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Kerf Loss Comparisons

Purpose

Kerf loss is associated with any type of cutting and sectioning of materials. Not only does it play a vital role in the overall dimension of a specimen it directly can determine edge quality and surface finish aspects. This note will detail findings of kerf loss and edge damage on silicon material as a function of blade type, thickness and abrasive particle size.

Materials & Methods

Equipment		Description
Model 650 Low speed diamond wheel saw with #4121, #4123, #3063 diamond cut off wheels		The Model 650 Low Speed Diamond Wheel Saw is a compact, multipurpose, precision saw designed to cut a wide variety of materials with minimal subsurface damage.
Model 850 Wire Saw with wire blades: .015", .010", .005" thickness.		The Model 850 is a versatile saw especially suited to applications where precision gentle mechanical cutting and sectioning is needed. Cutting crystals, semiconductors and any material that needs combination of delicate precision and good overall surface finish.

A silicon wafer sample of approximately 700µm thickness was used for comparing each cutting method for kerf loss and edge chip formation. Using the Model 650, three commonly used diamond cutting wheels were used for cutting. These wheels were as follows: 1) DWL 4121 (coarse diamond, low concentration); 2) DWH 4123 (fine diamond, high concentration); and 3) DWH 3063 (fine diamond, high concentration). Using the Model 850 Wire Saw, two different types of tests were done for comparisons. Cutting using a plain, stainless steel diameter wire was done using three different abrasive sizes and three different diameter wire blades. The other tests were done using the two different diameter diamond impregnated wire blades. Plain wires come in diameters of 0.005", 0.010", and 0.015", whereas the diamond impregnated wires are only available in 0.010" and 0.015" diameters. In the case of plain wire cutting, boron carbide (B_4C) abrasive powder mixed with water was used for the cutting slurry. Three sizes were used for comparison, including 8µm, 14.5µm, and 23µm abrasive powder sizes. Cuts were made into the silicon wafer about ¾ of the way through, allowing easy measurement of the amount of kerf produced by each cutting method.

Following the cuts measurements were taken to determine both the amount of edge chip formation produced by each cut as well as the amount of kerf loss created by each method. Measurements of the chip damage were done using a graduated reticle on an inverted optical light microscope. Each measurement was taken using the same magnification of 100x, and both the minimum and maximum chip size was recorded for each cutting method. These were taken laterally from the edge of the cut to the furthest point of the largest chip.

Results

The table below contains data acquired after cutting was performed.

Consumable Item	Thickness	Diamond Size	Concentration	Kerf Loss (um)	Edge Chip Min (um)	Edge chip Max (um)
Diamond wheel 4121	0.012	coarse	Low	360	20	240
Diamond wheel 4123	0.012	fine	high	360	10	340
Diamond wheel 3063	0.006	fine	high	210	<10	100
Diamond wire	0.015	--	--	730	<=10	160
Diamond wire	0.010	--	--	620	<10	240
Wire	0.015	8um BC		400	<5	105
Wire	0.010	8um BC		260	<5	135
Wire	0.005	8um BC		130	0	55

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Consumable Item	Thickness	Diamond Size	Concentration	Kerf Loss (um)	Edge Chip Min (um)	Edge chip Max (um)
Wire	0.015	14.5um BC		400	>10	140
Wire	0.010	14.5um BC		260	>10	150
Wire	0.005	14.5um BC		135	<5	75
Wire	0.015	23um BC		400	>10	160
Wire	0.010	23um BC		275	>10	110
Wire	0.005	23um BC		130	<10	85

Kerf Loss Discussion

The amount of material loss during a cutting process is referred to as the kerf loss. Instinctively the kerf loss would seem to follow a pattern of greater material loss as the abrasive size and the width of the cutting blade increases. However from these experiments it appears there is no clear relationship between these factors. Discussion of each method is given in the following sections.

Diamond Wheel

When comparing diamond wheel cutting and the kerf loss each one generated, there appears to be no strong relationship between kerf loss and wheel thickness. In fact it appears from the data that the difference between all three diamond wheels is less than 5µm. When comparing the amount of kerf loss to the actual width of the cutting blade, a difference of only 58µm from the physical width of the wheel is observed. This shows that total kerf loss on each side of the wheel is approximately 29µm. The data also shows no strong relationship between diamond particle size and kerf loss. Chart 1 below shows the results obtained from diamond wheel cutting.

