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Dicing before Grinding: A Robust Wafer Thinning and Dicing Technology

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The never-ending trend for package miniaturization has been driving the semiconductor industry to the brink of technology. Hence, development of new technologies is necessary to cope up with the demand for advance and aggressive process capabilities.

The paper is all about the challenges in developing and installing a robust 50 µm wafer thinning and dicing capability in ST Calamba. As silicon wafers are grinded thinner, the more it becomes sensitive to mechanical stress and vibration. The conventional mechanical dicing process induce a lot of mechanical stress and vibration during the cutting process which oftentimes lead to backside chipping and die crack issues. Backside chippings serves as fracture points at the back of the dice, which significantly reduce its die strength. This dilemma was addressed with the use of a breakthrough technology known as Dicing Before Grinding (DBG).

Keywords: Wafer; dicing before grinding; back grinding tape; half-cut; Die Attach Film (DAF).

1. INTRODUCTION

Several secured Micro module customers have raised a requirement for new package development: A package requiring a 50 µm thin dice that can withstand flexural or bending stress. Aligned with this package requirement, any abnormalities that will reduce the dice

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strength is a big no [1-3]. A 50 µm thin dice using a conventional grinding process is difficult to achieve hence a breakthrough and robust solution needs to be explored and developed.

Nowadays, there are is a lot of wafer thinning and dicing technology being develop and offered in the market. The paper will not cover the selection process done thus the focus of discussion will only be on the conventional wafer grinding and dicing process versus DBG [2,4,5]. Die Attach Film (DAF) separation will not be discussed also in this paper.

Fig. 1 shows the conventional wafer preparation flow with mechanical grinding and dicing process. Processes composed of Wafer Taping, Wafer Back grind, Detape and Wafer Mount then Wafer Saw.

Conventional wafer preparation process starts with back grinding or BG tapes are laminated onto the active side of the wafer during the wafer taping process. The BG tape serves as a protection to prevent damages or scratches on the active side of the wafer during the next process step. At wafer back grinding, BG tape serves as a cushion and ensures that wafers are properly vacuumed throughout the process. Once the target wafer thickness was achieved, the wafer then proceeds to wafer mounting process. The grinded wafer is mounted onto a dicing tape or Dicing Die Attach Film (DDAF) and ring frame. Lastly, Mechanical wafer saw or dicing wherein separation of dice from the wafer happens [6].

Mechanical wafer saw process uses a blade which acts as a grinder that can separate the dice. A blade mainly consists of abrasive grit and bond. The abrasive grit held by the bond does the cutting of the dies [7]. Fig. 2 shows a graphical representation of a dicing blade.

The process of cutting dies with the use of blade is like a “grinding” process, which shears away the work piece. In the case of wafer dicing process, the abrasive grit of the blade hits the silicon wafer material, shaves and dislodge grinded particles on the sawing street thus creating a cut area. Continuous grinding or cutting will go through the bottom part of the wafer that will separate the wafer into dice [7]. Fig. 3 illustrates the concept.

Fig. 1. Conventional wafer preparation flow

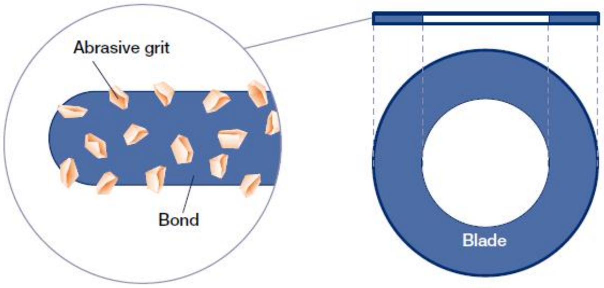


Fig. 2. Graphical representation of a blade [7]

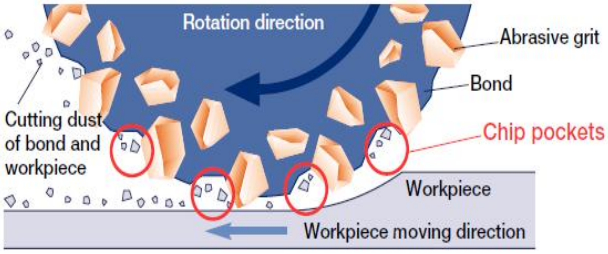


Fig. 3. Mechanical dicing process showing “grinding process” [7]

