Hybrid Cleaning to BGA … Is Plasma Still Relevant?

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Abstract

This seminar is intended to provide a general understanding of:

1. Do the issues we are used to in hybrid production still relevant?
2. What is plasma and can it address the issues previously mentioned?
3. What are the interaction mechanisms between organics and plasma?

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Many already concede that plasma is the most environmentally safe method of both the organic removal and surface modification to date, but is cleanliness still an issue? Hybrid circuits have begun to approach the critical dimensions of semiconductors in the late 1960's with the advent of CSP, BGA and FC. Rather than eliminate cleaning, these new Asmaller circuits presented a whole new criteria for cleaning and removal of organics. This seminar will review the current industry and how it addresses the cleaning issue in terms of effectiveness and application.

The BGA, CSP surge in a CFC free cleaning world

Electronic Trend Publication's estimates, as recently reported in HDI, July 1998, the growth of BGA and CSP to be in the order of 60% per year. The challenge this presents the industry is primarily one of higher densities and tighter tolerances. All of the current hybrid concerns about contamination are amplified instead of eliminated. It also appears that an estimated 80 to 90% of devices will still require wire bonding by the year 2002. In view of this what constitutes CLEAN and what contamination will cause "in package" problems, which can haunt you after market release. Most are aware of organic human contamination such as skin, creams, dandruff, etc. which can cause corrosion and leakage currents. Not so familiar are the bio-residual contamination caused by the aqueous cleaning systems recently presented as alternatives to CFC cleaning methods. Aqueous cleaning systems are an excellent method of removing inorganic contamination such as sodium and potassium but the sad truth is they also introduce microbial organisms which can cause metallization corrosion, organic surface interface problems and leakage currents. These problems amplify as the density of the package design increases. So what hope do we have as long as we live in a carbon based life form environment? Plasma still offers an extremely effective method of organic removal without any residual remaining contamination. When used in conjunction with aqueous methods a total cleaning solution can be obtained and in most applications plasma can be used alone for adequate cleaning levels.

What is Plasma?

Plasma can loosely be defined as a partially or wholly ionized gas with a roughly equal number of positively and negatively charged particles. It has been dubbed as the Afourth state of matter because of its general properties, which are similar to both a gas and a liquid.

Plasma exists naturally at atmosphere in the form of lightning. It also can be manmade using a high voltage arc and is the basis for the plasma torch used to vaporize and redeposit metals. Both of these conditions generate tremendous heat and energy which render plasma less then useful for most cleaning operations at atmosphere. Low temperature plasmas are possible if generated under vacuum during which the heat generated in the ionizing process is held by the electrons and not transmitted to the surrounding molecules. This process is often used in etching semiconductors, surface modification and organic cleaning. The ionization of the gas is accomplished by applying an energy field using one of three government regulated source frequencies:

1. Low frequency or < 100 kHz.
2. RF frequency or 13.56 MHz.
3. Microwave frequency or 2.45 GHZ.

International agreements set these frequencies to prevent use of sources, which would interfere with communication bands worldwide.

Low frequency plasmas are the least efficient for several reasons. The efficiency is related to the energy necessary to sustain the ionization and both the intensity and frequency of vacuum ultraviolet (VUV) radiation. Several papers have been written discussing these inefficiencies. The publication of “*Plasma Surface Modification of Polymers: Relevance to Adhesion*” from Journal of “*Adhesion Science and Technology* “, edited by M. Strobel, C.S. Lyons and K.L. Mittal is a good source for reference on this subject.

Most plasma system manufacturers use either RF frequency or MW frequency sources. RF plasmas have been shown to exhibit significantly higher levels of VUV, which in part explains the higher concentrations of electronically charged particles than found in the other plasma sources. RF plasmas have also been noted to be more homogeneous which is critical in treating irregularly shaped and critically small dimensions.

MW source plasmas are generated Adownstream or in a secondary environment. This means that the plasma is generated in one chamber and the active species are drawn by vacuum differential into the work area. This does produce a less homogeneous process and as a result provides reduced uniformity across the work area.

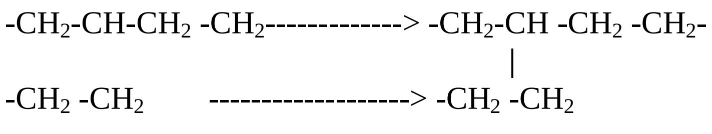
Plasma Reactions

All plasma reactions can be categorized as either chemical or mechanical. Chemical reactions are reactions as a result of an actual chemical interaction of the ionized gas species with the surface of the product or contaminant. These reactions would include oxidation and ablating the surface with such gases as fluorine or chlorine or reactions with organic elements using oxygen. Mechanical reactions are generated by a kinetic energy transfer with the use of noble gases such as argon or helium. These are inert gases existing in their monatomic state the reaction and it is by the acceleration of the molecule and the resultant collision with the contaminant that facilitates the reaction. The dislodged contaminants can be swept away in the vacuum stream before they can redeposit on the product. These inert gas plasmas are primarily used to remove organic and particulate contamination from surfaces that might readily oxidize such as silver or copper. Because of the mechanical nature of inert gas plasmas the reaction must be in the direct path of the ions. This direct path is referred to as primary plasma. Secondary plasmas are possible in chemical reactions but offer great inefficiencies when attempted using inert gases.

