A Clean SEM System - Why and How

Charles E. Bryson III, Surface/Interface, Inc.

If you were to examine surfaces in a typical SEM system using any number of surface analysis techniques, I think you'd be surprised at the results. You might expect to see all materials used to construct the vacuum chamber (e.g., plastic or stainless steel), but frequently the spectra will show mostly carbon, the most frequent culprit of SEM contamination. Carbon is adsorbed onto the walls of the vacuum chamber and builds up on the sample, thereby contaminating the SEM system and compromising image quality. By manufacturing and maintaining a clean SEM environment, this problem can be avoided, and you will increase the overall performance of your SEM system.

Cleanliness of the SEM environment is important because it can increase the resolution and accuracy of your SEM system while, at the same time, decreasing required maintenance. For example:

1) When taking spatial measurements, carbon contamination changes the dimensions of features on the sample and inhibits accuracy. SEM techniques are now being used more frequently for critical measurements. For example, as line widths in semiconductor designs shrink below 0.8 µm, more people will be turning from optical inspection techniques to SEM for critical dimension measurement. To ensure a high level of accuracy, the SEM environment must be kept clean.

2) The build-up of carbon and other contaminants on the sample puts a layer of material with a lower atomic number (i.e. carbon) on the surface of a sample that typically has a higher atomic number. Resolution, however, is dependent on the sample - the higher the sample's atomic number, the better the resolution. Therefore, when the sample is coated with a contaminant such as carbon. . .resolution is adversely affected.

3) A clean SEM environment makes the system easier to focus because carbon doesn't build up on the sample, and users don't have to keep moving the beam to new positions to get a clear resolution.

4) A clean SEM environment means less SEM maintenance. Without contaminants in the environment, there is a longer time between liner cleanings. Filament life is also extended because there is a reduced amount of materials present which could either bombard the filament or oxidize on its surface.

Sources of contamination of the SEM system result primarily from excess gases in the vacuum chamber. The sources of these gases include outgassing from materials in the chamber, leaks, and backstreaming. Eliminating these gases is vital to a clean SEM environment.

Design Issues

The materials used to manufacture the SEM system are often the biggest culprits of outgassing and its corresponding contamination. O-rings should be avoided whenever possible because they are 3% water by weight and can introduce a significant amount of carbon into the system, usually through lubricants. All-metal gaskets should be used instead. When insulating wires and light pipes, plastic should either be Teflon or polyimide, or replaced with ceramic. These materials, while they may be initially more expensive, have a lower cost of ownership because they significantly lower contamination, thereby reducing maintenance and resulting in better SEM performance.

Whenever practical, the SEM system should be designed without complicated shapes and pumping pathways. This will eliminate trapped volumes that cause contamination.

Manufacturing Issues

The manufacturing process should be kept as clean as possible. Any procedure that leaves residues of grease, oil, or glue should be avoided.

The finish of all parts in a SEM system is also an important aspect of cleanliness. The finish keeps materials from absorbing or outgassing hydrocarbons. Electropolishing and air baking are two very effective techniques to improve the finish of materials.

Operational Issues

It is difficult, but not impossible, to effectively clean a SEM system once it is contaminated, so every effort should be made to keep a system clean. Cleanliness can be maintained by adding and adjusting a few key procedures.

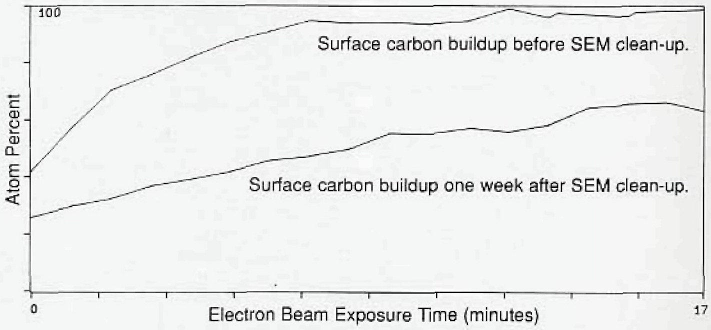
1) Many existing SEM systems use buna N O-rings. Where O-rings are still necessary, the buna N O-rings should be replaced with Viton® O-rings installed without grease when static and very lightly lubricated if moving. Grease is too often used to fill in gaps, and a switch to dry Viton O-rings may necessitate the correction of rough sealing surfaces and insufficient compression, problems that should be corrected anyway.

