Die Attach Film Application in Multi Die Stack Package

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Abstract

The trend for package miniaturization has created challenges to conventional die attach process. When wafers need to be thinned down beyond 100 µm, challenges in die attach process become great and die attach paste may not be suitable in most cases [1]. The selection of die attach material becomes critical to ensure package robustness and reliability. When die paddle of a package is reduced to less than 0.3mm, the control of bleed out of paste becomes critical. The rheology of paste will result in creeping of the material to the edge of die and contaminate the bonding pad when the die is placed and seated upon a certain amount of dispensed paste.

New generation of die attach material has been introduced amid this complication, die attach film (DAF) is commonly used for thin die stacked package (< 100 µm). DAF replaces paste in stacked packages for its good control of paste bleed, creeping effect to die edge and also consistent bondline thickness (BLT) at desired thickness. New generation of DAF tape incorporates wafer dicing tape and adhesive in one, namely the Dicing Die Attach Film (DDAF), which is mounted onto the back of wafer. The wafer which is mounted with DDAF will be diced into the predetermined die size and the diced chip will be picked and placed directly to a leadframe or substrate with adhesive at the back . Today, DDAF has been proved to reduce manufacturing process steps and improve productivity. The gain in productivity has improved total package cost, irrespect of the higher material cost when conventional die attach paste is replaced by DDAF.

Objective

The present work aims at studying the material selection criteria and process characterization of various DAF for memory stacked die package, to achieve a minimum reliability performance under IPC/JEDEC Moisture Sensitivity Level 3 (MSL3) at reflow 260°C [2]. The property of DAF is important for characterization of process flow in multiple stacked die package. The most important process consideration is the repeated heat cure during die attach which may affect the material property. If the DAF is cured before molding process, chances of delaimnation between die and DAF interface is high. Thus, heat resistance of a DAF has always been the key material property that is taken care of. Low modulus DAF is desired for large die package to reduce warpage and for better stress relaxation during temperature cycle test. However, if the DAF exhibits high fluidity behaviour, the attached die may not be rigid enough to serve as a stable underboard support for wire bonding. To ensure robust reliability performance using DAF, strategic material selection need to be coupled with die attach process optimization and redesign of die pick up collet and die bonder process block.

1. Material Consideration

One of the critical criteria of DAF selection is the heat resistance of the material. Figure 1 and Figure 2 are two Dynamics Scanning Calorimetry (DSC) graphs comparing the reaction ratio of two types of DAF under different cure temperature when it subject to continuous curing up to sixty minutes [3]. It is noted that under a same cure temperature, DAF 1 shows a higher reaction rate at a specific cure time. Take for example after 10 minutes curing time, DAF 1 exhibits reaction ratio at almost 90% but DAF 2 only at reaction ratio 60%. Higher cure temperature will aggrevate the reaction ratio compare to lower cure temperature. It is also observed that reaction ratio in DAF 1 is higher in the first 20 minutes, where a steep gradient of the curve is obtained. When the slope becomes gradual, it indicates that the cross-linking reaction has become less vigorous. A fully cured DAF will exibit a constant reaction ratio at 100%, indicating no cross-linking is taking place.

This reaction curve is important to design an optimum process flow when DAF is used as a die attach material. It is essential to prevent the DAF from being fully cured to maintain its fluidity and gap filling capability. Ideally, the DAF must only be fully cured under molding packaging pressure, so as to ensure the DAF will be compressed to fill the gap between two bonding interface. This is especially important when a organic substrate with uneven copper traces is used.

From the analysis of the DSC curve, it is important that heat treatment at wafer laminating, die attach and wire bond need to be taken into calculation into total heat cure time. This consideration is to ensure that the DAF will not be fully cured before molding process to prevent potential interfacial delamination due to the fact that cured DAF may be hardened [4]. If the hardened DAF is not adhered strongly to the interface, molding packing pressure will not be able to compress the DAF, thus delamination occurs. It is important to take various heat temperatures and times into consideration when designing an optimised process flow. In the event that higher process temperature was required, short process time will need to be implemented. Lower process temperature with longer heat treatment will give the same effect.

