REPORT: C-60 Solar Cell cutting by Laser-MicroJet®

for Anonymous

by Florent Bruckert, Synova SA

OBJECTIVE

The Laser-MicroJet® technology has been tested for cutting C-60 Sunpower solar cells and Anonymous composite solar cells.
Various cutting strategies have been performed, including the cutting with a one-pass strategy and a multi-pass strategy. Several laser and process parameters have been tested.

SAMPLES DESCRIPTION

SAMPLES	Material	Mono- Si solar cell	Mono- Si solar cell + PCB layer on backside	
	Dimension	125X125		mm^2
	Thickness	180-200	180-200 + 200 (PCB)	µm
	Quantity	10	5	pcs

PROCESS: INSTRUMENT & TEST PARAMETERS

Major advantages of Laser-MicroJet® technology with regards to Solar Cells cutting are:

- Advantageous process rates
- Negligible contamination / re-deposition
- Negligible heat damage to the material
- Negligible crack formation

Release of application report			
Project Leader		Responsible Application Group	
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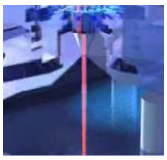
Date:	20.10.2014	Date:	20.10.2014
Visum:	FBR	Visum:	BC

PROCESS: INSTRUMENT & TEST PARAMETERS

For these experiments, the LCS300, Nd:YAG laser, has been selected as the most suitable machine configuration.

In the table below, the optimized processing parameters used in the experiments are summarized:

	**SYSTEM**	Machine type	LDS 300	
		Fixing type	*Laid out on a specific holder*	
	**MICROJET® PARAMETERS**	Nozzle diameter	50	*µm*
		MicroJet® diameter	45	*µm*
		Water pressure	100/300/500	*bar*
		Protect gas: Helium	0.9	*L/min*
	**LASER PARAMETERS**	Laser type	SP31G	
		Wavelength	532	*nm*

Theoretically, the bulk absorption in silicon is one thousand times higher at 532 nm (second harmonic Nd:YAG) than at 1064 nm (first harmonic Nd:YAG). In order to have the best energy conversion to enhance the “cold ablation effect”, a green laser source has been selected.
The previous development has shown a higher conversion efficiency of the final cell while cutting with a short pulse laser (<100 ns FWHM). So, the latest developments have been processed thanks to a SP laser.

The cutting parameters are variable and are described below.

OBJECTIVE

The main purpose of these tests was to cut through the C60 cells without generating additional shunts.

In general, shunts reduce the overall solar cell's conversion efficiency. There are two types of shunts, showing either a linear (ohmic) I-V characteristic or a non- linear (diode-like) characteristic.
As far as linear shunts are concerned, the resistance R is subject to vary (usually under low illumination I<1sun) with:
- The creation of aluminum or other metallic alloys with the silicon matrix.
- The inter-diffusion of dopants or metallic impurities. It generates a preferentially ohmic contact to the p-base.
- The crystallization of highly n-conducting SiC, SiN or AlSi filaments or crystallites crossing the cell
- The cracks induced by the cutting process.

It is possible to quantify this shunt effect with an usual multimeter. Under low illumination, the leakage effect is highlighted, thus decreasing the resistance between the "P" and the "n" fingers. The aim is to obtain more than 1 MΩ under a low illumination to guarantee a full capacity and efficiency of the final device.

