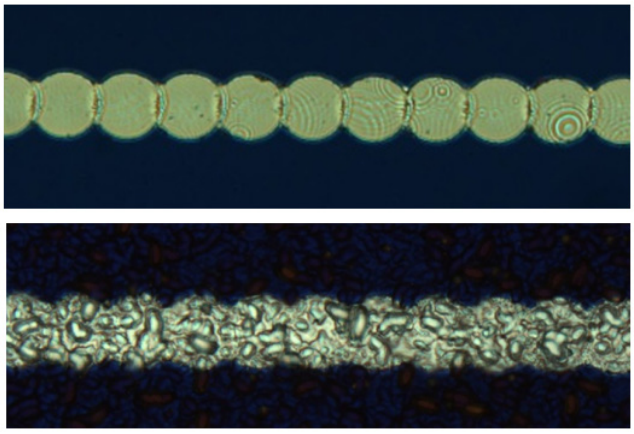
NEW APPLICATION NOTE

Patterning Silicon Nitride Anti-Reflection Coatings on Crystalline-Silicon Solar Cells Using a High-Energy Picosecond Fiber Laser Pulsed Fiber Laser

Picosecond fiber lasers provide a combination of reliability and ultra-high peak power, which makes them the ideal tool for industrial scribing of silicon nitride thin films on crystalline-silicon (c-Si) photovoltaic (PV) 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 incredible peak powers necessary for clean, non-thermal, and defect-free scribing of silicon nitride antireflection and passivation coatings on c-Si photovoltaic devices.

Fianium's high energy picosecond laser produces picosecond pulses with energies up to 10 µJ and ultra-high peak power along with tunable repetition rates from single shot to 1 MHz, which makes it a versatile tool for high-throughput laser micro-processing. Fianium's high energy picosecond lasers provide the capability of inexpensive, maintenance-free, virtually defect-free clearing of silicon nitride thin-films for c-Si thin-film solar cells in a variety of processing modes and at clearing rates exceeding 100 mm^2/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



Microscope images of linear scribes of a silicon nitride thin-film on textured (bottom) and non-textured (top) crystalline-Si thin-film photovoltaic devices. The material removal was conducted with Fianium's high energy picosecond fiber laser at a rate of over 100 mm2/s. The scribes show complete removal of the silicon nitride film and minimal damage to the underlying silicon absorber.

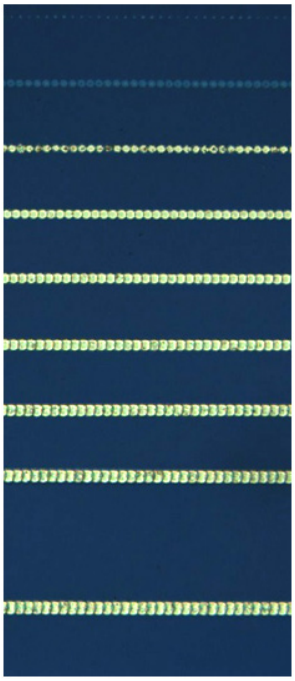
Applications Lab

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 Patterning of SiN Thin-Films on c-Si PVs

Silicon nitride (SiN) thin-films are commonly used for anti-reflection (AR) and passivation coatings for crystalline-silicon (c-Si) solar cells. It is the preferred coating because of its ability to act with the dual functionality of both passivation and antireflection. For certain advanced cell designs, small areas of the SiN AR/passivation layer must be removed or patterned. High-energy picosecond fiber lasers are the ideal tools and are becoming the industry standard for defect-free, high-quality, and non-thermal removal of many thin-film layers. The picosecond

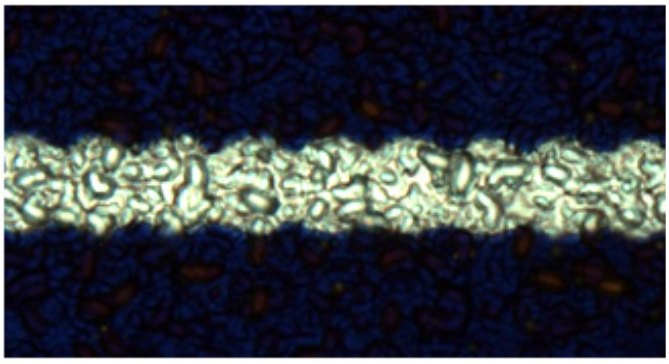
laser ablation process occurs on such short timescales that thermal effects are minimized. Without thermal effects, micro-cracking, melting, and other common defects that are commonly problematic in nanosecond laser processing are avoided.



