



Critical Insights in the Application of Convection and Pressure Curing in Eliminating DAF Voids

Bryan Christian S. Bacquian^{1*}, Rennier Rodriguez¹ and Edwin M. Graycochea¹

¹*New Product Development and Introduction, STMicroelectronics, Inc., Calamba City, Laguna, 4027, Philippines.*

Authors' contributions

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

Article Information

DOI: 10.9734/JERR/2020/v10i417047

Editor(s):

(1) Dr. David Armando Contreras-Solorio, Autonomous University of Zacatecas, Mexico.

Reviewers:

(1) Boyan Karapenev, Technical University of Gabrovo, Bulgaria.

(2) Christos N. Panagopoulos, National Technical University of Athens, Greece.

(3) Gilbert Makanda, Central University of Technology, South Africa.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/54708>

Received 21 December 2019

Accepted 28 February 2020

Published 05 March 2020

Original Research Article

ABSTRACT

The absent of reliable production controls for Die Attach Film (DAF) voids detection allowed defect escapee for Ball Grid Array (BGA) devices using non-conductive film material leading to gross assembly rejection and customer complaints. This paper presents the evaluation of pressure curing as an alternative to the convection curing in die attach process with additional capability to eliminate the DAF voids on non-conductive films. Through Analysis of Variance (ANOVA) analysis, green peeling test, Scanning Acoustic Microscope (SAM), cross section analysis and reliability test performed between samples arrives to the conclusion that pressure oven has a significant impact in die shear strength improvement and DAF voids elimination with positive response in reliability requirement. The result of the study improves the assembly flow and production control of BGA devices through the transition of convection to pressure curing technology.

Keywords: BGA; convection curing; pressure oven; DAF voids; process improvement.

**Corresponding author: Email: bryan-christian.bacquian@st.com;*

1. INTRODUCTION

One of the legacy packages of the Integrated Circuit (IC) is the Ball Grid Array (BGA). According to Oota et al. (2002), BGA is a development package to increase I/O's even with smaller body size compared to Quad Flat Packs (QFP) packages [1]. Due to its low cost solution, several issues were introduced at manufacturing level such package warp and hidden interconnects, Rao, [2] another development of the BGA package is its miniaturization wherein die thickness was significantly reduced to <100 um [3]. One main bill of material of an BGA package was Die Attach Film or DAF. DAF is known having many advantages like consistent bond line thickness and die tilting [4]. However there are multiple failures particular to BGA devices that can be attributed to machine, materials, environment, method or man. An example of material failure can be attributed to Die Attach Film (DAF) voids or the un-occupied/filled area inside DAF films material. As explained by Su, 2009, DAF void can be the interface substrate and the die [5]. The occurrence of DAF voids can be induced mechanically, or process related however there are instances that DAF voids is already inherited by the material from its manufacturing stage. Since voids in DAF material is an un-controllable factor during integrated assembly, the degree of DAF voids in the package is allowed at a certain level during assembly but with strong consideration to robust production controls and parameter identification however the introduction of non-conductive material in die attach process narrow down the employed production controls and practices. The DAF voids for non-conductive films cannot be accurately detected by the existing production controls such as X-ray inspection thus escapee of the reject is high.

DAF voids, when uncontrolled, is identified as a critical factor in the packaging structure that has a direct impact in the reliability of a device. Propagation and entry point of delamination may originate from single DAF voids during thermal cycle, while larger quantity significantly affect the material performance such as thermal and electrical characteristic, tensile and shear strength.

To improve the current performance, production controls and detection capability, there is a must to evaluate/explore an alternative technology that can be implemented as an "error-proofing" controls in eliminating DAF voids such as pressure oven technology. With this initiative, secondary matrix such as improvement in tensile and shear strength for package reliability, material performance and cost saving program can be also attained upon implementation.

