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THE EFFECT OF DELAMINATION BETWEEN MOLD COMPOUND AND Ni/Pd/Au LEADFRAME ON QFN PACKAGE

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ABSTRACT

The susceptibility of QFN package to delamination, particularly in the area between the Ni/Pd/Au leadframe die pad and mold compound, has been a major concern to many IC manufacturers. The presence of a Ni/Pd/Au oxide layer on the leadframe of QFN packages was found to cause delamination at the die pad or mold compound interface. Delamination refers to the disbonding between a surface of the mold compound and that of another material such as leadframe, die, die paddle or die attach material. It also means the loss of adhesion between the mold compound and one or more of the other materials. The objective of this study is to investigate the effect of delamination between 3 different types of compound and Ni/Pd/Au leadframe die pad. Some of the parameters are adjusted in the molding process in order to investigate the effects of delamination. In these studies the delamination of the QFN package measured by C-mode Scanning Acoustic Microscopy (C-SAM). The delamination is initiated under moisture condition if the maximum-shear-stress for the package exceeds the measured. The result shows that different mold compound properties will result in different percentage of delamination.

INTRODUCTION

The susceptibility of QFN package to delamination, particularly in the area between the Ni/Pd/Au leadframe die pad and mold compound, has been a major concern to many IC manufacturers. There is a corresponding greater demand for mold compound to be used as material for encapsulation in plastic IC packaging for better thermal and electrical performance. Package delamination is caused by poor adhesion between the mold compound and other parts of the package, such as die and leadframe. But even where there is good initial adhesion, some other causes may initiate and propagate delamination at the later processing steps such as after molding operation [1]. The increasing popularity of thin and QFN (quad flat no-lead) packages brings many challenges to an advanced semiconductor packaging, particularly in the area of delamination prevention. Delamination can occur at several interfaces[2], such as:

i) Bottom of the die to die attach epoxy
ii) Die attach epoxy to top surface of the leadframe
iii) Leadframe to molding compound
iv) Top of die to molding compound

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One of the main causes of delamination is the mismatch of coefficients of thermal expansion. But if there is some moisture present in the package, this problem is amplified during any operation involving high temperature. One example will be the soldering of the packaged chip to the circuit board. Water expands at a higher rate and for some operations; the temperature will be beyond the boiling point of water. This leads to the so called popcorn effect, but it also accelerates the delamination process. Once there is some delamination, moisture from outside can then penetrate the package even more easily and cause further delamination [3].

Hence, for Ni/Pd/Au leadframe, Copper (Cu) leadframes plated at the leadframe manufacturer with less oxidizable metals e.g. nickel (Ni), palladium (Pd) and gold (Au), are referred to as PrePlated LeadFrames (PPF). The key advantage of PPF's over leadframes plated after molding with tin/lead (Sn/Pb) or other solderable finishes is elimination of wet chemical treatment (plating) after molding. This shortens assembly process cycle time, frees manufacturing space and eliminates plating lines and support equipment at the assembly. Plating, before or after molding, ensures the solderability of the integrated circuit termination during board mounting. With its low melting point, Sn/Pb cannot be used for preplating. Sn/Pb will reflow during assembly of the integrated circuit (IC) where temperatures are generally equal to or greater than 175°C.

The purpose of this work is to investigate the following aspects: (1) the effect of delamination between three different types of compound and Ni/Pd/Au leadframe die pad; (2) the effective adjustment some of the parameters in the molding process caused delamination; (3) experimental investigation of thermal expansion behavior, adhesion strength behavior, and epoxy molding compound properties that caused delamination.

EXPERIMENTAL WORK

For QFN packages assembly process, the assembly process flow chart is shown in Figure 1. In the molding process, different combinations of molding temperature, transfer speed and post mold cure time were used. The information of package type used for the experimental works can be referred in Table 1.

The study involved two of experimentation, namely mold compound characterization and package delamination study and in this work, three factors were considered:

1. Three different mold compound: EMC TYPE A, TYPE B and TYPE C.
2. Different die size groups: 2000 X 1500 & 6000 X 6000.
3. Different process parameter: molding temperature, transfer speed, post mold cure time.

