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RIBE Flux vs. Position Monitor

Thomas W. Hamilton

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Thomas W. Hamilton
Lasers, Optics, and Remote Sensing
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-1423

Abstract

Recent work at SNL has demonstrated unique capabilities to experimentally measure a variety of ion and neutral particle parameters inside surface features being etched, including ion energy, angular distributions, ion and neutral species measurements.

This report details the construction of one recent laboratory tool designed to measure ion beam uniformity over the wafer surface in a reactive ion beam etch system, (RIBE). This information is critical to the development of accurate plasma processing computer models and simulation methods, and is essential for reducing the cost of introducing new processing technologies.

INTRODUCTION

We have designed and built a measuring tool for use in low temperature plasma chambers. The tool, designated the Flux vs. Position Monitor (FPM) provides the researcher with a real time measure of ion current at incremental radial positions above a substrate under active etching conditions.

An estimated 40% of the steps in the fabrication of microelectronics use plasma processes. Applications in flat panel displays, surface modification, cleaning, sterilization, sputter coating, and many other areas are rapidly growing, based largely on technological developments made for the processing of microelectronics.

A low temperature plasma is a partially ionized gas consisting of ions, electrons, radicals and neutral atoms and molecules. Fundamental understanding of plasma processes is now sufficiently advanced that plasma models are emerging as tools for developing new plasma equipment and processes, as well as diagnosing process difficulties. In addition, plasma diagnostics are now being implemented as process monitors, end point detectors, and process controllers to improve processing flexibility and reliability (Reference 1).

HISTORY

The FPM was designed specifically for a Reactive Ion Beam Etch (RIBE) system. Ion beam etching involves the ejection of atoms from the surface of a substrate as a result of variable angle bombardment by a beam of energetic ions. Reactive gases can be used to achieve the selectivity of plasma etching with the high degree of anisotropy associated with a physical etching process. Ion beam etching produces fine, sharp geometries. Ion beam etching produces less undercutting then wet etching and can provide precise control of wall slope. High aspect ratio etching with minimized undercutting is a state of the art issue.

The RIBE system is equipped with an Inductively Coupled Plasma (ICP) source. The desired etch gas flows into the discharge chamber at the base of the ion source. The discharge chamber consists of a quartz confinement cylinder with a cooled RF antenna coiled around the cylinder. Ions are extracted and accelerated by the potential difference between the source and the grounded sample stage. Dual graphite grids provide a means to control the divergence of the ion beam (Reference 2).

CONFIGURATION

The FPM was built within a 1¼ inch diameter tube, for ease of insertion into a plasma chamber through a standard vacuum port (Fig.1.).

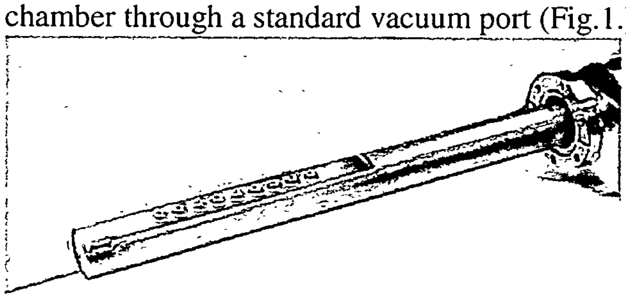

Figure 1. Tube enclosure for Flux vs. Position Monitor

Nine discrete detection pads were constructed upon a printed circuit strip (6.5" x 0.92"), with a ground plane in the area between each pad. The detection pads are isolated from the ground plane by a 0.035inch band of exposed KAPTON® film. (Reference 3). Both the pads and ground plane are covered by 0.002 inches of nickel by the electroless plating process. Figure 2 is a drawing of the FPM assembly located within the support tube.