2) Replace the mechanical roughing pump with a dry pump or add traps and metal hoses to eliminate rough pump backstreaming. Traps, if used, should be cleaned on a regularly scheduled basis. A loadlock system should be incorporated to avoid opening the chamber and contaminating the environment from repeated venting to air, and the system should be maintained above transition pressure between molecular flow and laminar flow, even when not in use. When using a leak detector, a dry pump is preferable to oil pumps, which can also introduce contamination.

3) If the chamber must be opened, several procedures would be observed. The inside of the chamber should never come in contact with bare hands or arms - clean, properly treated gloves and sleeves should be worn when handling internal components. Any parts or samples that are taken out of the chamber should be wrapped in fresh aluminum foil to keep them clean. After opening the chamber, it should be backfilled with nitrogen or helium to purge as much water as possible from the system before samples are loaded.

The Results

Careful attention to design and maintenance, as described above, will result in a significant reduction in carbon build-up in your SEM system. The graph below shows the reduction in carbon build-up over time, as measured by our AES system, in a cleaned-up SEM verses the same system prior to clean-up - and the results improve with time. In the cleaned-up AES, after a month, less than 5% build-up was detectable by AES analysis.



A clean SEM system means that equipment will be easier to focus, maintenance will be cheaper and less frequent, and accuracy and resolution will increase. In short, cleanliness will enable you to get the most from your SEM system. ■

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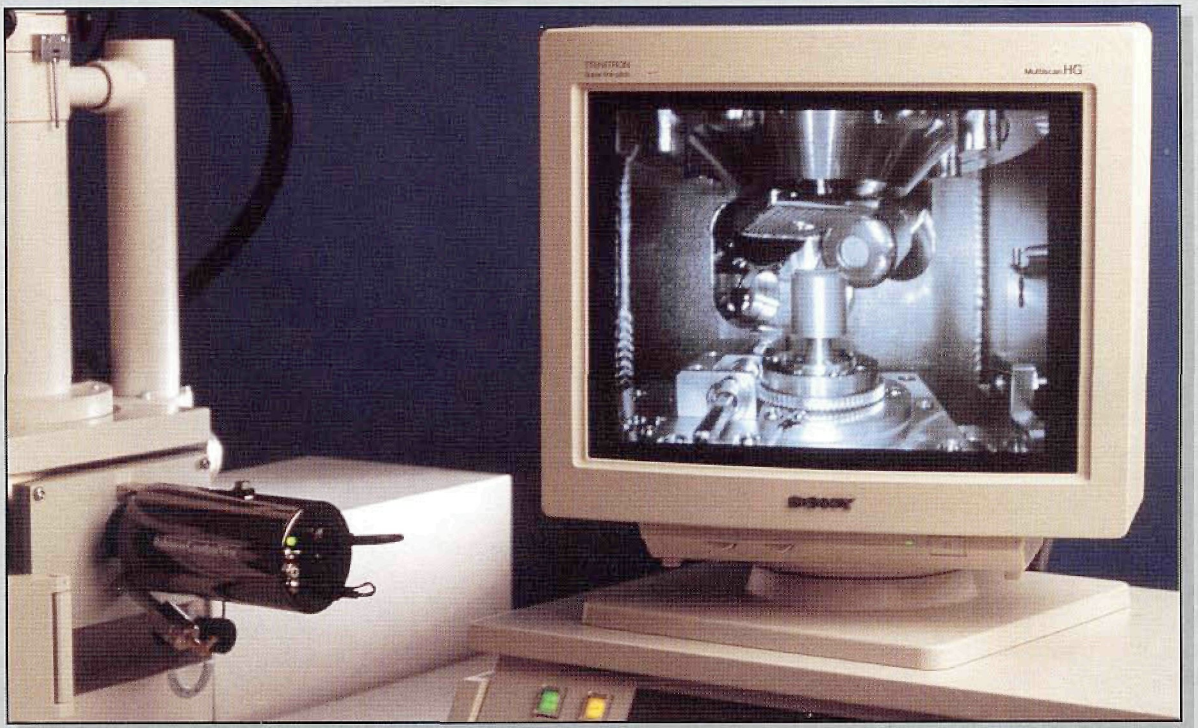

