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To cite this article: Koji Matsumaru *et al* 2005 *Sci. Technol. Adv. Mater.* **6** 120

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## Advanced thin dicing blade for sapphire substrate

Koji Matsumaru<sup>a</sup>, Atsushi Takata<sup>b</sup>, Kozo Ishizaki<sup>a,\*</sup>

<sup>a</sup>*Nagaoka Gijutsu-Kagaku Daigaku, Nagaoka University of Technology, Niigata 940-2188, Japan*

<sup>b</sup>*Nano-TEM Co., Ltd, 1-485 Shimogejo Nagaoka, Niigata 940-0012, Japan*

Received 10 September 2004; revised 20 October 2004; accepted 24 November 2004

### Abstract

Advanced thin dicing blades for cutting sapphire were fabricated and evaluated for cutting performance with respect to dicing blade wear and meandering of cutting lines. Three kinds of different commercial blades were used to compare the cutting performance. These blades had the same thickness and the same diamond grain size. The matrix material of one dicing blade was nickel–phosphorus alloy and two other were a vitric material. Newly developed dicing blades consisted of a vitric material with pore. A dicing machine was used for cutting sapphire. Turning velocity, cutting depth and feeding rate were  $20,000 \text{ min}^{-1}$ ,  $200 \mu\text{m}$  and  $1 \text{ mm s}^{-1}$ , respectively. Cutting directions were  $\langle 11\bar{2}0 \rangle$  and  $\langle 01\bar{1}0 \rangle$ . All blades could cut 1000 mm and more in the  $\langle 11\bar{2}0 \rangle$  direction. On the other hand, commercial dicing blades generated meandering lines and were broken only by 50 mm of cutting length in  $\langle 01\bar{1}0 \rangle$  direction. Fabricated blade can cut 1000 mm and more in  $\langle 01\bar{1}0 \rangle$  direction. The wear of fabricated dicing blade was the largest in the dicing blades. Although cutting performance of commercial dicing blades depended on the sapphire orientation, that of fabricated blade was independent of the sapphire orientation. It has been confirmed that the fabricated dicing blade was kept a cutting ability by flash diamonds on the dicing blade surface, which were created by wear of blade during cutting sapphire. Low cutting ability of commercial blades increased cutting force between with increase of cutting length. The increased cutting force produced to bend a blade and cutting lines, and finally a fracture of blade.

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**Keywords:** Dicing blades; Diamond; Sapphire; Porous material; Cutting ability

### 1. Introduction

Sapphire is used as the substrate of a blue light emitting diode (LED). In a commercial manufacturing process, a sapphire single crystal plate with LED device is scratched by diamond needle and divided into LED device chips by bending [1]. The yield of products in this process is low due to the corrugated edge of LED device chips. On the other hand, many electronic devices are produced by a dicing process, which is used thin grinding wheel, i.e. a dicing blade. Although advantage of a dicing process is high precision of cutting, commercial dicing blades are not enough for cutting of sapphire substrate. New dicing blades, which form a strait grooves without chipping, are required for higher yield in LED manufacturing process. Our research group developed advanced grinding wheels for

efficient and accurate machining of hard materials, such as engineering ceramics [2–5]. In this study, advanced thin blades are fabricated by using our research group knowledge and evaluated for cutting performance with respect to dicing blade wear and meandering of cutting lines.

### 2. Experimental procedure

Three kinds of different dicing blades with 40 mm in inner diameter and 54 mm in outer one were used to compare the cutting performance. Table 1 shows a classified table of dicing blades. These blades had the same thickness ( $200 \mu\text{m}$ ) and the same diamond grain size ( $10\text{--}20 \mu\text{m}$ ). The matrix material of a commercial dicing blade was a nickel–phosphorus alloy and two other blades were a vitric material. Newly developed dicing blades consisted of a vitric material with pores. A dicing machine (TOKYO SEIMITSU A-WD-10A) was used for cutting sapphire.

\* Corresponding author. Tel.: +81 258 47 9156; fax: +81 258 47 9156.  
E-mail address: [ishizaki-lab@ishizaki.nagaokaut.ac.jp](mailto:ishizaki-lab@ishizaki.nagaokaut.ac.jp) (K. Ishizaki).