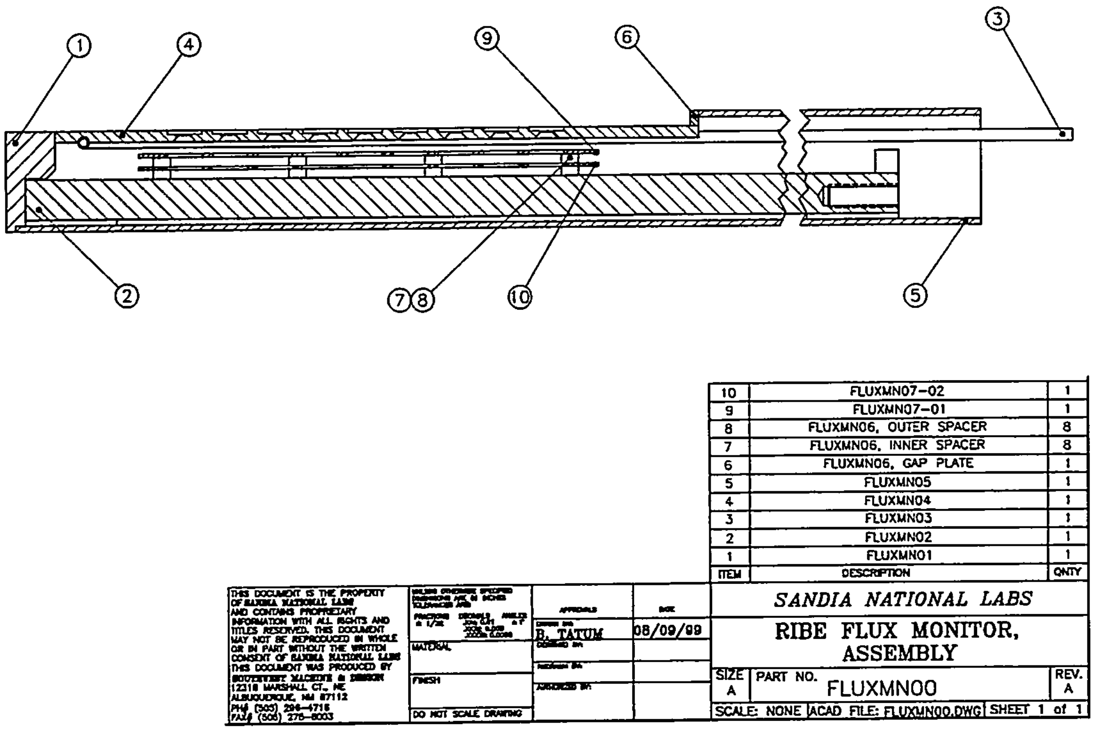

Figure 2. Mechanical Drawing, Flux vs. Position Monitor

Two wire screens (items 9 & 10) are located between the pinholes and the detection pads. The thin printed circuit strip is mounted on top of item 2 and held down by spacers (items 7,8). The screen nearest the pinholes was grounded to produce a field free drift region between the pinholes and the screen. The lower screen (item 10) closest to the detection pads, is typically biased at –10 volts. This negative potential repels and redirects any electrons that the incoming ions may have ejected from the sensor pads.

A water-cooled support welded to the 1¼ inch tube holds the pinhole apertures above each pair of screens and collection pad. One challenging exercise was to locate an adhesive to conductively bond each aperture to the support. Best performance was provided by Chemtronics brand CircuitWorks CW2400 adhesive epoxy, (Reference 4). The commercial pinhole apertures are 0.375" diameter by 0.0005-inch thick stainless steel disks. The pinholes themselves are 100 microns in diameter. These had to be electrically grounded to accommodate in-situ data collection without bias. As previously mentioned, two fine screens were placed between the apertures and the collection pads. The woven stainless steel screens had 100 openings per inch and used 0.001-inch diameter wires. Each screen had an open area of 81%, (Reference 5). Figure 3 shows a detail of the assembled detection pads and screens.