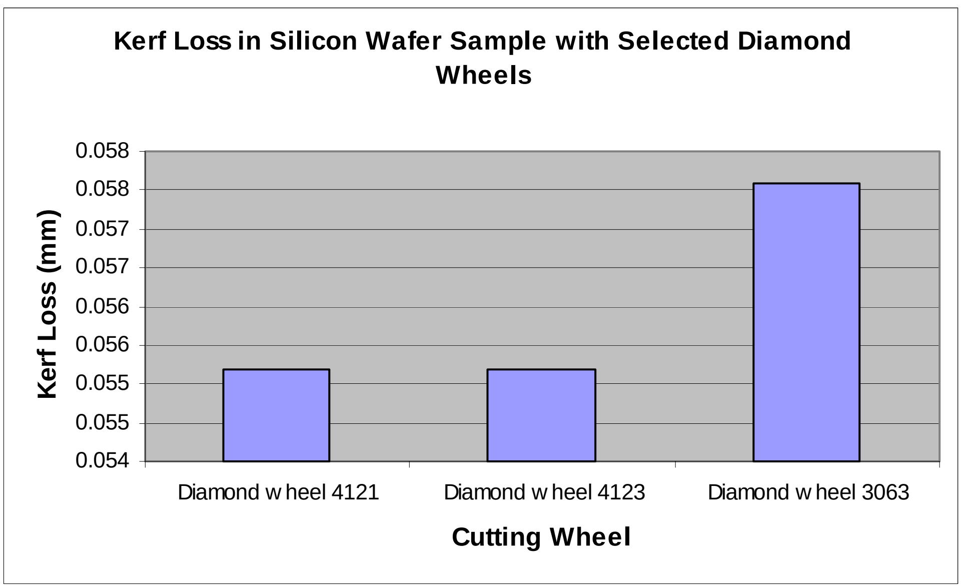

Chart 1: Illustration of the kerf loss in silicon samples cut using various diamond wheels on a Model 650 Low Speed Diamond Wheel Saw. The kerf loss difference observed from each wheel varies by only 3µm.

Diamond Wire

As with diamond wheel cutting it would be logical to assume that the larger the wire diameter, the greater the amount of kerf loss the sample will experience during the cutting process. However this does not seem to be the case as observed in the diamond wheel case. A difference of only 17µm between both diameter wires shows no correlation between kerf loss and wire diameter. These differences may be attributed to variations in diamond particle size. Interestingly enough the overall kerf loss was much larger than diamond wheel cutting, with the total kerf loss amounting to approximately 350µm, or roughly the diameter of the wire being used for cutting. Chart 2 below shows the results for diamond wire cutting.

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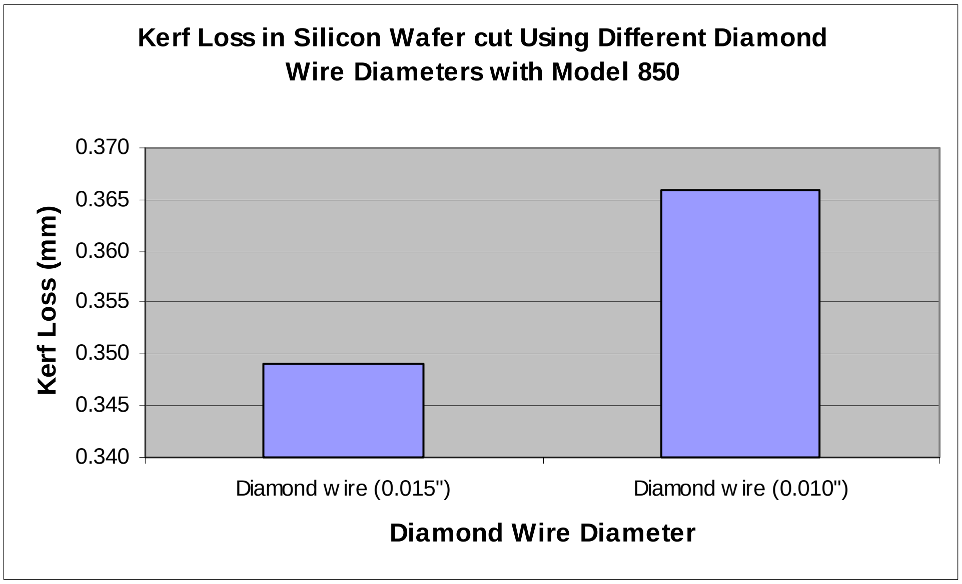

Chart 2: Illustration of the kerf loss in silicon samples cut using various diamond wire diameters on a Model 850 Wire Saw. The kerf loss difference observed from each wire varies by only 17µm.

