Kinetic and Hybrid Modeling of a Radio Frequency Hollow Cathode Discharge and Comparison with Experiments

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Radio frequency (RF) hollow cathode discharges (HCD) are used in various semiconductor manufacturing processes such as material etching and deposition. HCD cathodes have cavities, and the plasma forms inside these cavities under the right conditions. In the HCD, RF sheath heating as well as secondary electron acceleration can lead to plasma production. In this work, plasma simulation results for argon and oxygen HCDs are compared with plasma diagnostics measurements using non-invasive methods. These measurements include the emission spectra of plasma discharge using Phase Resolved Optical Emission Spectroscopy (PROES), which provides the spatio-temporal excitation rate of important species in the discharge. We use both kinetic and hybrid plasma models in this work to understand the plasma dynamics and elucidate with the experimental observations. The Particle-In-Cell with Monte Carlo Collisions (PIC-MCC) model includes evolution of charged particles and electrostatic field along with charged particle collisions with the neutral species using a Monte Carlo approach. The hybrid model only treats the electrons as particles and includes a fluid model for the other charged species. In both models, the charged species' densities are coupled with the Poisson's equation to calculate the electric potential, enabling a self-consistent plasma simulation. Plasma simulations are performed for different pressures, voltages, and feed gases (Ar & O_2). Our simulation results show good agreement with the spatio-temporal experimental measurements of metastable argon excited state at low pressures. With increase in voltage, the excited species is found to penetrate further into the hollow cathode slot. The modeling results also indicate that the secondary electron emission coefficient from surfaces significantly influences the plasma behavior.