PikaRay-10μJ

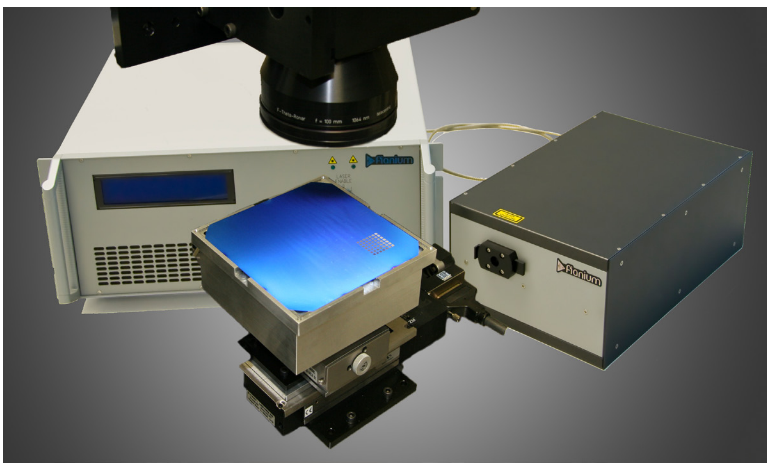
Ultrafast Laser Micromachining System

MICROTECH® instruments, inc.

Applications Notes:

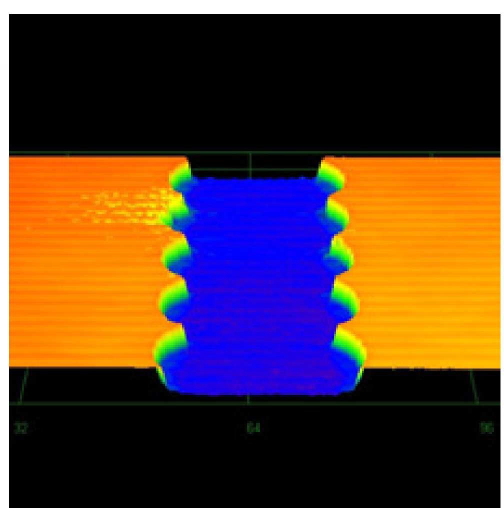
The PikaRay-10μJ system is based on an ultrafast fiber laser combined with an optical scanner, positioning hardware and control software. Ultrafast fiber lasers provide a combination of reliability and ultra-high peak power, which makes them the ideal tool for industrial material processing applications. Ultra-short picosecond pulse lengths provide the incredible peak powers necessary for clean, non-thermal, and defect-free scribing of thin films. Fiber lasers do not require routine alignment or cleaning, thus they are preferred over free-space embodiments for nearly all industrial applications.

Product Components:



The laser produces picosecond pulses with energies up to 10 μJ at 1064 nm and 5 μJ at 532 nm. Ultra-high peak power along with tunable repetition rates from single shot to 1 MHz make it a versatile source for high-throughput laser micro-processing. PikaRay-10μJ provides the capability of virtually defect-free clearing, patterning, and scribing of thin-films in a variety of processing modes at clearing rates exceeding 100 mm^2/s, and scribing rates reaching 10 m/s. 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, as illustrated by several applications described below.

PikaRay-10μJ includes a 2D galvo-based scanner system capable of linear scan rates of over 10 m/s. The input beam size and the focusing objective can be tailored to provide a customizeable spot size on the workpiece as small as 5 μm. The software synchronessly controls the laser output and the location of the focused spot on the work surface, so arbitrary patterns and text can be marked and machined with ease and at high speed.



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Processing of thin metal films on bulk substrates and plastic membranes

Thin metal films on bulk substrates, such as 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. 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 below). 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.

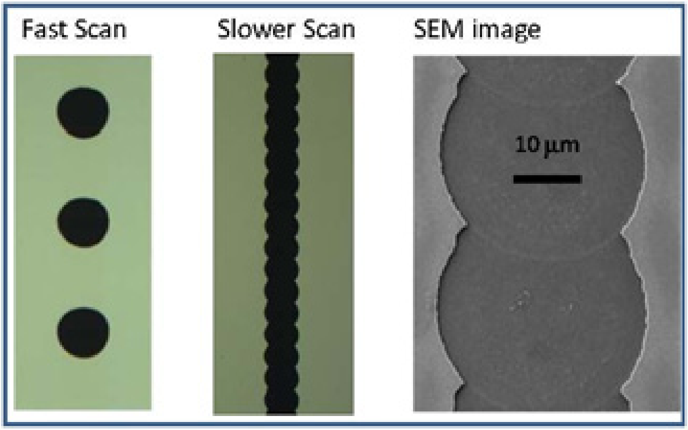

Figure 1: Microscope and SEM images of patterned metal films on a bulk substrate.

