

DICING OF HB-LED DEVICES EMBEDDED IN COPPER SUBSTRATES

Paper (M101)

Marie Di Marco ¹, Alexandre Pauchard ¹, Akos Spiegel ¹, Bernold Richerzhagen ¹, Notker U. Kling ²

¹ Synova SA, Ecublens, Switzerland

² Synova USA Inc, Fremont, USA

Abstract

High-brightness light emitting diodes (HBLEDs) are often embedded into a heat sink layer, providing an efficient and inexpensive method of expanding the surface area necessary to dissipate heat generated during operation. Copper (Cu), copper tungsten (CuW) and Molybdenum (Mo) layers offer high-performance thermal management due to high thermal conductivity and a low thermal resistance.

Classical dicing techniques, such as laser or diamond blade cutting, face a number of constraints and challenges when used to cut Cu and CuW embedded LED chips, such as fast wear of the blades, low speed and heat damages. The Laser MicroJet® technology, combining a hair-thin water jet with a high-power laser beam, offers wear-free, fast and damage-free cutting of LED devices.

The singulation of copper embedded LED devices has been successfully performed using the Laser MicroJet® technique. Q-switched solid-state lasers operating at a wavelength of 532nm and a repetition rate of 30kHz were combined with 40-µm diameter water jet. Copper substrate thicknesses of up to 600µm were processed with good cut quality, despite large film thickness non-uniformities. Secondly, 50-µm thick copper layers deposited on sapphire wafers were also diced successfully with 14 passes at 200mm/s. Thirdly, CuW wafers with a thickness of 250µm have been diced with an excellent quality.

Introduction

Since their introduction in 1962, light emitting diodes (LEDs) have gained widespread use. Today, special deposition techniques have made possible LEDs with much higher brightness than traditional devices. This opens up many new applications such as:

- Cell phone flash modules

- Automotive interior and backlighting
- Liquid-crystal display (LCDs) backlighting
- Broad general lighting applications

The advantages of these devices include their lower power consumption, long service life and design flexibility as compared to traditional lighting systems. The stability, and thus longer device lifetime, is critical for high-reliability applications.

An undesirable by-product of HBLEDs is excessive heat generation. For that reason, HBLED devices are embedded in a heat sink, like copper foil for example, which is then singulated to obtain individual HBLEDs.

The manufacturing process involves dicing on the emission side of the HBLED. The precision demanded is stringent, as the LED needs a very straight and smooth edge to have good performance. The total kerf tolerance for positioning, plus edge roughness, is of 1-2 µm. The copper foil edge must be within a few microns from the embedded component. Avoiding heat damage is the key issue for this application.

1. Laser MicroJet® Technology

In 1993, a laser light guiding water jet was successfully developed at the Institute of Applied Optics (EPFL, Lausanne, Switzerland) and patented as Laser MicroJet® (LMJ). The laser beam is focused into a nozzle where it is combined with a thin high-pressure water jet. The laser beam is guided onto the workpiece by total internal reflection on the water/air interface, similarly to a standard optical fiber. This yields a significantly longer working distance than for a conventional laser, and avoids focusing issues. A schematic of the working principle is shown in Figure 1.

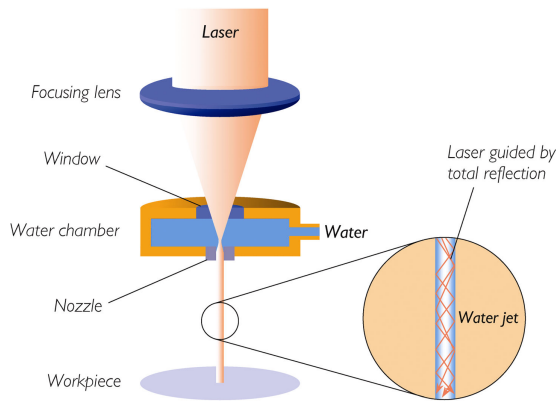


Figure 1: Laser MicroJet® principle.

The most commonly used laser for the LMJ is the Nd:YAG, the frequency doubled (green) Nd:YAG laser and the frequency tripled (UV) Nd:YAG. The water jet speed is proportional to the square root of the pressure and not dependent on the jet diameter. Directly after the nozzle, the water jet contracts to 83% of the diameter of the opening diameter of the nozzle, which makes it an even thinner and more precise tool for cutting and drilling.

The LMJ greatly reduces the heat input compared to other techniques, as the surroundings of the processed area are efficiently cooled by the water jet. The use of a pulsed laser allows the LMJ to cool down the workpiece even further during the time between the pulses. In addition, the surface contamination due to sputtering from the process is eliminated: the removed material is instantly cooled by the water jet and will not attach to or heat damage the surface. The particles caused by the dicing process are washed off with water.

2. Singulation of bare copper foil

Tests were performed on bare copper samples to determine the quality of the dicing using the LMJ technology. Two types of dicing were used:

- Continuous lines at a given pitch, which is adequate for workpieces with a regular pattern;
- Singulation of individual chips, in the shape of circles (diameter of 2.8 mm) or rounded squares (radius of the corners of 0.4 mm).

