Fianium

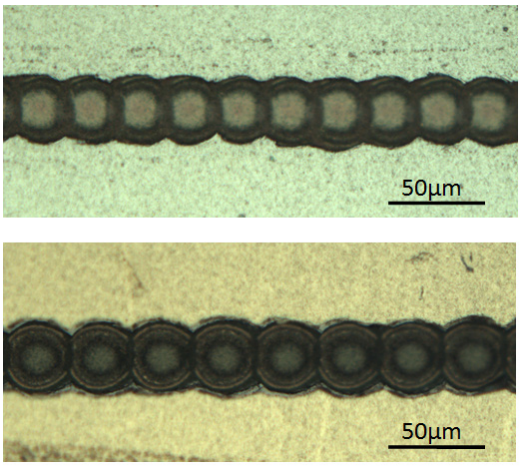
NEW APPLICATION NOTE

Amorphous-Silicon Thin-Film Photovoltaic P2 and P3 Scribing Using a High-Energy Picosecond Pulsed Fiber Laser

Picosecond fiber lasers provide a combination of reliability and ultra-high peak power, which makes them the ideal tool for P2 and P3 industrial scribing of amorphous-Si thin-film photovoltaic devices. Fiber lasers do not require routine alignment or cleaning, thus they are preferred over free-space embodiments for nearly all industrial applications. Ultra-short picosecond pulse lengths provide the exceptionally high peak powers necessary for clean, non-thermal, and defect-free scribing of thin-films of amorphous-Si photovoltaic (PV) absorber and top metal contact layers without damaging the underlying TCO layer or glass substrate.

Fianium's high energy fiber lasers produce picosecond pulses with energies up to 125µJ and ultra-high peak power along with tunable repetition rates from single shot to 40 MHz, making it a versatile tool for high-throughput laser processing of thin-film photovoltaics. Fianium's high energy picosecond fiber lasers provide the capability of inexpensive, maintenance-free, virtually defect-free P2 and P3 scribing of amorphous-Si thin-film solar cells in a variety of processing modes and at rates exceeding 5000 mm/s.

- Up to **125 µJ** pulse energy
- Ultra-short pulse widths of **<10 ps**
- 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



Microscope images of P2 (top) and P3 (bottom) scribes on an amorphous-Si thin-film photovoltaic device. The scribes were made with a high energy picosecond fiber laser from Fianium at rates of over 3000 mm/s. The scribes show complete removal of the a-Si absorber and metal back-contact layers with no damage to the underlying TCO.

Applications Lab

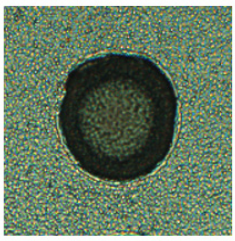
Fianium's application lab in Portland, Oregon is available for clients to evaluate the effectiveness of Fianium lasers for their custom application. We offer a host of micromachining application capabilities including but not limited to thin-film PV processing.

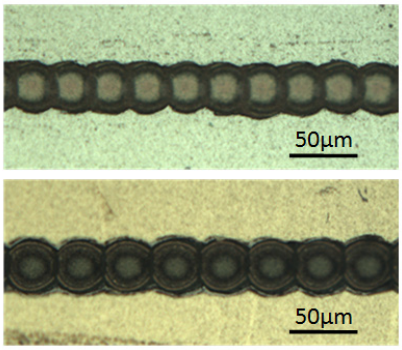
Picosecond Laser Scribing of a-Si Thin-Film PVs

High-energy picosecond fiber lasers are the ideal tools for making defect-free, high-quality P2 and P3 scribes of amorphous-Si (a-Si) thin-film PV devices. The picosecond laser ablation process occurs on such short timescales that thermal effects are minimal. Since thermal effects are not contributing factors, micro-cracking, melting, and other common defects that are frequently problematic in nanosecond laser scribing are not observed. Peeling of the top contact layer, which is often a problem in P3 scribes, is also avoided with ultrafast picosecond laser ablation.

A single high-energy picosecond pulse of 532 nm wavelength from Fianium's high energy picosecond fiber laser can cleanly remove areas of absorber material well in excess of 1000 µm2. With this single-pulse scribe area and repetition rates up to 40 MHz linear scribe rates of P2 and P3 PV materials in excess of 5000 mm/s are achievable. For P2 and P3 scribes of a-Si, a pulse energy density of only a few nJ/µm2 is necessary, so a single micro-Joule laser is capable of parallel processing multiple scribe lines, further expanding the total throughput capability and overall process speed.

