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PLASMA CLEANING, END-OF-PROCESS DETECTION

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SUMMARY

Activated gas plasma is being used extensively to remove trace organic contamination from electromechanical components prior to final assembly. Optical emission techniques are being used throughout the electronics industry to determine end-points of plasma processes for removing large amounts of photo-resist. The application of these techniques to detect the removal of trace organic residues was shown to be possible using a borrowed process monitor. Removal of organic contamination as low as 5 mg total was detected in an oxygen plasma. Auger analysis confirmed the cleanliness levels indicated by the end-point detector tested. The simplicity of this type of process monitor lends itself to production line use for the plasma cleaning of various parts and batch sizes. The monitoring of argon plasma cleaning processes using optical emission techniques has also been investigated.

INTRODUCTION

Removal of organic contamination from electrical and electromechanical components traditionally has been performed using acids and organic solvents. However, with the advent of increasingly sensitive devices, wet chemical cleaning of some materials is not satisfactory where trace contaminants can cause failure in electronic assemblies. In many cases, activated gas plasma can complete cleaning jobs left unfinished by acids or solvents. Plasma cleaning is particularly effective for removing the last traces of organic contaminants from materials or assemblies having inaccessible areas. The electronics industry is finding increasing use for gas plasma in etching, plasma polymerization, surface preparation for bonding, and surface cleaning. At The Bendix Corporation Kansas City Division, most plasma development work has been concerned with surface preparation[1] and cleaning[2].

Plasma is a condition in which a gas, subjected to an electrical field, is excited on an atomic level. When excited, the gas forms ions, free radicals, or other reactive species. The excited gas, when in contact with organic contamination, can break bonds to form smaller molecules which are swept away by the flowing plasma gas. Under vacuum, the gas can be excited at room temperature and below, so that heat build up or damage to parts from a hot environment is not a problem. Different gases react differently to electric fields and very little is known about the actual mechanisms by which activated gas plasma cleans.

A wide range of materials, in the form of various parts and assemblies with varying degrees of contamination, are plasma cleaned at Bendix. Different organic contaminants are removed at different rates so that current plasma processes tend to "overkill" by using, in some cases, more plasma treatment than is necessary to do the job. For this reason, the use of an optical emission-type, end-of-process detector to monitor plasma cleaning was investigated.

Optical emission spectroscopy is being used throughout the electronics industry to determine end-points of plasma processes that remove large amounts of photo-resist.[3] The simplicity of this type of process monitor is evident in Figure 1. A monochrometer or filter allows the detector to be exposed to only a narrow bandwidth of the light emitted by the plasma. The detector would be attached directly to glass or quartz reaction chambers. Most aluminum chambered machines are equipped with a quartz viewing port.

Since organic contaminant removal by activated gas plasma usually produces CO, CO_2, H_2O and other small molecules, the emission bands corresponding to those molecules, when excited, are monitored. The concentration of a reaction product in the plasma determines the intensity of light emitted in that band. The detector sends a light intensity proportional signal to the strip-chart recorder which records a trace indicative of the amount of contamination being removed. Detecting the removal of very small amounts of organic residues was shown to be possible with the cleaning of small ceramic insulators and small metal Z-bars. Tests were run at a vendor's facility, monitoring parts cleaned in a capacitively coupled oxygen plasma. Auger analysis was done at Bendix.

EXPERIMENTAL

The alumina ceramic parts, a ring and a disk, are each contaminated with approximately 0.5 mg of the paraffin wax used to hold the parts while they are being machined. Figure 2 is an Auger scan of a representative ceramic before plasma cleaning. It shows the carbon peak caused by organic surface contamination remaining after normal wet chemical cleaning by the part supplier. Ten of the ceramic rings were plasma cleaned while being monitored by the end-point detector. Figure 3 shows a computer enhanced graph of the detector trace produced during that cleaning run. Due to extremely fast removal of the paraffin in the plasma, no initial build-up signal was recorded. Instead, a gradually declining signal indicated that most of the organic contaminant was removed in the first few minutes. After 15 minutes, the detector signal remained relatively constant

and the ceramics were removed for Auger analysis. Figure 4 shows the absence of the Auger carbon peak, indicating removal of all detectable organic contamination.

