5. *Measurements and Models for Plasma Processing of Semiconductors*

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Objective: Develop advanced chemical and electrical measurement methods and models needed to characterize plasma etching and deposition processes important to the semiconductor industry, enabling continued progress in process optimization, process control, and model-based reactor design.

Problem: Plasma processing reactors have historically been designed and operated using empirical methods alone, but continued evolution of these tools requires a much greater reliance on process and reactor modeling. Indeed, model-based process design and control are important needs identified in the *National Technology Roadmap for Semiconductors*. To obtain more reliable predictions of the spatial uniformity, chemistry, and electrical properties of processing plasmas, further progress in model development and validation is required. Also, to enable improvements in process control, a need exists to develop sensors that are compatible with the manufacturing environment.

Approach: Our experimental program has made use of reference reactors as a testbed for validating models and testing new measurement techniques. The reactors, known as Gaseous Electronics Conference Radio-Frequency Reference Cells (GEC Reference Cells), provide a well-defined basis for comparison of measurements between laboratories. The cells are equipped with a wide variety of plasma diagnostic tools which measure the chemical, physical, and electrical properties of plasmas. Information provided by the set of diagnostics allows testing of models. Also, sensors designed for manufacturing environments can be installed on the cells and compared with diagnostic results.

Results and Future Plans: Work continues on the development of sensors for real-time monitoring of ion current and ion energy in plasma reactors. These sensors are based on rf electrical measurements, which are interpreted using models for the electrical properties of plasma sheaths. This year, a two-sheath model was developed which allows the ion energies at both the powered and grounded electrodes to be monitored simultaneously. The model was validated by comparison to measurements of sheath voltages at both electrodes and ion energy distributions at the grounded electrode. Further testing of ion energy sensors is planned for 2001.

We continue to investigate 2-D species densities in the GEC Reference Cell using 2-D planar laser-induced fluorescence (PLIF) imaging. In these studies, the concentration of CF_2 in fluorocarbon etching and chamber-cleaning plasmas is monitored as a marker of uniformity and chemistry for validation of 2-D plasma models. Recent measurements have characterized the effect of varying electrode gap on CF_2 uniformity and density. Present investigations focus on the effect of increased plasma power and the presence of a silicon wafer on the spatially-resolved CF_2 density. In 2001, we plan to extend our PLIF work to study etching plasmas in a high-density, inductively-coupled GEC cell.