High Power, Speed and Precision Processing with Picosecond Laser and Polygon Scanner

Application notes

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Picosecond lasers in many cases have shown excellent results of material processing for diverse applications. Limiting issues remains cost and efficiency of the processes.

Current developments in high repetition rate lasers provides plenty of laser pulses which are able to ablate the material. However, spatial control of focused laser beam with the high precision is needed.

Assessment of Next Scan Technologies polygon scanner LSE 170 (line 170 mm; 1064/532 nm) and Ekspla Atlantic 60 picosecond laser (60 W, 13 ps, 1 MHz). Polygon scanner is equipped with f-theta objective with focal length of 190 mm and provide telecentric imaging over 170 mm long scan line. Laser pulsing was controlled synchronizing it with polygon using SuperSync™ technology from Next Scan Technologies.

Applicability of laser-polygon pair in precise laser processing was tested, checking adjustment and corrections options in precise beam spot deposition to the material.

High Speed and Precision Surface Marking

Direct laser marking is a widely used flexible and modern method for obtaining permanent marks containing traceability and identification information: alphanumeric strings of characters, logos, barcodes and Data Matrix codes etc. To fulfill demands of modern industry marking speed and accuracy is an issue.

The high speed polygon scanner combined with the high power and repetition rate laser has proved to be the perfect combination for direct laser marking applications.

In this application note the results of laser-polygon marking are presented. The Ekspla logo was marked using scanning speed of 50 m/s and laser repetition rate of ~1 MHz (*Fig. 1*).

Fig. 1. Digital camera (left) and optical microscope (right) images of Ekspla logo marked on silicon wafer. The marking resolution was 50 µm in both transverse x and y directions.

Due to manufacturing accuracy limits, facets of the polygon are orientated with some deviation from exact position, thus resulting slight horizontal variation of the spot positions between the single lines (*Fig. 2 left*). Therefore, the most accurate processing can be done using only a single facet at the 8 times reduced processing rate. Precision of marking on separate scan line significantly increases, using only one facet because this eliminated any inaccuracy in polygon manufacturing. However, such regime uses only 1/8 of the processing speed and therefore is 8 times slower.

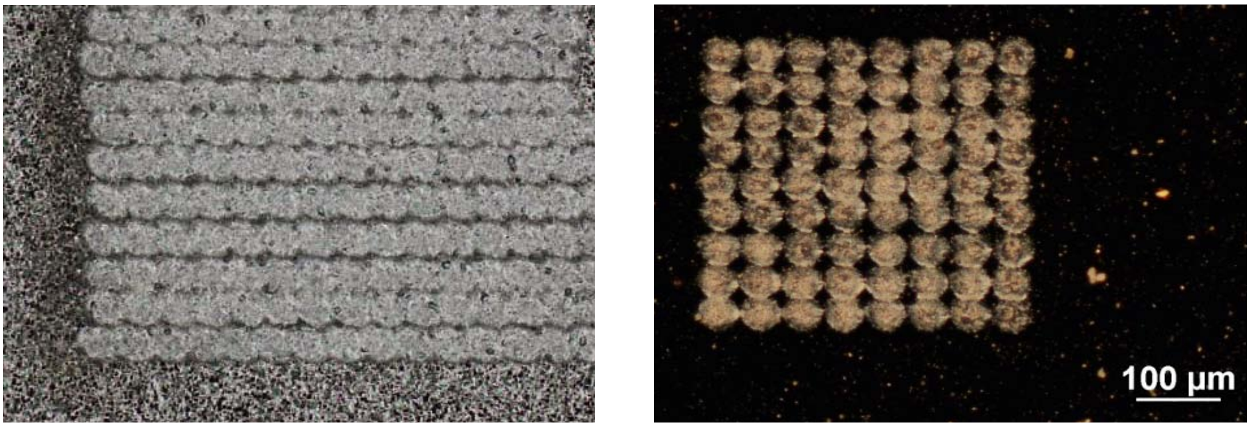

Fig. 2. Marking results without facer fine delay offset adjustment (left) and after iterative calibration (right).

In-line variations of facet position can be corrected to some extent programmable. Precise iterative calibration of the fine faced delay parameters were performed for every of 8 facets in the polygon at the center of the scanner field provided results similar to use of one facet (*Fig. 2 right*). Experiments on repeatability of laser marking through the polygon show that the in-line position accuracy of the laser marking spots is within ±3 µm with standard deviation of about 1.2 µm can be achieved at marking speed of 50 m/s.