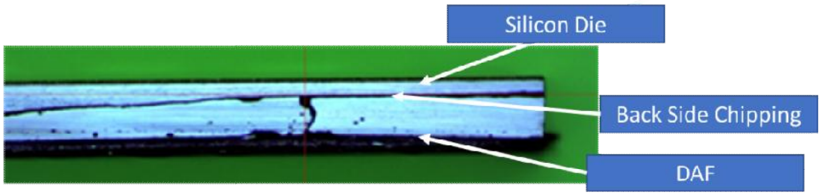


Fig. 4. A representative photo of a worst-case backside chipping viewed at the side of the die

As target wafer thickness becomes thinner, the more it becomes susceptible and sensitive to mechanical stress. The mechanical vibration that is inherent to mechanical dicing process can manifest back side chippin. Fig. 4 shows a representative photo of a worst-case backside chipping.

For a 50 μm thin dice, half of its thickness back side chipping will be very critical. Bending stress will be present in any thin package, especially for micro module package. The combination of thin package and presence of back side chipping will really result to reliability failure.

2. LITERATURE REVIEW

Dicing before grinding or DBG is a reverse flow of the standard wafer preparation process, wherein mechanical sawing comes first. Singulation or separation of wafers into dice happens during the back-grinding process. Fig. 5 shows the complete DBG process flow.

DBG flow starts with the wafer being partially cut to a target depth. As a rule of thumb, target depth is the final die thickness plus 40 μm. Wafer Taping process follows to laminate BG tape onto the active side of the wafer. Like the conventional

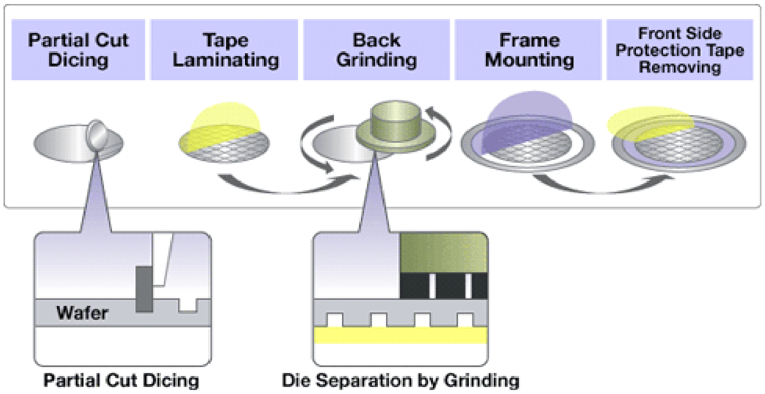


Fig. 5. DBG process flow [8]

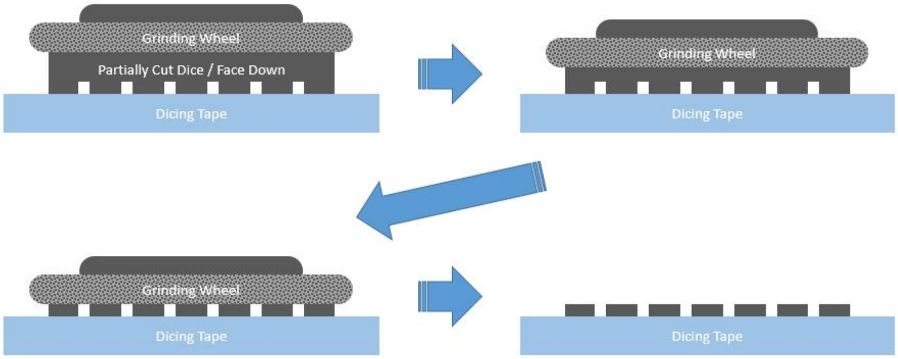


Fig. 6. Illustration showing the concept behind DBG grinding and dicing technology [9]

