High-Performance Conductive Film Technology for Large Die Automotive Applications: MSL and Board-Level Exposed Pad Performance

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RECENT RECALLS IN THE AUTOMOTIVE industry have reinforced the need for components with higher reliability. Applications such as air bag sensors and electronic system have underscored the importance of high levels of reliability for automotive customers. The JEDEC JESD22- A104D Temperature Cycle Standard is just one such example where the automotive industry is using severe reliability testing requirements.

This article will focus on reliability testing for conductive Die Attach Film (cDAF) technology, specifically on die applications ranging from 1x1 mm^2 to 10x10 mm^2. Our test results are showing zero delamination after Moisture Sensitivity Level 1 (MSL 1) with more than 2000 exposed pad board-level temperature cycles. When compared to die attach paste with similar product characteristics, cDAF technology is outperforming MSL 1 and temp cycle results.

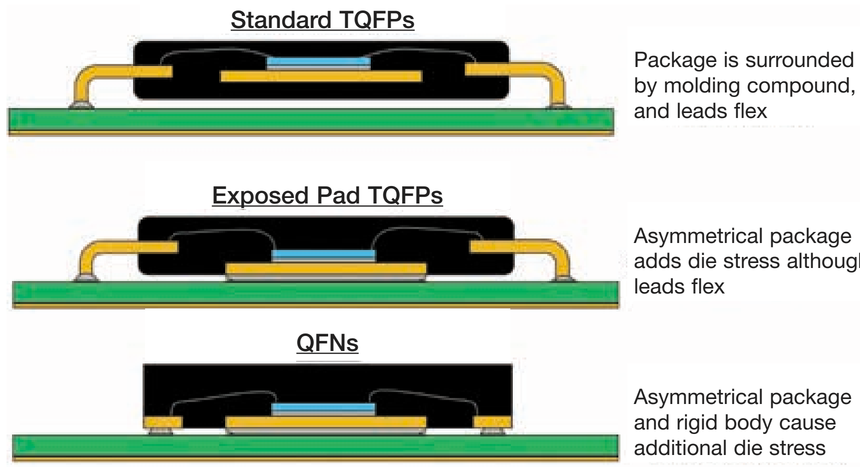

Figure 1. Depiction of three basic package types related to this study.

Product Application

The automotive industry often selects small outline integrated circuit packages (SOIC) or thin quad flat packages (TQFP) for automotive applications as historical reliability performance for this package is well known. Traditional TQFP packages are symmetrical, having molding compound above and below the pad, resulting in an optimized balance of forces on all sides of the die. As automotive electronics are integrating more and more functionality into these devices, heat dissipation is becoming an issue, which is why we are starting to see more exposed package SOIC or TQFP package types.

Exposed packages are components where the die pad is directly mounted to circuit boards through standard solder assembly processes. Asymmetric packages are the most effective method of creating a heat path from the die through conductive die attach, to the die pad and out to the circuit boards. However, asymmetric packages are also changing the stress points on the package directly to interface of the die and die attach materials, thus inducing die cracks and die attach delamination.

The worst case scenario for testing is when the die to die pad is maximized so that the die is almost the same size as the die pad. Larger dies exhibit more CTE mismatches, during heating and cooling cycles, than that of a smaller die on large die pad. For this study, a QFN 12mm x 12mm package was selected because of its stiffness especially due to having no leads, where the exposed pads and leads mounted to the board will exert the maximum stress possible on the package during temperature cycling, simulation. An image depicting each package is illustrated in Figure 1.

Automotive customers are primarily concerned with the reliability of their packages to perform under extreme operational conditions. When a package is mounted to the board with exposed pad and leads, much of the stress targets the die attach material. Since conductive die attach films (cDAF) are supplied on a continuous roll as a solid at room temperature, this format allows the use of non-traditional resins to form stronger cohesive bulk material properties to help reduce adhesive stress points. That is, cDAF performs better than traditional die attach paste because the material format allows the use of higher viscosity resins which simply can't be used in die attach paste formulations. In addition, cDAF technology allows formulations with lower cross-linking density, which helps to reduce warpage. Additional benefits can be seen in the manufacturing processes of film technology vs paste format which come from coating methods yielding high adhesion, good wetting and high material cohesive strength.

Resin bleed is a major issue of con-

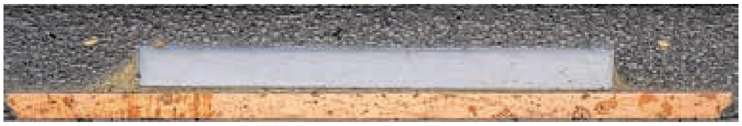

Figure 2. Traditional die attach paste with a fillet and die tilt and inconsistent fillet.

