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LASER MICROJET® TECHNOLOGY PROVES ITS SUPERIORITY IN CUTTING AND EDGE ISOLATION OF SILICON PV CELLS

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ABSTRACT:

Photovoltaics is a relatively young technology with almost no impact on the environment. As it quietly generates electricity from light, PV produces no air pollution or hazardous waste. The global production of photovoltaic power has seen a strong increase of more than 35% each year. In order to make it become more affordable and available, more efficient and less expensive manufacturing tools are desirable. Preventing short-circuits by isolating the edge of PV cells is a usual operation that increases cell yield. Several technologies are today available to prevent these shunts. However, conventional techniques such as laser cutting or plasma etching are not always satisfying, either because of excessive heat damages or high hourly running costs. This paper presents the high quality cutting and scribing results on silicon PV solar cells using the water jet-guided laser (Laser MicroJet®) without thermal or mechanical damage. Both contour cutting and edge isolation show the superiority of the LMJ technology. The study was conducted in cooperation with Solarwatt Solar-System GmbH and the Fraunhofer-Institute for Solar Energy Systems ISE. It includes testing the electrical parameters of the cells after edge isolation, thermography and SunsVoc measurements, SEM and optical microscope images and breakage tests. The water jet-guided laser was also compared to a standard dry laser edge-isolation process.

Keywords: Water jet guided laser, laser processing, edge isolation, cutting, silicon, PV cells

Explanatory pages

1 INTRODUCTION

Aside from cutting, a common step during PV cell production is edge isolation. This operation prevents parasitic shunts between the front and back sides of the cell, which may decrease the efficiency of the cell. For edge isolation, the cutting tool should be able to cut through both the metal layers and the silicon without any damage.

2 WATER JET-GUIDED LASER

The principle of this unique technology, also called Laser MicroJet®, is to couple a high-power, pulsed laser beam into a hair-thin, low-pressure water jet (Fig. 1).

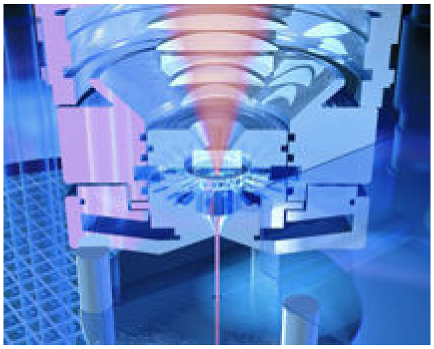


Fig. 1: Basic principle of the water-jet-guided laser

The laser beam is conducted by fiber to the system center and passes through a transparent window entering a chamber filled with water and is focused into a nozzle where it is coupled with the water jet exiting the chamber. From this point, the laser beam is guided along the cylindrical jet by total internal reflection at the air/water interface, due to the difference of refractive indexes. When it reaches the work piece, the laser removes the material by melting and vaporization.

Like the other laser-based technologies, the water jet-guided laser features omni-directional cutting. However, the process speed is higher on thin materials. For example, a cutting speed of up to 300 mm/s can be achieved on silicon that is 50 µm thick. Furthermore, using a water jet offers several benefits, well known as unobtainable when applying conventional, “dry” laser cutting. To cite a few, extended working distance, heat control and particle removal.

Finally, contamination is greatly reduced compared to conventional lasers since the water jet expels the molten material more efficiently than the assist gas usually applied in laser cutting. Additionally, a thin water film, maintained on the surface of the work piece during cutting, prevents the remaining particles to adhere to the material.

3 CONTOUR CUTTING OF SOLAR CELLS

In the cutting tests with the Laser MicroJet® in silicon cells, only very slight damage occurred to the layer of the processed edge. The surfaces of the cuts are visually flawless (Fig. 2). The measurements of the efficiency gradient across the cell surface area display no process-induced efficiency losses at the cut edges in the short-circuit current and reflection topography. The overall cutting speed is 80 mm/s for a wafer thickness of 330µm. This achieved cutting speed corresponds to that of a conventional laser but the quality and functionality of the cutting results are greatly improved.

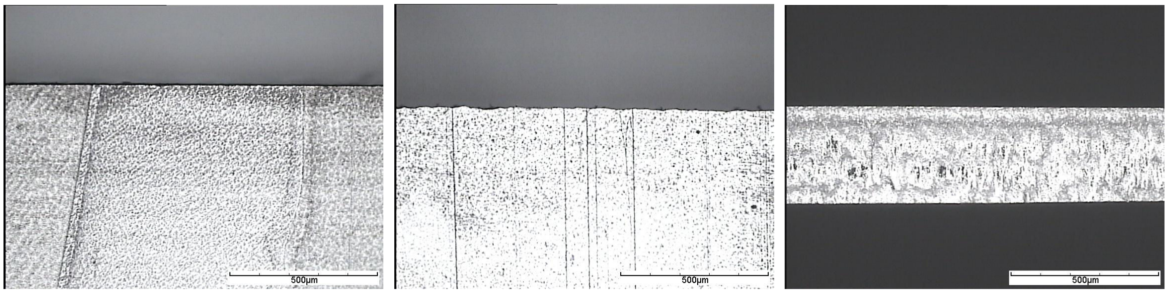


Figure2: a) Front side of a solar cell cut by LMJ, b) Backside of a solar cell cut by LMJ, c) Kerf wall

With the CNC-controlled Laser MicroJet®, any desired 2D contour can be cut in solar cells. Sectional cuts in the material involve no problems whatsoever, as illustrated in Fig. 3. Though no post-cleaning process was applied to these samples, the cutting results were superior. For this cutting process a 532 nm Q-switched laser with a 80 µm nozzle was employed.