TESTS SHAPES AND DELIVRABLES

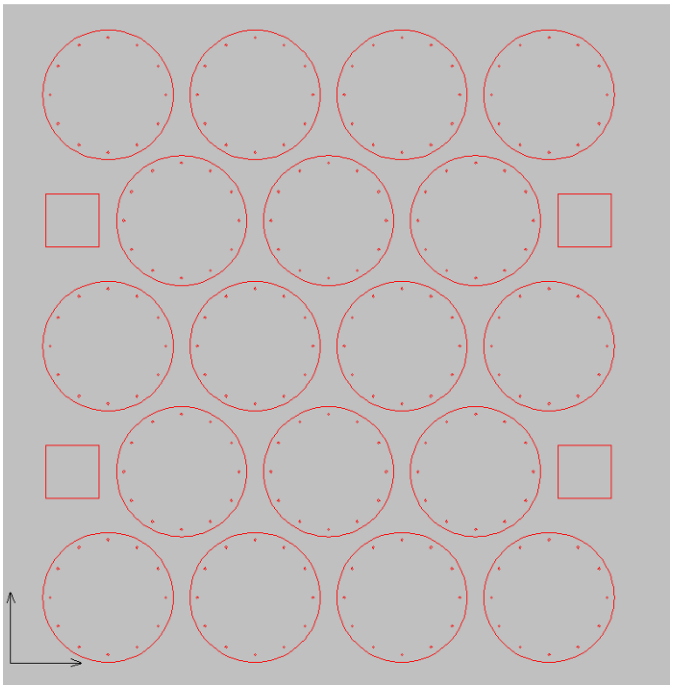


FIGURE 1: Drawing showing the requested cutting pattern

It has been requested to cut all cells from the active side (called front side) in order to be able to cut this pattern also on the Anonymous type cells (C60 cells set on a PCB layer). (See FIGURES 2 & 3)

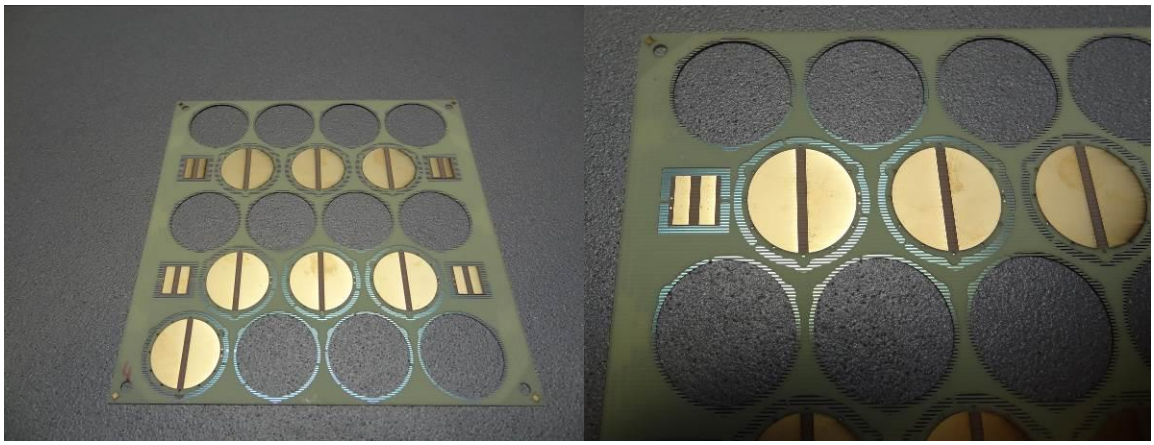


FIGURE 2: Pictures showing the backside structure on Anonymous type cells (circular shapes already cut)

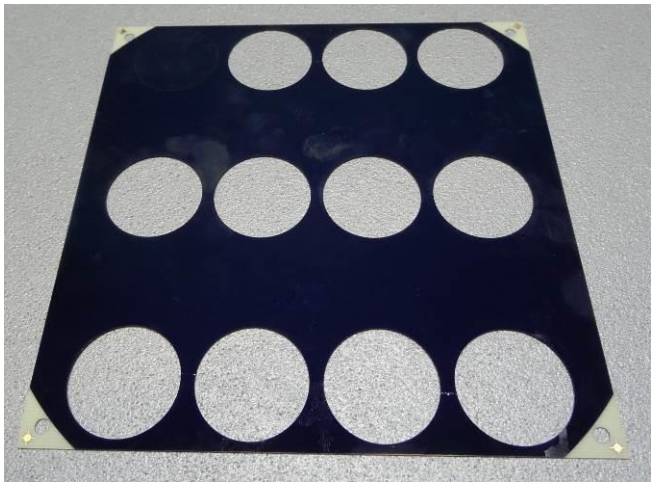


FIGURE 3: Picture showing the front side structure on Anonymous type cells and on C60 Sunpower cells (circular shapes already cut)

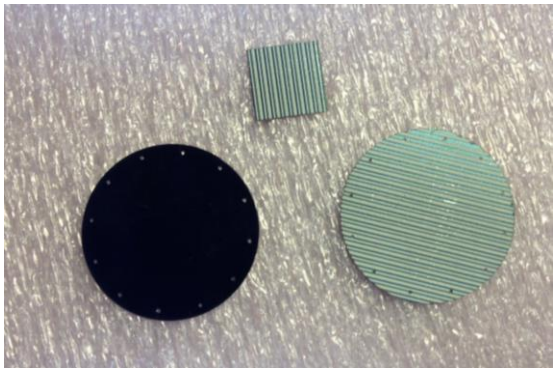


FIGURE 4: Picture showing the front side and backside structure of circular and square cuts on a C60 Sunpower cell

10 C60 cells and 4 compounds (C60 cells laid on a PCB substrate as shown on FIGURE 2) (4 squares and 18 circular shapes) have been sent in order to estimate the influences of the latest developed parameters.

