NEW MATERIALS IN 5G FLEX CIRCUITS PROCESSED WITH HIGH POWER PICOSECOND UV LASERS

Flex printed circuit (FPC) manufacturing has grown in tandem with the market for powerful, rugged and compact electronic devices. FPCs are found in large numbers in a wide range of consumer products including smartphones, watches, and a growing suite of “wearable” electronics. Lasers are integral to FPC manufacturing, with common processes including drilling for copper via formation and profile cutting (routing) for device singulation. The materials comprising flex circuits can be highly varied and often include copper foil conductors and polyimide sheet dielectric layers. To accommodate the progression to faster communications technology, newer materials have recently been introduced to FPC manufacturing. For example, mobile devices incorporating 5G technology can no longer rely on traditional polyimide as a dielectric material for some components in their flex circuitry. Instead, alternative polymers with lower dielectric constants are required. In some cases, modified polyimide (MPI), an alloy of epoxy resin and polyimide, is used. In other applications, liquid crystal polymer (LCP) is becoming an increasingly important material. With new materials, new laser technologies are being implemented in manufacturing, taking advantage of the quality, precision, and speed that can be obtained with short pulse widths, UV wavelengths, and high output power.

Recently, we have tested a newly released picosecond UV laser product (IceFyre® 355-50) for processing FPC materials that incorporate these alternative dielectrics. In one set of experiments, percussion microvias were drilled in a laminate of copper/modified polyimide/copper (Cu/MPI/Cu). Processes for blind- and through-hole vias were developed using the TimeShift™ programmable pulse capability of the IceFyre laser to generate a burst output of (4× pulses/burst), at a pulse repetition frequency (PRF) of 350 kHz and 50 W UV average power. For blind via drilling, just 21 burst pulse groups (84 total pulses) were sufficient to drill through the top 12 μm thick Cu and the middle 25 μm thick MPI layers and stop at the back 12 μm thick Cu layer. This equates to a drill rate of >16,500 vias/s. For through-hole via drilling, all three layers were ablated using 35 pulse bursts, for a corresponding throughput of 10,000 vias/s. Figure 1 below contains optical microscope images of the two types of vias that were formed.

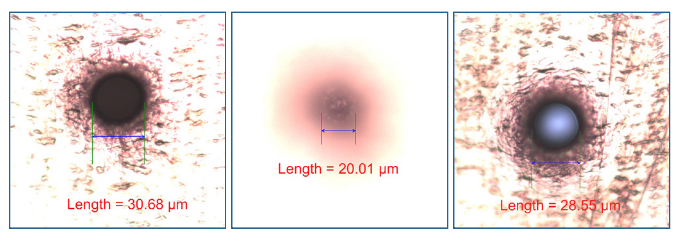

Figure 1. Blind via in Cu/MPI/Cu laminate with microscope focus on the top copper (left) and bottom copper (middle); through-hole via imaged at the top copper surface (right).

Both via types are of good quality, with minimal heat affected zone (HAZ) on the top Cu surface and no detectable burr along the edge of the ablated region. In addition, the blind via demonstrates clean ablation of the top Cu and MPI layers and stopping at the bottom Cu with minimal damage to it.

LCP is an increasingly important material in FPC manufacturing and a series of experiments were conducted to determine optimal parameters for processing it with the IceFyre 355-50 laser. To determine the optimal operating point of the laser for fastest processing, a series of scribes were processed in 45-50 µm thick bare LCP sheet material using a range of PRFs, with single pulse laser output and a scan speed of 1.5 m/s. The resulting depth data and calculated depth efficiency (depth per unit power) are plotted vs. PRF in Figure 2 below, which also shows the incident average power for select conditions (1.25, 2.0, 2.5 MHz).