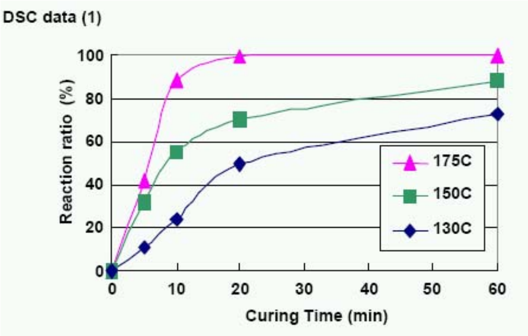

Figure 1: Effect of Curing Time on Reaction Ratio For Material A

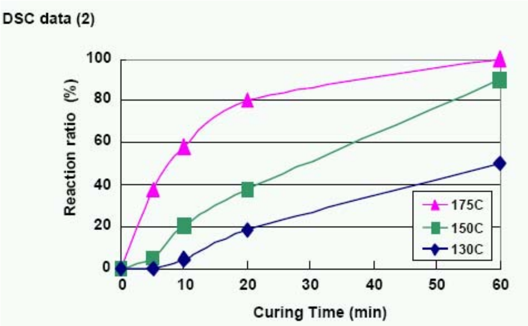

Figure 2: Effect of Curing Time on Reaction Ratio For Material B

Another important material property is the elastic modulus, which is shown in Figure 3 [3]. In this chart, 2 types of DAF under different curing time at curing temperature 175°C are compared. The Glass Transition Temperature (Tg) for both materials is the same, which is shown at 41°C. This Tg value is relative low and it can be explained that both the materials are able to flow at 120°C bonding temperature before cure [5]. Material B shows the lowest elastic modulus at 250°C, registered at ~4MPa. Compare to material A, which is also cured for the same duration, a higher modulus is shown, at ~8MPa. This result indicates that material B is less rigid than material A and material B shall conform and show a better gap filling capability compare to material A [6].

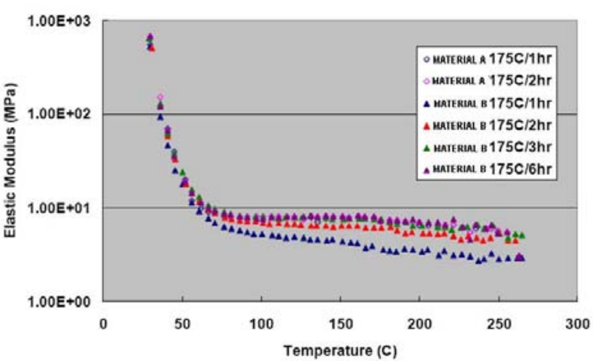

Figure 3: Effect of Temperatue on Elastic Modulus For Material A and Material B

2. Process Consideration

Die attach process optimization is unavoidable to ensure process robustness and package reliability when DAF is used. The major process difference as compare to conventional die attach process is the heat bonding. An experiment is performed on one of the selected material (Material B) to optimize the die attach parameters using ESEC die bonder. Three main process parameters are used in the Design of Experiment (DOE) using Jump Software. The parameters are (a) Bond force, (b) Bond Time, (c) Bond Temperature. This DOE optimization is targeted for die to die bonding on a 2 die stack window Chip Scale Package (wCSP) structure. The response of this experiment is interfacial delamination between DAF and die after die bonding. Scanning Acoustic Test (SAT) is used to check the delamination. The package structure and package information is showed in Figure 4 and Table 1 respectively. The experiment matrix is tabulated is Table 2:

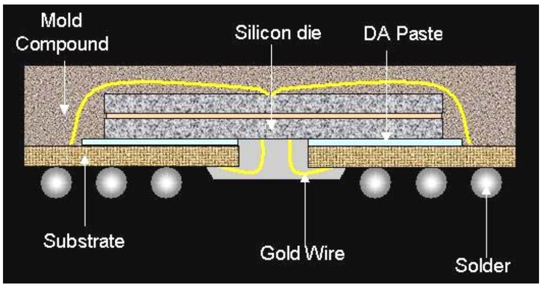

Figure 4: Package Structure of D2-wCSP

Package	13x8x1.2mm wCSP
Wafer Thickness	0.140mm for both die
LOC Tape Thickness	40 µm
Die Attach Film Thickness	20 µm
Substrate Thickness	0.208 mm
Mold Cap Thickness	0.55 mm

Table 1: Package Information for wCSP test vehicle

Leg #	Bond Temp (deg C)	Bond Time (sec)	Bond Force (N)
1	100	1	2
2	100	1	15
3	100	3	2
4	100	3	15
5	160	1	2
6	160	1	15
7	160	3	2
8	160	3	15

Table 2: Experiment Matrix for Die Attach Process

3. Result and Discussion

The experiment result is analysed using JMP software to determine the most significant parameter in minimizing delamination between die to die interface. From the result of Table 3 below, bond force is showing the most significant effect. With a prediction profiler, it is concluded that a combination of low bond force, long bond time and low bond temperature give the best result with no delamination can be achieved. This is also an indication of good adhesion betweeen the two bonding interface.