2. REVIEW OF RELATED LITERATURE

DAF is one of the breakthrough in semiconductor material used in advance packaging of IC assembly. As presented by Krishnan, et al. [6], the development DAF is driven by the continuous downsizing and thinning requirement ($\leq 100\mu\text{m}$ thickness) of integrated package and offers material solution to complex stacked die applications. DAF can be designed either non-conductive and conductive material depending on its actual application; (1) Non-conductive DAF is applicable for multiple die bonding and stack-up architecture while (2) conductive films is designed for power application where thermal and electrical property of the material is required factor. When DAF voids is present in the material usually measured at greater than 10% in area, the mechanical property such as interfacial

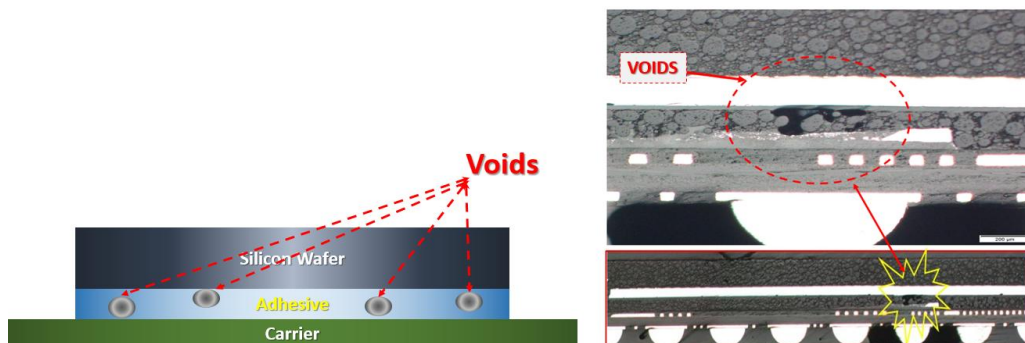


Fig. 1. DAF voids

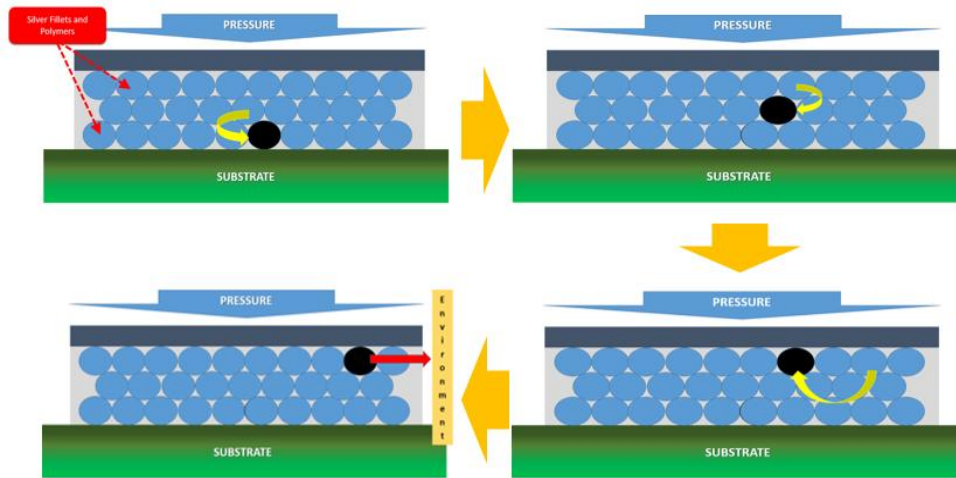


Fig. 2. De-voiding theory

starts to degrade [7,8]. There is a must to maintain minimal amount of DAF voids through process optimization, material improvement and equipment breakthrough. According to Hoon, et al. [9], Die attach material voiding can be improved by minimizing outgassing and optimizing cure profile. Another possibility of the removing voids was developed for solder process, cited by Yeo, et al. [10], is the introduction of negative pressure or vacuum to depressurize solder at highest point moving the voids to go outside the main solder. However, the paper will focus more the “positive pressure” to depressurize the DAF at highest point.

De-voiding DAF curing process have been introduced to remove the voids that are inherent to film materials through incorporating dissolution, diffusion and pressure modulation principle during convection curing. Technically, when temperature is increased, DAF material undergone glass transition (T_g) wherein the material transitions to viscous and rubbery state. A positive pressure is applied on the silicon that will suppress the silver filler at the same time to replace the position of the stationary voids. this sequence is repeated until the defined time of “de-voiding”.