Drilling Holes without Heat Accumulation

Laser drilling is one of the few techniques for producing holes with depth-to-diameter ratio much greater than 10. Laser drilled high-aspect-ratio holes are used in many applications, including the oil gallery of engine blocks, laser fusion components, aerospace turbine-engine cooling holes, etc. The use of high power laser with repetition rate in MHz range is one of the ways how to increase productivity. However, with the MHz rep. rate the heat accumulation comes in to play which cannot be avoided in percussion drilling and limits the throughput of the process. The fast polygon beam scanning at high speed (100 m/s) enables spatial separation of the laser pulses (1 MHz) in transverse direction by 100 µm. Thus empowers the every next laser pulse hit the exactly the same spot only after 2.5 ms (400 scans/sec.), letting fully cool down the sample, eliminating any heat accumulation, keeping high processing speed and accuracy.

In this application note the results of laser-polygon drilling of multiple holes in repetitive way are presented. One laser pulse is applied per hole during a single scan and the process was repeated 2000 time to drill a sequence of holes in silicon wafer (*Fig. 3*).

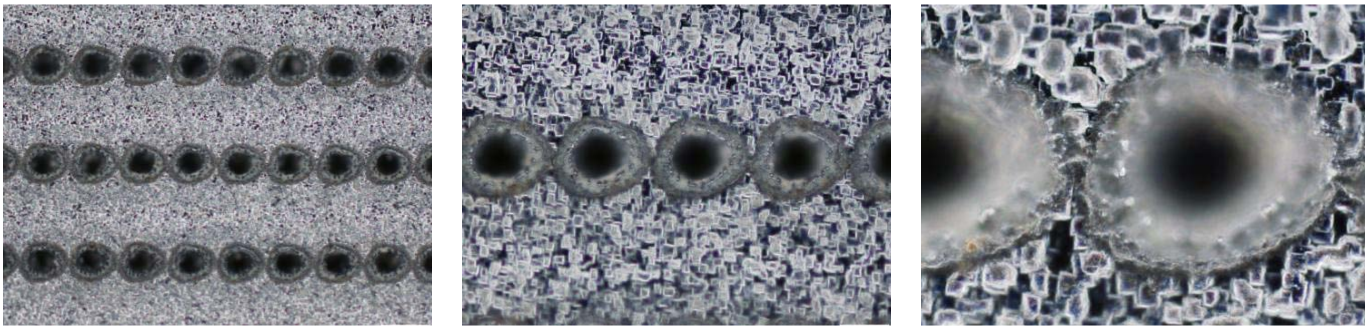

Fig. 3. Optical microscope images of laser-polygon drilled holes in polycrystalline silicon at different microscope magnifications: 10X – left; 20X – middle; 50X – right.

The 2000 laser pulses were applied per hole. Each of the holes was drilled with the laser pulse arriving from the next scan from the adjacent facelet: the time span between two laser pulses hitting the same spot was 2.5 ms. The each adjacent hole was drilled by every next laser pulse separated time by 1 µs and in space along the scanning line by 100 µm. The distance between the lines of the holes in vertical direction was 200 µm.

Good circularity of deep hole is evivdent from the pictures, showing excellent results of drilling. During all 2000 scans, pulses were deflected to particular hole from randomly selected facets. Shape of the hole on the top (deviation from circularity) is disturbed due deviation in facet mirror position and partially can be eliminated by fine adustment of facet delay.

Flexible 3D Cavity Engraving

Flexible 3D cavity engraving by using ultrafast laser is extremely fast growing technological field and has numerous applications. In order to fulfill demands of competitiveness in laser micro-machining, high productivity is an important aspect. The high-yield can be increase by scaling up the ablation process i.e. linearly increasing the laser repetition rate together with the average power and the scanning speed. In the MHz laser repletion rate regime high scan speeds are required which cannot be provided by commercially available galvanometer scanners.

In this application note the results of engraving 3D pyramid type cavities using a polygon line scanner having a maximum scan speed of 100 m/s and a 60 W picosecond laser system, synchronized via the SuperSync™ technology is presented. Flexibility of laser-polygon action is shown in making 3D cavities in stainless steel. 3D CAD drawing of the cavity was sliced into layers, and bitmap images of those layers were sent to the system for ablation. Left and right side pictures provide the ablation results with opposite layer sequence: top-down and down-top (*Fig. 4*).