Picosecond laser scribes of SiN on c-Si made with increasing (top to bottom) fluence.

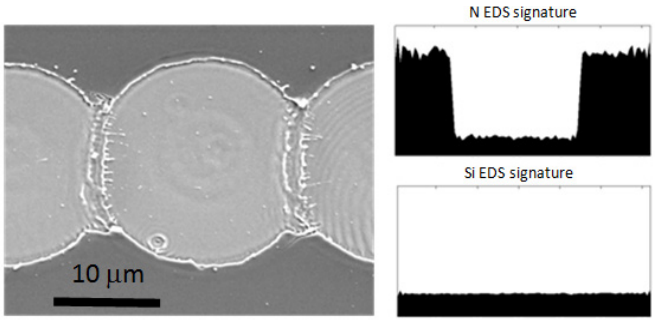
A single picosecond pulse with 532 nm wavelength from Fianium's high energy picosecond fiber laser can cleanly remove areas of a SiN passivation and anti-reflection coating in excess of 500 μm^2. With this single-pulse scribe area and with repetition rates up to 1 MHz, a clearing or patterning rate in excess of 100 mm^2/s is achievable.

SiN does not absorb well at 532 nm, but can be removed by using a lift-off process. With this method the SiN layer is removed by ablating the top few 10's of nanometers of the c-Si substrate, which is unlikely to have significant negative effects on device performance. The top scribe of the group in the figure on the left is just below the ablation threshold of 0.1 J/cm^2 and the SiN is dimpled but not removed. The high quality removal of SiN for remaining fluence values between 0.1 and 0.4 J/cm^2 demonstrates the very wide processing window that is available. The flexibility in laser fluence makes industrial application of the process quite feasible.



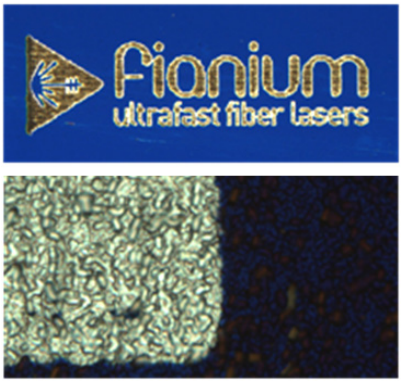
Reflection microscope image of a scribe of a SiN thin-film on a textured crystalline-Si photovoltaic device using the Fianium HE1060/532 picosecond fiber laser.

Microscope and SEM images of the cuts demonstrate the micron-level control of the edge location and straightness that is achievable with picosecond laser scribing. The images specifically show unmodified silicon except for the pulse overlap areas, which exhibit a small degree of substrate melting. Elemental analysis data shows complete removal of the SiN layer within the scribe channel.



SEM image of the scribe channel (left) demonstrates a sharp edge with minimal damage to the underlying Si substrate. X-ray EDS data across the width of the scribe channel (right top) and along the center of the cut (right bottom) demonstrates complete removal of the SiN with no residual material.

The picosecond laser ablation process can also be used to clear large areas of SiN or to selectively pattern the coating. The microscope images below demonstrate a 4 x 1 mm area cleared of SiN on a textured Si solar cell, and the Fianium logo patterned into the SiN layer on a c-Si solar device. The cleared areas are defect free aside from a small amount of debris that can be washed away with an ultrasonic bath.



Top: microscope image of a SiN layer patterned with the Fianium logo. Bottom: image of a portion of a cleared area that demonstrates removal of an area of the SiN layer on textured c-Si.

Summary

Picosecond pulsed fiber lasers are capable of high-quality removal and patterning of SiN AR and passivation thin-films for advanced c-Si photovoltaics at very high process rates. Microscope and SEM images along with EDS elemental analysis demonstrate the high quality of the scribes, and that the SiN layer is completely removed from the channels with minimal damage to the underlying c-Si layer. Complete removal of the SiN is demonstrated on both textured and non-textured substrates. The high repetition rate of Fianium's high energy picosecond fiber laser allows for scribe speeds in excess of 5000 mm/s, and a clearing rate of over 100 mm^2/s. The unmatched quality and speed of scribing silicon nitride thin-films on next generation c-Si PVs with Fianium's high energy picosecond fiber laser makes it the ideal tool for the process.