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3-Dimensional Modeling of Capacitively and Inductively Coupled Plasma Etching Systems

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Low temperature plasmas are widely used for thin film etching during micro and nano-electronic device fabrication. Fluid and hybrid plasma models were developed 15-20 years ago to understand the fundamentals of these plasmas and plasma etching. These models have significantly evolved since then, and are now a major tool used for new plasma hardware design and problem resolution. Plasma etching is a complex physical phenomenon, where inter-coupled plasma, electromagnetic, fluid dynamics, and thermal effects all have a major influence. The next frontier in the evolution of fluid-based plasma models is where these models are able to self-consistently treat the inter-coupling of plasma physics with fluid dynamics, electromagnetics, heat transfer and magnetostatics. We describe one such model in this paper and illustrate its use in solving engineering problems of interest for next generation plasma etcher design. Our 3-dimensional plasma model includes the full set of Maxwell equations, transport equations for all charged and neutral species in the plasma, the Navier-Stokes equation for fluid flow, and Kirchhoff's equations for the lumped external circuit. This model also includes Monte Carlo based kinetic models for secondary electrons and stochastic heating, and can take account of plasma chemistry. This modeling formalism allows us to self-consistently treat the dynamics in commercial inductively and capacitively coupled plasma etching reactors with realistic plasma chemistries, magnetic fields, and reactor geometries. We are also able to investigate the influence of the distributed electromagnetic circuit at very high frequencies (VHF) on the plasma dynamics. The model is used to assess the impact of azimuthal asymmetries in plasma reactor design (e.g., off-center pump, 3D magnetic field, slit valve, flow restrictor) on plasma characteristics at frequencies from 2 – 180 MHz. With Jason Kenney, Ankur Agarwal, Ajit Balakrishna, Kallol Bera, and Ken Collins.