High Quality Flex Printed Circuit (FPC) Processing with UV Picosecond Lasers

Ultrashort pulse (USP) lasers are increasingly used for industrial manufacturing, with key application spaces including glass processing, metal engraving, and medical device manufacturing. At the infrared (IR) wavelength of ~1 µm, the short pulse duration enables high quality processing with low heat effects compared to longer nanosecond and microsecond pulse widths, resulting in minimal melting and burrs when processing metals and reduced chipping and cracking when processing glass.

In many cases, however, a shorter ultraviolet (UV) wavelength introduces additional benefits. The shorter wavelength enables smaller focus spot sizes and a longer processing depth of field. In addition, the UV wavelength increases coupling of the laser energy to a wider variety of materials compared to IR. One industry that incorporates widely varied materials is flex printed circuit (FPC) manufacturing. FPCs are incorporated in various compact electronic devices such as smart phones, watches, and a growing suite of "wearable" electronics. Materials are highly varied, including copper, polymers, adhesives, and even paper. Common processes include via drilling and profile cutting.

Recently, we tested a newly released picosecond pulse UV laser product (Spectra-Physics IceFyre® 355-30) for processing various FPC materials. Materials included polyimide-based coverlay (25 µm thick polyimide + adhesive layer on a paper backing), a laminate of copper/liquid crystal polymer/copper (Cu/LCP/Cu), and bare liquid crystal polymer (LCP) material. LCP is an important dielectric material for high speed radio frequency (RF) data transfer technologies such as that required for 5G mobile devices. The goal of the tests was to determine throughput and quality for processing the FPC materials and optimized process parameters.

For FPC, polyimide coverlay performs the same purpose as solder mask for FR4-based printed circuit boards (PCBs). The polyimide is typically ~12–25 µm thick, coated with a pressure sensitive adhesive, and is attached to a paper backing material. The key challenge is to ablate patterns in the polyimide at high speeds while at the same time avoiding heat effects such as melting the adhesive and burning/charring the paper backing. The current state-of-the-art for coverlay patterning is pulsed nanosecond UV lasers combined with 2D galvo scanners for high speed processing with low heat effects. In some applications, however, quality is of critical importance and therefore UV picosecond pulse widths are beneficial. Figure 1 below shows high quality coverlay scribing using the IceFyre 355-30 laser.

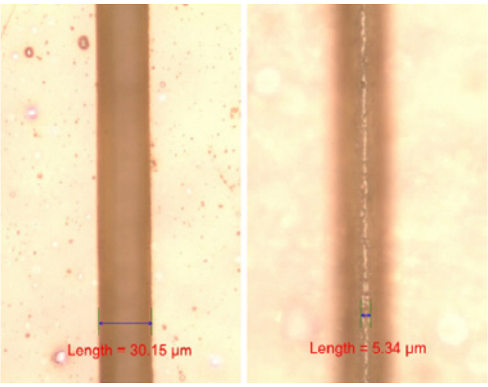

Figure 1
High quality polyimide coverlay patterning with UV picosecond laser pulses.

The left-hand image shows the very good surface edge quality with no visible debris and the right-hand image, with the microscope defocused down to the bottom of the scribe, shows there is no heat damage to the underlying adhesive. Compared to ns UV, ps UV lasers generate less debris and at the same time can process at higher pulse frequencies and therefore higher speeds without causing undesirable heat affects in the adhesive and paper backing layers.

A laminate comprised of Cu/LCP/Cu is increasingly important for FPC manufacturing for high speed RF devices such as upcoming 5G mobile devices. Because of the improved dielectric performance of LCP over PI, this material is supplanting the typical Cu/PI/Cu laminate that is widely used. Processes such as via drilling and profile cutting are typically performed. Figure 2 shows ns UV (left) and ps UV (right) straight line cuts in Cu/LCP/Cu with thicknesses of 9/25/9 µm.

