Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
Annals of DAAAM International

ELECTROLYTIC IN-PROCESS DRESSING (ELID) GRINDING FOR SILICON WAFERS

DOBRESCU, T[iberiu] G[abriel]; GHINEA, M[ihalache]; ENCIU, G[eorge] & NICOLESCU, A[drian] F[lorin]

Abstract: *Mirror surface grinding of silicon wafers operations were conducted by using ultrafine grain metallic bond wheels with electrolytic in-process dressing (ELIC). Workpieces of hard and brittle materials, such as monocrystalline silicon, glass and ceramic, was ground. Wheel abrasive grains used mainly were diamond of several microns down to submicrons. Ground surface roughness versus grit size was shown. Subsurface damage was evaluated through X-ray. High surface accuracy, good surface finish, and low subsurface damage were all successfully achieved. The advantage of a constant in-feed pressure in ultrafine grinding was shown.*

Key words: *damage, dressing, ELID-grinding, removal mechanism, silicon wafers*

1. INTRODUCTION

Advanced precision grinding techniques, especially those aiming at perfecting finish processes of silicon wafers, play a significant role in replacing conventional loose abrasive machining processes, such as lapping and polishing (Inasaki, 1987). Furthermore, the latest manufacturing processes for semiconductors and optical components necessitate the use of ultraprecision grinding which enables simultaneous achievement of three performance requirements:

- Good surface finish;
- High surface accuracy;
- Low subsurface damage.

The authors have proposed a new grinding technique for silicon wafers using metallic bond grinding wheels with electrolytic in-process dressing (ELID-grinding). This technique is expected to achieve the strict performance requirements by using:

- Wheels of fine grits with a rigid metallic bond;
- Electrolytic in-process dressing;
- Ultraprecision grinders.

This paper describes the possibilities of electrolytic in-process dressing as a practical ultraprecision mirror surface grinding technique for silicon wafers through investigating ground surface topography, subsurface damage, and removal mechanism (Dobrescu et al., 2009).

2. ELID-GRINDING TECHNIQUE

Figure 1 show the ELID-grinding principle, which was invented through the application of cast iron bonded diamond (CIB-D) wheels to silicon wafers. The wheel becomes the positive pole by a brush smoothly contacting its surface. The electrode fixed below the wheel surface is the negative pole. In the clearance of around 0.1 mm between the two poles, electrolysis occurs by the supply of an electrically conductive fluid.

The ELID-grinding system is composed of essential elements which generate typical electrolyzing phenomena. These are: a metallic bond grinding wheel, a power supply, a grinding fluid, and an electrode (Ohmori & Nakagawa, 1990).

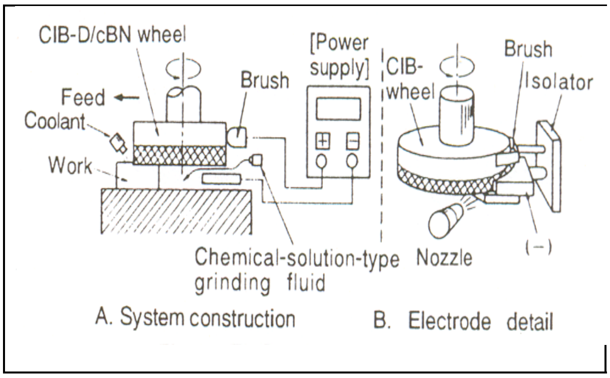

Fig. 1. ELID-grinding principle

The authors have proposed ELID-grinding using CIB-D wheels with fine grains. Relatively coarse grit wheels can also be applied in ELID-grinding. In order to ensure successful fine grinding operations, the following factors should be considered:

- The type of the metallic bond in the wheel used affects the rate of the electrolysis;
- Direct current power supply which generates high frequency pulse voltage is needed for fine grinding with electrolytic in-process dressing;
- Chemical-solution-type grinding coolant diluted by water is used as both the grinding fluid and the electrolyte;
- Materials of good electric conductivity such as copper and graphite are used for the negative electrode which is not itself electrolyzed.

