Application of Wheel Scribing/Breaking Technique to Brittle Materials for High Efficient Cutting

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Abstract. Wheel scribing/breaking technique is widely used for cutting LCD glass substrates. Its advantages are lack of kerf-loss, high speed, and dry process in comparison with dicing. In addition, it does not bring any thermal damage in the substrates. In this presentation, wheel scribing/breaking is newly applied to brittle materials used to electronic components for high-efficient and low-cost cutting process.

As brittle materials for electronic components, alumina substrates were prepared to cutting test by scribing/breaking technique. In the result, it was possible to cut straight similarly glass substrates. However, lifetime of a conventional wheel for glasses was very short because alumina was harder than glasses. Therefore, we investigated its wear process and developed a new scribing wheel for alumina ceramic substrates. This enables us to obtain 10 times longer lifetime for scribing even if it is used for alumina.

Introduction

In general, scribing/breaking technique is employed for cutting LCD glass panels, because it is a very simple method[1-3]. Figure 1 shows illustration of scribing/breaking technique[4]. In the scribing process, a cutting tool called a scribing wheel is used. During the scribing process, the scribing wheel creates a groove on the glass substrate, and a median crack initiates at the bottom of the groove. In the breaking process, bending stress causes the median crack to propagate further, and the glass substrate is separated into two. This technique gives us several advantages, which are high-speed dry process, without kerf loss and with less thermal damage compared with dicing and laser cutting.

Recently, brittle substrates for electronic components become small and thin because that electronic instruments is reduced in size and weight. The purpose of this study is to achieve high efficient cutting brittle materials for electronics by using scribing/breaking technique.

Experimental procedure

Figure 2 shows the geometry of a scribing wheel used as a cutting tool. A scribing wheel used in this study had a

![Fig. 1 Illustration of scribing/breaking technique](image1)
![Fig. 2 geometry of a scribing wheel](image2)
diameter, $D$ of 2.0 mm, an inside diameter, $H$ of 0.8 mm, a thickness, $T$ of 0.65 mm, and a tip angle of the wheel, $V$ of $140^\circ$, respectively. Material of a scribing wheel is described in a later chapter. The scribing speed was constant at 100 mm s$^{-1}$, and the scribing load was increased stepwise from 22 N to 32 N. The alumina substrate used in this study was 96%-Al$_2$O$_3$ for electronics (A476T; Kyocera Corporation, Kyoto, Japan) with a thickness of 0.635 mm. After scribing and breaking with hands, a scribing groove and cracks were observed using an optical microscope (KH7700; Hirox, Tokyo, Japan). Substrate edges were observed with a laser microscope (VK-9700; KEYENCE Corporation, Osaka, Japan).

In order to compare the quality of the substrate edge cut off by scribing/breaking technique and the conventional method, the alumina substrate was cut by dicing. The dicing blade used in this comparative experiment was made of resinoid bond with a #400 mesh size (Noritake Co., Limited, Nagoya, Japan), and attached into the dicing equipment (A-WD-100A; Tokyo Seimitsu Co., Ltd., Tokyo, Japan). The processing conditions of dicing were feed speed, $V_w$ of 0.5 mm s$^{-1}$, spindle rotation, $V_s$ of 30,000 rpm (rotation speed was around 80 mm s$^{-1}$), cut depth, $a$ of 0.7 mm. Cutting direction was counter, that is to say down-cut.

In addition, lifetime of scribing wheels for glass and ceramic substrates were investigated. Because that lifetime of a scribing wheel is affected from the hardness of substrates, those were measured by Micro Vickers Hardness Tester (HM-100; Mitutoyo Corporation, Kanagawa, Japan). The testing conditions were Vickers Hardness tests were performed on five times at constant speed of 10 $\mu$m s$^{-1}$, Vickers load of 0.3 kg and holding time of 15 s.

Results and Discussion

**Alumina substrate cut by scribing/breaking.** Figure 3 shows cutting plane of alumina substrate after wheel scribing at 32N and breaking with hands. Very deep crack in the direction of a substrate thickness was formed by scribing. That was around 60 % of the thickness. In order to make post-breaking process easy, the depth of the crack is desirable to be not less than 50 %. By the scribing, the crack was formed into enough depth for breaking.