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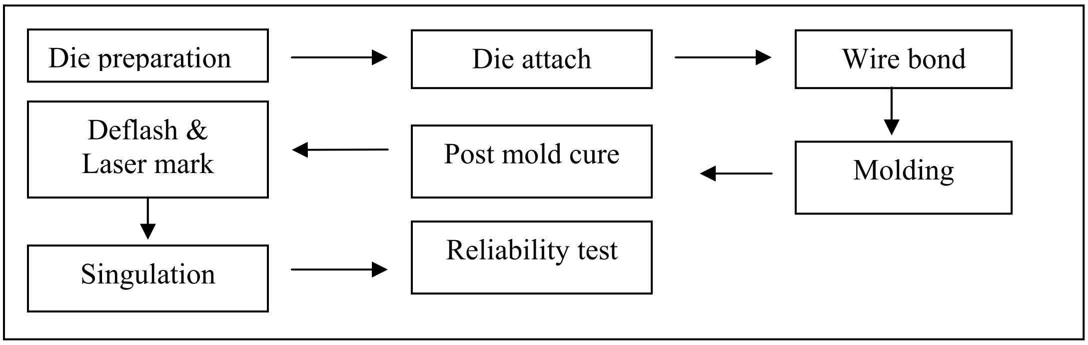

Figure 1: QFN Process flow

Table 1: QFN Package information

Package type	Qua flat no-lead (QFN)
Package size	3.5mmx4.0mm and 14mmx14mm
Leadframe	Ni/Pd/Au

Mold compound characterisation

Three epoxy molding compounds are investigated in this study, as the related properties are tabulated in Table 2. The filler is spherical silica with a maximum particle size of 75μm. Other properties present in the formulation include the coefficients of thermal expansion (CTE), glass temperature (T_g), flexural strength, flexural modulus, percentage of water absorption, percentage of filler content and sieved filler size.

Table 2: Epoxy molding compound physical properties

Types of EMC		**Type A**	**Type B**	**Type C**
CTE 1	X 10^{-5}/°C	0.7	0.7	0.7
CTE 2	X 10^{-5}/°C	3.0	3.0	3.0
Tg	°C	130	130	130
F. Strength @RT	N/mm2	180	180	180
F. Strength @260deg.C	N/mm2	24	23	23
F. Modulus @RT	N/mm2	28000	28000	29000
F. Modulus @260deg.C	N/mm2	900	900	900
Water Absorption	(%)	0.11	0.13	0.13
Filler Content	(%)	90.5	90	90
Sieved Filler Size	(um)	55	75	75

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Coefficients of thermal expansion (CTE) control of the epoxy molding compound is probably the most important task formulating a epoxy molding compound (EMC) recipe. As well known, filler content is the primary factor controlling CTE. Epoxy molding compounds offer improvements in thermal expansion coefficients (CTE) and moisture absorption levels relative to liquid underfill materials. Increased filler content offers the ability to adjust the thermal expansion characteristics of the molding compound to match the package requirements. Molding compound composition parameters also determine JEDEC level performance, with level2a performance at 260°C reflow obtainable. In this paper the performance of three different epoxy molding compounds prepared for this research. The properties of the three molding compounds are summarised in Table 3. From the table showed that, epoxy molding compounds Types A, B and C are similar, the difference being a filler content and filler size. The compounds have relatively high glass transition temperatures and decreased coefficients of thermal expansion and rates of moisture absorption.

Effect of mold compound properties on MSL Reliability

Package reliability is a major concern for electronic devices. Moisture/reflow induced damage occurs when moisture absorbed during storage causes package delaminations during solder reflow from the vapour pressure formed. This delamination failure could be resulted from both moisture sensitivity and thermal mismatch of mold compound with its interfacial. Leadframe paddles are typically coated with silver plating for the purpose of ground bonding. However, silver surface had known to have weak adhesion to mold compound and is expected to be the weakest link to reliability failures. Mold compound characterisations were used to select the most suitable compound for the qualification of this QFN package. Three mold compounds were chosen for selection and the tests include:

a) Interfacial adhesion shear testing
b) Mold compound and moisture absorption characterization

Package delamination study

Contaminants on the surface of the leadframe, die, or die paddle can prevent good adhesion with the plastic material and lead to delamination. The use of incorrect leadframe texture, dimensions, and design can also reduce adhesion strength. The use of molding compounds with excessive mold release agent can also lead to delamination. Excessive mismatches between the thermal coefficient of the plastic and those of the leadframe, die, and die attach material can also result in delamination.