The SEM image confirms 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 demonstrated that the channels are completely free of any residual metal.

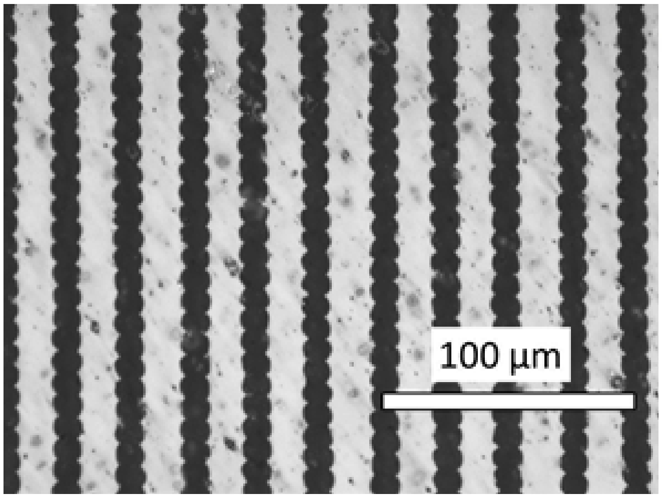

Figure 2: Microscope image of a patterned metal film on a plastic membrane.

Another illustration of PikaRay-10μJ capabilities is presented in Figure 2, which shows a patterned 400 nm thick Aluminum film on a transparent 3 μm thick polymer membrane substrate. Laser ablation of the metal results is no observable damage to the transparent membrane. Removing all metal from the area of several square inches has not affected integrity of the membrane stretched on a metal frame.

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Application Notes

Patterning Silicon Nitride Anti-Reflection Coatings on Crystalline-Silicon Solar Cells

Silicon nitride (SiN) thin-films are commonly used for anti-reflection (AR) and passivation coatings for crystalline-silicon (c-Si) solar cells. 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 figure 3 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.

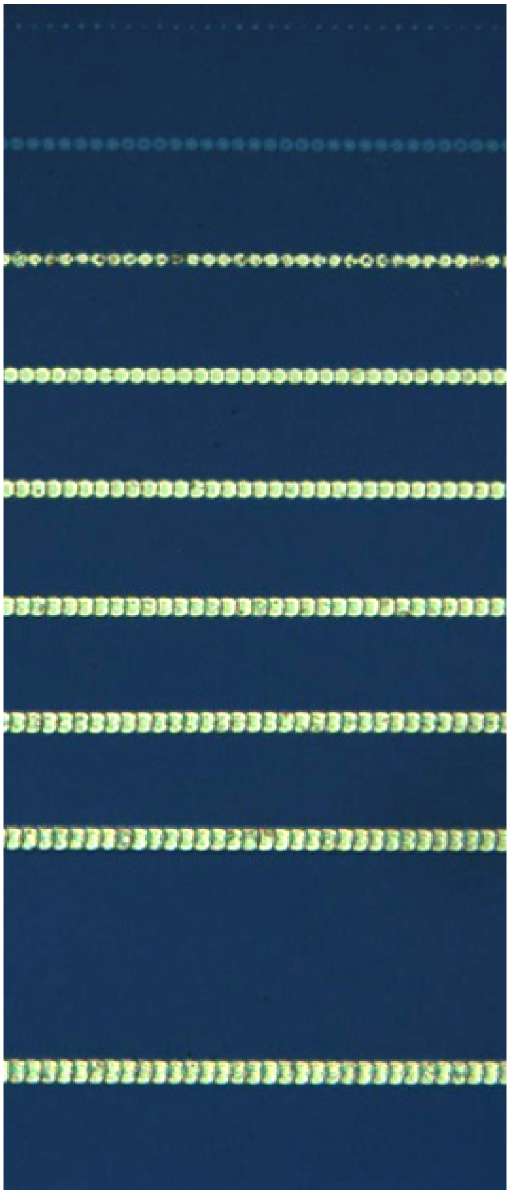
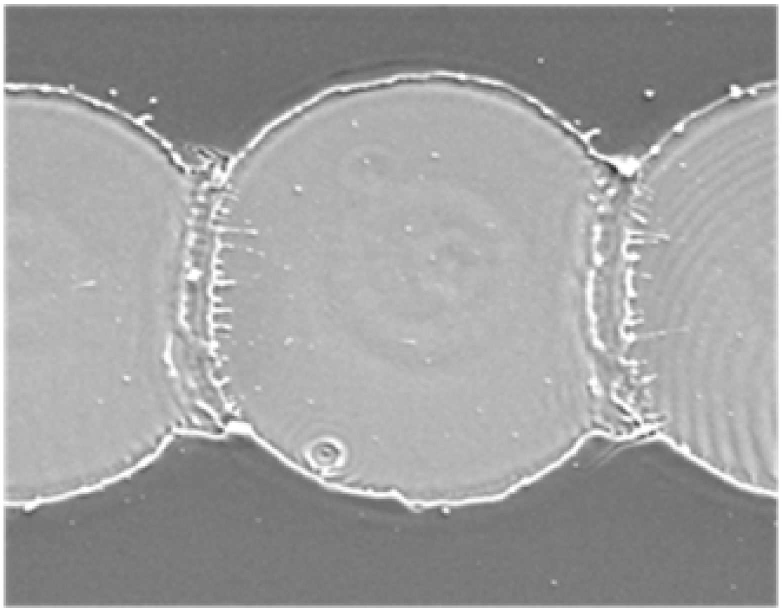


