

# Epoxy Molding Compound bleeding reduction on surface mount semiconductor device

Fulvio Viviani  
Backend Manufacturing and  
Technology R&D  
STMicroelectronics  
Agrate Brianza, Italy  
fulvio.viviani@st.com

Federico Leone  
Backend Manufacturing and  
Technology R&D  
STMicroelectronics  
Agrate Brianza, Italy  
federico.leone@st.com

Hidetoshi Seki  
Information & Telecommunication  
Materials Research Laboratory  
Sumitomo Bakelite  
Singapore  
hseki@sumibe.co.jp

Masami Ishii  
Information & Telecommunication  
Materials Research Laboratory  
Sumitomo Bakelite  
Singapore  
ishii-masami@sumibe.co.jp

**Abstract** – Epoxy Molding Compound (EMC) bleed consists of a transparent layer of resin which mainly could occur during molding injection at material packing stage. Resin bleeds on exposed pad of a Surface Mount Device (SMD) can significantly impact the solderability performances of the package, causing failure of the product. De-flashing process after molding is generally performed to eliminate the resin bleed. However, de-flashing can be performed on post-plated leadframes without critical drawback, while it is not recommended on pre-plated leadframes due to the high risk of damaging the finishing surface. In this study, an alternative approach aimed to reduce or eliminate molding compound bleed by optimizing the inorganic part of the molding compound formulation is presented. Besides the quality improvement, the presented approach provides an economical advantage since, by tuning the properties of the filler inside the EMC, it is possible to eliminate the de-flashing process from the assembly flow of a package and consequently reduce the manufacturing cost.

**Keywords** - epoxy molding compound, molding compound bleed, solderability, de-flashing.

## I. INTRODUCTION

Nowadays, in the semiconductor market, two main Surface Mount Device (SMD) package families are used: full plastic and exposed pad/slug (Fig. 1). On full plastic type the die pad on which the die is bonded is completely embedded in the molding compound. Whereas in the exposed pad type, the die pad enhances the thermal dissipation of the product, representing a surface of contact between the die and the environment. For both types of SMD package families, two types of leadframe finishing can be used: post-plated and pre-plated. For the post-plated family (i.e., Bare Cu/Ag spot) the plating process is mandatory to grant the solderability of the package on Printed Circuit Board (PCB). For the pre-plated family, the plating process can be skipped thanks to the multiple layers finishing structure (for instance, NiPdAu) that preserves the solderability of the package on PCB, enhancing the total production cycle time. Focusing on exposed pad package type, one of the requirements is the cleanness of the die pad. One concern is the Epoxy Molding Compound (EMC) bleeding, a residue that can form nearby the end of EMC injection step, at the material packing stage. Molding

compound bleeds on exposed pad of Surface Mount Device can significantly impact the solderability performances of the package causing failure of the product. On the exposed pad with post-plated leadframes, epoxy molding compound bleed can be easily removed/reduced by de-flashing process but on pre-plated leadframes finishing, the de-flashing process can induce cosmetic or functional defect of the product. In this study an alternative solution to eliminate/reduce the epoxy molding compound bleeds without the usage of de-flashing process was evaluated. The selected test vehicle is a Thin Quad Flat Package (TQFP) exposed pad package, with pre-plated leadframe finishing.

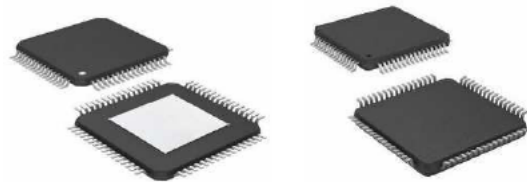


Fig. 1. Images of an exposed pad QFP (left) and a full plastic QFP (right).

## II. MATERIALS AND METHOD

Typically epoxy molding compound formulation includes organic and inorganic contents (Ellis, 1993). The organic content is made of polymeric molecules that react during molding and curing processes, forming mutual cross-linking. The inorganic content (generally a silica-based filler) takes the predominant part in the molding compound formulation (around 80% in weight or more). The fillers are loaded to modify several EMC features including the flowability (i.e., the rheology), thermomechanical and electrical properties, and to add bulk (mass). Depending on the application of the package, the EMC manufacturer controls the filler content, the size and distribution, which can be represented by Gaussian curve, and the maximum particle size. In this study the effect of filler on molding compound flowability, viscosity and so bleeding was investigated by adjusting fillers sphericity and sizes and in some cases by intentionally adding a given content of submicron filler (size < 1 $\mu$ m), that normally is not present in the formulation, without changing the total filler content in the formulation.

