# Scribing Tool and Cutting Method for Ultra-thin Glass

**Tomoki Nakagaki[1], Takashi Kawabata[1], Hiroshi Takimoto[2], Tadahiro Furukawa[3]**

[1]Mitsuboshi Diamond Industrial Co., Ltd., 32-12 Koroen Settsu, Osaka 566-0034, Japan
[2]Nippon Electric Glass Co., Ltd., 1979 Takatsuki Takatsuki-cho, Nagahama, Shiga 529-0292, Japan
[3]Yamagata University, 1-808-48 Arcadia Yonezawa, Yamagata 992-0119, Japan

Keywords: Mechanical Cutting, Scribing Tool, Ultra-thin Glass, OLED

**ABSTRACT**

*We developed a new scribing tool for ultra-thin glass, since ultra-thin glass cannot be cut well by general cutting methods. Using this tool, we examined not only the cutting of ultra-thin glass but also the cutting of ultra-thin glass during fabrication process for OLED lighting device.*

## 1 INTRODUCTION

Mitsuboshi Diamond Industrial (MDI) is an equipment manufacturer that provides scribing, breaking, drilling, patterning, and other processing methods with original cutting tools and laser systems, as well as automatic equipment that enables high productivity [1][2]. MDI uses cutting technologies for various types of glasses. MDI provides processing equipment and tools compatible with all kinds of hard and brittle materials, as well as multi-layered structures including metal and organic materials [3][4].

MDI has joined Yamagata University Flexible Electronics Japan-Germany International Collaborative Practical Utilization Consortium (YU-FIC) since 2017, and has been developing ultra-thin glass cutting technology. Yamagata University has been developing technologies to formed transparent electrodes on substrates for OLED lighting by roll-to-roll processes. Ultra-thin glass is one of important substrates [5] [6]. YU-FIC has developed OLED lighting device fabrication by roll-to-roll with Fraunhofer FEP and companies in Germany. In this project, cutting for ultra-thin glass is the most important technical issue. The ultra-thin glass cut by the general glass scribing method has fine split in edge, and the crack progresses in the glass from that point. N. Inayama et al. reported five cutting methods for ultra-thin glass [7]. And they recommended “Simultaneous laser thermal stress cutting method” (SLTSC) with good edge quality.

In this study, we report new mechanical scribing tool and cutting method for ultra-thin glass. This scribing tool was specially designed for ultra-thin glass, and it was possible to cut with high quality by optimizing the tool and process. In addition, for developing OLED lighting devices, we also need to cut substrates for encapsulation and devices fabricated on ultra-thin glass. We also report on the cutting technology of these structures.

## 2 Cutting for Ultra-thin Glass

Ultra-thin glass has good transparency, gas barrier property, thermal stability and surface flatness. Therefore, ultra-thin glass is the most important substrate for flexible OLED lighting. We used "G-leaf" made by Nippon Electric Glass. This glass thickness was 50 micrometers.

### 2.1 General Scribing Tools for Glass

The general scribing tool has a wheel shape as shown in the figure 1.

Fig. 1 General scribing tools

The material of the scribing tool is selected from not only standard super hard materials, but also diamond sintered materials. Furthermore, if a jagged wheel-shaped head is used, it is possible to make a deeper crack in the vertical direction as shown in the figure 2. This jagged wheel-shaped head has greatly improved the productivity of the cutting process.

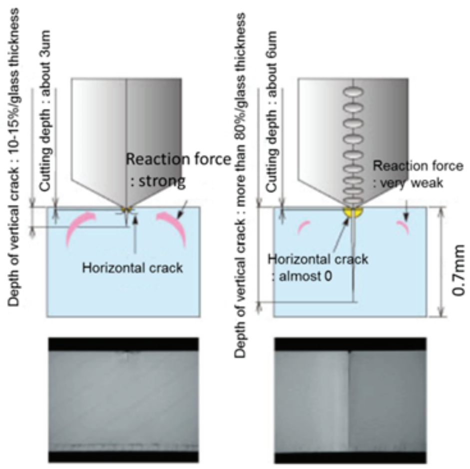



Fig. 2 Mechanism of glass cutting

### 2.2 New Scribing Tool for Ultra-thin Glass

We have developed a new scribing tool for glass with a thickness of 10 micrometers to 100 micrometers. We named this tool SOLID-D. The material of the head was diamond. When scribing using SOLID-D, vertical cracks did not occur in ultra-thin glass. By generating a trigger crack at the end point of the scribe, the vertical crack progressed toward the starting point from the end point.

