NEW APPLICATION NOTE

Thin-Film Photovoltaic P1 Scribing of Molybdenum with a High Energy Picosecond Pulsed Fiber Laser

Picosecond lasers provide ultra-high peak power and large pulse energy, which makes them the ideal tools for scribing thin-film photovoltaic (PV) devices. In particular the molybdenum back-contact layer used in many thin-film PVs can be cleanly scribed at rates exceeding 5000 mm/s with high-energy picosecond lasers. Fiber lasers are the preferred embodiment over conventional free-space lasers due to their low operating costs, start-up cost, and extremely low maintenance needs. Being fiber-based, there are no optics that can go out of alignment or attract dirt, thus these lasers require no regular maintenance.

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 40MHz, 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 P1 scribing of molybdenum metal contact layers in thin-film solar cells in a variety of processing modes and at rates exceeding 5000mm/s.

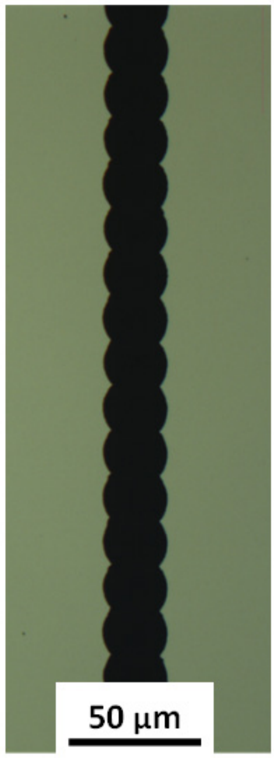
- Up to **125 μJ** pulse energy
- Picosecond pulse widths
- Single-shot to **40 MHz** variable repetition rate
- **1064 nm** or **532 nm** wavelength
- Designed for **24/7** operation and OEM integration
- Maintenance-free and air-cooled

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.

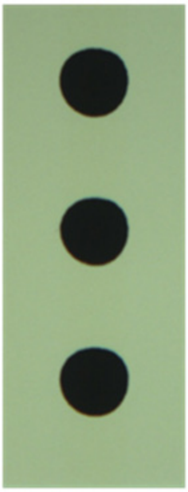
Picosecond laser P1 scribing of thin-film molybdenum layers

Thin metal films on bulk substrates, such as P1 molybdenum (Mo) layers for thin-film photovoltaic (PV) devices, are some of the most conducive materials for high-energy picosecond laser micro-machining. These thin films can be scribed with picosecond lasers very cleanly and in a fully controllable manner. Fianium's high-energy picosecond fiber laser is designed for zero-maintenance, 24/7 operation in any industrial environment. With pulse energies up to 125 μJ and repetition rates up to 40 MHz, extremely high process rates and total throughput are possible. The combination of reliability, quality, and speed make Fianium's high-energy picosecond fiber laser the ideal tool for such an industrial process.



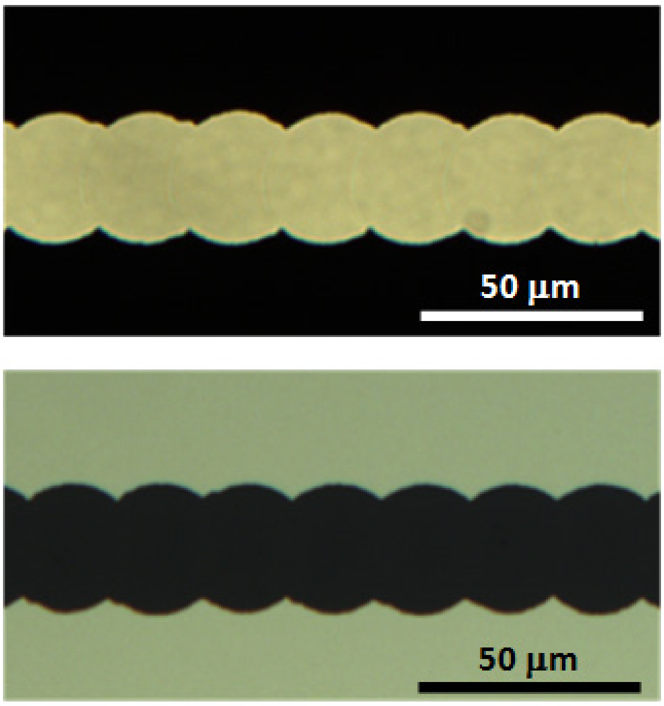
P1 scribe of a Mo back-contact layer cut with the Fianium high energy picosecond fiber laser.