A metallic bond wheel is pre-dressed electrically before grinding operations. During this pre-dressing of around 20 min, the working current for electrolysis decreases by a factor of around five. This is because an isolating layer, composed of hydroxides and oxides, is generated on the wheel surface in accordance with the ionization of the metallic bond. After ELID-grinding starts, the isolating layer is scraped off by friction between the wheel and the workpiece surface. As a result, the working current recovers and the grain protrusions can be maintained even in ultrafine grinding.

3. EXPERIMENTAL EQUIPMENT

Figure 2 shows the grinding type employed with ELID-grinding. An ultraprecision rotary surface grinder equipped with an ELID-system was used (Dobrescu & Dorin, 2007). This CNC machine has air-spindle and feed-resolution of 0.1 microns with a closed-loop feedback system. CIB-D wheels of different grit size from #400 to #120000 were used. The wheel dimensions are 143 mm in diameter and 3 mm in width. Workpieces of monocrystalline silicon were ground. Surface measuring instruments using a laser and diamond stylus of 2 microns radius were used in investigations of the ground surface. X-ray was applied in order to detect subsurface damage, and crack depth was evaluated through angle-polish and step-etching for silicon wafers (Dobrescu, 1998).

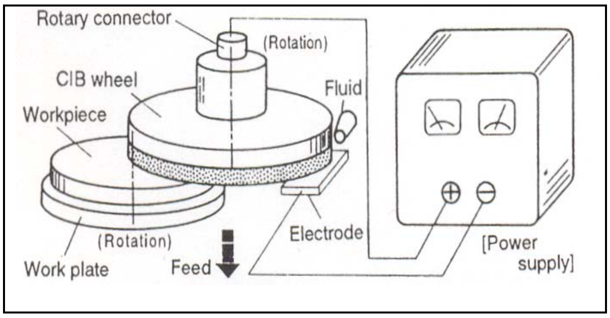

Fig. 2. In-feed grinding type with ELID

4. EXPERIMENTAL PROCEDURES

Each wheel was trued by a #325 bronze bond diamond wheel, and was pre-dressed electrolytically. Total depth of cut by each wheel was set at 20 microns. The wheel grit sizes and the ELID-grinding conditions are summarized in Table 1. The subsurface damage was detected and evaluated through X-ray topography and angle-polish respectively. The X-ray topographies of the silicon wafers of 152.4 mm in diameter which were ground by #2000, #4000, #6000 and #8000 wheels was evaluated and compared. The surface of each of the ELID-ground silicon wafers produced by #2000, #4000, #6000 and #8000 wheels was polished with an angle and treated with a chemical etching, and the depth of cracks in the subsurface damage was evaluated and compared. Step-etching was applied to evaluate the depth of the damaged subsurface layer on silicon wafers produced by an ultrafine grit wheel. Chemical processes combined with chemical-mechanical polishing, chemical-etching and heat treatments were all applied to bring the damage out in relief. #120000 and #3000000 wheels were tried under constant depth of cut and constant pressure grinding, and the surface quality produced was compared. For constant pressure grinding, a conventional lapping machine equipped with an ELID-system and a #120000 metallic bond wheel was used. Surface accuracy was also evaluated in an ultrafine grinding. Accuracy of a flat surface was inspected by a laser interferometer. This surface was produced by ELID-grinding using #8000 and #40000 CIB-D wheels and an ultraprecision rotary surface grinder.

Table 2 shows the surface finish of silicon wafers using ELID-grinding with different grit sizes. The results show that the ground surface finish could be improved proportionally to the grit size, and the surface finish of 18 nm in Rmax, 2.8 nm in Ra was obtained by use of #40000 CIB-D wheels.

