SURFACE PREPARATION FOR IMPROVED ADHESION

Application Note

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INTRODUCTION

Surface preparation through surface activation and contamination removal, by plasma processing is widely used in industries such as the microelectronic and optoelectronic device assembly, printed circuit board (PCB) manufacturing and medical device manufacturing industries. Surface preparation by plasma removes the contaminants from the surface and activates the surface for various applications including improving adhesion and promoting fluid flow.

Plasmas are highly reactive mixtures of gas species consisting of large concentrations of ions, electrons, free radicals, and other neutral species. Plasma is a proven technology, which provides an efficient, economic, environmentally friendly, and versatile technique for modifying the surface properties of materials. Plasma treatment can be used for surface activation and contamination removal without creating any hazardous by-products and without changing any bulk properties [1, 2].

Surface activation is a process where surface functional groups are replaced with different atoms or chemical groups from the plasma. Surface activation of materials is achieved utilizing plasma source gases such as argon, oxygen, hydrogen, or a mixture of these gases [2].

Surface contamination removal by plasma is an ablation process, where physical sputtering and chemical etching are the key processes involved. The plasma process removes organic contaminants such as residual organic solvents, epoxy residue, oxidation, and mold release compounds, on the surface of most industrial materials. These surface contaminants undergo repetitive chain scission under the influence of ions, free radicals and electrons of the plasma until their molecular weight is sufficiently low to volatilize in the vacuum [2, 3].

In microelectronic assembly applications the surface contaminants include metal oxides and organic substances introduced by overexposure to atmospheric air, bond grease during manual handling, soldering process, Figure 1. photoresist used for photoprocessing substrates, and oil fumes in the atmosphere. Surface contamination is difficult to avoid during the manufacturing process. Plasma processing removes the contaminants and makes surface clean and active resulting in improved wire bonds and decreased occurrence of delamination at the interface as surface contamination is a major cause of poor wire bond pull strength and adhesion [4-6]. Therefore, it has been widely used for enhancing improves die attachment, removing oxides, promoting void-free underfill, improving wire-bond strength and eliminating delamination in microelectronic and optoelectronic industries [2. 4-9].

EXPERIMENTAL METHODS

General experimental methods for surface property evaluation are contact angle measurement, SEM, AFM and XPS. Contact angle measurement is a simple and inexpensive method for evaluating the effectiveness of the surface contamination removal and surface activation processes.

Plasma treatment and surface modification of plastics, metals, and ceramic surfaces increases the wettability of those surfaces as measured by the contact angle. In general, the lower the contact angle the higher the surface energy. The increase of energy and decrease of contact angle, usually correlates directly with improved adhesion since organic contaminants have been removed during the plasma treatment and the free radicals and polar function groups form on the surface allowing for a better interface between the surface and the typically polar fluid.

The correlation of the level of interfacial organic contamination as determined by XPS, relative to the contact angle measured on the copper leadframe for Ar and O2 plasma treatment is shown in Figure 1. The data indicates that as the contact angle decreases the level of organic contamination decreases proportionally. The result clearly shows that the contact angle measurements are indeed a good indication of the level of organic contamination on copper substrates.

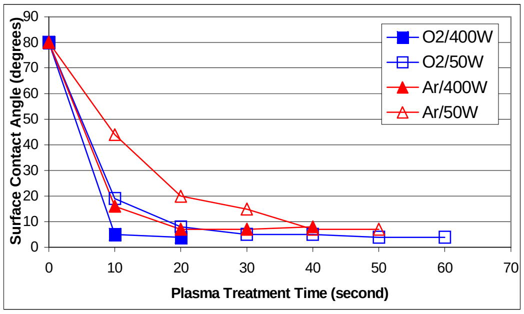

Figure 1.

APPLICATIONS

Component Attach

Surface activation and contamination removal by plasma process can improve the adhesion between the substrate and components, such as die, diodes, fiber, and thermoelectric coolers. A clean die and substrate surface is desirable because it promotes better adhesion of the die attach compound to both the die and the substrate. Plasma cleaning prior to component attachment provides better contact, better heat transfer, and minimal voiding.

Wire Bonding

The presence of oxides and organic contaminants on bond pads inhibits successful wire bonding. Assurance of an oxide-and-contaminant-free surface is important to obtain good bond yields.

The data shown in Table 1 indicates the effect of argon plasma cleaning on wire bond yield.

