APPLICATION NOTE 59

HIGH-QUALITY CUTTING OF THIN POLYMER FILMS WITH A HIGH-POWER FEMTOSECOND UV LASER

Polymers are increasingly being used in various technology sectors such as OLED displays, flexible circuit boards, microelectronics, medical devices, batteries, etc. They often possess excellent thermal and electrical insulating properties, high strength, and resistance to corrosion. Three such polymers used in many applications are polyimide (PI), polyethylene terephthalate (PET) and polytetrafluoroethylene (PTFE), which is commonly known by the trade name Teflon®. With its high mechanical strength as well as good chemical and heat resistance, PI continues to be a mainstay in the flexible printed circuit board (FPCB) market, serving as a robust dielectric material to manage the flow of electrical current. PET, on the other hand, is a general-use polymer, with applications ranging from medical devices to food packaging. As a bulk material, PET is attractive due to its good strength-to-weight ratio and overall break resistance. In fiber form it comprises durable, water resistant and wrinkle-free fabrics.

One application space common to both PI and PET is OLED display manufacturing, where both materials are used extensively. Currently, thicknesses used throughout an entire display range from thin films of several microns to thicker sheets of several 10's of microns or more. As devices and displays become increasingly lightweight, and as they become "foldable" and "rollable", and not merely "curved" or "flexible", overall thicknesses are likely to decrease.

Similarly, PTFE is another general use polymer that is resistant to nearly all industrial chemicals and solvents and possesses excellent thermal and electrical insulation properties. It is known for its smooth, low-friction surface, and it is hydrophobic in nature. Being relatively expensive, it is used in value-added situations such as waterproof fabrics and specialty medical devices and instrument coatings. For RF/microwave and very high-speed circuits, PTFE is a preferred dielectric due to its low and stable dielectric constant along with the aforementioned thermal and chemical stability. In sheet/foil form, this benefit is obtained with flexible circuits, where lasers are used for such tasks as profile cutting and via hole drilling.

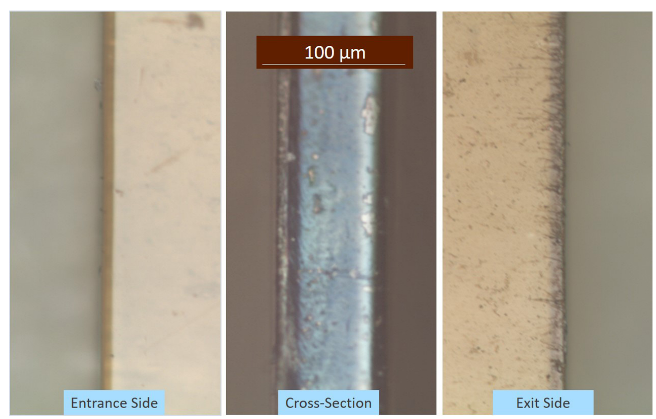

Figure 1. Microscope images of the entrance side, cross-section and exit side of a 75 µm thick PI film cut using IceFyre® FS UV50 femtosecond UV laser.

To process these materials, lasers are rapidly replacing traditional mechanical methods, and due to their unique ability to deliver high intensities with minimal heating, femtosecond pulse lasers are increasingly common. Depending on the application and the requirements, femtosecond infrared and green wavelength lasers are already being used extensively in many applications. For applications that demand still higher precision and quality, femtosecond UV lasers offer a solution.

In addition to the benefits of low HAZ (heat-affected zone) associated with short pulse durations, the short wavelength of UV lasers allows for higher absorption, enabling higher throughput, especially in high-bandgap materials. Additionally, the pulses can be focused to a smaller spot size, enabling the fabrication of smaller and more precise structures.

To verify the benefits of using femtosecond UV lasers in processing polymer materials, engineers at MKS industrial applications lab have demonstrated the cutting of the PI, PET and PTFE polymers using the recently introduced Spectra-Physics® IceFyre® FS UV50 high-power femtosecond UV laser.

PI film of 75 µm thickness was cut at 1 MHz repetition rate in multi-pass mode. Figure 1 shows the microscope photos of the cut region imaged "as-is" after processing (no post-process cleaning). With 40 W UV incident on the sample, the film was cut with an effective speed >300 mm/s. The entrance-side cut images show excellent cut quality and without any debris or HAZ. The exit-side images show slight blackening at the edges, probably due to back-side reflections. Similarly, Figure 2 shows the microscope photos of 75 µm thick PET film cut at 1 MHz repetition rate in multi-pass mode. With 40 W UV average power on the sample, the PET film was cut with an effective speed >500 mm/s. The images summarize the excellent cut quality without any debris and HAZ.