Plain Wire with Abrasive Slurry

Plain wire cutting differs from diamond wire cutting in that abrasive slurry is used as the cutting media rather than diamond particles affixed directly to the diamond wire. This provides a less damaging cut and results in a smoother cut surface. Logically the larger the abrasive particle size the larger the kerf loss should be, however the data obtained from these experiments shows no clear correlation between abrasive size or kerf loss. In fact, kerf loss from each abrasive size is nominally the same, with a difference of roughly 10µm between all three abrasive sizes. The wire diameter also seems to have little effect on the kerf loss, with the overall kerf loss being less than 20 µm for all three wire diameters. In fact, kerf losses were as follows: 0.015" Ø: 19 µm / 0.010" Ø: 6 µm / 0.005" Ø: ~ 5 µm

Charts 3-5 show the results obtained from wire cutting with abrasive slurry.

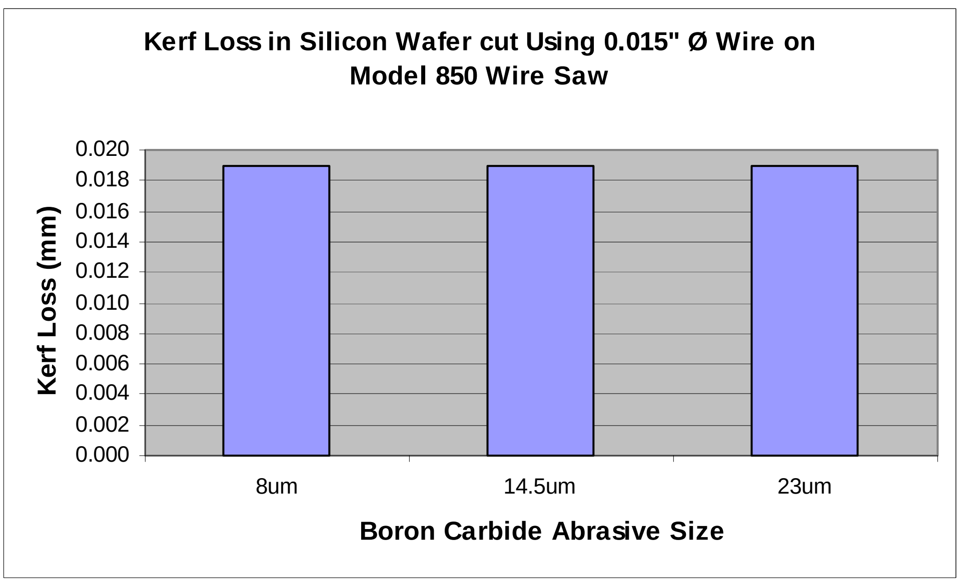

Chart 3: Illustration of the kerf loss in silicon samples cut using various abrasive slurry sizes with 0.015" Ø wire diameters on a Model 850 Wire Saw. The kerf loss difference observed from each wire does not vary.

