Space charge neutralisation of continuous dual ion beams

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A continuous dual ion beam is formed by successive acceleration of positive and negative ions. This ion beam is accelerated from an ion-ion plasma by electrostatic grids biased with square waveforms in the kHz frequency and with acceleration voltages less then ±300 V. We show that the positive and negative ions are accelerated in the positive and negative bias period, respectively, and that the respective beam energies can be controlled independently. The effect of the waveform frequency and acceleration voltage on the beam space charge neutralisation will be discussed.

In this work we present the development of an ion-ion plasma source where positive and negative ions are alternately accelerated out of the source such that space charge and current neutralization is provided by the accelerated product. The motivation for this work is twofold: i) In the context of the PEGASES thruster development, the aim is to accelerate ions to high velocities to generate thrust without the need for electron neutralisation. The targeted end product is a high-performance gridded thruster with a plume composed mainly of fast neutral particles. ii) Polymers are used more and more in various products due to their favourable bulk properties (light, flexible, easy to shape etc), but these properties are often compromised by their unfavorable surface characteristics. Applying functional coatings such as protective layers, optical coating, gas permeation barriers and others can enhance the performance of polymers. However, this require soft plasma treatments where high-energy bombardment, either by electrons or ions destroys the polymer surface. The source developed here is promising for polymer surface treatments.

The experimental setup is shown in Fig. 1, and has been described previously [1, 2]. The source is a purely Inductively Coupled Plasma (ICP) source, symmetrically driven at 4 MHz with a ferrite enhanced planar inductor separated from the plasma by a thin (3 mm) ceramic window. An ion-ion plasma is formed within and downstream of a magnetic barrier when operating the source in SF_6. This ion-ion formation is detailed in the poster presented by J. Bredin et al. A set of two electrostatic grids are placed in the ion-ion region. The first grid in contact with the plasma is biased with alternating voltage waveforms while the second downstream grid is grounded. A Retarding Field Energy Analyser (RFEA) is placed 2 cm downstream of the grid and used to measure the energy distribution function of

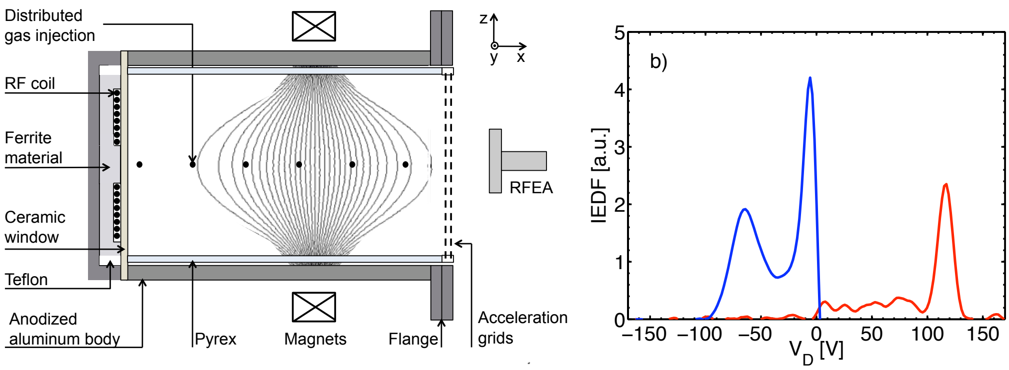

Fig. 1: Left: Schematic of the experimental setup. Right: The averaged energy distribution function measured during the positive (red) and negative (blue) bias period for a square waveform with ±100 V at 1 kHz applied to the first grid in contact with the ion-ion plasma.

both positively and negatively charged ions. The RFEA is composed of three grids and a collector; the first and the third grid are grounded while the middle grid is swept from negative to positive polarities. This voltage distribution allows to measure the time resolved energy distribution of both positive and negative charges entering the RFEA, however the drawback is that effects of secondary electrons are not efficiently prevented.

Fig. 1 (right) shows the averaged time resolved energy distribution functions measured by the RFEA when the grids are biased with a square waveform of ± 100 V at 1 kHz. The red curve is obtained during the positive bias period and the blue during the negative bias period. It is clearly seen that positive and negative charges are measured during the positive and negative bias period, respectively. The positive ion beam energy is 117 V and mono-energetic with a small tail due to charge exchange collisions. The distribution of negative charge is double peaked. One peak correspond to a negative ion beam with the peak energy at -64 V and with an amplitude equivalent to the positive ion beam. The higher and narrower peak at -5 V is most likely due to secondary electrons and/or electron detachment of the negative ions occurring within the analyzer. The effective acceleration potential for negative ions is lower than the one for positive ions. It has been seen that the difference in ion beam energy between the positive and negative ions increases with increasing bias voltage. We believe that the difference can be understood by the mechanism for space charge neutralization of the two different beams. When positive ions are accelerated, their space charge can be quickly neutralized by mobile secondary electrons. However, when negative ions are accelerated, their space charge can only be neutralized by the successive positive ion beam. The effect of the slower negative ions should therefore be decreasing with increasing waveform frequency. The space charge neutralization mechanisms will be thoroughly discussed in this presentation.

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References

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