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ARTICLE

Analysis of the Influence of Different Plastic Packaging Materials on Product Delamination of IC Components

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ABSTRACT

Due to the high hygroscopicity of the plastic packaging material, the device is inevitably subjected to high temperature or high humidity environment during the production and testing process. After the moisture is expanded, the internal stress is too large, and the delamination and gold wire breakage are formed. At the same time, due to the difference in the coefficient of thermal expansion (CTE) between the plastic packaging material and the materials such as Si and Cu, it is easy to form delamination under a relatively large shear force. The water vapor remaining in the plastic packaging material is the root cause of delamination, and the reflow process and temperature are the predisposing factors leading to delamination. However, it has been found through experiments that different plastic packaging materials have different hygroscopicity and cohesiveness, and they have obvious improvement effects on delamination.

1. Epoxy Resin Plastic Package for IC Components

The package is a must for the chip and is also critical. The package not only protects the chip, but also enhances its thermal conductivity. It is a bridge between the internal and external circuits of the chip.

The plastic package is a package form of a component shell using a polymer-synthesized epoxy resin. The IC package not only requires excellent electrical conductivity, thermal conductivity, and mechanical properties of the packaging material, but also requires high reliability and environmental friendliness of the plastic package. The plastic sealing function is to provide physical protection to the chip, prevent impurities in the air from corroding the chip circuit, cause electrical performance degradation, and protect the chip surface and connecting leads from external damage and external environment. The thermal expansion coefficient of the chip is matched with the thermal expansion coefficient of the frame or the substrate by the package, thereby alleviating the stress generated by the

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change of the external environment such as heat and the stress generated by the heat generated by the chip, thereby preventing chip damage and failure.

The advantages of plastic package: light weight, small size, low cost and simple manufacturing process. At the same time, plastic packaging is widely used in IC component packaging and processing operations, which greatly improves the production efficiency of electronic components.

The disadvantages of plastic package: The plastic sealing material is easy to absorb moisture, and the moisture in the air easily penetrates into the device through the plastic sealing material. The plastic packaging material is a polymer synthetic material, and the inside thereof inevitably contains various impurities (Cl^-, Na^+ plasma, etc.). The presence of impurity ions and water vapor will also have an effect on the internal delamination of the component. In severe cases, the "popcorn" effect occurs during subsequent SMT reflow processing.

2. The Composition of Epoxy Resin

The epoxy resin contains an epoxy group in its molecular structure and is a multi-component polymer composite, under the action of heat and curing agent, the epoxy group chemically reacts with the curing agent phenolic resin to produce cross-linking curing, which becomes a thermosetting plastic, after curing, the epoxy resin has good physical and chemical properties. It has excellent bonding strength to the surface of metal and non-metal materials, good dielectric properties, small set shrinkage, good stability, high hardness and good flexibility. The epoxy resin includes various organic and inorganic components, such as: o-cresol novolac epoxy resin, novolac resin, filler silica powder (commonly known as silicon micropowder), accelerator, coupling agent, modifier, flame retardant, colorant and other components.

Its basic composition and roles are as follows:

Table 1. The basic composition and roles of epoxy resin

Composition	Composition / %	Main Roles
Polymers	Epoxy resin: 5~20	Basic resin, polymerization, bonding
	Curing agent: 3~10	Cross-linking reaction
Catalysts	Coupling agent: <1	Bridge of inorganic and organic matter
Fillers	Curing accelerator: <1	Speed up the cross-linking reaction
	Packing: 70~92	Improve physical properties, reduce expansion coefficient, water absorption and cost
Additives	Release agent: <2	Improve mold release performance and improve fluidity
	Flame retardant: <3	Meet UL-94 requirements
	Colorant: <0.5	colors
	Ion adjuvant: <1	Improve reliability
	Stress absorber: <2	Reduce internal stress
	Binder: <0.5	Improve L/F, ST adhesion

3. Effect of Hygroscopicity on IC Components

3.1 Delamination and Corrosion Failure

Since the epoxy resin package is a non-hermetic package, the tolerance and ability to the external environment are poor. When the epoxy resin is exposed to a humid environment, it has strong water vapor hygroscopicity.[1] On the one hand, in a humid environment, water vapor diffuses inward along the interface of the molding body and the molding body and the pin, and enters the surface of the device chip; on the other hand, due to the certain water absorption of the resin itself, water vapor is directly diffused to the surface of the chip through the molding material. The inhaled moisture, if it has more ion contaminants, will cause corrosion of the bonding area of the chip. If there is a defect in the passivation layer on the surface of the chip, moisture will invade the metallization layer of the chip.[2] Regardless of the corrosion of the bonding area or the corrosion of the metallization layer, the mechanism can be attributed to the chemical reaction of the metal lead and the ionized dirt: Due to the immersion of water vapor, the dissociation of the hydrolyzed substance (Cl^-, Na^+ plasma) from the resin is accelerated, and the substance dissociated during the corrosion process changes due to physical properties, such as an increase in brittleness, an increase in contact resistance value, and a change in thermal expansion coefficient.