TABLE I. FORMULATION COMPARISON BETWEEN DIFFERENT EMC GRADES

Leg #	#1	#2	#3	#4	#5	#6	#7
Main filler (average size > 10um)	STD	STD	STD	STD	STD	STD	STD
Fine filler (average size < 5um)	STD	UP ↑	UP ↑	UP ↑↑	UP ↑↑	STD	STD
Sub-micron filler (average size < 1um)	No	No	No	No	No	Yes	Yes
Filler sphericity	STD x 1.15	STD x 1.15	STD	STD x 1.15	STD	STD x 1.15	STD

In order to verify the effect of filler sphericity and sizes on exposed pad molding compound bleeding, seven different epoxy mold compound formulations (Legs) were prepared by the EMC manufacturer as shown in Table I. The relative contents are not specified to preserve the manufacturer confidentiality.

#### A. DEFINITION OF THE FILLER SPHERICITY

The sphericity of the filler is defined according to the equation appearing in Fig. 2. The projected contour (L) and projected area (A) are measured by a particle analyzer, while the circle's contour (L') is the perimeters of a perfect circumference. The sphericity is then defined as the squared ratio between the real perimeter of the filler and the perimeter of an ideal circle.

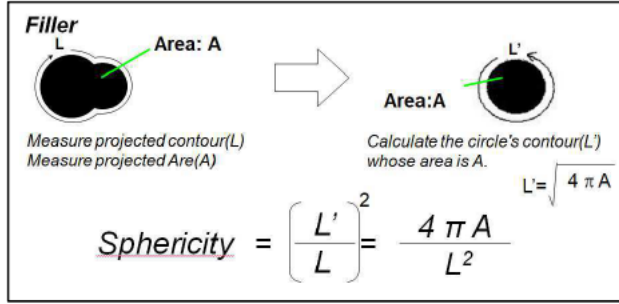


Fig. 2. Definition of Filler Sphericity.

#### B. MEASUREMENT METHOD OF EMC BLEEDING

The molding compound bleeding of the seven legs was measured by using a dedicated mold chase, as represented in Fig. 3. This tool is made of one resin pot, two runners and seven cavities for each runner. Every cavity has a vent located at the opposite side with respect to the gate to allow the evacuation of the air during the injection of the molding compound and the bleeding during the compaction phase. The process parameters are kept fixed for every trial.

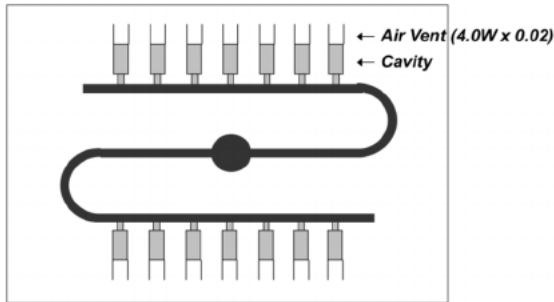


Fig. 3. Mold die tool with 14 cavities.

### III. RESULTS AND DISCUSSION

The evaluation was split into two parts: the first step was the assessment of the bleeding and a test on package at the EMC manufacturer; the second test was the evaluation of the workability properties on a real device at STMicroelectronics (STM).

#### A. EVALUATION AT EMC MANUFACTURER

Fig. 4 shows the comparison of the seven EMC in terms of bleeding length, collected using Fig. 3 tool.

