ABSTRACT

The drive for thinner package architecture is already becoming a necessity. There were a need of thinner Integrated Circuit or IC in order to fit in to thinner applications like mobile phones. One of the major semiconductor process that enables miniaturization was wafer back grinding. The process involves wafer thinning to a required thickness with the use of back grinding wheels that serve as the abrasive material. The paper will discuss the effect of back grind input parameters like step grinding and wheel grit size to its output characteristics like total thickness variation, edge chippings and die strength. Total thickness variation will define if the new wheel will not affect the variation with the wafer. On the other hand, edge chippings and die strength will define the reliability of the die on different conditions of the package. Lastly, these 3 characteristics will establish the manufacturability of the process as it will eliminate the probability of wafer breakage.

Keywords: Wafer; wafer back grind; back grinding wheel; edge chippings; die strength.
silicon was chipped out from the wafer, in which act as the work piece, while the abrasive material is the back grinding wheel. Selection of abrasive material is also critical since different surface roughness finish of the work piece. The grinding wheel is defined by the type of its abrasive material, mesh or grain size and its bonding material [3]. As IC goes thinner and thinner, the drive for thinner wafer and dies are becoming a necessity. However, several factors should be considered when introducing new process developments. The paper will discuss the effect of back grind wheels on wafer edge chippings and die strength.

1.1 Backgrinding Wheels

Grinding wheels are the abrasive material used to scraped out silicon from the wafer back side using diamond and chip pockets. Diamond classified as the strongest cutting material is a perfect match to chipped out hard and brittle crystal-like silicon [4,5,6]. On the other hand, Chip pockets is the spacing between abrasive to ensure that there was proper cooling during high stress process like grinding, which friction is at very high motion. Several critical characteristics of grinding wheels were grit and bond [7]. Grit refers to the abrasive particle size of the wheel while the bond refers to the material used to hold the abrasive particle. The paper will discuss the relationship of the two different grinding materials to edge chippings.

1.2 Wafer Edge Chippings

Wafer Edge Chippings was one critical factor being monitored during wafer back grinding process. Wafer edge chipping is a portion of a wafer was chiseled out from the edge (Fig. 1) due to stress applied by back grinding wheels. During the development of ultrathin wafers, the risk of damage induced by the process was increased due to its high surface friction [8]. The paper will discuss the relationship of introducing new wafer back grinding wheel and grinding steps to wafer edge chippings.

1.3 Die Strength

Die strength is one critical output characteristic during wafer back grinding characterization. As integrated circuit becoming thinner the silicon die strength has becoming a critical package reliability under severe condition [9,10]. There were four factors influencing the die strength: The surface roughness of the wafer, the backside chipping of die, the weak plane of the crystal lattice of silicon and the test methods with different loading types [11]. Die Strength was measured by 3-point bend tester, wherein there were a vertical load is used to break the die, which is fixed on a two-point lever. The paper will discuss the relationship of die thickness and die strength.

2. ACTUAL EVALUATION

2.1 Materials

Wafer Back grinding was evaluated using a target final thickness of 50 µm and 70 µm. Wafer size was set to 200 mm diameter and standardized with a bare silicon wafer.

Two evaluation equipment were used, two step and three step grinding. Two Step uses Rough and Fine grinding in order to achieve the defined thickness. In contrast, three step grinding has its additional step to achieve the defined thickness with mirror finish surface. The process also uses rough and fine grinding compared to two step grinding. The additional step was polishing step which uses chemical mechanical polisher.

Two different back grinding wheels was evaluated in order to see the effect of mesh and bond with respect to wafer back grinding step in-process control. Table 1 shows the back-grinding wheels’ comparison.

Existing wheels have mesh of #325 and #2000 for its rough and fine grinding steps. The existing wheels were used for high volume manufacturing of final thickness: > 100 µm. However, for the new grinding wheels, it has #600 and #3600, for rough and fine grinding, respectively. The Mesh of the new grinding wheels was with smaller grit.
sizes and finer particle size distribution. Another difference between the current and new grinding wheels was its bond: Resin and Vitrified. Resin Bond are organic bonds and known for its soft cutting action [12]. On the other hand, vitrified bond is stronger than organic bond but softer than metal bonds, which offers flexibility of the nature of the work piece [13].

