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EFFECT OF MOLDING COMPOUND AND DIE ATTACH ADHESIVE MATERIAL ON QFN PACKAGE DELAMINATION AND WARPAGE ISSUES

U. Mokhtar, R. Rasid, S. Ahmad, A.E. Said, F.L.A. Latip and C.C. Ng

School of Applied Physics, Faculty of Science and Technology,
Universiti Kebangsaan Malaysia,
43600 UKM Bangi, Selangor

ABSTRACT

The presence of thermal mismatch between different materials of plastic IC packages was found to cause reliability and moldability issues such as delamination and warpage phenomenon. Delamination and warpage between the mold compound and die attach adhesive material were evaluated for Quad Flat No-lead (QFN) package. Evaluation was conducted on two set of different materials combination of epoxy mold compounds (EMC A & EMC B) and epoxies (Epoxy A and Epoxy B). The objective of this evaluation is to qualify QFN green compound with die attach adhesive material and pass MSL-1 with 3xIR reflow @ 260 °C. The effect of material properties performance of both materials were also studied. The delamination was observed between the mold compound and epoxy by using C-SAM technique. From the C-SAM image, delamination almost occur at bottom of the die to epoxy die attach, epoxy die attach to top surface of the leadframe, leadframe to mold compound and top of die to mold compound. While the warpage of QFN stacked die were measured using Smartscope Gaging 250 optical testing. The warpage are warp into crossbow warpage type according to the combined expansion characteristics of the different materials. It is found that not only the EMC properties, but also the epoxy die attach properties will also affect the warpage and delamination phenomenon.

INTRODUCTION

Plastic packaging in the electronic industry has become important since the past decades. One of the reasons is its low cost compared to ceramic packaging. Epoxy molding compounds (EMC) are used in plastic packages due to their lower cost and good environment resistance ability [1]. EMC is the material that easily uptake moisture under ambient conditions. This can cause delamination at various interfaces in the different materials of the package. Delamination can occur at several interfaces, such as at bottom of the die to epoxy die attach, epoxy die attach to top surface of the leadframe, leadframe to mold compound and top of die to mold compound.

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

Corresponding Author: umi_libra30@yahoo.com

amplified during any operation involving high temperature. One example will be the soldering of the packages chips 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 package crack or generally known as called popcorn effect which also accelerates delamination process. Once there is some delamination, moisture from outside can then penetrate the package easily and thus causing further delamination [2].

In addition, different coefficients of thermal expansion (*CTE*) values of different epoxy compound formulations and assembly materials are also considered as the main cause of package warpage. The formulation percentage can be adjusted and materials properties can be changed accordingly. It is meaningful to control package warpage through manipulating materials properties of molding compounds, such as T_g and *CTE*. *CTE*s of molding compounds are largely controlled by filler contents, such as percent loading of silica fillers.

In this paper, different combinations of mold compounds and epoxies were performed to investigate the excessive warpage and delamination of the QFN packages under moisture/Pb-free reflow (260 °C) requirement.

EXPERIMENTAL METHOD

Materials

In this study, the QFN single die was evaluated using different mold compounds and epoxies die attach. The process flow for manufacturing the QFN packages is shows in Figure 1. All test vehicles were 48 lead devices with a body size of 7 mm X 7 mm and a body thickness of 0.85 mm. This evaluation are using the 5 x 5mm square die with size of die attach paddle (DAP) for the leadframe is 5.8 x 5.8 mm. This package was evaluated because larger packages tend to exhibit more warpage and larger die size had high potential of separation than smaller die size. This larger die size had the larger interface area between die and epoxy, the level of stress induced is higher when exposed to temperature change. The basic construction of the packages strip are shown in Figure 2.

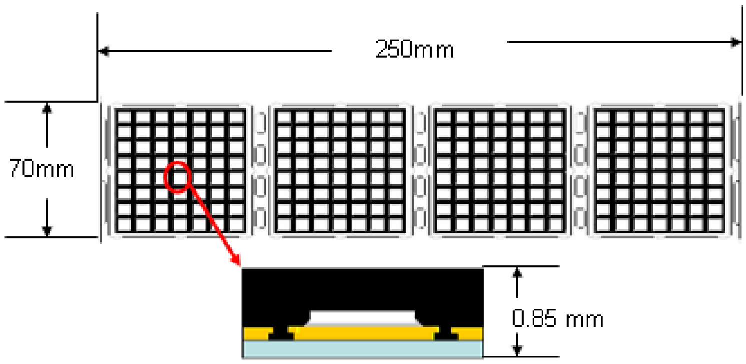

Figure 1: QFN process flow.