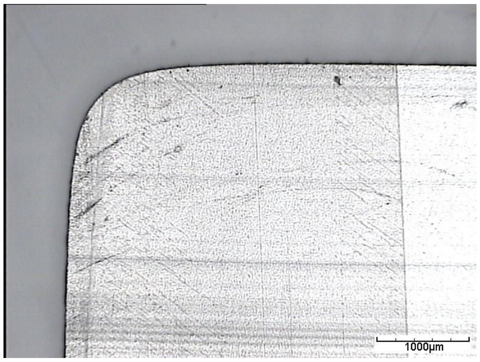


Fig. 3: A rounded corner cut by LMJ (top view)

4 LASER MICROJET FOR EDGE ISOLATION

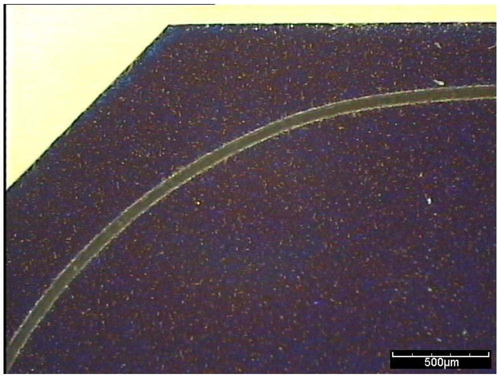


Fig. 4: Microscope image of a groove at the corner of the cell, **Scribing speed: 300 mm/s**

The scribing parameters were optimized to result in a minimum amount of debris in the grooves that could possibly lead to shorts over the groove, while keeping a high process rate.

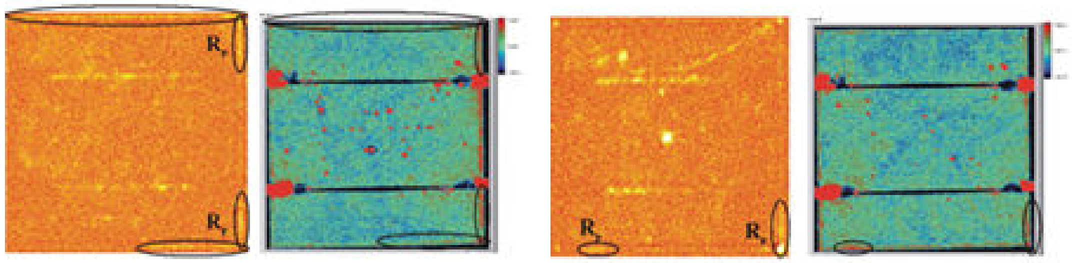
125 commercial solar cells were edge-isolated by a standard edge isolation (EI) and the LMJ process

4.1 Electrical parameters

Successful edge isolation on the backside of the solar cell was observed. In principle, this kind of isolation is preferred to the front side edge isolation, because the active cell area is reduced in the latter case. Similar efficiencies were found as achieved by the front side isolation. A 20µm deep laser groove was sufficient for good edge isolation while a 5 µm deep groove seemed to be too shallow. The isolation process was carried out with a fast scanning speed of 250 mm/sec. Consequently a 156 x 156 mm2 solar cell could be edge isolated in 4 * 156 mm / 250 mm/s = 2.5 sec. Even higher scanning speeds for used lasers are possible, because a groove depth of 10 µm (compared to standard lasers) is enough. A transfer rate of 1-2 sec per wafer is for this reason realistic for the LMJ.

4.2 Thermography measurements

The thermography images in Fig. 5 depict that for the standard-industry-EI still ohmic? shunts exists, whereas with LMJ they are generally removed. For the edge isolations on the back side, both kinds of shunts (RP, J02) are still present; there is a demand of further optimization.



a) Standard-industry process, front side b) LMJ, front side

Fig. 5: Thermography measurements (left: V_{oc}; right: reverse bias)

4.3 SunsV_{oc} measurements

A series of resistance free IV-curve were measured with SunsVoc in order to find out what the potential of the solar cell would be if the series resistance were zero. The losses by series resistance were for all cells approximately equal. This denotes that series resistances of the analyzed cells did not spread in a wide range and reduced the maximum achievable fill factors by approximately 5% rel.

4.4 Breakage test

To analyze the mechanical strength, all cells were break tested with a Zwick BasicLine 4-line-bending apparatus. The maximum breakage force was detected. The required breakage force area depicted in Fig. 5 stands for all EI-methods.

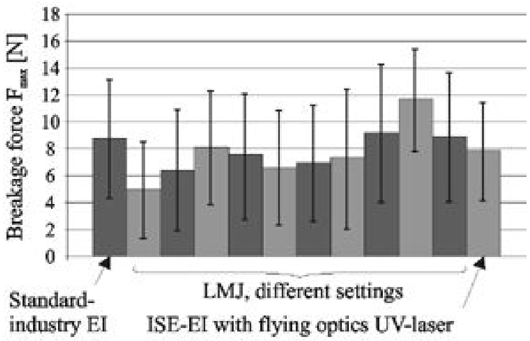


Fig. 5: Comparison of the breakage forces of different EI-methods