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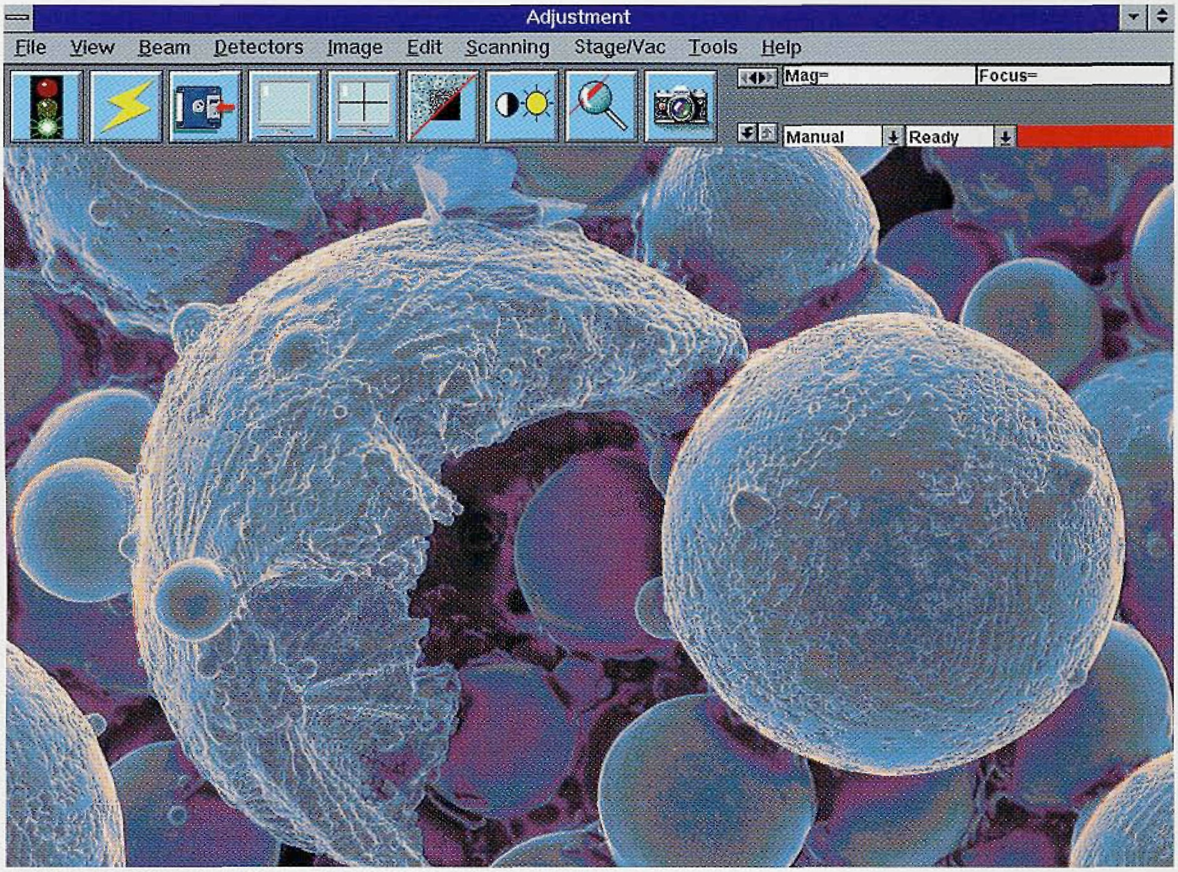

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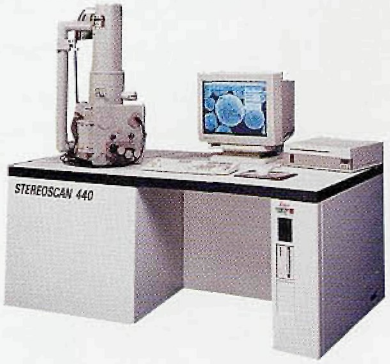