The list of samples with the type of dicing used is displayed in Table 1.

Sample	Dimension	Thickness	Dicing
1	70 x 70 mm ²	50 μm	Continuous
2a	4 x 4 cm ²	100 μm	Continuous and individual
2b	4 x 4 cm ²	300 μm	individual (circles)
2c	4 x 4 cm ²	300 μm	Individual (rounded squares)

Table 1: Samples of bare copper foil.

Sample 1 was cut into 1mm² squares with good edge qualities, as shown in Figure 2. The kerf width was measured to be of 30μm. Burrs of ~10μm have been observed, but could probably have been avoided by cleaning the sample before dicing. The cutting speed could be increased, but it would also increase the burr width.

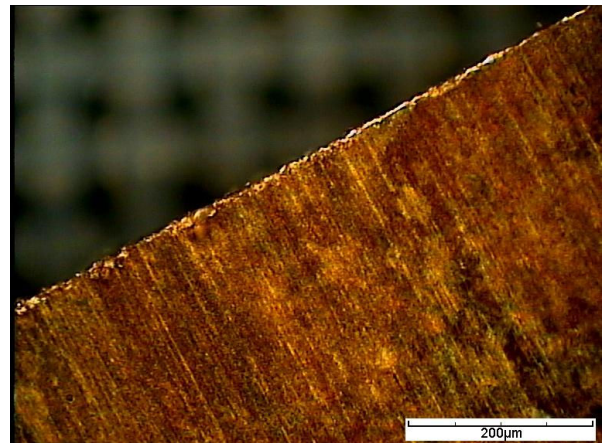


Figure 2: Backside view of sample 1 singulation into 1mm² squares.

Samples 2a, 2b and 2c have been diced with different chip layout geometries, shown in Figure 3. Note that the LMJ® technology allows almost any shape to be diced, like hexagonal or octagonal chips for example.

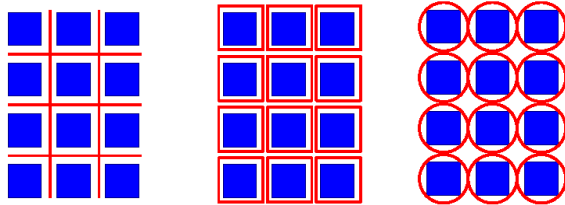


Figure 3: Patterns of singulation for sample 2a, 2b and 2c.

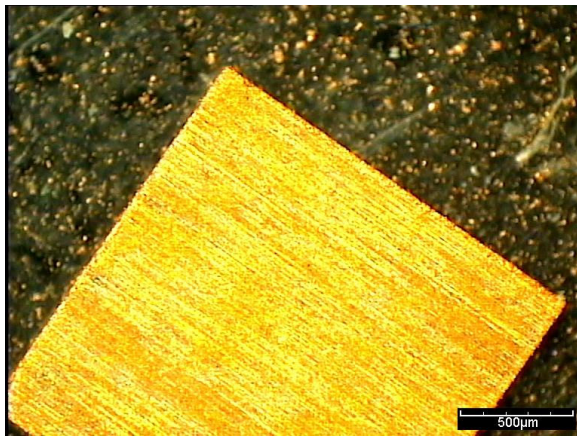


Figure 4: backside view of 100-um Cu square chip.

The cutting quality achieved is excellent for all samples. It was found that for 300- μm thick samples cut in a continuous way, the copper sheets bend during the process, not allowing the water jet to fully penetrate the groove. This results in poorer cut quality; therefore, singulation of individual chips is recommended for copper foil with thickness larger than 300 μm .

The surface of non-oxidized copper sheets causes the laser beam to be reflected much more than in the case of oxidized copper surface, resulting in a lower absorption efficiency. For non-oxidized copper, the laser power needs to be tuned in order to achieve good process rate.

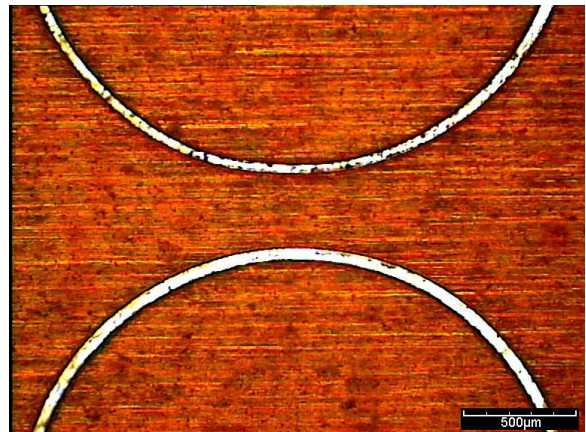


Figure 5: Front-side view of 100-um Cu round chips.

Table 2 shows the cutting speed and number of passes to process samples 1, 2a, 2b and 2c.

Sample	Cutting speed	Nb of passes
1	100 mm/s	3
2a	200 mm/s	10
2b	200 mm/s	35
2c	200 mm/s	42

Table 2: Duty cycle for bare copper foil.

