**Real-Time In Situ Plasma Monitoring in Semiconductor Reactors**

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**The Challenge:** Real-time in situ monitoring of plasma intensity and uniformity in semiconductor reactors, with intuitive data presentation and data logging for follow-on analysis.

**The Solution:** Developing a mobile data acquisition system called PlasmaVIEW™, using DAQ cards, SurfaceVIEW™, and LabVIEW.

**Introduction**

The semiconductor manufacturing industry relies heavily on plasma chambers for etching, material deposition, and other processes necessary for fabricating silicon-wafer-based electronic devices. Several primary factors significantly affect the conditions inside the chamber – component gas concentrations, chamber pressure, and surrounding electromagnetic fields. Generally, a computerized chamber control system controls these parameters to successfully “strike” (create) plasma, maintain the plasma conditions for a fixed time while processing a silicon wafer, and then return the chamber to normal atmospheric conditions. The manner in which these factors are controlled during the process determines the quality and uniformity of the plasma field and thus the quality of the wafer produced.

Applied Materials, a prominent manufacturer of plasma chamber systems, produces tools that make field measurements of the conditions existing inside a plasma chamber during a typical semiconductor manufacturing process to verify that the desired conditions are being achieved inside the chamber. PlasmaVIEW (patent pending) is one of these tools developed with programming and consulting assistance from VI Technology, a National Instruments Alliance Program member.

In designing the PlasmaVIEW data acquisition system, we used several off-the-shelf components – DAQ Cards, LabVIEW, and the LabVIEW Application Builder from National Instruments, along with SurfaceVIEW™ from Metric Systems.

**System Description**

We designed the PlasmaVIEW system to perform two-dimensional, real-time monitoring of the field characteristics inside a plasma chamber; to display the readings in an intuitive fashion for the user; and to record the data for follow-on reduction and analysis. Ion flux (a measure of the flow of free ions per unit area) was the primary quantity to measure because it yields great insight into the intensity and uniformity of the plasma in the chamber.

PlasmaVIEW™

![PlasmaVIEW 3D Surface Plot of Plasma Intensity across Wafer Sensor](image)

We used a specially modified silicon wafer as our sensor. The wafer has 20 sensor tabs on its surface at various locations. We placed the sensor wafer in the plasma chamber and wired it to custom signal conditioning electronics outside the chamber through an electrical pressure barrier. After striking plasma, we apply a DC bias to the sensor tabs of the modified wafer, which causes charged particles in the plasma to be drawn out of the “soup” and to flow into the signal conditioning electronics. By measuring the charge collected in a given time (current) from a known area (sensor tab area), we calculated the ion flux of the plasma field.

The custom excitation and signal conditioning unit provides the DC voltage used to bias the sensor tabs on the modified wafer; it also amplifies the signals from the sensor into 0-10 V signals, which are digitized by the two DAQ Card-700 cards installed in a laptop PC. The unit is powered by 120 V AC or by special batteries located inside the unit for mobile or field measurements.

The PlasmaVIEW software orchestrates the data collection and the real-time display, recording, reduction, and analysis of...
As an alternative to being configured as a mobile system using a laptop with DAQ Cards, we can install the system permanently in a research lab using a desktop PC with PCI or ISA DAQ boards. In either case, the PlasmaVIEW program is identical.

Analyze Data, Edit Data Files, Calibrate Electronics, Export Data, and Exit.

In the typical sequence of an experiment, the user selects Run Experiment from the main menu. The system then performs a DAQ checkout. If the checkout is successful, the test sequence proceeds. A screen prompts the user for the conditions of the test, which are entered and recorded in the header of the data file.

The user selects one of several displays to view the data—a 3D bar graph, an intensity plot, a 3D surface, or a 2D surface profile. Additionally, some statistical data and center-to-edge variations are provided in real time. Data readings are streamed to disk at the originally specified sampling frequency; however, the user can independently adjust the display update rates in real time.

Conclusions
The PlasmaVIEW system is a very successful tool. It completely eliminates turnaround time between collecting plasma chamber data and obtaining meaningful results. Researchers can view conditions inside the plasma chamber in real time, while adjusting items, such as gas pressure regulators, RF generators, and magnetic devices. Thus, they can view the impact of these adjustments on the quality and uniformity of the plasma. With its sampling rates in excess of 50 S/s, researchers can take advantage of PlasmaVIEW to analyze nonsteady-state conditions, such as plasma formation. As an alternative to being configured as a mobile system using a laptop with DAQ Cards, we can install the system permanently in a research lab using a desktop PC with PCI or ISA boards. In either case, the PlasmaVIEW program is identical.

With clean-room operating costs at several thousands of dollars per square foot per month, and with limited plasma chamber resources in great demand, every minute of chamber time becomes extremely expensive. Innovative tools such as PlasmaVIEW give researchers, chamber designers, and process engineers a real-time insight into the sealed plasma chamber never before available.

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The PlasmaVIEW Main Menu Screen