ADVANCED GREEN NANOSECOND LASERS EXCEL AT THIN SiP AND THICK PCB CUTTING

Printed circuit board (PCB) manufacturing requires a wide variety of processes, many of which are now performed using lasers. The migration towards laser technology has been largely driven by a reduction in feature sizes and increased complexity, which ultimately allows for higher-performing electronic devices in smaller form factors and with reduced power consumption. Processes such as via drilling have seen a progression from mechanical drill to CO_2 laser, and more recently UV nanosecond pulse lasers, as the required diameters have continued to shrink. Devices and modules have also become more compact through advanced packaging. Recognizing there is a large disconnect between semiconductor node and PCB dimensionality—from nanometers to millimeters in extreme cases—developers continue to focus on advanced packaging techniques for these interconnections. One such technique is system in package (SiP) architecture, wherein, prior to final packaging and singulation, individual integrated circuit (IC) devices are bundled together on a PCB substrate that incorporates embedded metal trace interconnects. An interposer layer is often implemented to distribute the high-density chip connections into the PCB. Final packaging, which typically incorporates epoxy mold compound (EMC) encapsulation or other methods, occurs with the modules still arrayed on a single large panel. Afterwards they are singulated with a laser cutting process.

The ideal laser for SiP singulation depends on specific requirements and must strike the right balance of throughput, quality, and cost. When highly sensitive components are involved, the lower heat effects inherent with ultrashort pulse (USP) lasers and/or UV wavelengths may be needed. In other cases, the lower cost and higher throughputs of nanosecond-pulse and longer-wavelength lasers are more desirable. To demonstrate high processing speeds for SiP PCB substrate cutting, MKS applications engineers tested a high-power nanosecond pulsed laser in the green wavelength.

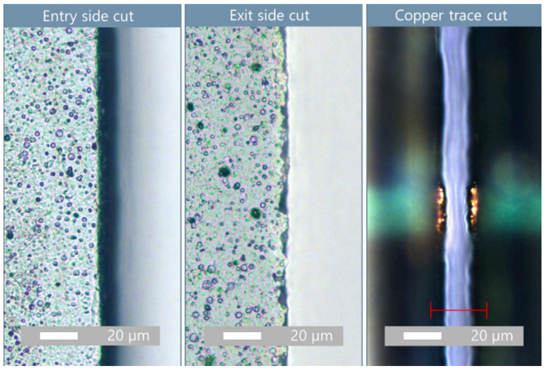

Figure 1. Optical microscope views of entry and exit side cuts as well as buried Cu trace for laser-cut 250 µm thick SiP material (200 mm/s net cutting speed).

Using a Spectra-Physics Talon® GR70 laser, SiP material comprised of thin FR4 with embedded copper traces and solder mask layers on both sides was cut with a high-speed, multi-pass processing technique using a 2-axis scanning galvanometer. The total thickness of the material is 250 µm, 150 µm of which is (ultrathin) FR4 board, with the remaining 100 µm being polymeric solder mask on both sides. Severe thermal effects and heat-affected zone (HAZ) formation are mitigated by using a high scanning speed of 6 m/s. Since the material is relatively thin, a smaller focus spot size (~16 µm, $1/e^2$ diameter) combined with a higher laser pulse repetition frequency (PRF) of 450 kHz is used. This combination of parameters takes advantage of the laser's unique ability to maintain high power at high PRFs (67 W at 450 kHz in this case), which is beneficial for maintaining proper energy densities and spot-to-spot overlap at the higher scanning speed. The overall net cutting speed achieved after multiple high-speed scans is 200 mm/s. Figure 1 shows entry and exit surfaces of the cut as well as a subsurface area where the cutting path crossed over a buried copper trace line. Both the entry and exit surfaces are cleanly cut with little or no evidence of HAZ. In addition, the presence of the copper trace did not adversely affect the cutting process and, although the viewing perspective is somewhat limiting, the quality of cut copper edges appears very good.

Further information about the quality around the copper trace—and indeed the overall cut in general—can be obtained by cross-sectional inspection of the cut sidewall, shown in Figure 2 below.