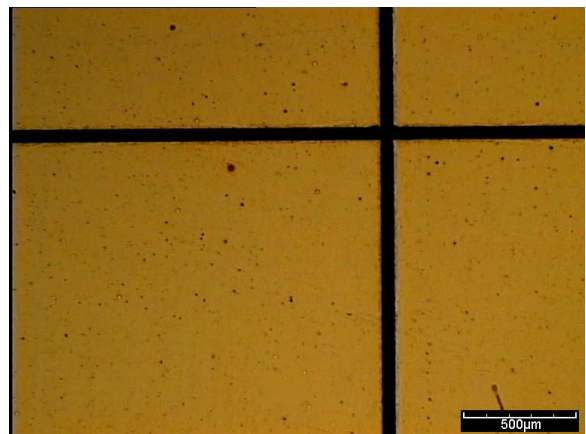


Figure 6: Front-side view of diced copper sheet.

3. Singulation of HBLED devices embedded in copper foil

The dicing of HBLEDs embedded in copper foil was tested using the LMJ® technology. More complex applications such as copper foil coated with silver, copper foil on sapphire (Al₂O₃) substrate and copper foil on sapphire substrate with gallium nitride (GaN) were also tested. The characteristics of the samples used in the present study are displayed in Table 3.

Sample	Cu layer	Dimension	Thickness	Feature
3a	100 μm	4 x 4 cm ²	140 μm	
3b	200 μm	4 x 4 cm ²	250 μm	
3c	300 μm	4 x 4 cm ²	600 μm	
3d	500 μm	4 x 4 cm ²	900 μm	
4	100 μm	4 x 4 cm ² [KD1]		Ag coating
5a	50 μm	Ø 50 mm	400 μm	sapphire substrate with GaN
5b	100 μm	Ø 50 mm	450 μm	sapphire substrate with GaN
5c	50 μm	Ø 50 mm	400 μm	sapphire substrate
5d	100 μm	Ø 50 mm	450 μm	sapphire substrate

Table 3: List of samples for singulation of HBLED devices embedded in Cu foil

3.1 HBLED singulation in Ag-coated copper foil

For sample 4, the silver coating is very thin and there is no need to adopt the process parameters. Figure shows that the cutting quality is as high as was observed for bare copper foil.

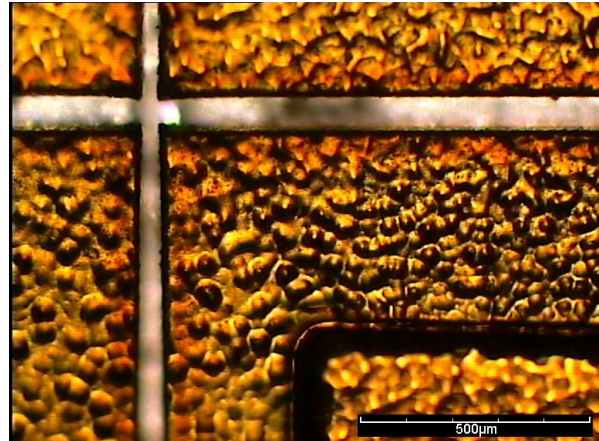


Figure 7: Front-side view of sample 4.

A cutting speed of 200 mm/s was achieved, needing 12 cutting passes to cut through the sample. The process rate could be increased by 20% by fine-tuning the setup, and by using a laser that is more adequate to copper dicing.

3.2 Scribing of copper layer on sapphire substrate

The process tested on samples 5 consisted of the ablation of the copper from the sapphire substrate along the dicing streets (scribing). This way, the dicing of the sapphire wafer itself can be performed in a more efficient way using an abrasive saw, such as a diamond saw. The LMJ yielded perfect cutting quality.

A cutting speed of 200 mm/s and 14 cutting passes were performed on sample 5c. Unfortunately, samples 5a, 5b and 5d showed delamination of the copper layer from the sapphire substrate, and could not be processed properly.

4. Comparison to other techniques

The water jet acts as a liquid fiber that remains coherent while penetrating into the material, which

means that the spot size impacting the material is always constant, resulting in an excellent kerf parallelism. By controlling the laser pulse parameters, the shape of the bottom of the groove can be well controlled. The LMJ is a very fast, efficient alternative for thin wafer dicing (thru-cut), scribing and edge grinding—where the outer 1-2 mm of the wafer is cut off to ensure a crack-free wafer edge.

Diamond saw can cut the substrate efficiently, but leaves a wafer with a lot of chipping along the eds from break off and delamination as the GaN layer partially separates form the substrate.

The main competitor for the LMJ for applications related to HBLED singulation is etching, which yields a good cutting quality, but is very time consuming due to the pre- and post-processing steps (i.e., masking and de-masking). Due to the exploding market for HBLEDs, the cycle time is now crucial, and makes the Laser MicroJet[®] technology a strategic choice.

Conclusion

It is expected that LEDs will provide greater efficiency, longer lifetimes, and economic payback in replacing traditional lighting sources. As this market continues to grow, the Laser MicroJet[®] yields unprecedented cutting quality for the singulation of HBLED components embedded in bare copper foil, Ag-coated copper foil and copper foil on sapphire substrate, with a competitive process speed.