Study on Scribing Sapphire Wafer for LED

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Abstract

LED chips are produced by cutting the sapphire on which GaN is evaporated. To cut the sapphire wafer into each LED chip, at first the wafer is scribed by diamond tool. To get the sharp groove shape for the nice cutting plane it is important the diamond tool shape, load, etc when the wafer is scribed. Here we tried to simulate the scribing process and get the scribing condition to reduce the wear rate of diamond tool for the sharp groove shape.

1. Objectives and Background

High luminance LED is used for backlight unit of LCD screen of mobile phone. To increase luminance of the LED we try to increase the efficiency of LED. One of these efforts is the sapphire wafer on which GaN is evaporated is scribed by diamond tool instead of laser cutting method to get LED chips from the wafer, because laser cutting method makes much heat that reduces the luminance efficiency of the LED chips.

But diamond scribing has a demerit. When the wafer is scribed and broken, GaN layer is broken because the crack propagated into the wrong direction like the upper right corner of LED of Figure 1.

To reduce this demerit, diamond scribing process is studied and simulate by finite element method in this paper.

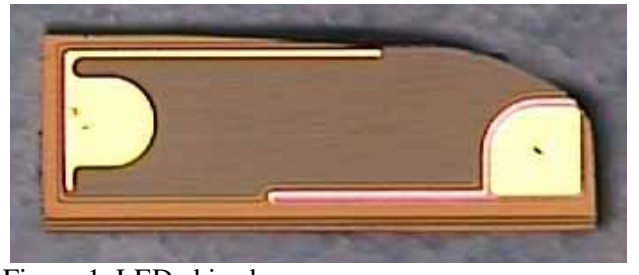


Figure 1. LED chip shape

2. Results

2-1. Measurement

It is important to measure groove shape of wafer after scribing by diamond tool to understand breaking process. Sapphire wafer of Figure 1 has 50mm diameter and 80 micrometer thickness. Figure 3 shows the groove shape at the position of wafer at Figure 2 that is made by diamond scribing. We can learn from Figure 3 the grooves on wafer become smoother and the depth and width is smaller because the diamond tool is worn according scribing is processed. The depth and width of groove on wafer is measured from the cross section image by SEM equipment like Figure 4 and the results are shown at Table 1.

Edge shape of Diamond tool is shown in Figure 5 before and after scribing. After scribing the edge of diamond is worn as Figure 5. The radius of diamond tip edge is about 5 micrometers before scribing that is very large comparing scribing groove depth and width (Table 1). That means only diamond tip edge keeps in contact with sapphire wafer during scribing process.

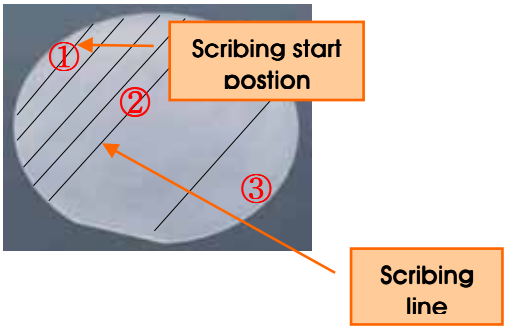
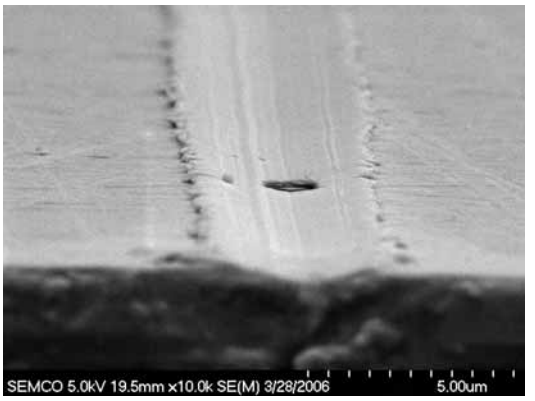
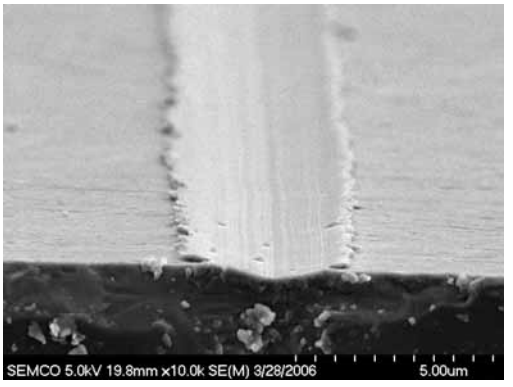


