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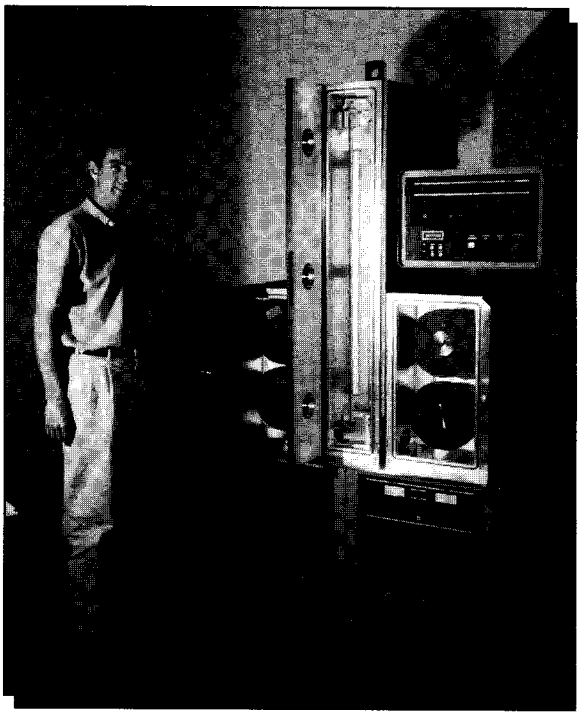
Plasma Cleaning of Electronic Materials

Cleaning processes designed to remove contaminants from surfaces of materials play a central role in many electronic manufacturing processes. These contaminants originate from several sources that include cutting fluids used in machining and potting compounds, adhesives used in fabricating subassemblies, carbon residues from laser drilling and laser cutting, and airborne contamination generated on the factory floor. Failure to remove these contaminants can adversely impact assembly operations, such as wire bonding of thick and thin film circuit assemblies, bonding of components using adhesives, or the end use operation of the devices themselves.

Wet chemical techniques employ solvents designed to dissolve the organic and inorganic contaminants or acids to lightly etch the surfaces where bonding is to take place. The choice of materials used in fabricating these devices often necessitates the use of hazardous chemicals in order to clean and prepare the surfaces for subsequent processes. In spite of the use of aggressive chemicals, the desired level of cleanliness is often difficult to achieve. Part of the difficulty stems from the fact that these cleaning solutions tend to leave residues behind. These cleaning compounds often include corrosive acids and chlorofluorocarbons that pose hazards to the environment and health hazards to the workers exposed to them.

There is an alternate technology that not only offers better results, but does so while using innocuous gases: this alternative technology is cold gas plasma. Gas plasma achieves a higher degree of cleanliness than that achieved by solvent cleaning or acid etching. In many cases, plasma surface cleaning methods used alone have proven to be better substitutes to wet chemical methods.

PS 2020 Tape System



Activated Gas Plasma Cleaning

A plasma is a partially ionized gas containing electrons, ions, and various neutral species at many different levels of excitation. Ionization of the gas molecules is accomplished by subjecting the gas which is enclosed in a vacuum chamber to RF energy. Gases or mixtures of gases used for cleaning and contaminant removal include argon, oxygen, air, tetrafluoromethane, and helium. The free radicals and active species that are generated in the plasma react with the surface contaminants to produce volatile byproducts that include water vapor, carbon monoxide and carbon dioxide. Although the electron temperature in a plasma can be as high as 5000°K, the bulk temperature of the gas in the reactor is essentially ambient. Thus, activated gas plasmas can also be used to remove contamination from

delicate substrates. The nature of the volatile products that are created is dependent on the gas chemistry used for the cleaning process. These reaction products are pumped from the reaction chamber by the vacuum system and typically require no post treatment before release to the environment.

CASE HISTORIES - CLEANING

Cleaning of thin film hybrids: Bonham and Plunkett of Rockwell International[1] have shown that large amounts of hydrocarbon surface contamination adversely affect thermocompression bonding of lead frames to circuits. In addition to demonstrating the effectiveness of plasma cleaning prior to bonding, the authors also developed a parametric envelope for cleaning aluminum, gold, and sliver hybrid metallizations. Using an oxygen plasma, a six fold decrease in hydrocarbon contamination was demonstrated with desired wire breaks being observed in place of bond line failures. Similar results in bond performance were obtained by Baranyi, Seto and Chang of Litton Systems[2] who used an argon plasma for their study.

Cleaning of ceramic insulators: Ceramic insulators used in various electronics assemblies are typically machined while potted in a paraffin wax. The normal hot water/detergent or solvent cleaning methods were found to be inadequate in removing all traces of organic residue. The presence of these contaminants often led to electrical contact resistance failures in these devices. In studies by Smith at Allied-Signal Aerospace, Kansas City Division, both oxygen and dry air plasma processes were shown to be effective in removing the contamination and thus contributing to improved device performance. Allied-Signal routinely uses plasma for critical cleaning of electronics and electromechanical assemblies. In addition to removal of machining aids, plasma treatment is frequently used to remove residual binder from ceramic packaging materials used in sensitive electronic systems.

Cleaning of metals: Metals such as stainless steel, brass and header pins used in the electronics industry were cleaned in oxygen containing plasmas in a PS0150 plasma reactor. The plasma treated parts were shown to have significantly lower contamination than parts cleaned using solvents.[3] Where the metal to be cleaned is easily oxidized, such as sliver, the use of an argon plasma for cleaning is preferred. The following table illustrates the efficacy of plasma treatment in removing organic contaminants from metal surfaces. The substrate used for the study was 316L Electropolished Stainless Steel coupons contaminated with WD 40.

