# Capacitively Coupled Plasma Analysis

Multiphysics simulations can be used to assist with the development of new CCP processing technology.

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Plasmas consist of electrons, ions, and neutral species interacting with each other and with externally imposed electromagnetic fields. Plasma etching and deposition of thin films are critical processes in the manufacture of advanced microelectronic devices. These processes commonly utilize a capacitively coupled plasma (CCP), in which the plasma is initiated and sustained by an oscillating electric field in a region between two or more electrodes. While CCPs are typically generated at frequencies in the 10-100 MHz range, some applications benefit from operation at lower frequencies. In this regime, free electrons are generated both by collisions between electrons and atoms or molecules, and by secondary electron emission caused by ion bombardment of the electrodes.

The multiphysics nature of plasmas presents enormous challenges for numerical simulations; analysis of the CCP process presents added difficulty due to the existence of a plasma sheath, the dynamic behavior of the plasma, and the large number of RF cycles required to reach a periodic steady state. Power deposition into the plasma is highly non-linear and the strong gradient of the electric field in the plasma sheath may lead to numerical instabilities unless a sufficiently fine mesh is applied. Typical CCP reactors may also contain sharp geometric corners that can cause a substantial local electric field that provide unphysical ion fluxes.

AltaSim Technologies has performed one- and two-dimensional simulations of low-frequency RF discharges in axisymmetric CCP reactors for Maxwellian and non-Maxwellian cases using COMSOL Multiphysics. Electron transport properties and Townsend coefficients were calculated using the two-term Boltzmann approximation as a preprocessing step to the numerical analysis of the plasma. Ion densities are shown in Figure 1 for a 1D simulation of a non-Maxwellian plasma. Extensions of the model to analyze the plasma behavior for a Maxwellian plasma in a 2D case are shown in Figures 2 and 3. The simulations incorporate the multiphysics nature of plasmas and consequently can be used to assist with the development of new CCP processing technology. ■

## ACKNOWLEDGEMENTS

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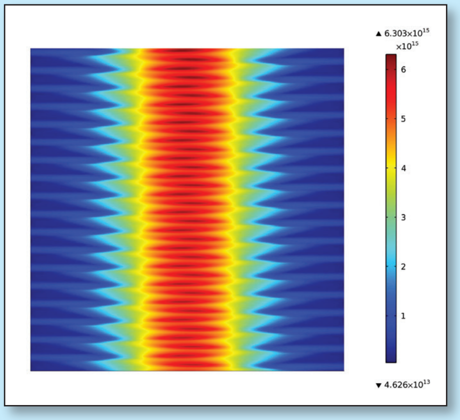

**Figure 1. 1D Simulation of the CCP Process showing ion number density as a function of time.**

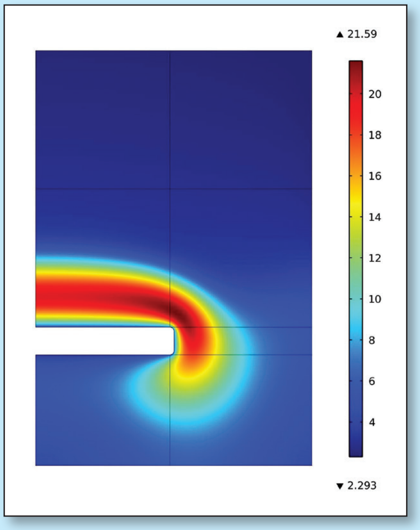

**Figure 2. Electron Temperature in the sheath region from 2D simulation of the CCP process.**

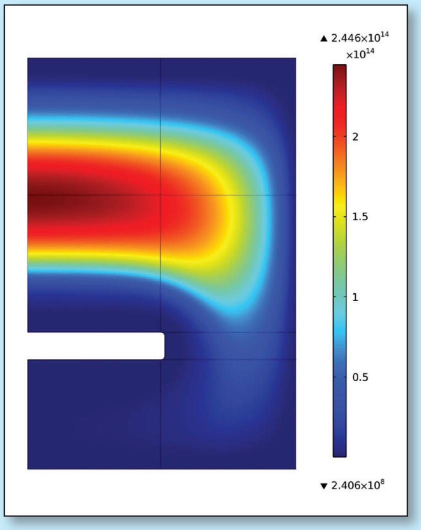

**Figure 3. Electron Density in the plasma from 2D simulation of a CCP process.**