

INVESTIGATIONS ON THE WEAR PROFILE OF DICING WHEELS

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ABSTRACT

During wafer separation through a dicing process the grinding wheel is subjected to wear. This wear not only changes the wheel's diameter but also its cross sectional profile by a rounding of the edges. The actual wear profile of a wheel substantially affects the kerf's geometry and surface finish. For many processes it is attempted to stay as close to a rectangular wheel profile as possible. This is accomplished by periodically interrupting the production process to square the wheel in a truing process. The disadvantage of this method is obvious: the wheel never reaches a stable wear profile, a condition highly undesirable in any production process.

This paper describes a different approach to wheel wear: allowing a wheel to approximate a wear profile and to keep this profile stable. It describes how to simply monitor the wear profile and how to find cutting parameters at which the profile stabilizes. By choosing an appropriate combination of pre-process and in-process dressing stick, grinding wheel, and process parameters a stable wear profile could be reached.

INTRODUCTION

For dicing or slicing ceramic wafers the cutting tool is a diamond wheel, with the abrasive diamond grit embedded in a resin or metal binder. Typically, the depth of cut is great compared to the cut width. Therefore, some unique process features evolve: the vast majority of the cutting action is executed by the wheel's circumference while the cutting conditions at the wheel's sidewall are very poorly defined. Radial wear will reduce the wheel diameter. Furthermore, if the wheel starts out with a rectangular profile, both edge areas of the wheel's circumference are subject to excessive wear which causes a rounding of the corners. All in all, due to wear, a dicing wheel not only changes its diameter, it will also change its shape.

The actual wear profile of a wheel substantially affects the kerf geometry and the surface finish. Furthermore, due to the wheel's edge rounding, the depth of cut has to exceed the workpiece thickness by more than the edge radius; else, the wheel will create a burr at the kerf's bottom.

For many processes it was felt to be desirable to stay close to a rectangular wheel profile. Whenever the inevitable rounding of the corners exceeds a given value, the wheel's profile has to be brought back to a square one in a truing process. The disadvantages of this approach are obvious: the wheel is constantly changing its profile, with the greatest changes right after truing. It is never reaching a stable wear profile. These are conditions, which are highly undesirable in any production process.

An alternative (and novel) approach is to allow the wheel's starting profile to change into a wear profile. Obviously, such a process will only be practical if a stable wear profile will be reached. However, if this is the case, such an approach seems to be vastly superior than maintaining a square profile through repeated truing.

WHEEL PROFILE MEASUREMENT

A precondition for developing a dicing process resulting in a stable wear profile is a simple way to determine the wheel profile. During the experiments, we came up with one to do so. It is based on the following idea: while direct measurements of the wheel contour are time consuming, it is rather easy to optically inspect the kerf's intersection with the workpiece's surface. This measurement not only provides us with the actual kerf width. By the wheel exiting the workpiece vertically before having cut all the way to the end, the contour at the kerf's end represents closely a stretched negative of the wheel's profile. Furthermore, the difference in length of two consecutively cut kerfs represents the reduction of the wheel diameter due to radial wear. A wheel moved up vertically at the same feed position will have cut a shorter kerf if its diameter is smaller, in our case smaller due to radial wear.

Besides establishing a simple way to determine the wheel profile, we also needed an equally simple approach to describe it. Figure 1 depicts the proposed approach. Pairs of lines parallel to the kerf's symmetry axis representing a distance of 95%, 80%, and 50% of the nominal (i.e. fully cut) kerf width are established. Next, the y-coordinates of the intersection of lines and kerf contour are determined. These three y dimensions are adequately describing the wear profile. In order to convert the measured values into the absolute kerf profile, a geometric correction factor had to be applied. This factor takes into account both the actual wheel diameter and the depth of cut.

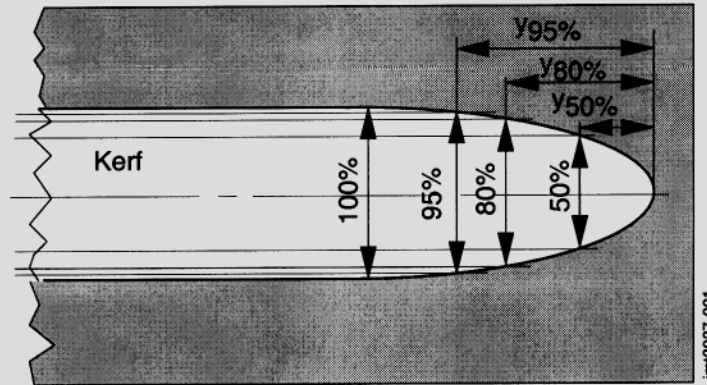


Fig. 1: Kerf end measurements to determine the wheel's wear profile

A combination of radial wear and wear profile measurement allowed to easily establish and describe all required wheel wear data. Such an easy method was a precondition for executing the following wear profile tests.