Ten of the ceramic disks were then plasma cleaned in the same manner as the rings. Figure 5, the computer enhanced detector trace of that cleaning run, indicates a declining concentration of contaminant reaction products similar to the previous cleaning trace, Figure 3. The ceramic disks were also cleaned for 15 minutes, until the detector signal remained relatively constant. As with the ring-shaped parts, Auger analysis of the ceramic disks indicates a thorough removal of organic contamination (Figure 6).

Analysis of the detector trace, Figure 5, suggested that after 5 minutes, the plasma cleaning process was still removing significant contamination and that almost no significant contamination remained after 8 minutes. In order to test the accuracy of the detector trace, Auger analyses of parts cleaned at 5 minute and 8 minute process times were done. Analysis of the parts cleaned for 8 minutes, Figure 7, indicated that most detectable organics were gone. Analysis of parts cleaned by the same process for only 5 minutes, Figure 8, showed that some organic contaminant still remained. The Auger analyses confirmed the results indicated by the detector trace.

In order to test the versatility of the detector, a metal substrate having a different contaminant was test cleaned. Z-bars made of Neyoro G gold alloy were plasma cleaned after being contaminated with a low viscosity lubricating oil. Figure 9, an Auger scan of a typical Z-bar before plasma cleaning, showed a significant carbon peak, indicative of organic surface contamination. The computer enhanced detector trace of the metal Z-bar cleaning run, Figure 10, indicated that the oil initially was removed slower than the paraffin, as evidenced by the peak intensity occurring at about 45 seconds into the test. However, the oil contamination, being in smaller quantity than the paraffin, was gone after about 3 minutes. An Auger scan of Z-bars cleaned for 2 minutes, Figure 11, shows a small amount of organic contamination remaining as indicated by the detector trace.

CONCLUSIONS

The results of this investigation show that optical emission, end-point detection can be used to monitor the plasma removal of small amounts of organic contamination associated with most electromechanical final assemblies. The device is simple and small enough to be made integral with the plasma

machine. The detector output trace is simple, straightforward, and of sufficient accuracy to be usable by production personnel for routine cleaning operations.

Some plasma cleaning processes are limited to non-reactive gases such as argon or helium. Some work has been done and investigations are continuing concerning the feasibility of using optical emission techniques for monitoring organic contamination removal in argon plasma. It is felt that by monitoring the proper emission bands, end-point detection can be accomplished for plasma cleaning with non-reactive gases as well as with oxygen.

Plasma cleaning offers unique opportunities to the electronics industry. Rapid low temperature removal of organic contamination to produce atomically clean surfaces can lead to higher standards of cleanliness and reliability for present and future designs. Optical emission end-point detection makes plasma cleaning a true production cleaning system.

REFERENCES

[1]L. C. Jackson, Effects of Gas Plasma on Printed Circuit Board Materials (Topical Report). Bendix Kansas City: BDX-613-2030 (Rev.), November 1979 (Available from NTIS).

[2]M. D. Smith, Effect of Various Gas Mixtures on Plasma Cleaned Ceramics (Final Report). Bendix Kansas City: BDX-613-2107 (Rev.), March 1979 (Available from NTIS).

[3]B. B. Stafford and G. J. Gorin, "Optical Emission End-point Detecting for Monitoring Oxygen Plasma Photoresist Stripping", Solid State Technology, September 1977, p 51.

