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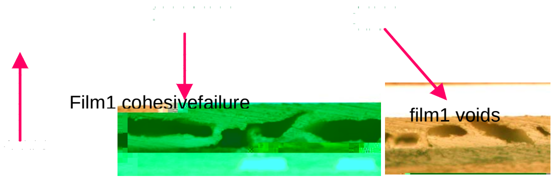
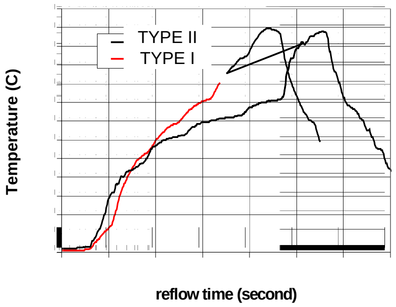
Wafer-level dicing tape format die-attach (DA) film and the corresponding lamination method provide a suitable solution for handling thin-wafers. However, such die-attach films typically have a Young's modulus less than 10MPa at soldering reflow temperature (e.g. 260°C). This introduces a new failure mode, i.e., cohesive failure in the DA film. Through extensive experimental DOE studies described in this paper, it has been observed that some CSP packages with such film are very sensitive to substrate thickness and reflow profiles. In this work, a fundamental understanding of failure mechanisms was obtained through comprehensive finite element simulation and material characterization. It was noted that there might be a risk of cohesive failure with low-modulus die-attach film during reflow. Further, several types of die-attach films were evaluated based on full stack and discrete packages. Experimental results showed that not all die-attach films with very low modulus are sensitive to reflow profiles with cohesive failures. A general methodology for selecting die-attach film for ultra-thin stacked-die packages was developed based on the advanced measurement techniques and finite element simulation. If the film is not sensitive to reflow profile, even though the die-attach film has very low modulus, the film modulus, moisture diffusivity, and saturated moisture concentration will not be critical the parameters for screening the DA films. In this case, interfacial adhesion and the film voids become the key modulators. Since the stress state in the film is hydrostatic in a confined constraint condition, the effective hydrostatic stress in the film is not as high as vapor pressure, the low-modulus die-attach film can be used without cohesive failure. On the other hand, when cohesive failures are present, the integrated modeling approach with material characterization can be



After L3 preconditioning, massive cohesive delamination was seen in the first layer die attach film (film 1). The cohesive delamination is a consequence of void growth and coalescence induced by vapor pressure during the reflow process.



Two reflow profiles both meet the JEDEC standard. The main difference is that TYPE II ramps much slower up to the temperature peak than the TYPE I.

In this study, we demonstrated that moisture escape and transport behavior during reflow was determined to be the root cause for this type of failure. A fundamental understanding of the failure mechanisms was obtained through comprehensive finite element simulation and material characterization. The root cause finite element model established the relationship between moisture uptake, material

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properties such as diffusivity and porosity, and vapor pressure buildup. Further, several types of die-attach films were evaluated based on full stacked and discrete die packages. It has been found that not all die-attach films with very low modulus are sensitive to the reflow profiles and substrate designs. A general methodology for selecting die attach films for UT/SCSP applications was developed based on the advanced measurement techniques and finite element simulation.

A controlled experiment with varying substrate material components was evaluated to determine the effect of thickness on moisture related reliability performance. Die-attach film labeled ‘DA1’ has been applied throughout this experiment. The substrate contains solder mask (SM)/BT core/copper layer (Figure 3). The following parameters were varied (1) BT core thickness to study the thickness effect of the diffusion path on delamination; (2) SM thickness to check its high solubility effect which makes it as a moisture reservoir. After preconditioning stress, the delamination rate was monitored by TSAM.

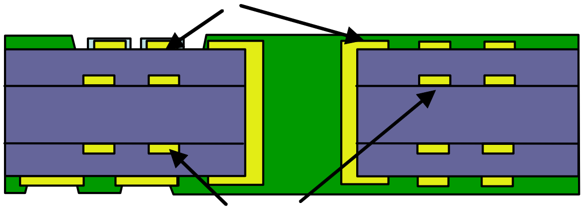

Table 1 summarized JEDEC moisture sensitivity Level (MSL) 3 test results with TYPE I reflow profile shown in Figure 2. Results clearly showed that the thicker the BT-core, the higher the delamination rate. All failures occurred at the first die-attach film layer with cohesive voiding/cracking. In each experimental leg the sample size was 240. Please note that only the relative thickness values were shown in Table 1, in which x represents solder mask reference thickness, y the BT-core reference thickness and z the total reference thickness, respectively.