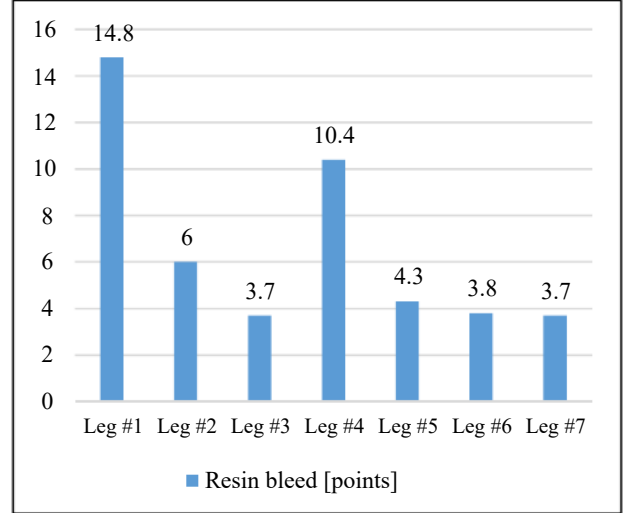


Fig. 4. Molding compound bleed measurements with dedicated mold tool.

From the couples LEG2/LEG3 and LEG4/LEG5, which have the same content of main filler, fine filler and no sub-micron filler, it is evident that the reduction of the filler sphericity (moving from “STD x 1.5” to “STD”) cause a reduction of the resin bleeding. From the couple LEG1/LEG6 we can observe the significant reduction of the bleeding length simply by introducing the sub-micron filler inside the resin formulation. Finally, LEG7 confirms that the implementation of a lower sphericity together with a sub-micron filler allows a further reduction of the bleeding. This test provided indication on how to modify the resin formulation theoretically. However, in order to confirm that these changes do not impact significantly the rheology of the resin, the Flow Pressure was measured and confirmed to be within the specification limits of the reference formulation (LEG1). In addition, an assembly was performed on a Quad-Flat-Package (QFP) exposed pad package to correlate the bleeding measurement obtained by the dedicated tool with the EMC bleeding on a real package.

On LEG1 (reference grade), LEG3, LEG6, LEG7 (having the lowest bleeding) the workability assessment was completed with the visual inspection of the plastic body (incomplete fill check) and wire sweep measurement. The results presented in Table II and Fig. 5 confirm the previous findings, assuring also that a change in the formulation does not imply any drawback in quality.

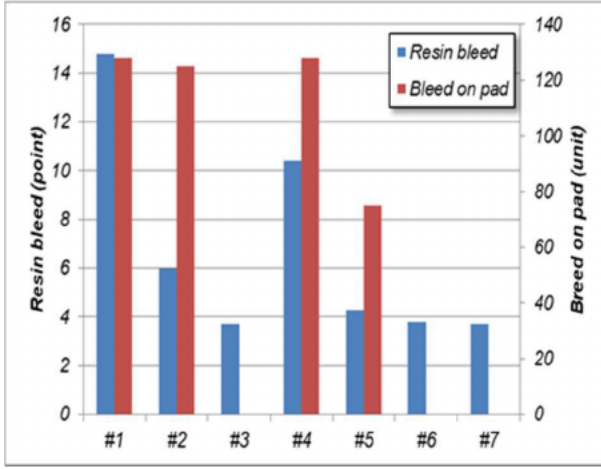


Fig. 5. Relationship between molding compound bleed and bleed on pad.

#### B. STM EVALUATION

After the evaluation at the resin manufacturer, the seven grades were tested by STM in a production environment. A new workability assessment was performed, adding external voids and delamination checks after post mold curing (PMC). A first screening to select the best candidates was performed by molding all the seven legs in the same conditions (i.e., molding parameters, material utilization, machine, mold chase type) and assembly flow. Table III shows the first screening results. The trials confirmed the preliminary evaluation results conducted by the supplier. LEG1, LEG2, LEG4 and LEG5 showed severe bleeding on the exposed pad. LEG6 had only 1 failure, while all the units of LEG3 and LEG7 passed the bleeding check (0/128 pcs). Having passed all the quality checks and being the best EMC candidate according to both STM and resin supplier assessments, LEG7 was finally selected. Fig. 6 shows a visual comparison of the bleeding

phenomena before (LEG1) and after (LEG7) the resin formulation improvement.



Fig. 6. LEG1 (left) and LEG7 (right) molding compound bleeding comparison.

Subsequently, LEG7 samples were submitted to standard reliability assessment to verify the absence of any package quality issue, passing all the requirements. To complete the full qualification, LEG7 has been further evaluated reproducing the typical corner conditions of mass production scenarios, both for material properties, utilization and equipment conditions. Results confirmed LEG7 to eradicate bleeding without any negative drawback on the quality of the final product.

