

Impact of Thermal History on Gap Filling Capability of Die Attach Film

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Abstract

Die attach film(DAF) has being widely applied to various high density packages due to its bleedless, consistent bond line thickness and simple operation without dispensing even skip cure post attachment compared with traditional liquid-type die attach material. However, void always is one of major concerns, especially for DAF applied between die and substrate in plastic ball grid array packages. In this paper, the thermal history of DAF for encapsulated units is analyzed since it is put into assembly and the experiment is designed with different thermal history to illuminate its impact on void performance. Simultaneously void formation mechanism also is studied by tracking void status during the whole assembling process. As the result, it was shown that the void issue is caused by insufficient gap filling and thermal history play an important role in gap filling capability. Based on thermal history analysis, heating at wire bond process is a key step due to its long staging time and high temperature. DAF with short thermal history has super gap filling capability. Even voidless result can be achieved if skipping heating at wire bonding compared with about 10% void percentage for encapsulated samples under normal building condition. It can be explained that cross-link occurs under thermal condition and gap on the substrate can not filled completely because it became rigid. Scenarios for void reduction also are addressed based on this investigation in this paper.

Keywords: DAF, void, thermal, history, and gap filling

1. Introduction

With the trend of package size shrinkage, conventional liquid-type die attach material has been restricted in die bond process due to its resin bleed toward narrow distance available and inconsistent bond line thickness. Novel die attach material is urgently demanded to meet the requirement of various high density packages such as SIP, CSP, POP and so on. Dry film type attach material has being widely employed with good control of bleed, consistent bond line thickness, and simplified manufacture steps without dispensing and oven cure process after die bond process[1-5]. There have two main kinds of film product, dicing die attach film and cutting film. For the former, die attach film is integrated with dicing tape and attached to wafer backside during lamination process under thermal condition, namely 2in1 film. For the latter, die attach film is to cut by same size as die firstly and attached to substrate, which need die bonder with film cut/paste function. Except heating function needed for laminator and die bonder, there is no special requirement for assembly equipment. Therefore, 2in1 film is usually used. However, void always is a major concern for both of them, especially as adhesive between die and substrate. There are many process parameters relative with void performance including bond time, bond force, heating temperature, molding pressure and so on. While sometimes the desired

result can not be achieved by process optimization. In this paper, the impact of thermal history on gap filling capability in a plastic ball grid array package is focused on. Simultaneously, void formation/reduction mechanism of die attach film also is addressed as well as ways to improve die attach performance.

2. Experimental Procedure

In this study, 2in1 DAF is used with 25um stick layer of epoxy. Test vehicle is 4 × 15 MAPBGA (substrate layout: 4rows, 15columns) with 12×12 mm package size. Multi-layer substrate is used and its thickness is 0.3mm. Die size is 8.6×6.2mm with 0.180mm thickness. All process parameters have been setup in previous work. CSAM is performed first on encapsulated sample under normal building conditions. Simultaneously, substrate surface topography is plotted to find the correlation between and gap filling capability. The samples post different staging time (0min, 0.5min, 1.5min, 6min) at wire bond process are built followed by void inspection. In order to fully understand the gap filling mechanism, void tracking also is performed during whole assembly. Finally two scenarios, increase film thickness and improvement of substrate surface flatness are conducted to identify the result of void reduction.

3. Results and Discussion

3.1 Void issue and its characteristic

Fig 1. (a) shows the typical CSAM picture of one unit after assembly with optimized process parameters. Within the attach area, black spots can be found as the evidence of voids. Cross-section is done along the dot line through black spots to indentify at which interface issue occurs and it is very clear that void occurs at the film/substrate interface, refer to Fig 1. (b).

