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Application Note No. 110

Cutting of Photovoltaic (PV) Solar Cells with SYNOVA Laser-Microjet®

Description of Product

Photovoltaic (PV) cells convert sunlight directly into electricity. PV cells are the solar cells that are commonly used to power calculators and watches.
PV cells are made of semi-conducting materials similar to those used in computer chips. When sunlight is absorbed by these materials; the solar energy releases electrons from their atoms, allowing the electrons to flow through the material to produce electricity. This process of converting light (photons) to electricity (voltage) is called the *photovoltaic effect.*

Photovoltaic Solar Cell

Description of Material

The chemical element Silicon (from Silex, hard stone) is abundantly available in nature in many different compounds. In fact, Silicon is the second most abundant element in the earth's crust, next to oxygen. Pure silicon is an intrinsic semiconductor. By chemical purification of sand, one obtains blocks of electronically pure silicon. The next step is the conversion from pure poly-crystalline material to crystalline bulk silicon. Two types of bulk crystallization exist: firstly pulling mono-crystalline silicon using the Czochralski technique and secondly multi- or poly-crystalline silicon formation techniques. For semiconductor applications, mono-crystalline silicon is used
The typical thickness of thin wafers is between 200 and 300 microns, its standard size is 100 x 100 mm or 150 x 100 mm.

Description of Manufacturing Task

The standard form of 100 x 100 of solar cells must sometimes to be reshaped in order to fit into a given module. To improve the energy exploitation, the cells have to cover the maximum of a given surface, requiring the cells to be either cut or drilled. The method applied for this shall not influence the electrical efficiency of the cell.

Description of Conventional Manufacturing Process (State of the Art) and Problem

As long as the cuts are straight, a low-cost scribing/breaking process can be applied. But in most cases, the cell has to be cut in a contour.
When a conventional laser is applied, the heating of the edge leads to structural changes and to micro cracks. In addition, re-cast metal on the edge creates short-circuits of the p-n transmission zone. In the case of high-pressure water jet cutting, the cell is strongly damaged and the cell is partially ineffective. Therefore, there is a demand for a damage-free, flexible process for 2D cutting of solar cells.

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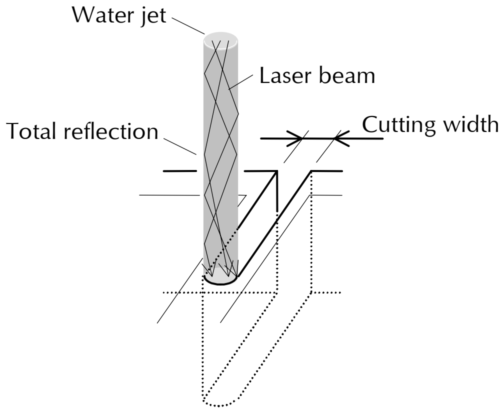
Water Jet Guided Laser Technique

In 1993, scientists at the Institute for Applied Optics at the Swiss Federal Institute of Technology Lausanne succeeded in creating a water jet guided laser, called by its inventors Laser-Microjet®.
The laser beam is focused in a nozzle while passing through a pressurised water chamber. The geometry of the chamber and nozzle are decisive to coupling the energy-rich laser beam in the water jet.
The low-pressure water jet emitted from the nozzle guides the laser beam by means of total reflection at the transition zone between water and air, in a manner similar to conventional glass fibres. The water jet can thus be referred to as a fluid optical wave-guide of variable length.



Cutting with water jet guided laser

Because a pulsed laser is used, the continuous water jet is able to immediately re-cool the cut, resulting in only a very slight depth of thermal penetration. The result is a very narrow, parallel, burr-free, clean cut, without any thermal damage.

Solution with Laser-Microjet® Process

It has been shown in a recent study[1] that the Laser-Microjet® process is able, thanks to its efficient cooling by the water jet, to cut solar cells without influencing the electrical efficiency; the measurements have shown no significant changes.
In addition to cutting a wide range of different shapes, the Laser-Microjet® allows scribing for isolating, drilling for through-contact, edge isolation, edge truncation, surface structuring, and surface texturing.

As the following pictures show, special shapes can be easily obtained.

Solar cells cut by Laser-Microjet®

[1] "Effective Cutting of Solar Cells: Evaluation of beam Technologies for contour cutting of Silicon", Heikenwälder et al., 2000; made by the German research institute, ITW, in Chemnitz.

