Displacement of charge and conduction current during voltage transients in low-temperature plasmas

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Low temperature plasmas are used in a wide range of technological applications; such as etching and deposition for semiconductor manufacture and thin film depositions of functional coatings. Often these processes encompass transient phenomena associated with instabilities and external modulations or perturbations. Here we examine the relaxation of a positive ion (boundary) sheath following a step reduction in the magnitude of the potential across it; the capacitance of the external circuit plays a key role in determining the timescale of the relaxation. The system modelled comprises a self-sustaining bulk plasma adjacent to space charge dominated boundaries. The situation is very similar to transients that arise after a step change of input power or after other types of voltage transient on surfaces exposed to a plasma.

In order to model details of the currents associated with a relaxing sheath we have used analytical and numerical approaches. The numerical model is a 1-D particle in cell (PIC) code that has been modified to include external circuit elements. Displacements of charge within the sheath in addition to charge arriving at surfaces contribute to the overall external circuit current. It is clear that when the effective capacitance associated with charge in the sheath is compatible with or dominates the capacitance of the external circuit then displacement current makes a major contribution. The numerical model also provides information on additional non-linearities associated with large electrical perturbations. The numerical model is also able to show that for the parameter range studied the electron energy distribution function of the bulk plasma is not affected by the sheath relaxation.