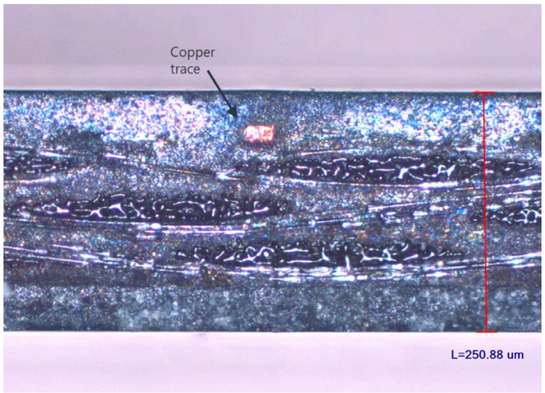

Figure 2. Sidewall view of laser-cut SiP demonstrates excellent quality, particularly within the glass fiber weave and adjacent to the buried copper trace.

The quality is very good, with minimal presence of HAZ, carbonization, and particulate debris. The individual fibers in the FR4 layer are clearly discernible, with melting limited to the cut fiber end faces oriented outward from the sidewall (i.e. perpendicular to the fibers running along the face of the cut). Importantly, we do not observe any delamination amongst the layers. Furthermore, it is confirmed that the area surrounding the Cu trace line is of good quality and did not suffer detrimental thermal effects, such as outflow of molten copper or delamination from the surrounding FR4 or solder mask layer.

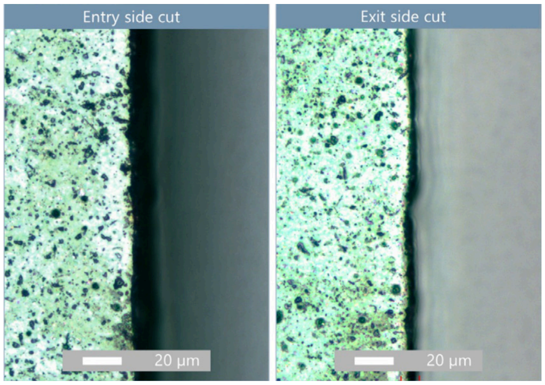

Figure 3. Entry and exit surfaces of 900 µm thick FR4 PCB after laser cutting (20 mm/s net cutting speed).

A more established PCB application for ns pulse lasers is cutting thick FR4 for device depaneling, in which arrayed devices are separated from a panel by cutting small connecting tabs. The Talon GR70 was also tested for this, with development of a tab-cutting process for a device panel comprised of ~900 µm thick FR4 board. With this thicker material, using the largest possible focal diameter while still having sufficient fluence (energy density, in J/cm^2) is important for maximizing throughput. Due to the laser's high pulse energy (>250 µJ) at the nominal PRF of 275 kHz, a larger spot size of ~36 µm is used; and with its exceptional beam quality, the focused beam has a large Rayleigh range of >1.5 mm—more than 1.5× the material thickness. Hence, there is a relatively large but unvarying spot size through the entire thickness of the material, which is helpful for efficient cutting due to a uniform irradiation volume and the formation of a wider trench which facilitates debris exfiltration. Figure 3 shows entry and exit microscope images of a cut that was processed using multiple high-speed scans at 6 m/s, resulting in a net overall cutting speed of 20 mm/s.

Similar to what is seen with the SiP board, the surfaces of both the entry and exit sides of the cut exhibit very good quality with minimal HAZ. The exit cut edge typically deviates slightly from a perfectly straight line due to the non-homogeneous nature of the glass/resin FR4 matrix as well as the somewhat lower energy density at the far side of the laser-ablated kerf. Cross-section sidewall imaging (Figure 4 below) reveals more detail about the quality of the cut.

