

Development of Dicing Die Attach Film (DDAF) for small dies

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Abstract

In recent years, the demand for ever smaller dies including Micro Electro-Mechanical System (MEMS) and sensors is dramatically increasing. Technologies such as automated driving technology are taking off and market pressures to reduce package size and increase the performance in mobile devices are increasing. DDAF increasingly is being utilized in these applications to bond dies to substrates and other dies. DDAF can be used both in the dicing and the die bonding process replacing the need for two separate materials to dice and bond dies. It is composed of DAF (Die Attach Film) and base material, and the DAF layer is what bonds small dies to substrates and other dies. Conventional DDAF however is susceptible to Transfer Failure (TF) with smaller die sizes. It is a failure mode in which the DAF layer peels off from the backside of the die during the die picking up (PU) process. There are multiple root causes for this issue; small dies have small DAF attachment area and smooth die backsides for increased die strength results in an inability of the DAF to anchor to the die itself. TF on PU process was improved by using a DAF with a high melt viscosity to allow the DAF to better anchor itself to the die. However, package reliability was decreased due to the material's inability to embed itself on to the substrate. Effect factors for suppression of TF with high substrate embedding were explored. To explore these factors a right-angle tear strength method was implemented. Upon analysis of the data a new parameter for the suppression of TF was discovered. This parameter showed a strong correlation to TF. A new DDAF was developed that mitigates TF during PU process.

Key words

Blade Dicing, Dicing Die Attach Film, MEMS, Right-angle tear strength method, Transfer Failure

I. Introduction

In recent years, the demand for increasingly smaller dies, such as the case with Micro Electro-Mechanical System (MEMS) sensors, is dramatically increasing. Technologies such as automated driving technology are taking off and market pressures to reduce package size and increase the performance in mobile devices is increasing [1]. LINTEC has been developing Dicing Die Attach Film (DDAF) which are specialized for small MEMS dies [2],[3],[4]. DDAF is a multifunctional tape. It functions both as a dicing tape and a die attach film[5]. It is not necessary for customers to apply die attach paste. LINTEC's DDAF is composed of a DAF (Die Attach Film) and base material, and the DAF layer is what bonds small dies to substrates and other dies.

Process flow using DDAF is shown in Figure 1. 1) DDAF is mounted on to the back surface of the wafer and the back grinding tape is removed, 2) UV irradiation of the DDAF. This step helps minimize chipping during dicing process by increasing elastic modulus, 3) Singulation of the wafer using

a dicing saw, 4) Pick up process (needle), 5) Die bonding process, 6) Heat curing of DAF with substrate, 7) Wire bonding, 8) Transfer molding using EMC (Epoxy Mold Compound).

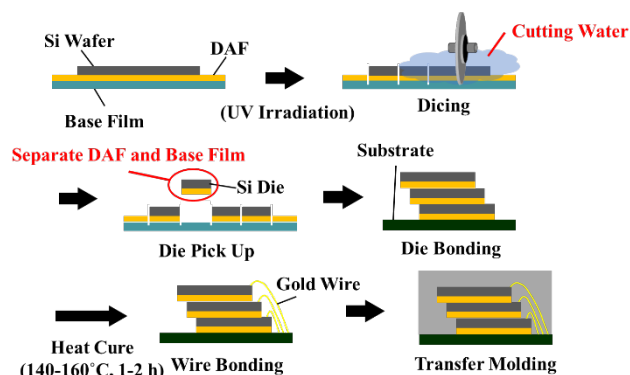


Figure 1. Process flow using DDAF.

Conventional DDAF is susceptible to Transfer Failure (TF) with smaller die sizes. It is a failure mode in which the DAF layer peels off from the backside of the die during the die picking up (PU) process. TF is shown in Figure 2. There are multiple root causes for this issue; small dies have small DAF attachment area and smooth die backsides for increased die strength which results in an inability of the DAF to anchor itself to the die. Decreasing PKG reliability is caused by TF due to the decreasing adhesive area of small dies to substrates and other dies. We focused on dicing conditions and water absorption of cutting water during dicing to eliminate TF from occurring. To improve the DAF, a right-angle tear strength method was implemented.