Leg #	Bond Temp (deg C)	Bond Time (sec)	Bond Force (N)	Delamination between die to die
1	100	1	2	No
2	100	1	15	Yes
3	100	3	2	No
4	100	3	15	Yes
5	160	1	2	Yes
6	160	1	15	Yes
7	160	3	2	Yes
8	160	3	15	Yes

Table 3: Result form DOE on Bond Temp, Bond Time And Bond Force

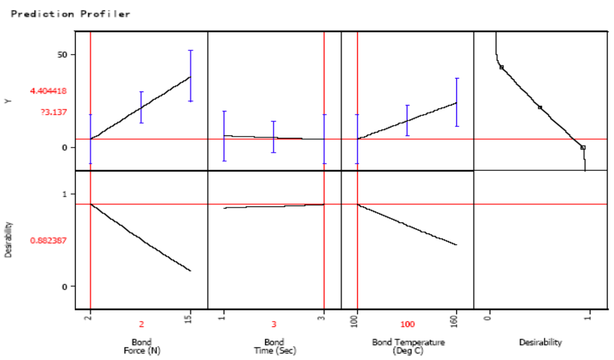

Figure 5: Prediction Profiler Result From Jump Software

The common concept of having high bond force to eliminate delamination when DAF is applied has been proven to be inaccurate from this experiment. From the result obtained, a further investigation into the tooling used has been carried out. The design of die attach collet and shank in affecting the delamination is then observed. It is essential to have a completely flat surface on the pick up collet to ensure 100% adhesion between two interface whenever high bond force is used. In reality, high temperature rubber collet tends to warp after it is inserted into collet shank as there is a need for interference fit to hold it in place during die bonding process. As shown in Figure 6, the thin die will warp together with the contour of the collet when it is inserted into collet shank. During die bonding, DAF will be placed on the heated bottom die surface, the peripheral of DAF underneath the top die will be melt faster than the center portion. Air will be trapped in between DAF and bottom die as the peripheral of the DAF has already been "sealed" by the high bond force. In contrary, when low bond force is used, sealing effect along the peripheral of the die is not significant. Air trapped in the center is able to escape when the die is released from the collet and it will be adhered onto the bottom die surface with minimum force.

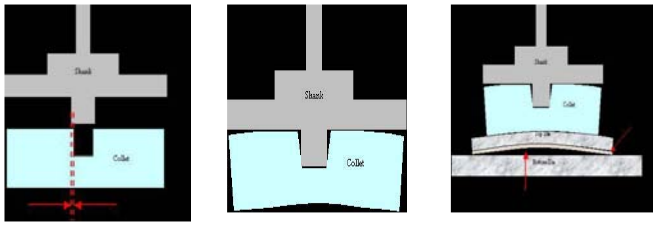

Figure 6: Illustration of Die Warpage Using High Temperature Collet

From this understanding, a few types of collet and process block with different design have been tooled up in sloving the problem of delamination due to the warpage of die caused by concave die pickup collet [7]. Firstly, the current process block with a cross vacuum groove pattern has created vacuum leakage problem during die bonding. The new process block is designed to improve the vacuum leakage. The X vacuum groove is changed to the peripheral vacuum groove to hold the substrate firmly without vacuum leakage to ensure bouncing free during die bonding. Figure 7 and 8 below show the pictures of the new and old design.