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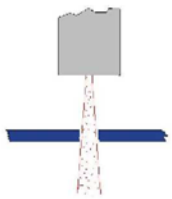
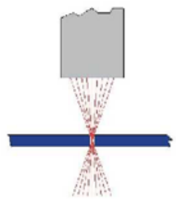
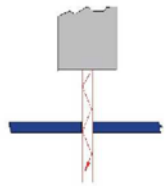
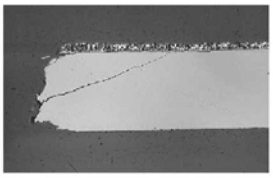
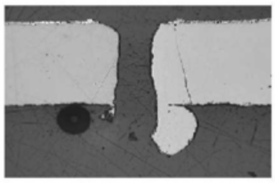
The following table shows the results in comparison to high pressure water jet and conventional laser:

Abrasive water jet	Conventional laser	Laser- Microjet®
		
		
Chipping, cracks, large kerf	**Burrs, re-cast, heat damages**	**Precise cut, no damages in the edge**

Benefit for the Customer

The customer now obtains the following advantages:

- No influence on electrical efficiency of the solar cell after cutting
- No mechanical stress, force free
- No chipping
- No burrs, no slag
- No heat damages
- Omni directional cutting, cutting of straight and round shapes
- Process can be used for drilling, scribing, grooving, edge grinding, thinning, and marking
- Kerf width 25 - 80 micron
- Cutting speed up to 100 mm/s in both directions
- Ideal for thin solar cells
- Wafer thickness 25 micron - 5 mm
- LaserTape® can be used
- No tool-wear
- Very few consumables, low running costs

Consequence of the Benefits

Because of the huge improvement in quality, flexibility and productivity compared to the conventional sawing process, the Laser-Microjet® process will be the future choice for cutting of solar cells.

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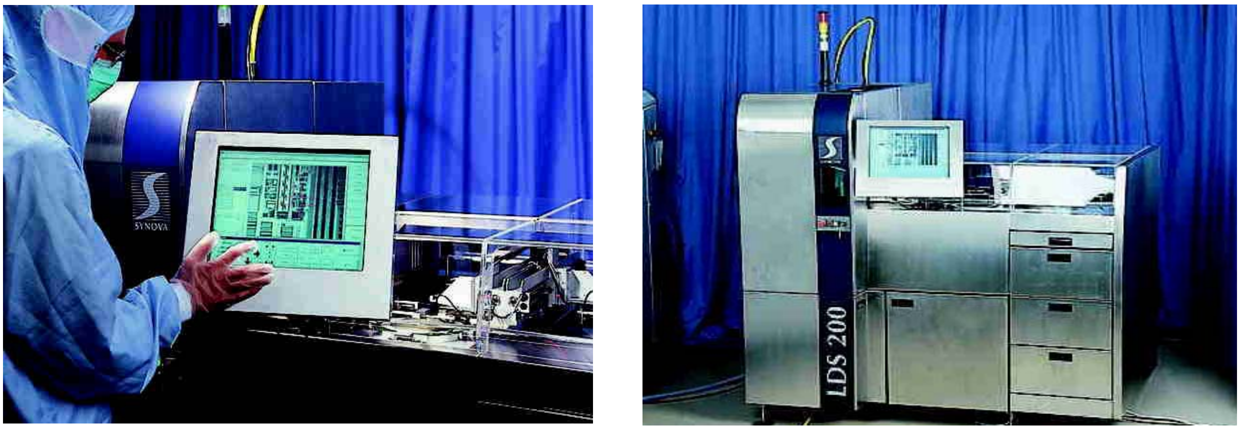
Machine for Laser-Microjet®[2] Cutting of Solar cells

Synova offers a state-of-the-art, clean-room compatible machine, especially adapted for dicing of thin wafers. Optimum cutting parameters are preloaded. The machine designation is LDS 200. A cleaning unit and an automatic loading system are available as well.

The machine has a precision of +/- 3 microns, a processing area of 240 x 240 mm (8-inch wafers) and a maximum axis velocity of 1000 mm/s. The system is equipped with a CCD camera and a fast image treatment software allowing automatic alignment and inspection. The operation interface is a 15-inch flat colour screen with touch panel. The machine's software is based on MS Windows NT®[3]. The machine can be connected to a LAN network for data transmission. The integrated modem allows remote diagnostic service. Adapted CAM software can convert all DXF data, fast and easy without special programming. This data interface is important, especially for multi-project wafers.



LDS 200 A (Fully Automatic Laser Dicing System)

A complete list of options is available such as chiller, alternative laser sources, water treatment system, 2D-reference scales, and transformers.

The CE and S2 certified Synova machines have been repeatedly field proven and are used for 24h industrial production.

[2] Laser-Microjet® and LaserTape® are international protected trademarks of Synova S.A, Switzerland.
[3] Windows NT® is a trademark of Microsoft Corp, USA.