Abstract for an Invited Paper
for the GEC07 Meeting of
The American Physical Society

Electron heating in dual-frequency capacitive discharges

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Capacitive discharges excited by a superposition of two frequencies are important tools in applications where precise control of the plasma conditions is important, as when the energy and flux of ions leaving the plasma must be controlled independently. Elementary discussion of these discharges assumes that the two frequencies control the ion flux and energy practically independently, but more detailed investigation shows that that this is true only to a limited extent. In this paper, we focus on electron heating in dual frequency discharges. Such heating can be attributed to three mechanisms: Stochastic heating, Ohmic heating and secondary emission from plasma facing surfaces. We consider the processes contributing to these three mechanisms and their relative importance. We will discuss recent work on collisionless or stochastic heating in dual-frequency discharges, the relative importance of Ohmic and collisionless heating, and the effect of secondary electron emission. We will show that stochastic and Ohmic heating typically depend on both the low- and high-frequency current densities, so that the net heating depends strongly on both. We will also show that recent phase-resolved optical emission spectroscopy measurements are difficult to understand without the assumption that secondary electron emission is an important process. These results show that the two-frequencies coupled in a complex fashion, which does not however necessarily preclude effective independent control of ion flux, ion energy, and other important process parameters