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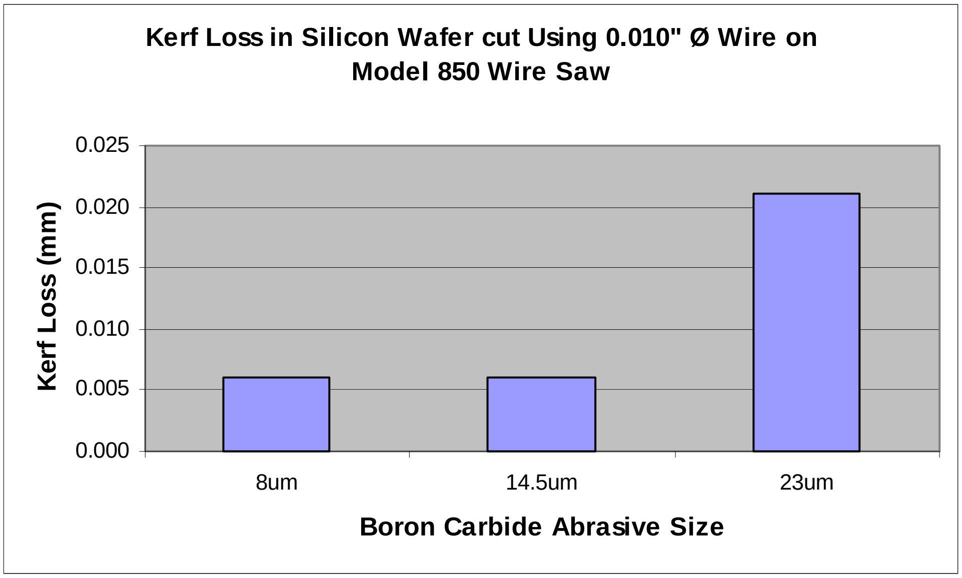

Chart 4: Illustration of the kerf loss in silicon samples cut using various abrasive slurry sizes with 0.010" Ø wire diameters on a Model 850 Wire Saw. The kerf loss difference observed from each wire varies by only 15 µm.

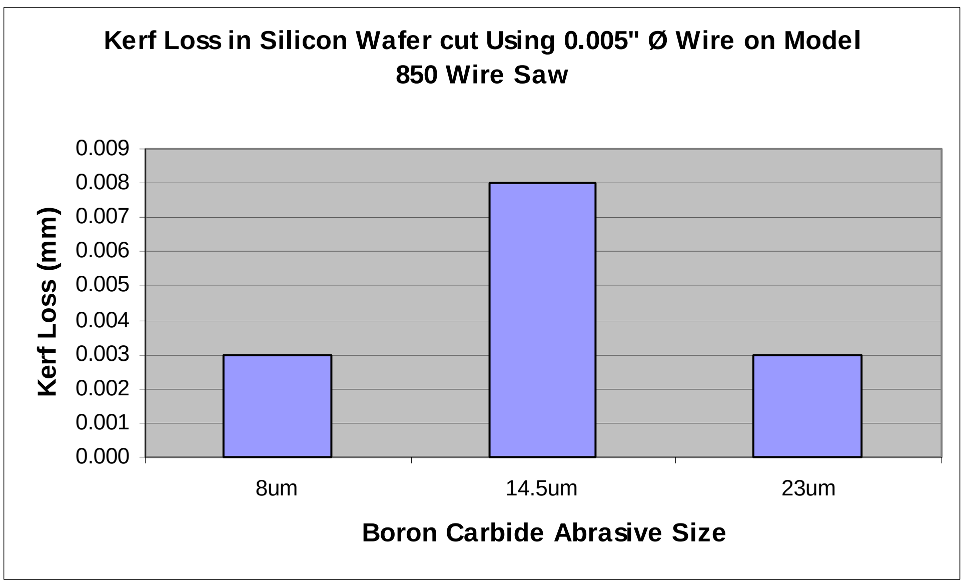

Chart 5: Illustration of the kerf loss in silicon samples cut using various abrasive slurry sizes with 0.005" Ø wire diameters on a Model 850 Wire Saw. The kerf loss difference observed from each wire varies by only 5 µm.

Edge Chipping Discussion

Edge chipping is also a critical factor in cutting applications where samples are being cut to specific sizes and for electron microscope applications. Quite often samples are cut as close to a final dimension as possible to minimize further processing stages such as lapping and polishing techniques. Evaluating the amount of chipping these cutting methods produces can be helpful in determining how much material to leave during a particular cutting process.

The size of the chips induced by a cutting process is generally dependent on the material properties and the abrasive particle size used. After evaluating the cutting methods used in this report it was clear the diamond wheels in general produced more chipping than compared with the wire blade cutting methods. However, the thin diamond wheel (DWH 3063) showed less chipping than some of the wire blade cutting methods, indicating a similar behavior as to the wire blade methods. Overall it is clear that cutting using abrasive slurry with a plain wire is the best choice when considering the amount of chipping tolerable. Chart 6 shows an overall comparison of all of the methods used for cutting in this report.

