ABSTRACT

In every new technology developed and introduced to the manufacturing floor, particularly in the wafer preparation, entails problems that later induce defects affecting the wafer yield. This paper discusses the optimization of wafer preparation parameters, particularly the tensionless backgrinding tape lamination and DAF cut vacuum control, that mitigates wafer yield detractors such as edge cut, kerf shift and dice pop-out. Based on the evaluation results, tensionless backgrinding lamination affects the kerf shifting and edge cutting, and with proper vacuum control to attain zero dice pop-out process.

Keywords: Wafer preparation; dicing before grinding; DAF; laser DAF cut; kerf shift.

1. INTRODUCTION

The development of thinner die configuration has evolved from the conventional wafer preparation process into dicing before grinding process. Traditional wafer preparation process in Fig. 1 involves wafer taping to wafer backgrinding (3 steps grinding from rough to fine and to polishing.
to attain required final wafer thickness) to wafer mounting (lamination of dicing tape or die attach film (hereinafter referred to as DAF) into the wafer backside) to backgrinding (BG) tape peeling or removal and last is the wafer mechanical sawing (involves cutting of the wafer into the desired die size using diamond blades). It is important to know also that manufacturing assembly and test process flow varies with the product and the technology [1-4].

Dicing before grinding (DBG) was introduced to attain the required thin wafer thickness (50 µm) without compromising the die strength. DBG focused on the removal of backside chipping that may cause breakage on the silicon area of the die, thus improving its quality [5]. However, DBG is not enough to cater the increasing demand for thinner packages. The inclusion of the DAF material attached underneath the pre-sawn ground wafer pose another challenge [6-7] for a breakthrough process development which is the laser DAF cut. Laser DAF cut focus on the successive singulation of the DAF material underneath the pre-sawn wafer using low power lasers. Thus, the introduction of DBG with laser DAF cut enables the integration of the wafer thinning process and the use of DAF without compromising the quality requirement of thinner dice.

1.1 Dicing before Grinding and Laser DAF Cut

Dicing before grinding in Fig. 2 reverses the usual process of fully dicing the wafer after backgrinding. With DBG process, wafer will be grooved or half-cut into a desired depth first with a special dicing saw machine designed for grooving. Then wafer will be laminated at the front side to ensure protection at the latter processes, specifically wafer backgrinding. After BG tape lamination, wafer backgrinding will be performed to singulate wafer into die and removal also of the mechanical artifacts coming from the wafer half cutting process. After wafer backgrinding, the wafer then goes to the mounting section. The mounting section includes DAF mounting and BG tape peeling.

Laser DAF cut [8] illustrated in Fig. 3 is the process developed for the cutting of DAF material by means laser. Laser have more advantages compared to a conventional mechanical blade cutting in terms of processability of dice processed using DBG process. Three advantages noted were the capability to adopt with the inconsistent kerf shifting, adjustable cut width to penetrate thinner kerf opening, and last is faster processing speed due to the use of light. Laser uses a special low power laser with high frequency in order to cut the DAF.

One major advantage of laser DAF cut is the ability not to subject the silicon wafer and DAF to any mechanical stress thus removing the possibility of chippings or burrs. The laser will pass through the die opening (kerf width) without hitting the silicon side wall thus eliminating mechanical stress. An actual photograph in Fig. 4 shows a good and smooth separation of the silicon and DAF using DBG and laser DAF cut process.

1.2 Edge Cut

One of the problems encountered during the DBG and laser DAF cut introduction was edge cut. Edge cut shared in Fig. 5 refers to the misalignment of the actual laser cut versus the defined kerf width. The misalignment happens when the laser machine failed to follow the maximum kerf shift. The laser will therefore hit and cut through the edge of the die.

1.3 Kerf Shift / Die Alignment

Another inherent problem encountered at DBG process is kerf shifting in Fig. 6. Kerf shifting refers to the movement of dice induced after wafer backgrinding and mounting process. The higher tension being applied to the wafer, the higher disturbance will be applied into the singulated dice. This will result to the movement of the dice or kerf shifting. Therefore, the control of tension during the DBG process is highly recommended. From the tension applied during BG tape lamination, stress applied during die
1.4 Dice Pop-out

Dice pop-out refers to the flying of dice after laser DAF cutting, shown in Fig. 7. The dice are detached from the dicing tape after laser DAF cutting, and also before and after wafer washing and drying process. Manifestation occurs when the dicing tape are disturbed when placed at the chuck table at cutting and even washing station. The die will fly once bulging happened when wafer is vacuumed at the chuck table.
With all the identified technical challenges, abovementioned such as large kerf shift and dice pop-out. The paper discusses the laser DAF cut optimization and corresponding DBG process parameters to address the technical issues during the introduction of 20 µm DAF tape.

2. ACTUAL EXPERIMENTATION

2.1 Materials

A 200 mm silicon wafer with a 20 µm DAF was used as carrier for the evaluation, depicted in Fig. 8. Wafers were processed using the DBG process with 50 µm target final thickness and a specified final die size.

2.2 Procedure

The evaluation done to be able to understand and solve the large kerf shift and dice pop-out issue can be categorized into the following legs: (1) backgrinding (BG) tape lamination tension effect validation using tension and tensionless lamination process; (2) wafer mount parameter optimization.