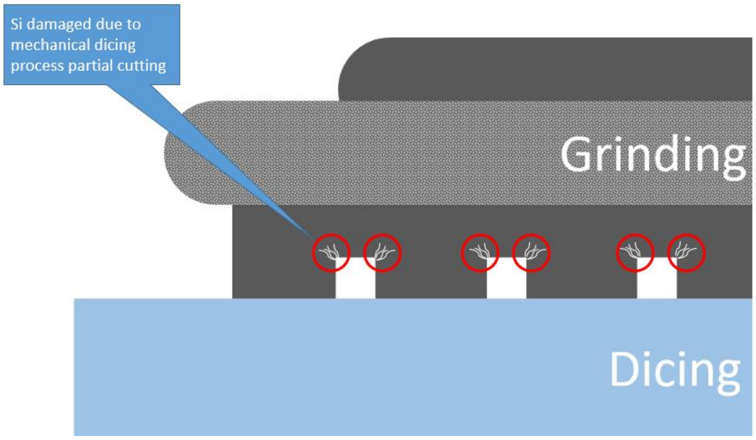


Fig. 7. Figure on top illustrates Si damaged brought by partial cutting, figure at the bottom showing the removal of the Si damage during grinding process in the DBG flow [9]

flow, the tape will serve as a protection and a medium to hold the wafer during the Backgrinding process. When the grinding wheel reached the pre-cut depth, the wafer is singulated or separated into dice, see Fig. 6.

The grinding process will continue until the target die thickness is achieved. During the process, the damage induced in the silicon wafer during the partial cutting process was removed. Fig. 7 illustrates the concept.

Therefore, DBG technology offers a more robust solution for wafer thinning and dicing process compared to the conventional flow. The paper will discuss the introduction of DBG for dies to be used for Micro module package, 50 μm in final thickness.

3. ACTUAL EVALUATION

3.1 Materials

Two sizes of wafers were evaluated to assess the 200 mm and 300 mm handling capability of all the system or equipment involved in the DBG process flow. Target final wafer thickness is 50 μm. The thickness will be measured with a Measuring microscope with accuracy of +/- 0.1 μm.

The team used two different UV-type back grind tapes or BG tapes (E-1 and E-2), with different adhesion strengths) as shown in Table 1.

Different DAF Tapes were evaluated to fully characterize the effect of adhesive layer thickness on the wafer mounting and succeeding process steps. Table 2 shows the different DAFs used with corresponding thickness.

Table 1. BG tapes

BG tape characteristics	E-1	E-2
Adhesive Thickness (μm)	40	20
Before UV (mN/25mm)	5800	12000
After UV (mN/25mm)	90	49

Table 2. DAF tapes

DAF tape type	Thickness (μm)
D-1	7
D-2	20
D-3	25
D-4	30

3.2 Equipment

The following equipment was used to define the materials and process parameters for 50 μm wafer thickness using DBG process. Half Cut Dicer used was DFD6362 with wafer handling capability. DFD6362 have +/- 2.5 μm depth accuracy. DGP8761+DFM2800 is an inline equipment develop by Disco Corporation for DBG process. DGP8761 is the wafer back-grind machine capable of catering 25 μm with +/-2.5 μm accuracy. On the other hand, DFM2800 is the DAF laminator capable on laminating 5 μm wafers with thin DAF. The laminator has +/-0.5 mm mounting accuracy.

3.3 Procedure

Design of Experiment or DoE was performed to analyze the effect of different BG tape and DAF tape on all equipment included in DBG process flow. Table 3 shows the agreed evaluation matrix.

Table 3. Design of experiment matrix

Process	**Half Cut**	**Wafer back grinding**			**Wafer mounting**
Test no.	**Spindle revolution (RPM)**	**BG tape**	**Lamination temperature (deg. C)**	**Parameters and condition**	**DAF tape**
1	40,000	E-1	RT	Same	D-1
2	50,000	E-2			
3					
4			60		
5					D-2
6		E-1			
7		E-2			D-3
8		E-1			
9		E-2			D-4
10		E-1	RT		

Design of Experiment will start on understanding the half-cut dicing to top side chippings manifestation Spindle revolution is the speed of the blade (commonly in revolution per minute) during cutting.

For BG tape lamination, different BG tapes were evaluated to select the essential tape to be used. In addition, two lamination temperatures were also taken into consideration to check if this will affect the different laminating conditions. Three visual mechanical defects were monitored under high magnification microscope. The following defects are Bubbles, whiskers and Bond Pad Contamination. Bubbles refer to the presence of air in between BG tapes and wafer that can affect final wafer thickness and can create die crack. Whiskers refer to the presence of BG tape remnants on the edge of the half-cut area, which can be a foreign material on latter process steps such as wire bonding. Lastly, Bond pad contamination is the uncleanliness of bond pad that can create defects such as lifted ball, also during wire bonding.

Over-all, the DoE is designed to establish an optimized DBG process critical visual mechanical defects across the process. DoE will also establish the capability of DBG process on handling different DAF thicknesses from 30 µm down to 7 µm.

