Ion velocity distribution functions in the positive sheath of an insulated BNSiO2 surface in a plasma

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Abstract

We present first measurements of Argon Ion Velocity Distribution Function (IVDF) in the vicinity of an insulated BNSiO2 ceramic in a non magnetized plasma by laser induced fluorescence diagnostic. Results show a surprising self-consistent formation of a positive sheath. The positive potential repels ions from the insulated BNSiO2 ceramic and is not explained by any sheath theory, except by a recent Hall thruster simulation supporting the fact that electron secondary emission of the ceramic can be a good candidate to explain the experimental results.

Measurements are done in a multipolar plasma device producing non magnetized Argon plasma by collision of ionizing energetic electrons (50 eV) thermo-ionically emitted by hot tungsten filaments. The plasma has a density of 5.10^9 cm^{-3} for a neutral pressure of 2.510^{-4} mbar and is composed of Argon ions, secondary electrons (plasma electrons) and primary electrons (energetic electrons) [1]. The plasma has a diameter of 40 cm and is 80 cm long.

We present Ion Velocity Distribution Functions (IVDF) measured with 0.1 mm space resolution laser induced fluorescence (LIF) diagnostic in the sheath of an insulated BNSiO2 surface. BNSiO2 is currently used as a material for the walls of the plasma channel in Hall plasma thrusters and this motivated the present research. LIF is a non intrusive diagnostic which allows the recording of IVDF [2] with a high degree of velocity resolution (up to several m/s), space definition (up to 0.1 mm) and time resolution (up to 10 ns) [3]. Temporal resolution is not used here since time-averaged IVDF are measured.

With respect to the distance to the surface, IVDF exhibit a surprising positive sheath: ions move away from the surface, and faster as they are close to it. Fig. 1 exhibit IVDF with qualitatively the same shape as IVDF in a classical negative sheath of a conducting surface previously measured in the same device [3] but in the opposite velocity direction. Negative velocities go away from the ceramic. The BNSiO2 is at $x = 14.4$ cm. The positive peak for positive velocity at $x = 13$ cm, $x = 14$ cm and $x = 14.3$ cm is the effect of the laser beam reflexion on the ceramic. A candidate to explain these exiting results could be the secondary electron emission by

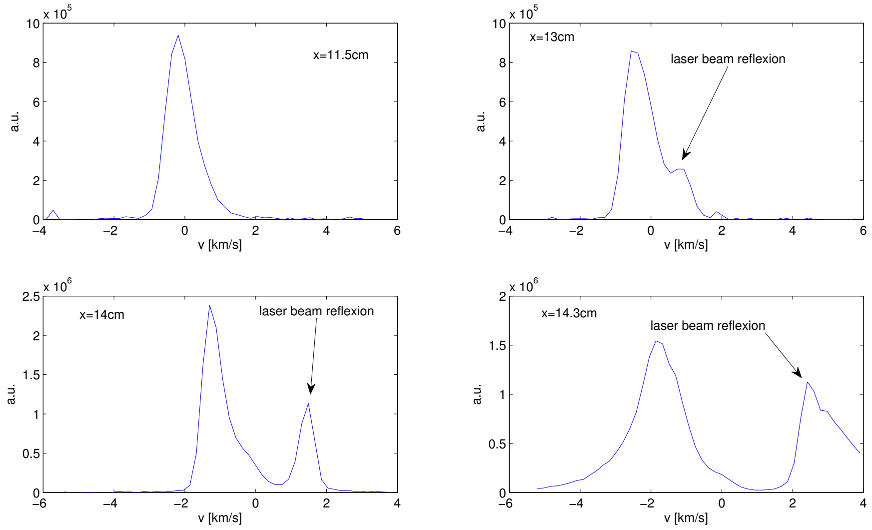

Figure 1: IVDF for 4 typical positions $x = 11.5$ cm, $x = 13$ cm, $x = 14$ cm, $x = 14.3$ cm. BNSiO2 is at $x = 14.4$ cm

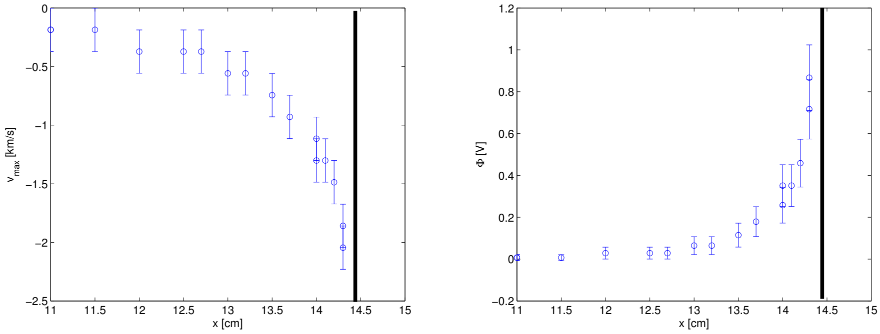

Figure 2: v_{max} and Φ with respect to the distance to BNSiO2 surface represented by a black line.

the ceramic subject to primary electron collisions with an energy around 50 eV[5, 6]. A Hall effect thruster simulation has recently exhibited the absence of Debye sheath and formation of a positive sheath due secondary electron emission [7]

The potential Φ with respect to the distance to the insulated ceramic can be estimated assuming $\frac{1}{2}m_i v_{max}^2 = e\Phi$ where v_{max} is the velocity at the maximum of the IVDF, m_i the ion mass, e the electron charge. Φ is shown with v_{max}, in Fig.2. The black line represents the BNSiO2 surface position. Error bars are due to the used laser frequency step and can be drastically reduced (increasing the recording duration). The positive surface potential can be estimated to a few eV.

The width of the sheath + presheath is, in this case, of about 2 cm, against 10 cm for the conducting case[3].

These measurements can have important implications for electron transport in Hall plasma thrusters[7, 8] and greatly influence our comprehension of the thruster physics.

Even if plasma wall interaction or sheath studies can be considered as the oldest problems in plasma physics, a full understanding of their complex behavior is far from being achieved although it has important implications in all the branches of plasma applications: fusion[9], material plasma processing (etching and deposition)[10], plasma thrusters[8]. To our knowledge, no simple theoretical model exists to explain this auto-coherent positive sheath and this is the first time that a self-consistent positive sheath is observed with good spatial resolution.

Similar experiments has been done with an insulated microscope glass. It also shows a positive sheath but very thin, below 1 cm. Since glass is expected to lead to less electron secondary emission (ESE), we indeed suspect that ESE plays an important role in the formation of the observed positive sheath. More investigation is under progress.

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