Corresponding Author: umi_libra30@yahoo.com

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The thermal and mechanical properties of the epoxies die attach and mold compounds material used in this package are presented in Table 1 and Table 2. The different mold compound properties are major factors affecting the delamination performance were evaluated. The new generation low stress mold compounds were evaluated that can reduce the warpage and delamination failure. The new mold compound (EMC B) are based on the fine filler and low stress additives. This compound have higher flexural modulus, lower coefficient of thermal expansion, and lower viscosity than the old mold compound (EMC A) according to increase filler contents.

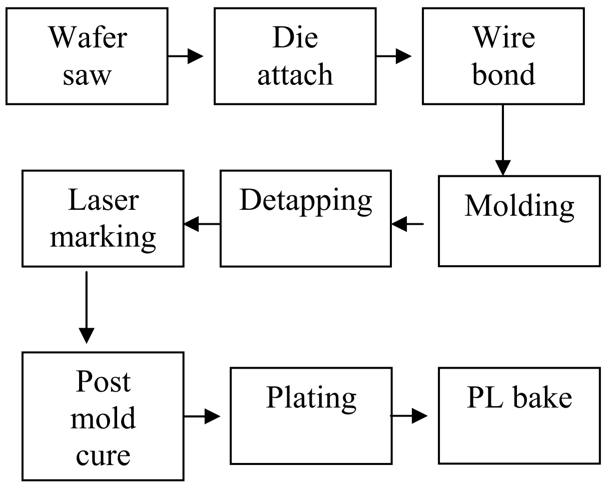


Figure 2: QFN strip and QFN Single Die package.

Table 1: Material properties of EMC A and B.

Items	Unit	EMC A	EMC B
Filler size	µm	75	55
Filler content	%	90	90.5
*CTE*1	$x10^{-5}$/deg.C	0.8	0.7
*CTE*2	$x10^{-5}$/deg.C	3.9	3.4
T_g	°C	140	140
Modulus @ RT	N/mm^2	28000	29000
Modulus @ 260 ºC	N/mm^2	800	900
Viscosity	poise	108.2	100
Moisture absorption	%	0.15	0.14

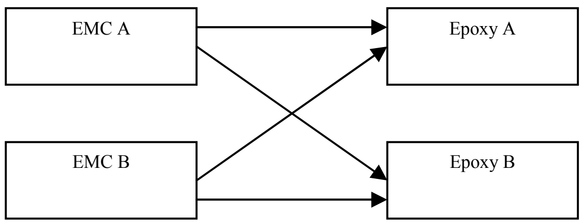
Furthermore, the material properties for Epoxy B was evaluated with new formulation different than Epoxy A. Both the epoxies used are conductive adhesive. The behaviours of epoxy properties such as thermal conductivity, tensile modulus and *CTE* have to take into consideration carefully [3]. Normally, epoxy material are used consider to thermal conductivity properties as a heat transfer medium of die to

Corresponding Author: umi_libra30@yahoo.com

the leadframe. Regarding to epoxy, the characteristics of epoxy is lower stress distributions and higher adhesion to stand the thermal stress, and delamination or popcorn prevention. Considering productivity, the epoxy must have short resin bleeding to avoid contaminating on the bonding pad of bottom die [4]. Four samples were assembled for each of the current and new mold compounds. Fig. 3 illustrates the combinations of evaluated materials.

Table 2: Material properties of Both Epoxies.

Items	Unit	Epoxy A	Epoxy B
Die shear Strength @ 250 ºC	N/mm^2	11.8	12
CTE α1	ppm	50	50
CTE α2	ppm	80	130
T_g	ºC	110	60
Thermal Conductivity	W/mK	1.5	0.9
Elastic modulus @250 ºC	MPa	340	100
Moisture absorption	%	0.25	0.4
Viscosity	PS	200	170



Leg 1	EMC A + Epoxy A
Leg 2	EMC B + Epoxy A
Leg 3	EMC A + Epoxy B
Leg 4	EMC B + Epoxy B

Figure 3: Combination of mold compounds and epoxies in this evaluation.

Warpage Measurement
The technique of Smartscope Gaging 250 Optical testing was used to measure package body warpage after encapsulation process and after post mold cure. This microscope offers versatility and high performance three-axis measurement of parts and electrical components, with very high precision. Each strip has four blocks. The

Corresponding Author: umi_libra30@yahoo.com

locations of warpage measurement were chosen at the four diagonal corners of each block as illustrated in Figure 4. The difference between the vertical displacement value at the central point and the minimum value at the four corner points is defined as the block warpage. The maximum warpage value of the four blocks is taken as the warpage of the molded strip [5].

C-SAM Analysis

This equipment (*SONIX SAM*) is a failure analysis technique used to observe the delamination of failed sample for examples interfaces between the plastic resin package materials, the die, the die paddle, the leadframe and the die attach material before and after the MSL 1 according to JEDEC conditions.