4. RESULTS AND ANALYSIS

The evaluation results can be summarized in the Table 4. Top Side chippings were monitored after half-cut process using high power measuring microscope. On the other hand, bubbles, whiskers, bond pad contamination, and mounting condition were observed using high power microscope after wafer mounting process. Details were discussed on the succeeding sub discussion points.

Table 4. Evaluation matrix results

Process	**Results**				
Test no.	**Top Side Chippings Criteria: <10um**	**Bubbles (Accept: 0 Reject: 1)**	**Whiskers (Accept: 0 Reject: 1)**	**Bond Contamination (Accept: 0 Reject: 1)**	**Mounting Condition (Accept: 0 Reject: 1)**
1	Passed	Passed	Passed	Passed	Passed
2	Passed	Failed	Failed	Failed	Passed
3	Passed	Failed	Failed	Failed	Passed
4	Passed	Passed	Passed	Passed	Passed
5	Passed	Passed	Passed	Passed	Passed
6	Passed	Passed	Failed	Passed	Passed
7	Passed	Passed	Passed	Passed	Passed
8	Passed	Passed	Failed	Passed	Passed
9	Passed	Passed	Passed	Passed	Passed
10	Passed	Passed	Passed	Passed	Passed

4.1 Top Side Chippings

Top side chippings, which is measured using a measuring microscope with +/-0.1 µm. ANOVA with p-value of greater than 0.05: 0.6317 shows that there no significant difference between two data points. Over-all, 40k RPM and 50k RPM has no significant difference for top side chippings response.

Visual inspection using high power microscope shows that top side chippings is comparable for wafers processed using 40k and 50k RPM spindle speed (Fig. 9).

4.2 Cutting Depth

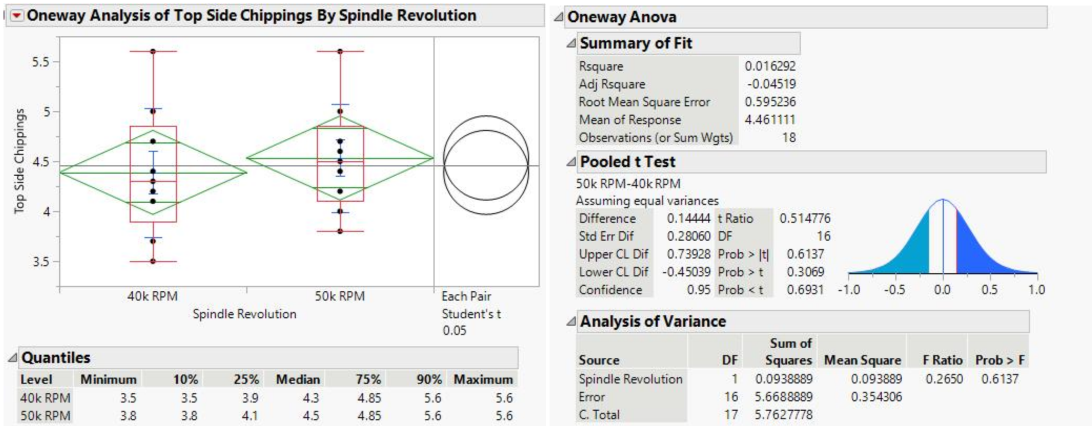
Measurement of cutting depth consistency was performed using a measuring microscope with +/-0.1 µm accuracy. Cutting depth was measured in order to establish the capability and stability of the wafer partial cutting process to sustain long-term process. The data shows that after mean shift of 1.5 sigma, it could sustain from 50.2 µm mean to the maximum reading of 51.0 µm, which is within the declared working range of 50 +/-2.5 µm.

4.3 Bubbles

In terms of bubbles formation during BG tape lamination, variability gauge for bubbles shown in Fig. 11 shows that the lamination temperature has no significant effect or no influence on BG tape E-1.

4.4 Whiskers

On the other hand, lamination temperature shows significant effect or big influence on both BG tapes E1 and E2. Variability gauge shown in Fig. 12 shows that whiskers can be eliminated when room temperature is used during lamination process. On the other hand no whiskers were observed for E2 when it is laminated at higher temperature.