Ni/Pd/Au Leadframe have finish die bond and wire bond process were mold with different mold compound, leadframe preheat, molding temperature, transfer speed, post mold cure time during the assembly of the packages for the delamination study. Adhesion to Ni/Pd/Au Leadframe usually measured by shear test. Package delamination inspection was performed using C-mode scanning Acoustic Microscopy (C-SAM). The degree of package delamination was characterized by

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measuring the area of delamination detected at the die pad and mold compound.

RESULTS AND DISCUSSION

Mold compound characterization

From studied the material properties of mold compound, the effect of composition such as fluidity, moisture absorption and adhesion strength on package delamination was investigated using one type of encapsulated QFN Package. The C-mode scanning Acoustic Microscopy (C-SAM) was used for this study.

Table 3 shows results from the C-SAM analysis of the Ni/Pd/Au leadframe and mold compound delamination as a different of process parameter and different of mold compound. This observation results as EMC type C have a good package because low of percentage of delamination and EMC type A and EMC type B have the same percentage of delamination. Investigations will be presented showing that for the QFN packages size 3.5 mm x 4.0 mm the full delamination after 500 cycles on die pad. For packages size 14 mm x 14 mm for three different mold compound showed delamination area propagates slightly after 500 cycle. This result showed that MSL determines EMC type C better than EMC type A and EMC type B.

Effect of mold compound properties on MSL Reliability

It is widely accepted that the properties of packaging materials have a strong influence on the reliability performance of IC packages under JEDEC MSL-reflow reliability. Packages are constructed based on the integration of materials with different thermal expansion properties. The thermal mismatches between these materials under thermal excursion as well as the coupling flexural responses would be important reliability parameters. In this paper, the various properties of the different mold compound and their impact on package reliability especially delamination will be investigated. In all analyses, a QFN package with body size of 3.5mm x 4.0mm and 14mm x 14mm has been used respectively. As shown in Table 4, the normalized percentage of delamination increase for different epoxy mold compound. QFN packages using mold compound with EMC Type A shown a good package because low of percentage of delamination along the die-mold compound interface. Kapoor et al [5] has reported that, it is envisaged that a mold compound with high CTE would aggravate CTE mismatches with the die inducing large strain, especially at the peak reflow temperature, where adhesion could be severely compromised.

Table 3: Types of EMC

TYPE A			
Test Item	Test Condition	Results	
		3.5mmx4.0mm	14mmx14mm
MSL Level 2a	60C/60%RH 120hrs	8/12	10/10
Thermal cycle	-65/150C, 500 cycles	12/12	10/10