EXPERIMENTAL PROCEDURE AND RESULTS

Let us now move on to the actual wear experiments and first discuss the wheel break in procedure. At the beginning of each test run, a new wheel was mounted on the dicing machine. Both resin and metal wheels were hubless and were mounted between a pair of flanges on the dicing machine's air bearing spindle. To break them in, we followed industry practice: a wheel was first trued to establish both wheel concentricity and a square wheel profile and then dressed to expose the diamond by receding the binder. The processes for metal bonded wheels differ from the one for resin bonded wheels.

For resin wheels, truing was performed by executing a series of shallow cuts in a dresser board, e.g. made out of SiC. During the workpiece cutting process, resin bonded wheels are self dressing. This is due to the fact that the forces holding a diamond are small enough to allow diamonds to break out after becoming dull. To achieve a wear profile, the resin wheel simply had to be subjected to cutting tests. No further dressing was performed during the tests.

For metal wheels, truing is accomplished by means of a SiC cup wheel. Pre-process dressing is done by executing a couple of dozen cuts in a dressing stick. The stick material (e.g. SiC), as well as grit size, density, porosity, and hardness may be chosen to match the wheel parameters. When cutting the workpiece, metal bonded wheels contrary to resin bonded ones require in-process dressing. This is due to the fact that the forces holding a diamond are much greater than for resin bonded wheels (which also is the reason for their greater longevity). As a result, dull diamonds are not breaking loose during the regular cutting process. To remove dull diamonds and recede the binder in-process dressing is performed by mounting a dressing stick in front of the workpiece. For each feed the metal wheel first cuts the dressing stick before dicing the work piece.

For the investigations, one wheel with a hard resin bond and one with a soft metal bond was used. The material used for the experiments was Altic, a uniaxially hotpressed advanced ceramic consisting of appr. 70% Al_2O_3 and 30% TiC, and a Vickers hardness of 2000 HV. The data storage industry uses it extensively as a wafer material for thin film recording heads. The 1.25 mm thick wafer was cut in a single step, every pass ending within the workpiece in order to allow the inspection of the kerf's end. Figure 2 depicts the test setup. To be able to observe the rather quick change of the wheel profile during the early test phase, we started out with a short first cut. On the consecutive cuts,

the cut length is increasing in increments of 5 mm each. Table I depicts the experiment's dressing and cutting parameters.

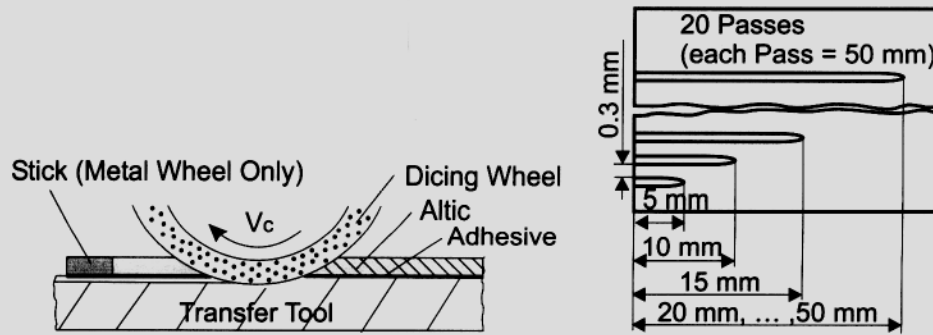


Fig. 2: Test setup

TABLE I
CONDITIONING AND DICING PARAMETERS

Binder	Diamond Grain Size d_p	Rotational Velocity	Cutting Speed v_c	Feed Rate v_f	Depth of Cut a_r	Cut length l_b
Pre-Process Dressing Parameters						
Hard Resin	8 – 16 μm	30,000 RPM	86 m/s	-	0.15 mm	1,500 mm
Soft Metal	6 – 15 μm	20,000 RPM	55.5 m/s	3 mm/s	1.5 mm	625 mm
Dicing Parameters						
Hard Resin	8 – 16 μm	20,000 RPM	55.5 m/s	2 mm/s	1.5 mm	300 mm
Soft Metal	6 – 15 μm	20,000 RPM	55.5 m/s	3 mm/s	1.5 mm	1,250 mm

As mentioned above, resin wheels were used without employing a stick during the cutting of the work piece. Any wear was strictly a result of cutting the Altic wafer. Figures 3 shows the development of the radial wear and the wear profile, respectively. The values $y_{50\%}$, and $y_{80\%}$ were becoming stable very quickly. However, this was not the case for $y_{95\%}$. The radial wear was stabilizing once a cut length of 50 mm has been reached.