Oneway Analysis of Top Side Chippings By Spindle Revolution

Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
40k RPM	3.5	3.5	3.9	4.3	4.85	5.6	5.6
50k RPM	3.8	3.8	4.1	4.5	4.85	5.6	5.6

Oneway Anova

Summary of Fit

Rsquare	0.016292
Adj Rsquare	-0.04519
Root Mean Square Error	0.595236
Mean of Response	4.461111
Observations (or Sum Wgts)	18

Pooled t Test

50k RPM-40k RPM

Assuming equal variances

Difference	0.14444	t Ratio	0.514776
Std Err Dif	0.28060	DF	16
Upper CL Dif	0.73928	Prob > |t|	0.6137
Lower CL Dif	-0.45039	Prob > t	0.3069
Confidence	0.95	Prob < t	0.6931

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Spindle Revolution	1	0.0938889	0.093889	0.2650	0.6137
Error	16	5.6688889	0.354306		
C. Total	17	5.7627778			

Fig. 8. ANOVA of spindle revolution

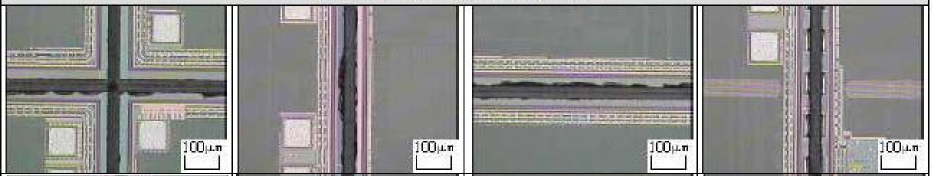
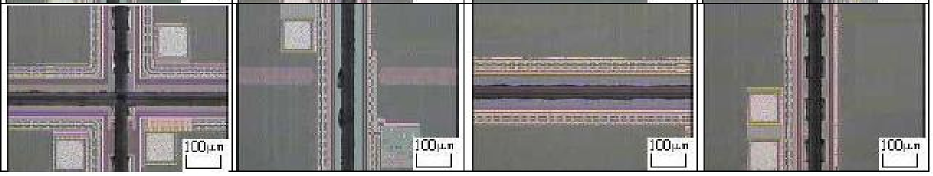
Spindle rotations	Front side chipping after half cutting
40000 min^{-1} (No.1)	
50000 min^{-1} (No.2)	

