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Simulations of plasma formation and sustainment in an RLSA (radial-line slot antenna) microwave plasma source[1]

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Microwave surface-wave plasma sources are promising alternatives to capacitively- or inductively-coupled sources. The source and wafer are decoupled so that the wafer may be independently biased without affecting the source. Also, they are known to produce relatively dense, quiescent, low-temperature plasmas near the wafer surface, minimizing wafer damage. Our device consists of an RLSA that transmits 2.45 GHz microwaves into a large quartz resonator disk that then couples to the plasma. Because of natural modes in the disk, regions (nodes) of enhanced electric fields exist at the plasma/dielectric interface. For sufficient input power the density at these nodes can rise to the cutoff density ($\omega = \omega_{pe}$). It is well known that resonances then occur in which the electromagnetic fields grow to large amplitudes and convert to electrostatic plasma waves, which in turn transfer the field energy into electron energy. We investigate these phenomena through simplified 2-D PIC (particle-in-cell) simulations using the Tech-X VORPAL code. The simulations include ionization using a Monte-Carlo model with an energy-dependent cross section. We specifically study the complex interaction of the plasma waves with electrons. We observe that the electrons are strongly accelerated into the underdense regions ($\omega < \omega_{pe}$) and raise the density there to the cutoff density as well through enhanced ionization. For sufficient power, the density is driven to an overdense state ($\omega > \omega_{pe}$) everywhere. We present plots of the E-field, density, electron phase-space, and EEDF's (electron energy distribution functions) throughout the resonance period.

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