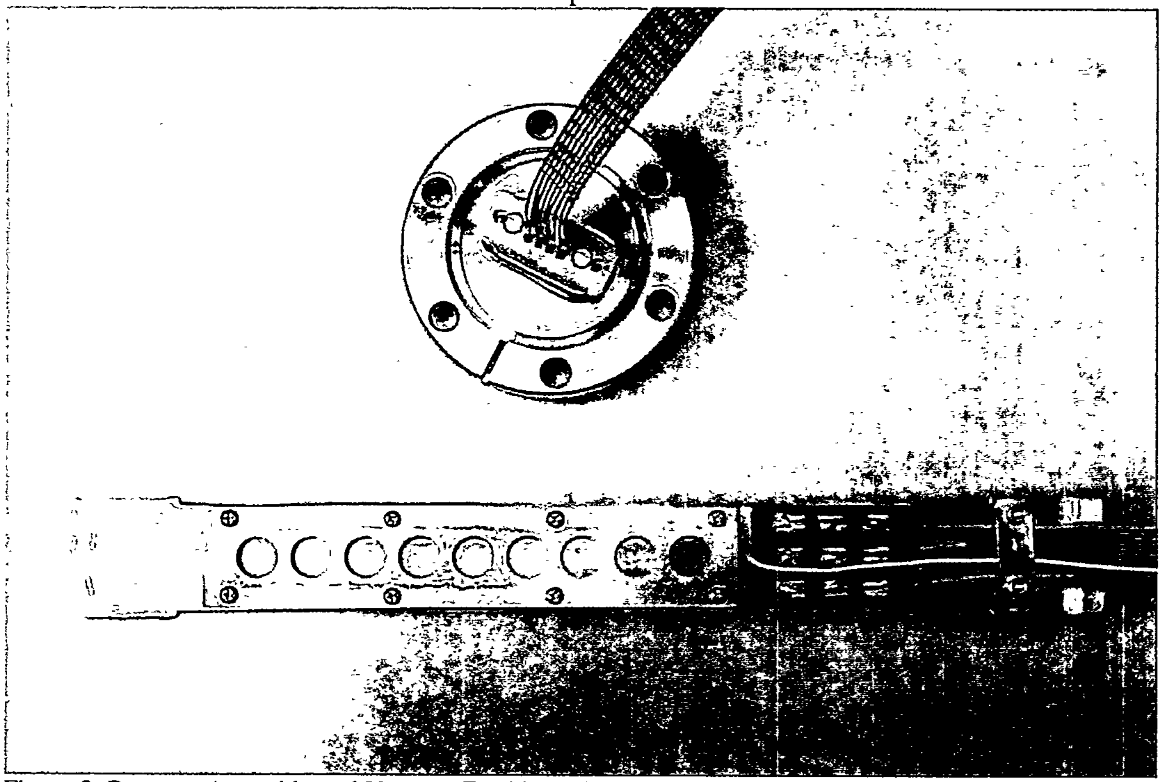

Figure 3. Detector Assembly and Vacuum Feedthrough.

Small rectangular contacts, the in vacuum ribbon cable, and the "D-style" vacuum feed through are also visible. Figure 4 shows how the wire screens are spot-welded onto the stainless steel holders.

