FLATTENING OF SILICON WAFERS

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Abstract: Most of today's IC (integrated circuit) chips are made from 200 mm or 150 mm silicon wafers. It is estimated that the transition from 200 mm to 300 mm wafers will bring a die cost saving of 30–40%. A series of processes are required to manufacture high quality silicon wafers. As one of processes to flatten silicon wafers simultaneous double side grinding (SDGS) has a great potential to meet the demands for high quality wafers at low cost. This paper reviews manufacturing process flow for silicon wafers using SDGS and lapping. The interaction effects of three process parameters (wheel rotation speed, chuck rotational speed and federate) with surface roughness and grinding marks are presented

Key words: silicon wafers, lapping, grinding, polishing, flattening

1. INTRODUCTION

Manufacturing of silicon wafers starts with growth of silicon ingots. A sequence of processes is needed to turn an ingot into wafers (Dobrescu & Dorin, 2008). This typically consists of following processes:

- Slicing, silicon ingot into wafers of this disk shape;
- Edge profiling (chamfering), to chamfer the peripheral edge portion of the wafer;
- Flattening (lapping or grinding), to achieve a high degree of parallelism and flatness of the wafer;
- Etching, to chemically remove the damage induced by slicing and flattening without introducing further mechanical damage;
- Rough polishing, to obtain a mirror surface on the wafer;
- Fine polishing, to obtain final mirror surface.

Two processes can be used to flatten the sliced wafers: lapping and simultaneous double side grinding (SDSG).

The lapping operation is shown in figure 1.

The loaded wafers are then lapped by the abrasive slurry (typically a mixture of alumina and glycerin) injected between two lapping plates rotating in opposite directions.

The lapping operation would generate sub surface damages in silicon wafers, which need to be removed by its subsequent processes. Simultaneous double side grinding is illustrated in figure 2. A pair of diamond cup wheels is located on the opposite side of a rotating silicon wafer. Both side of the rotating silicon wafer are ground simultaneously by the two wheels, which are synchronously fed towards the wafer.

Table 1 compares lapping and SDSG in five aspects. It can be seen that SDSG is better in almost every aspect.

Characteristics	Lapping	SDSG
Waviness removal	Very good	Good
Throughput	Low	High
Consumable cost per wafer	High	Low
Automation level	Low	High
Environmental benignity	Poor	Good

Tab. 1. Comparison of different approaches for flattening silicon wafers

Fig. 1. Illustration of lapping process

Fig. 2. Illustration of SDSG process

2. PROCESS FLOWS USING SDSG

SDSG was introduced into semiconductor industry in 1990s (Li et al., 2006). The diamond grinding wheels with different mesh size were used for different process flows:

- Slicing – SDSG – Lapping – Chamfering – Polishing;
- Slicing – SDSG – Lapping – Etching – Polishing;
- Slicing – SDSG – Chamfering – Etching – Polishing;
- Slicing – SDSG (fine) – Chamfering – SDSG (second) – Etching – Polishing;

Since the main purpose of the coarse SDSG is stock removal, the diamond grits in the coarse wheels have large size (mesh # 300 – 2000). The mesh size of the wheels used in the fine SDSG process is in the range of # 2000 – 10000.

The bond materials for the SDSG wheels could be resin, metal or vitrified ceramic (Chidambaram et al., 2003).

3. THE EFFECTS OF PROCESS PARAMETERS ON GRINDING

Grinding marks (figure 3), or grinding linear are the traces left by the grinding wheel on the wafer surface A (figure 3) and the “cress-cross” on the wafer surface B (Sun et al., 2004). In this paper only the distance between the adjacent lines of wafer surface A will be presented. Development of the model in this paper is based on the assumption that the grinding wheel behaves like a single-point tool. Two output variables are registered: grinding marks and surface roughness.

The major requirement for fine grinding of silicon wafers include: the grinding force should be low and constant; the grinding wheel should have a reasonable life; the ground wafers should have very good flatness; this usually means sub micron total thickness variation; surface and subsurface damage should be minimized (Dobrescu et al. 2009). The results on grinding marks are including in Table 2. We obtain the mathematical model for dependence. Actual grinding mark distance (GMD) of wheel speed and respectively of wafer speed.

$$GMD = -0.01n_W + 51.685 \quad (1)$$

$$GMD = 0.45n_{WF} - 11.5 \quad (2)$$

The distance between the grinding marks (GMD) decreases as the wheel speed n_W increases. The effect of wheel speed is stranger at the high level of wafer speed for each output variable.

Fig. 3. Grinding marks

Wheel speed	Wafer speed	Feed rate	Grinding mark distance
+	+	+	22.39
+	+	-	22.28
+	-	-	5.53
-	-	+	12.98
-	+	+	51.08
-	+	-	52.18

Tab. 2. Grinding mark distance data

Wheel speed	Wafer speed	Feed rate	Surface roughness R_a [nm]		
			Wafer 1	Wafer 2	Wafer 3
+	+	+	99	98	93
+	+	-	105	96	90
+	-	-	82	86	79
-	-	+	170	160	182
-	+	+	127	131	129
-	+	-	92	96	88

Tab. 3. Surface roughness data

Three process parameters are chosen to study their effects and interactions: the rotational speed of the grinding wheel, the rotational speed of the wafer and the feed rate of grinding wheel towards the wafer.

The results on surface roughness are included in Table 3. Surface roughness of the ground surface is measured along a direction approximately perpendicular to the grinding lines. The experiments are conducted on a Nanogrinder, Grinding Machines Nuremberg. The grinding wheel used is a diamond cap wheel. The grit size is mesh # 1200 and the diameter of the wheel is 300 mm. The instrument used is a Surf analyzer 5000. The measurement is done at approximately the same location for each wafer. The main effects of wheel speed n_W and feed rate S are significant. Lower wheel speed and higher feed rate produce rougher surface as indicated the mathematical models:

$$R_a = -0.014n_W + 143 \quad (3)$$

$$R_a = 100S - 25 \quad (4)$$

4. CONCLUSION

The following conclusions can be drawn:

- When the two grinding wheels rotated in different directions the surface on one side of the wafer was different from the other side. This was a limitation for SDSG if the identical wafer surface on both sides were required. But, the limitation could be reduced when the wheels rotated at a high speed report $n_W / n_{WF} \gg 1$.
- Lower wheel speed and higher feed rate produce rougher surface.
- The distance between the grinding marks GMD is determined by wheel speed and wafer speed through the equation (1) respectively (2).
- In silicon wafer manufacturing, the removal amount of the subsequent polishing process to be large enough to eliminate all grinding marks generated in the SDSG operation.

Further reduction of polishing amount necessitates optimization of the grinding process so that the grinding marks can be eliminated with minimum amount of polishing

5. REFERENCES

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