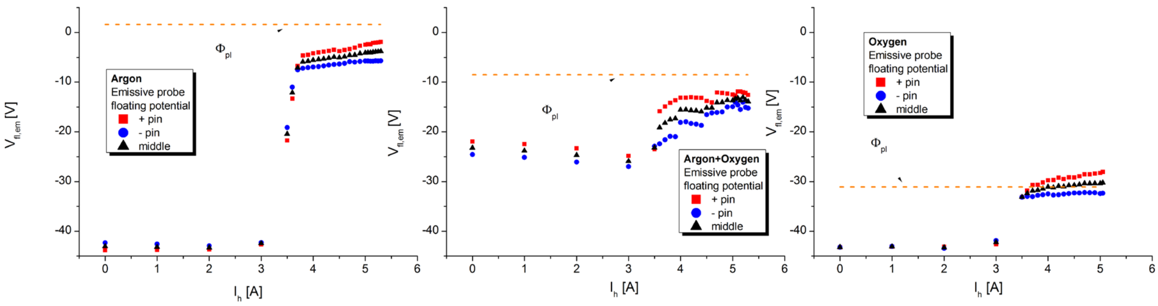

Figure 3: Floating potential of the emissive probe depending on the heating current 25 mm from the centre of the discharge. Different symbols and colours of plots represent measurements on different pins of the probe. Dashed line represents the plasma potential as obtained from Langmuir probe measurements.

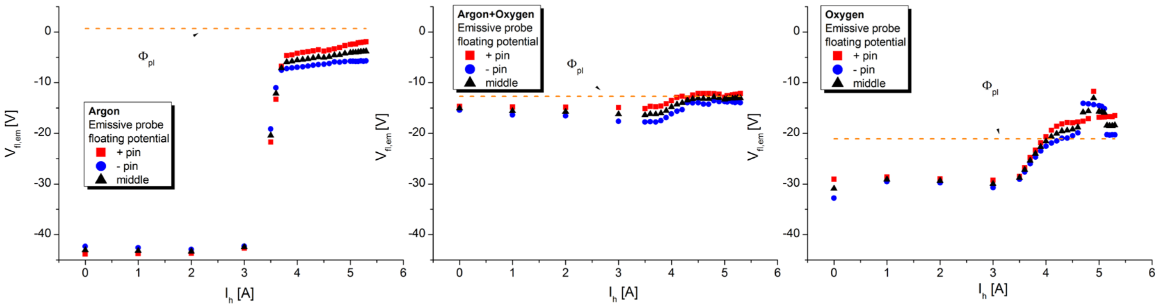

Figure 4: Floating potential of the emissive probe depending on the heating current 25 mm from the centre of the discharge. Different symbols and colours of plots represent measurements on different pins of the probe. Dashed line represents the plasma potential as obtained from Langmuir probe measurements.

In the future, theoretical model and particle-in-cell simulations of negative ion plasma with negligible density of electrons will be constructed for further insight into the subject .

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