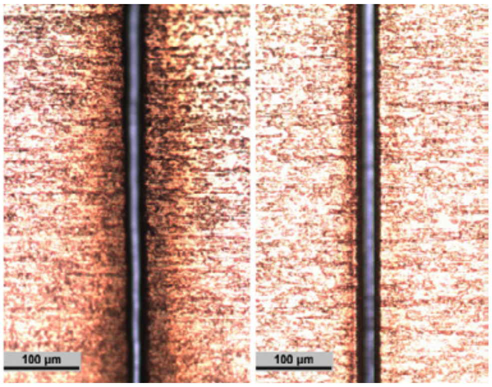

Figure 2
Nanosecond (left) and picosecond (right) UV laser cuts in Cu/LCP/Cu laminate.

While both ns and ps cuts in the laminate appear good in quality, the feature cut with ps pulses shows less debris and/or oxidation at the cut edge, which could be an important factor for downstream processes such as adhesion of patterned polyimide coverlay material. The cutting speed with the Icefyre UV laser was optimized at 200 mm/s.

Some FCP applications requiring cutting of bare LCP material without copper cladding. Using the IceFyre 355-30 laser, an optimized process was used to cut 45 µm thick bare LCP material. Figure 3 below shows a microscope photo of the resultant cut.

The fastest process with best quality was achieved by using the IceFyre's TimeShift™ ps functionality, which allows pulse burst generation with adjustable pulse separation time, burst envelope shape, etc. The net cutting speed of 200 mm/s was ~30–40% faster compared to cuts made with the conventional single pulse output of the laser.

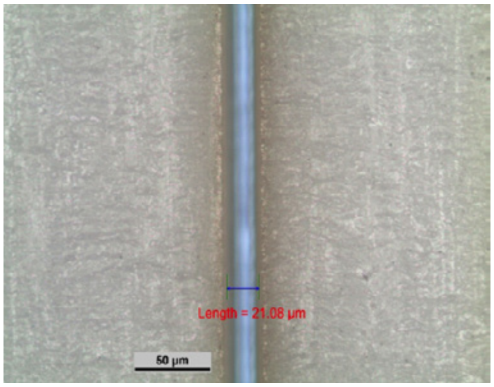

Figure 3
High quality cutting of bare LCP using the IceFyre picosecond UV laser.

With shorter pulse widths and shorter wavelengths, laser processes tend towards higher quality, as demonstrated here with various FPC process results. The shorter interaction time and shallower optical penetration depth result in finer control and resolution of the ablation process and at the same time with reduced heat effects. While this higher quality sometimes comes at the expense of throughput, the IceFyre laser's TimeShift ps feature allows for tailoring the quality and throughput for various laser machining processes.

PRODUCT: *ICEFYRE 1064-50 & ICEFYRE 355-30*

IceFyre redefines picosecond micromachining lasers with a patent-pending design to achieve exceptional UV and IR performance and unprecedented versatility at industry leading cost-performance. Based on Spectra-Physics' It's in the Box™ design, IceFyre integrates laser and controller into the industry's smallest package. The new IceFyre 355-30 provides >30 W of typical UV output power at 500 kHz (>60 µJ) and delivers exceptional performance from single shot to 3 MHz. The IceFyre 1064-50 provides >50 W of IR output power 400 kHz single pulse and delivers exceptional performance from single shot to 10 MHz.

	IceFyre 1064-50	IceFyre 355-30
Wavelength	1064 nm	355 nm
Power[2, 3]	>50 W @ 400 kHz	>30 W typical @ 500 kHz >25 W @ 800 kHz >20 W typical @ 1 MHz
Maximum Pulse Energy, typical (greater pulse energy per burst possible with TimeShift ps)	>200 µJ single pulse @ 200 kHz	>60 µJ typical @ 500 kHz >31 µJ @ 800 kHz >20 µJ typical @ 1 MHz
Repetition Rate Range[6]	Single shot to 10 MHz	Single shot to 3 MHz
Pulse Width, FWHM[2]	<20 ps (15 ps typical)	
TimeShift ps	yes	
Pulse-to-Pulse Energy Stability[2]	<1.5%, 1 σ	<2.0%, 1 σ
Power Stability (after warm-up)[2]	<1%, 1 σ, over 8 hours	

1. IR specifications are at 400 kHz single pulse with the diode current set to achieve 51 W, unless otherwise noted. UV specifications are at 800 kHz single pulse with the diode current set to achieve 25.5 W, unless otherwise noted.
2. IR power shown is without optional AOM.
3. Please consult factory for IR operation below 400 kHz without output AOM option.

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