GEC14-2014-000356

Abstract for an Invited Paper
for the GEC14 Meeting of
the American Physical Society

Capacitively Coupled Plasma Modeling at Low and Moderately High Pressures

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Capacitively coupled plasmas have been used in both deposition and etching processes in semiconductor industry. The etching processes are typically performed at low pressure (5-500 mT) as directionality and energy of ions are important. The deposition processes are performed at moderately high pressure (1-10 T) to achieve higher process deposition rates with minimal ion bombardment damage. Our plasma model includes the full set of Maxwell equations in their potential formulation. The equations governing the vector potential are solved in the frequency domain after every cycle for multiple harmonics of the driving frequency. Current sources for the vector potential equations are computed using the plasma characteristics from the previous cycle. The coupled set of equations governing the scalar potential and drift-diffusion equations for all charged species are solved implicitly in time. In the low pressure regime, stochastic heating is important. This effect is considered in the model using modified transport parameters. The model was validating using experimental data. At 13 MHz, secondary electron emission is found to play an important role in enhancing ionization through collisions. At higher frequency, the effect of secondary electron emission is less significant. At very high frequency, the electromagnetic standing wave leads to peak in plasma density at the center of the discharge. In the moderately high pressure regime, secondary electrons are important as they participate in bulk plasma heating. At very high frequency, under moderately high pressure, the electromagnetic effect is also found to be important, with the shape of the plasma profile varying according to aspect ratios of reactor structure. In this paper we will present plasma modeling that adequately represents plasmas at low and moderately high pressures at different frequency.