Table 1  
Certification of dicing blades

Nomenclature	Matrix material	Grain size of diamond ( $\mu\text{m}$ )	Blade thickness ( $\mu\text{m}$ )
A	Ni–P alloy (dense)	10–20	$200 \pm 10$
B	Glass (dense)	10–20	$200 \pm 10$
C	Glass (porous)	10–20	$200 \pm 10$

The outer diameter of flange for fixing dicing blade was 50 mm. The exposure length of dicing blade was 2 mm in the initial condition. Turning velocity and feeding rate were  $20,000 \text{ min}^{-1}$  and  $1 \text{ mm s}^{-1}$ , respectively. Cutting depth was  $200 \mu\text{m}$  at the initial line by controlling of a distance between the center of a dicing blade and a sapphire surface. That distance was kept in a constant. Wear of dicing blade was evaluated by groove depth. Sapphire substrates with 50.8 mm in diameter and 0.5 mm of thickness were used as workpieces. Cutting directions were  $\langle 11\bar{2}0 \rangle$  and  $\langle 01\bar{1}0 \rangle$  of sapphire substrate.

### 3. Results and discussions

Figs. 1 and 2 show cross-sections of commercial dicing blade which is a nickel–phosphorus alloy and a fabricated dicing blade which is vatic material. Commercial dicing blade is dense, a fabricated dicing blade has pores. All blades can cut a sapphire substrate in 1000 mm and more in the  $\langle 11\bar{2}0 \rangle$  direction, as shown in Fig. 3. On the other hand, commercial dicing blades generate meandering lines and are broken only by 50 mm of cutting length in  $\langle 01\bar{1}0 \rangle$  direction, as shown in Fig. 4. A fabricated blade can cut a sapphire substrate in 1000 mm and more in  $\langle 01\bar{1}0 \rangle$  direction. Fig. 5 shows groove depth,  $D$ , as a function of cutting length,  $L$ , in the  $\langle 11\bar{2}0 \rangle$  direction with different dicing blades. Groove depth of the fabricated dicing blade is the lowest in the

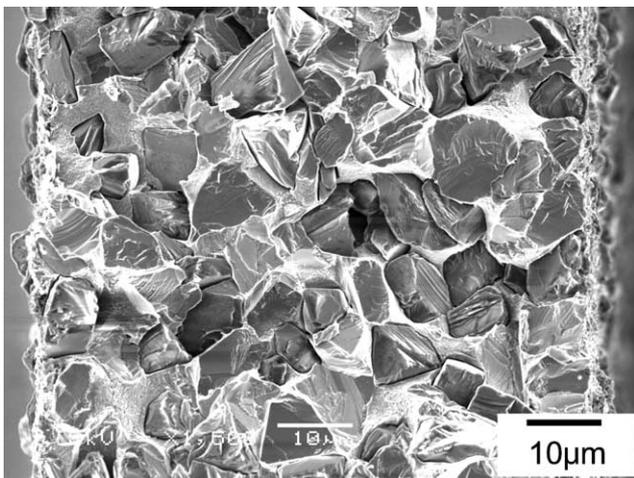


Fig. 1. Cross-section of commercial dicing blade which is a nickel–phosphorous alloy dense matrix.

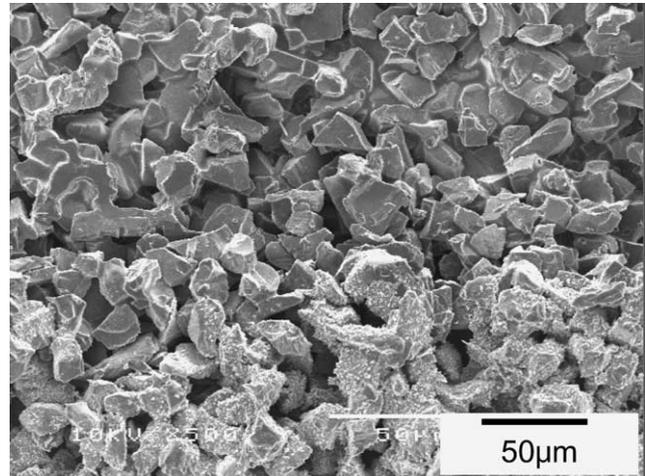


Fig. 2. Cross-section of fabricated dicing blade which is porous glass material.

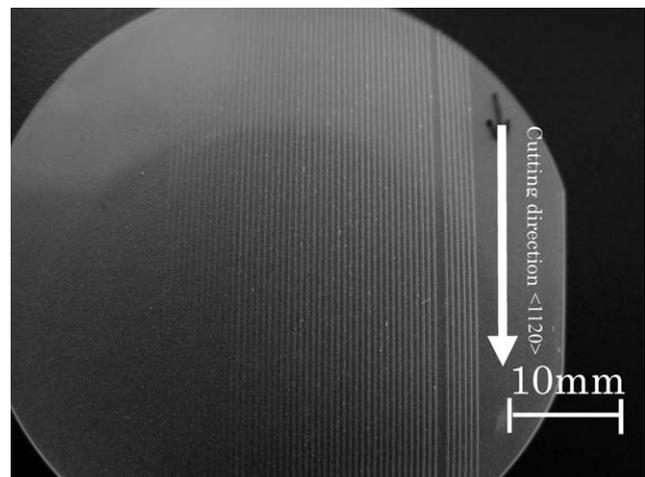


Fig. 3. Sapphire surface after cutting by fabricated dicing blade. All blades can cut 1000 mm and more in the  $\langle 11\bar{2}0 \rangle$  direction.

