Crystalline-Silicon (c-Si) solar cells continue to be a leader amongst the various competing solar cell technologies. Reasons for this include stable supply of silicon, well-developed manufacturing processes, and, of course, the high and growing conversion efficiencies that can be achieved. Here, we report on Laser Dopped Selective Emitters (LDSE) - a relatively straightforward, laser-based manufacturing process that has been demonstrated that it can increase cell efficiency by up to 1-2% points over conventional cells.

A conventional p-type wafer c-Si solar cell has a thin but heavily-doped n++ region of silicon on the front surface. This region, generated via high-temperature phosphorus gas furnace diffusion, forms a p-n junction, directing current flow into a grid pattern of thin conducting strips on the cell surface. These are referred to as finger lines, and consist of a metallic paste material that is screen printed onto the cell surface and subsequently "baked-in" at high-temperature, creating electrical contacts to the heavily-doped n++, or emitter, region of the cell.

### Application Focus

**PCB Processing Using the Mosaic™ Laser**

The growing trend towards miniaturization and cost reduction in the production of electronics products and devices has led to the ever increasing demand for laser micromachining applications. With innovations in laser technology – as nanosecond pulsed Q-switched laser sources become more compact, robust, reliable and affordable – more micromachining applications have become commercially viable. The use of lasers in the printed circuit board (PCB) manufacturing processes is one example. The driving factor for the use of laser technology as a solution is its ability to process small, high-precision features in a non-contact manner at high speed in a cost effective way. Lasers are routinely used in a variety of PCB manufacturing processes including via drilling, depaneling, profiling (cutting), laser direct imaging (LDI), repair, trimming, marking, and skiving processes.

We have investigated the use of our new generation of Q-switched DPSS nanosecond pulsed Mosaic 532-11 laser for some of the rigid PCB and flexible PCB (FPCB) processes and have demonstrated that the Mosaic laser is a good candidate.

#### Laser Depaneling of Thin Rigid PCB

The thin rigid PCB sample consisted of 300 μm thick PCB resin material without copper or stiffening material. Operating the Mosaic 532-11 laser at high pulse repetition frequency (PRF) of 150 kHz with 64 μJ energy was found to be optimal to achieve good quality cuts and low carbonization. Multiple scans were used to achieve higher throughput, resulting in an average cutting speed of 50 mm/s.

Microscope picture showing a) rigid PCB panel with individual boards linked together, b) entrance side cut quality of depaneled thin rigid PCB, and c) cross-section of a cut

Example of Rigid PCB
a) Rigid PCB and b) schematic cross-section of rigid PCB showing 1) blind via and 2) through via

Example of Flexible PCB
a) Flexible circuit board and b) schematic cross-section of flexible PCB showing 1) blind via and 2) through via

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PCB Processing Using the Mosaic Laser

Laser Drilling of FPCB
The sample drilled was a 180 µm thick FPCB consisting of polyimide-copper-polyimide with acrylic adhesive in between. For this particular material combination, the copper layer strongly absorbs 532 nm wavelength and couples the energy more efficiently into the neighboring polyimide material resulting in a good quality through vias. The data shows that hole size and the drill rate achieved depends on the pulse energy and corresponding PRF.

A good compromise between hole quality and throughput is achieved at 50 kHz PRF with ~200 µJ energy. With these settings, 65 µm entrance and 35 µm exit holes were drilled at the rate of <1 ms/hole.

Laser Profiling of Thick FPCB
Two different PCB materials were used: A) 180 µm thick FPCB layered structure of polyimide-copper-polyimide with acrylic adhesive between layers, and B) 160 µm thick all-insulator FPCB structure of polyimide-polyimide with acrylic adhesive in between. Using the Mosaic laser, 5 mm circles were trepan cut in both FPCB materials using multiple passes with an average speed of 11.5 mm/s. The optimized setting is low PRF of 20 kHz where ~390 µJ pulse energy was available at the work piece. Good quality cuts were achieved. The results demonstrate that the Mosaic 532-11 is ideal for profiling/cutting of FPCB material consisting of polyimide and copper materials.

Microscope picture shows 50 µm target diameter through vias drilled in 180 µm thick polyimide-copper-polyimide FPCB sample at various PRFs.

Microscope picture (a) entrance side and (b) exit side showing 5 mm circular trepan cuts in FPCB processed at 20 kHz PRF.

Products: Mosaic 532-11
The Mosaic 532-11 laser is an innovative new product that unites an array of proprietary technologies and solutions to address market pressure for greater efficiency and lower cost. Its integrated It’s in the Box™ design includes both the laser head and power supply in a single package, making it a very compact laser that is simple to integrate into any machine tool. The Mosaic laser is designed specifically for micromachining applications in a 24/7 manufacturing environment where system uptime is critical.

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