Green light for cutting printed circuit boards

The production of printed circuit boards (PCBs) requires a wide variety of processes, many of which are now performed using lasers. As the diameters of the vias required are becoming smaller and smaller, lasers with **UV NANOSECOND** pulses are increasingly being used.

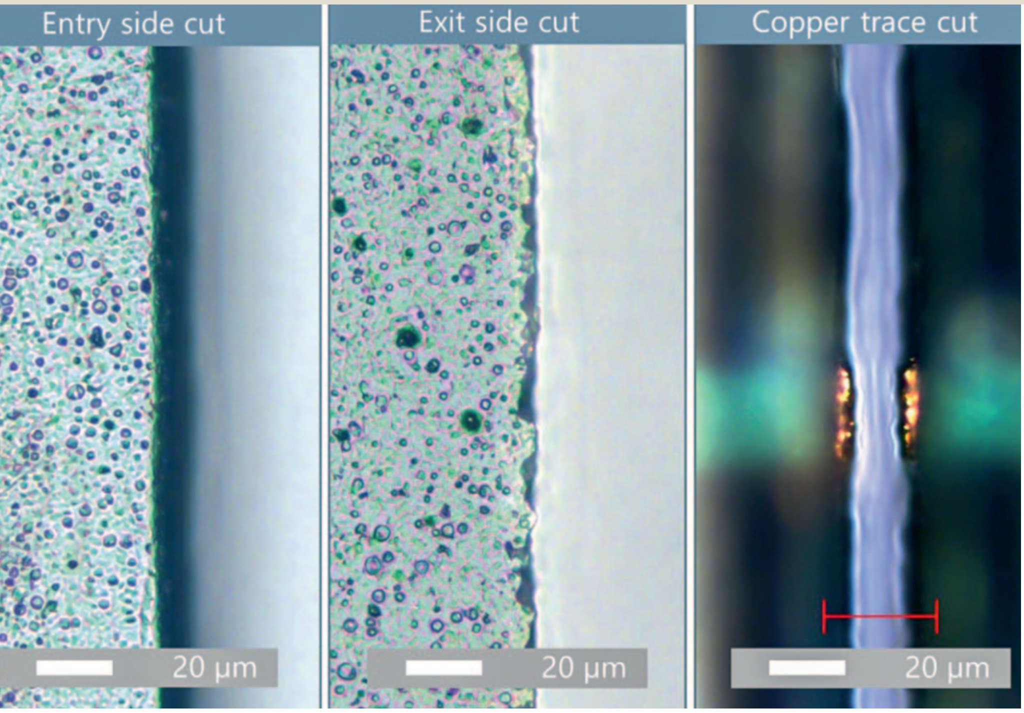

Figure 1. Light microscope views of the entrance and exit side sections as well as of the embedded copper track for laser-cut 250-µm-thick SiP material (200 mm/s net cutting speed)

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Devices and modules have become increasingly compact through advanced packaging. Recognising that there is a large disconnect between semiconductor node and PCB dimensionality – from nanometres to millimetres 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 mould 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.

Throughput, quality and costs must match

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. 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 two-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

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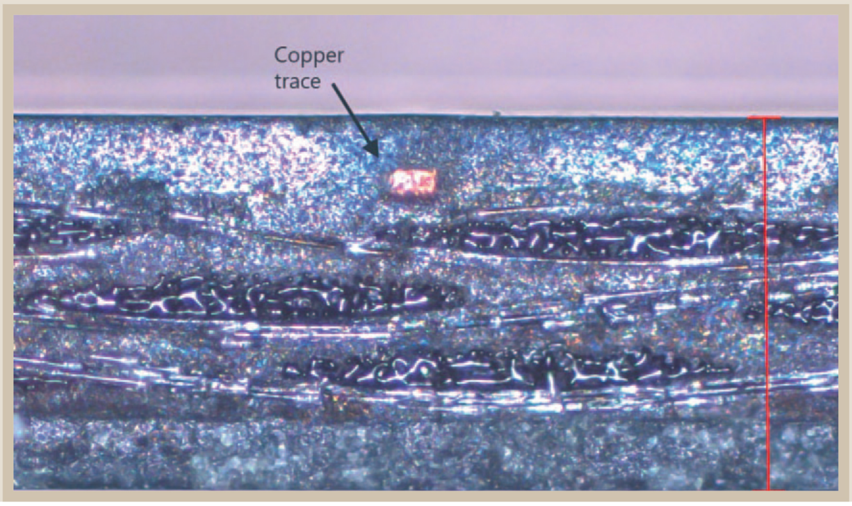

Figure 2. The side wall view of the laser-cut SiP shows an excellent quality, especially within the glass fibre fabric and in near the embedded copper track

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.