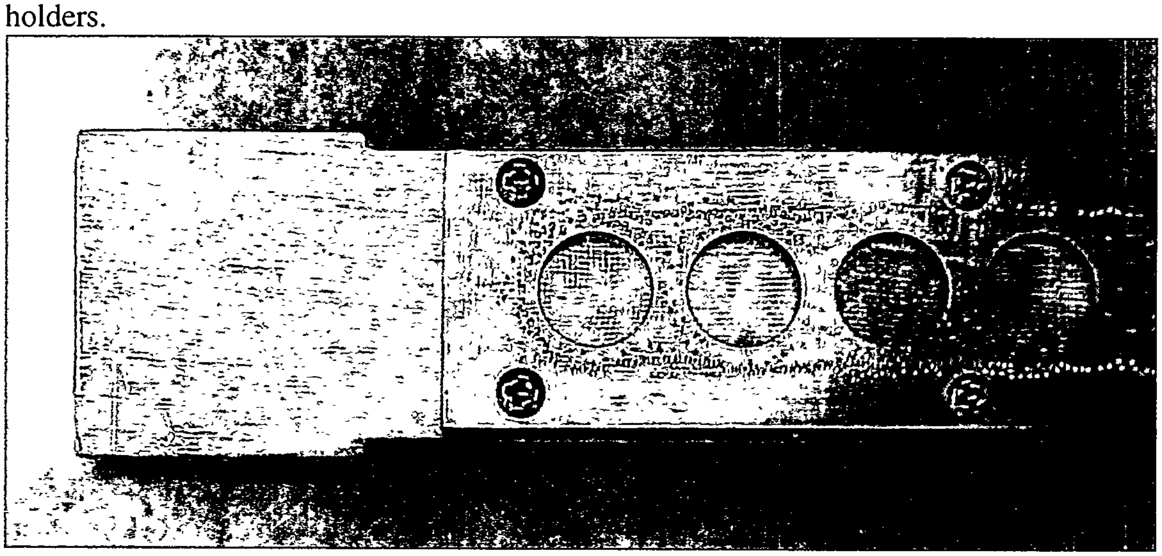

Figure 4. Topmost Wire Screen, Showing Spotwelding Detail.

Care was taken to use only vacuum compatible materials. A vacuum sub-system was required to evacuate the interior of the FPM to a pressure below 1 x 10^{-4} Torr. This "differential" pumping scheme is designed to keep the detector section clean, and to reduce stress on the weakly supported, thin pinhole membranes.

APPLICATION

In practice the FPM detects ion flux during active etching conditions within a plasma chamber at nine discrete points almost simultaneously. An ion, which has passed through a small aperture and the screens, hits a sensor pad and induces a measurable current. The current passes through a scanner system (Keithley 6512) which connects one detection pad at a time to the input of a Keithley 6517 electrometer. Signals are read from the electrometer to a computer operating LabVIEW software, over a GPIB buss connection. Figure 5 shows an electrical schematic of the system.