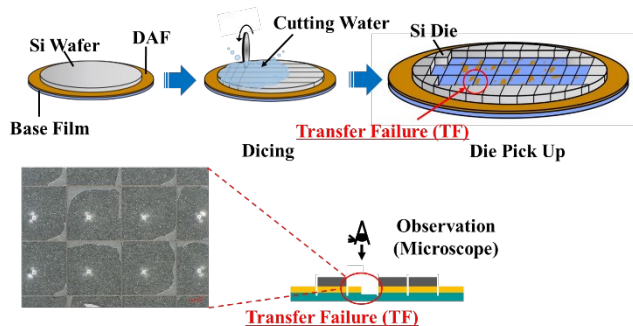


Figure 2. Appearance of Transfer Failure (TF)

II. Experiment and Result

2-1. Effect of dicing conditions.

We investigated the relationship between dicing conditions and TF using conventional DDAF. Dicing rotation speed, grit size, and concentration of Z2 blade were investigated cutting DAF and base film.

Si wafer

Diameter size: 200 mm (8 inch)
Thickness: 50 μm

DDAF

Conventional DDAF (Sample A)
DAF thickness: 20 μm

Dicing

The wafer was diced to a die size of 2 mm² by using a dicing saw. A commercially available blade dicer (DISCO Co.; Model DFD6362) was utilized for testing.

Dicing condition

Step-cut mode was used.

Z1 blade

Blade: ZH05-SD4500-N1-90 DD
Blade rotation: 40,000 rpm
Blade height: 20 μm into Si wafer
Cut speed: 25 mm/sec.

Z2 blade

Blade: ZH05-SD[X]-N1-[Y] BB
Blade rotation: [Z]
Blade height: 20 μm into base film
Cut speed: 25 mm/sec.

[X] (grit size) = 2500, 3500, 4500, 4800

【rough 2500<<4800 smooth】

[Y] (concentration) = 50, 90, 110

【a little of abrasive grain 50<<110 a lot of abrasive grain】

[Z] (rotation) = 30,000, 50,000 rpm

PU conditions

Expansion: 4 mm
Needle: 4 pins
Needle speed: 20 mm/sec
Pick up waiting time: 500 milliseconds
Pick up height: 300 μm

A commercially available die bonder (Canon Machinery Co.; Model BESTEM D-510) was utilized for testing.

Table 1. shows the result of Z2 blade conditions and TF. In the case below when Z2 rotation was low, TF frequency was higher (Table 1(a)). TF more often occurred with rougher grit sizes and low concentration with high rotation conditions (Table 1(b)).

**Table 1. Effect of dicing condition
(a) Z2 blade rotation: 30,000 rpm**

Grit Size	Concentration		
	50	90	110
2500	TF	TF	-
3500	TF	TF	TF
4000	TF	TF	TF
4500	small TF	small TF	-
4800	small TF	small TF	-

(b) Z2 blade rotation: 50,000 rpm

Grit Size	Concentration		
	50	90	110
2500	TF	No issue	-
3500	TF	No issue	No issue
4000	small TF	No issue	No issue
4500	No issue	No issue	-
4800	No issue	No issue	-

Figure 3. shows SEM images of the die edge. Condition (d) which showed poor TF conditions with a good dicing line. However, conditions (a) - (c) which showed TF showed base film and DAF residue in the dicing kerf. Condition (b) seems to show that TF occurred caused by residue. From these results, we believe that TF is caused by residue in dicing kerf at the edge of the die, and base film and DAF are attached to the side of the die because of blade friction at lower blade RPM. The reason why the amount of TF changes depends on the blade conditions, with a large amount of DAF is cut in one rotation of the blade. The base film and DAF crawl up and adheres to the edge of the die at lower RPM. When a rough grit size and low concentration blade is used, the base film and DAF easily melt and adhere through heat.

