Application Note

Gas Plasma Cleaning Compliments Traditional Wet Methods

Introduction

Ever-tightening restrictions on chemical use have intensified the search for substitute liquid cleaners. Some manufacturers have discovered, however, that the best approach is to minimise or eliminate gross cleaning altogether and do a final dry clean with a gas plasma.

Plasma is not a laboratory curiosity. This process has been an essential production tool for more than 20 years on the fabrication of microelectronic devices. Over this period, plasma has gradually been accepted by a much broader range of industries: automotive, medical, textiles, and plastics to name a few. Today it is routinely used to clean and surface treat plastic automotive bumpers, stainless steel syringe needles, angioplasty balloon catheters, plastic lenses, golf balls, and many other diverse products.

This non-toxic gaseous (usually oxygen or air) discharge process will remove even the toughest organic residues from parts within minutes and, best of all, chemical safety, storage, disposal, and cost are virtually non-issues.

Chemical safety is assured since all cleaning takes place in a closed vacuum chamber and the reaction by-products are evacuated through a vacuum pump as soon as they are formed. These vapours do not require scrubbing and are simply vented to the atmosphere through a standard exhaust.

Plasma Cleaning

When gas atoms are ionised, the collision of high energy particles knocks electrons out of their orbits. This results in the characteristic “glow” or light associated with plasma. Gas plasma’s activated species include atoms, molecules, ions, electrons, free radicals, metastables, and photons in the short wave ultraviolet (vacuum UV or VUV) range.

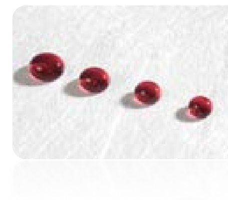
Plasmas are generated in closed vessels at low pressures, typically < 1.0 Torr. The low pressure results in a long mean free path of the plasma species, so that they remain reactive until contact with a surface. The overall reactor temperature at the commonly used power levels and pressures is close to ambient so even temperature sensitive materials can be treated.

How Does It Clean?

If the gas used is oxygen, the plasma is an effective, economical, environmentally safe method for critical cleaning. The VUV energy is very effective in the breaking of most organic bonds (i.e., C-H, C-C, C=C, C-O, and C-N) of surface contaminants. This helps to break apart high molecular weight contaminants. A second cleaning action is carried out by the oxygen species created in the plasma (O_2^+, O_2^-, O_3, O, O^+, O^-, ionised ozone, metastably-excited oxygen, and free electrons). These species react with organic contaminants to form H_2O, CO, CO_2, and lower molecular weight hydrocarbons. These compounds have relatively high vapour pressures and are evacuated from the chamber during processing. The resulting surface is ultra-clean.

If the part to be treated consists of easily oxidised materials such as silver or copper, inert gases such as argon or helium are used instead. The plasma activated atoms and ions behave like a molecular sandblast and can break down organic contaminants. These contaminants are again vapourised and evacuated from the chamber during processing.

Most of these by-products are small quantities of harmless gasses such as carbon dioxide, and water vapor with trace amounts of carbon monoxide and other hydrocarbons. To put this in perspective, 10 minutes of automobile exhaust is approximately equivalent to one year of plasma cleaning exhaust.



Whether or not organic removal is complete can be assessed with contact angle measurements. When an organic contaminant is present, the contact angle of water with the device will be high. After the removal of the contaminant, the contact angle will be reduced to that characteristic of contact with the pure substrate.

Plasma cleaning requires optimisation of a number of interrelated variables, most notably gas species, pressure, time in reactor, nature of substrate and contaminant, and power. Thus, a series of experiments designed to optimise processing conditions is carried out. This process, or method development step, is a key part of our service. The net result is a high degree of day-to-day repeatability and higher yields.

The True Cost of Poor Cleaning

Inefficient wet chemical procedures ultimately lead to higher costs and reduced yield. Even prolonged treatments can be ineffective in removing seemingly insignificant trace levels of organic contaminants that can ultimately affect how fit for purpose a particular component is.

An illustrative example is the quadrupole rod assembly of a mass spectrometer. Owing to its critical dependence upon the accuracy and stability of the r.f. and d.c. fields applied to the rods, the filter is most sensitive to the build up of electrostatic charge. A 10mV variation on an applied d.c. potential of 100V for example is equivalent to a 1% change in sensitivity. 100V is typically around the maximum for most analysers and the same change in surface potential at lower values of $V_{d.c.}$ (for example at lower masses) is even worse. This can be put into context when consideration is given to the fact that a normal fingerprint impurity can lead to the localised development of 400mV potentials on the analyser rods!

Additional Benefits

In addition to contaminant removal, plasma cleaning with oxygen can lightly oxidise the substrate, giving the surface a hydrophilic character that is essential for many adhesives, leading to significantly enhanced bonding properties.

Another benefit of plasma cleaning is its inherent safety. With short processing time, no hazardous chemicals, and no liquid waste disposal, plasma cleaning is an efficient, cost effective, and highly reproducible alternative to wet cleaning.

Conclusion

While the vacuum industry continues to drive its manufacturers to higher and higher standards of cleanliness, conventional cleaning techniques still result in unacceptable levels of contamination. New legislation will also restrict the use of many currently used chemicals. Plasma cleaning of UHV critical components offers significant advantages over wet cleaning methods alone and can enable a leading market position for those adopting it early.

Diener manufacture the most comprehensive range of low pressure plasma treatment systems, from small, low cost bench-top units to large scale industrial machines. Each is delivered with fully tested application specific recipes and fully application customised. We also offer a completely free proof of concept treatment service.