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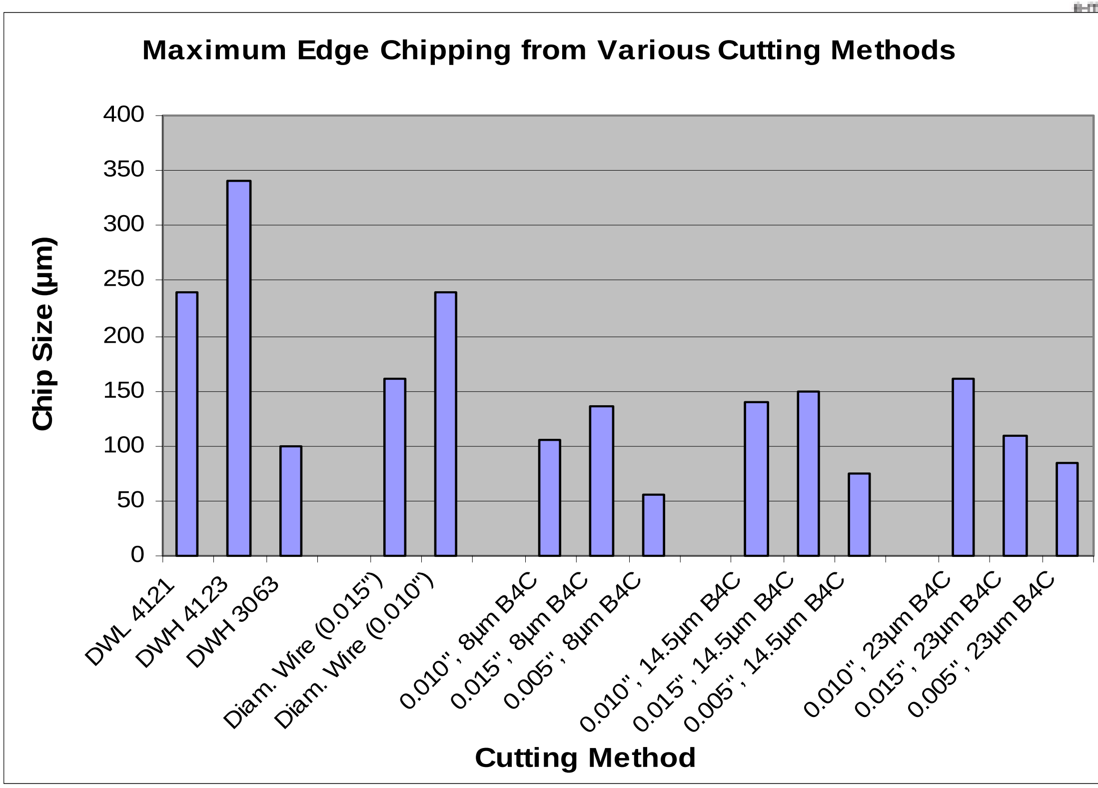

Chart 6: Overall comparison of edge chipping using different cutting methods used in this report. Diamond wheel and diamond wire cutting exhibited similar edge chipping characteristics while the abrasive slurry method for cutting using plain stainless steel wire produced less chipping.

Summary

Kerf loss and edge chipping were found to have little relationship to the thickness of the cutting blade, wire or wheel. In fact the kerf losses were nominally less than expected with the following results:

1. Kerf losses for diamond wheels were found to be approximately 55µm in addition to the width of the cutting wheel. Little material loss is seen from this method.
2. Kerf losses for diamond wire blades were found to be approximately 350µm in addition to the diameter of the wire.
3. Kerf losses for plain wire blades in conjunction with abrasive slurry were found to be less than 20µm in addition to the diameter of the wire. No clear relationship between abrasive particle size and kerf loss were found, with all three sizes investigated producing nearly the same amount of kerf loss.
4. Kerf losses for the same wire diameter and different abrasive slurry sizes were the same.
5. Edge chipping was the highest with the 4" diameter diamond wheels. Diamond wire cutting also produced similar chip sizes in the samples.
6. Using abrasive slurry and plain wires for cutting produced the least amount of edge chipping.