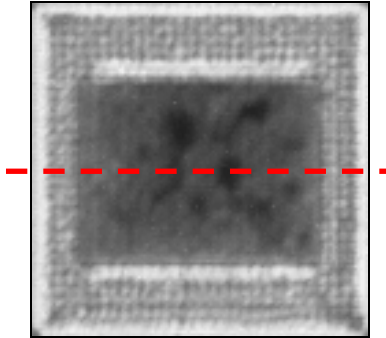


Fig. 1 (a) A typical CSAM picture of a unit

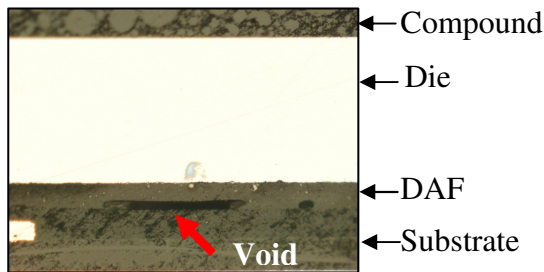


Fig. 1 (b) Cross-section of voids

Characteristics of void are investigated firstly including distribution, location and pattern. Not same as void issue of liquid die attach materials, these voids distribution within attach area on every unit is almost same with fixed location and similar pattern. Fig2. shows the voids status of 30units from one strip of substrate. These phenomena can be observed on other units from other strips of substrate.

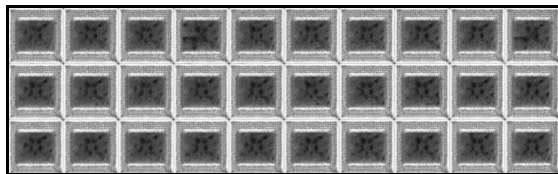


Fig.2 Void characteristic (Throgh SCAN)

3.2 Correlation between voids and gap filling

Due to fixed pattern of voids at the film/substrate interface, substrate surface characteristic is investigated first to identify whether there has correlative between them. Through optical microscope, it is clearly shown uneven substrate surface with copper trace is coated by solder mask within die paddle area. Detail of substrate surface is scanned through FRT, see Fig. 3(a). In order to easily comparison between topography of substrate and void pattern, the void pattern is dealt by image software, refer to Fig. 3(b). It was found that the pattern is similar with concave areas of substrate surface, namely voids occur at the spots with large gap. Gap profile also was plotted by scanning 5000 points along diagonal of die paddle refer to Fig.4. It indicates the max. value of gap is more than 10um, equivalent to 40% of film thickness (25mm). It is proven that the void issue is caused by incompletely gap filling by film.

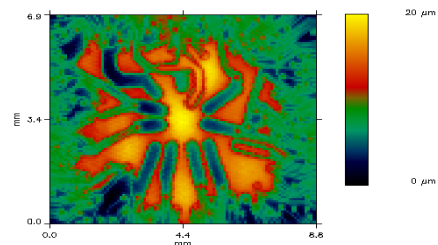


Fig.3(a) die paddle topography

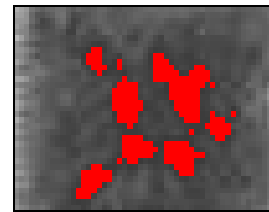


Fig.3(b) void maps (red color pattern)