During the use or storage of the device, as the temperature and the load voltage change, it will exhibit electrical parameter drift, excessive leakage current, and even short circuit or open circuit failure, which will bury hidden dangers for the long-term reliability of the device,[2-3] the most common phenomenon is the occurrence of stratification. When the package changes in ambient temperature, the sum of the internal stress and the vapor pressure of the moisture is greater than the adhesion between the epoxy resin and the chip, the carrier and the surface of the frame. As a result, peeling occurs between their interfaces, and delamination occurs. In reflow soldering, water vapor expands due to thermal stress caused by rapid heating,

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which in turn causes device failure.

3.2 "Popcorn" Failure

There are three sources of heat that the molded electronics conduct to the device during soldering: infrared reflow heating, vapor reflow heating, and wave soldering heating. The infrared reflow soldering temperature is 235~240°C, the time is about 10S; the vapor reflow soldering temperature is 215±5°C, the time is about 40s; the wave soldering heating temperature is 260±5°C, and the time is about 5S. During the heating process of the plastic electronic device, the moisture adsorbed in the plastic body is rapidly vaporized, and the internal water vapor pressure is too large, so that the epoxy resin expands, and delamination and cracking occur, which is commonly called "popcorn" failure. However, in the case that the plastic body does not fail during welding, but the plastic body is cracked due to moisture and thermal expansion or cooling or shrinkage, the crack will corrode the dirt and moisture into the passage, which affects long-term reliability in later use. At the same time, in the welding, the epoxy resin will expand due to heat, and the shear stress generated inside the epoxy resin will affect the integrity of the bonding wire. The corner stress of the chip is relatively concentrated, which may cause the bonding wire to be lifted, the bonding point to be cracked, or the bonding wire to be broken, resulting in failure of electrical performance.

4. The Delamination of IC Components

In component packaging, delamination is a major aspect of reliability evaluation. The delamination is a slight peeling or cracking between the interfaces inside the molded body (PKG).

Most delamination occurs at the interface of the internal material of the package, including between the encapsulating resin and the chip interface, between the encapsulating resin and the substrate interface, between the chip and the bonding material interface, between the bonding material and the substrate interface, and inside the bonding material, etc. The delamination phenomenon occurs at the interface between the plastic resin of the plastic package device and other materials, which may cause device performance degradation or even failure. For example, if the delamination occurs at the interface between the resin and the chip, it will not only cause the bond wire of the chip to be mechanically damaged due to mechanical stretching or bond wire, but the connection resistance is increased or opened; it may also cause damage to the passivation layer on the surface of the chip, resulting in increased chip leakage, etc.; or delamination of the interface between the resin and the chip, which makes it easier for water vapor to enter the surface of the chip, degrading the performance of the chip. The interface between the epoxy resin and other materials in the molding device is delamination. Even if the delamination area is small, the adhesion of the delamination part is seriously reduced, and the structural stress is also changed. In the subsequent device use, due to the effect of thermal strain or mechanical stress, the delamination condition is intensified, and as the delamination area increases, the device eventually fails.

There are many factors leading to delamination, in which the plastic sealing resin, chip, frame and the like are different due to different materials, the thermal expansion coefficient is different at high temperature, and the CTE mismatch between the plastic sealing material, the chip and the frame causes shearing force on the contact surface.

When the components are in the SMT process, when the device is in a high temperature state, the reflow soldering environment temperature rises rapidly to about 260 °C, the stress inside the laminator is concentrated due to thermal expansion for a short time. In addition, the moisture accumulated in the encapsulation interface layer diffuses into the micro-cavities, and the wet heat stress and the rapidly rising pressure in a short time may cause the package to fail.[4] The diffusion of moisture and the formation of high pressure conditions also led to the occurrence of delamination. The process of delamination and even cracking caused by the plastic components after moisture absorption under high temperature conditions can be simply expressed as follows:

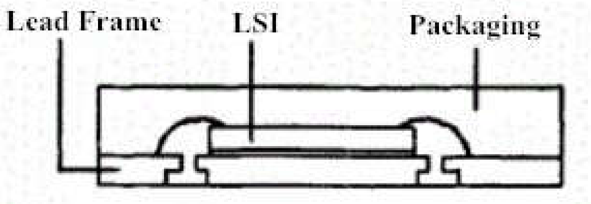

Figure 1. Plastic components before hygroscopicity

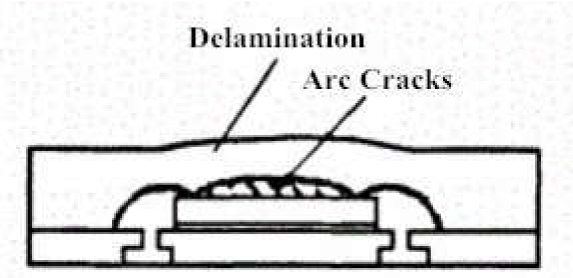

Figure 2. Vapor expansion and delamination under high temperature conditions

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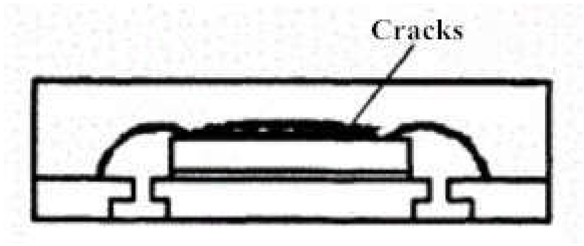

