BLADE MODIFICATION AND WATER TEMPERATURE CONTROL UNIT (DTU) APPLICATION FOR TAPE WHISKER RESOLUTION

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ABSTRACT

The key factors for die attach film (DAF) breakthrough are package miniaturization and die thickness reduction. However, processing of DAF materials presents certain difficulties, especially in the wafer dicing process. Due to the additional layer of soft DAF material, 93500 ppm was noted during automatic optical inspection (AOI) due to tape whiskers affecting succeeding processes like Die attach and Wirebond

Through modification of blade, recipe optimization such as Blade dressing, blade height, feed speed and spindle revolution and application of DTU. This study focused on wafer saw challenges in terms of material selection and dicing optimization to integrate DAF into 300mm wafer size with 70micron wafer thickness.

Qualification of new dicing blade and implementation of DTU significantly improved whisker occurrence from 93500 ppm to < 300 ppm and critical process output responses. This study demonstrates that good processability and robust performance with DAF can be achieved with proper material selection and optimized process parameters.

1. 0 INTRODUCTION

The drive for smaller size and thinner thickness has created new package assembly process challenges. The creation of (DAF) had been a breakthrough because of certain advantages over the conventional glues. The die is bonded using (DAF) that is laminated on the back of a wafer prior to singulation. The singulation of DAF laminated wafers with wafer thickness <75 microns are challenging, especially for devices used in automotive applications. Part of the singulation challenge is that it involves two different hard materials Silicon (Si) and the DAF polymer.

For thin die with DAF material, a step-cut saw process is better than single cut, but backside chipping and residual tape whiskers must be resolved.[1] As a workpiece grows thinner, backside chipping caused during the dicing process also tends to increase. It is generally advisable to dice thin wafers with an extremely fine-grit blade, but the trade-off is reduced cutting power due to the presence of films, structure in saw street and other elements in wafer frontside. Clogging can result which compromise processing quality on the wafer backside. In such a case, the use of a step cut (instead of single pass dicing) as shown in Figure 1 often solves the problem. Further, when performing blade dicing with a view to stable, long-term processing, it is essential to maintain a consistent processing load and preserve the self-sharpening mechanism of the blade.

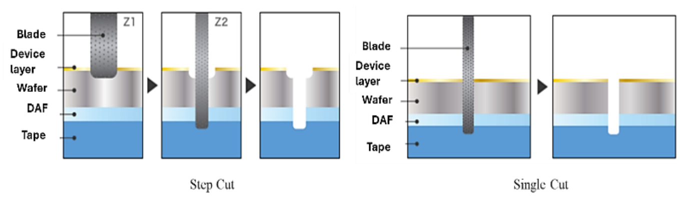


Figure 1. Illustration Comparison Between Step Cut vs. Single Cut

The Water Sawing Process involved wafer cutting into individual dice. Blade is to singulate the silicon wafer according to the required die size and pattern. Cutting will be done within the street width (Kerf) of the wafer pattern.

Smaller blade width versus street width is mandatory to avoid damaging the active seal ring of the dice. Potential damage on the seal ring will result in rejection or malfunction within the unit.

The cut depth covers the total thickness of the die multiplied by the required cutting ratio appropriate with the wafer family. Defining cut depth is critical for chipping response, optimum cutting ratio between spindle 1 and 2 must be achieved based on device requirement.

Figure 2. Demonstration of Mechanical Wafer Dicing Saw Process.

Figure 2 shows the actual cutting of wafer to form individual die. Illustration shows that the wafer is mounted to the tape to hold the wafer during the cutting process.

Tape whiskers shown in Figure 3 are thin filaments of die attach film induced during dicing process and further aggravated during die attach process. This defect may cause bondability, electrical, and reliability issues if not resolved.

