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Simulations of Plasma Sources for Semiconductor Device Manufacturing

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First being applied to etching [1] and deposition [2] more than four decades ago, plasma unit processes are now ubiquitous in the semiconductor industry. However, in many cases the use of plasma discharges for semiconductor process development has far outpaced our fundamental understanding of plasma unit processes. Fortunately, state-of-the-art modeling and simulation is now applied both in the capitol equipment and device manufacturing sectors fortified by close relationships with academic institutions and national laboratories globally. The simulation tableau, modeling and simulation for semiconductor device manufacturing community may be broken into the following categories: new concept development, new process development, equipment physics and equipment engineering. This presentation will focus on simulation modalities that highlight how the physics of production equipment result in beneficial processes. Two classes of examples with be provided. [3] The first will illustrate the behavior of microwave plasma source; the second will explore the electron kinetics associated of capacitively coupled plasma sources. The common thread linking these topics is the importance of the frequency dependence of the electron energy distribution function (eedf) to the fidelity of the simulation results. With respect to the microwave driven plasma sources, in addition to comparing predictions of different modeling approaches to experimental data, the relationship between the microwave network and the plasma dynamics in addition will be highlighted. While the criticality of the eedf to all of capacitively coupled systems will be discussed, particular focus is paid to dc augmented capacitively coupled sources where management of how the ballistic electron population reaches the substrate is critical to process results. Fluid, test particle and full particle-in-cell Monte Carlo simulations will be used to illustrate different discharge behavior.

[1] H. Abe et al. Jpn. J. Appl. Phys. 12, 154 (1973)
[2] L.L. Alt et al. J. Electrochem Soc. 110, 465 (1963)
[3] see companion papers by Upadhyay et al. and Kaganovich et al.