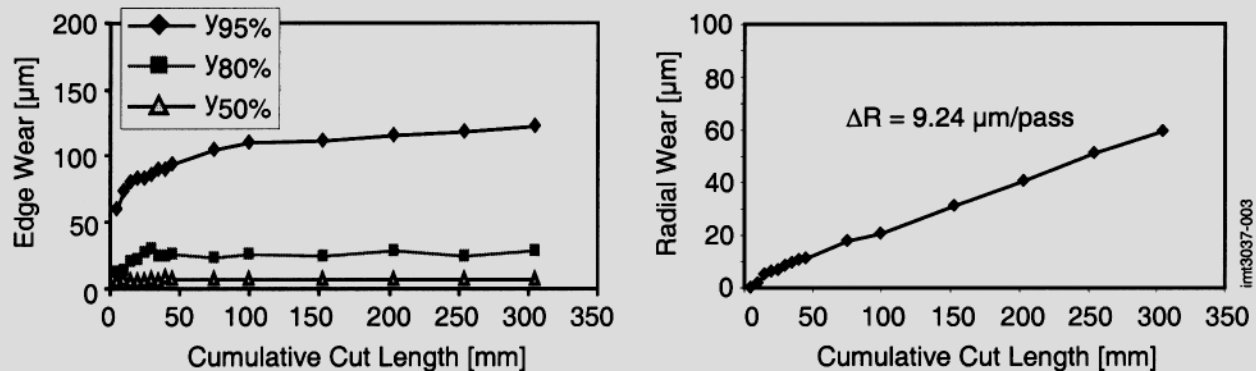


Fig. 3: Development of edge wear and radial wear of a hard resin bonded dicing wheel over cut length.

Of even greater interest was the wear behavior of the metal bonded wheel. Since it wears substantially less than a resin bonded one, in general it is the wheel of choice of production. Due to the mandatory use of a dressing stick during workpiece machining, there was also more potential for process variations dependent on what dressing stick was used. To find an optimal wear profile, four different dressing stick combinations for pre-dressing and in-process dressing were used in combination. Table II demonstrates the wear profile and radial wear results. The minimal

length of cut to achieve a stable wear profile was 450 mm. The radial wear per pass was between 0.45 μm and 0.78 μm .

TABLE II
CHARACTERISTIC WEAR DATA

Dressing Stick Combination	Edge Wear			Radial Wear	Stable State
	$Y_{95\%}$	$Y_{80\%}$	$Y_{50\%}$	ΔR	Above a Cut Length of
A	31 μm	13 μm	4 μm	0.45 $\mu\text{m}/\text{pass}$	500 mm
B	78 μm	30 μm	7 μm	0.50 $\mu\text{m}/\text{pass}$	450 mm
C	-	-	-	0.49 $\mu\text{m}/\text{pass}$	No stable state
D	117 μm	34 μm	7 μm	0.78 $\mu\text{m}/\text{pass}$	700 mm

Obviously it is desirable that a wheel not only reaches a stable wear profile, it also has to create a good kerf sidewall quality. Therefore the wear profile results were compared to kerf wall waviness and flatness. Figure 4 shows the respective average and mean root square waviness and roughness data, respectively. Of particular interest are the waviness results since they are directly related to the wheel's wear profile curvature. By far the best results were achieved by dressing stick combination B. Since it also yielded both wear results and a state of the art surface finish, it is the combination of choice.

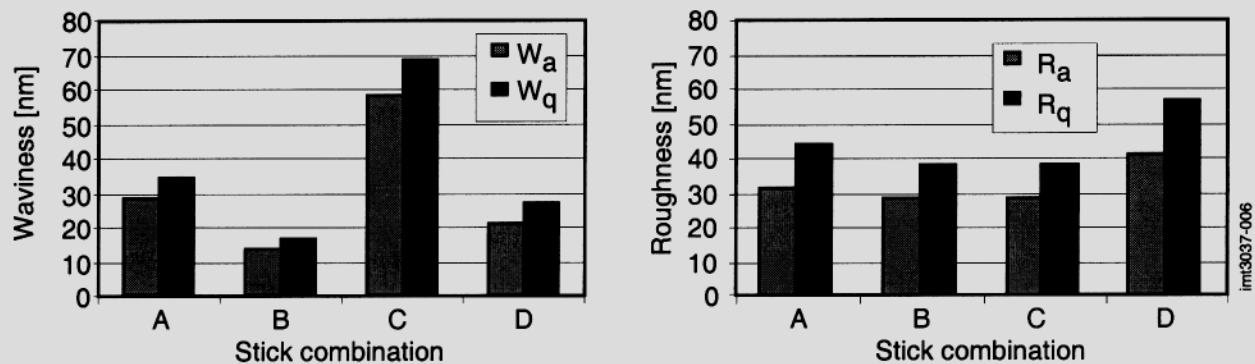


Fig. 4: Stick dependent waviness and roughness of the kerf sidewall using a soft metallic bonded wheel

CONCLUSION

By allowing the dicing wheel to change its profile into a wear profile, the dicing process is greatly simplified. It eliminates the need to squaring up the wheel regularly which in the case of a metal bonded wheel had to be done by cup wheel truing. A stable wear profile was accomplished by using an appropriate combination of dressing sticks for initial and inline dressing. A wheel with a stable wear profile achieved a state of the art flatness and surface roughness. Therefore, a substantially simplified production process was achieved without, in any way, compromising the parts' quality.

Furthermore, a simple method was devised how to measure a wheel's profile. It was accomplished by allowing the wheel to exit the wafer vertically before having cut all the way through. By doing so, the contour at the kerf's end represents the wheel's profile.

Key words: Dicing, Slicing, Wheel wear, Wear profile, Wear profile measurement method