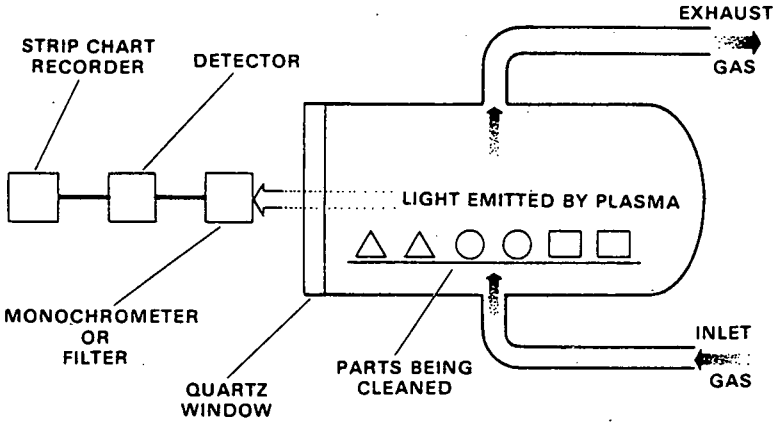

Figure 1. Schematic of Optical Emission Detector System

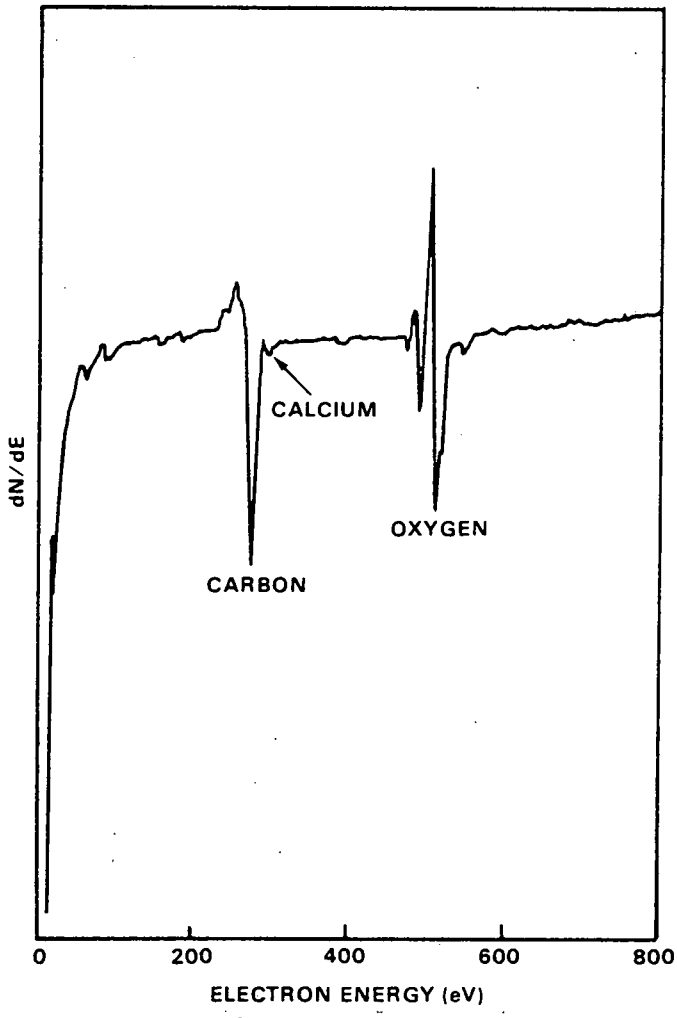

Figure 2. Auger Scan of Typical Contaminated Ceramic

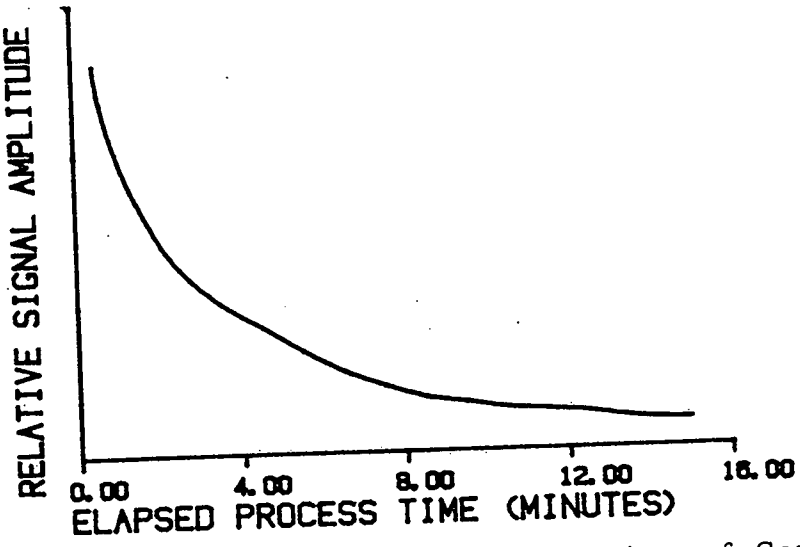