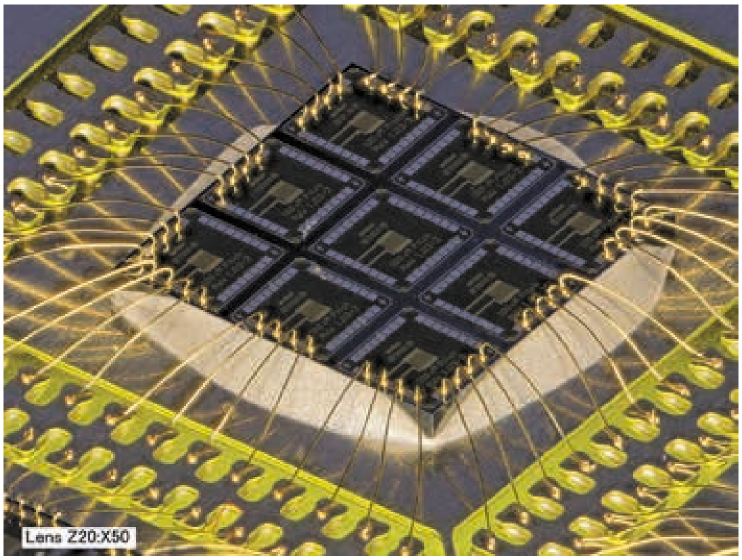

Figure 3. Top view of traditional die attach paste with extensive squeeze out and fillet.

Figure 4. Limited material flow with cDAF demonstrating no fillet, no die tilt, and no bleed with a larger die size.

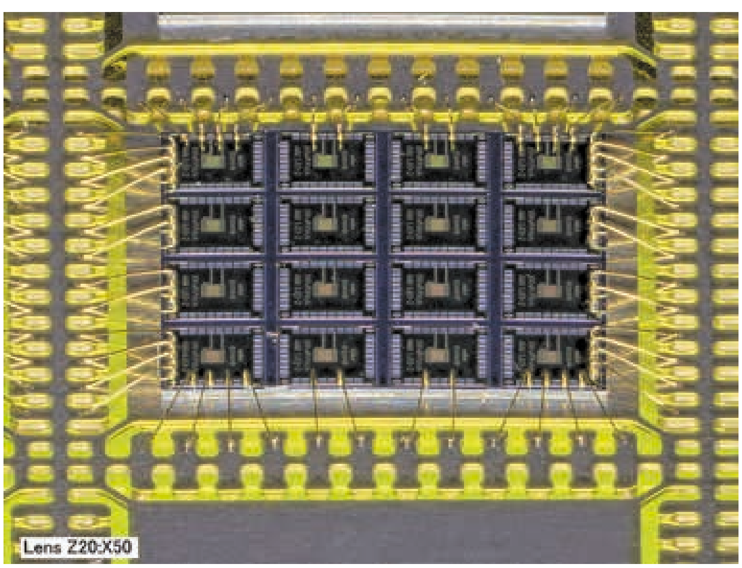

Figure 5. Top view of cDAF showing large die-to-pad ratio with no squeeze out or fillet.

cern for automotive temperature cycling, as this resin flow can compromise package integrity ultimately causing bondline failure. Resin that separates from die attach during cure can cause failures between the molding compounds to the package leaframe, typically these failures can be seen at the edge of the die. With higher viscosity resins, we do not typically see these type of bleed issues with film Technology.

In addition to providing robust package reliability, many automotive applications also require a flexible die size range to bond semiconductor chips to their substrates (leadframes). Conductive die attach film (cDAF) materials have been designed to have lower stress (low modulus) and higher adhesion for die sizes ranging from small (1 mm x 1 mm) to large (10 mm x 10 mm) die sizes. Studies have also shown that packages with no bleed or die tilt and consistent die fillet tend to have better reliability results. The images below display the vast difference in flow between cDAF and traditional die attach paste, where cDAF enables larger die bonding capability for a fixed pad size.

Conductive die attach films are able to bond to various leadframe surfaces, including bare copper, silver, and nickel palladium gold (NiPdAu), which is the preferred metallization for high reliability applications. Other metallization's can also be processed with cDAF, including bare silicon (Si), silver (Ag), and gold (Au). Although cDAF is compatible with rough surfaces, smooth surfaces are preferred to achieve ideal wetting. Wetting the interfaces sufficiently is helpful for reducing interfacial thermal and electrical resistance, hence improving conduction; the metal-filled nature of the film also dissipates much of the heat from the die surface. Large die conductive films meet all these demanding requirements.