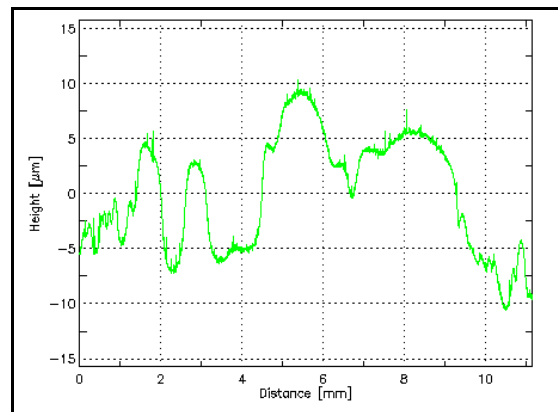


Fig.4 profile of substrate surface

3.3 Impact of thermal history on gap filling capability

3.3.1 Thermal history analysis of DAF

The assembly flow with DAF as die attach material is shown as Fig.5. It can be found that most operations are implemented under heated condition during the assembly and for DAF encapsulated in the units at the end of line, it has gone through the long thermal history since it is put into assembly. Simultaneously, process time at all thermal stages also was added, refer to Fig.6. It is noted that value of heating time marked in Fig.5 is nominated by unit because the heating time at every process can not be compared simply even at the same temperature as far as individual DAF attached to die is concerned. For example, wire bond and molding are processed by strip level, but whole strip is heated during molding and part of strip is heated at the heating block and heating time for single DAF depends on heating block area. In this work, heating block cover 20% of substrate (including 12 dies, wire bond time: 3min/unit). Therefore, the total heating time for single unit is 36mins. Highest temperature is at reflow process of ball attach, 260 centi-degree and longest heating time happens at the post molding cure(PMC), about 300min.

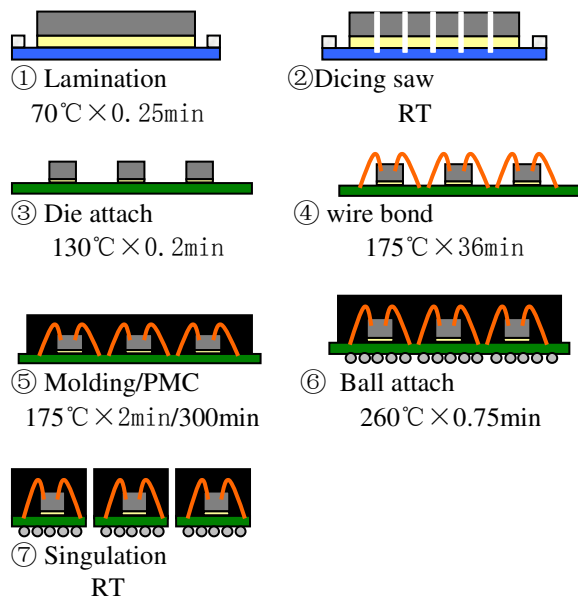


Fig.5 Assembly flow with DAF as die attach material

3.3.2 Gap filling capability vs. thermal history

To understand impact of thermal history on gap filling capability, the mechanism of void formation/reduction is investigated and CSAM inspection is taken post each stage for tracking void change status. See to Fig.6. It can be found there have

large-scale voids after die attach process and hardly any change after wire bonding process. However void is reduced significantly after molding process and no change is observed for afterward process including long heating time at PMC and high temperature reflow at ball attach. It indicates that film die attach is accomplished till molding process since it was attached to substrate. Based on the characteristic of DAF as an adhesive, cross-linking reaction will happen under thermal condition. Therefore, the thermal history should be closely relative with void performance, namely gap filling capability.

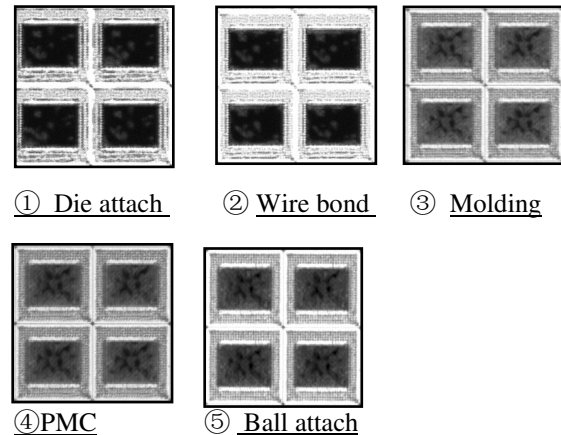


Fig.6 Gap filling with void reduction post every assembly stage

Based on the previous analysis, wire bonding should be focused on among the thermal history of DAF due to long time and high temperature at this stage. It takes 3min per unit in wire bonding with normal parameters. In this work, in order to investigation of impact of thermal history on gap filling capability, wire bonding time is designedly changed to 0.5min, 1.5min and 6min by parameter adjusted as well as skipping this stage. Fig. 7 shows die attach film void performance results with different wire bonding time. It is very evident that void is decreased significantly with wire bond time reduction. Even void-free result can be achieved if wire bond stage is skipped. At the same time, the extreme experiment of further adding wire time also been carried out, it shows void performance gets worse greatly. The relation between heating time at wire bonding and void coverage is plotted in Fig. 8.