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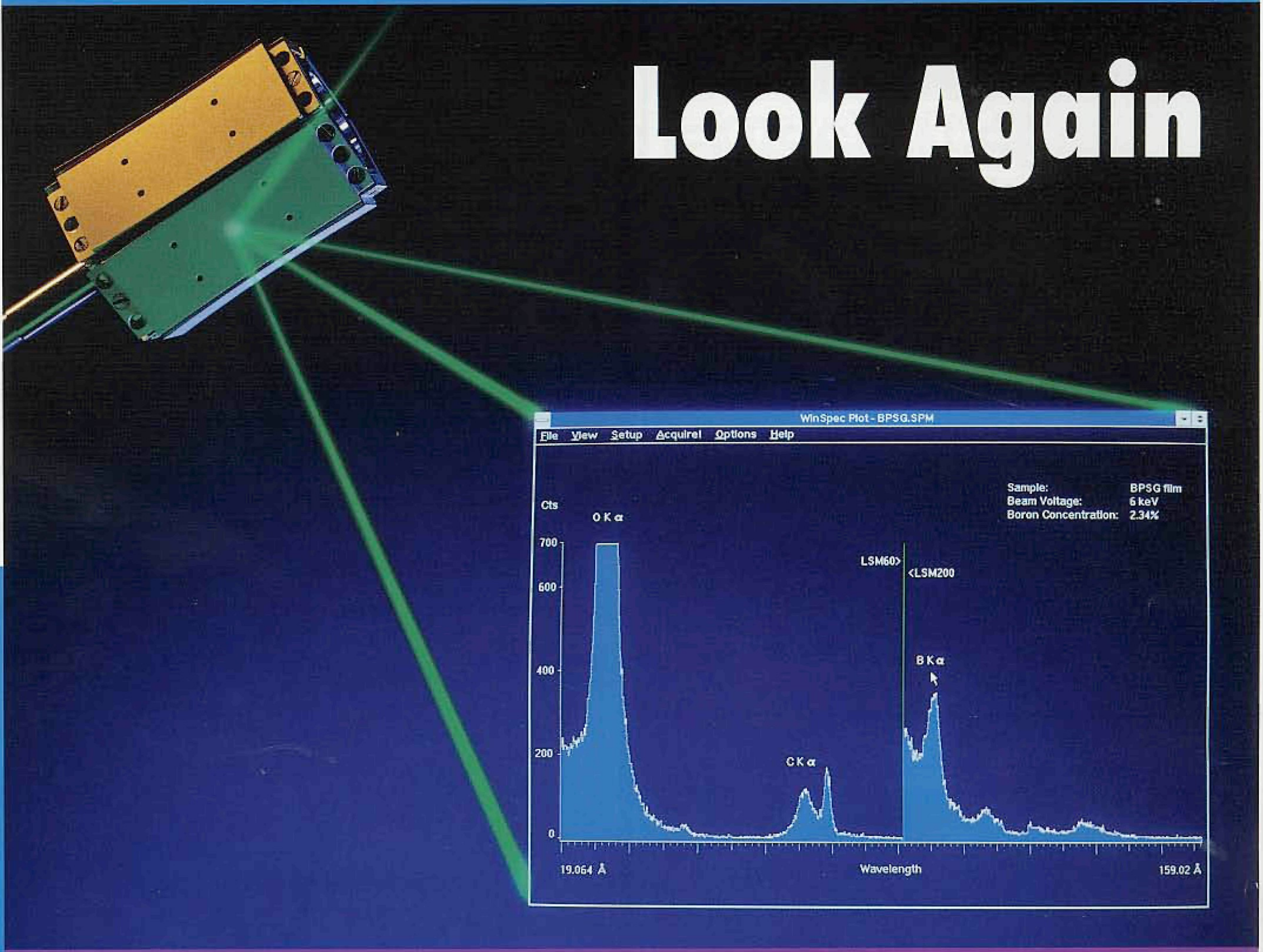