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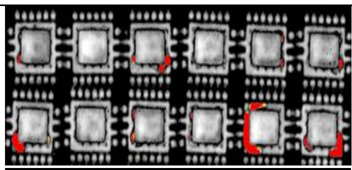
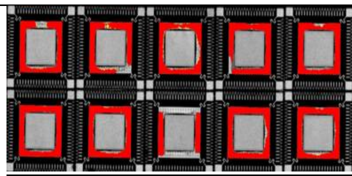
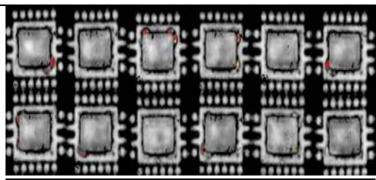
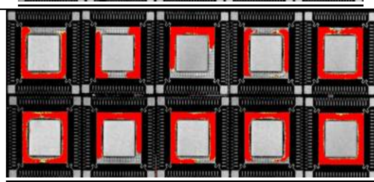
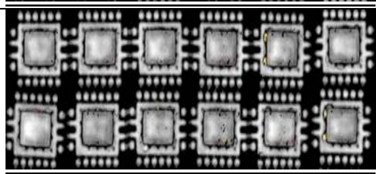
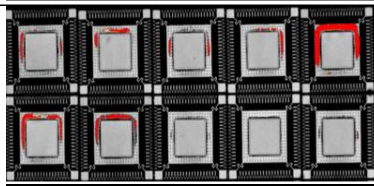
TYPE B			
		Results	
Test Item	Test Condition	3.5mmx4.0mm	14mmx14mm
MSL Level 2a	60C/60%RH 120hrs	7/12	10/10
Thermal cycle	-65/150C, 500 cycles	12/12	10/10
TYPE C			
		Results	
Test Item	Test Condition	3.5mmx4.0mm	14mmx14mm
MSL Level 2a	60C/60%RH 120hrs	0/12	9/10
Thermal cycle	-65/150C, 500 cycles	12/12	5/10

Package delamination study

However the factors which evolve from the mold compound, also contribute to delamination :

- Voids
- Moisture absorption
- Resin bleed
- Volatile deposition
- Modulus of elasticity
- Adhesion

Table 4: C-SAM image showing delaminated interface between die pad and mold compound. (MSL Level 2a)

	3.5 mm x 4.0 mm	14.0mm x 14.00 mm
EMC type A		
EMC type B		
EMC type C		

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Package reliability

During reflow-soldering processing at temperatures, delamination cracks may initiate at the die surface, lead-frame fingers, or die-paddle interface because of the thermal mismatches between the package components and degraded interfacial-bond strength. Plastic molding compounds are inherently hygroscopic and absorb moisture to a level dependent on the ambient humidity and temperature. The moisture absorbed within the molding compound preferentially gathers around the lead frame/molding compound interface and tends to expand into a gas at high temperature. Hegan et al [3]. reported that plastic packages absorb water from the atmosphere. This water vaporizes when exposed to high temperatures during surface mounting. Stresses inside the package can cause delamination at interfaces, such as those between the die, diebond epoxy, leadfirame, and epoxy mold compound. In some surface mount components, especially those with large die, the delamination propagates into a crack during the surface mounting process [3].

The material, process, and design factors were extensively evaluated by the experiments. The evaluation results showed that adhesion strength, moisture absorption and post mold cure were major factors affecting the package integrity and could produce the delamination initiation at the edge of the die attach paste and propagate down to the lead-frame paddle/mold compound interface due to high stress concentration and weak adhesion strength. Schmidt, R et al [4] has reported that the adhesion strength is decreasing with increasing temperature. The results also showed that it is not possible to extrapolate the adhesion strengths obtained at room temperature to higher temperatures as the correlation between different sample types according to their adhesion strength at room temperature differs strongly from the correlation at higher temperatures.

CONCLUSIONS

This study investigates the effect of delamination between 3 different types of compound and Ni/Pd/Au leadframe, the effective adjustment some of the parameters in the molding process caused delamination and experimental investigation of thermal expansion behavior, adhesion strength behavior, and epoxy molding compound properties that caused delamination. Based on the results in this study, we conclude the following that EMC type C is a good package because low of percentage of delamination and EMC type A and EMC type B have a high of percentage of delamination. The process parameter such as mold temperature and post mold cure must be consider in the molding process to prevent delamination and to prevent delamination from occurring, semiconductor device manufacturers have sought ways to improve the interfacial adhesion between the polymer and the substrate. Interfacial delamination between the mold compound-bottom die interfaces has been identified as a potential cause of reliability failures. It is envisaged that the cause of such delamination could be multi-faceted, including both moisture related (multiphysical impact both mechanical and chemical) as well as thermo-mechanical factors. Molding compound properties is equally important for controlling polyimide interfacial adhesion. Coupling agent type also was significant

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in determining adhesion characteristics. As a conclusion, from the study of delamination was affected by adhesion, moisture absorption and the mismatch of coefficients of thermal expansion between mold compound and leadframe.

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