Figure 3. Detector Trace Cleaning of Ceramic Rings

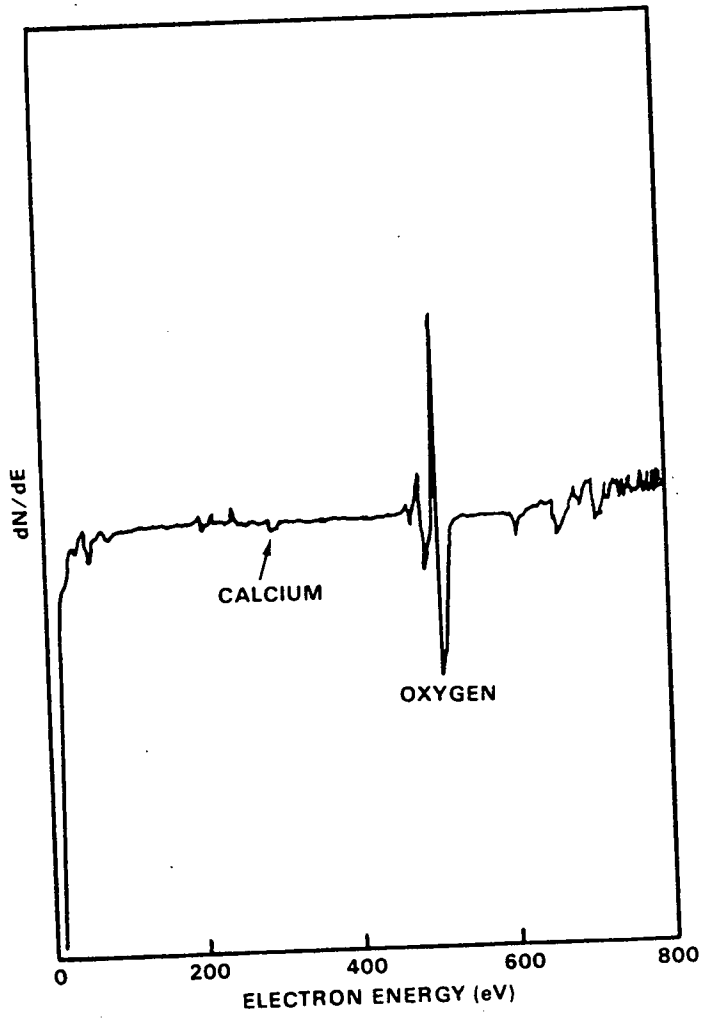

Figure 4. Auger Scan of Plasma Cleaned Ceramic Rings, Cleaned 15 Minutes

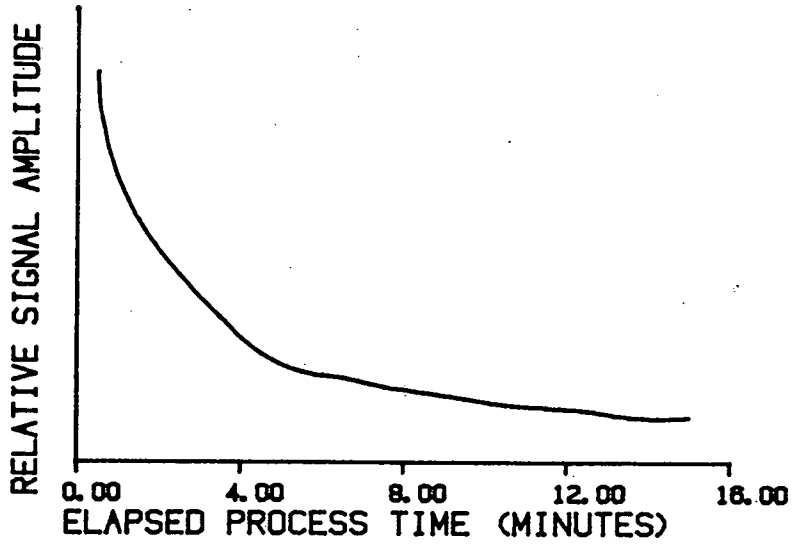