Fig. 9. Front side chipping

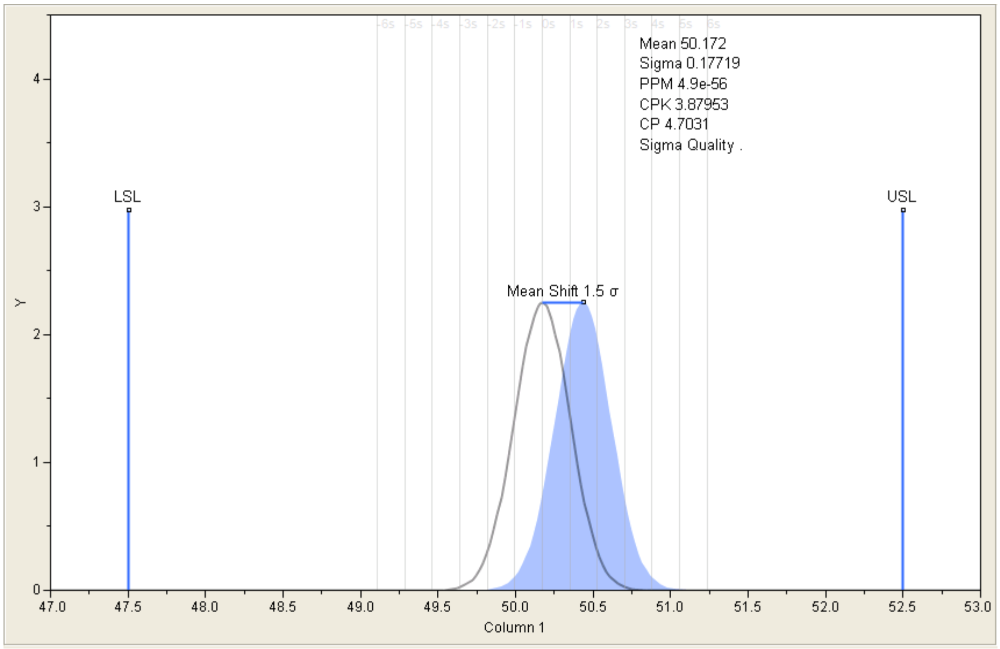


Fig. 10. Graph showing process capability analysis for wafer cutting depth

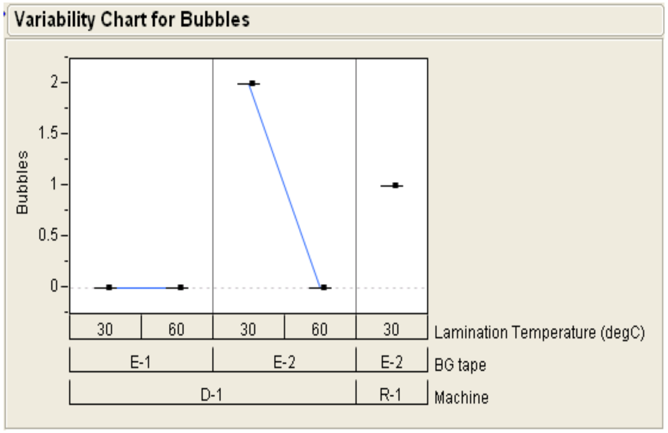


Fig. 11. Variability gauge for bubbles

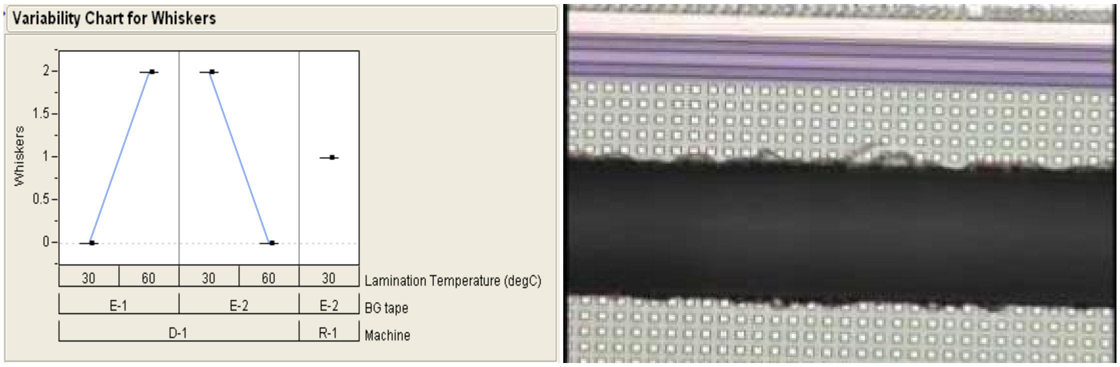


Fig. 12. Whiskers (a) Variability gauge (b) Optical photo

4.5 Bond Pad Contamination

Same with the bubble response, lamination temperature doesn't have significant effect on bond pad contamination for BG tape E-1 compared to E2.

Based on the whiskers, bubbles and contamination effect result of the evaluation shows that the following BG tape lamination condition should be considered:

> BG Tape E-1 must be laminated at room temperature while BG tape E-2 should laminated at 60°C.

4.6 Grinding Condition

At wafer backgrinding process, target thickness was achieved. No manifestation of cracks from the wafer back side and as well as on the die side wall as shown on Fig. 14. Compared to conventional wafer sawing process results on previous pages, DBG is significantly better.

Further measurement was performed in order to verify that there are no sidewall chippings after wafer backgrinding. The data shows that almost 50% of the sides show no backside chippings while the maximum is at a very controllable range of 4 µm. Refer to Fig. 15.

Measurement of total thickness variation was performed to check the capability of the DBG process to sustain the long term process and to ensure that the process is within the specified wafer thickness specification of +/- 2.5 µm.

The data shows that after the mean shift of 1.5 sigma, it could sustain from 49.8 µm mean and a maximum reading of 52.5 µm, which is within the declared working range of 50 +/-2.5 µm.

4.7 Wafer Mounting Condition

Good wafer lamination condition was observed across DAF without manifestation of bubbles and die fly off after DBG process. Fig. 17 shows that all DAF (7 µm to 30 µm) lamination condition. Therefore, DAF thickness has no significant different in terms of DAF lamination condition.