Single-pulse picosecond laser ablation areas

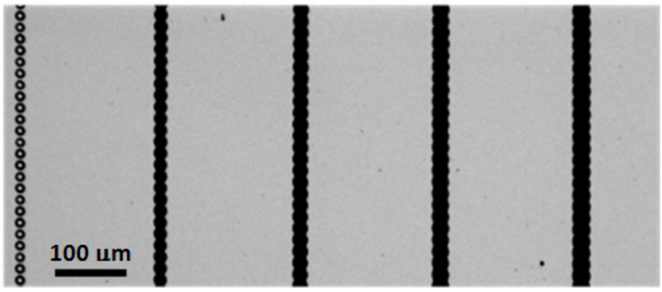


A single picosecond pulse of only a few µJ and either 532 or 1064 nm wavelength is capable of cleanly removing an area of material in excess of 1000 μm^2. With spot sizes of this order and repetition rates of hundreds of kHz, overall linear processing rates on the order of many meters per second are achievable. Even at such rapid scribe speeds the results are high-quality scribes that fully isolate the two remaining sides of the metal sheet. Scribe channel widths can be customized from a few to a few hundred microns depending on the application needs, and the scribes demonstrated in the images below are between 30 and 40 µm wide. The scribe sidewalls are extremely sharp (sub-micron) and are completely repeatable (refer to the microscope and SEM images that follow). The scribe channels display no heat-affected zone defects and are completely free of any residual metal or debris that can be catastrophic to the final device functionality.

Pulse energy of only a few micro-Joules at a wavelength of 1064 nm is required to produce approximately 30 µm wide Mo P1 scribes. In addition, the process window of illumination power or pulse energy is quite flexible. In fact, the image that follows shows four high-quality scribes created with pulse energies that are varied by over 65%. This flexibility of applied pulse energy makes high throughput industrial applications of the process quite feasible.

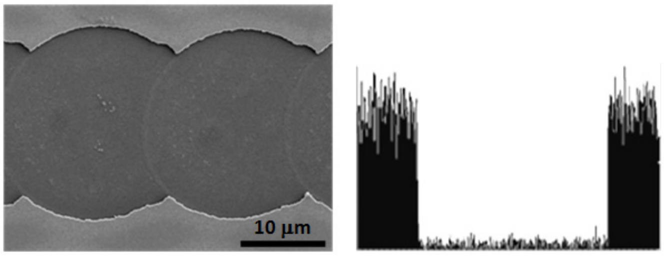


Transmission (top) and reflection (bottom) microscope images of P1 scribes in Mo back-contact thin-film PV devices using 1064 nm (top) and 532 nm (bottom) laser wavelengths. Both cuts were made using the Fianium HE1060/532 picosecond fiber laser on a Mo P1 layer.



Microscope image of scribes of increasing pulse energy (from left to right). The scribe on the far left is just below threshold and does not fully break through the Mo layer. The next four scribes sequentially increase in power and all create high-quality cuts in the thin film.

SEM images below confirm that the edge sharpness is sub-micron and that the substrate within the scribe channel has been unaffected. The image also shows the high degree of repeatability to the ablation process. X-ray elemental analysis also demonstrates that the channels are completely free of any residual Mo.



SEM image of a P1 scribe of a Mo back-contact layer (left). The image demonstrates defect-free edges with sub-micron sidewalls. The SEM image along with EDS Mo signature data across the scribe channel (right) demonstrate defect-free clearing of Mo from the channels.

Summary

Fianium's high-energy picosecond lasers can be used to produce high-quality P1 scribes on thin-films of Mo with scribe channels that are customizable, straight, and defect free. There is no heat-affected zone melting or cracking observed in the scribe sidewalls or channels, and there is no lift-off or peeling of the thin metal film from the substrate. SEM images and X-ray EDS show that all of the metal is removed from the channels with no damage to the underlying substrate. The high repetition-rate of Fianium's high-energy picosecond fiber laser allow for scribe speeds in excess of 5000 mm/s. Laser processing of PV devices with Fianium's high-energy picosecond fiber lasers can minimize the inherent ineffective regions, improve device efficiency, and virtually eliminate the fabrication of defective devices.