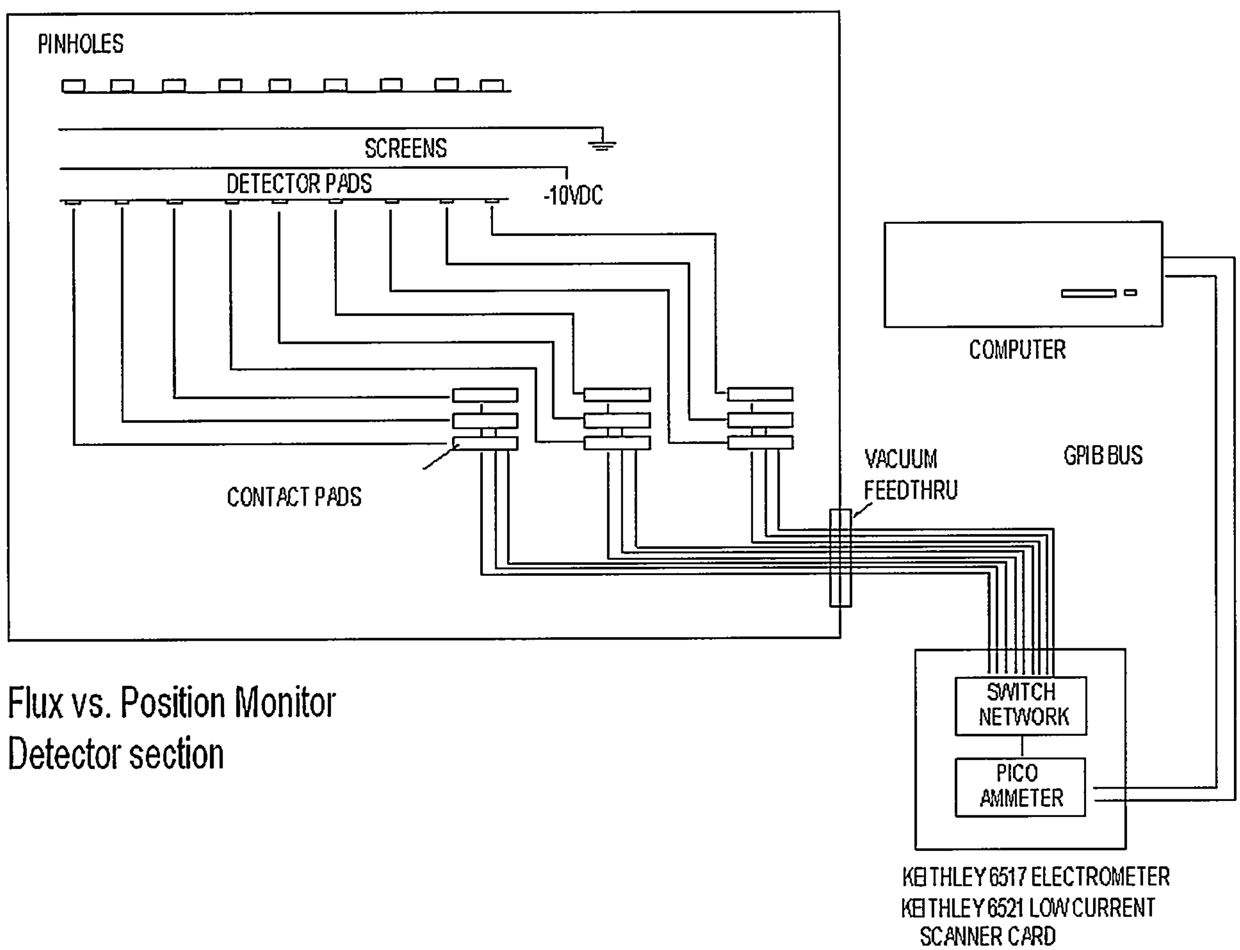

Figure 5. Flux vs. Position Monitor, System Electrical Schematic.

When the FPM was tested in a Gaseous Electronics Conference Reference Cell, (Reference 6), operating conditions for the bulk plasma generated above the apertures was generally: Argon gas at 20 millitorr pressure, 300 watts RF excitation. For these settings the known ion energies approach 20 volts. Under these conditions the average current on the sensor pads was about 0.7 nanoamps, (Reference 6).

Support equipment includes a water chiller, vacuum pumps, pressure monitoring instruments, an electrometer, computer, and power supply.

Data acquisition programs using LabVIEW software were written by Ben Aragon, (Dept. 1118) to include elective sample averaging, adjustable wait time between samples, on screen bias voltage adjustment, and automatic scaling features. The program may be located under the Virtual Instrument folder; Lab VIEW VI Library named RIBE, as file Vawter Current vs. Position Keithley 6517A. Figure 6 is a screen print of a sample data acquisition run.

