Influence of electrode area asymmetry on harmonics generated in a direct coupled radio frequency discharge

A. Rawat, A. Ganguli, R. Narayanan, R.D. Tarey

Indian Institute of Technology Delhi, New Delhi, India

Radio frequency (RF) discharges have been serving modern plasma processing technologies for several decades [1]. In this context, an important issue that arises is the mechanism of power coupling in RF discharges. For instance, while at high pressures, collisions are responsible for the net power transferred to plasma (ohmic heating), it is conjectured that at low pressures nonlinear RF sheath oscillations may be responsible (stochastic heating) for sustaining the discharge [2]. However, the latter mechanism is unable to explain fully power absorption at low pressures. A key feature of low pressure (few mTorr) RF discharges is the presence of harmonics of the fundamental RF frequency. It is well known that the non-linearity of sheaths can generate multiple harmonics and so it may be expected that detailed characterization of the harmonics may provide important signatures of absorption mechanisms. Although numerous theories and simulations have been proposed so far, experimental studies on nonlinear characterization of RF discharges are very rare.

In this work, a novel non-invasive plasma diagnostic technique using a Dual Directional Coupler (DDC) was used to investigate these nonlinear phenomena in RF discharges. Different electrode geometries were used (A_P/A_G = 1, 0.91, 0.51, where A_P and A_G are the area of powered and grounded electrodes respectively). The technique not only determines the harmonics present in plasma, but also yields accurately the power in the forward and reflected waves of the fundamental and each harmonic generated in the plasma. Plasma is ignited using 13.56 MHz RF generator with argon pressure ranging from 5 mTorr to 200 mTorr. The experiments were performed in a *directly coupled* capacitive RF discharge (without a blocking capacitor) since a blocking capacitor induces a large, negative DC self-bias on the powered electrode, that damages the coupler. Experimental results show the presence of even and odd harmonics for symmetric geometry (A_P/A_G = 1) along with a high plasma potential. Both these facts contradict the theoretical models [3] for A_P/A_G = 1. Also, the power content of these harmonics increases with increasing geometrical asymmetry and decreasing pressures. Some of the results from the ongoing experiments will be presented in the conference.

References

[1] P. Chebert et al, Physics of radio-frequency plasmas, Cambridge University Press (2011).

[2] J. Schulze et al, Plasma Sources Sci. Technol.18**,** 034011 (2009).

[3] M. A. Lieberman, IEEE Trams. Plasma Sci. 16, 6 (1988).