Experimental Processing and Setup

For the purposes of this study we focused on the worse-case scenarios for reliability tests, this experiment focuses on MSL 1 and 2000 temperature cycle results on an exposed pad QFN package. MSL 1 insures the package integrity during the solder mounting process for an unlimited shelf life. In addition, since many of these parts are mounted under-

Test	Temperature Requirements	Reason for the Test	Assessment Method
MSL 1	260°C reflow three times	Determines the shelf life of the package before mounting on the board	Scan the acoustic image before and after testing. Measure delamination when needed.
Board-level Temperature Cycling 2000 cycles	-55° to 125°C a cycle	Simulates a lifetime of automotive operation with accelerated reliability testing	Scan the acoustic image before and after testing. Measure delamination when needed.

Table 1. MSL 1 and board-level temperature cycling reliability testing.

the-hood or on critical applications with brake systems, temperature cycling guarantees a lifetime of material performance simulating the stress exerted on the material during the heating and cooling cycles of normal automobile use.

Our reliability tests, required an MSL 1 (260°C reflow three times) rated package with 2000 cycles of board-level JEDEC JESD22- A104D Standard "B" Temperature Cycling (20 minute cycles of -55° to 125°C). The thermal cycling causes stress build up from the CTE mismatch, where the die attach material is under tension during the coldest portion of the cycle and in compression during the hottest portion.

In addition to the above stringent requirements, a zero-level delamination specification is a key component of testing criteria for critical automotive applications. This reliability process relies heavily on acoustic imaging to verify no delamination of the bond-line and general package integrity. Inspection was performed with reflective acoustic imaging, as the woven pattern of the laminated board prevented acoustic through-scan imaging. Once the package is mounted on the board, the test results are referred to as pertaining to a "board-level" test (see Table 1).

The purpose of this experiment is to compare the MSL 1 and 2000 temperature cycling reliability performance of the following three materials: traditional paste (Material 1), an older generation of large die cDAF (Material 2), and a newer generation of cDAF (Material 3), where the newer generation has a lower modulus with less crack initiation points than the latest generation.

Regarding the processing to build this package for both MSL and temperature cycling testing, the cDAF product is laminated onto a metallized (gold for added thermal conductivity) backside wafer and dicing ring with a standard 2-in-1 laminator. This wafer is then diced to an 8.0 x 8.0 x 0.3 mm^3 die size and bonded onto a NiPdAu leadframe using traditional die attach equipment with a heater block. After curing, wirebonding, molding and singulation, the packaging process is complete; see Figure 6 for the process flow of the packages used for this study.

The package is then mounted onto a printed circuit board (PCB) using a screen or stencil printing technique, pick-and-place technology, and a solder reflow process. The board used for this experiment was found to be extremely rigid, made of several layers of copper and laminated substrate. Once the parts are mounted onto the PCB and start temperature cycling, the expansion and contraction from the CTE mismatches (the different packaging materials' coefficients of thermal expansion) cause stress, which is primarily exerted on the die attach material itself due to the rigid nature of the board: the more rigid the board, the more the die attach material will be stressed.

Additionally, QFN packages are generally quite rigid, approximately 12 x 12 mm^2 in size, without extended leads and a large die-to-pad ratio. After stencil printing and reflow, the board will appear as in Figure 7 with some of the locations occupied by packages. The package will be mounted onto the center of the board location with solder under the exposed pad and also on the leads fixing the package edges and center pad firmly in place.

Reliability Results

Initial results for large die Material 2 cDAF results show good wetting and adhesion to the die and leadframe compared to traditional die attach paste and Material 1 cDAF; the warpage is as low as the leading paste products. In addition, the package exhibits good thermal and electrical performance after the packaging process.

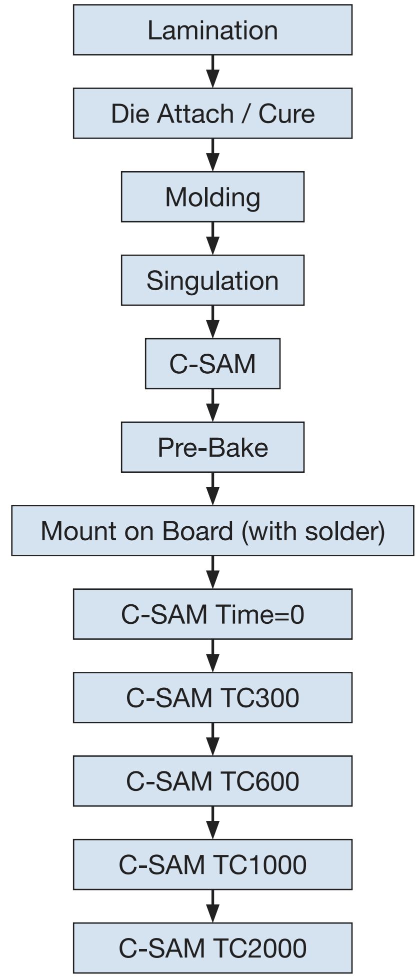

Figure 6. Package Process Flow Chart.