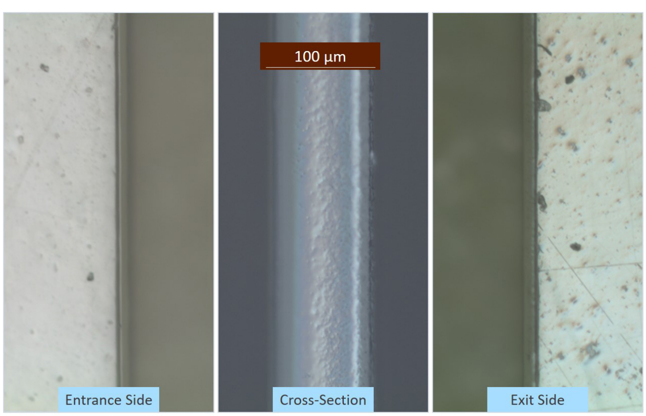

Figure 2. Microscope images of the entrance side, cross-section and exit side of a 75 µm thick PET film cut using IceFyre FS UV50 femtosecond UV laser.

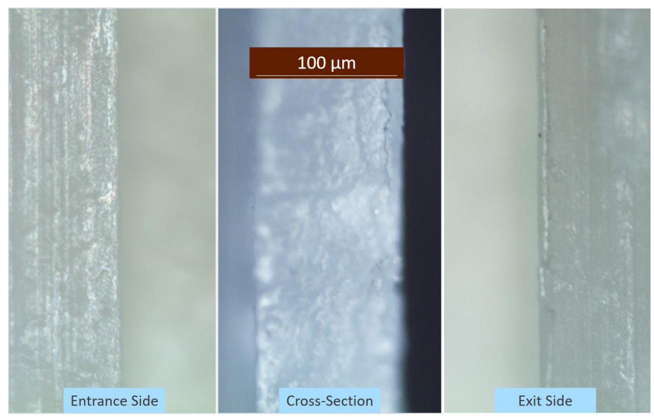

Figure 3. Microscope images of the entrance side, cross-section and exit side of a 110 µm thick PTFE film cut using IceFyre FS UV50 femtosecond UV laser.

Figure 3 shows the microscope photos of 110 µm thick PTFE film cut at 1 MHz repetition rate in multi-pass mode. With 40 W UV on the sample, the sample could be cut with an effective speed > 570 mm/s. The images confirm the excellent cut quality without any debris. Minimal melt region (<20 µm) is observed at the edges on the exit side.

The excellent quality combined with high throughput demonstrate the potential of femtosecond UV lasers in cutting polymers, making it an ideal choice for processing polymers particularly for advanced displays and microelectronic devices.

PRODUCT

Product: IceFyre FS UV50 Laser

The new IceFyre® FS UV50 laser is the highest performing UV femtosecond laser on the market, providing >50 W of UV output power at 1 MHz and pulse widths of <500 fs. It is the latest addition to the industry-proven IceFyre platform offering impressive versatility and performance, enabling a variety of high-precision femtosecond micromachining applications at lowest cost-of-ownership. The user-configurable TimeShift™ burst-mode capability enables micromachining with increased ablation efficiency, and thus increased throughput and quality for certain materials. Pulse energy of up to 50 µJ and repetition rates from single shot to 10 MHz make the IceFyre FS UV50 the ideal source for ablation and cutting applications. 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. Customers benefit from the shortest industrially available pulse duration and superior beam quality at the UV wavelength, enabling machining complex and challenging parts with highest precision and quality with negligible heat affected zone (HAZ) at the highest throughput. IceFyre FS laser is designed for industrial use and offers reliable and robust 24/7 operation at industry leading cost-performance. Based on Spectra-Physics' *It's in the Box*™ design, IceFyre FS integrates laser and controller into the industry's smallest package.

	IceFyre FS UV50
Wavelength	343 ±2 nm
Output power at optimization PRF	>50 W @ 1 MHz and 1.25 MHz
Maximum Pulse Energy	>50 µJ @ 1MHz
Repetition Rate Range	Single shot to 10 MHz
Pulse Width	<500 fs
Power Stability (after warm-up)	<1% rms over 8 hours
Pulse-to-Pulse Energy Stability	<2% rms
Spectral Bandwidth (FWHM)	<1 nm
Spatial Mode	TEM_{00} (M^2 <1.3)
Beam Diameter at Exit	5.0 mm ±0.5 mm
Beam Divergence, full angle	<0.20 mrad
Polarization	>100:1, vertical

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