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Establishing Robust Control for Epoxy Open Time

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The Open time is called the time it takes for this chemical transition from liquid to solid. The epoxy moves into a gel state from the liquid state as it recovers, until it enters a solid-state. This article will address the development of a new, regulatory-compliant in die attach epoxy that establishes robust Epoxy Open Time control to improve the performance of product reliability with the following quality output response characteristic in Die Attach was consider; Epoxy Coverage, epoxy voids, Bond Line Thickness (BLT), and Die Shear Test (DST) strength response.

Keywords: Die Attach; open time; epoxy coverage.

1. INTRODUCTION

With the use of epoxy adhesive, an epoxy bond is created by connecting the die to the leadframe. A drop of epoxy is dispensed on the leadframe and the die placed on top of it. To effectively cure the epoxy, the epoxy needs to be heated at a required temperature properly [1]. This process uses adhesives such as polyimide, epoxy and silver-filled glass as die attach the material to mount the die on the die pad. The mass of epoxy on the die peripheral of the die is known as the Epoxy Coverage area after die bonded, this provides mechanical strength along the die edge [2] as shown in Fig. 1. The standard criteria or requirement for epoxy coverage is 100%. The problems in achieving and controlling the epoxy coverage and inadequate corner coverage can lead to delamination at the die corners [3].

This article aims to share and discuss the study of actual experimental for Die Attach Epoxy

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Open time as part of the control to achieve good epoxy coverage.

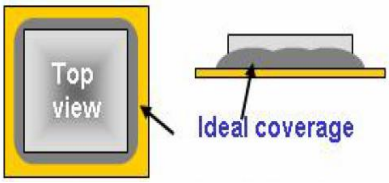


Fig. 1. Ideal epoxy coverage

Mixing epoxy resin and hardener begins a chemical reaction that transforms the combined liquid ingredients into a solid. Understanding epoxy behavior or characteristic is essential in using epoxy safely and effectively. From the time it takes for this chemical transformation from liquid to solid is called cure time. As it cures, the epoxy passes from the liquid state, through a gel state, before it reaches a solid-state. As it cures, mixed epoxy passes from a liquid state, through a gel state, to a solid-state as illustrated [4] in Fig. 2.

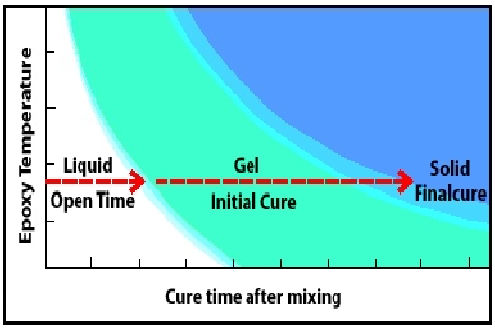


Fig. 2. Epoxy curing state

Open time (also working time or wet lay-up time) is the portion of the cure time, after mixing the resin and hardener to incite an epoxy chemistry reaction, that the mixture remains a liquid and is workable and suitable to apply. Open time starts upon epoxy dispense, up to Die placing or bonding [4] as illustrated in Fig. 3. All assembly and clamping should take place during the open time to assure a dependable bond.

2. PROBLEM IDENTIFICATION

Open time is the time it takes for a mixed resin system to gel or become so highly viscous that it can no longer be considered workable or able to be spread during die bonding which causes Insufficient Epoxy Coverage. A thermoset resin system converts from a liquid mixture of chemicals to a dry type material that has a highly cross-linked polymer as the major structural material. The Open time is the moment when the polymer formation is in its early stages of cross-linking to the point that if the polymer gel state is disturbed then the final polymer will have properties that are not well established [5].

Staging of epoxy, especially when there is a major machine down that may lead to insufficient epoxy covered. Insufficient epoxy coverage after Die bond can lead to separation or gap at the die edge during curing due to mismatch between the die and leadframe or the effect of material CTE or coefficient of thermal expansion. The leadframe is going to be expanded during curing, but the adhesive is being shrunken because of its polymerization [6].

And during Molding process, the mold compound or EMC can be penetrated through a gap that causes reliability failure of Delamination as illustrated in Fig. 4, the Failure mechanism for Insufficient epoxy coverage [7,8].

One of the solutions is to study the optimum Open Time control to prevent epoxy drying before die bonding. Below is the Evaluation flow to define suitable Open Time control shown in Fig. 5. The Quality response characteristic that we will consider are the; Epoxy Coverage, epoxy voids, Bond Line Thickness (BLT), and Die Shear Test (DST) strength response.