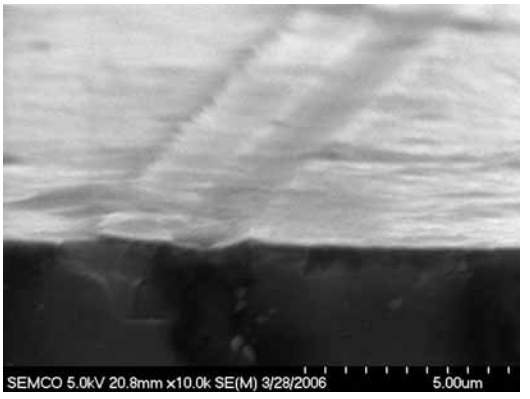
Figure 2. The measured position of scribing line on sapphire wafer



(a)



(b)



(c)

Figure 3. SEM images of groove on sapphire wafer at the position of Figure 2. ((a):①, (b):②, (c):③ of Figure 2.)

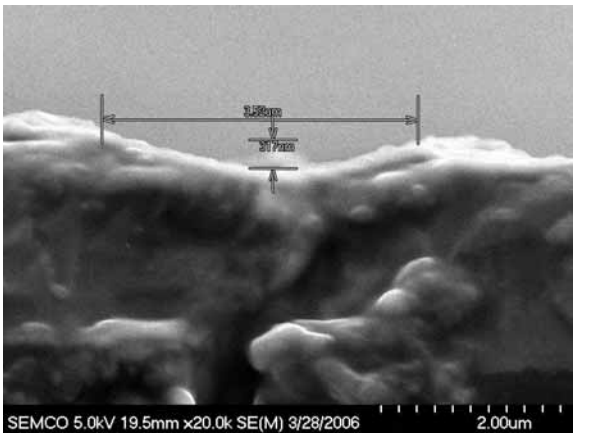
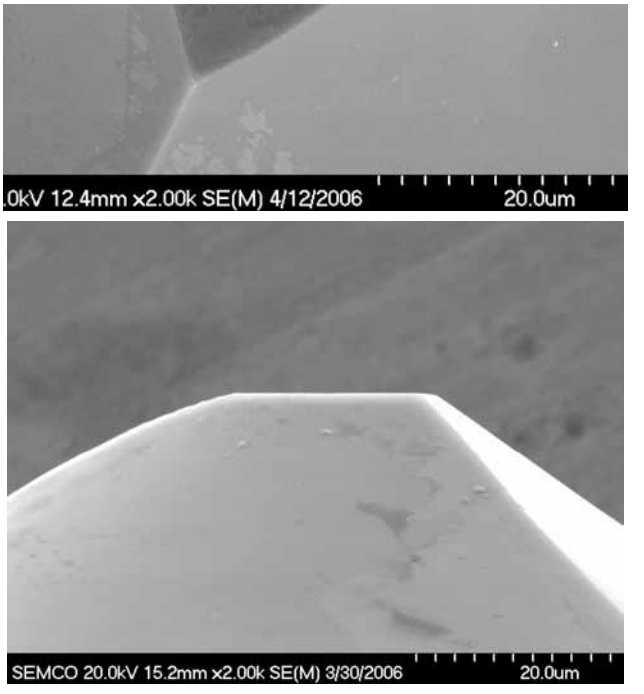


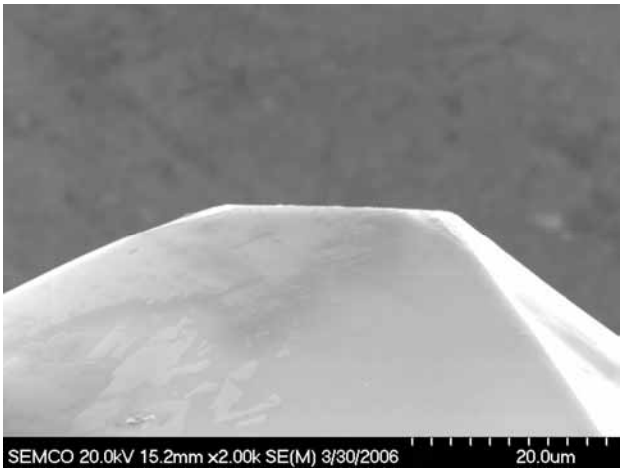
Figure 4. Cross section of the sapphire wafer that has a groove

Table 1. Measurement results of groove depth and width at each position of sapphire wafer after the wafer is scribed by diamond.

position	depth	width
①	0.32	3.52
②	0.28	2.45
③	0.23	1.85



(a)



(b)

Figure 5. Diamond tool edge shape
((a): before scribing, (b): after scribing)

2-2. Simulation

To simulate the diamond scribing process using finite element method, we assumed sapphire wafer behaves in a ductile manner even though it is so brittle because scribing depth is so small.[1]