Current Process Block

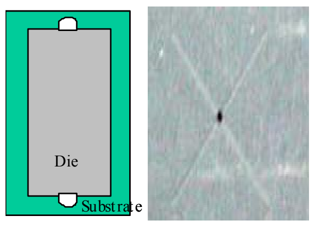

Figure 7: The Effect of Curent Process Block Design

New Process Block

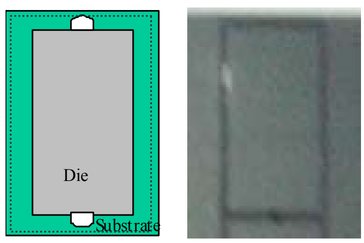

Figure 8: The Effect of New Porcess Block Design

The die collet design is also investigated in this experiment. The current design is a flat surface design with peripheral wall in 0.5mm width and 0.2mm thickness over a center square vacuum hole. Figure 9 illustrates the current collet design and its problem. It is observed that the collet contact area onto the die surface is minimum, only at the peripheral of the die. Warpage of die is experienced during bonding and this results in delamination in the center, between the DAF and bottom die.

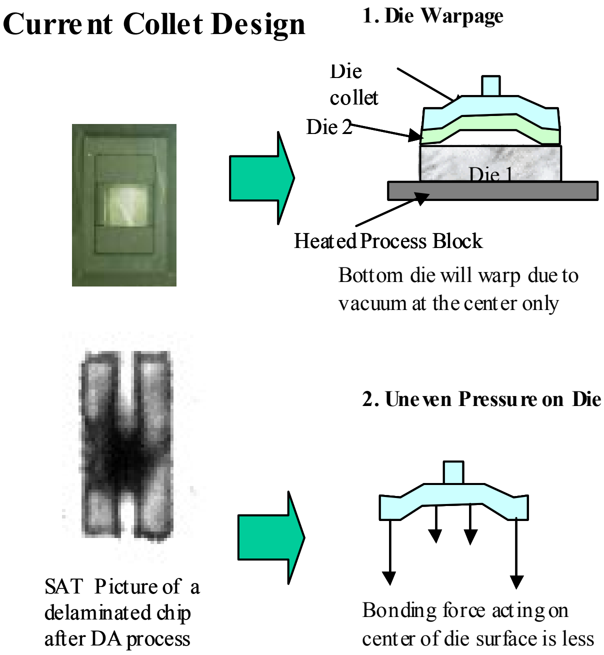

Figure 9: Current Die Collet Design and Its Problem

After confirming this phenomenon, another two new collet designs are tooled up and tested. The first design is a flat surface with center hole, namely the Flat Collet. With this design, the collect surface is 100% in contact with the die surface during die bonding. This design has helped to improved the die delamination, but not totally eliminating it. The problem with this collet is the contact surface of the collet to die is too big, causing some difficulties to release the die from collet after bonding. Figure 10 is the illustration of the first new collet design and the problems faced when using this collet.

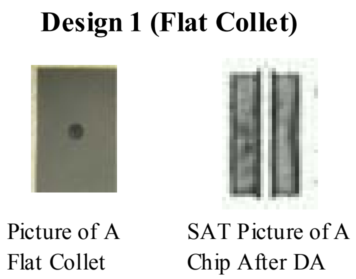

Figure 10: Flat Collet Design and Its Effect

Following this result, another new collet design is tooled up to improve the vacuum release problemand eliminate the delamination between die interface concurrently. The new design is called the X Collet, with vacuum groove run across the entire die collet. By using this collet, the SAT after die attach shows no delamination in the center of the two interface and the releasing of the die from die collet is feasible at all times.

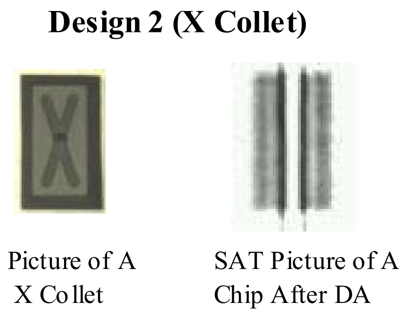

Figure 11: X Collet Design and Its Effects

4. Conclusions

The objective of this work is to develop a robust die attach process and tooling design using a selected type of DDAF after studying the material characteristics and knowing the effects of each important property relating to the performance of final package. The result of material selection shows that a DDAF with lower reaction rate and lower dymanics modulus is better in ensuring its fluidity and gap filling characteristic for better adhesion and reliability performace in the package. The process DOE study shows that lower die attach temperature, lower bond force is critical in eliminating delamination during die attach process, which will also ensure better reliability. The process block with peripheral vacuum groove couples with the X Collet give the process control a wider margin. All the delamination free untis have been submitted to reliability testing. The result shows that all the units have passed IPC/JEDEC MSL3.

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