



Laser Scribing Thin Silicon Nitride Films

Summary:

The use of nitride films is increasing in both photovoltaic (PV) cells and in the semiconductor industry. This thin film absorbs near infra-red laser pulses very well and so, only low pulse energy is required for ablation. This process is therefore well suited for the SPI 20W directly modulated MOPA laser as this laser can deliver these pulses at a repetition rate unmatched by any other comparable laser.

Introduction:

Silicon dioxide and titanium dioxide have been used as AR coatings in solar cells but SiO₂ has a low refractive index whereas TiO₂ does not contribute to surface passivation. ²²Silicon nitride is an important exception to the general rule that carbide and silicide films are usually electrically conductive. Thin films of SiN refractory material are used to provide diffusion barriers, as a dielectric layer or for producing stable, electrically conductive metal contact layers. Many films are essential in both silicon based and thin film solar cell fabrication. In striving to reduce costs by simplifying cell structure, layers that perform multiple functions become attractive. SiN has been used for some years as an anti-reflective (AR) coating. Due to the recent acceptance of the passivation capability of silicon nitride films, it has become the highly favoured dielectric in silicon solar cell production.



Figure 1: Thin Film Solar Cells

For overall efficiency, solar cells must absorb as wider range of solar wavelengths as possible for efficient energy conversion, and an efficient thin AR coating (<1µm thick) hence these rough low reflectance SiN coatings absorb near infra-red laser beams very well.

Laser Processing for Thin Film PV Technology:

This high IR absorption requires only low pulse energy at a moderate power density to cleanly ablate this material. The real benefit of the SPI fiber laser in this application is that it delivers a 50µJ pulse, adequate to ablate this highly absorbing layer, at far higher repetition rates than any other comparable laser. Hence ablation rates can be as high as 100mm²/s for a single 20W laser.

Due to the direct modulation of the seed diodes, these lasers are able to maintain 20W average power up to 500 kHz. This repetition rate is far above that of any other comparable laser. Scanning speeds, well above those currently used (due to the speed limitations of current direct drive motion systems), can be achieved by galvanometer scanned mirrors to produce complex patterns if required.



Figure 2: Pulsed MOPA laser

Set-up:

Laser: SPI 20 W directly modulated MOPA Fiber
Scanlabs Hurriscan 2 scan-head
Focal length: 163 mm, 6 mm beam diameter

Results:

A matrix of 5 mm squares were produced using a Scanlabs Hurriscan 14 scanner and Winlase software and RTC 4 scanner control board. Along the horizontal axis, scan speed is increased from 1 to 6 m/s in increments of 1m/s. On the vertical axis, waveforms 0-5 are used. Each 5 mm square is ablated using a 20µm raster overlap. Examination by optical microscope has shown that a very smooth surface with very efficient removal of the silicon nitride is achieved at up to 500 kHz; removal of the silicon nitride layer is complete with a minimal disruption to the substrate.

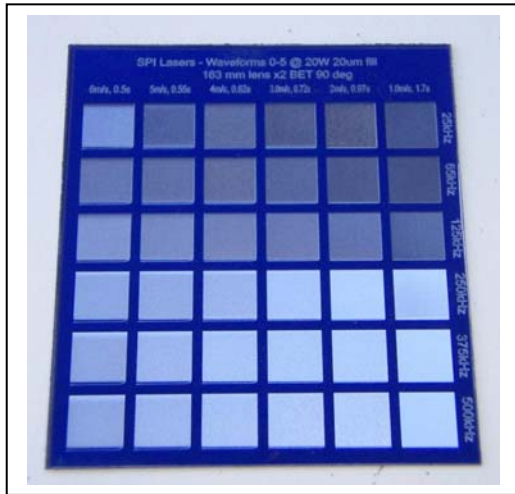


Figure 3: Fiber Laser Scribing of SiN on silicon at up to 500 kHz, 5 m/s

Here are a number of benefits using a very high repetition rate fiber laser for processing of these films:

- 1) No apparent damage to the substrate even though both thick and thin (0.2 mm) thick silicon was tested.
- 2) The peak power and pulse energy capability of the SPI fibre laser allows high repetition rate to be used. At >375 kHz, at the highest scan speeds high pulse overlap yields no edge corrugation marks.
- 3) Very clean precise surface removal is obtained by utilising the additional level of parameter control available.

Process Advantages of Fiber Lasers:

- The advantages of such a system are as follows
- Compact BDO (Beam Delivery Optic) outputting a 3.1mm collimated laser beam into the focussing optics of the head
 - Fiber delivery allows much simpler integration onto the motion system, whether galvo delivered or by direct optics
 - Fiber delivery allows the laser to be totally isolated from vibration and particulate contamination

Conclusions:

PV technology is developing rapidly and the timely arrival of pulsed fiber lasers is now able assist in reducing costs of PV manufacturing. The high repetition rate capability of directly modulated MOPA fiber lasers allows ablation of thin SiN films at greatly increased processing rates up to 100mm²/s

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