3. RESULTS AND DISCUSSION

As a result, Epoxy Coverage verification show there is good epoxy coverage and fillet formation with all open times up to 60 minutes after the die attach process as shown in Fig. 6.

No Epoxy Voids show in the X-Ray result with all open times up to 60 minutes after die attach process after Oven Cure process as shown in Fig. 7.

Using the Statistically ANOVA test, the Bond line thickness (BLT) shown there is no significant difference with all open times (0/10/20/45/60 minutes) after curing with P value of 0.430 as shown in Fig. 8.

In Die Shear Test (DST) response, since the P value of statistical ANOVA is 0.223, less more than the set alpha 0.05. All the results of the Die Shear Test are equal, under 0 to 60 minutes of Open Time as shown in Fig. 9.

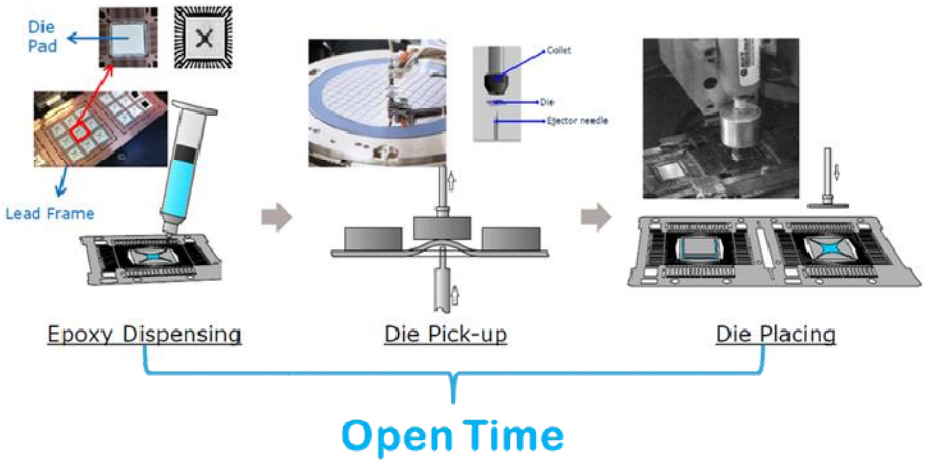


Fig. 3. Epoxy open time

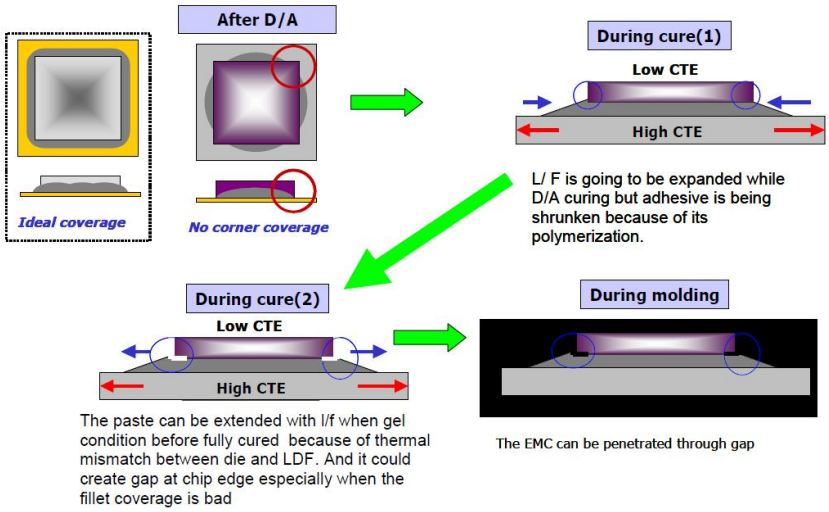


Fig. 4. Failure mechanism for insufficient epoxy coverage

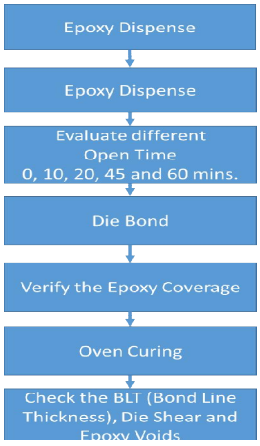


Fig. 5. Evaluation Flow

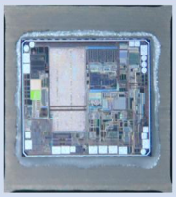
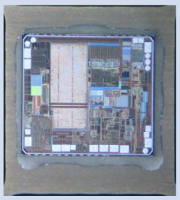
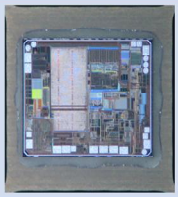
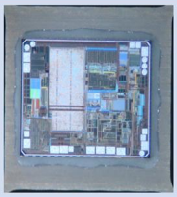
Open Time 0 mins	10 mins	20 mins	45 mins	60 mins
				
