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Hybrid three-dimensional electromagnetic and plasma simulation

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Plasma uniformity is critical to plasma-based process chambers, which are often driven by capacitively-coupled RF. However, as the electrode dimension becomes an appreciable fraction of the RF wavelength, the plasma density becomes increasingly non-uniform. This is a three-dimensional problem since the RF propagates in the plane between the electrodes while the electric field perpendicular to this plane determines the plasma characteristics, which affect the propagation of the RF. A computationally-inexpensive model can simulate this RF/plasma interaction. The model represents the transmission of RF within a two-dimensional surface bounded above and below by electrodes. The media between the electrodes are assumed to be linear, but this is not valid where plasma is present. A one-dimensional plasma model is used to calculate the local current-voltage behavior, and a lookup table describes their relationship. Following this approach, the three-dimensional Maxwell equations can be reduced to a Helmholtz equation for the voltage between the electrodes. The model is validated against several sets of experimental data, and it captures the behavior of the plasma distribution. First, the plasma profile in an AKT 60K PECVD chamber (Gen 8.5 size substrate) with an asymmetric 13MHz input is predicted. Also, plasma distributions are simulated for 40MHz RF fed into multiple locations on the electrode. Finally, the model predicts the plasma profile with 60MHz applied to two RF feeds.