Dicing Blade Conditions		Rotation	
		30,000 r.p.m.	50,000 r.p.m.
Grit Size	2500	(a)	(b)
		Transfer Failure	Poor
Grit Size	4500	(c)	(d)
		Transfer Failure	Good

Figure 3. SEM images of die edge

We considered parameterization of TF by measuring edge peeling force. Figure 4. shows measurement conditions and methods for edge peeling force. To measure edge peeling force a strong adhesive tape was attached to the surface of the diced die, and the peeling strength at the die edge was measured as the DAF was peeled off from the base material.

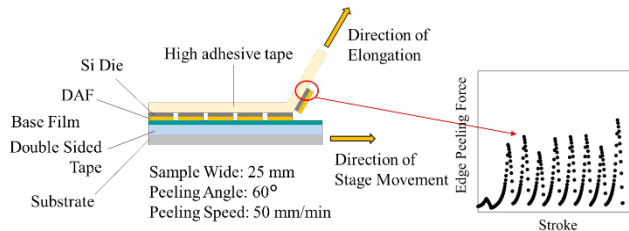


Figure 4. Measurement conditions and methods for edge peeling force

Table. 2 shows evaluation method of edge peeling force. Condition (d) which is not shown, TF with low edge peeling force. However, conditions (a) - (c) showed a high edge peeling force. Edge peeling force was correlated to TF. We believe it can be used as one parameter for TF.

Table 2. Evaluation of tensile test

Run	Z2 Blade Condition			TF	Edge Peeling Force (N)		
	Grit Size	Cut	Rotation (rpm)		Max	Min.	Ave.
a	2500	Single	30,000	Poor	6.0	2.0	4.0
b			50,000	Poor	4.9	3.0	4.2
c	4500	Step	30,000	Poor	5.9	2.4	4.0
d			50,000	Good	4.1	1.7	2.8

2-2. Effect of water absorption during dicing.

First, the relation between the water absorption rate of DAF and TF was investigated. The evaluation method is as follows.

DAF (Sample A) underwent dip treatment in pure water for 2 hours. The sample was removed from the pure water, and the weight of the sample was measured. The water absorption was calculated by the formula below (1).

$$\text{Water absorption (\%)} = \{(b-a)/a\} \times 100 \quad \dots (1)$$

a) The weight before water submersion

b) The weight after storage

Figure 5. shows the relation between water absorption and rate of TF. After 2 hours of dip treatment, the water absorption rate of DAF decreased with storage at room temperature, and at the same time, the occurrence of TF rate trended lower. After 24 hours storage time, the TF rate reached 0%, and the water absorption rate of DAF at this time was 0.2%. We set 0.2% water absorption as the TF threshold. Next, we confirmed how water absorption affects the physical properties of DAF.

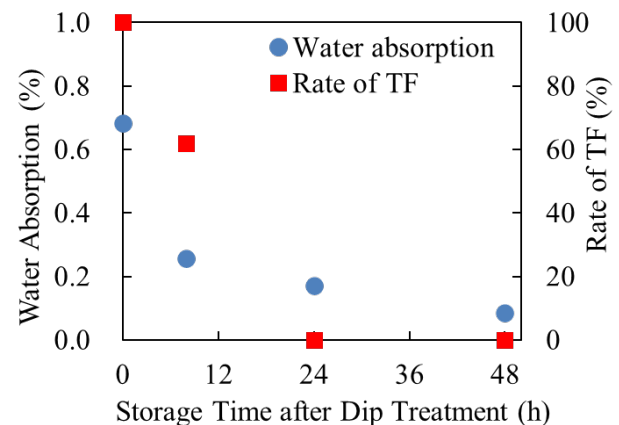


Figure 5. Relation between water absorption and rate of TF

The change of tensile properties of DAF were evaluated in relation to water absorption. The evaluation method is as follows.