100% Epoxy Coverage	100% Epoxy Coverage	100% Epoxy Coverage	100% Epoxy Coverage	100% Epoxy Coverage

Fig. 6. Epoxy coverage verification result

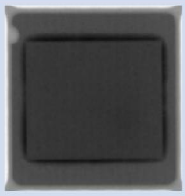
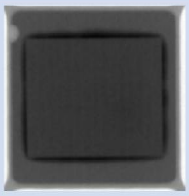
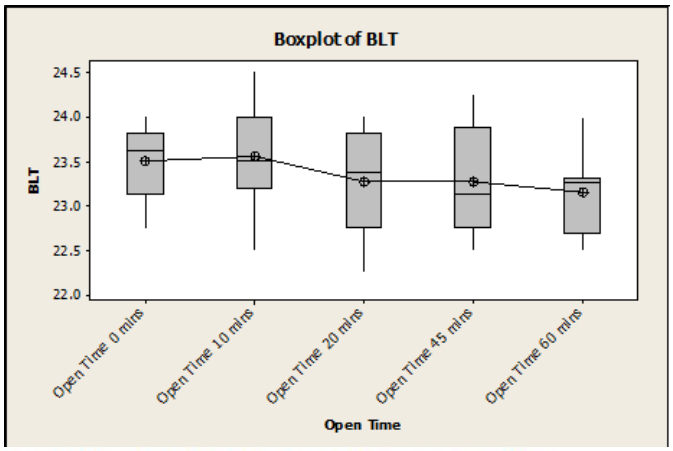
Open Time 0 mins	10 mins	20 mins	45 mins	60 mins
				
No Voids	No Voids	No Voids	No Voids	No Voids

Fig. 7. Epoxy voids verification

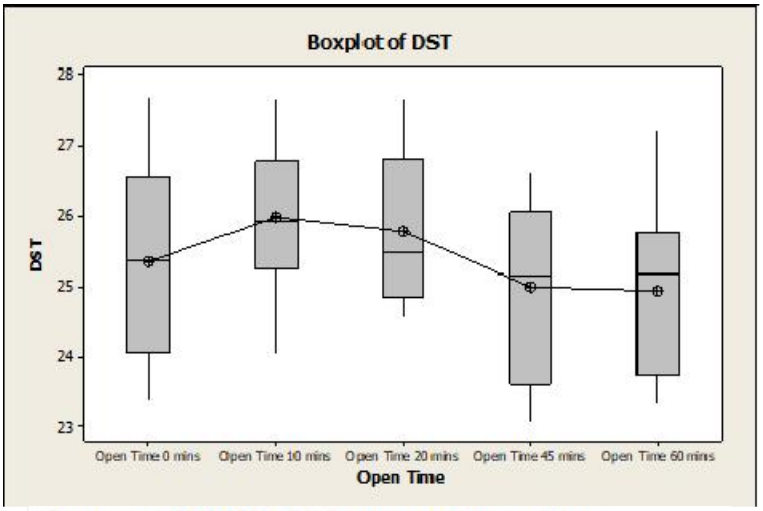


One-way ANOVA: BLT versus Open Time

Source	DF	SS	MS	F	P
Open Time	4	1.138	0.284	0.98	0.430
Error	45	13.112	0.291		
Total	49	14.250			

S = 0.5398 R-Sq = 7.98% R-Sq(adj) = 0.00%

Fig. 8. Bond line thickness (BLT) verification result



One-way ANOVA: DST versus Open Time

Source	DF	SS	MS	F	P
Open Time	4	8.51	2.13	1.48	0.223
Error	45	64.52	1.43		
Total	49	73.03			

S = 1.197 R-Sq = 11.66% R-Sq(adj) = 3.81%

Fig. 9. Die Shear Test (DST) Verification result

4. CONCLUSION

At an open time of up to 60 minutes, the overall result shows consistent epoxy coverage. During an interval of 0 to 60 minutes before the die attachment, no epoxy void was built-up. Under 0 to 60 minutes Open Time, Bond Line Thickness (BLT) and Die Shear Test (DST) strength response are not significantly different. One of the important controls for epoxy that needs to be established for high-performance power packages is open time, working time as well as wet lay-up time.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by the personal efforts of the authors.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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