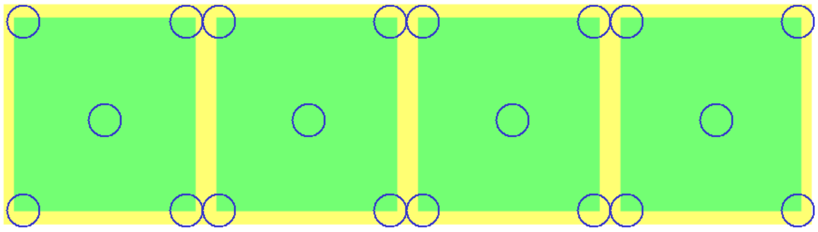


Figure 4: Measurement points of warpage.

RESULTS AND DISCUSSIONS

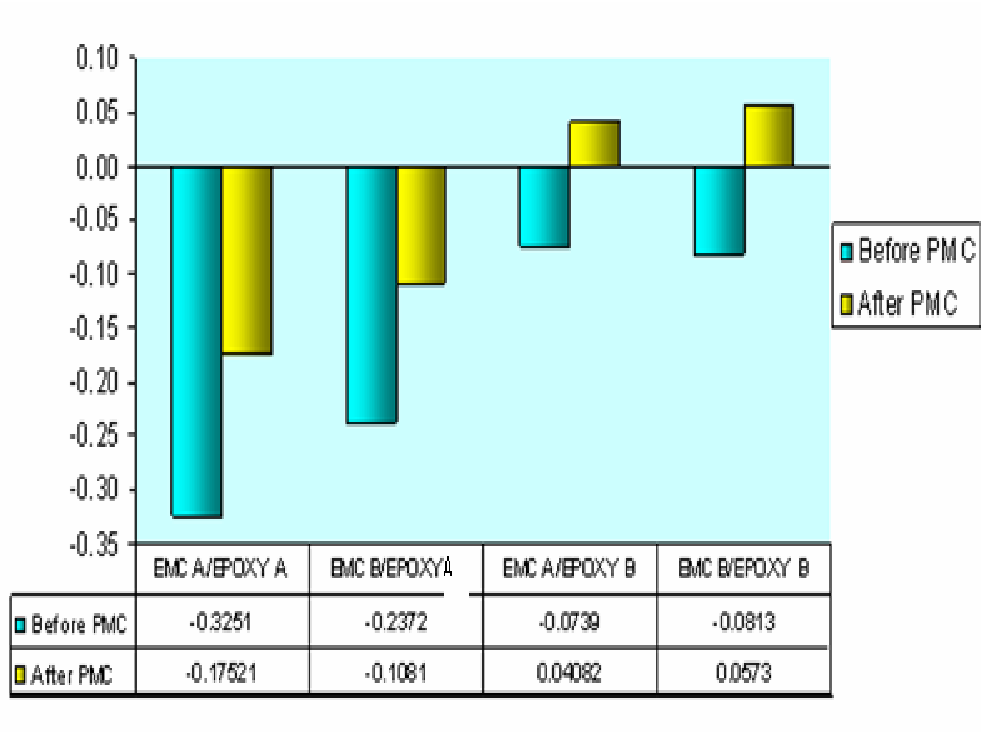


Figure 5: Package warpage before PMC and after PMC.

Corresponding Author: umi_libra30@yahoo.com

Package warpage

The warpage evaluation was using 2 EMCs and 2 epoxies die attach as described in Table 1 and 2, 4 strips were molded under the molding condition at 175 ± 5 °C and then Post Mold Cure (PMC) was conducted at 175 ± 5 °C for 5 hours. Warpage of package was measured before and after PMC, and compared to it as shown in Fig. 5. As the facility of warpage measurement, Smartscope Gaging 250 Optical testing was used. From Figure 5, combination Leg 1 and 2 is the highest warpage value than combination Leg 3 and 4. The result shows warpage level decrease after PMC process.

CTE control of the EMC is probably the most important task in formulating an EMC recipe. As well known, filler content is the primary factor controlling *CTE*. Increasing the filler content to reduce *CTE*1, so as to minimize the warpage was a straightforward approach. The smaller mold shrinkage of the higher filler content formulation could also help to reduce the degree of warpage [6].