Figure 5. Detector Trace Cleaning of Ceramic Disks

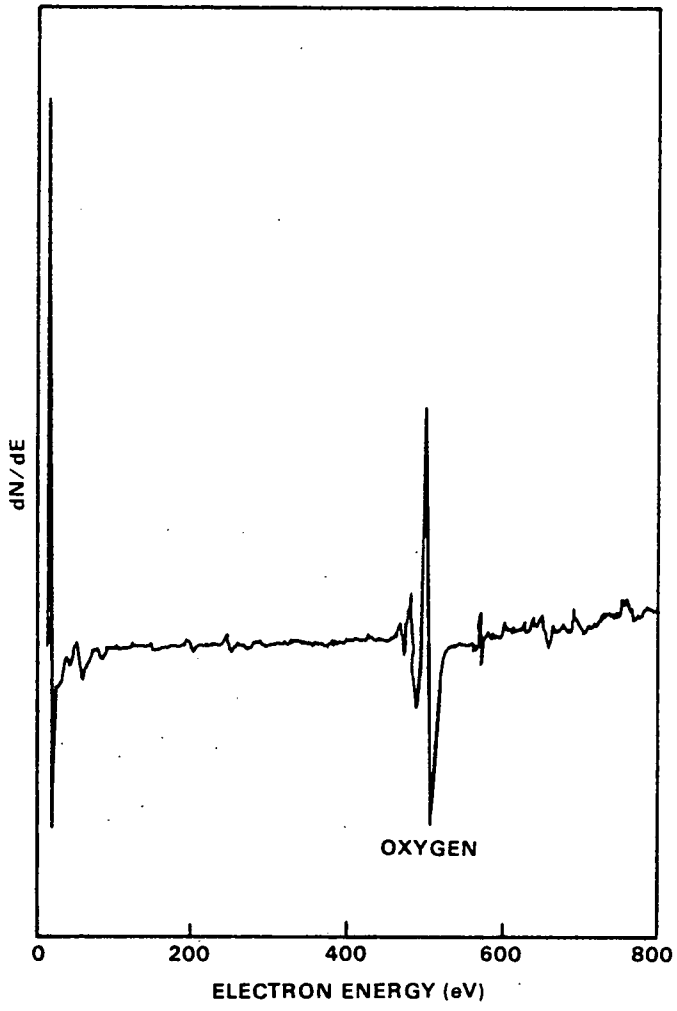

Figure 6. Auger Scan of Plasma Cleaned Ceramic Disks, Cleaned 15 Minutes

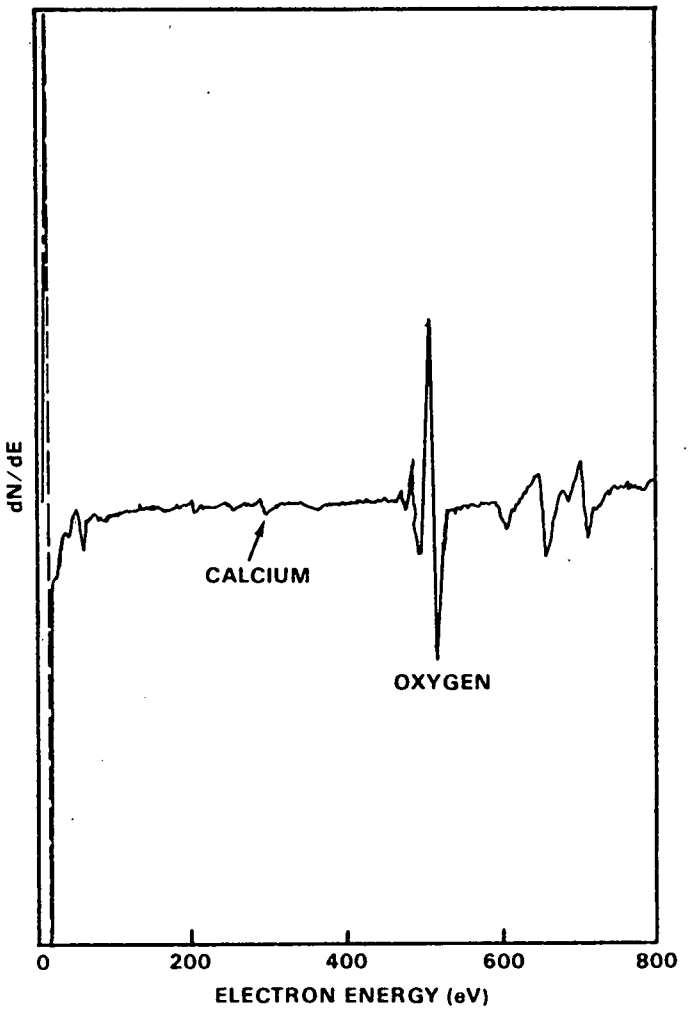