The direction of the voids in Fig. 2, as defined by diffusion process, is to move from a less concentrated environment to larger concentration when its’ position is replaced by the silver fillers. The escaping voids is purge outside the chamber that will be removed by the vacuum system of

the machine to avoid foreign material contamination.

Die attach film material are becoming a necessity due to the advancement in integrated circuit packaging. DAF voids, which is found to be a technical barrier with the material, is a detrimental factor to future integrated device therefore there is a must to upgrade the current assembly resources to a more robust set-up.

3. METHODOLOGY

The test vehicle is presented in Table 1. The package test vehicle used ball grid array configuration with package size of 4 x 7 mm. A silicon die with < 100 um thickness will be used mounted on a non-conductive die attach films. the unit used in the evaluation used same equipment and material.

Table 1. Test vehicle

Test vehicle	BGA
I/O	87
Package Size	4x 7 mm
Die Size	2.5 x 4.5 mm
Die Thickness	70 um
Substrate Thickness	0.1 mm

The course of the trial is presented in Table 2. Two curing machine will be evaluated using the units with same condition and configuration. To measure the success of the evaluation, the result from the two trials will be recorded such as die shear, green peeling, SAM, cross section and reliability. An ANOVA analysis will be used to evaluate the result.

Table 2. Trial matrix

	Oven machine	Die shear	Green peeling	SAM	X-section	Reliability
1	Conventional oven					
2	De-voiding oven					

4. RESULTS AND DISCUSSION

Die Shear test is performed to determine the adhesion property of the DAF films once it is cured. Different conclusion can be derived from the test such as the interfacial strength between the interface or the amount of material that is in-contact. From the result, a significant amount of DAF voids present in the DAF material is anticipated to produce lower shear response in the study.

Prior to the analysis, all data were checked for normality then chose ANOVA analysis to guide the researcher with the conclusion. A P-value < 0.05 achieved from the result states that there is a significant difference between the set of data with Rsquare measurement of 53% at 95% confidence level.

Green Peel Test is performed to analyze the wetting condition of the material either on die or substrate after the unit is cured. The test is required to check for an obvious un-wet area or part between material that don't manifest physical contact after curing. Fig. 4A shows an illustration of un-wet reference used in the study. The result of the green peel test is shown in Fig. 4B wherein there is no obvious un-wet area observed between pressure oven and convection curing.

SAM is performed to verify the delamination and adhesion condition of the adhesive through focused sound to produce a clear visual of the samples. Fig. 5 shows that there was no delamination observed on samples at time 0.