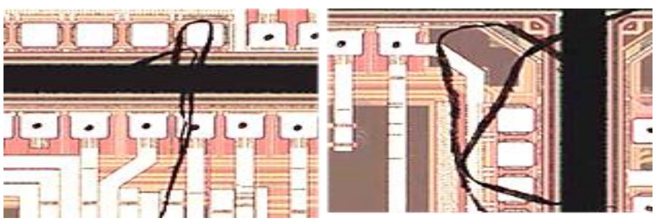


Figure 3. Sample Photo of Tape Whiskers Defects

The main component of whisker is base film. During dicing process, the blade-DAF interaction generates friction heat. The base film is partially melted and stretched by the blade causing some thin filament of base film to be formed and reached die surface as shown in Figure 4.

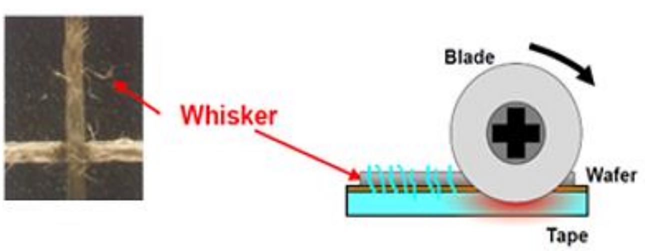


Figure 4. Tape Whisker Formation During Cutting Process

According to Buenviaje S., et.al (2023), in the material aspect the viscoelastic properties of DAF are vital especially in package bill of materials which is crucial for understanding how materials behave under stress, especially in long-term designs and when considering factors like temperature and deformation rate. As shown in Figure 5, packages of diverse product applications could require varied sets of properties. One critical consideration is elastic modulus. Also known as Young's modulus, it is the measure of a material's resistance to a temporary and elastic deformation upon application of stress. In literature, this quantity is often used to characterize the elastic behavior of a polymers like DAF.[3]

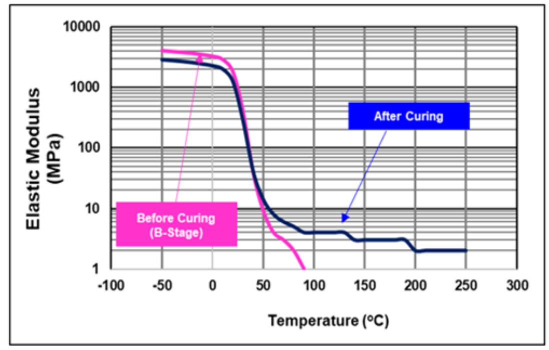


Figure 5. Elastic Moduli of Soft DAF at Varied Temperatures

To consider material compatibility, small grit size and low concentration dicing blade incorporated with controlled Deionized (DI) water temperature was validated. Lower DI water temperature reduces the heat induced by friction during cutting process as shown in Figure 6.

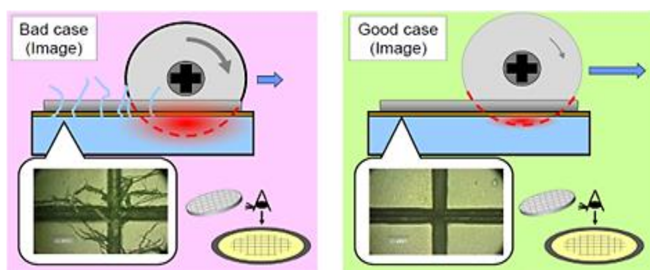


Figure 6. Illustration between with and without DAF Whisker induced during cutting in POR condition

The impact of high elastic modulus of die attach film was examined in this study. Soft DAF types may affect dicing response thus blade-DAF interaction was monitored for possible repercussions in assembly process.