Figure 7. Auger Scan of Plasma Cleaned Ceramics, Cleaned 8 Minutes

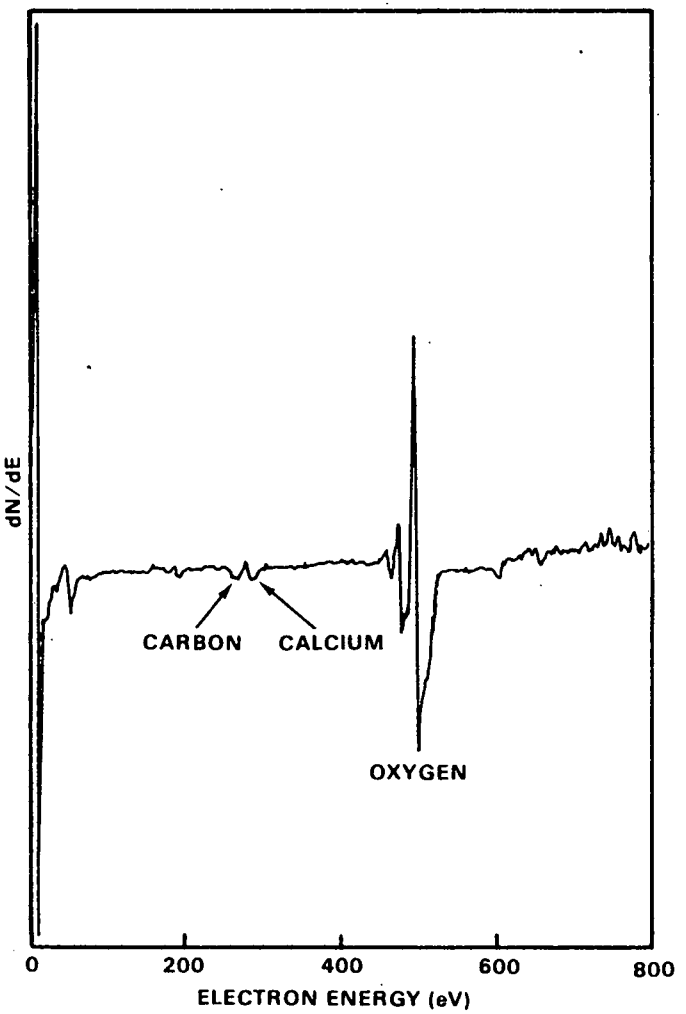

Figure 8. Auger Scan of Plasma Cleaned Ceramics, Cleaned 5 Minutes

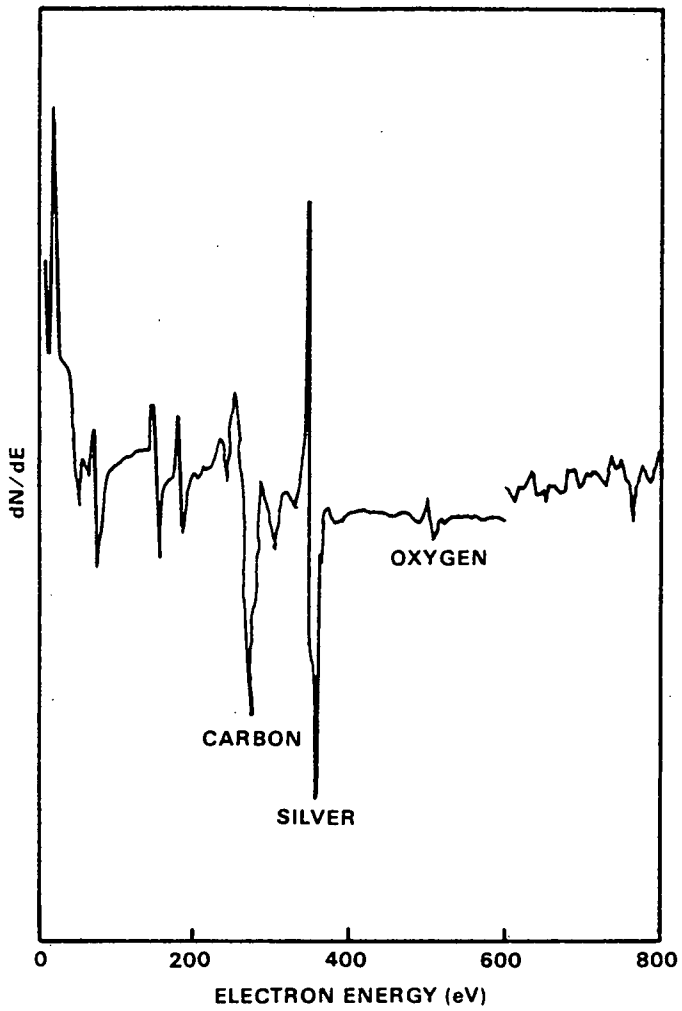