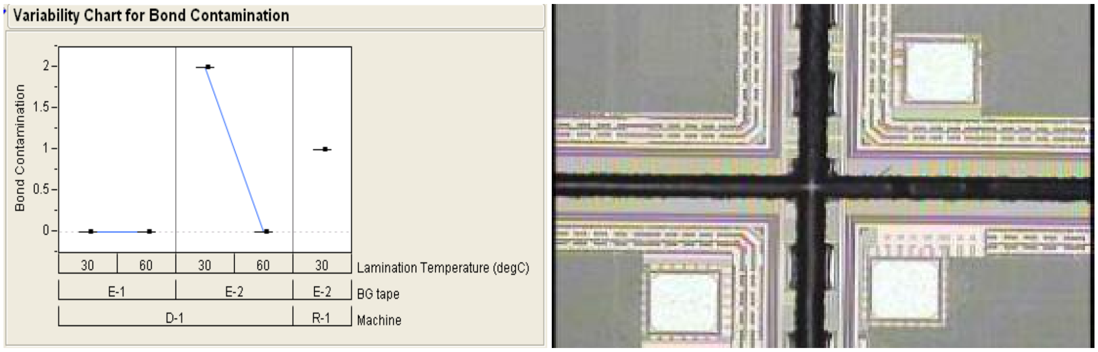


Fig. 13. Bond pad contamination (a) Variability gauge (b) Optical photo

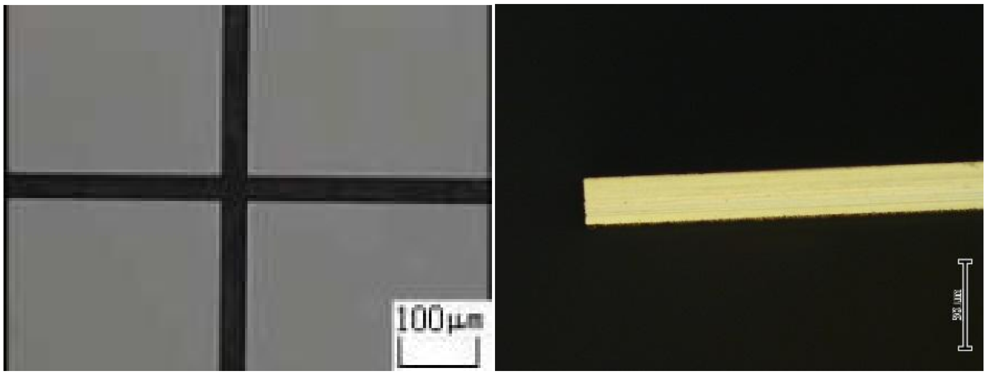
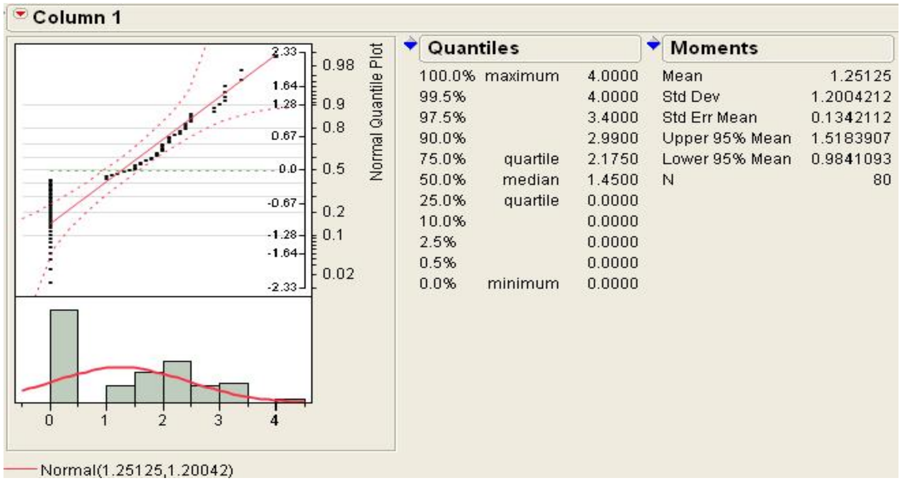


Fig. 14. Backside and side photo of a die showing result of DBG process



Quantiles

100.0%	maximum	4.0000
99.5%		4.0000
97.5%		3.4000
90.0%		2.9900
75.0%	quartile	2.1750
50.0%	median	1.4500
25.0%	quartile	0.0000
10.0%		0.0000
2.5%		0.0000
0.5%		0.0000
0.0%	minimum	0.0000

Moments

Mean	1.25125
Std Dev	1.2004212
Std Err Mean	0.1342112
Upper 95% Mean	1.5183907
Lower 95% Mean	0.9841093
N	80