DAF (Sample A) was laminated 200 μm thick, and a sample size of 15mm x 30mm was prepared. The sample was dipped in pure water for 2 hours and then stored at room temperature. After storage, the samples were tested using a tensile tester at a speed of 200 mm/min.

Table 3. shows the evaluation results of tensile properties. Immediately after dipping treatment, both the breaking strength and Young's modulus showed a decreasing trend compared to before dipping treatment.

Table 3. Evaluation of tensile test

	Storage Time (h)	Breaking Elongation (%)	Breaking Strength (MPa)	Young's Modulus (MPa)	Rate of TF (%)
Before Dip Treatment	-	400	4.5	200	-
After Dip Treatment	0	430	3.0	130	100
	8	380	3.8	170	62
	24	380	4.4	190	0
	48	390	4.6	200	0

The TF rate at that time was 100%. When the sample was kept at room temperature, both the breaking strength and Young's modulus increased. After 24 hours, the values were almost the same as those before dip treatment. In 24 hours the TF rate became 0%. This result was found to correlate with the water absorption rate of DAF.

Next, we evaluated the change in peeling force with DAF water absorption. The evaluation method is as follows.

Peeling force between DAF and Si wafer

DAF was laminated to a Si wafer, the base film was peeled off, and a situation was created where DAF could be exposed to pure water. The prepared sample was dipped in pure water for 2 hours, then placed under room temperature for a specified storage time. A 25mm wide strong adhesive tape was laminated to the DAF surface and peeled off at a speed of 200 mm/min using a peeling tester.

Peeling force between DAF and base film

Double-sided tape was laminated to the Si wafer, and the base film surface of DDAF was adhered to the surface. The release film was peeled off to create a situation in which the DAF could be exposed pure water. The prepared sample was dipped in pure water for 2 hours, then placed under room temperature for a specific storage time. A 25mm wide strong adhesive tape was attached to the DAF surface and peeled off at a speed of 200 mm/min using a peeling tester.

The evaluation results are shown in Figure 6. The peeling force between DAF and the base film did not change before and after dip treatment.

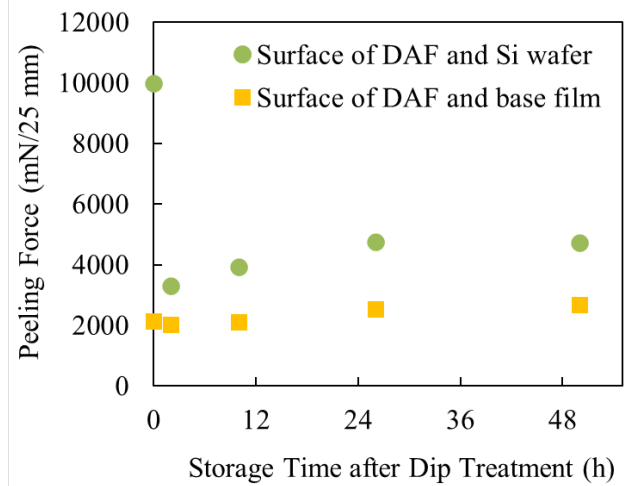


Figure 6. Evaluation of peeling force

The peeling force between the DAF and the Si wafer significantly decreased after dip treatment and became close to the peeling force between the DAF and the base film. We believe that the smaller difference in peeling force correlates with TF occurrence. It was also found that the peeling force between DAF and Si wafer gradually increases when the wafer is kept at room temperature after dip treatment. The difference between the peeling force of DAF and that of the base film became larger. This trend was correlated with the rate of TF. From the above evaluation results, it is necessary to remove the influence of water absorption after dicing in order to prevent the occurrence of TF.

2-3. Method of improvement TF in DAF design

We considered a study of DAF formulations that can achieve both reliability, which is important for DAF performance, and reduction of TF. We focused on embeddability, which is correlated with package reliability. Melt viscosity, which affects the physical property of embeddability, was also investigated.