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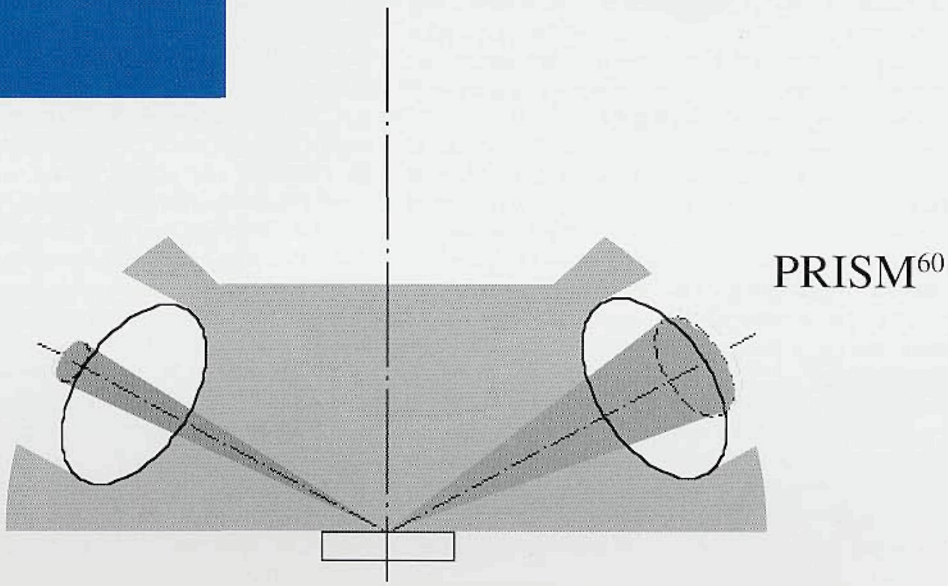

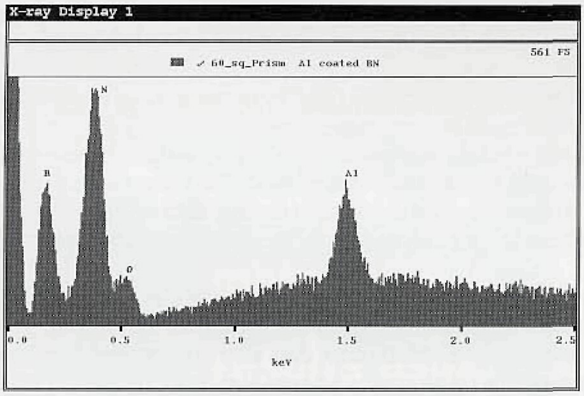

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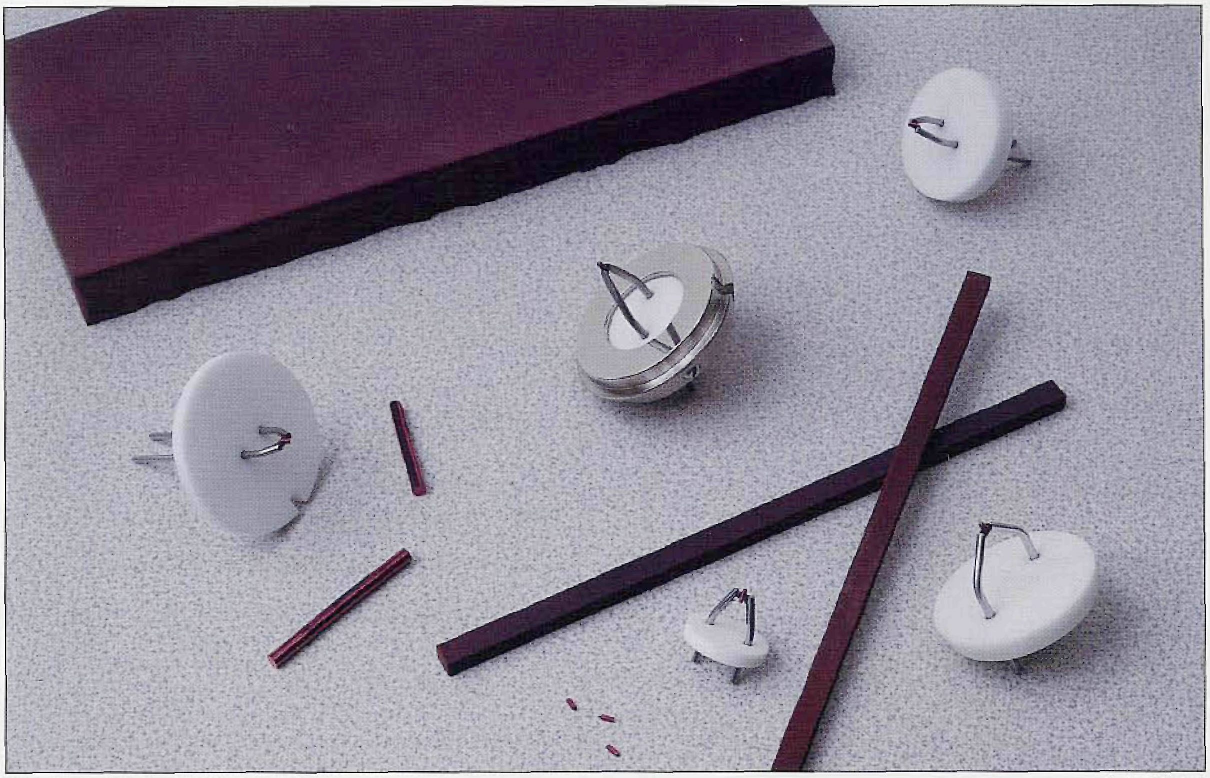

