Flexible OLED Manufacturing with High Power Femtosecond Laser

As the flat panel display market moves from liquid crystal display (LCD) to organic light emitting diode (OLED) display technology, laser structuring and cutting of heterogeneous materials (comprised of multiple organic material films) with high quality and accuracy is needed. Within OLED technology, substrate material is changing from glass to flexible plastics to create lighter, thinner and more durable displays. Flexible OLED structure consists of a multilayer stack of functional materials deposited on heat sensitive plastic films such as Polyimide (PI) and Polyethylene Terephthalate (PET) (see Figure 1). The different thermal and optical properties of these films makes these stacks difficult to machine using conventional laser sources.

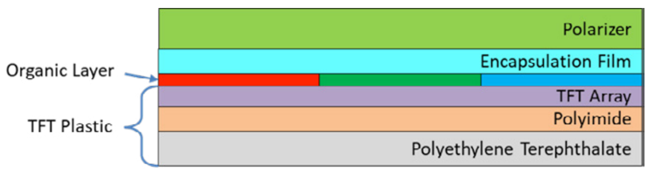

Figure 1. Schematic representation of a flexible OLED structure

Femtosecond lasers are capable of machining plastic materials with very minimal heat affected zone (HAZ) and very precise control of the material removal. Although the processing quality achieved meets industrial demands, processing speed needs to be improved to satisfy an industrial user. To process parts quickly and cost-effectively a femtosecond laser system with high average power is required. Additionally, the laser system has to be robust and stable to sustain the demands of the production floor. The Spirit® 1030-100-SHG laser from Spectra-Physics® (Figure 2) sets new standards for femtosecond lasers in high-precision industrial manufacturing. This laser offers impressive versatility and performance, enabling a variety of applications. High average power (>100 W) and high pulse energy (>100 µJ) at a wavelength of 1030 nm combined with high repetition rates (up to 10 MHz) and short pulse duration (<400 fs) pushes femtosecond micromachining applications to high levels of throughput at low cost-of-ownership. The user-configurable burst mode further enables processing with increased ablation efficiency, and thus increased throughput and quality for certain materials. Additionally, the integrated second harmonic generation (SHG) module offers an output power of >50 W at a wavelength of 515 nm which is useful in machining stacks of materials with different optical properties.

The Spirit 1030-100-SHG laser system at the wavelengths of 515 and 1030 nm has been tested for cutting of 75 µm thick ribbons of PI and PET plastics, typically used for flexible OLED displays. We have studied the maximum possible cutting speed in a high quality machining regime as a function of applied average power and wavelength.

Figure 2. Spectra-Physics' Spirit 1030-100-SHG high power industrial femtosecond laser.

Figure 3 shows the microscope images of PI and PET plastics machined using Spirit 1030-100-SHG laser. Using the laser at 100 W average power at 1030 nm resulted in cutting speeds over 1 m/s for the both plastics. Additionally, high quality of machining with very minimal thermal damage (HAZ < 50 µm) was achieved. The demonstrated cutting speed and quality meets the requirements of the OLED display manufacturers.

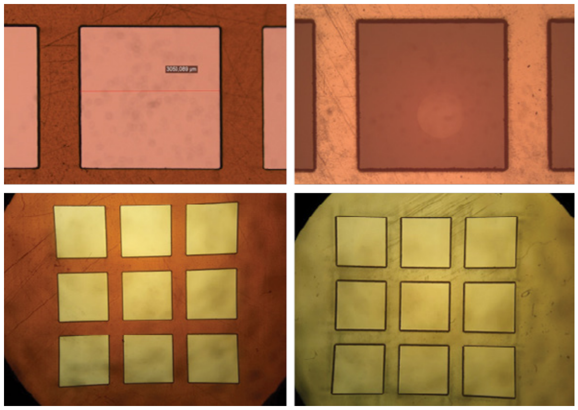

Figure 3. Microscope images of Polyimide (left) and PET (right) plastics cut using Spirit 1030-100-SHG laser from Spectra-Physics. Application of a femtosecond laser with the average power of 100 W at 1030 nm results in a cutting speed above 1 m/s for 75 µm thick plastics and very high quality (HAZ < 50 µm).

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The machining quality of plastics can be further improved by using femtosecond lasers at shorter wavelengths. In this case laser energy can be used more efficiently for ablation of transparent plastics, so that plastics can be machined with higher spatial resolution and with even smaller thermal damage. Figure 4 shows features cut in PET using a Spirit laser with an average power of 50 W at 515 nm. As it can be seen from Figure 4, the shorter wavelength resulted in significantly reduced HAZ. A HAZ of less than 10 µm and a cutting speed of over 400 mm/s were demonstrated.

Our results show that a high power industrial femtosecond laser, Spirit 1030-100-SHG laser from Spectra-Physics is an ideal choice for machining of heat sensitive plastics, such as PI and PET, which are widely used for manufacturing of flexible OLED displays. The ultrashort laser pulses (<400 fs) at wavelengths of 515 and 1030 nm result in precise and clean cutting of these plastics at processing speeds required by industrial users.

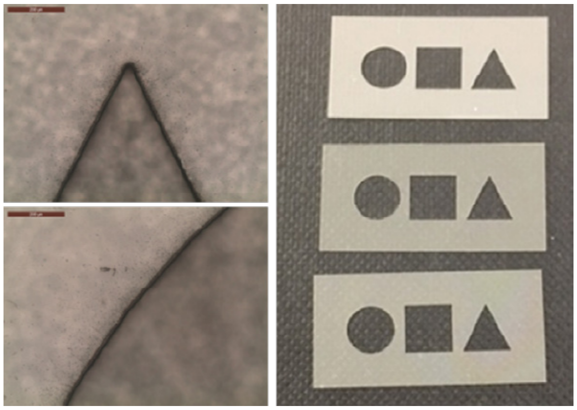

Figure 4. Microscope images of PET plastic ribbon cut using femtosecond Spirit 1030-100-SHG laser at 515 nm. An average power of 50 W at 515 nm allows cutting of 75 µm thick film with a cutting speed above 0.4 m/s with superior quality (HAZ < 10 µm).

PRODUCTS: *SPIRIT 1030-100, SPIRIT 1030-70 & SPIRIT 1030-100-SHG*

The Spirit 1030-100 and 1030-70 lasers set new standards for femtosecond lasers in high-precision industrial manufacturing. These lasers deliver high average power, high pulse energy, and high repetition rates for increased throughput. Customers benefit from the shortest industrially available pulse duration and superior beam quality that in turn enable machining complex and challenging parts with highest precision and quality with no heat affected zone (HAZ) at the highest throughput. Spirit 1030-100 and 1030-70 are designed for industrial use and offer reliable and robust 24/7 operation with lowest cost of ownership.

	Spirit 1030-100	Spirit 1030-70	Spirit 1030-100-SHG
Wavelength	1030 nm ±5 nm		515 nm ±3 nm
Output Power	>100 W	>70 W	>50 W
Pulse Energy	>100 µJ	>70 µJ	>50 µJ
Repetition Rate	Single shot to 10 MHz		
Pulse Width	<400 fs		
Pulse-to-Pulse Energy Stability	<2% rms		
Power Stability	<1% rms over 100 hours		
Spatial Mode	TEM_{00} (M^2 <1.2)		

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