

PV PROCESSING

Improved PV-Cell Scribing Using Water Jet Guided Laser

Twelve years ago, a new cutting process, combining laser and water, was invented in Switzerland. This original concept focuses the light of a laser into a hair-thin water jet, which then uses total internal reflection to guide the laser. Originally developed for medical applications, the process is being adapted for solar PV cell processing. Delphine Perrottet, Christophe Boillat, Simone Amorosi, and Bernold Richerzhagen from Synova SA, Switzerland describe the technique.

Although the water jet guided laser was originally developed for medical applications, nowadays, the semiconductor field primarily benefits from this innovative technology. However, it is also used in an increasing number of other fields, including tooling and energy, and is particularly well-fitted for processing silicon PV-cells, especially for performing edge isolation. Global production of photovoltaic power has increased more than 35% each year. As the market develops the need for efficient manufacturing tools is on the increase. Laser guided water jet cutting is one process that is improving efficiencies in solar PV cell manufacture.

For solar cell processing, conventional laser cutting is not a satisfactory solution because it generates heat-induced damage

and damaging particles. Diamond saws can be problematic due to mechanical damage, especially for very thin silicon wafers. The process reduces the active cell area, thus wasting silicon, and cannot be used on curved contours. Therefore, there is a real need for a versatile, gentle process that is capable of cutting through both the silicon and the metal layers without any damage.

Water jet guided laser

The principle of the water jet guided laser entails the use of a laser beam focused into a nozzle while being passed 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. The water jet can thus be described as a fluid optical waveguide of variable length (see Figure 1) that delivers the laser power directly onto the work-piece with negligible losses.

Like other laser-based technologies, the water jet guided laser features omni-directional cutting. Moreover, 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 microns thick. However, using a water jet offers several advantages over conventional "dry" laser cutting as far as working distance, heat control and particle removal are concerned (see Table 1).

The water jet guided laser is thus a "gentle" process. An examination of its technical

parameters reveals that it is also 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 microns. New, smaller nozzles are currently undergoing lab tests, and these nozzles allow a kerf width of only 18 microns. 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 that typically ranges from 1 to 5 N, 10 times higher than the water jet guided laser.

Edge isolation

A usual step during PV cell production is edge isolation, which prevents parasitic shunts between the front and back sides of the cell. Several technologies are available today to prevent or remove these shunts that decrease the efficiency of the cell.

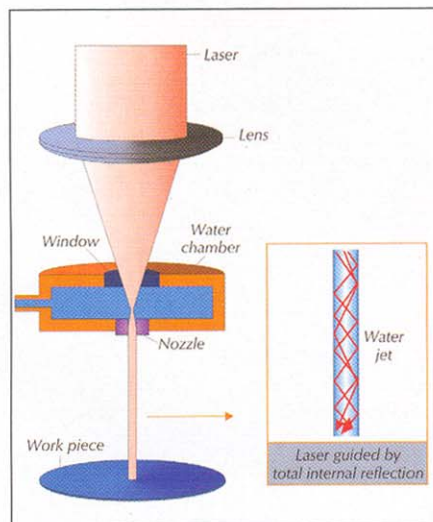


Figure 1: Water jet guided laser principle

Further information

Contact: Delphine Perrottet, SYNOVA SA, Chemin de la Dent d'Oche, 1024 Ecublens, Switzerland. Tel: +41 21 694 35 00; Fax: +41 21 694 35 01; e-mail: perrottet@synova.ch; website: www.synova.ch

A common process for edge isolation is plasma etching. A voltage source (RF or microwave) generates an electric field to create a plasma - i.e. splitting of a neutral gas (such as oxygen) into ions and electrons - at the material surface. Plasma etching gives satisfactory isolation results; the process is robust and requires relatively low-cost equipment. However, 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.

Another process for this application is conventional laser cutting. The laser beam is focused on the work piece and absorbed by the material, which is heated until melting and vaporization occur. The main drawback with this technique is heat damage; additionally, re-melting may occur at the cut surface areas, 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.

Groove quality

Recently, the water jet guided laser technology has also been used for edge isolation of PV cells, which is performed, like with conventional lasers, by grooving the cell close to its edge. The process achieves high groove quality, generating no thermal or mechanical damages to the material and significantly reducing contamination. Cells do not lose efficiency due to the grooving process. A significant advantage of the water jet guided

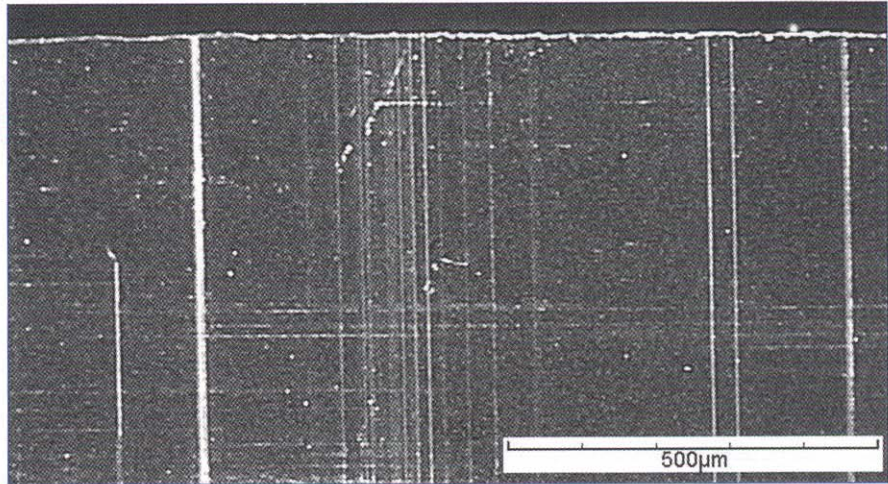


Figure 2: Backside of a silicon cell processed with the water jet guided laser (the lines were present on the wafer prior to cutting)

laser over conventional laser is the long working distance, which enables uneven surfaces to be processed. Like other laser-based technologies, the water jet guided laser presents low running costs, since there is no tool wear; water consumption is negligible.

Flexibility

With the water jet guided laser technology, several parameters can be set to meet the requirements of each specific application - mainly the laser source and the nozzle diameter. For example, 30 microns 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 microns in diameter are chosen.

Figure 2 displays the backside of a silicon cell that has been completely cut using the water jet guided laser. To achieve the high

edge quality, the cutting speed has been decreased on the last 10% of the thickness. The surface of the material is visually undamaged.

Summary

With the advantages provided by the use of water, 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 microns 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. To sum up, the Laser-Microjet is a well-fitted tool for fast and clean PV-cell processing.

Table 1: Comparison between the water jet guided laser and a conventional dry laser

	Water jet guided laser	Conventional dry laser
Working Distance	- Cylindrical and constant microjet - Working distance: up to several centimetres long	- Conical beam - short working distance
Cooling	- Water jet cooling the material between laser pulses - negligible heat effects	- significant heat damage
Material removal	- water jet expelling molten material	- Assist gas, 800 times less efficient
Cleanness	- water film on the material - no contamination	- protective coating required - increased cost of ownership