Fig. 6. Kerf shift

Fig. 7. Sample photo of dice pop-out

In order to check the firmness of the wafer during wafer backgrinding with different BG tape lamination condition, one BG tape was used throughout the experiment. The effect will be differentiated using different conditions, with tension and tensionless lamination. Tension lamination refers to the standard backgrinding tape lamination process wherein pressure is applied horizontally and vertically with respect to wafer surface. On the other hand, tensionless lamination refers to the process wherein BG tapes are applied onto the wafer free from any pressure or tension.

2.2.2 Wafer mount parameter optimization

After wafer backgrinding process comes the sawing or singulation of the dice. Having the dice singulated prior wafer mounting, it is important that the wafer mounting process parameter is considered and evaluated carefully. The effect of lamination speed, roller pressure and table height settings should be understood to check its impact regarding the tension applied towards the singulated dice during wafer mounting.

Lamination speed refers to the speed of DAF application. The speed could generate horizontal stresses during DAF application that could results to die movement and kerf shifting. Roller pressure is the downward vertical pressure applied by the laminating roller. Table height settings refers to the upward vertical pressure applied during DAF application. The control of the height will control the amount of roller pressure to be applied into the wafer.
Table 1. Backgrinding tape lamination type effect

| Type of lamination | Kerf shift | Edge cut | Dice pop-out | Remarks |
|--------------------|------------|----------|--------------|---------|
| With tension       | Present    | Present  | Present      | Failed  |
| Tensionless        | No manifest| Passed   | Present      | Failed  |

Table 2. Wafer mount parameter optimization

| Wafer mount parameter | Kerf shift | Edge cut | Dice pop-out | Remarks |
|-----------------------|------------|----------|--------------|---------|
| Lamination speed      | Passed     | Passed   | Present      | Failed  |
| Roller pressure       | Passed     | Passed   | Present      | Failed  |

2.3 Quality Requirements

The experiment results were assessed based on the following criteria: (1) any occurrence of dice pop-out; (2) any occurrence of edge cut or misalign cut; and (3) large kerf shifting.

3. RESULTS AND DISCUSSION

The experiment results are analyzed on the different evaluation trials.

3.1 BG Tape Lamination Effect Validation

Table 1 indicates that the two BG tape lamination processes have no significant impact for both dice pop-out and edge cut problem. On the other hand, tensionless lamination help eliminate the horizontal pressure applied into the tape thus will help prevent kerf shifting problem. With the kerf shifting problem addressed during tape lamination, edge cutting was also eliminated.

3.2 Wafer Mount Process Parameter Optimization

For the wafer mounting parameter optimization, focused was on the dice pop-out problem. Evaluation performed was concentrated on the following parameters in Table 2. Lamination speed was reduced from 30 mm/s to 20 mm/s, to reduce the horizontal pressure during DAF lamination. Roller pressure was also reduced to lessen the downward vertical pressure thus helps reduce the movement of dice during DAF lamination.

The two different adjusted parameters showed no significant effect in terms of kerf shifting and edge cut problems. However, dice pop-out was existent after three different adjustments meaning that the control of tensions during DAF lamination will not suffice to correct the dice pop-out issues.

3.3 Laser DAF Cut Vacuum Optimization

After establishing that tensionless lamination will solve the presence of kerf shift and edge cut, dice pop-out is still eminent. In order to mitigate the issue, the focus was shifted from wafer mount process to laser DAF cut. One parameter to control was the amount of vacuum applied prior laser DAF cut. After several arbitrary evaluations, elimination of dice pop-out was established by using very small amount of vacuum level. This is to ensure that no bulging is present prior cutting.

4. CONCLUSION AND RECOMMENDATIONS

Based on the evaluation results, tensionless backgrinding lamination affects the kerf shifting and edge cutting. Overall, tension control is the critical characteristics on handling thin wafers processed using DBG. Tensionless BG tape lamination and low lamination pressure at DAF mounting process is key for kerf shift control. Proper vacuum control at laser DAF cut is critical to attain zero dice pop-out process.

For further improvement and studies, discussions in [6,9-10] are helpful in reinforcing robustness and optimization of front-of-line assembly processes.

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.
ACKNOWLEDGEMENT

The authors would like to thank the New Product Development & Introduction (NPD-I) team and the Management Team for the usual great support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. STMicroelectronics. Assembly and EWS design rules for wire bond Interconnect dice. rev. 54.0; 2019.
2. May GS, Spanos CJ. Fundamentals of semiconductor manufacturing and process control. 1st ed., Wiley-IEEE Press, USA; 2006.
3. Sumagpang A, Gomez FR. A methodical approach in critical processes optimization of new scalable package semiconductor device for ESD applications. Asian Journal of Engineering and Technology. 2018;6(6):78-87.
4. Geng H. Semiconductor manufacturing handbook. 1st ed., McGraw-Hill Education, USA; 2005.
5. Disco Corporation. Dicing before grinding (DBG) process. Available: http://www.disco.co.jp/eg/solution/library/dbg.html
6. Rodriguez R, Gomez FR. Pick and place process optimization for thin semiconductor packages. Journal of Engineering Research and Reports. 2019;4(2):1-9.
7. STMicroelectronics. Work instruction for tape/DAF and glue diebond process. rev. 66.0; 2018.
8. Koechner W. Solid-state laser engineering. 6th ed., Springer-Verlag New York, USA; 2006.
9. Bacquian BC, Gomez FR. A study of wafer backgrinding tape selection for SOI wafers. Journal of Engineering Research and Reports. 2019;6(2):1-6.
10. Huang HH, Wey J. Research on the high-speed pick and place device for die bonders. 8th IEEE International Conference on Control and Automation. 2010;2:2.