Figure 7. shows the evaluation result of melt viscosity of Sample A and Sample B. Sample A, whose melt viscosity is in a lower temperature range, has good embeddability and package reliability. However, it has a good thermal response and is easy to melt at lower temperatures. When it melted TF occurred due to heat generated by blade rotation. Sample B however, had a higher melt viscosity. Therefore, although embeddability is low, it tends to be more difficult for TF to occur. This result demonstrates that there is a trade-off between embeddability and TF. As a result of various investigations, the right-angle tearing strength method was found to be a new physical property parameter for TF.

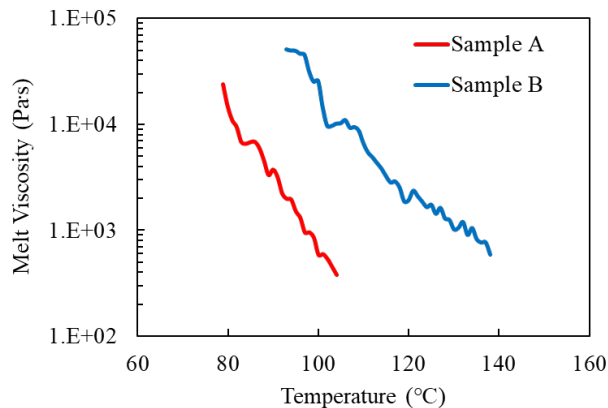


Figure 7. Melt viscosity of DAF

Figure 8. shows the appearance of Right-angle tear strength sample. Easy to tear sample is broken at the center. Therefore, the maximum strength and breaking elongation is low. On the other hand, not easy to tear sample is stretched and broken without tearing at the center. We believe that the ease of tearing by the concentration of stress is affects TF.

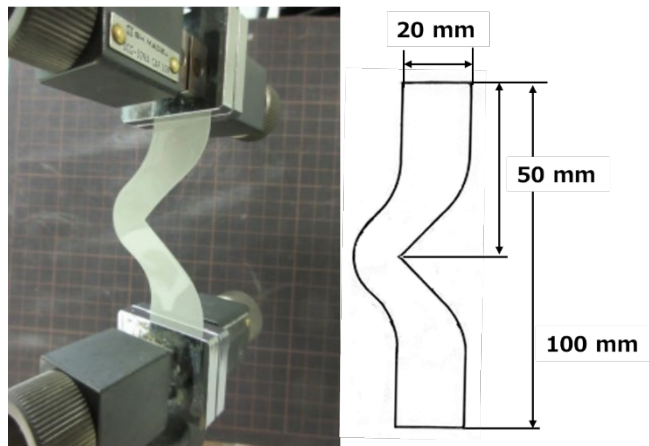


Figure 8. Appearance of Right-angle tear strength sample

Figure 9. shows the right-angle tear strength results for each DAF, including the newly developed Sample C. Sample A where TF occurred, did not tear at the center, and broke after elongation. Sample B had high tearing strength and broke after slight elongation. Sample C had low tear strength and elongation at breaking, and the center of the sample was torn immediately after the start of the measurement. When the TF of this sample was measured, it had good PU property without TF. These results confirm a correlation between the right-angle tear strength method results and TF.

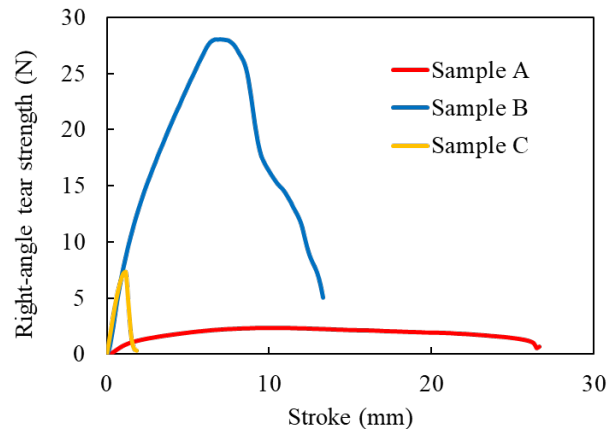


Figure 9. Right-angle tear strength of DAF

Finally, the melt viscosity of the developed sample C with no TF was measured. Figure 10. shows measurement results of melt viscosity for each sample. Sample C had melt viscosity similar to Sample A, which has good embeddability and also passed the package reliability test.

