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The Electrical Asymmetry Effect in geometrically asymmetric discharges

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Capacitively coupled radio frequency (CCRF) discharges are of special interest, since they are an effective processing tool. Separate control of ion energy and ion flux at surfaces in contact with the plasma is essential for many processing applications of these discharges. However, this separate control is not possible in single frequency discharges and is limited in conventional dual frequency discharges [1].

The recently discovered **Electrical Asymmetry Effect** (EAE) [2-9] provides a promising opportunity to obtain this independent control of ion energy and ion flux. The basic idea of the EAE is to apply a voltage waveform consisting of a fundamental frequency and its second harmonic to one electrode in a capacitive discharge ($V_{ac}=0.5V_0[\cos(\omega t+\theta)+\cos(2\omega t)]$). The symmetry of this waveform, and, consequently, the symmetry of the discharge, can be controlled by the phase shift θ between the driving frequencies. The dc self bias η is an almost linear function of θ for $0° \leq \theta \leq 90°$ (Fig. 1). The ion energy can be controlled by the phase angle while the ion flux only depends on the voltage amplitudes. This effect is self-amplified at low pressures and sufficiently high voltage amplitudes.

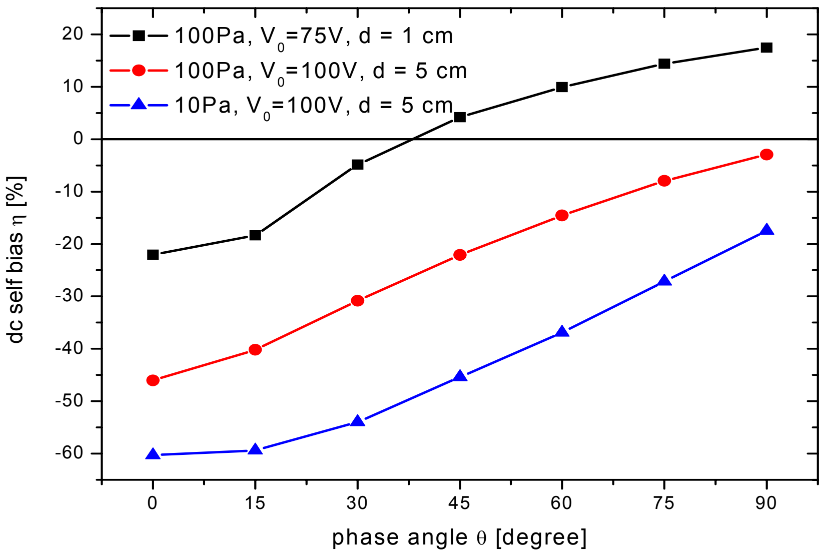

Fig. 1: DC self bias η (normalized to the applied voltage amplitude) as a function of the phase angle θ between the driving frequencies for different chamber geometries (squares: plasma confinement by a glass cylinder, 1 cm electrode gap / circles and triangles: plasma confinement by a metal mesh, 5 cm electrode gap).

Until now the EAE has only been investigated in geometrically symmetric discharges [2-9]. Here, the EAE is investigated experimentally in a geometrically asymmetric discharge set up in a modified GEC reference cell for the first time. A superposition of 13.56 MHz and 27.12 MHz is applied to the bottom electrode. The plasma is confined by either a glass cylinder or a metal mesh to the region between the bottom powered electrode and the top grounded electrode. In the former case, a small discharge asymmetry is caused by the capacitive coupling between the glass cylinder and the outer grounded chamber wall. Using the metal mesh the geometrical discharge asymmetry can be varied by changing the electrode gap. In this way, the control range of the dc self bias η is shifted to more negative values. The discharge asymmetry introduced by the chamber geometry can be reduced via the EAE, leading to a higher voltage drop across the sheath adjacent to the grounded surface. This in turn leads to an enhanced bombardment of the chamber wall by highly energetic ions that should allow a much more efficient chamber cleaning process.

In asymmetric CCRF discharges non-linear plasma series resonance (PSR) oscillations of the RF current are known to be self-excited at low pressures [10, 11]. These high frequency oscillations of electrons excited by the fast sheath expansion enhance electron heating by nonlinear electron resonance heating [10]. The EAE allows the excitation and control of the PSR in geometrically symmetric discharges for the first time [9]. Here, the RF current to the chamber wall is measured using a Self Excited Electron Resonance Spectroscopy (SEERS) sensor implemented into the grounded electrode. The overall behavior of the PSR is understood by a model taking into account the asymmetry that is caused electrically and/or geometrically.

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