Figure 9. Auger Scan of Typical Contaminated Z-Bar

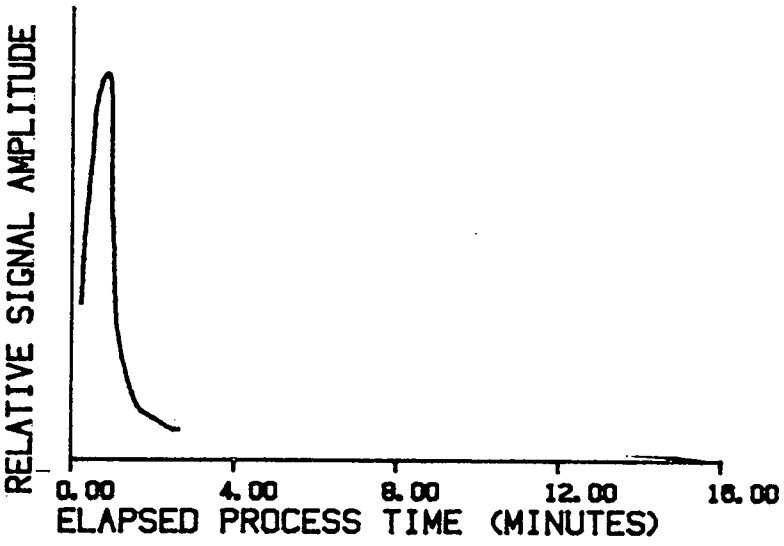

Figure 10. Detector Trace Cleaning of Metal Z-Bar

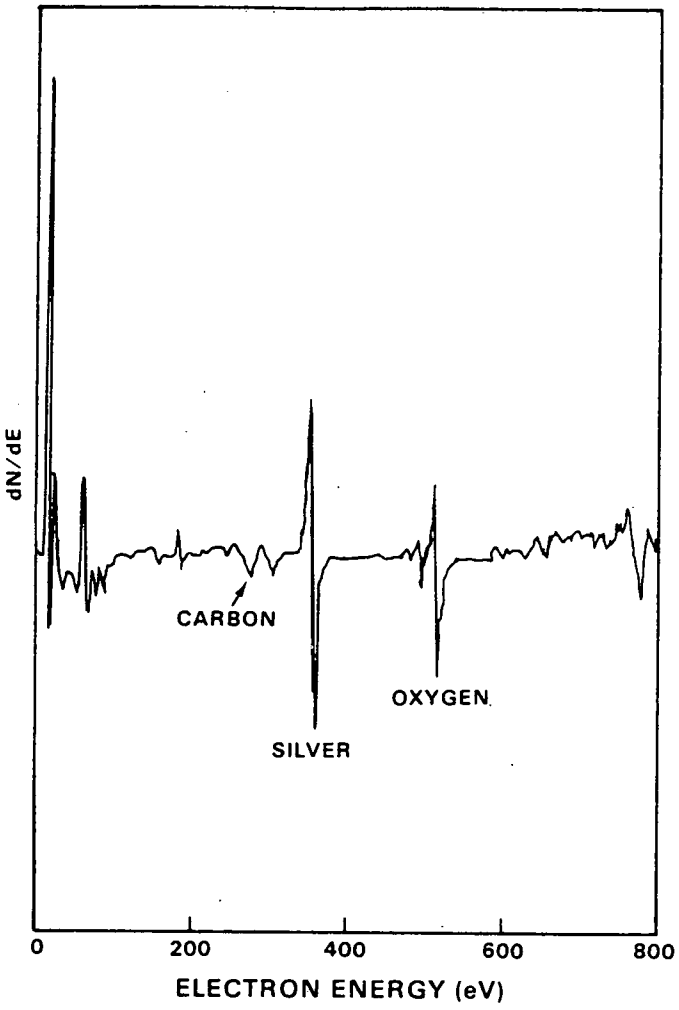

Figure 11. Auger Scan of Plasma Cleaned Z-Bar, Cleaned 2 Minutes