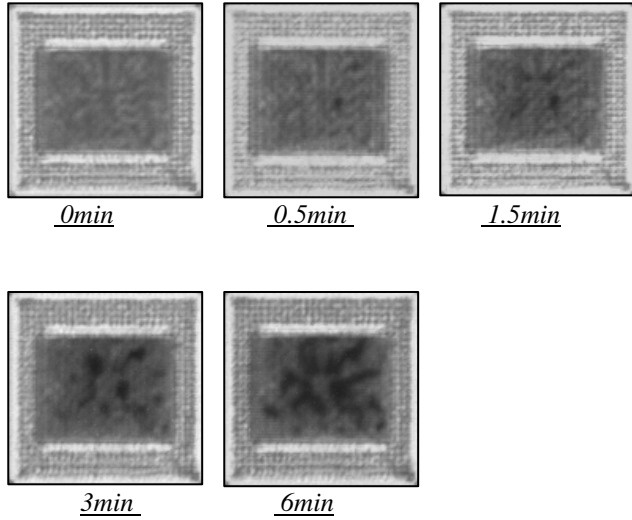


Fig. 7 Voids status of units at different wire bonding time (CSAM photos)

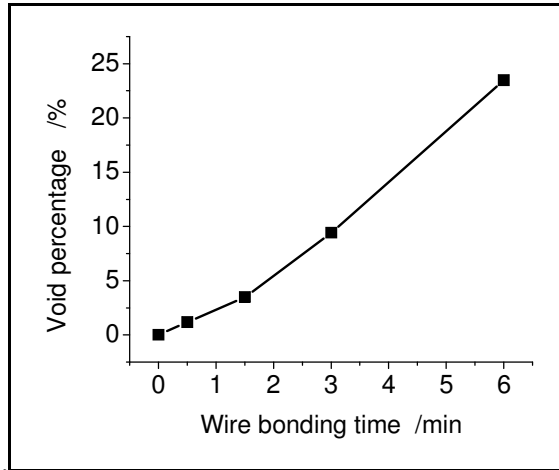


Fig.8 voids percentage under different wire bonding time

Under heating treatment, the organic materials in DAF will react with cross-link, which make it harden. Hardened DAF is difficult to compress to fill gap under molding pressure[2]. Fig.9 is its reaction ratio curve at 175°C. The longer heating time is, the higher ratio is. During wire bonding, unit is not heated individually, but by block. So the heating time for every unit is accumulated. In this working, 3 columns of units are on heating block and it adds up to 12 units. (4units/column × 3columns). Therefore, the heating time for every unit is 12 times of wire bondtime. Accumulative heating time for every unit and DAF reaction ratio are shown as Table 1. It can explain the fact that thermal history influences the void performance distinctly. For normal assembly, reaction ratio is about 90%, large gap can not be

filled well and void performance get worsen due to full cure if wire bond time is extended to 6 minutes. The void performance is improved significantly with wire bond time is reduced and even void-free can be achieved without heating at wire bond process.

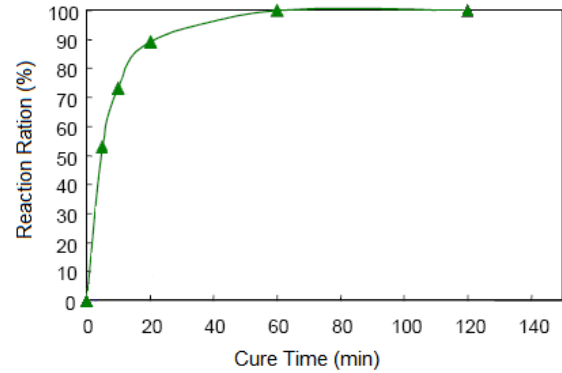


Fig.9 cure curve of DAF material under heating treatment (175°C)