	# of Devices	# of Wires	Wire Size (mils)	Pull Test	# of Bond Failures	Failure Rate
Lab#1						
Plasma Cleaned	25	1380	1.5	5 g	6	0.43%
Plasma Cleaned		100	1.0	3 g	11	11%
Control	25	1378	1.5	5 g	10	0.73%
Control		94	1.0	3 g	23	24.5%
Lab#2						
Plasma Cleaned	50	1375		3.5 g	8	0.58%
Control	50	1375		3.5 g	26	1.89%
Lab#3						
Plasma Cleaned	10	840			1	0.12%
Control	10	840			29	3.45%

Table 1

The samples were plasma cleaned with argon for 10 minutes using the following plasma condition: 100 watts and 0.2 Torr, and were then subjected to pull tests. The plasma cleaned samples showed average pull strength of 6.65 grams with a standard deviation of 1.57. The control showed average pull strength of 5.3 grams with a standard deviation of 1.89. The data indicates that the bonding strength has been improved after plasma cleaning.

Flip Chip

The unique challenge in flip chip packaging is the underfill process, particularly designs that use large dies, tight gaps, and high-density ball placement. Plasma has proven to increase surface energy promoting adhesion, minimizing voiding and increasing wicking speeds. The contact angle under the die and on the covered substrate surface decreases with the increasing plasma treatment time as shown Figure 2. Also displayed in Figure 2 is the effect of die size; the larger the die the more difficult it is for the plasma to penetrate between the die and the substrate.

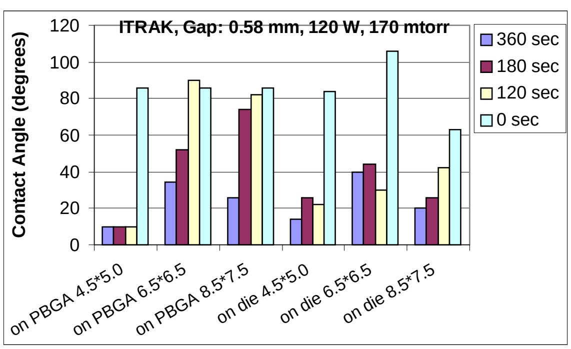

Figure 2. Surface contact angle under the beneath of die after plasma treatment with different plasma exposure time.

Encapsulation and Mold

The purpose of the plastic encapsulant for semiconductor applications is to provide adequate mechanical strength, adhesion to various package components, good corrosion and chemical resistance, matched coefficient of thermal expansion to the materials it interfaces with, high thermal conductivity and high moisture resistance in the temperature range used. In particular, the ability to form good adhesion with package components and to remain bonded is of paramount importance as delamination along the interfaces is a major reliability issue for plastic encapsulated microcircuits (PEMs). Plasma treatment improves this adhesion and bond strength.

The data shown in Figure 3 demonstrates about a factor of two increase in the bond strength. The material used in this case was a PPS plastic molded into a multi-pin connector. Cadmium and nickel wires were bonded into position by epoxy cement (Abelbond #789-3), cured, and the bonds tested. Plasma treatment was run in the March PX-500 system.

Gas: Argon
Power: 200 watts
Pressure: 180 mTorr
Time: 15 minutes

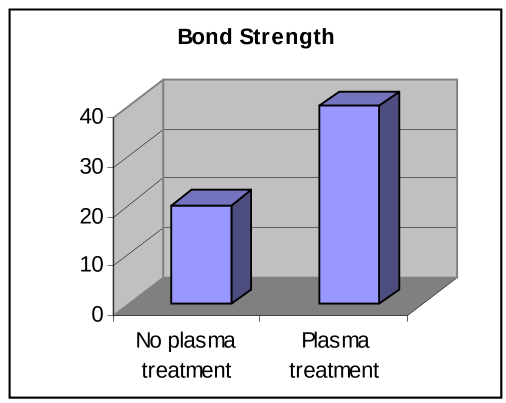

Figure 3

The adhesion between leadframe and encapsulant in plastic encapsulated microcircuits is characterized by leadframe pull-out test (See Figure 4) [4]. The maximum de-bond load decreases with the increase of plasma exposure time. The debond load is a measure of the strength of the bond between the encapsulant and the leadframe. The larger the debond load the better the adhesion. Figure 4b displays the relationship between contact angle and debond load. In general, with decreasing contact angle the debond load increases. Thus the contact angle measurement method is a good indicator of bond strength in encapsulation processes.

