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Die Attach Process Optimization with Enhanced Epoxy Control on Leadframe Package

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Authors' contributions

This work was carried out in collaboration amongst the authors. All authors read, reviewed and approved the final manuscript.

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ABSTRACT

The paper presents a practical procedure in selecting the best candidate for die attach epoxy control or anti-epoxy bleed-out (anti-EBO) concentration during the introduction of new leadframe configuration. Three different criteria were implemented to measure the relative impact of the anti-EBO into the different interfaces inside a quad-flat no-leads multi-row (QFN-mr) leadframe unit. Die shear test is performed to measure the shear strength and the compatibility of the anti-EBO to the adhesive material. EBO measurement is performed herewith to study the propagation of epoxy bleed-out on the surface of the leadframe with reference to the different level of anti-EBO concentration. Package reliability is employed study the response of different interfaces directly in-contact with anti-EBO through thermal-cycling scenario. Ultimately, understanding the effect of anti-EBO into different set of tests provided a systematic way of selecting appropriate leadframe parameters for QFN-mr leadframe product.

Keywords: QFN; die attach; epoxy control; leadframe; reliability.

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1. INTRODUCTION

Quad-flat no-leads multi-row (QFN-mr) is a type of leadframe packaging technique under surface mount devices wherein it is designed to be capable of higher number of input/output (I/O) than conventional QFN design. The package is composed of a die glued to the die pad of the leadframe, either with a conductive or non-conductive adhesive. Electrical interconnections from the bond pad of the die to the terminal pads are connected with semiconductor wires. Encapsulation material is made up of epoxy mold compound (EMC) to conceal the wiring and functional circuitry of the die. This type of technology undergoes a chemical process of etching using a strong acid or mordant to cut into the unprotected parts of a metal surface to expose the design of the metal.

Epoxy bleed-out (EBO) is a phenomenon that takes place when working with filled, adhesive systems dispensed onto various surfaces like lead frames and substrates. It is often described as a clear, colorless or amber organic stain surrounding the die attach epoxy and when inspected through low mag scope, this appears as a shadow or a halo ring around the silicon die as shown in Fig. 1. The occurrence of EBO is common on roughened leadframe due to the "capillary effect" or the continuous flow of the non-solid (organic) substance of the glue to the surface of the frame. The assembly difficulties are the uncontrollable rate of EBO is uncontrollable, and the negative effect of EBO to the reliability of the package. Note that with new and continuous technology trends and state-of-the-art platforms, challenges are inevitable [1-5]. The delamination between the interface of glue to pad or mold to pad was the key to establish the introduction of anti-EBO compound, an organic material usually hydrophobic that is integrated in the outer layer of the leadframe to stop the propagation of EBO.

Delimitations in studying anti-EBO substances is the intellectual property protection of the substance from disclosing yet it became a practice for integrated circuit manufacturing to implement series of assembly evaluations in bringing-up the correct anti-EBO parameters. In this paper, multiple assembly evaluations for anti-EBO concentration is presented to accurately identify the correct anti-EBO parameters for QFN-mr packages which are encountered with delamination issue during the first initial workability.

2. METHODOLOGY

To robustly select the best anti-EBO concentration, 3 parameters composed of different anti-EBO concentrations is proposed, namely 5 ml/L and 10 ml/L and a control anti-EBO called T13 will be processed in series. The ml/L unit used by the supplier is said to be the ratio of anti-EBO per Liter of liquid solution. The success of the evaluation will be measured from the Actual EBO measurement, die shear strength and package reliability as shown in Table 1.

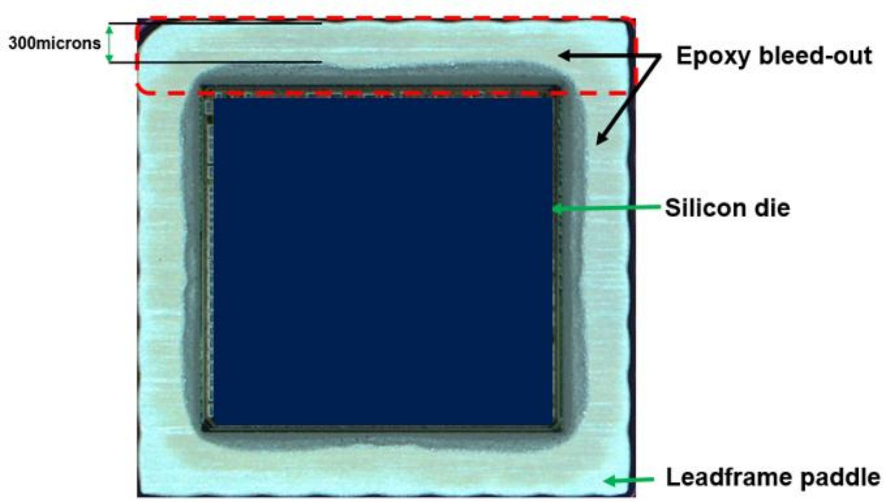


Fig. 1. Epoxy bleed-out on actual unit

Table 1. Evaluation plan

Trial	Parameter	EBO	Die shear	Package reliability
1	5 ml/L	To be measured on the 3 trials		
2	10 ml/L			
3	T13 (control)			

