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Advances in Plasma Process Equipment Development using Plasma and Electromagnetics Modeling

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Plasma processing is widely used in the semiconductor industry for thin film etching and deposition, modification of near-surface material, and cleaning. In particular, the challenges for plasma etching have increased as the critical feature dimensions for advanced semiconductor devices have decreased to 20 nm and below. Critical scaling limitations are increasingly driving the transition to 3D solutions such as multi-gate MOSFETs and 3D NAND structures. These structures create significant challenges for dielectric and conductor etching, especially given the high aspect ratio (HAR) of the features. Plasma etching equipment must therefore be capable of exacting profile control across the entire wafer for feature aspect ratios up to 80:1, high throughput, and exceptionally high selectivity. The multiple challenges for advanced 3D structures are addressed by Applied Material's plasma etching chambers by providing highly sophisticated control of ion energy, wafer temperature and plasma chemistry. Given the costs associated with such complex designs and reduced development time-scales, much of these design innovations have been enabled by utilizing advanced computational plasma modeling tools. We have expended considerable effort to develop 3-dimensional coupled plasma and electromagnetic modeling tools in recent years. In this work, we report on these modeling software and their application to plasma processing system design and evaluation of strategies for hardware and process improvement. Several of these examples deal with process uniformity, which is one of the major challenges facing plasma processing equipment design on large substrates. Three-dimensional plasma modeling is used to understand the sources of plasma non-uniformity, including the radio-frequency (RF) current path, and develop uniformity improvement techniques. Examples from coupled equipment and process models to investigate the dynamics of pulsed plasmas and their impact on plasma chemistry will also be discussed.

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