E×B probe measurements in strongly electronegative plasmas

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An E×B probe allows to accurately determine the velocity distribution function (VDF) of ion species in a plasma or a beam [1]. The probe concept, which is also called a Wien filter, can be seen as a velocity filter contrary to a RPA which is an energy filter. The basic principle of the probe relies on the drift of a charged particle in crossed electric and magnetic fields. Using the Lorentz description of a charged particle motion, one can derive the velocity when not net force is acting on the system, that means when the particle follows a straight trajectory. This specific velocity v reads:

$$v = \frac{E}{B} = \frac{V}{dB},$$

where E is the electric field, B is the magnetic field, V is the applied voltage and d the distance between the electrodes. The design of the probe has been explained in details elsewhere [2]. The undisturbed trajectory is defined by means of two apertures. The B field is fixed and it is produced using permanent magnets. The voltage is generated between two planar electrodes. Ions are collected with a graphite plate. A picoammeter is used to record the low-level current. The ion VDF is constructed by sweeping the electrode voltage while acquiring the current. A probe spectrum does not directly correspond to the ion VDF as the device is non ideal. A calibration is needed to retrieve the true ion velocity.

Probe calibration is obtained by using a RF source with two polarized grids to extract and accelerate the ions. Noble gases like Ar, Kr and Xe are used for this sequence. The E×B probe was calibrated for an acceleration voltage up to 400 V. It appears that the calibration factor depends on both the velocity and the mass. In addition to measure the ion velocity, the probe can provide the plasma composition like a mass spectrometer as the velocity of ions depends on the mass under electrostatic acceleration.

The probe was operated in electronegative plasma like O_2 and SF_6 in the frame of the investigation of the PEGASES ion-ion plasma thruster [3]. SF_6 discharges have often been used for various applications and a lot of articles can be found in the literature. All studies show the complexity of SF_6 plasmas in terms of molecular fragments. The plasma composition depends on parameters like the pressure and the input power.

The PEGASES thruster is a gridded ion source powered with RF at 4.2 MHz in ICP mode. Currently SF_6 is used as a working gas. Permanent magnets create a transverse magnetic filter for electrons at the end of the dielectric cavity. The filter reduces the axial diffusion of electrons and it improves the dissociative attachment of electrons on molecular fragments to produce negative ions. Therefore, in the final section of the cavity, just ahead of the grid assembly, the plasma is electron free. This state of matter is referred to as an ion-ion plasma. PEGASES operates with an alternate voltage on the grid to extract negative and positive ions.

The goal of this work is to study the acceleration of the various molecular fragments and to determine their respective fraction with an E×B probe. The thruster was fired in continuous mode with a neutralizer as well as in alternate voltage mode to capture negative ions for a broad range of conditions. Figure 1 shows two E×B spectra in alternate voltage mode with an SF_6 discharge. When the grid is in turns negatively biased and at ground negative ions are detected.

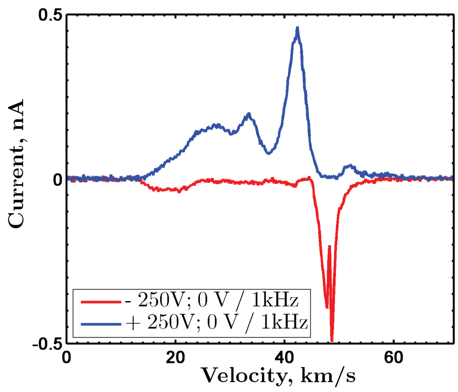

Fig. 1: E×B probe spectra in alternate voltage mode in the beam of PEGASES (SF_6 plasma).

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[3] T Lafleur, D Rafalskyi and A Aanesland, Plasma Sources Sci. Technol. **24** 015005 (2015)