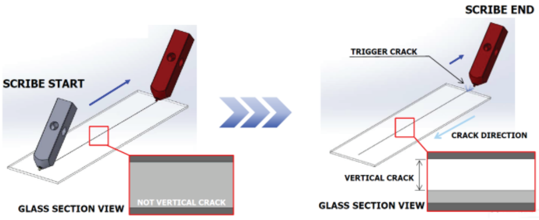
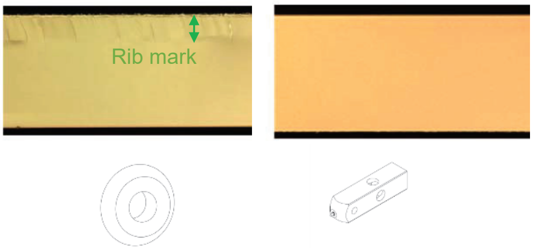



Fig. 3 Mechanism of glass cutting by SOLID-D

We cut ultra-thin glass by the general scribing tool and SOLID-D. When a general scribing tool was used, a rough area called "Rib mark" was generated. On the other hand, the edge of ultra-thin glass cut by SOLID-D was flat and smooth.




General cutting tool SOLID-D

Fig. 4 Cross section of cut part of ultra-thin glass

When ultra-thin glass was bent, the ultra-thin glass cut by the general tool was easily broken. Crack progressed from the rib mark. On the other hand, ultra-thin glass cut by SOLID-D was able to bend to a small radius.

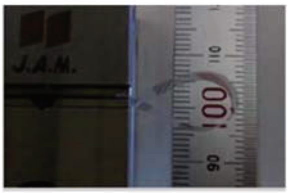


Fig. 5 Bending test of ultra-thin glass cut by SOLID-D

Further fracture stress [8] of ultra-thin glass cut be SOLID-D was measured. Ultra-thin glass was fixed to two plates as shown in the figure 6 and pressed. The glass size was 20x250mm. And the break distance was measured. The fracture stress is calculated from the break distance according to $\sigma = 1.198 \times E \quad d \ / \ (D - d)$ . Break distance and fracture stress are shown in Table 1.

σ : Fracture stress
E : Young's Modulus
D : Break distance
d : Glass thickness

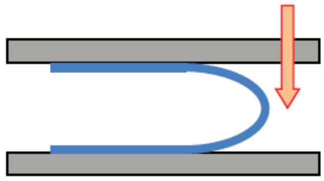


Fig. 6 Measurement method for break distance

Table 1 Break distance and fracture stress

| Break Distance, mm | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5 | 1.1 | 5.0 | 1.1 | 3.8 | 6.5 | 1.0 | 1.2 | 4.5 | 2.2 | 1.1 | 1.2 |
| **Fracture Stress, MPa** | | | | | | | | | | | |
| 3016 | 4164 | 883 | 4164 | 1166 | 678 | 4603 | 3802 | 983 | 2034 | 4164 | 3802 |

### 2.3 Relationship between Glass Thickness and Scribing Tool

Based on our previous knowledge and this result, the relationship between the glass thickness and the suitable scribing tool was summarized in the figure 7.


Fig. 7 Relationship between glass thickness and cutting tool

## 3 Cutting for Ultra-thin Glass with Adhesive for Encapsulation

OLED devices cannot emit light when exposed to moisture. Therefore, OLED devices are encapsulated to protect them from moisture. For encapsulation of flexible OLED lighting, it is advantageous to laminate a gas barrier substrate to the lighting element with an adhesive. Ultra-thin glass is one of the flexible substrates with perfect gas barrier properties. The adhesive layer with a protective film was set on ultra-thin glass. The protective film was peeled off when ultra-thin glass with the adhesive was laminated on the light emitting element. Therefore, we tried to cut ultra-thin glass with the adhesive and the protect film .