For simulating the scribing process of sapphire wafer, AdvantEdge commercial software is used on the base of the constitutive equation like the followings. [1]

$$\left(1+\frac{\dot{\varepsilon}^p}{\dot{\varepsilon}_0^p}\right)=\left[\frac{\bar{\sigma}}{g(\varepsilon^p)}\right]^{m_1} \quad for \dot{\varepsilon}^p \le \dot{\varepsilon}_t^p \tag{1}$$

$$\left(1+\frac{\dot{\varepsilon}^p}{\dot{\varepsilon}_0^p}\right)\left[1+\frac{\dot{\varepsilon}_t^p}{\dot{\varepsilon}_0^p}\right]^{\frac{m_2}{m_1}}=\left[\frac{\bar{\sigma}}{g(\varepsilon^p)}\right]^{m_2} \quad for \dot{\varepsilon}^p > \dot{\varepsilon}_t^p$$

where, $\bar{\sigma}$: effective Mises Stress

ε^p : accumulated plastic strain

$\dot{\varepsilon}_0^p$: reference plastic strain rate

m_1, m_2 : low and high strain rate sensitivity exponents

$\dot{\varepsilon}_t^p$: threshold strain rate

$g(\varepsilon^p)$: flow stress

(accounts for the thermal softening and strain − hardening effects)

According to this constitutive equation and material properties of sapphire wafer and diamond tool, scribing process is simulated like Figure 6 that shows stress distribution at the wafer and the diamond tool. Groove shape from simulation is similar with experimental results as shown in Table 2.

Diamond wear rate can be expressed like equation (2).

$$V=\frac{kPA}{3h} \tag{2}$$

where, V : wear volume

k : wear coefficient

P : normal pressure

A : contact area

h : hardness

According to the equation (2) if the normal pressure of diamond is reduced, the wear volume of diamond tool can be decreased because the other factors are constant. Figure 7 shows the pressure distribution of diamond tool from simulation result that makes diamond tool worn during scribing like Figure 5(b).

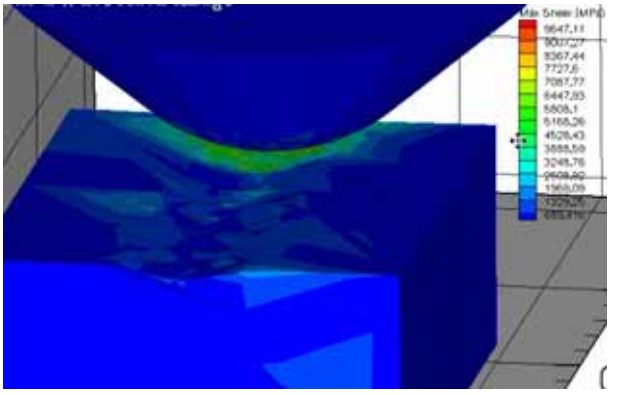


Figure 6. Simulation result of diamond scribing.

Table 2. Comparison between measured groove shape and simulated one of sapphire wafer after scribing

	depth	width
Measurement	0.32	3.52
simulation	0.34	3.38

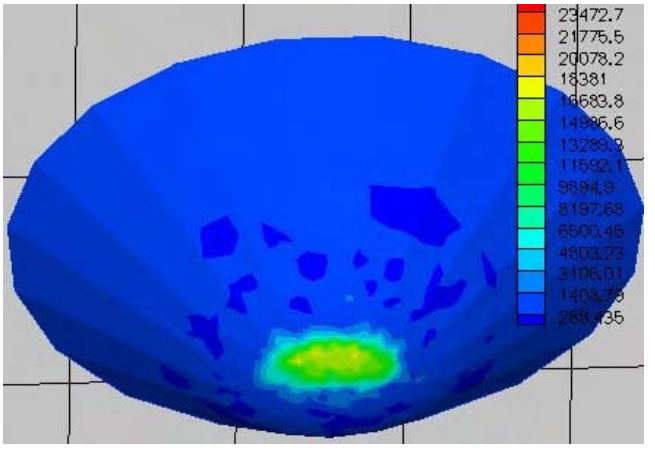


Figure 7. Pressure distribution on the diamond tool tip that keeps in contact with sapphire wafer during scribing process

3. Impact

It is predicted LED will replace fluorescent lamp in future, if the cost of LED is decreased and the luminance efficiency is increased. So diamond scribing process will be used more than laser cutting because it can increase the luminance efficiency of LED chips. I want this paper contributes to improving diamond scribing process of sapphire wafer for LED. Scribing process of sapphire wafer is simulated by using measured diamond shape, and the simulation result is similar with experimental results.

4. References

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