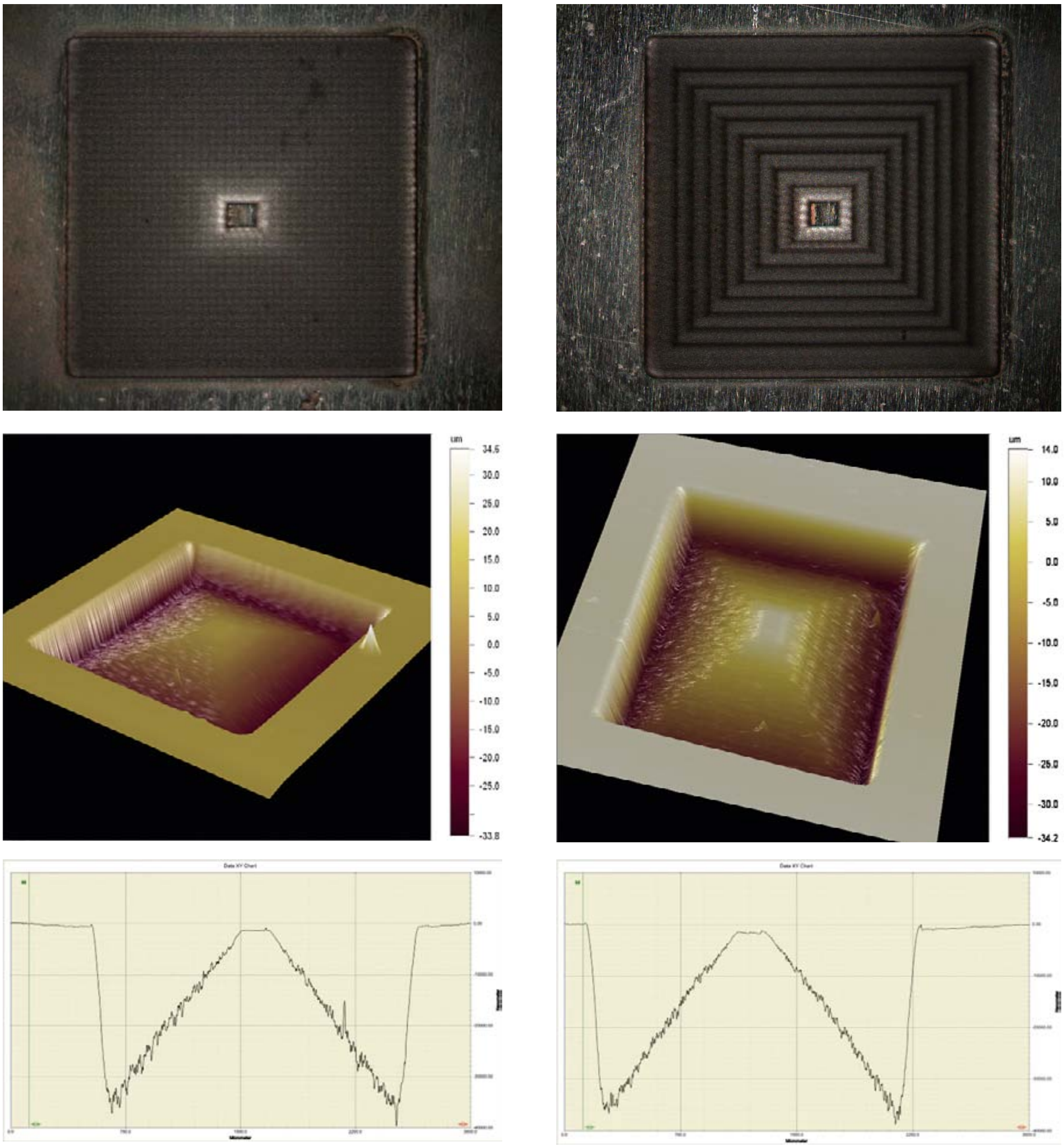

Fig. 4. Optical microscope images (top), 3D profilometer images (middle) and 2D profilometer profiles (bottom) of 3D cavity engraved in stainless steel by laser-polygon duet system. The sequence of engraving: top-down (left); down-top (right).