Adhesives were provided from tesa. The product numbers were 6150x series and 6153x series. Thicknesses of the adhesives were 25 micrometers and 50 micrometers. And the adhesive contained desiccants. The adhesive was protected on both sides with a protective film. Thickness of the protective film was 50 micrometers. The protective film on one side was peeled off, and the adhesive layer was laminated on ultra-thin glass.

| |
|---|
| Ultra-thin Glass |
| Adhesive |
| Protect Film |

Fig. 8 Ultra-thin glass with adhesive for encapsulation

### 3.1 Cutting Tool for Plastic film

The film could not be cut with the tools used for glass. For film cutting, we used a special tool that was named Solidbow. Solidbow was a sharp-edged wheel.

Fig. 9 Solidbow

### 3.2 Cutting Process of Ultra-thin Glass with Adhesive for Encapsulation

First, scribe lines were drawn on ultra-thin glass by SOLID-D. Next, the protective film was cut by Solidbow. The tip of the cutting tool penetrated into the adhesive layer, but it did not touch the glass. Cutting process and process conditions are shown in the figure 10 and table 2. And the cut cross section image is shown in figure 11. The thickness of the adhesive layer was 25 micrometers. It was confirmed that the cut section of the ultra-thin glass was flat and smooth.

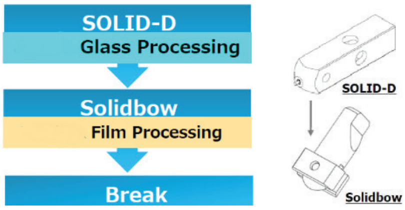



Fig. 10 Cutting process of Ultra-thin glass with adhesive.

Table 2 Process conditions

| | Glass | Film |
|---|---|---|
| Pressure | ≈0.9N | ≈0.6N |
| Depth | 0.06mm | 0.7mm |
| Speed | 100mm/sec | 50mm/sec |

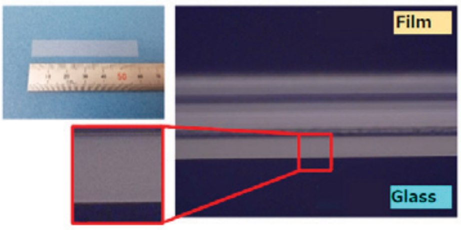



Fig. 11 Cut section of ultra-thin glass with adhesive (tesa 6153x)

### 3.3 OLED Lighting Fabricated Using Ultra-thin Glass

After cutting the ultra-thin glass with a transparent electrode fabricated by Roll-to-Roll, Insulating patterns were printed by screen printing and the OLED element was deposited on it. And it was encapsulated with ultra-thin glass and adhesive. Device structure and lighting device photos are shown in Figure 12 and Figure 13.

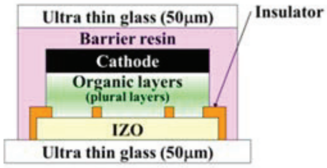



Fig. 11 Structure of flexible OLED lighting


Fig. 12 Photos of OLED lighting using ultra-thin glass

## 4 Cutting for Ultra-thin Glass + Adhesive + Ultra-thin Glass

YU-FIC has developed OLED lighting device fabrication by Roll-to-Roll. Therefore we need to cut roll lighting sample after encapsulation to sheets. Structure of cut position was ultra-thin glass + adhesive + ultra-thin glass.

### 4.1 Cutting process of Ultra-thin Glass + Adhesive + Ultra-thin Glass

The cutting samples were ultra-thin glass laminated with ultra-thin glass using adhesive. Thickness of adhesive was 50 micrometers or 25 micrometers. And the adhesive contained desiccants. After scribing both glass surfaces by SOLID-D, the sample glass was broken along the scribe line. The adhesive was torn off with the power to separate. Cutting process and process conditions are shown in the figure 14 and table 3.