Fig. 15. Regression plot of backside chippings measurement, maximum is at 4 µm only

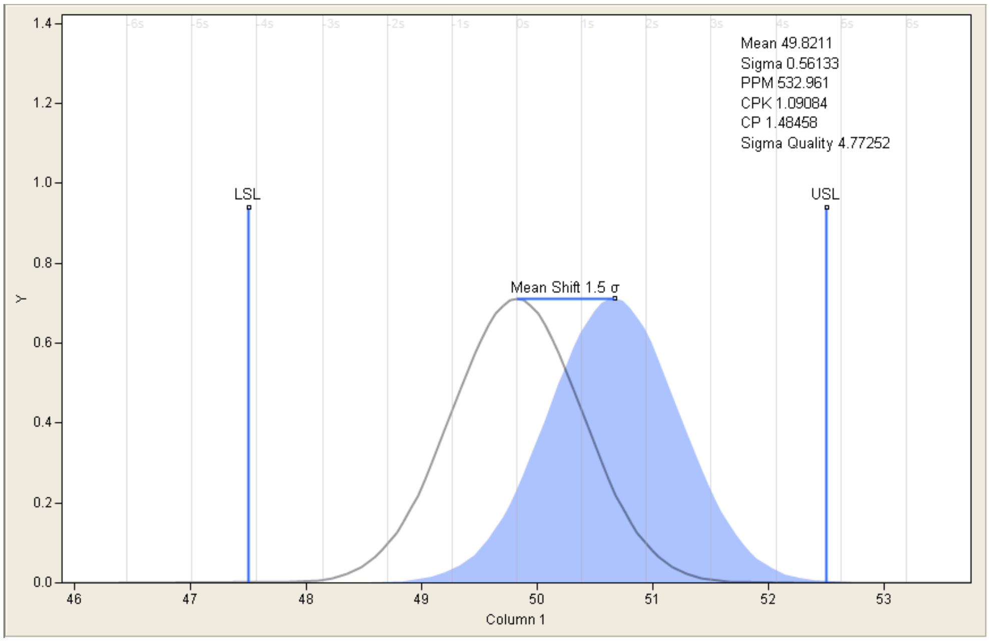


Fig. 16. Capability analysis for wafer thickness

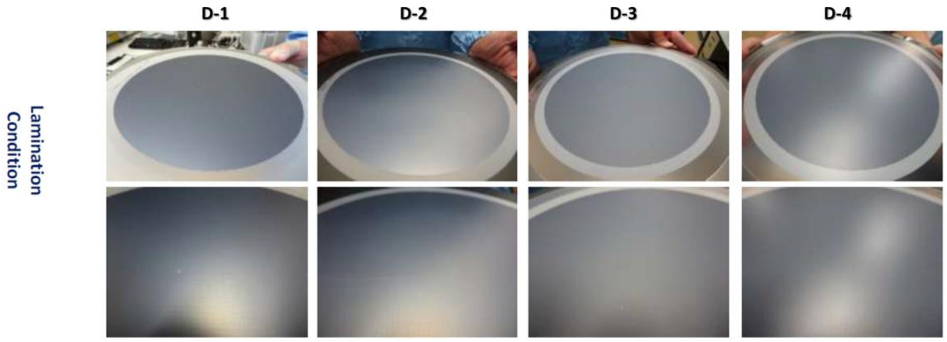


Fig. 17. Wafer mounting condition

5. CONCLUSION

Based on the Design of Experiments for Dicing before Grinding Process development. Half Cut Dicing should maintain spindle revolution of 40 to 50k rpm to achieve good top side chipping response. Partial cut depth, wafer thickness and backside chipping shows stable process with of +/- 2.5 μm specification. During BG tape lamination, in order to eliminate whiskers, bubbles and contamination, the process should use BG Tape E-1, which has lower before UV adhesion compared to E-2. In addition, BG tape E-1 must be laminated at room temperature to achieve optimum condition. Lastly, wafer lamination shows no significant effect from 7 μm to 30 μm DAF thickness. Therefore, DBG process can offer defect free process obtaining 50 μm final thickness.

6. RECOMMENDATION

In developing <100 μm wafer thickness with almost zero back side chipping, Dicing before Grinding should be implemented. Extensive Design of Experiments comprehending material selection should be considered to establish the quality requirements of the product.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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