1.1 Die attach Film (DAF)

DAF as shown in Figure 7 is an ultra-thin film adhesive used to connect semiconductor chips to circuit boards or chips to chips in the semiconductor packaging process. It is an essential material used in manufacturing flash memories, etc. in the post-manufacturing process of semiconductors. Lamination and manufacturing of thin layers of semiconductors are possible with its excellent reliability and easy processability.[5]

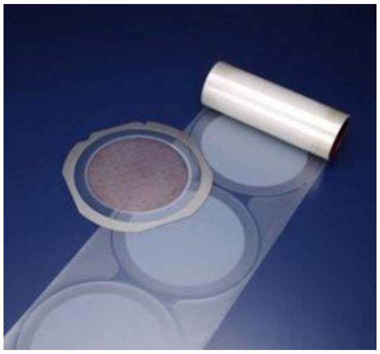


Figure 7. Sample Photo Die Attach Film (DAF)

1.2 Grit

One of the compositions of the blade which performs the processing is the grit as shown in Figure 8. There are many grit sizes, the selection of which depends on the workpiece, processing conditions, and quality response. Grit size is sometimes referred to as mesh size. The larger the number, the smaller the grit.[6]

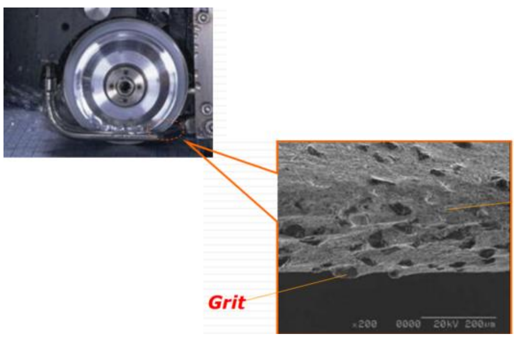


Figure 8. Illustration of Dicing Blade Grit[6]

1.3 Water Temperature Control Unit (DTU)

DTU as shown in Figure 9 maintains wheel coolant and spindle coolant at a fixed temperature, improves processing precision and maintains uniform cutting conditions.[4]

Figure 9. Water Temperature Control Unit (DTU)[4].
Sawing machine accessory which help to control the Cutting water Temperature.

DTU is designed for controlling the temperature of water-cooled processes from an external cooling system. DTU was used in the evaluation to maintain the water temperature at 15 ± 2 °C.

1.4 Nozzle

Nozzle as shown in Figure 10 has some differences in adjustment position, basically they all supply cutting water equally to the working side of the blade.

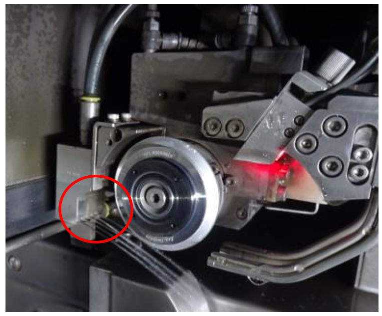


Figure 10. Sample Photo of Cutting Nozzle

In the study, blade nozzle was adjusted to 5 o'clock to focus water flow on the tip of the dicing blade to help achieve cooling effect during cutting process.

2. 0 REVIEW OF RELATED WORK

In the study conducted by Buenviaje S. et al. [1], it was found that soft-type DAF has elasticity falling to 1 to 10 MPa at 250 ºC. This property can be quantified as a function of temperature and its behavior must be investigated in the assembly.[3]

According to Teo M. [2], it was found that minimum chipping and whisker formation can be achieved using a 2-step dicing process with optimized cutting depths and feed rate. It was also observed that whisker formation can be overcome with proper material modification.

AnySilicon [3] published an article stating that mechanical blade dicing, or simply blade dicing, uses a high-speed rotating blade called a dicing saw. Dicing blades, often made of diamond or other hard materials, make cuts or streets through the wafer's surface. This traditional method is known for its reliability and is suitable for a wide range of semiconductor materials. The process requires adjusting feed rates and blade types according to the wafer material to minimize thermal damage and improve yield.

LG Chem [4] shared information about DAF which is an ultra-thin film adhesive used to connect semiconductor chips to circuit boards or chips to chips in the semiconductor packaging process. It is an essential material used in manufacturing flash memories, etc. in the post-manufacturing process of semiconductors. Lamination and manufacturing of thin layers of semiconductors are possible with its excellent reliability and easy processability.