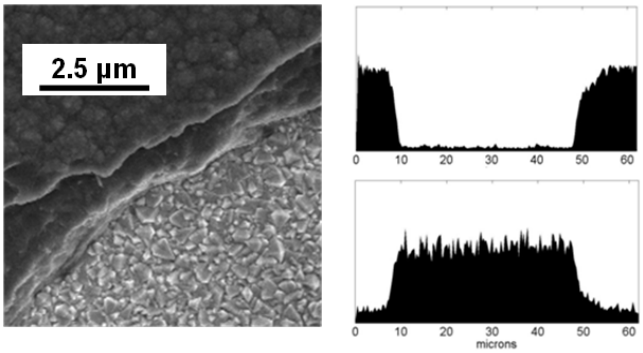
Single pulse ps laser ablation of P2 a-Si





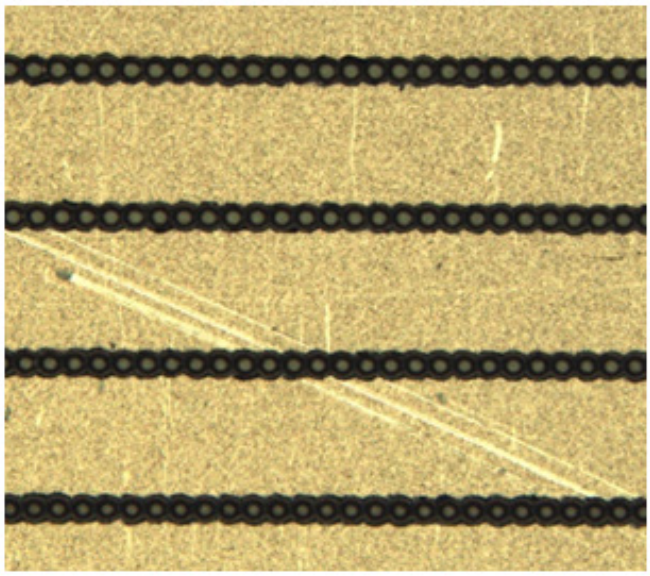
Microscope images of P2 (top) and P3 (bottom) scribes on an amorphous-Si thin-film photovoltaic device using the Fianium HE1060/532 picosecond fiber laser. The scribes show complete removal of the a-Si absorber and metal back-contact layers with no damage to the underlying TCO. The process speed was over 3000 mm/s for both scribes.

Microscope images (above) show the results of picosecond laser scribes of P2 and P3 a-Si thin-film devices. They demonstrate the micron-level control of the channel edge location and straightness achievable with picosecond laser scribing. The enormous ablation threshold difference between the TCO layer and the absorber layer allows the picosecond ablation process to completely remove the absorber while the underlying TCO layer is unaffected. The SEM image confirms that the TCO grain structure is completely undamaged. Not only is the TCO layer undamaged, but no significant debris is left behind by the backside picosecond laser scribing process, even without sophisticated debris collection or removal equipment, and thus no subsequent cleaning processes are necessary. X-ray EDS data also confirms clean and complete removal of the absorber material.



SEM image of the scribe channel sidewall (left) demonstrates a sharp edge with no heat-affected zone and an undamaged underlying TCO. X-ray EDS data across the width of the scribe channel (right). The image on the top-right is the silicon signature and the bottom right is the TCO signature.

The scribe channels are 40 µm wide in this demonstration, but can be customized over a broad range of sizes. The laser power process window for picosecond scribing in a-Si is also quite flexible. The microscope image below demonstrates four high-quality scribes for which the scribe power is varied by over 40%. This flexibility makes the process reliable and simple to implement in a 24/7 industrial production setting.



Multiple P3 scribes each separated by 200 µm demonstrate the quality and repeatability of picosecond laser scribing of thin-film PV devices. The scribe power is varied by over 40% from top to bottom, which demonstrates the broad processing window.

Summary

Picosecond pulsed fiber lasers are capable of creating high-quality P2 and P3 scribes of a-Si thin-film PVs at very high process rates. Microscope and SEM images along with EDS elemental analysis demonstrate the high quality of the scribes, and that all of the absorber material is removed from the channels with no damage to the underlying TCO grain structure. The scribe channels can be customized in width and are extremely straight and free of defects. There is no peeling off of the thin metal back contact or heat-affected zone melting or cracking, and no residual debris material is observed even without a subsequent cleaning process. The sidewall steepness and repeatability of the scribes provides an avenue to minimize the ineffective regions of the final devices and to virtually eliminate the scribe-induced device defects. The high repetition rate of the Fianium high energy picosecond fiber laser allows for scribe speeds in excess of 5000 mm/s, and the potential for parallel scribing further increases possible throughput rates. The unmatched quality and speed of picosecond laser scribing of amorphous-Si thin-film PVs with Fianium's high energy picosecond fiber laser makes it the ideal tool for the process.