Figure 3. Occurrence mechanism of Packaging delamination and cracks

5. Effect of Different Plastic Packaging Materials on Packaging, Hygroscopicity and Delamination

The characteristics of epoxy resin are the basic factors leading to delamination inside the plastic body.[5] In the package, the adhesion of the epoxy resin to the frame, coefficient of thermal expansion (CTE), the strength and the conductivity of the material have a significant effect on the internal delamination of the plastic body. The differences in elongation, hygroscopicity and adhesion of epoxy resin also have different effects on delamination.[6]

In materials selecting, the first thing to consider is the adhesion between the epoxy resin and the frame. In addition to the necessary physical bonding, it is more important that a certain chemical bond can occur between the epoxy resin and the frame to ensure better bonding performance. The occurrence of chemical bonding will have a more powerful influence on the structural strength of the plastic-sealed components, resulting in a tighter bond between the epoxy resin and the chip, the carrier, and the frame, thereby improving the mechanical structure and reliability of the device. Electronic components with good and reasonable mechanical structure can maintain excellent reliability even under reflow soldering. In order to evaluate the influence of different molding materials on the package, two epoxy resins were specially selected for package verification and comparative analysis.

The composition and characteristics of the two materials are compared as follows:

Table 2. Comparison of the composition and characteristics of two epoxy resins

Type	Compound 1	Compound 2
Series	700	8240
Remark	Contain adhesion promoters	NA
Filler content	87	88.5
Filler type	Spherical	Spherical
Filler sieved size(um)	75	75
Epoxy type	MAR	LMWE9+MA
Hardener	MAR	LWAH2
Flame retardant	MAR	NA
Spiral flow(cm)	135	101
Gel time	50	35
CTE1(PPM)	10	9
CTE2(PPM)	39	32
Tg	125	120
Flexural strength RT (kgf/mm2)	17	15
Flexural modulus RT (kgf/mm2)	2250	2500
Water absorption (%)	0.13	0.3

By comparing the composition and characteristics of the two epoxy materials, it is found that the thermal expansion coefficients of the two resins are relatively close, and there is no significant difference in the coefficient of thermal expansion between the two. However, the 700 resin is compared with the 8240 resin, the former contains a binding accelerator, and the water content is also lower. The wafers were selected from different batches of different batches, and the two resins were used for package verification. After on-line verification and reliability evaluation, it was found that: the components encapsulated with 700 resin have better bonding strength between epoxy resin and other materials, and can better improve the phenomenon of delamination of 8240 resin.

Table 3. Effect of two epoxy resins on delamination

Leg	Compound	SAT 0 Delam Qty	TCT 200 cycles Delam Qty	TCT 500 cycles Delam Qty	TCT 800 cycles Delam Qty
1	700	0/77ea	0/77ea	0/77ea	0/77ea
2	8240	0/77ea	1/77ea	2/77ea	4/77ea

Through reliability test verification and evaluation, it was found that the resin of 700 exhibited better performance than the 8240 resin in the experiments of TCT200, TCT500 and TCT800, and the structural adhesion, product moisture absorption and delamination improvement of the product package were greatly improved. And through the subsequent multi-batch, large-volume package verification and regular sample tracking and evaluation results, the stability and reliability of 700 resin is better than 8240 resin with high hygroscopicity and no adhesion promoter.

6. Conclusion

In the interior of the plastic body, there is a problem of interfacial adhesion between the epoxy resin and the surface of the chip, the lead frame, and the carrier. The use of an epoxy resin with a bonding accelerator can better improve and enhance the problem of interface adhesion, improve the bonding firmness of the interface, and at the same time effectively enhance the packaging structure and strength of the molding body.

Through analysis and research, it was found that the internal delamination of the plastic body can be achieved by using a less hygroscopic epoxy resin, and by selecting an epoxy resin containing a binding force promoter, increasing the adhesion between the resin and the frame, the chip, the carrier, and enhancing the structural strength, an effective improvement is obtained. In addition, there are many reasons for the occurrence of delamination inside the plastic package. In addition to the analysis and research by changing the angle of epoxy resin, we can also try to explore the optimization of package structure design, frame design, and packaging process improvement, increasing the structural strength, bonding force and reducing the risk of moisture absorption inside the plastic body can more effectively reduce or avoid the occurrence of delamination inside the plastic body.

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