Scribing and Patterning of Transparent Conducting Oxides with a High Energy Picosecond Fiber Laser

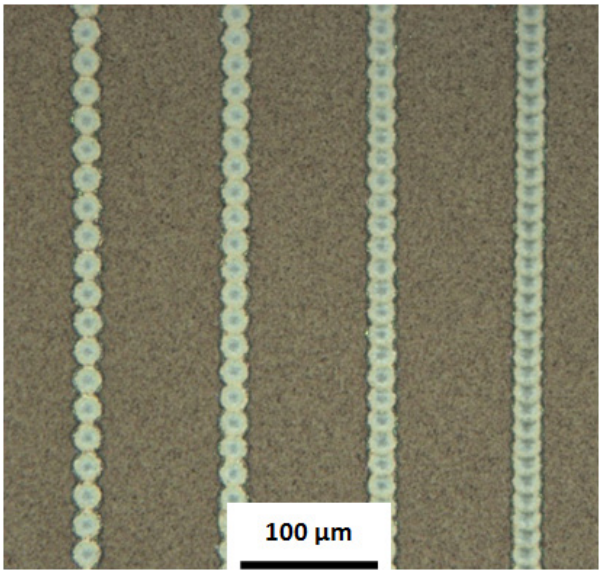
Picosecond lasers provide ultra-high peak power and large pulse energy, which makes them the ideal tools for scribing and patterning transparent conducting oxides (TCOs) like fluorine-doped tin oxide (FTO) and indium tin oxide (ITO). Laser patterning and scribing of these TCOs is preferred over chemical etching because it is a dry, chemical waste-free, and single-step high throughput process. TCOs are widely used in the thin-film photovoltaic and flat panel display markets, and in these industrial settings, fiber lasers are the preferred embodiment over conventional free-space lasers due to their low operating and start-up costs and extremely low maintenance requirements.

Fianium's high energy picosecond laser produces picosecond pulses with energies up to 125 µJ and ultra-high peak power along with tunable repetition rates from single shot to 1MHz, which makes it a versatile tool for high-throughput thin-film laser processing. Fianium's high energy picosecond lasers provide the capability of inexpensive, maintenance-free, virtually defect-free scribing and patterning of TCO films for flat panel displays, back-contact layers in thin-film photovoltaics, as well as other applications at linear rates exceeding 1000 mm/s.

- Up to **125 µJ** pulse energy
- Picosecond pulse widths
- Single-shot to **40 MHz** variable repetition rate
- **1064 nm** or **532 nm** wavelength
- Designed for **24/7** operation and OEM integration
- Maintenance-free and air-cooled

Applications Lab

Fianium's application lab in Portland, Oregon is available for clients to evaluate the effectiveness of Fianium lasers for their custom application. We offer a host of micromachining application capabilities including but not limited to thin-film PV processing.

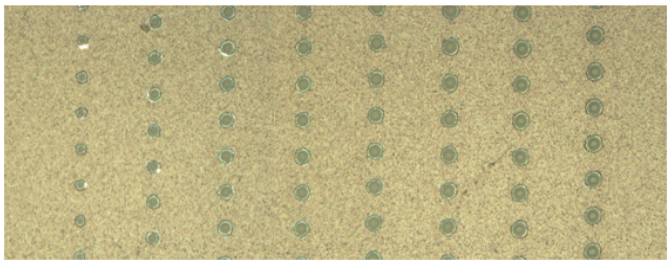


Linear scribes of a FTO thin-film TCO on a glass substrate made with Fianium's high energy picosecond fiber laser.

Picosecond laser scribing and patterning of thin-film TCO layers

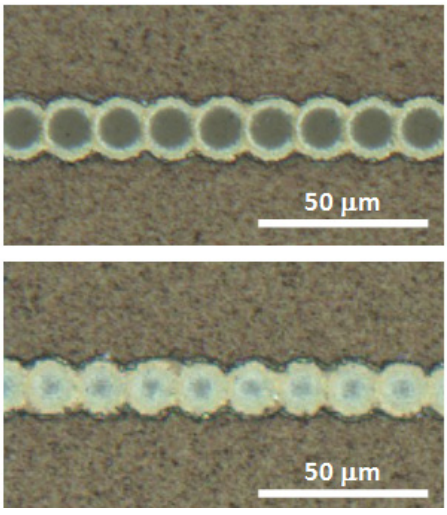
Thin transparent conducting oxides (TCO) films, such as fluorine-doped tin oxide (FTO) or indium tin oxide (ITO), on bulk substrates are extremely common materials for use as P1 contact layers for thin-film photovoltaic (PV) devices or with flat panel and touch-screen displays. These thin films can be selectively scribed and patterned with picosecond lasers cleanly and in a highly controllable manner with feature sizes down to a few micrometers. Fianium's HE1060/532 picosecond fiber laser provides pulse energies up to 10 µJ and repetition rates up to 1 MHz for extremely fast processing of TCO layers. The laser is designed for zero-maintenance and 24/7 operation in an industrial environment. The combination of reliability, process quality, and speed make the Fianium HE1060/532 an ideal tool for selective patterning and removal of TCO layers for PV and display applications.