### 2.2 Procedure

In order to have a full characterization of the back-grind wheels’ impact to thin silicon wafer. Output characteristics were identified and established as measure of success; these are:

- Total Thickness Variation
- Wafer Edge Chippings
- Die Strength

Moreover, different correlations below were evaluated in order to establish its relationships:

- Total Thickness Variation vs. Final Wafer Thickness.
  - To check if the total thickness variation differs as the final wafer thickness becomes thicker or thinner.
- Edge Chippings vs. Grinding Wheels
  - To check the effect of different grinding wheels with respect to edge wafer chippings.
- Edge Chippings vs. Wafer Thickness
  - To check if Edge Chippings changes as wafer thickness varies using the new grinding wheels'.

### 3. RESULTS AND ANALYSIS

#### 3.1 Total Thickness Variation vs. Final Wafer Thickness

Total Thickness variation has no relation with respect to wafer thickness, shown in Fig. 2. Both 50 µm and 70 µm has passed the +/-5 µm variation with 5 positions of the wafer. In addition, both grinded silicon wafer has achieved target final thickness with an average of 49 µm and 70.2 µm, respectively.

#### 3.2 Edge Chippings vs. Grinding Wheels

Analysis of variance shows that there is significant difference between two grinding wheels in terms of edge chippings. New Grinding wheel edge chippings are lower than the Current Grinding Wheel. The finer diamond grits and denser mesh of new grinding wheel have helped to gain lower edge chippings. Based on Analysis of Variance or ANOVA shown in Fig. 3, with a p-value of below 0.05, shows that the new grinding wheel is significantly improved the edge chippings compared to Current Grinding wheel.

| Wafer Thickness | 50um       | 70um       |
|-----------------|------------|------------|
| Sample          | 1          | 2          | 3          | 4          | Center     |
| Target Thickness| 49         | 50         | 51         | 47         | 48         | 73         |
| Target Thickness| 73         | 69         | 72         | 67         | 70         |

**Fig. 2. Total thickness variation**
Fig. 3. Edge chippings vs. Grinding wheels ANOVA

Fig. 4. Edge chippings vs. Wafer thickness ANOVA
Fig. 5. Edge chippings vs. Equipment platform ANOVA

Fig. 6. Die strength vs. Wafer thickness ANOVA
3.3 Edge Chippings vs. Wafer Thickness

Based on the Fig. 4, Analysis of variance shows that there is no significant difference on edge chippings in terms of wafer final thickness. 70 µm Wafer Final Thickness edge chippings is lower than the 50 µm wafer thickness. Consequently, as the wafer goes thinner will increase the probability of higher edge chippings.

3.4 Edge Chippings vs. Equipment Platform

Different Equipment process steps: 2-step and 3-step grinding was used to evaluate if edge chipping also have significant effect on edge chippings, this is to gain flexibility at manufacturing. But based on Fig. 5, 3-step grinding is significantly better compared to 2-step grinding, which has lower edge chippings.

3.5 Die Strength vs. Wafer Thickness

Die Strength has a significant difference compared to its wafer final thickness. 70 µm Wafer Final Thickness die strength is higher than the 50 µm wafer thickness, as shown in Figure 6. Analysis of variance, with p-value of below 0.05, shows that as wafer goes thinner the lower die strength.

4. CONCLUSION

Wafer back grinding characterization and correlation was completed. The several results were below:

- Total Thickness Variation vs. Final Wafer Thickness
  - Both grinded silicon wafer has achieved target final thickness with an average of 49 µm and 70.2 µm, respectively. Hence, no major difference.

- Edge Chippings vs. Grinding Wheels
  - New grinding wheel is significantly improved the edge chippings compared to Current Grinding wheel.

- Edge Chippings vs. Wafer Thickness
  - As the wafer goes thinner will increase the probability of higher edge chippings

- Edge Chippings vs. Equipment Platform
  - 3-step grinding is significantly better compared to 2-step grinding, which has lower edge chippings.

- Die Strength vs. Wafer thickness
  - Wafer Thickness is indirectly proportional to die strength which means as the wafer goes thinner, its die strength will be lower.

Therefore, edge chippings can be reduced by introducing new grinding wheel using 3-step grinding machine. In addition, thicker wafer will also reduce the probability of edge chippings. Though, both 50 µm and 70 µm have passed die strength compared to its respective minimum requirement. Finally, total thickness variation has no direct correlation to its wafer thickness.

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.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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