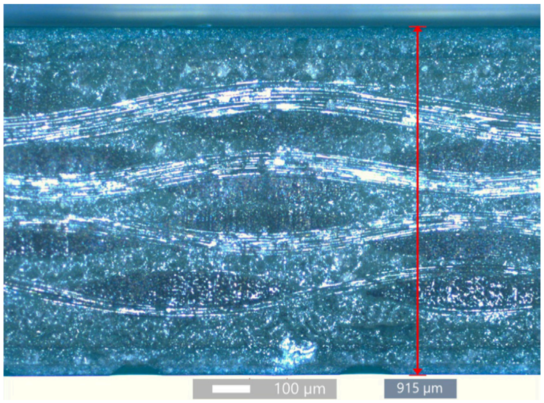

Figure 4. Sidewall view of 900 µm thick laser-cut FR4, showing excellent quality, low/no carbonization, and nearly melt-free fiber strands.

In Figure 4 we see excellent quality is achieved. There is very little evidence of HAZ and carbon product ("char") formation on the cuts. In addition, there is negligible evidence of glass fiber melting. With the high net cutting speed of 20 mm/s, the Talon GR70 is clearly a viable option for depaneling thicker FR4-based PCBs with both excellent quality and high throughputs.

The development of higher-performing electronic devices requires manufacturing processes to continually evolve and excel while at the same time maintaining or improving upon existing standards for both quality and throughput. Laser technology continues to meet the challenge. Herein we have shown the processing capabilities of the Talon GR70 ns-pulse laser for both new and traditional PCB applications, demonstrating high speed and excellent quality results when cutting both thin SiP and thicker FR4 PCB materials.

PRODUCT

The Talon® UV and Green Lasers

The Talon laser platform is a family of UV and green diode-pumped solid state (DPSS) Q-switched lasers that deliver an unprecedented combination of performance, reliability, and cost. Talon is based on Spectra-Physics' *It's in the Box*™ design, with the laser and controller combined in a single, compact package. Talon exhibits high pulse-to-pulse stability and excellent TEM_{00} mode quality for tens of thousands of operating hours. The Talon laser is designed specifically for micromachining applications in a 24/7 manufacturing environment where system uptime is critical. As presented in this Application Focus, there is a strong advantage to having available a broad range of powers and wavelengths, which is provided with the complete Talon portfolio. The Talon provides disruptive cost-performance: lowest cost-of-ownership in the industry with no compromise in features, performance, or reliability.

	Talon UV45	Talon UV30	Talon UV20	Talon UV15	Talon UV12	Talon UV6	Talon GR70	Talon GR40	Talon GR20
Wavelength	355 nm	355 nm	355 nm	355 nm	355 nm	355 nm	532 nm	532 nm	532 nm
Power[2]	>30 W @ 100 kHz	>15 W @ 50 kHz	>10 W @ 50 kHz	>15 W @ 50 kHz	>12 W @ 50 kHz	>6 W @ 50 kHz	>70 W @ 275 kHz	>20 W @ 50 kHz	>20 W @ 50 kHz
	>45 W @ 150 kHz >35 W @ 200 kHz	>30 W @ 100 kHz >23 W @ 200 kHz	>20 W @ 100 kHz	>13 W @ 100 kHz	>10 W @ 100 kHz	>4 W @ 100 kHz		>40 W @ 100 kHz >36 W @ 200 kHz	>18 W @ 100 kHz
	>23 W @ 300 kHz	>17W @ 300 kHz	>11 W @ 300 kHz	>3 W @ 300 kHz	>3 W @ 300 kHz	>1 W @ 300 kHz		>30 W @ 300 kHz	>13 W @ 300 kHz
Repetition Rate	0-500 kHz						0-700 kHz	0-500 kHz	
Pulse Width	<35 ns @ 150 kHz	<25 ns @ 100 kHz					<43 ns @ 550 kHz	<25 ns @ 100 kHz	
Pulse-to-Pulse Energy Stability	<2% rms @150 kHz	<2% rms @100 kHz, typical				<2% rms @50 kHz, typical	<3% rms up to 550 kHz	<2% rms @ 100 kHz, typical	
	<3% rms up to 300 kHz <5% rms above 300 kHzl	<3% rms up to 150 kHz <5% rms up to 300 kHz, typical						<3% rms up to 300 kHz <5% rms above 300 kHz	

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