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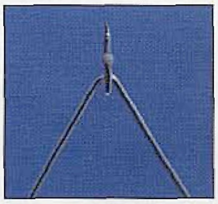

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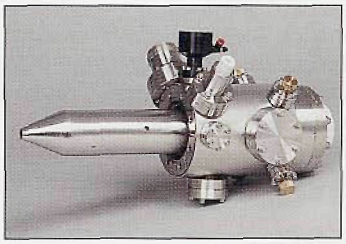

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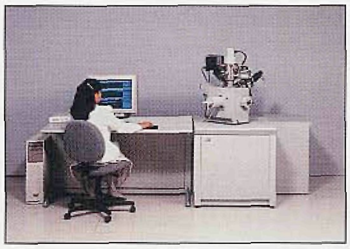

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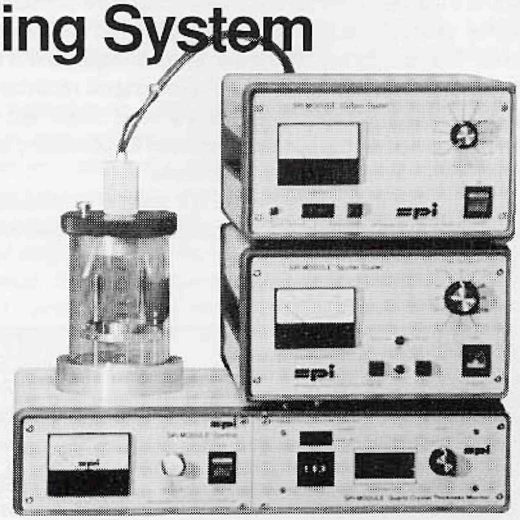

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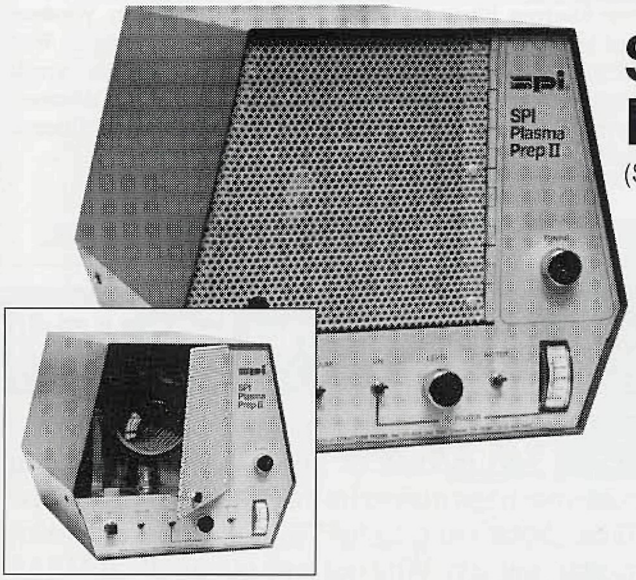

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