# SiC SCRIBING WITH HIGH-POWER PICOSECOND LASERS AND THE ADVANTAGES OF TIMESHIFT PROGRAMMABLE PULSE CAPABILITY

The semiconductor substrate material silicon carbide (SiC) has generated intense interest amongst electric vehicle (EV) and power electronics manufacturers because it offers many advantages over traditional silicon electronics for these applications. But SiC has very different material characteristics from silicon, which means that many of the current IC fabrication processes do not work the same way with SiC—or they do not work at all.

Singulation (wafer dicing) is a prime example of this. Mechanical sawing, which is the dominant method for singulating silicon wafers, does not cleanly translate to SiC. One issue is that SiC is one of the very hardest known materials – nearly as hard as diamond. As a result, sawing SiC produces chips, rapidly wears out expensive diamond saw blades, is relatively slow, and generates heat (which can affect the material properties).

In this Applications Focus, we review the techniques for applying our latest laser technologies to overcome these challenges and provide solutions for processing SiC materials.

Non-contact laser cutting offers an attractive alternative in processing SiC. The ideal laser process would reduce or eliminate edge chipping and produce minimal mechanical changes in the material (cracks, stress or other defects). Plus, it would minimize kerf width to keep the "street" size (empty area between adjacent circuits) small in order to maximize the number of dies per wafer. Ultrashort pulse (USP) lasers, particularly in the ultraviolet (UV) wavelength, are known to deliver exactly these benefits in high-precision cutting and ablation of materials that are hard, transparent, or brittle. At the same time, however, achieving high throughputs with combined short pulse width and short wavelength can be challenging.

With these considerations in mind, experiments were conducted to optimize cutting processes for SiC using an MKS Spectra-Physics® IceFyre® UV picosecond laser. The impact of TimeShift™ programmable pulse capability for pulse burst tailoring was explored, in particular.

The samples tested were 340 μm thick 4H-SiC. Using the laser's programmable pulse burst capability, a variety of scribes were produced using pulse configurations ranging from single pulses through 12-pulse bursts.

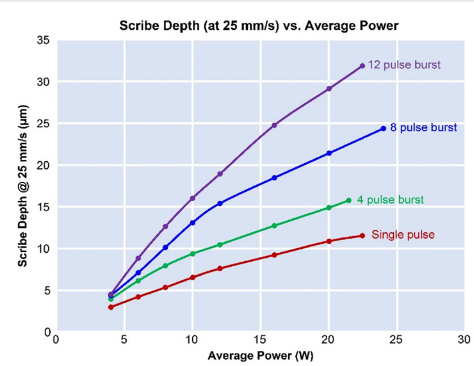


*Figure 1. Scribe depth at 25 mm/s net speed as a function of power for single pulses and various burst configurations (4-12 burst sub-pulses). Clearly pulse bursts improve ablation rates.*

The overall results are displayed in Figure 1, which plots scribe depth as a function of average laser power for various pulse burst configurations. For each test, scribing involved a total of eighty high-speed passes over the same location on the material. The TimeShift feature of the IceFyre laser allows the placement of each individual pulse burst on the work surface (e.g. the total pulse overlap) to be carefully controlled. In this case, the effective spatial overlap of the pulses was ~84%, achieved with a staggered arrangement of multiple, lower-overlap passes.

This data clearly shows that the use of pulse bursts significantly improves ablation rate, a result that is consistent with the use of burst processing in other materials and with other pulse widths as well.

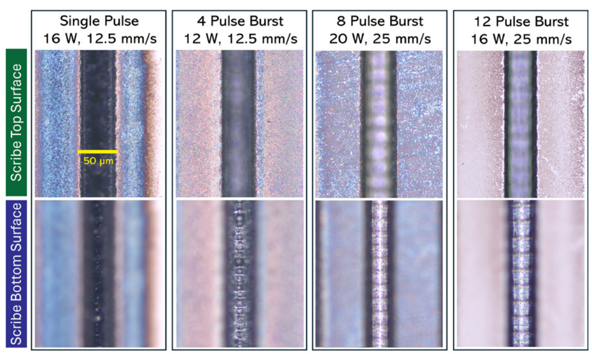


*Figure 2. Microscope images showing tops and floors of 25 µm deep grooves. These show a steady improvement in scribe quality as the number of pulses in the burst increases.*

A series of photographs were made to allow qualitative assessment of the scribes. These are shown in Figure 2. Specifically, these are images from a series of 25 µm depth grooves produced using 1, 4, 8 and 12 pulse bursts, with laser average power and net speed adjusted to deliver the best quality (at 25 µm depth) in each case.