Table 1 and reaction ratio Heating time per unit

Wire bond time/unit Min	0 ^{*1}	0.5	1.5	3 ^{*2}	6
Accumulative heating time Min	0	6	18	36	72
Reaction ratio %	0	55	90	95	100

*1 Skipping wire bonding process

*2 Normal wire bonding time

4. Solutions

There is finding that voids are caused by insufficient gap filling and thermal history greatly impacts its capability. However, generally it is unavailable to shorten the thermal history because the heating temperature/time almost is fixed for given device once parameters are optimized. Just as we known, the wire bond is the important segment of thermal history and cure reaction is proceed basically at this stage. While temperature can not be reduced much due to bondability concern and time can not be shorten yet due to high I/O pin number. How to enhance gap filling capability under same thermal condition is taken into consideration.

4.1 Increase of DAF thickness

Based on the previous study, gap filling mainly is completed at molding process. Under molding pressure, DAF is compressed into the gap between film and substrate furthest. The thicker DAF is, the larger deformation is. In this work, DAF thickness is 25μm with substrate gap is more than 10μm. It means that deformation ratio for this DAF under molding pressure is at least 40%. It is challenge for gap filling capability for almost fully cured film post long thermal history. To get the same

deformation amount, the thicker DAF should be selected. For 40um DAF, gap can be filling by 20% deformation ration. Further experiment is implemented to verify this idea. The samples are assembled under the same condition with 40um DAF, the same material characters as original 25um DAF. All samples are scanned by CSAM. Perfect result is achieved with void-free performance. Refer to Fig.10.

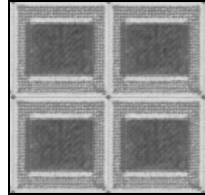


Fig. 10 Void performance improvement by thicker film application (SCAM photo)

4.2 Improvement of Substrate surface flatness

According to the previous analysis, void issue is result from insufficient gap filling. Reduction of substrate surface gap should be a practical approach to eliminate voids issue. Besides, it is an alternative for some cases with loop concern if thicker film is used. Generally, substrate surface planarization is not complex and flatness can be improved by multi-printing of solder mask or using dry-film solder mask. Samples also were built on substrate with improved flatness. No void was observed, See to Fig.11. Simultaneously, reliability tests are followed with function dies including MSL3@260 °C × 3, TC1000(-50 °C ~125 °C), ubiar-HAST144hrs and HTB1008hrs@150 °C without void issue and 100% electrical test pass.

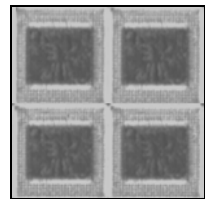


Fig. 11 Void performance improvement by substrate surface planarization. (SCAM photo)

5. Conclusion

Voids occur at the die/substrate interface in the plastic ball grid array package with film as attach material, which is caused by insufficiently gap filling. Actually DAF has supper gap filling capability, while this capability decreases post long thermal history due to cure reaction. Among whole thermal history, heating at wire bond stage is an important segment due to long time and high temperature. Under normal

building conditions, void percentage is about 10% and it is reduced if time at wire bond is shortened. Even zero void can be achieved by skipping heating at wire bond. Gap filling process is mainly accomplished at the molding process and almost no any change at next processes including PMC and ball-attach. It is desired that DAF gone through a short thermal history with low cure ration to ensure gap filling capability, namely good void performance. On the contrast, void likely occurs for DAF with long thermal history, because it is difficult to compress gap on the substrate surface due to complete cure. Film thickness increase or substrate surface planarization can be taken into consideration to solve the void issue due to insufficient DAF's gap filling capability radically.

Acknowledgement

The authors would like to thank my colleagues Zhai Yi and Zhimei Sun for their assistance in CSAM and cross-section experiment.

Reference

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