Cuts without thermal degradation

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 side wall **(Figure 2)**.

The quality is very good, with minimal presence of HAZ, carbonisation, and particulate debris. The individual fibres in the FR4 layer are clearly discernible, with melting limited to the cut fibre end faces oriented outward from the side wall (i.e. perpendicular to the fibres running along the face of the cut). It is important that no delamination can be observed 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.

Thicker FR4 plates require larger focus diameter

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/cm²) is important for maximising 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

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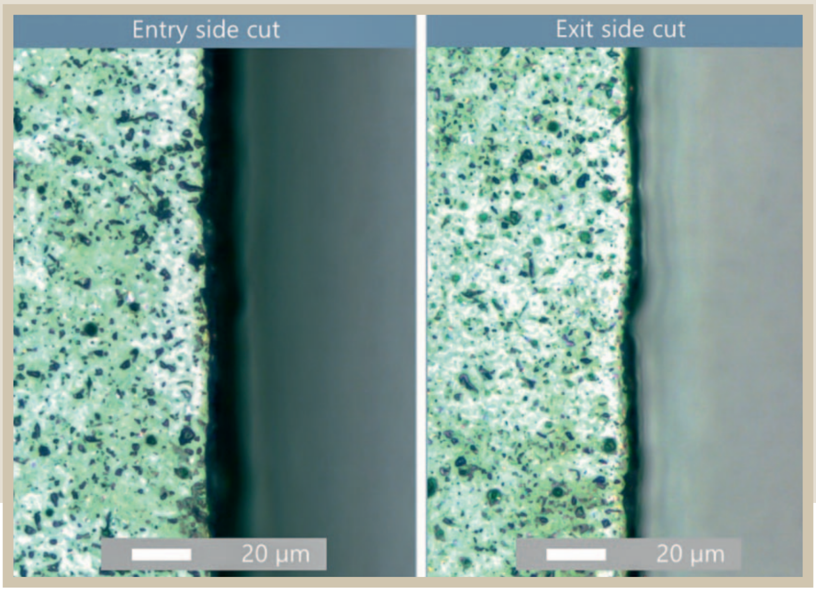

Figure 3. Entry and exit surfaces of a 900 µm thick FR4 PCB after laser cutting at 20 mm/s net cutting speed

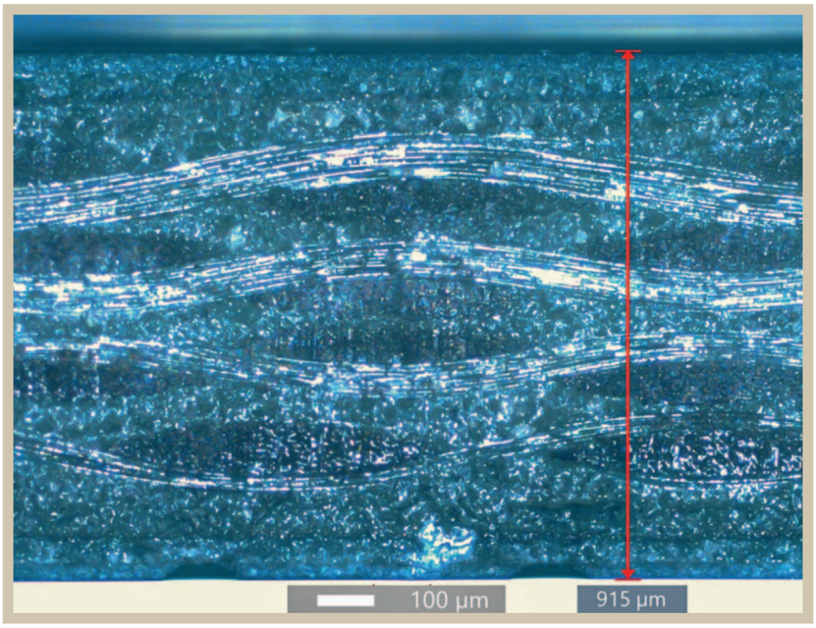

Figure 4. Side wall view of a 900 µm thick laser-cut FR4 showing excellent quality. You can see little or no carbonisation and almost melt-free fibre strands

exceptional beam quality, the focused beam has a large Rayleigh range of >1.5 mm – more than 1.5 times 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 side wall imaging reveals more detail about the quality of the cut **(Figure 4 below)**.

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 fibre 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 of results when cutting both thin SiP and thicker FR4 PCB materials. ■

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Figures: MKS I Spectra-Physics