For the top row of photos, the microscope was focused on the top surface of the wafer, and for the bottom row, the scribe floors (bottoms) are in focus. There is an obvious improvement in overall feature quality with increased number of burst sub-pulses. Of particular note is that the discoloration around the scribe progressively shrinks and then completely disappears as pulse count increases. This sort of discoloration usually indicates some sort of change in the surface or bulk material – perhaps surface oxidation due to excessive heating of the material.

The photos in Figure 3 show just the bottoms (floors) of a series of scribes, this time at higher magnification. In this case, each scribe was made under the same laser operation conditions, namely 16 W average power and a net scanning speed of 25 mm/s. The scribe depth for each condition is given in the figure.

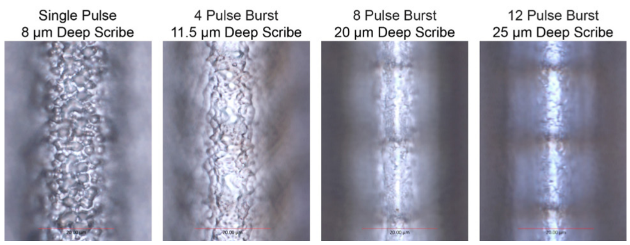


*Figure 3. The excellent machined surface quality that can be achieved with picosecond UV laser processing is seen in these images. The advantage of higher pulse count bursts is plainly evident here.*

This higher resolution view makes the improvement in surface smoothness with increasing pulse count even more apparent. It is noteworthy that for a constant average power and overall processing speed, tailoring the pulse output using TimeShift capability delivered a threefold increase in scribe depth.

This testing shows that UV picosecond lasers can produce very high-quality scribes in SiC wafers. Plus, it clearly proves the benefits of TimeShift pulse burst programming. In particular, it demonstrates that higher pulse counts deliver both better scribe quality and also higher feed rates. This is encouraging because it indicates that SiC scribing with the IceFyre picosecond laser with TimeShift capability can deliver both the throughput and quality required for cost-effective implementation in production.

## PRODUCT

# IceFyre Industrial Picosecond Lasers

The IceFyre UV50 is the highest performing UV ps laser on the market, providing >50 W of UV output power at 1.25 MHz (>40 µJ) with 100's µJ pulse energies in burst mode, and pulsewidths of 10 ps. The IceFyre UV50 sets new standards in power and repetition rates from single shot to 10 MHz. The IceFyre UV30 offers >30 W of typical UV output power with pulse energy >60 µJ (greater pulse energies in burst mode) and delivers exceptional performance from single shot to 3 MHz. The IceFyre IR50 provides >50 W of IR output power at 400 kHz single pulse and delivers exceptional performance from single shot to 10 MHz.

IceFyre laser's unique design exploits fiber laser flexibility and Spectra-Physics' exclusive power amplifier capability to enable TimeShift ps programmable burst-mode technology for the highest versatility in the industry. A standard set of waveforms is provided with each laser; an optional TimeShift ps GUI is available for creating custom waveforms. The laser design enables true pulse-on-demand (POD) and position synchronized output (PSO) triggering with the lowest timing jitter in its class for high quality processing at high scan speeds, e.g. when using a polygon scanner.

| | IceFyre UV50 | IceFyre UV30 | IceFyre GR50 | IceFyre IR50 |
|---|---|---|---|---|
| Wavelength | 355 nm | | 532 nm | 1064 nm |
| Power | >50 W @ 1250 kHz | >30 W typical @ 500 kHz<br>>25 W @ 800 kHz<br>>20 W typical @ 1 MHz | >50 W @ 500 kHz | >50 W @ 400 kHz |
| Maximum Pulse Energy, typical (greater pulse energy per burst possible with TimeShift ps) | >40 µJ @ 1250 kHz | >60 µJ typical @ 500 kHz<br>>31 µJ @ 800 kHz<br>>20 µJ typical @ 1 MHz | >100 µJ @ 500 kHz | >200 µJ @ 200 kHz |
| Repetition Rate Range | Single shot to 10 MHz | | | |
| Pulse Width, FWHM | <12 ps (10 ps typical) | | <15 ps (13 typical) | |
| TimeShift ps | yes | | | |
| Pulse-to-Pulse Energy Stability | <2.0%, 1 σ | | | <1.5%, 1 σ |
| Power Stability (after warm-up) | <1%, 1 σ, over 8 hours | | | |

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