3.0 METHODOLOGY

3.1 Test Vehicle Description

The test vehicle is stated below on Table 1. The wafer is a 12-inch, low-k device with CMOSE40ULP 7m wafer technology. The die size is around 4.916 mm x 2.500 mm with a die thickness of 70 ± 10 µm and raw silicon backside. Sawing Street is 80 µm.

Table 1. Test Vehicle Information

Test Vehicle	
Wafer size (mm)	300
Wafer technology	CMOSE40ULP 7m
Die size (mm)	4.916 x 2.500
Die Thickness (um)	70 ± 10
Sawing Street (um)	80 x 80

3.2 Process Flow

The process flow is described in Figure 11. The wafer was received ungrinded to be processed at backlap to achieve desired thickness, and laser groove process is required since the test vehicle is a low-k device.

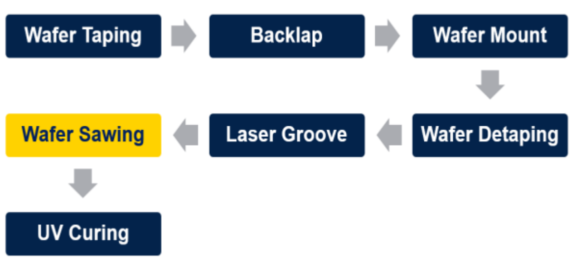


Figure 11. Wafer Preparation Process Flow

The improved output response of optimization at wafer saw process will be the focus of this study. Occurrence of gross tape whiskers was encountered during validation of POR parameter, defect is already evident after 100% Automatic Optical Inspection but further aggravated during Die Attach process and affecting Wirebond process as shown in Figure 11. Series of evaluation legs were planned and validated during fine tuning.

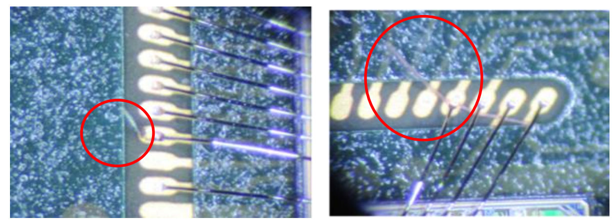


Figure 11. Tape Whiskers observed during Wirebond process

3.3 Wafer Saw Set-up and Parameters Optimization

Defining critical parameters, set-up, and materials at wafer saw depends on product requirement. Optimization requires a systematic approach to have the most optimum settings without affecting other critical process output responses. Parameters used in the evaluation are summarized in Table 2.

All critical parameters with contact with mounting tape were optimized to minimize tape whisker. The lower grit size blade for spindle 2 was used to achieve finer cut and less workpiece damage since the diamond particles of these blades are smaller in size, typically 2-4 microns. To lessen the stress in blade, shallower cut depth, slower feed speed, and slower spindle revolution were used. Reduced values of these parameters tend to decrease the amount of work exerted by each grain of diamond grit thus supports blade's self-sharpening mechanism.

Cleaning parameters were enhanced to help in removing foreign materials in wafer surface and add cooling effect during cutting. Lower water cutting temperature setting with water flow pointing to the tip of the blade using 5 o'clock nozzle decrease the heat generated by blade-DAF interaction. In addition, blade dressing cut lines were increased to fully expose grits and to achieve finer cut.