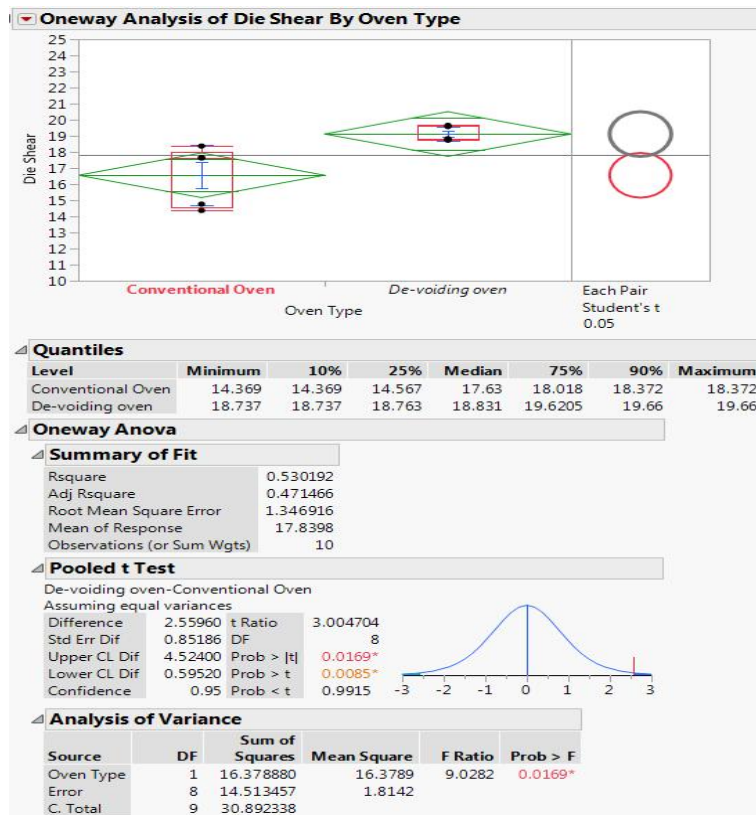


Fig. 3. ANOVA result

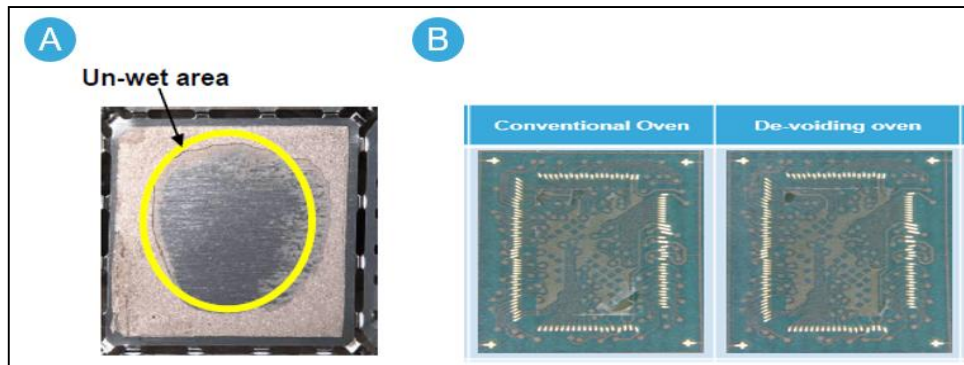


Fig. 4. Green peeling result

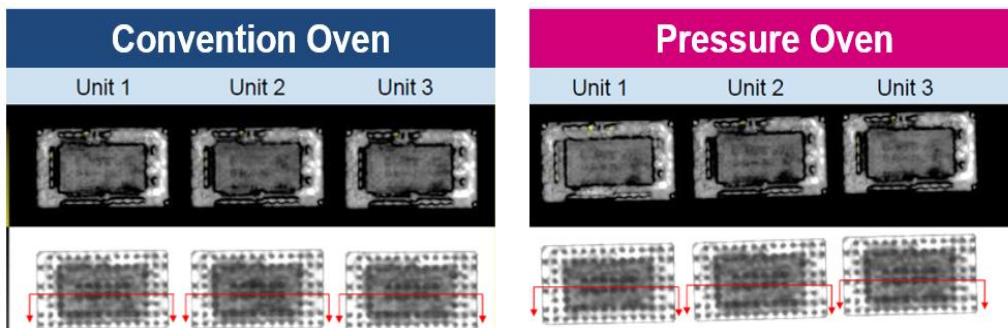


Fig. 5. Same result

A cross sectional analysis of the samples is performed to analyze the evidence of micro-voids instead of x-ray inspection due to inaccurate detection and measurement observed using x-ray for non-conductive material. The result as shown in Fig. 5 shows evidence of micro-voids on convection curing and no micro-voids observed for pressure oven.

The reliability performance will be the final parameter to look into to check any adverse effect of the new process into the package parameters. Both Samples have passed Moisture Sensitivity Level (MSL) 3 assessments

and thermal cycling up to 500 cycles as shown in Fig. 6. The result shows that both process helped the test vehicle package to achieve the necessary reliability performance based on its applications.

Based on the over-all assessment, shown on Table 3, De-voiding oven shows significant improvement in terms of Die Shear and voids performance. But the reliability test, such as MSL 3 and TC 500 cycles have confirmed that de-voiding oven shows no significant adverse effect of the new process on the package performance.