Grinding conditions	Mesh [#]						
	400	2000	4000	6000	8000	40000	120000
	Grit size [μm]						
	30	7	4	3	2	0.4	0.13
Wheel rotation	2500 rpm					1500 rpm	
Work rotation	500 rpm					150 rpm	
In-feed speed	1 μm/min					0.5 μm/min	
Open voltage	60 V					90 V	
Peak current	10 A					10 A	
On, off-time	2 μs					2 μs	
Pulse wave	square					rippled	

Tab. 1. Grit sizes and ELID-grinding conditions

Grinding conditions	Mesh [#]						
	400	2000	4000	6000	8000	40000	120000
	Grit size [μm]						
	30	7	4	3	2	0.4	0.13
Rmax [nm]	340	110	64	55	35	18	22
Ra [nm]	34	16	7.7	6.7	5.3	2.8	3

Tab. 2. Surface finish due to wheel grit size

5. CONCLUSION

Surface finish due to wheel grit size, and mirror surface of silicon wafers generation by ultrafine grits was investigated. Smooth surface of 2.8 nm in Ra, 18 nm in Rmax was obtained by a #40000 wheel.

Subsurface damage in ground silicon wafers was inspected though X-ray and angle-polish. The cracked layer could be reduced by using a finer grit size, and the depth of the cracked layer was evaluated as 1.3, 1.1, 1.0, 0.4 microns, produced by using #2000, #4000, #6000 and #8000 wheels respectively. Both surface finish and quality could be improved at the same time by using fine grit wheels, and a #8000 wheel generated cracks lower than 1 micron. All of the damaged layer was completely removed after an etching of 1 micron in depth on an ELID-ground wafer produced by a #40000 wheel; therefore the damaged layer was proved to be less than 1 micron in total.

Difference in surface generation due to material was investigated. The advantage of employing constant pressure grinding for ultrafine wheels such as #120000 and #3000000 was proven through surface analysis, and ground surface of around 3.3 angstroms in Ra, 23.5 angstroms in Rmax were successfully achieved. Better surface finish was easily achieved by the employment of constant pressure grinding than by constant depth of cut.

Surface accuracy of silicon wafers produced by ELID-ground using ultrafine grinding wheels was inspected by a laser interferometer. High surface accuracy of 158.2 nm was also achieved through grinding with ultrafine metallic bond wheels and ELID for silicon wafers of 60 mm in diameter.

6. REFERENCES

Dobrescu, T. (1998). Cercetari privind optimizarea masinilor de superfinisat materiale fragile, *PhD Theses,* University „Politehnica“ of Bucharest, Romania

Dobrescu, T.; Dorin, A. (2007). A Study of Silicon Wafers Plane Lapping Process, *Annals of DAAAM for 2007 & Proceedings of the 18th International DAAAM Symposium “Intelligent Manufacturing & Automation: Focus on Creativity, Responsibility, and Ethics of Engineers”*, Katalinic, B. (Ed.), pp. 229-230, ISBN 3-901509-58-5, Zadar, Croatia, October 2007, Published by DAAAM International, Vienna, Austria

Dobrescu, T.; Enciu, G.; Nicolescu, A. (2009). Selection of Process Parameters in Grinding Ceramics, *Annals of DAAAM for 2009 & Proceedings of the 20th International DAAAM Symposium “Intelligent Manufacturing & Automation: Focus on Theory, Practice and Education”*, Katalinic, B. (Ed.), pp. 0361-0362, ISBN 978-3-901509-70-4, Vienna, Austria, November 2009, Published by DAAAM International, Vienna, Austria

Inasaki, I. (1987). Grinding of Hard and Brittle Materials, *CIRP Annals*, no. 36, pp. 463-471

Ohmori, H.; Nakagawa, T. (1990). Mirror Surface Grinding of Silicon Wafers with Electrolytic In-Process Dressing, *CIRP Annals*, no. 39, pp. 329-332