Table 2. Summary of Wafer Saw Parameters Optimized

PARAMETERS	POR	LEG A	LEG B	LEG C	REMARKS
Z1 blade type	POR Sp1 blade				No change
Z2 blade type	POR (higher grit size) Sp2 blade	Lower grit size blade	Lower grit size blade	Lower grit size blade	Different grit size
Cut Method	Step Cut	Step Cut	Step Cut	Step Cut	Different cut method
Z1 cut depth (mm)	0.060				No change
Z2 cut depth (mm)	0.030	0.040	0.020	0.020	Different Z2 cut depth
Z1 spindle rev. (rpm)	50000	50000	50000	50000	No change
Z2 spindle rev. (rpm)	50000	50000	30000	30000	Different settings
Feed speed (mm/sec)	30	20	20	20	Different settings
Wash Time (sec)	250	250	120	420	Different settings
Wash Speed (rpm)	1200				No change
Flow rate (L/min)	0.8 – 1.2	0.8 – 1.2	0.8 – 1.2	1.2 – 1.8	Different settings
DTU (°C)	20-26	15	15	15 ± 2	Different settings
No. of Z2 dress cut lines	45	60	60	60	Different settings
Nozzle type	3 o'clock	5 o'clock	5 o'clock	5 o'clock	Different settings

3.4 Process Critical Output Response

Wafer saw process critical output response as shown in Table 3 will be checked if will pass based on criteria after process parameters and set-up optimization, and implementation of controlled DI water temperature through inclusion of DTU which is a water supply unit for dicing saws that provide a stable supply of spindle cooling water or dicing water at a constant temperature and suitable pressure.[4]

Table 3. Wafer Saw Output Response

Process Response	Specification
Whisker after post WSW AOI	Any evidence
Sidewall Chippings (Z-axis)	35 µm maximum
Backside Chippings (Y-axis)	35 µm maximum
Topside Chipping	Not exceeding die internal seal ring
Backside Chipping	No excessive chipping and crack
Dice Fly off	Any evidence
Die Crack	Any evidence

4.0 RESULTS AND DISCUSSION

After wafer saw validation using different conditions, wafers were subjected to 100% AOI. Inspection results showed that Leg C has significant improvement in terms of whisker occurrence shown in Figure 11.

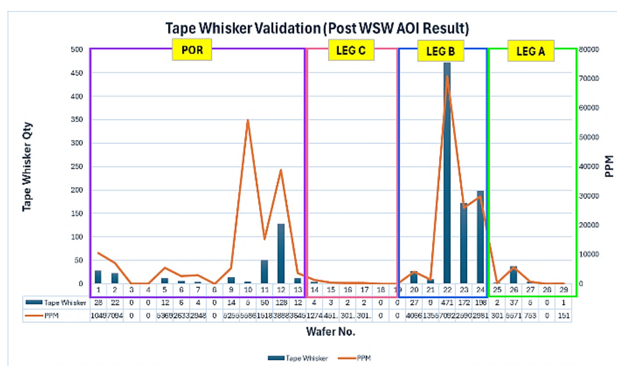
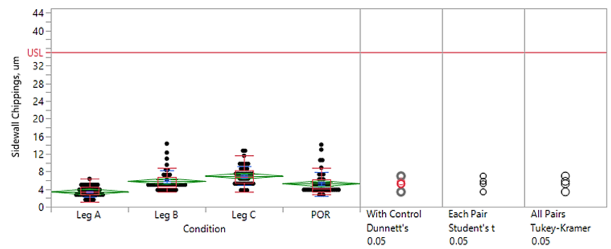


Figure 11. Post WSW AOI Evaluation Result

At wafer saw, sidewall chippings (Z-Axis) as one of the critical process output responses passed based on required criteria (50% of die thickness). Using One way Analysis, Leg A and Leg C are significantly different (p value = 0.0007, <0.05) to POR with Leg A showing the most optimum result as shown in Figure 12.

Oneway Analysis of Sidewall Chippings By Condition



Means Comparisons

Comparisons with a control using Dunnett's Method

Control Group = POR

Confidence Quantile

|d|	Alpha
2.37210	0.05

Difference Matrix

Dif=Mean[i]-Mean[j]

	Leg C	Leg B	POR	Leg A
Leg C	0.0000	1.2120	1.7582	3.6031
Leg B	-1.2120	0.0000	0.5461	2.3910
POR	-1.7582	-0.5461	0.0000	1.8449
Leg A	-3.6031	-2.3910	-1.8449	0.0000

