# Model PC-2000

# Plasma Trimming Applications

US Patent No. 5,510,624*

SBT
TEM Sample
Preparation

## The PC-2000 Plasma Cleaner

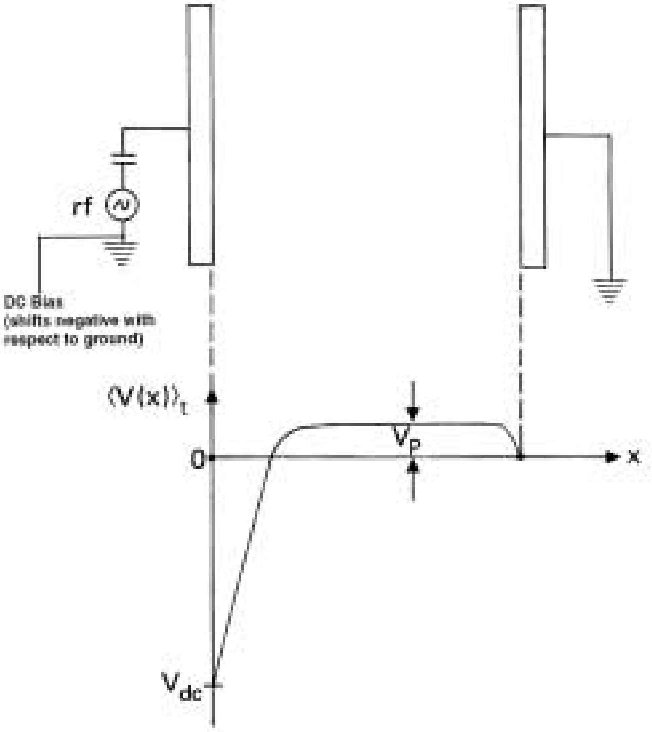
In recent years plasma cleaning technology has become a standardized method for preventing and eliminating hydrocarbon contamination from the surfaces of electron microscopy specimens and specimen holders. With the advent of high beam current, high current density electron microscopes, minute amounts of hydrocarbon contamination have become a nuisance during imaging of specimens, creating large deposits on the specimen surface which are difficult to remove. The application of a reactive and inert gas plasma has proven to be an excellent method in removing hydrocarbon contamination before it can become deposited onto the specimen surface. Recent advances have shown that other interesting applications can be applied to traditional methods to enhance specimen throughput and success rate. This paper will describe applications of the Model PC 2000 for Plasma Trimming.

## Plasma Basics

A plasma is an ionized, conductive, gaseous form of matter in which ions, electrons, and neutrals coexist simultaneously. A plasma is generated when a strong electromagnetic field interacts with a reduced pressure gas contained in a specific volume. The field can be produced by DC, RF, or microwave generators with the net effect causing electrons to be removed from the reduced pressure gas near any electrode surface. The electrons are then accelerated by the same imposed field through the remaining gas and loose energy through collisions with other gas molecules, forming a variety of active species including electrons, free radicals, ions and neutral atoms. Plasma generation using RF frequencies operating in the 13.56 MHz range are most commonly used for low power plasma cleaning and etching processes. Capacitively coupled plasma generation uses an electrode immersed into the working chamber area, with the surrounding chamber walls acting as ground. A reactive or inert gas is bled into the chamber at a fixed rate and the chamber volume is pumped down to an operating pressure of approximately 200 millitorr. The power of the plasma can be increased using a control knob and affects the energy of the gas species generated within the system. Based on the applied power and chemistry of the plasma/specimen interaction, both specimen cleaning and specimen thinning can occur depending upon the input settings (1,2).

## Plasma Trimming$^{TM}$

Plasma Trimming$^{TM}$ is a technique by which material is removed from a TEM specimen by use of a moderate energy Ar plasma discharge. By using an Ar gas plasma, the sample can be thinned very, very slowly and in an extremely controlled manner. This allows further thinning of specimens that have been previously ion or FIB milled to



Schematic illustration showing the basic configuration of plasma generating system with approximate time averaged potential versus distance. (Adapted from Plasma Etching and Reactive Ion Etching, AVS Monograph Series, J.M Coburn)

SBT SOUTH BAY TECHNOLOGY INC.
1120 Via Callejon, San Clemente CA 92673 USA
Voice: 949 . 492 . 2600 • FAX: 949 . 492 . 1499 • Sales: 800 . 728 . 2233
e-mail: sbt@southbaytech.com • Visit us at http://www.southbaytech.com

remove surface damage, ion milling defects or surface artifacts.