dicing blades. This result means that wear of the fabricated dicing blade is the largest in the dicing blades. It is suggested that the fabricated dicing blade has flesh diamonds on the dicing blade surface. Fig. 6 shows groove depth as a function of cutting length in the  $\langle 01\bar{1}0 \rangle$  direction. Cross marks show a broken point of commercial dicing



Fig. 4. Sapphire surface after cutting by commercial dicing blade. Commercial dicing blades generate meandering lines and are broken only by 50 mm of cutting length in  $\langle 01\bar{1}0 \rangle$  direction.

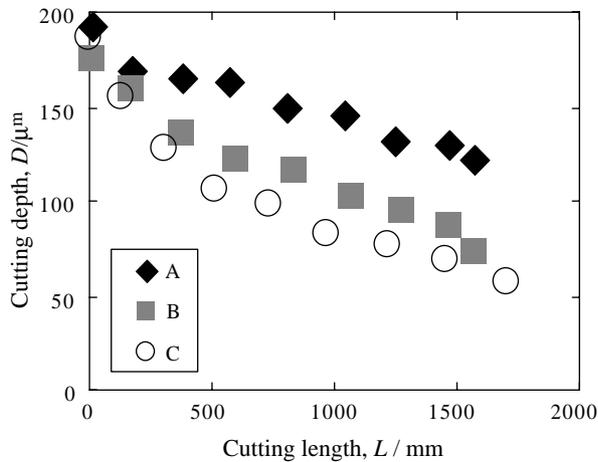


Fig. 5. Groove depth as a function of cutting length in the  $\langle 11\bar{2}0 \rangle$  direction. Groove depth of fabricated dicing blade is lowest in the dicing blades.

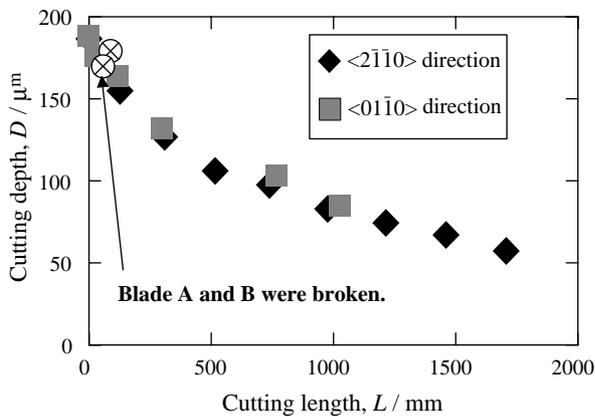


Fig. 6. Groove depth as a function of cutting length. Cross marks show broken point of commercial dicing blades in  $\langle 01\bar{1}0 \rangle$  direction. Groove depths of fabricated dicing blade of different cutting directions are almost same.

blades in  $\langle 01\bar{1}0 \rangle$  direction. Groove depths of fabricated dicing blade of different cutting directions are almost same. It is recommended that the fabricated dicing blade is independent of the sapphire orientation. Although cutting performance of commercial dicing blades depend on the sapphire orientation, that of fabricated blade is independent of the sapphire orientation. It has been confirmed that commercial blades have lower cutting ability than that of fabricated blade. Low cutting ability of commercial blades increase a cutting force with increase of a cutting length.

The increased force produced to bend blade and cutting lines, and finally a fracture of blade.

#### 4. Conclusions

Advanced thin dicing blade for cutting sapphire was fabricated, that blade was vitric material with pores. Three different dicing blades were evaluated and concluded for cutting performance with respect to dicing blade wear and meandering of cutting lines.

1. Cutting performance of commercial dicing blades depend on the sapphire orientation, that of fabricated blade is independent of the sapphire orientation.
2. The wear of fabricated dicing blade is largest in the dicing blades.
3. The fabricated dicing blade is kept a high cutting ability by flesh diamonds on the dicing blade surface which created by wear of blade during cutting sapphire.

#### Acknowledgements

The authors thank the Ministry of Education, Culture, Sports, Science and Technology of Japan for financial support of this work through the 21st Century Center of Excellence (COE) Program. A part of this research was also supported by New Energy and Industrial Technology Development Department (NEDO), Japan.

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