Delamination rate for different substrate designs

Thickness	Leg 1	Leg 2	Leg 3	Leg 4	Leg 5
Solder Mask	1x	1.02x	1.04x	1.04x	1.4x
Inner Cu density	0%	50	50	50	50
BT-Core	1y	1.1y	1.4y	1.5y	1.5y
Total	1z	1.20z	1.47z	1.47z	1.53z
Delam Rate	0%	7%	32%	47%	100%

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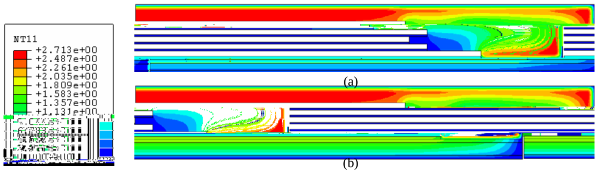
We further investigated the sensitivity on reflow profil-6()-3.3( )9(Totae.6 0.4w-0.f66775 Tc0 Tw[(Del.197icknessAs.9(r)shown)3.9(i

Figure 6 plots the saturated moisture concentration at)3.4(vari)41ou-1.742.7(.3(1.73(pt)3.4(e2(d 4(.7(s for .74sat)3.4(e 70 µ1.

thinner substrate was much less than that with the thicker substrate. The contours of vapor pressure at 260^{o}C are shown in Figure 11. For the package with the thinner substrate, the vapor pressure in DA film 1 is 50% less compared to that with the thicker substrate. The results correlated very well with the experimental results shown in Table 1.



Moisture distribution after reflow for two different substrate thicknesses (a: thinner substrate, b: thicker substrate)

Vapor pressure distribution at the reflow temperature of 260°C for the two different substrates (a: thinner substrate, b: thicker substrate).

It is clear that die-attach film with low modulus poses a new risk for cohesive failures. However, it is not known at this point if the modulus is the key parameter for the reliability performance. This is because cohesive failure not only depends on modulus, but also on material microstructure, such as porosity [6-7]. In the following, further experiments were conducted with several different die attach films to understand the failure mechanism.

In order to investigate whether the materials with high Tg and/or high Young's modulus are necessary for preventing cohesive failures, four different die attach films (DA1, DA2, DA3 and DA4) were selected to build both stack and discrete assemblies, with the same substrate (thicker option). DA1 is the die-attach film we discussed in previous section and is used here as the control leg. The details of the design of experiment (DOE) are shown in Table 2.

With the built units, the stress tests were performed by following flow: assembly Ą time zero failure analysis (FA) Ą time zero TSAM analysis Ą bake Ą temperature cycling (5 cycles) Ą moisture soaking (MSL 3) Ą reflow at 260°C Ą TSAM analysis Ą FA. The results are summarized in Table 2. As expected, the DA1 film had a high cohesive failure rate. Figure 12 showed the cross-section picture at film 1 region and the top-town lapping image, both confirmed the cohesive rupture and formation of voids after reflow.

For the DA2 film, no failure was observed for the discrete leg, but there were few failed units captured by TSAM for stacked packages. Failure analysis found there were the cohesive failures at the film 2 /die 1 interface but not in the film 1, as shown in Figure 13. Further analysis confirmed that the failure captured at the film 2/die 1 interface were caused by the film 2 contamination. This implies that DA2 is an acceptable candidate with no cohesive failure.

The DA3 film showed a very high failure rate. By the top-down lapping, large voids were observed at the center of film 1 for both discrete and stack packages. The cross-section images on the packages further captured that the failure mode was interface delamination at film 1/solder mask interface, as shown in Figure 14. The investigation confirmed that large voids were generated by the high pressure of the pick-up tool on the film 1 during the die attach process. The new builds after modifying the process parameters demonstrated 100% clean results, indicating that the DA3 film can be used as for both discrete and stack packages without failure.

The DA4 film exhibited the best performance. There were not any voids and delamination captured by the top-down lapping on a few units and the cross-sections on those speculative units identified by TSAM, as shown in Figure 15.

From the above experiments, it was found that only the DA1 film had cohesive failure when combined with the TYPE I reflow profile and a thicker substrate. The rest three films were not sensitive to the reflow profile or the substrate

Summary of the DOE and TSAM results*

Leg	Substrate	Stack	DA Film	Quantity	TSAM Results (delamed units/total units)	
					Pre-stress	Post-stress

Summary of Young’s moduli of the four films**

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DA1	Low	1X
DA2	Low	2X
DA3	High	Very high
DA4	Low	1.5X

** Values of Young’s modulus at 200°C, 160°C and 150°C are characterized by digital image correlation (DIC), dynamic mechanical analyzer (DMA) and Intel’s material suppliers, respectively.