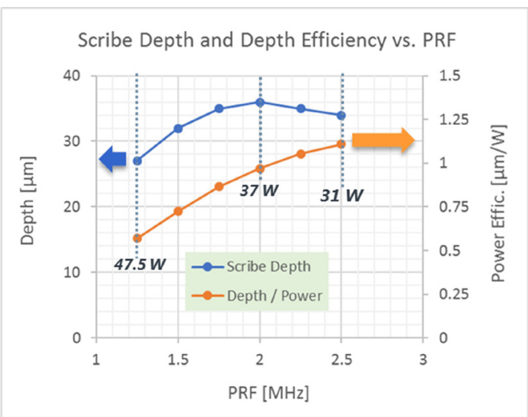

Figure 2. Scribe depth and depth efficiency vs. PRF for IceFyre 50 W picosecond UV laser at 1.5 m/s scan speed. The incident average power at select conditions is also noted.

The data in Figure 2 shows that a maximum single-pass scribe depth occurs with the laser operated at 2 MHz PRF, despite the average power being 37 W vs. 47.5 W at 1.25 MHz. This phenomenon of lower power generating deeper scribes is explained by the consideration that although the pulse energy is lower, the removal rate per pulse is not significantly lower, and the significantly higher number of pulses per second more than compensates for the difference. It is also of note that the depth/power efficiency metric continues to rise with further increases in PRF (and coincident reductions in power); however, for >2 MHz PRF, the power is sufficiently lower such that the more efficient process does not translate to a deeper scribe. Having established the laser's most efficient point of operation with the given focusing condition, maximum speed for full cutting of the material was then determined by forming scribes at incrementally lower scan speeds. The result was a cutting speed of 1 m/s, and an optical microscope image of the cut is shown in Figure 3 below.

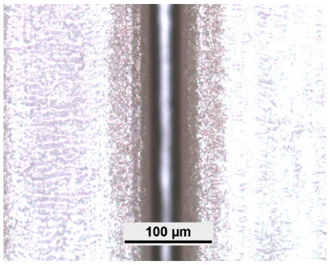

Figure 3. Full cut in 45–50 µm thick bare LCP sheet material with a single pass at 1.0 m/s scan speed.

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 process control and resolution while at the same time achieving reduced heat effects. Higher quality sometimes comes at the expense of throughput, but with the IceFyre laser's TimeShift ps feature as well as high output powers available at higher pulse frequencies, quality and throughput for various laser machining processes can be tailored to match the manufacturing requirements. The end result can be an optimized blend of manufacturing speed/productivity and quality.

PRODUCT

IceFyre Industrial Picosecond Lasers

The IceFyre 355-50 is the highest performing UV ps laser on the market, providing >50 W of UV output power at 1.25 MHz (>40 µJ) with 100's µJ pulse energies in burst mode, and pulsewidths of 10 ps. The IceFyre 355-50 sets new standards in power and repetition rates from single shot to 10 MHz. The IceFyre 355-30 offers >30 W of typical UV output power with pulse energy >60 µJ (greater pulse energies in burst mode) and delivers exceptional performance from single shot to 10 MHz. The IceFyre 1064-50 provides >50 W of IR output power at 400 kHz single pulse and delivers exceptional performance from single shot to 10 MHz.

IceFyre laser's unique design exploits fiber laser flexibility and Spectra-Physics' exclusive power amplifier capability to enable TimeShift ps programmable burst-mode technology for the highest versatility in the industry. A standard set of waveforms is provided with each laser; an optional TimeShift ps GUI is available for creating custom waveforms. The laser design enables true pulse-on-demand (POD) and position synchronized output (PSO) triggering with the lowest timing jitter in its class for high quality processing at high scan speeds, e.g. when using a polygon scanner.

	IceFyre 1064-50	IceFyre 355-30	IceFyre 355-50
Wavelength	1064 nm	355 nm	
Power	>50 W @ 400 kHz	>30 W typical @ 500 kHz >25 W @ 800 kHz >20 W typical @ 1 MHz	>50 W @ 1250 kHz
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	>40 µJ @ 1250 kHz
Repetition Rate Range	Single shot to 10 MHz		
Pulse Width, FWHM	<20 ps (15 ps typical)		<12 ps (10 ps typical)
TimeShift ps	yes		
Pulse-to-Pulse Energy Stability	<1.5% rms, 1 σ	<2.0% rms, 1 σ	
Power Stability (after warm-up)	<1%, 1 σ, over 8 hours		

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Application Note_55_11/03/21
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