Figure 4 shows a relationship between crack depth and scribing load. The crack depths were determined from the arrest lines of cutting plane (Fig. 3). The crack depth increased linearly with an increase in scribing force. It is possible that the crack depth in the direction of the thickness is controlled by scribing load.

**Quality of substrate edges cut off by scribing/breaking technique.** In order to examine quality of substrate edge after cutting, there are compared between scribing/breaking with dicing. Figure 5 shows 3D images of substrate edges cut off by each process. By dicing process, the chipping with width of 30 $\mu$m and depth of 8 $\mu$m was found intermittently at the dicing tape side ((Fig. 5 (a)). It
is thought that because of down-cut, the chipping is predisposed to occur at the side where the dicing blade exit (tape side). On the other hand, by wheel scribing, imprint of wheel with width of 10 $\mu$m and depth of 2 $\mu$m was found at substrate edge, but chipping was not found ((Fig. 5 (b)).

**Lifetime of a scribing wheel.** In order to examine the lifetime of a scribing wheel for glass cutting, the crack depths were measured every 10 m in scribing at 32 N. Figure 6 shows the relationship between crack depth and scribing distance. Using a conventional wheel for glass, the crack depth was decreased drastically after scribing 20 m. Thereafter, the alumina substrate was unable to separate into two (unbreakable) at scribing 100 m.

Because that lifetime of a scribing wheel is affected from the hardness of substrates, Vickers hardness of glass (non-alkaline glass) for LCD panel and ceramics for electronic components were measured. Vickers hardness shown in Table 1 were determined by five times tests. The alumina substrate used in this study was about four times harder than non-alkaline glass. Other ceramics were about three times harder than glass, too. It is considered that a wheel tip was abrasive drastically because the hardness of substrate. The abrasion of a wheel tip cause the decreasing of the crack depth.

Therefore, a new wheel for ceramics cutting, “Toughheel®” is developed. Figure 7 shows illustration of a new wheel. The geometry of a new wheel is same a conventional wheel for glass. A conventional wheel for glass is made of sintered PolyCrystalline Diamond (PCD). On the other hand, Chemical Vapour Deposited (CVD) polycrystalline diamond grown on sintered Tungsten Carbide (WC) is used at the tip of a new wheel. Because the hardness of sintered PCD is about 50 to 70 GPa, while CVD polycrystalline diamond is about 80 to 100 GPa$^{5}$, the abrasibve resistance of a wheel tip

![Fig. 5 Substrate edge cut by (a) dicing, (b) wheel scribing](image)

![Fig. 6 Relationship between crack depth and scribing distance using a conventional wheel](image)

<table>
<thead>
<tr>
<th>Substrate materials</th>
<th>Hv 0.3 [N mm$^{-2}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass (non-alkaline glass)</td>
<td>535</td>
</tr>
<tr>
<td>Alumina (96%-Al$_2$O$_3$)</td>
<td>1983</td>
</tr>
<tr>
<td>Si$_3$N$_4$</td>
<td>1469</td>
</tr>
<tr>
<td>8Y-ZrO$_2$</td>
<td>1410</td>
</tr>
</tbody>
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![Fig. 7 Illustration of a new wheel, “Toughheel®”](image)
can be expected to upgrade.

Figure 8 shows the relationship between crack depth and scribing distance using a new wheel. The crack depths were measured every 100 m in scribing at 32 N. Using a new wheel, the crack depth kept constant during scribing 1000 m. Compared with the result of a conventional wheel (Fig. 6), the lifetime of a new wheel was more than ten times longer than the previous one. Figure 9 shows the shapes of the wheel tip. Before scribing, the shapes of a conventional wheel and a new wheel were almost the same. However, after scribing, the wheel tip of a new was still sharp compared with the previous one. The cause of the difference of the abrasive resistance is thought to be because in addition the hardness, the grain of the CVD polycrystalline diamond grown in columnar is harder to drop off than the PCD.

Summary

As Brittle materials for electronic components, alumina substrates were cut using wheel scribing/breaking technique, the following results were obtained.

A deep crack in the direction of a substrate thickness was formed by scribing, chipping was not found in substrate edge after separated into two. In addition, in order to extend lifetime of a scribing wheel, a new wheel “Tougheel®” for ceramics cutting was developed. By using a new wheel, scribing/breaking technique can be applied to brittle materials for electronic components, high efficient cutting can be achieved.

References