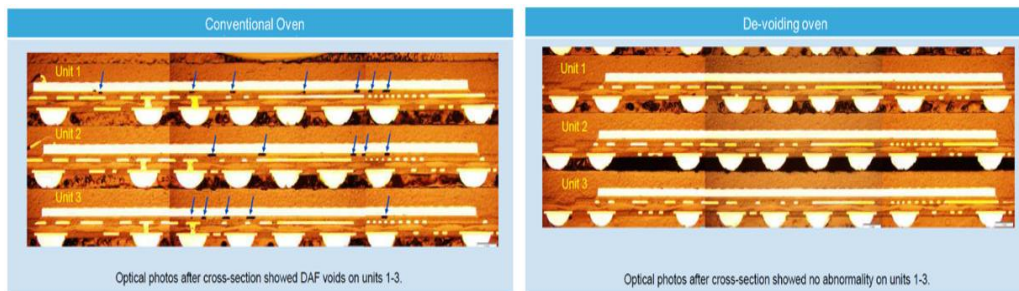


Fig. 6. Optical photo after cross section analysis

Table 3. Optical photo after cross section analysis

Expt	Oven machine	MSL3	TC500cyc
1	Conventional oven	Passed	Passed
2	De-voiding oven	Passed	Passed

Table 4. Overall result

Test	Conventional oven	De-voiding oven
Die shear	16.56	19.1196
Green peeling test	Passed	Passed
SAM	Passed	Passed
X-section	Voids	No voids
Test results	94.07%	98.26%
Reliability performance	Passed	Passed

However, this result may vary according to different configuration such as package dimension and stack-up, material and the amount of amount of input factor such as the amount of voids.

5. CONCLUSION

In this study, it has been shown that de-voiding oven can totally eliminate the voids and micro-voids that could be present in the incoming die attach film material. With this result, de-voiding oven is treated as an error-proofing action that will not allow any defect escapee of voids that could reach customer's end. In addition, the implementation of de-voiding oven reduced the production cycle time and inspection requirement since the inspection after curing and SAM after molding is eliminated from the assembly flow of BGA.

The application of this technology also increases the shear strength between silicon die and substrate. The increase in the die shear reading is correlated to the amount of voids, the presence of voids in the material lowers the die shear strength while absent of the voids produces better shear reading. The shear strength is the primary component to measure the resistant of the material to mechanical stress. Through shear improvement, de-voiding oven indirectly improve also the integrity and reliability performance of BGA devices.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely 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 personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Oota K, Iida H, Saka M. Measurement of water absorption in ball grid array package. *IEEE Transactions on Components and Packaging Technologies*; 2002.
- Rao ST. Ball grid array assembly issues in manufacturing. *Proceedings of 16th IEEE/CPMT International Electronic Manufacturing Technology Symposium*; 1994.
- Teo M, Kheng SC, Lee C. Process and material characterization of Die Attach Film (DAF) for thin die applications. *International Conference on Electronic Materials and Packaging*; 2006.
- Abdullah S, et al. Dicing die attach film for 3D stacked die QFN packages. *Int'l Electronics Manufacturing Technology Symposium*; 2007.
- Su Y, et al. Effect of transfer pressure on die attach film void performance. *11th Electronics Packaging Technology Conference*; 2009.
- Krishnan, Premila, et al. Die Attach Film (DAF) for Breakthrough in Manufacturing (BIM) application. *International Conference on Electronic Materials and Packaging*; 2014.
- Kovac O, et al. Image processing of die attach's X-Ray images for automatic voids

- detection and evaluation. 39th International Spring Seminar on Electronics Technology (ISSE); 2016.
8. Biswal L, Krishna A, Sprunger D. Effect of solder voids on thermal performance of a high-power electronic module. Electronic Packaging Technology Conference; 2005.
 9. Hoon KL, et al. High thermal conductive die attach material process characterization challenges. IEEE 15th Electronics Packaging Technology Conference (EPTC); 2013.
 10. Yeo SM, et al. Vacuum reflow process characterization for void-less soldering process in semiconductor package. IEEE 38th International Electronics Manufacturing Technology Conference (IEMT); 2018.

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Peer-review history:
The peer review history for this paper can be accessed here:
<http://www.sdiarticle4.com/review-history/54708>