Package Delamination

After end of assembly, all units were investigated by external visual inspection. Typically, images of top scan was captured and analyzed to determine the performance of package delamination by using Scanning Acoustic Microscopy (SAM) method. Once external visual inspection and delamination was observed, all units were subjected through preconditioning as per JEDEC standard which include dry bake, MSL 1 (Moisture Soak) and reflow at leadfree temperature 260°C. Packages were reflowed through the standard IR reflow profile. After reflow, units were again checked for delamination. The result was observed at the die to epoxy, epoxy to paddle and mold compound to lead. From Figure 6, top scan for leg 1 and 2 have the delamination. Most the delaminations were observed between leadframe and die attach adhesive. No delamination was detected on any units for leg 3 and 4. The result showed that the epoxy had maximum effect on the delamination failed as compared to the EMC. Due to the material properties epoxy had higher moisture absorption than EMC. Thermal conductivity of epoxy also contributes in this situation. Regarding to water expands and heat transfer during the high temperature of MSL-1 condition.

To ensure there was a discontinuity layer as reflected in top scan pictures, 1 unit from each failed leg were then cross sectioned and studied under SEM to capture the delamination or separation as shown in Figure 6. Physical cross-section on selected units was observed by Scanning Electron Microscopy (SEM) and Optical Microscope (OM). The main causes of delamination are the *CTE* mismatches between the various interface of molding compound and epoxy die attach. In addition, decrease adhesive strength between the molding compound, epoxy die attach at the die paddle and leadframe also affected to delamination failure. From the Figure 7 also shown the internal crack that occur from delamination along epoxy to die paddle and crack propagate downwards through the package. Poor adhesive adhesion to the epoxy die attach to interfacial delamination which eventually

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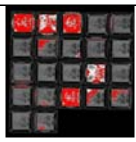
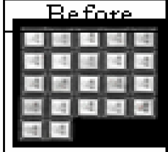
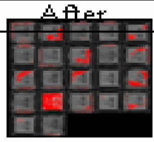
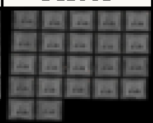
propagates package cracking after MSL-1.

Leg 1		Result		
Before	After	TODD	TOPD	TOLD
		11/22	8/22	7/22

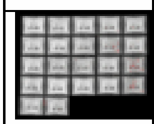
(a)

Leg 2		Result		
Before	After	TODD	TOPD	TOLD
		11/22	16/22	10/22

(b)

Leg 4		Result		
Before	After	TODD	TOPD	TOLD
		0/22	0/22	0/22

(c)

Leg 3		Result		
Before	After	TODD	TOPD	TOLD
		0/22	0/22	0/22

(d)

Figure 6: Top scan images before and after reconditioning with MSL; (a) EMC A and epoxy A (b) EMC B and epoxy A (c) EMC A and epoxy B and (d) EMC B and epoxy B.

Corresponding Author: umi_libra30@yahoo.com

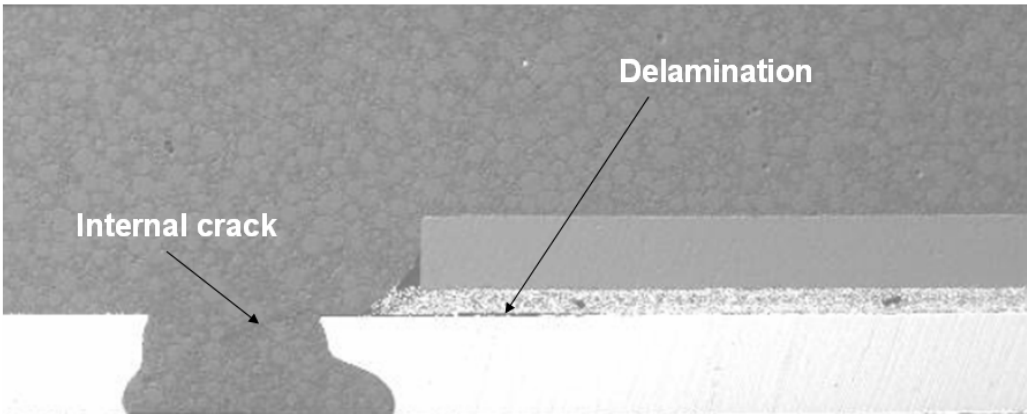


Figure 7: SEM image for package crack and delamination on selected unit of QFN package.

CONCLUSIONS

According to this study, leg 3 and 4 were found to be the best combination between mold compound and die attach material because low of percentage of delamination and warpage issues. From the warpage result showed the process condition such as after molding process and after post mold cure are contribute on the warpage value. The increased of the filler contents EMC induced the decreased of *CTE* and of strip warpage. In addition, the strip warpage result from structure of constitutes and the presence of thermal mismatch *CTE* between EMC and die attach material. For delamination result that combination using new epoxy performed better than the old epoxy regardless of the EMC used. This also suggested that epoxy had a stronger influence on the package warpage and delamination comparing to EMC. In choosing the best candidate of epoxy, one should determine the thermal conductivity and moisture absorption as a function of temperature and moisture whenever possible.

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