Effect of Die Bonding Condition for Die Attach Film Performance in 3D QFN Stacked Die.

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Abstract: Consumer demand for smaller and lighter products in wireless application with maximum functionality had drive the semiconductor industries toward the development of 3-dimensional stacked die. One of the key technology is relies on die stacking process. A suitable bonding condition and material set are essential to achieve required reliability performance. This study is to relate the effects of variables bonding parameter on the mechanical adhesion and delamination of the die attach film in QFN stacked die. Samples are deliberately built with nine combination sets of die attach parameters including bonding temperature, force and time to achieve a minimum reliability performance under IPC/JEDEC Moisture Sensitivity Level 3 at reflow 260°C. Characterisation of die attach film was carried out using differential scanning calorimetry whereas it performance was carried out using shear testing machine and scanning acoustic test (SAT) is used to detect the interfacial delamination between DAF and die. The best die attach process is characterized by stable values of die attach film thermal resistance properties and optimum touch area between die/die attach film and die attach film/die.

Key-words:- Die attach film, QFN, delamination

1 Introduction
The trend towards miniaturization of wireless devices, more functionality and high performance can be described by QFN 3-dimensional packaging. This innovation introduced the third or Z height dimension by stacking another die on the base die using die attach film (DAF). 3D packaging offers attractive way to reduce transmission delays, since 3D packaging configuration provides much shorter access to several surrounding chips [1]. Schematic cross section of the stack QFN package can be seen in Fig. 1.

There are two common adhesive material used for die stacking in the microelectronic packaging of high-density surface mount i.e epoxy paste and die attach film (DAF). The application of epoxy paste for die stacking is well documented as a standard die bonding material. Challenge in controlling the resin bleed and creeping effect to the die edge especially for stacked die need an advanced solution for optimum performance. To overcome this problem, the usage of DAF was introduced in the development of 3-D stacked die. Table 1 shows the usage comparison of DAF and epoxy paste.

Fig.1 Stacked die QFN package

Table 1. Comparison of DAF and epoxy paste.

<table>
<thead>
<tr>
<th>Item</th>
<th>Die Attach Film</th>
<th>Epoxy Paste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Condition</td>
<td>Room Temperature</td>
<td>Freezer</td>
</tr>
<tr>
<td>Adhesive formation</td>
<td>Uniform amount</td>
<td>Dot patterning</td>
</tr>
</tbody>
</table>
Die mounting Method | Direct bonding | Dispenser system
---|---|---
Die mounting Temperature | Required | Not necessary
Bleeding | No | Possible
Bond line Thickness | Uniform | Varied

Compared to epoxy, the DAF requires some bonding delay and temperature to allow the DAF to melt, solidifies and stick to the leadframe. One of the important discussion focuses in the stack QFN process flow is on die to die bond process. Basically, when choosing the DAF there are two considerations need to be taken into calculation. First consideration is on the DAF material repeated heat cure during the die attach, wirebond and moulding process. If the DAF is cured before moulding process, chance of delamination between die and DAF interface is high [2]. Secondly, the optimization on the methods of the die attach process, to ensure the robustness and reliability of the package.

Theoretically, it is well agreed that process condition and material properties related to polymeric materials give high impact to the surface mount adhesion. Results from the engineering study shows water absorption and work of adhesion between silicon die and substrate interface decreased with increasing filler [3]. On the other hand, it is clear that after die attach process, the curing reaction of DAF should be stable in the followed process before mold, to increase the effective touched areas and prevent weak interface or delamination in the stack die product [4].

2 Experimental works
The samples were deliberately built with nine combination sets of die bonding parameters. Samples were prepared using thin film of Al die with the package size of 7 x 7 x 0.9 mm³, QFN 48 leads package (Fig. 2). The base die size is 5 x 5 mm² and the top die size is 3.3 x 3.3 mm², with thickness for both dies are 0.15 mm. DAF Y were used to stack up the top die on the base die using ESEC 2008HS die bonding machine.

![Fig. 2 Top view and side view of the unmolded, 48 leads QFN package](image)

This experiment was designed to evaluate the die bonding reliability of the adhesive tape and to understand the effects of likely sources of manufacturing variation. Therefore three factors were evaluated: bonding temperature, bonding force and bonding time. A common parameter window was established for the DAF system that allowed both DAF to produce die bond that met established production physical and visual inspection criteria. Each of the combinations was run as a separate assembly lot in a completely randomized order.

Initially, evaluation on die pick up conditions have been earlier made to observe the effect of pick up force, needle size and height on the die crack and needle mark. These results are important to ensure that any failure at pick up process will not affect the bonding results while running the die bond evaluation. Final results concluded that 5 mil needle type with force 50 gf and 0.6 mm needle height are able to give good pick up condition with no needle mark and no die crack observed by visual inspection. Fig.3 illustrate the comparison of the poor and good DAF surface after die pick-up process.