Table 2. Test vehicle

Package details	Value
Package size	< 8 x 8 mm
Die size / die finish / die thickness	3.5 x 3.5 mm / Cr/NV/Au / 280 µm
Leadframe / cavity size	Roughened PPF / 4.5 x 4.5
Glue	Conductive, silver filled
Mold	EMC

Fig. 2. QFN-mr assembly process flow

The details and the configuration of the direct material needed for the evaluations is presented in Table 2. The silicon die with backside metallization is suggested that will be attached to a roughened pre-plated finish (PPF) leadframe of 4.5 x 4.5 mm cavity size using a highly conductive glue then the unit is encapsulated by EMC.

The chronological order of the QFN-mr assembly is presented in Fig. 2. The EBO measurement and die shear strength test applies after die attach stations and package reliability test is expected after the unit is singulated. Note that assembly manufacturing process flow depends on the technology and the product [5-8].

3. RESULTS AND DISCUSSION

The test required in this study focused on the areas directly in-contact with the organic substance or anti-EBO. The key interface that is closely studied in this paper are the adhesive to cavity and mold to cavity interface.

3.1 Die Shear Test

Die shear test (DST) is performed to check the shear strength of the adhesive material to the anti-EBO compound present at the outer layer of the leadframe cavity. The expectation is to achieve a similar or better response from the control trial (Trial 3) and measurably less than the control suggest that the newly introduced anti-EBO is incompatible with the adhesive material. Analysis of variance in Fig. 3 shows that Trial 1 has a better shear strength reading than the control while Trial 2 has a similar die shear strength response than the control.

From the result, the anti-EBO parameters both from Trial 1 and 2 is compatible with the adhesive material and passed the requirement standard.

3.2 Epoxy Bleed-out

Other factors such EBO measurement is checked to determine the propagation of epoxy bleeding, with trials done given in Fig. 4. Based from assembly standard, EBO propagation should be maintained at a minimum level or < 200 µm from the actual epoxy coverage due to the possibility of package delamination that may originate from the bleed-out.

EBO result for the 3 trials shows that Trial 1 has the worst EBO propagation with a measurement of average 300 µm which failed the industry requirement of less than 200 µm. Trial 2 and 3 shows minimal to none EBO propagation and passed industry requirements.

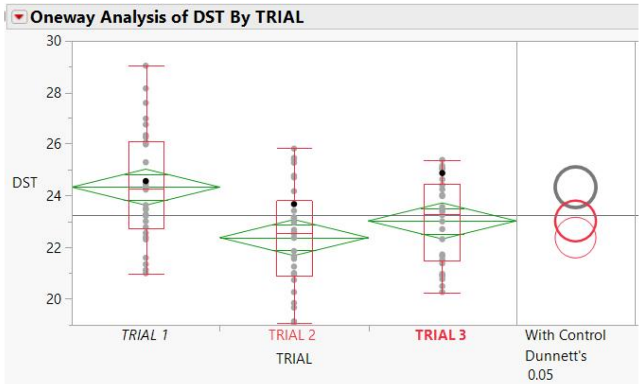


Fig. 3. Die shear test statistical comparison

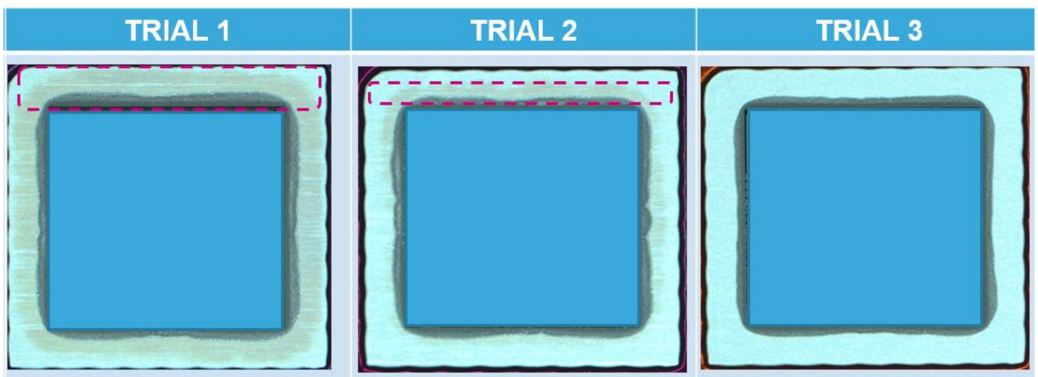


Fig. 4. Epoxy bleed-out

3.3 Package Reliability

In package reliability, the main objective is to check if delamination especially on the focus interfaces such mold- cavity and glue – cavity which is relevant to the anti-EBO evaluations. Delamination is evident on Trial 1 and 3 and no delamination is seen on Trial 2, as shown in Fig. 5. The delamination seen on Trial 1 is correlated to the worst epoxy bleeding encountered after die-attach. The signature of the delamination for Trial 1 is originating from the mold- cavity interface, where bleed-out resides, and propagating to the glue and cavity interface under the silicon die. For Trial 3 which is the control Trial, similar delamination signature is seen wherein there is a total delamination of the die.