#### C. RESULTS EXPLANATION

Summarizing, a bleeding optimization can be achieved by modifying the formulation of the EMC. LEG7 is a combination of two factors: the reduction of the filler sphericity together with the addition of a sub-micron filler content in the formulation. A lower sphericity triggers phenomena of mechanical interlocking and indentation, producing higher friction of the molecules within the resin flow. This is confirmed by the increase of the Koka viscosity, moving from the reference LEG to LEG6 (Table II). The submicron filler produces a similar effect, but according to a different mechanism: it easily fills the gap between the exposed pad and mold chase due to its small particles size, resulting in a local increase of the EMC viscosity during material packing stage (Fig. 7). Opposing more resistance to the resin flow, the bleeding can be drastically reduced.

TABLE II. SUPPLIER EVALUATION AND RESULTS

LEG	#1	#2	#3	#4	#5	#6	#7
Flow Pressure [MPa]	2.1	2.3	2.5	2.6	2.4	2.2	2.6
Koka viscosity [Poise]	116	151	170	154	175	140	163
Resin bleed [points]	14.8	6	3.7	10.4	4.3	3.8	3.7
Bleed on pad [units]	128/128	125/128	0/128	128/128	75/128	0/128	0/128
Wire Sweep (%)	< 2		< 2			< 2	< 2
Incomplete fill [units]	1/128		0/128			0/128	0/128

TABLE III. STM EVALUATION AND RESULTS

LEG	#1	#2	#3	#4	#5	#6	#7
Bleed length [points]	14.8	6	3.7	10.4	4.3	3.8	3.7
MAX wire sweep (%)	2		4			2	2
Bleed on pad [units]	128/128	125/128	0/128	128/128	75/128	1/128	0/128
Incomplete fill [units]	0/128		0/128			0/128	0/128
External voids [units]	0/128		0/128			0/128	0/128
Delamination after PMC [units]	1/128		0/128			1/128	0/128

#### IV. CONCLUSION

The present paper shows a feasible and advantageous solution to reduce/prevent epoxy molding compound bleeding on exposed pad for pre-plated leadframe. It was proven that a lower filler sphericity and the addition of a submicron filler inside the EMC formulation have significant impact on this phenomenon. The study was developed in two main phases.

- An assessment at the EMC manufacturer: thanks to a dedicated tool it was possible to measure the effect of the resin formulation changes on the length of the bleeding: the candidates were later molded on a QFP exposed pad package.
- An assessment at STM: seven grades prepared by the supplier were tested in a production environment, confirming the improvement, and assuring the absence of quality issues for the final product.

At the end of the evaluation, LEG7 was chosen as the best formulation to eradicate the molding compound bleeding on exposed pad without affecting other key material properties and performances.

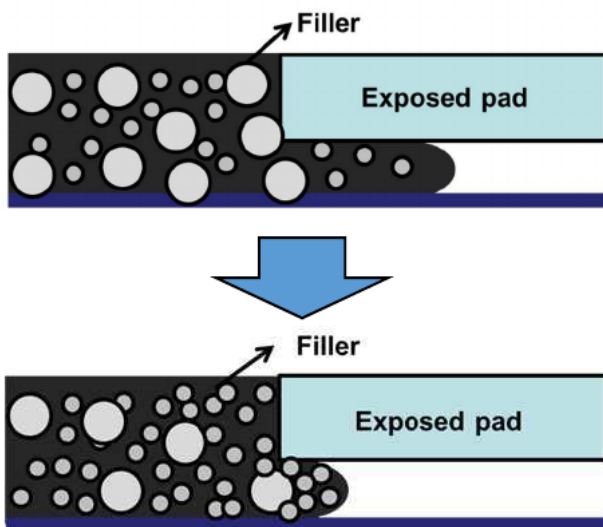


Fig.7. Effect of sub-micron filler on molding compound bleed.

The proposed approach grants the possibility to remove the de-flashing operation that could damage pre-plated leadframes. There are two immediate consequences: the improvement of the reliability of SMD on PCB and the reduction of the assembly costs.

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