LSD Threshold Matrix

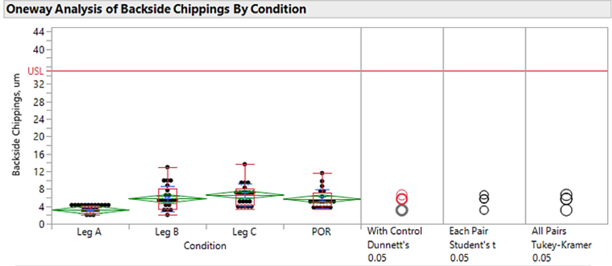
Level	Abs(Dif)-LSD	p-Value
Leg C	0.597	0.0013*
Leg B	-0.62	0.5452
POR	-1.16	1.0000
Leg A	0.683	0.0007*

Positive values show pairs of means that are significantly different.

Figure 12. One way Analysis for Z-axis chipping of different leg condition

In terms of backside chipping (Y-axis) response, using One way Analysis Leg A is significantly different (p value = 0.0014, <0.05) to POR and showing the most optimum result as shown in Figure 13.

Oneway Analysis of Backside Chippings By Condition



Means Comparisons

Comparisons with a control using Dunnett's Method

Control Group = POR

Confidence Quantile

|d|	Alpha
2.39688	0.05

Difference Matrix

Dif=Mean[i]-Mean[j]

	Leg C	Leg B	POR	Leg A
Leg C	0.0000	0.8878	0.9560	3.4822
Leg B	-0.8878	0.0000	0.0681	2.5943
POR	-0.9560	-0.0681	0.0000	2.5262
Leg A	-3.4822	-2.5943	-2.5262	0.0000

LSD Threshold Matrix

Level	Abs(Dif)-LSD	p-Value
Leg C	-0.7	0.3770
Leg B	-1.59	0.9993
POR	-1.66	1.0000
Leg A	0.868	0.0014*

Positive values show pairs of means that are significantly different.

Figure 13. One way Analysis for Y-axis chipping of different leg condition

Among four evaluation legs, Leg A showed the most optimum result in terms of sidewall and backside chipping response, but Leg C was selected to be used during qualification since the most improved response was attained in terms of tape whisker occurrence.

Summarized data of evaluation legs and POR is shown in Figure 14. No out of specifications topside chipping, any evidence of crack, and dice fly off observed. Critical process output response at wafer saw process were summarized for ease in comparison.

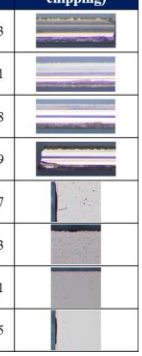
Process Response	Leg	Photo	Process Response	Leg	Min	Max	Ave	Photo (maximum chipping)
Topside	POR		Sidewall Chippings (Z-axis)	POR	2.731	13.655	5.223	
	C			C	3.414	12.290	6.981	
	A			A	1.155	6.353	3.378	
	B			B	3.414	14.338	5.769	
Backside	POR		Backside Chippings (Y-axis)	POR	3.414	11.607	5.667	
	C			C	3.414	13.655	6.623	
	A			A	2.048	4.097	3.141	
	B			B	2.048	12.973	5.735	

Figure 14. POR and Evaluation Legs Data

Wafer saw a critical process output response for Leg C was summarized in Table 4. Results complied with the criteria defined for the test vehicle.

In the dicing process, temperature control using DTU reduces thermal stress on the material during the cutting process. Thermal expansion and contraction of material may result due to excessive heat which may induce crack and chipping. A low and stable water temperature must be maintained to achieve high quality cutting response particularly in processing thin wafer mounted in soft DAF type.

