EDGE ISOLATION OF PV CELLS USING THE WATER JET GUIDED LASER TECHNOLOGY

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ABSTRACT: 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, these techniques are not always satisfying, either because of important heat damages (conventional laser cutting) or high hourly running costs (plasma etching). For some years, a new laser-based technology – the water jet guided laser – has been successfully used to process silicon PV cells without thermal or mechanical damage. The basic principle of this technology is to couple a laser beam into an ultra-thin water jet, in which it is guided by means of total internal reflection at the water/air interface, in a manner similar to conventional glass fibers. Using the water jet guided laser, edge isolation is realized by grooving the cell close to its edge. High grooving quality is achieved at high speed (up to 300 mm/s for a grooving that is 30 µm deep). The hourly running costs remain low, since there is no tool wear and because the water consumption is very low.
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1 EDGE ISOLATION OF SILICON PV CELLS

Since 2000, the global production of photovoltaic power has increased of more than 35% each year. As the market of PV solar cells is fast growing, the need for efficient manufacturing tools is increasing as well. Besides cutting, a usual step during PV cell production, which requires an efficient machining tool, 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 silicon and the metal layers without any damage.

A common process for edge isolation is plasma etching. To create a plasma – i.e. splitting of a neutral gas (such as oxygen) into ions and electrons –, an electric field is generated at the material surface using a voltage source (RF or microwave). Although this technique gives satisfactory isolation results for relatively low-cost equipment, the demand on personnel is very high and the process flow is rather low. Additionally, the process creates some damage to the silicon surface, which may penetrate into the junction, causing a loss in fill factor.

Conventional laser cutting may also be used for edge isolation. The laser beam is focused on the work piece and absorbed by the material, which is heated until melting and vaporization. The main disadvantage of this technique is heat damage; additionally, re-melting may occur around the cut, resulting in stress-induced cracks in the boundary layer. Drops of molten metallic particles from circuit tracks may also be present on the surface, inducing short-circuits that reduce the PV capability of the cell.

Mechanical methods, such as diamond saws, can generate mechanical damage that is problematic during handling, especially for very thin silicon wafers. The process also reduces the active cell area, thus wasting silicon, and cannot be used on curved contours.

For a few years, a new technology – the water jet guided laser – has been used for edge isolation of PV cells, which is performed, like with conventional lasers, by grooving the cell close to its edge. However, contrary to conventional laser-based techniques, the process does not generate heat damage and contamination is negligible.

2 WATER JET GUIDED LASER

2.1 Basic principle

The principle of this process is to use a water jet to guide the laser light. A laser beam is focused into a nozzle while passing through a pressurized water chamber. The water jet that is emitted from the nozzle guides the laser beam by means of total internal reflection at the water-air interface, similar to conventional glass fibres. The water jet can thus be described as a fluid optical wave-guide of variable length (see Fig.1) that delivers the laser power directly onto the work-piece with negligible losses.

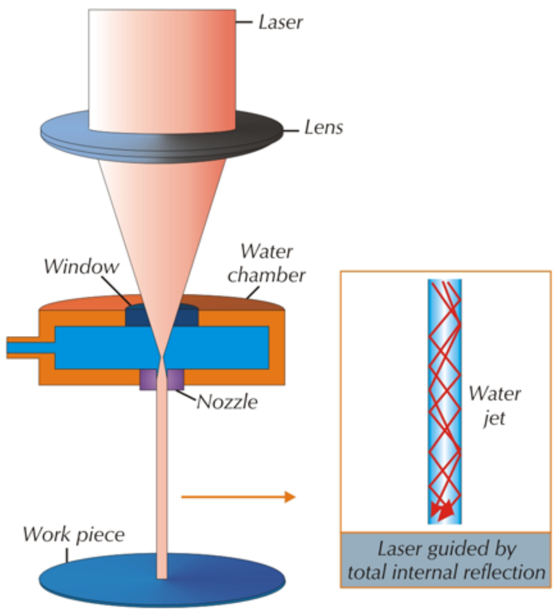

Figure 1: Basic principle of the water jet guided laser

2.2 Technical parameters

The water jet guided laser is a versatile tool. Among the various available laser sources, the most commonly used are Nd:YAG lasers operating at 1064 nm (infrared) or 532 nm (green light). The only constraint on the laser wavelength is that it must fit the water transmission spectrum. The laser power can be applied either as a continuous wave or in the form of pulsed light. However, for many applications, pulsed laser power should be preferred because the water jet will be able to cool the material during the pause between the pulses.