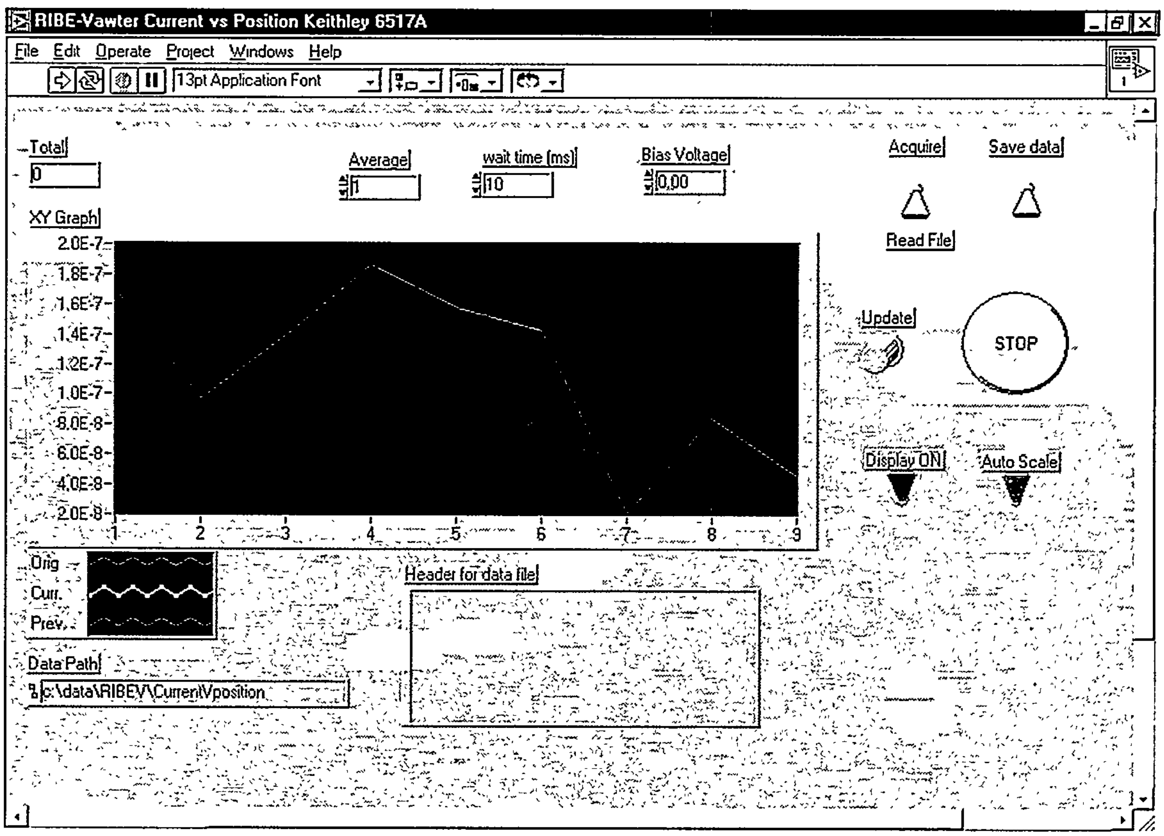

Figure 6. Sample Data Acquisition Run

The vertical axis indicates current, while the horizontal axis indicates the relative position of each detector as it samples ion flux linearly across the chamber. Each of the nine discrete sensors is spaced 0.47 inches apart. The time interval between each detector point is approximately 11 milliseconds, with an initial trigger to read delay of 350 milliseconds. The operator may select data averaging and choose various wait times between successive samples.

ACKNOWLEDGEMENTS

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Personnel who contributed to the project include Joseph Woodworth (Dept. 1118), Ben Aragon (Dept. 1118), and Alan Vawter (Dept. 1742).

Additional design, welding, mechanical fits, and machining was provided by Bill Tatum of Southwest Machine and Design, (Reference 7). Miscellaneous vacuum fittings were produced by Scientific Sales Associates, Albuquerque N.M. The printed wiring board was fabricated at General Technologies Corporation, Albuquerque, NM.

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3. KAPTON® a polyimide film by DuPont is an electrical insulation material with outstanding thermal, mechanical, chemical and electrical properties.

4. Chemtronics 1-800-645-5244, or www.chemtronics.com, available in Albuquerque at Electronics Parts Co.

5. Screen material available from Unique Wire Weaving 908-688-4600, or www.uniquewire.com .

6. GEC Reference Cell Publications are available at http://physics.nist.gov/MajResProj/rfcell/pubs.html.

7. Southwest Machine and Design (swmachdsn@aol.com)

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