Table 4. Summary of Wafer Saw Output Response (Best Leg – C)

Process Response	Specification	Results	Remarks
Whisker after post saw AOI	Any evidence	No tape whisker	Passed
Sidewall Chippings (Z-axis)	35 µm maximum	6.15 µm (maximum)	Passed
Backside Chippings (Y-axis)	35 µm maximum	13.655 µm (maximum)	Passed
Topside Chipping	Not exceeding die seal ring	No chipping exceeded die seal ring	Passed
Dice Fly off	Any evidence	No dice fly off	Passed

Die Crack	Any evidence	No die crack	Passed

Additional risk assessment was incorporated during qualification using optimized wafer saw set-up and parameters (Leg C) to support stability of data and will not affect device performance.

Reliability testing is essential for ensuring the mechanical and functional integrity of semiconductor devices.[2] Temperature cycling (TC) with standard moisture sensitivity level 3 (MSL3) was employed to assess mechanical integrity and simulate moisture absorption of the package. These tests were done to evaluate the product's resilience and performance in severe temperatures. Based on the results, no issue after 1000 cycles of TC and Scanning Acoustic Microscopy (SAM) inspection as shown in Figure 15.

Reliability Trial		Test Conditions	Duration	Result
PC + TC	Preconditioning: Moisture Sensitivity Level 3a + Thermal Cycling JESD22 A104	Bake (125°C / 24 hrs) Soak (30°C / 60% RH / 192 hrs, 3x reflow @ 260°C) + TC (-55°C + 125°C) (100 units)	T0 SAM	Done
			MSL3	Done
			ATE	0/96* All Passed
			SAM	Done
			TC500cy	Done
			ATE	0/96 All Passed
			SAM	Done
			TC1000cy	Done
			ATE	0/96 All Passed
			SAM	Done
PC + THS	Preconditioning: Moisture Sensitivity Level 3a + Temperature Humidity Storage JESD22A118	Bake (125°C / 24 hrs) Soak (30°C / 60% RH / 192 hrs, 3x reflow @ 260°C) + 85°C / 85% RH (100 units)	T0 SAM	Done
			MSL3	Done
			ATE	0/100 All Passed
			SAM	Done
			TC500cy	Done
			ATE	0/99* All Passed
			SAM	Done
			TC1000cy	Done
			ATE	0/98* All Passed
			SAM	Done

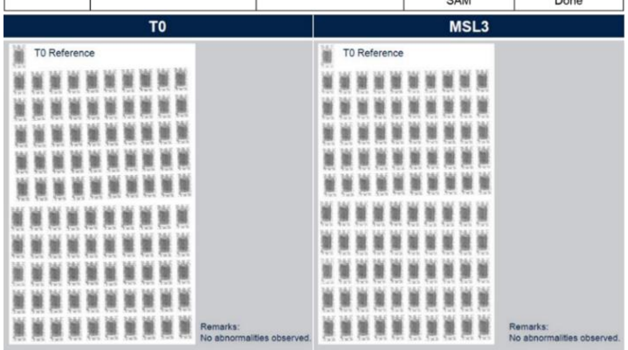


Figure 15. Reliability Test Result for Using Optimized Settings

5.0 CONCLUSION

In this study, the impact of using low grit size dicing blade, optimized wafer saw parameters, optimized blade dressing, and lower DI water temperature through DTU implementation to soft DAF type was investigated. It was observed that through usage of this set-up at wafer saw, tape whisker occurrence was reduced from 93500 ppm to < 300 ppm.

Evaluations showed that using combination of lower grit size spindle 2 dicing blade, slower feed speed and spindle revolution settings, shallower cut depth for spindle 2, increased wash time and water flow rate, lower DI water temperature setting, increased blade dressing cut lines, and usage of 5 o'clock nozzle showed significant improvement in terms of tape whisker occurrence with comparable result in chipping response.

6.0 RECOMMENDATIONS

To enhance the performance of the wafer saw response specifically for tape whisker, our team suggests four key improvements. First apply the DTU in wafer saw machine for those devices with DAF to control the cutting water temperature during processing. Second, to use the smaller grits size to minimize the surface damage. Third, to use the slower feed speed to control the tape burrs during cutting and lastly, continuous monitoring of response up to 3rd optical inspection.

7.0 ACKNOWLEDGMENT

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