![Fig. 3 Die pick up results (a) needle mark observed (b) no needle mark observed with optimized pick-up condition.](image)

Completely flat contact surface is very important to ensure maximum adhesion between DAF and bottom die. It is observed
that minimum contact area between die surface which effected by needle mark can create voids and prone to delamination. During “sealing” process by bond force, air will be trapped in between the needle mark at DAF surface and bottom die that will results in delamination propagation after prolonged reliability test.

2.1 Differential Scanning Calorimetry
Mettler Toledo DSC 821e is used to monitor changes in cured properties of DAF depends upon temperature. DAF is subjected to temperature in ranges of 30 - 350ºC and 130 - 500ºC with the heating rate of 20º/min.

2.2 Die Shear
Results of mechanical adhesion for each DAF was obtained using a DAGE 4000 series shear testing machine. Correct position of shear tool is illustrated in Fig. 4.

Fig. 4 Correct position of shear tool

30 units of die were sheared for each run. For the purpose of this study, only the top die was sheared or forced to move while the base die was kept stationary. Thus the DAF layer will move relatively between the dies and present the adhesion strength for the DAF and die attach condition.

2.3 Scanning Acoustic Test
Scanning Acoustic Test (SAT) is perform by using SONIX® HS-1000 with the transducer pulse echo T-scanning Frequency of 25MHz to detect the air gap or interfacial delamination between DAF and die.

3 Results and Discussion

3.1 DAF Curing Properties
Change in DAF curing properties is known depend upon the temperature. Knowledge on how these changes occur over a range of temperature can guide to better understanding and help to define the processing technique that need to be used. In this study the DSC was run in dynamic mode to measure the changes in the heat flow characteristics for both adhesive tapes when the material was heated under controlled temperature. Results for dynamic DSC trace are shown in Fig. 5 (a) and (b).

The curve trace presents the starting point of polymerization temperature, maximum of reaction temperature achieved, rate of cristanility and melting point for both DAF. Results were summarized as in Table 2.

Table 2 DSC results for DAF Y at 30 - 350ºC and 130 - 500ºC
The curve traces for DAF Y presents roughly equivalent pattern in the heat flow although exposed at different range of temperature of 30 - 350°C and 130 - 500°C, which exhibited stable heat flow properties. The DAF present a rapid and sharp cure reaction peak, the initial point is about 125°C and maximum reaction achieved at 200°C. Ideally, the recommended cure conditions should be followed, with the understanding that the true bondline temperature of the adhesive may not necessarily be identical to the oven set temperature [5].

### 3.2 Die Shear Result

Fig. 6 reported the shear test measurement results for DAF Y on different combination of die bonding parameter. It can be seen that the bond force, bond temperature and bond time give a significant impact to the adhesion strength of the top die.

![Die Shear Results for DAF Y](image)

Fig. 6 Die shear measurement results for both DAF.

DAF Y presents increasing in die shear reading as bonding force, temperature and time increase, with failure mode of more than 50% to 100% silicon remains on die pad after shearing and little number of units illustrated no silicon remain on die pad as shown in Fig. 7.

![Specified modes for die shear](image)

(a) more than 50% to 100% silicon remains on die pad
(b) no silicon remain or less than 10% on die pad.

### 3.3 Delamination

Pulse-echo (reflected) mode image for all cases of DAF Y before and after MSL3 at reflow 260°C have been well presented in Fig. 8. Any air gap or delamination will show up as a bright area in the SAM image. The scanned image clearly shows the 100% coverage of the DAF underneath the top die. No any samples failed with no sign of delamination or adhesive voids can be found before reliability test. Equivalent results were also observed for all cases after reliability test and achieve a minimum reliability performance under IPC/JEDEC Moisture Sensitivity Level 3 (MSL3) at reflow 260°C.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>T(peak) °C</th>
<th>Cristainility %</th>
<th>Melting Point °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 - 350°C</td>
<td>200.20</td>
<td>2993.44 %</td>
<td>-</td>
</tr>
<tr>
<td>130 - 500°C</td>
<td>200.54</td>
<td>3824.04</td>
<td>417.06</td>
</tr>
</tbody>
</table>
Run 6
Run 7
Run 8
Run 9
(a)                             (b)
Fig. 8 SAT scanned image of (a) DAF Y before reliability test (b) DAF Y after reliability test.

4 Conclusion

The results from this investigation shows that all the units have passed IPC/JEDEC MSL3 and indicate that the best die attach process is characterized by stable values of DAF thermal resistance properties and optimum touched area between die/DAF and DAF/die. For this case, where the bonding temperature used is equal to 150°C and below, good adhesion and reliability performance was achieved by the combination of the highest bond force, temperature and time. But, if higher process temperature is required, short process time will need to be used with an adequate force. Based on DSC curve results, it is suggested that bonding temperature for DAF Y must be used below than 200°C to make sure the DAF not fully cured after die mount. It is because, after die-mount process, the curing reaction of DAF must be stable in the followed process before moulding. The DAF should only be completely cured under transfer pressure and elevated temperature during moulding process to ensure the DAF will be compressed to fill the gap between top die and bottom die interface.

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References