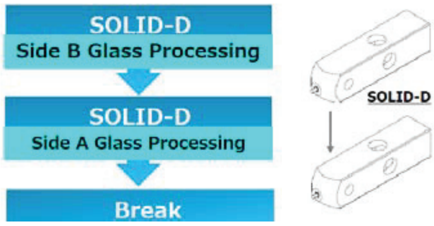
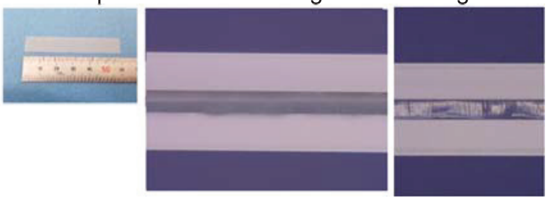



Fig. 14 Cutting process of ultra-thin Glass + adhesive + ultra-thin Glass

Table 3 Process conditions

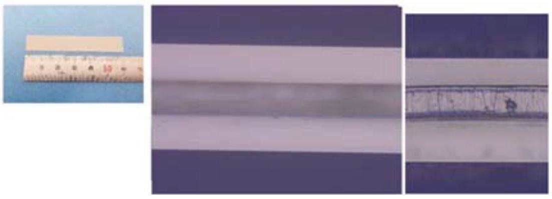
| | Glass |
|---|---|
| Pressure | ≈0.9N |
| Depth | 0.06mm |
| Speed | 100mm/sec |

When the adhesive film thickness was 25 micrometers and 50 micrometers, the samples could be cut perfectly. The cut samples are shown in Figure 15 and figure 16.



tesa 6153x tasa 6150x

Fig. 15 Cut section of ultra-thin glass + adhesive (25um) + ultra-thin Glass



tesa 6153x tasa 6150x

Fig. 16 Cut section of ultra-thin glass + adhesive (50um) + ultra-thin Glass

## 5 CONCLUSIONS

We developed the new scribing tool for ultra-thin glass. The edge of the ultra-thin glass cut by this tool was flat and smooth. Therefore the cut glass could be bent to a small radius. In addition, we were able to cut ultra-thin glass with adhesive and substrate consisting of ultra-thin glass + adhesive + ultra-thin glass.

## REFERENCES


[1] K. Yahata, E. Ohmura, S. Shimizu, M. Murakami, "Clarification of Crack Curvature Mechanism and Estimation of Crack Shape in Laser Scribing of Glass", The Review of Laser Engineering, Vol.20, No.1, pp. 46-53 (2012).

[2] N. Tomei, "Cutting Technology of Glass Sheet by Scribing and Breaking", NEW GLASS, Vol.29, No.112, pp. 37-43 (2014).

[3] N. Tomei, K. Murakami, T. Hashimoto, M. Kitaichi, S. Hirano, T. Fukunishi, "Development of a Scribing Wheel for Cutting Ceramic Substrates and its Wheel Scribing and Breaking Technology", Journal of the Japan Society for Abrasive Technology, Vol.59, No.12, pp. 705-710 (2015).

[4] N. Tomei, K. Murakami, T. Hashimoto, T. Fukunishi, "Crack propagation behavior of hard-brittle materials by wheel scribing", Journal of the Japan Society for Abrasive Technology Vol.62, No.9, pp. 473-478 (2018).

[5] T. Furukawa, K. Mitsugi, S. Akiyama, H. Itoh, D. Kobayashi, T. Suzuki, H. Kuroiwa, M. Sakakibara, K. Tanaka, N. Kawamura, M. Koden, "ITO Pattern Formed by Roll-to-Roll Process on Ultra-thin Glass", Proc. IDW' 14, FLX3-4L, pp. 1428-1429 (2014).

[6] T. Furukawa, N. Kawamura, T. Noda, Y. Hasegawa, D. Kobayashi, M. Koden, "Novel Roll-to-Roll Fabrication Processes of Transparent Electrodes on Ultra-Thin Glass", Proc. IDW '17, pp.1535-1538 (2017).

[7] N. Inayama, S. Miwa, and T. Fujii, "Cutting Method for Electronic Device Made Using Ultrathin Glass", Proc. IDW '16, pp511-514 (2016).

[8] M. Inoue, S. Yoshida, J, Matsuoka, Y, Kato, H. Yamazaki, "2-Point bending Strength of Glass Fibers", Journal of the Society of Materials Science, Japan, Vol. 57, no. 6, pp. 557-561 (2008).