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Control of the Ion Energy Distribution on Plasma Electrodes[1]

DEMETRE ECONOMOU, University of Houston

The energy of ions bombarding the substrate is of critical importance in plasma etching and deposition. For example, precise etching with high selectivity and no substrate damage requires a nearly-monoenergetic ion energy distribution (IED) with tight energy spread. The IED may be controlled by applying "tailored" bias voltages on the substrate, or on a nearby electrode (boundary electrode) immersed in the plasma. A PIC-MCC simulation was conducted of the application of DC waveforms on a boundary electrode, during the afterglow of a pulsed discharge. Staircase voltage waveforms with selected amplitudes and durations resulted in IEDs with distinct narrow peaks, having controlled peak energies and fraction of ions under each peak. A model was also employed to achieve "designer" IEDs, i.e., distributions with a desired (pre-selected) shape and energy spread. This was accomplished by solving the "inverse" problem, i.e., that of finding the voltage waveform that must be applied on the electrode to yield a desired IED. IEDs were measured in a Faraday-shielded inductively coupled plasma. Narrow distributions with well-controlled ion energy were obtained by pulsing the plasma and applying a synchronous DC bias on a boundary electrode during the afterglow. The peak ion energy was controlled by the DC bias, as the plasma potential and T_e decayed drastically in the afterglow. IED measurements were performed in Ar, Kr and Xe plasmas. The full width at half maximum (FWHM) of the IEDs followed the order Xe>Kr>Ar. Higher electron temperature in the afterglow correlated with larger FWHM. The width of the IED could also be controlled by varying the pulsed plasma frequency and duty cycle, or the time window of the application of the DC bias during the afterglow. Model predictions in terms of IEDs or voltages to produce given IEDs were in agreement with experimental data.

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