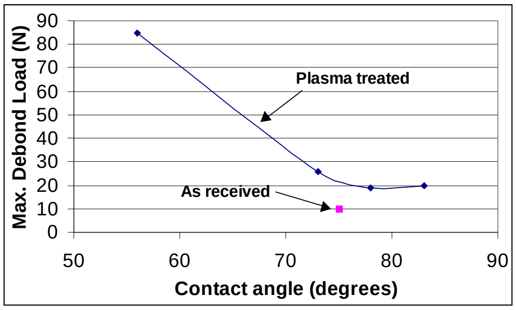

Figure 4. Maximum de-bond load as a function of after plasma exposure time (a) and surface contact angle (b). The plasma condition: H2 (50%) and Ar (50%), 5 min. 234-300 mTorr, and 400 W. [4]

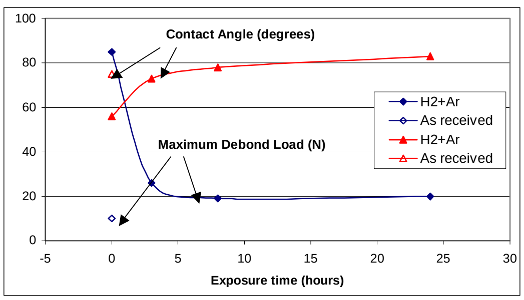

Figure 4b

Figure 5 shows the surface contact angle on copper leadframe with the plasma treatment time. The surface contact angle decreases with increasing plasma treatment time. The surface contact angle also depends on the plasma operating conditions, such as gas selection, power input, pressure, and time. The figure displays that reducing the power impacts the plasma treatment effectiveness.

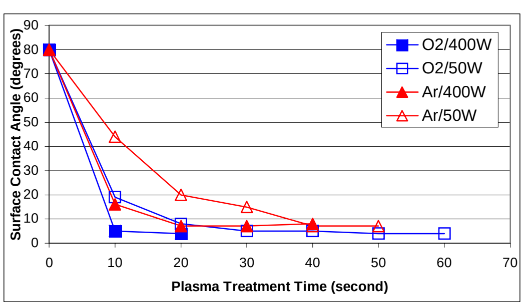

Figure 5

Marking

Plasma surface preparation is also used in marking. The activated surface can improve the adhesion of aqueous ink. The plasma prepared surface improves adhesion of aqueous based inks.

Hermetic Sealing

Plasma technology can be used to prepare the surface prior to hermetic sealing of laser diode device. Plasma cleaned surface improves the adhesion at the interface allowing for a more reliable weld.

CONSIDERATIONS

Plasma Conditions

Plasma conditions are very important for the plasma surface activation and contamination removal. The important factors of plasma process include gases, input power, operating pressure, plasma exposure time, location of the sample in the chamber, and electrode configuration. All of the parameters should be determined carefully for the different applications. Principally, a lower operating pressure needs to be applied in argon plasma process as it is a physical plasma process. However, a higher operating pressure is necessary in oxygen or other reactive gas plasma as chemical reaction is dominant on the surface.

Life Time

The question often asked is "how long does a surface remain active?" since the activated surface is sensitive to the environment. Generally, the activated surface will gradually lose its wettability because of air contamination, self-contamination and storage contamination. One example, using the same PPS plastic and plasma treatment conditions is shown in Figure 6. The data illustrates the change in contact angle as a function of time. Due to the surface recontamination illustrated in Figure 6, the adhesion strength will decline with increasing exposure time after plasma treatment.

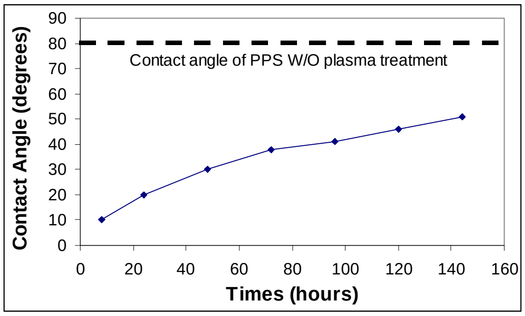

Figure 6

Storage

Another issue that arises is how to store the treated samples. In this study, the same PPS plastic samples were plasma treated and placed in a Teflon FEP bag, a polyethylene bag, or wrapped in a plasma treated aluminum foil (see Figure 7 below). The surface activation of all samples degrades with time, except for those stored in FEP.

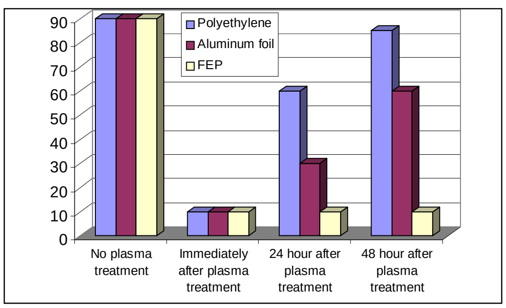

Figure 7

APPLICATIONS LABORATORY

The technical staff at March is pleased to offer its experience in plasma technology for your applications. We would also be happy to publish any data you would like to share with others in the field. Direct your calls and faxes to March Plasma Systems, Attention: Applications Laboratory.

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