Organic Removal

The presence of organic contamination from either the atmosphere or from bio-residue can create not only bonding problems but also potentially future corrosion. Oxygen plasmas are excellent in removing organic contamination but they will also cause oxidation of metals as silver. Oxygen plasma is a chemical reaction and thus is viable in both the down-stream configurations and in the secondary plasma.

O_2 when exposed to the RF energy field is broken down into monatomic oxygen (O), O^+ and O^-. The O, at pressures above .1 torr, is the most reactive element in the plasma and will readily combine with any organic hydrocarbon. The resultant combination is water vapor, CO and $CO_{2,}$ which is carried away in the vacuum steam. The reaction is by its nature complete with no residual surface products; however, non-organic contaminates such as salts are not so readily removed. Sufficient RF energy must be applied to produce a high plasma density. Lower power densities do not just remove contamination at a slower rate but can actually impede the removal process. While the top layers of organics are being removed with low power density, underlying layers may actually cross-link in three dimensions creating a stable but unremoved new structure.



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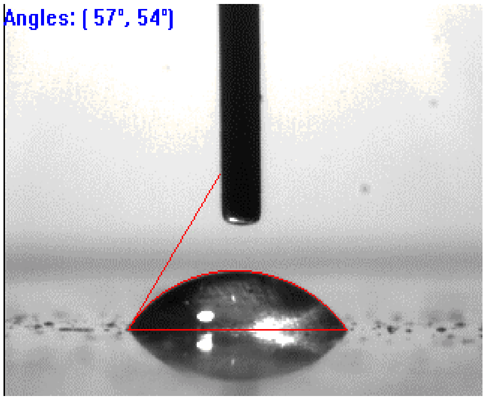
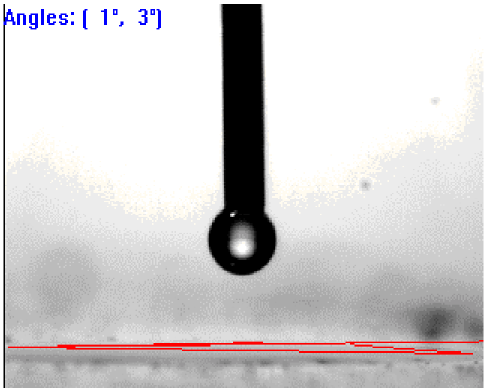
Based on the above situation it can be seen that the power density must be carefully monitored. Complete removal can be illustrated by the use of contact angle measurement. The actual surface energy can be calculated using the same method and the application of three different liquids. The tests in all of the following cases were conducted using an Advanced Surface Technology, Inc. model VCA 2500 contact angle device.



Aluminum coupon with organic contamination

Contact angle before treatment of 57/54^0 using certified water



Contact angle after plasma treatment below readable limits

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Plasma Damage Possibilities

Ceramic surfaces often exhibit a yellowing after treatment. This effect is a result of surface cross-linking and will disappear over time. If the hybrids can be annealed in a 300C the effect can be removed immediately. In either case the effect is both temporal and of no effect on performance. Ion damage may be possible on un-passivated devices if improper power levels are utilized. Care must be used as in any cleaning method to insure correct parameters are established. Each manufacturer should be able to provide basic parameters for most applications and there is a large amount of printed material on plasma cleaning. One of the better references is produced by IMAPS titled, AReliability and Yield Problems of Wire Bonding in Microelectronics≅, by George Harman.

The Physical Equipment

All current plasma systems fall into the same basic configuration:

1. A chamber for the reaction.
2. An energy source for the gas ionization.
3. Control circuitry to regulate the time, gas flow and amount of energy.
4. A vacuum system to provide low-pressure environment.

The Chamber

Chambers are manufactured in either metal or glass depending on the application and the method of ionization. Quartz chambers are used in highly critical environments where submicron particulate generation is an issue. Quartz reactors can also be inductively coupled which will produce the most uniform results on populated devices. This is especially useful in removing contamination from even the underside of die edges.

For industrial applications, metal chambers are becoming more prevalent and allow for the greater volume and throughput necessary to maintain pace with industry. Aluminum chambers offer an advantage over stainless steel chambers in that the chamber material does not inhibit the plasma reaction. This tendency of stainless steel to inhibit reactions is called wall effect and is a result of the material causing a recombination of the ionized gas thus reducing the effectiveness of the process.

Plasma Today

Plasma systems range from a small two-inch chambers to as large as over 100 cubic feet. Though there are standard sizes available, your needs should dictate the system.
The many configurations of BGA and CSP devices call for several different recipes or processes. The system you select should offer the versatility to accommodate these variations and possible future requirements. Plasma can be applicable to any geometry making it especially useful in cleaning populated hybrids, BGA’s and CSP devices. As the density of hybrids and the associated dies increases the need for surface preparation and complete cleaning processes will increase.

Plasma cleaning prior to wire-bonding will continue to grow as a cost effective and environmentally friendly alternative or adjunct to wet processes. The greater the density of the devices the more critical the level to which the cleaning method is capable achieving becomes. There have been significant advances in both our understanding of the plasma process and the application of highly uniform processes in the carrier based production environment.

Conclusions

BGA and CSP methods will continue to grow as density requirements increase. The yield rate will also become more crucial as the cost per device increases. With the need for higher yield will come the realization that one step in facilitating this is by increased cleanliness prior to bonding and encapsulation. Plasma can provide the level of confidence necessary to carry the chip industry into the next millennium.

References:

S. Berry(1998)"High-Density IC Packaging Substrate Market,"HDI,July 1998,pp12-13,Vol.1,No.3.