The nozzles are sapphires or diamonds whose diameter varies between 25 and 100 µm. New, smaller nozzles are currently undergoing lab tests, and these nozzles allow a kerf width of only 18 µm. Depending on that diameter, the pressure of the water – usually pure de-ionized water – ranges from 50 to 500 bars. However, the mechanical force applied by the water jet can be considered negligible, as the material remains unscathed when exposed to the bare jet (less than 0.1 N). As a comparison, the assist gas jet used in conventional laser cutting applies a force around 1 N – 10 times higher than the water jet guided laser.

2.3 Comparison with conventional lasers

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. Moreover, using a water jet offers several advantages over conventional "dry" laser cutting as far as working distance, heat control and particle removal are concerned.

Indeed, in conventional laser techniques, the laser beam, conically shaped, is focused directly on the work piece, resulting in a short working distance. When a water jet is used to guide the laser beam, the working distance is much longer (up to several centimeters long, depending on the nozzle diameter) and, as the jet is cylindrical, the kerf walls are parallel.

The heat-affected zone, which is problematic with conventional lasers, is negligible, thanks to the water jet that cools the material between the laser pulses.

At last, 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.

2.4 Water jet guided laser for edge isolation

When applied to silicon PV cells for edge isolation, the water jet guided laser achieves high groove quality. Cells do not lose efficiency due to the process. Thanks to the long working distance, uneven surfaces can be processed. The process presents low running costs, since there is no tool wear; water consumption is very low.

3 EXAMPLES

Several parameters can be set to meet the requirements of each specific application – mainly the laser source and the nozzle diameter. For example, 30-µm deep grooving of a silicon PV-cell (1 mm from the edge) may be achieved at a speed of 300 mm/s if a frequency-doubled laser (wavelength 532 nm, average power 50 W) and a micro-jet of 60 µm in diameter are chosen.

Figure 2 displays the backside of a silicon cell that has been completely cut using the water jet guided laser. The surface of the material is undamaged.

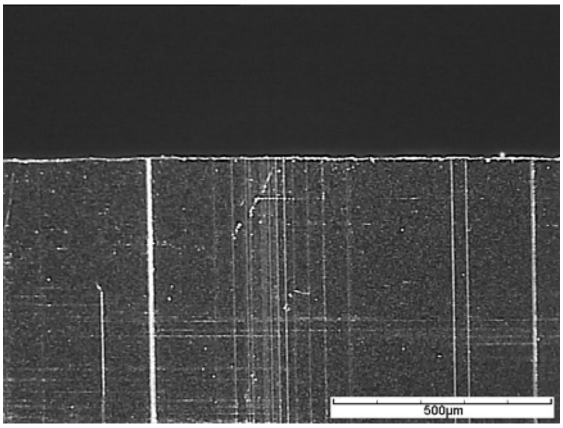

Figure 2: Through-cutting of a silicon PV cell (backside)

3 SUMMARY

With the advantages provided by the use of water, the water jet guided laser technology overcomes the drawbacks of conventional dry lasers. Scribing of silicon PV-cells is achieved at high speeds (up to 300 mm/s for a grooving that is 30 µm deep), with a level of cleanliness that cannot be attained by conventional dry lasers. There is no chipping due to mechanical stress, which may occur with abrasive saws, and any cutting design can be achieved. The water jet guided laser also works with wafers that are not completely flat, which is often the case with solar cells.