The gradient decay of cavity depth was achieved in top-down layer scanning scheme (*Fig. 4 left*). The step decay of cavity depth was was achieved in down-top layer scanning scheme (*Fig. 4 right*). The highest depth of 50 µm was achieved employing overall of 2000 polygon scans (10 layers with 200 scans for each layer).

Selective Ablation of Thin Films

Continuous growth of the thin-film electronics market stimulates the development of versatile technologies for large-scale patterning of thin-film materials on rigid and flexible substrates, and laser technologies are a promising method to accomplish the scribing processes. The high repetition rate ultrafast laser paired with polygon scanner capable of producing extreme scanning speed has proved to be a successful duet for solar cell scribing applications (*Fig. 5*).

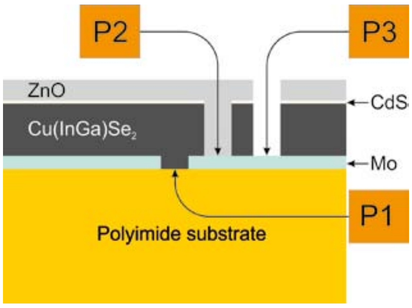

Fig. 5. P1: metallic back-contact formation; P2: absorber stripping (trench) for making interconnections; P3: front contact isolation.

Polygon is running at very high speed, when even lasers with pulse repetition rate of 1 MHz are too slow to provide overlapping pulses on the material. In this case, repetitive scanning with interleaving can be applied to get necessary beam overlap. The pulse interleaving allowed us to have the distance between laser pulses of 6.25 µm, providing overlap close to 90% when scanner was running at 49.35 m/s.

The P3 type scribe is used for isolation of the adjacent cells. It can be made by removing only the top-contact or the full structure up to the molybdenum back-contact. Transparent conductive oxide removal requires less laser power and small laser pulse overlap, therefore no laser pulse interleaving was required for such regime (*Fig. 6 left*). EDS analysis confirmed the removal of the top-contact (ZnO) leaving the CIGS layer exposed with the process speed of 49.35 m/s (*Fig. 6 right*).

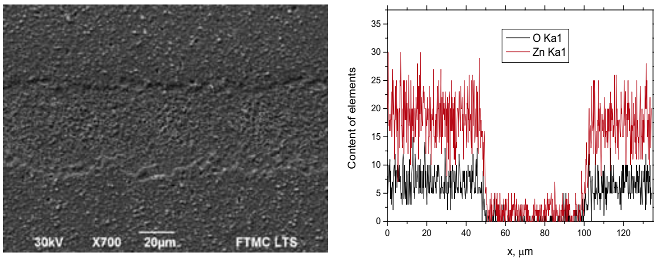

Fig. 6. R1, 30 W, 987 kHz, 49.35 m/s, single pass, no interleaving.

Removal of the full CIGS structure to expose the molybdenum back-contact required high laser pulse overlap, therefore laser pulse interleaving with multi-pass scanning was used. Overall scanning speed of 3 m/s was reached (49.35 m/s 16 passes) by applying pulse interleaving technique to expose the molybdenum layer (*Fig. 7*).

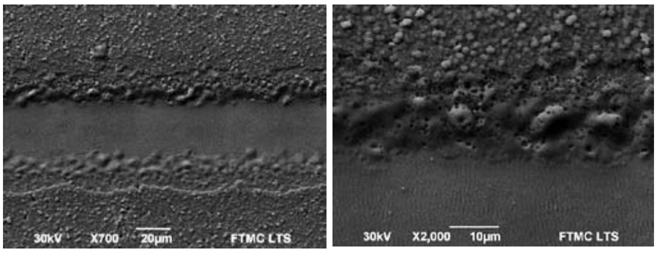

Fig. 7. R2, 25.56 W, 987 kHz, 49.35 m/s, 16 lines, (overall speed 3 m/s), pulse interleaving.

Conclusions

High power and repetition rate picosecond laser from Ekspla combined with high speed polygon scanner with SuperSync™ technology from Next Scan Technologies has been tested and proved to be a perfect combination for various applications unifying processing qualities: speed, power and precision. The applications assessed and validated in this application note are: high speed and precision surface marking; drilling holes without heat accumulation; flexible 3D cavity engraving and selective ablation of thin films. The laser-polygon pair equipped with SuperSync™ technology has a bright future in infinite number of applications where production rate, accuracy and capacity is needed.

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