Figure 3: Microscope image of scribes in SiN on crystalline Si at increasing laser pulse energies.

A single picosecond pulse with 532 nm wavelength from 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.

SEM images of the cuts, shown in Figure 4, 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.

Figure 4: SEM image of SiN removed from crystalline Si substrate by lift-off.



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Application Notes

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Picosecond laser scribing and patterning of transparent conducting oxide (TCO) thins films.

The removal of TCO from the glass substrate using a picosecond laser occurs over a very wide window of processing parameters. 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. 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.

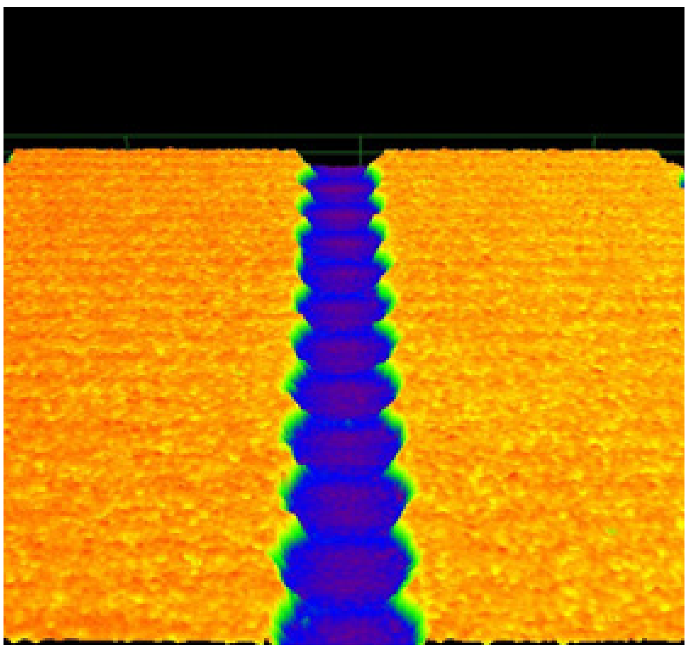

Figure 5: Confocal microscope image of patterned TCO film

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. Figure 5 proves that individual pulses can fully remove the TCO layer. Figure 6 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

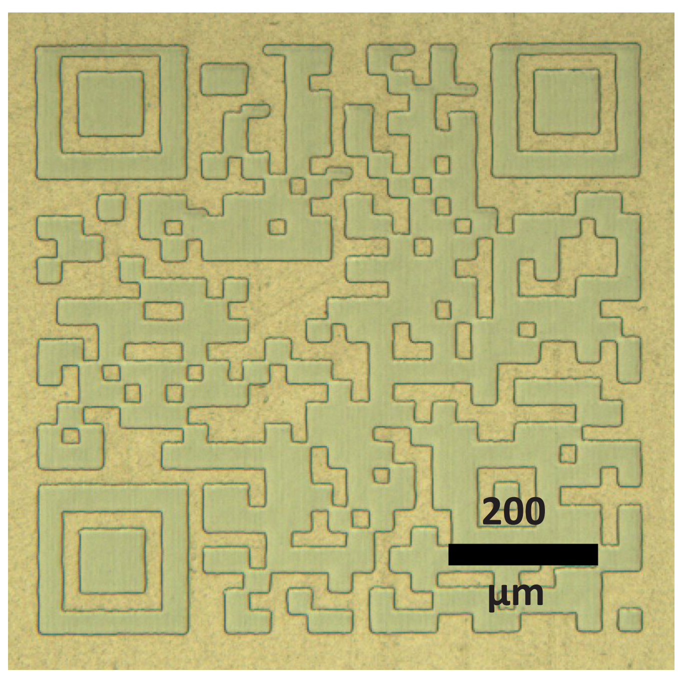

Figure 6: Microscope image of a patterned area of TCO. The image demonstrates the capability to selectively remove and pattern the TCO layer in arbitrary and complex shapes.

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.

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