A sample unit is taken off from the Trial 1 and 2 and a cross-sectional analysis is performed. Fig. 6 shows the cross-sectional image of Trial 1. Delamination is seen on the mold-cavity interface where bleed-out of the epoxy is also visible while there is no delamination seen under the silicon die. This confirms that the origin of the delamination is from the outside and later propagate under the silicon die.

The cross-sectional photo of the sample taken from Trial 2 is shown in Fig. 7. Trial 2 shows no delamination of the mold-cavity and adhesive-cavity interface.

All three trials conducted in this study have been passing die shear test response wherein it confirms that there is a good interfacial strength between adhesive material and anti-EBO. Criteria for assembly rejects and visual inspection are governed by internal specifications and work instruction documents [9,10].

The best die shear test response is seen on Trial 1 which has the least concentration however this is indirectly proportional to the epoxy bleeding response wherein the less concentration of anti-EBO produces worst bleeding on the surface of the leadframe cavity. The occurrence of epoxy bleeding on surface produces delamination between the mold – cavity interface that would negatively affect the package reliability of the unit. From the result of the Trial 2 although it has a die shear strength less than Trial 1, it produces acceptable epoxy bleed-out and a passing package reliability. Based from the assembly criteria, Trial 2 is the best candidate for the concentration of anti-EBO.

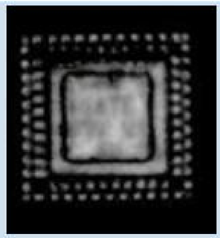
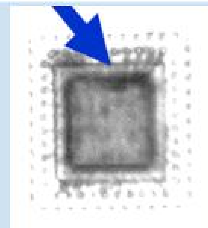
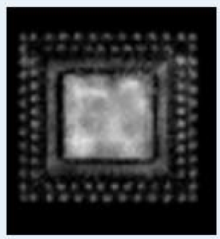
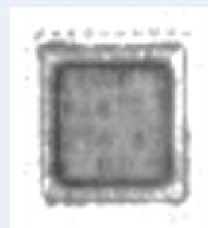
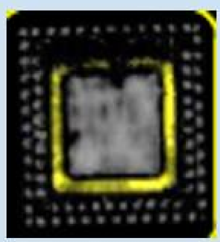
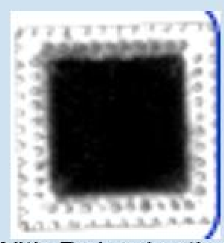
TRIAL	CSAM(TC1000)	SAM (TC1000)
1		 With Delamination
2		
3		 With Delamination

Fig. 5. Package reliability results

Fig. 6. Cross-sectional analysis for Trial 1

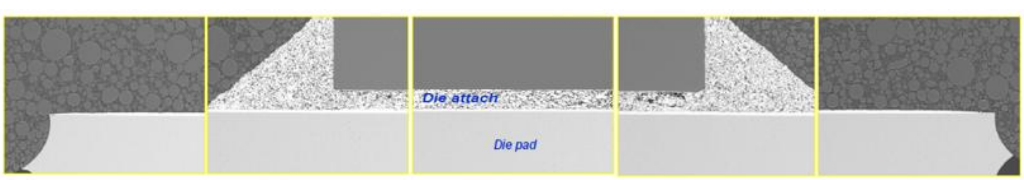


Fig. 7. Cross-sectional analysis for Trial 2

4. CONCLUSION AND RECOMMENDATIONS

A practical approach such as studying the die shear test, epoxy bleed-out measurement and package reliability responses is suggested when selecting appropriate leadframe parameters. The lower concentration of anti-EBO produces better shear strength response for roughened PPF leadframe however it produces worst bleeding response. The bleeding of epoxy produces delamination between mold-cavity interface that may propagate on other interface such as adhesive-glue. When selecting the best candidate for anti-EBO, the material should be balanced with the other direct material such as mold and adhesive response in such a way it will pass the industry standard. Note that continuous process and design improvement is necessary to maintain high quality performance of assembly manufacturing. Studies and works in [1,4,5,11,12] are helpful in deeply understanding the material and its experiments and to improve the die attach process.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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