Regarding reliability results, Material 3 passed MSL 1 on the QFN12x12 package with an 8x8mm^2 die due to its high adhesion to the die and substrate and high moisture resistance, while Materials 1 and 2 failed due to their low adhesion.

In regards to board-level temperature cycling, Material 3 also passed the required 2000 cycles with zero delamination, with the bond-line integrity also verified by cross-sectioning. However, Material 1, the paste product, would fail after 1000 cycles with predictable delamination on the edge of the die, the

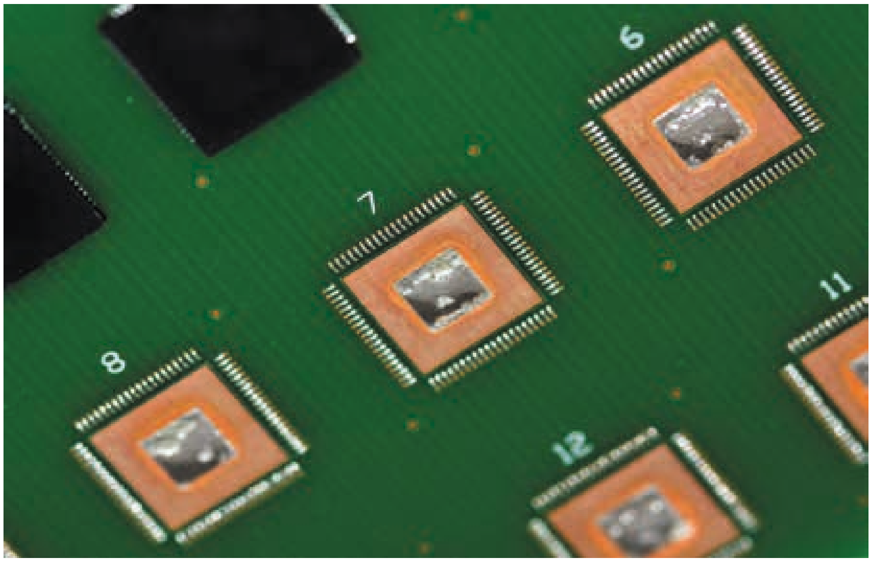

Figure 7. Board after reflow showing solder on both the leads and the exposed pad (bottom right) are also soldered to the QFN component, demonstrating the strenuous nature of board-level temperature cycling. QFN12x12 parts are also mounted on the board (top left).

Number	Material	MSL Result	Board-level Temperature Cycling Result
1	Traditional Paste	Failed MSL 1	Predictable delamination on the edge of the dies after 1000 cycles
2	First generation of cDAF	Failed MSL 1	Unpredictable delamination under the dies after 1000 cycles
3	Second generation of cDAF	Passed MSL 1	Zero delamination after 2000 cycles

Table 2. Reliability test results.

area of highest stress. Material 2, on the other hand, showed poor temperature cycling performance as the modulus is high resulting in brittle material breakage around crack initiation points during temperature cycling, resulting in unpredictable delamination anywhere under the die. The adhesion of Material 2 to the die was also low causing further separation between both the die attach material and the die and leadframe interfaces. Table 2 further summarizes the results of the tests.

The modulus was found to be a major contributing factor to the passing of this rigorous temperature cycling testing, where lower modulus materials will experience less stress during the cycling. In addition, the size of the particles in the bond-line and the resulting reduction in crack initiation points and good wetting of the material were also contributing factors to the success of Material 3's positive temperature cycling testing. Due to these reasons, the new generation of cDAF outperforms paste in temperature cycling. Further investigation is on-going into the effects of fillet and die tilt on the failure of die attach paste temperature performance.

Summary

With regards to the severe reliability testing required by the automotive industry, Henkel's new generation of large die cDAF is the only product that meets and exceeds these rigorous MSL and exposed pad board-level temperature cycling testing expectations with no delamination, while maintaining the necessary thermal conductivity. This unique combination of low modulus, high adhesion, and high moisture resistance produces a material platform with high reliability performance, outperforming traditional die attach paste. Film technology also bonds to the leadframe in a clean, easy process that eliminates squeeze-out, fillet, bleed, and die tilt, enabling larger die sizes in a fixed package size further enhancing reliability. ◆

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