The removal of TCO from the glass substrate using a picosecond laser occurs over a very wide process window. In fact, the pulse energy can be more than double the ablation threshold while still creating high quality results with no significant damage to the glass substrate and cleanly removing the TCO layer. The only changes that occur as pulse energy increases is the buffer layer begins to be removed (which can be detrimental for some applications), and the feature size increases from around 10 µm to 30 µm in this particular example (see figure below).



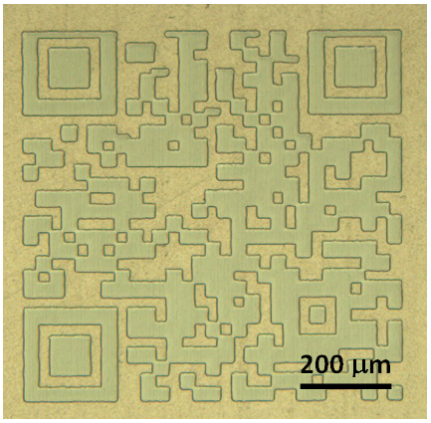
Microscope image of scribes of increasing pulse energy (from left to right). The lines sequentially increase in power to the right and each creates an increasingly large mark.

TCO layers are usually bonded to glass substrates with a buffer layer, which can be important to leave unmodified for some applications. A picosecond laser provides the ability to selectively remove the TCO only, or to remove both the TCO and the buffer layer by simply tailoring the applied pulse energy. The image below demonstrates that two scribes made with different fluence values both result in complete removal of the TCO layer creating excellent isolation (>20MΩ), while selectively leaving (bottom) and removing (top) the buffer layer between TCO and substrate.



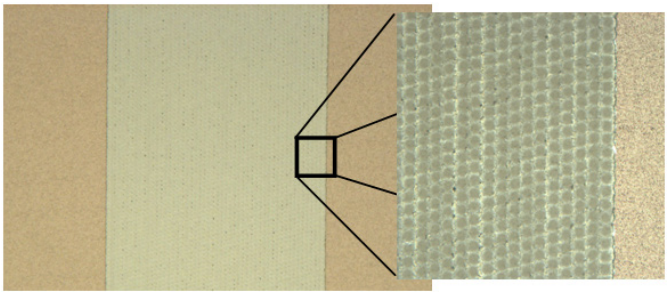
Reflection microscope images of scribes in FTO TCO back-contact thin-film PV devices using relatively high and low power levels to demonstrate the ability to remove TCO and buffer layer or to selectively remove the TCO layer only.

Other advanced thin-film solar as well as most display applications require intricate patterning of the TCO layer, which picosecond laser processing is particularly well suited for. The previous images prove that individual pulses can fully remove the TCO layer. The images below demonstrate that picosecond laser micromachining can selectively remove or pattern the TCO layer in a completely arbitrary fashion to meet virtually any application's requirements.



Microscope image of a patterned area of TCO. The image demonstrates the capability to selectively remove and pattern the TCO layer in arbitrary and complex shapes.

All of the scribes and patterns demonstrate the high quality results of a picosecond laser ablation mechanism for material removal. There were no shunts measured between areas intended to be isolated, which proves the functionality and reliability of the process. There were also no defects, no cracking of the glass substrate, virtually no debris even without a wash step, and the process has excellent resolution and repeatability.



Microscope image of an area cleared of the TCO layer. The image demonstrates the capability to cleanly remove large areas of TCO that are fully insulating.

Summary

Fianium's high energy picosecond fiber lasers can be used to produce high-quality scribes and arbitrary patterns on thin-films of TCO for thin-film photovoltaic and display markets. The high repetition-rate of Fianium's high energy picosecond fiber laser allows for linear scribe rates in excess of 1000 mm/s. Laser processing of thin-film TCOs with Fianium's high energy picosecond fiber lasers can significantly increase process throughput, reduce hazardous chemical waste, and can virtually eliminate the fabrication of defective devices. The combination of reliability, quality, and speed make Fianium's high energy picosecond fiber laser the ideal tool for such an industrial process.