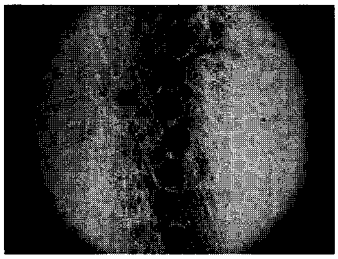
Cleaning Process	Atom % of Carbon by ESCA
Control (contaminated sample)	88
5 minute sonication in non-ionic surfactant	47
Cleaned for 5 minutes - O_2 Plasma	38
5 minute sonication in non-ionic surfactant + 5 minute O_2 Plasma	35
5 minute sonication in non-ionic surfactant + 5 minute Ar/O_2 Plasma	27

PLASMA PROCESSING SYSTEMS

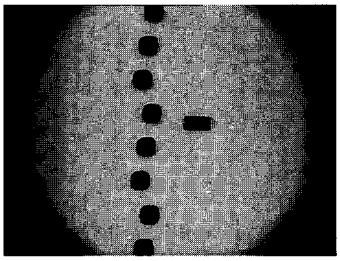
Both batch and roll-to-roll treatment systems are available for cleaning of electronic components. Discrete parts are best treated in a batch system where the parts to be cleaned are held in trays and exposed to the active species in a plasma chamber. When the part to be cleaned is a continuous roll of material, it can be treated in the PS2020 or the PS0524 system. The PS2020 can treat Kapton® or other flexible circuit materials in tape form up to 4 inches in width in reel diameters of 10 inches. The PS0524 is ideally suited for treating such films that are up to 24 inches in width. Work in our laboratory has shown that plasma treatment of Kapton® and polyimide films dramatically increases the adhesion during lamination bonding and metallization of these films. Plasmas are also used to remove the carbon residues left by laser drilling and laser cutting of flexible circuits using continuous systems. At BOC Coating Technology, we have found that high pressure oxygen containing plasmas are best suited for cleaning hydrocarbon or carbonaceous contaminants and deposits left behind by fabrication processes.

Micrographs taken of polyimide film clearly demonstrate the effective performance of plasma to remove carbon residue. (Figure 1)

Figure 1 - Polyimide Film



Pre-plasma cleaning

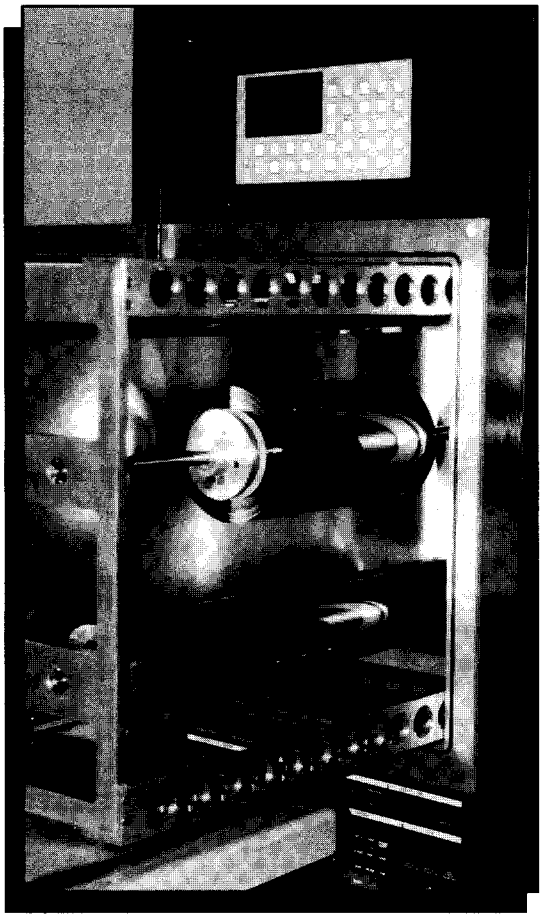


Post-plasma cleaning

ENVIRONMENTAL EFFECTS

An independent laboratory, Ecoserve Environmental Services, Pittsburg, CA., a licensed air testing concern was contracted to test stack emissions at Plasma Science's laboratories in California.[4] Testing was conducted in accordance with EPA code of Federal Regulations, Title 40, Part 60, Appendix A, Method 3 and 4, 1985, Appendix A, Method 5, 1981. NO_x, CO and SO_2 were continuously monitored during this test. CO and SO_2 remained at ambient levels during the entire six hour test. NO_x was measured at 6 ppm when N_2O was being used in the process (not continuously in use). Oxygen was also analyzed during this test and was found to be at ambient levels.

PS0524 Web System



Particulate emissions were measured at a level of 0.001 lbs/hr. At this rate, an increase of orders of magnitude in particulate emission rate could be tolerated without exceeding government mandated or recommended limits.

All of the case studies cited suggest the use of benign and innocuous gases for plasma cleaning processes. Under these circumstances, environmental issues would be of least concern to the industry while enjoying the benefits of superior process performance.

CONCLUSIONS

Studies have shown plasma based processes to be very effective in removing surface contamination from many different materials. Analysis of exhaust gases from plasma reactors have been shown to contain ambient levels of chemicals and extremely low particulate matter. The effectiveness of innocuous gases in achieving contamination removal further strengthens the role of plasma processes as being the environmentally safe alternative to chemical methods of contaminant removal. Such cleaning processes can be used for both discrete parts and continuous tape and web products.

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