One-dimensional Particle-In-Cell simulations of the sheath dynamic in ion-ion plasmas

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Ion-ion plasmas are discharges with few (or no) electrons and can be used in low temperature plasma applications (microelectronics, propulsion, etc.) by accelerating alternately positive and negative ions from the plasma bulk with a bias voltage. A Particle-In-Cell model has been used to understand the time dynamic of the sheath under the influence of a bias voltage in the context of ion-ion plasmas. Comparisons with fluid model have also been performed.

In low temperature plasmas, electrons are needed to initiate the discharge by ionization of the neutral gas. Nevertheless, for some applications such that microelectronics electrons can play a harmful role by charging the wafer [1]. Electrons are also used for charge and current neutralization of the positive ion beam in plasma propulsion [2]. A system where no neutralizer is used can simplify the thruster technology. In some situations, pure ion-ion plasmas (almost free from electrons) are consquently more adapted for low temperature plasma applications. Ion-ion plasmas can be formed in electronegative gases in the afterglow of pulsed discharges [1] or by magnetic filtering [3-4]. In pulsed discharges, the electron temperature decreases in the afterglow and negative ions can be formed by dissociative attachment. When magnetic filtering is used, the region of formation of the negative ions by dissociative attachment is spacially localized, downstream the magnetic field barrier where the electron temperature drops. The formation of the ion-ion plasma using a magnetic barrier will also be presented during this conference. Industrial applications require the use of bias grids either to alternately accelerate positive and negative ions (e.g. for microelectronics [1] and propulsion applications [3]), or to accelerate only negative ions (e.g. for the neutral beam injection in Tokamaks [4]). In the latter example, a magnetic field upstream the accelerator grid is used to prevent the electrons to be accelerated by the positive voltage.

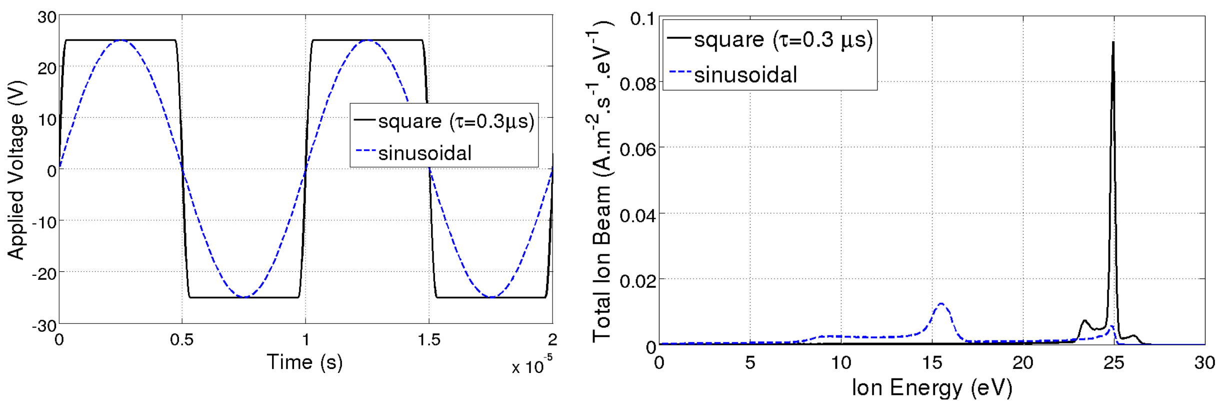

Fig. 1: Ion beam energy distributions for different applied waveforms to the biased electrode.

A standard Particle-In-Cell (PIC) code has been used in one-dimension to study the sheath evolution when varying the bias voltage waveforms applied to the electrodes [5]. The same problem has been studied with a fluid approach coupling ion continuity and momentum equations to Poisson equation by Midha and Economou [6]. In Ref. [6] a sinusoidal waveform potential is assumed at the driven electrode and the potential at the grounded electrode is fixed at zero. Fluid modeling results emphasize the strong correlation between the bias frequency and the plasma frequency on the ion fluxes bombarding the electrodes. Comparisons between PIC and fluid simulations will be presented. We illustrate in Fig.1 the effect of non-sinusoidal waveforms applied to the biased electrode on the ion beam energy distributions. Analysis of the sheath dynamic will be detailed at this conference.

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