Process flow of package reliability is shown in Figure 11. 1) DDAF is mounted on to the back surface of the wafer and the back grinding tape is removed, 2) UV irradiation of the DDAF, 3) Singulation of the wafer using a dicing saw, 4) Pick up process (needle), 5) Die bonding process, 6) Heat curing of DAF with substrate, 7) Transfer molding using EMC, 8) Moisture absorption of package samples (JEDEC MSL2), 9) IR reflow (260°C, 90 sec.), 10) Scanning Acoustic Tomograph observation.

Until now, TF has been suppressed by increasing the melt viscosity. But now, after implementing the right-angle tearing strength method, a new parameter of TF, it was possible to produce samples with both package reliability (embeddability) and suppression of TF (Table 4).

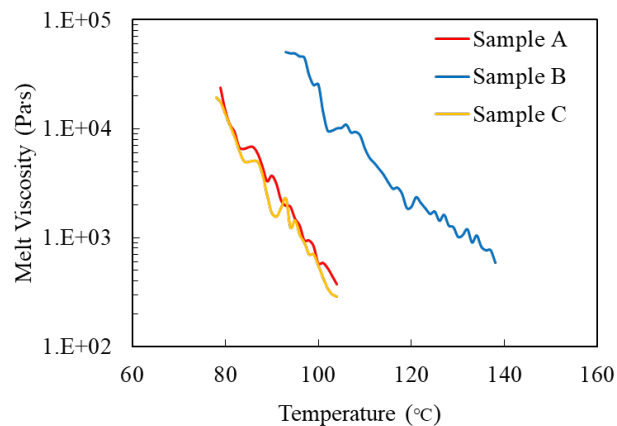


Figure 10. Melt viscosity of DAF

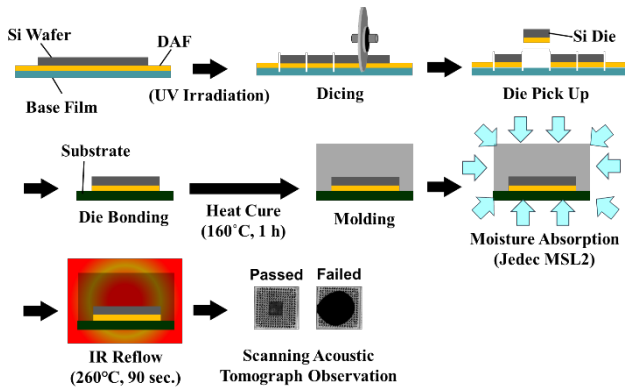
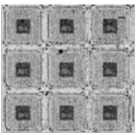
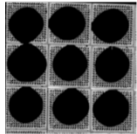
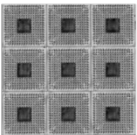


Figure 11. Process flow of package reliability test.

Table 4. Summary of evaluation result.

Sample	Package Reliability (Embeddability)	TF
A (Low melt viscosity)	 Good (9/9 Passed)	Poor
B (High melt viscosity)	 Poor (0/9 Passed)	Good
C	 Good (9/9 Passed)	Good

III. Conclusion

TF occurrence in DAF samples is improved by changing the dicing conditions and water absorption of cutting water at dicing.

TF DAF design improvement by using new a right-angle tear strength method was achieved. Based on this improvement we developed a new DAF with high package reliability (embeddability) and reduced TF.

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