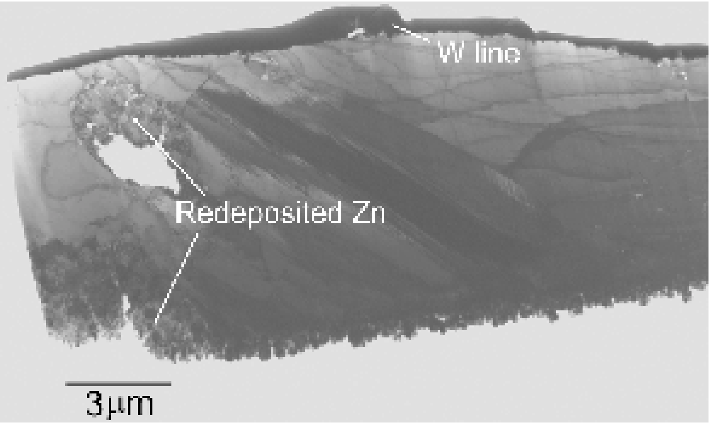
## Plasma Trimming$^{TM}$ Process

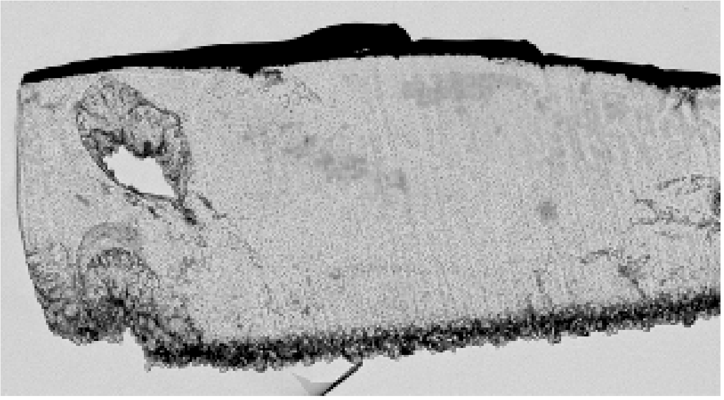
The Ar gas plasma used for this process is a moderate energy discharge creating an isotropic thinning profile. Since Ar is inert, the Plasma Trimming$^{TM}$ is strictly a physical removal process and not a chemical reaction on the specimen. This also means the plasma discharge is non-selective, attacking everything in the chamber with equal force. The energies used for this application do not have sufficient power to dislodge stainless steel or aluminum molecules and present no danger in etching or modifying specimen holding devices. For Plasma Trimming$^{TM}$ to be completely effective, the TEM specimen must be "suspended" in the plasma discharge. This is accomplished using a common ion milling stage, whereby the specimen is supported on the edges and the center open on both the top and bottom. Using the South Bay Technology Model PC-2000 Plasma Cleaner, argon is bled into the working chamber to achieve an operating pressure of approximately 200 millitorr. The system termination timer is set at 10 minutes and the RF discharge started. The system is operated at approximately 75 watts of forward power with the reflected power reduced to the minimum allowable setting. Following termination the specimen thickness can be measured using EELS and the subsequent etch rate can be determined.

## Applications to FIB Lift Out Specimens

Specimen preparation for semionductor and other difficult materials is commonly performed using focused ion beam (FIB) tools. FIB instruments utilize an accelerated beam of $Ga^+$ directed at the specimen approaching 30 keV. The advantages FIB offer are high milling rates, in situ observation of the specimen during milling, and finely focused probes. However, the specimen is not always as thin as desired and under normal operating conditions the specimen cannot be reinserted into the FIB tool for further thinning. With Plasma Trimming$^{TM}$ specimens can be thinned further to obtain the desired specimen thickness for TEM imaging. Thi is highly advantageous for FIB Lift Out specimens as further processing can be carried out without the need to begin preparing a new specimen(3).

The Plasma Trimming$^{TM}$ technique is suitable for a wide range of TEM specimens, to accurately thin the specimen after ion milling or FIB has been completed. It is useful in removing surface damage, revealing specific surface structures, and further thinning of the specimen. With the versatility of the SBT PC-2000, all of the required process parameters are displayed on the front panel and controllable. This allows repeatable custom Plasma Trimming$^{TM}$ recipes for each type of sample encountered. Overall the process is easy to accomplish and quick to implement.





TEM images of a ZnO FIB Lift Out specimen. The top image was taken immediately following FIB milling, while the image at the bottom was taken following Plasma Trimming$^{TM}$. Based on the change in image contrast it is clear that the Plasma Trimming$^{TM}$ process has thinned the specimen and made the specimen much more suitable for TEM imaging. (Images courtesy L. Gianuzzi, S. Collins, B. Prenitzer from AVS publication; see Reference 3)

## References

1. Plasma Processing of Specimens for Electron Microscopy and Microanalysis; N. Zaluzec, 1999.
2. Application of Reactive Gas Plasma Cleaning in Mitigating Contamination of Specimens During TEM and AEM. S. Roberts; S. Walck; N. Zaluzec; J. Grant; MRS Vol. 480, 1997.
3. In Situ Transformation of a Zinc TEM Lift Out Specimen. B. Prenitzer, S. Collins, L. Gianuzzi; AVS 1999.
4. Plasma Etching and Reactive Ion Etching. AVS Monograph Series, J. Colburn.