SAMPLES DESCRIPTION

The strategies have been processed on the C-60 wafers and on the final compounds with the following optimized cutting parameters:

Cell ref.	Cell type	Water pressure (bar)	Laser freq. (kHz)	Internal power (W)	Power in the waterjet (W)	Pulse width (ns)	Number passes internal contour	Cutting speed for the internal contour (mm/s)	Number passes outer contour	Cutting speed outer contour (mm/s)	Process time (min-s)	Measured R (average) R2(kΩ)	Note
A	C60 thick	100	150	28.4	20	28	10	100	1	5	7min42s	67	Stable
B		200	170	26	18.5	30			1	5	-	-	not cut through
C									1	3	-	-	not cut through
D									1	5	-	-	Unstable
E									1	3	11min25s	24	High variance
F		100	150	28.4	20	28			1	5	7min42s	66	stable
G			130	30	21	26			1	7	6min21s	65	stable
H			100	34	24.3	22			1	10	4min55s	0.5	Unstable
I		500	170	26	18.5	30			5	100	5min55s	67	Unstable (speed)
J		300	100	34	24.3	22	15	50	5	100	3min20s	45	unstable
C1	Comp. thick	**300**	**100**	34	24.3	22	**10**	**100**	**5**	**100**	**3min20s**	-	Stable
C2												-	
C3												-	
C4		**100**	**150**	28.4	20	28	**10**	**100**	**1**	**5**	**7min42s**	-	
C5												-	

The optimal process time for the full pattern with the multi-pass strategy is close to 3 minutes and 20 seconds which is within your expectations concerning a potential industrialization.

The following microscope pictures give an overview on the quality obtained with the Laser-Microjet® technology.

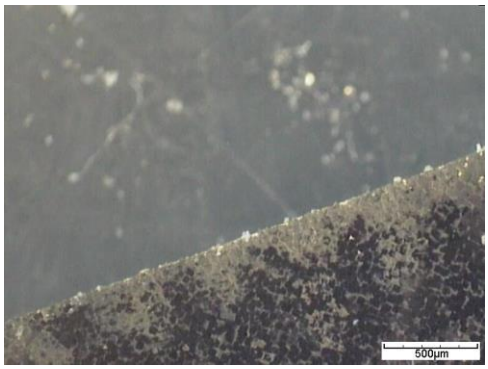


FIGURE 5: C 60 cell cut, front side view

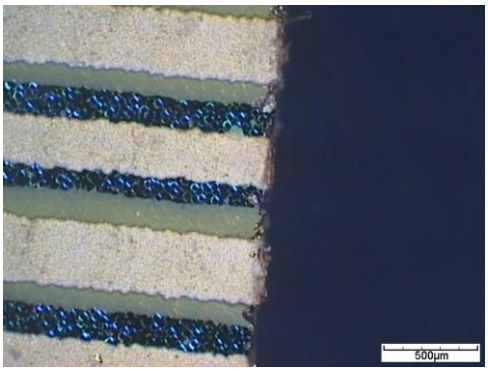


FIGURE 6: C 60 cell cut, back side view

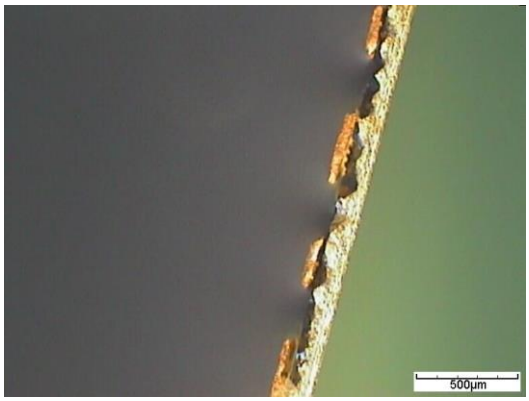


FIGURE 7: C 60 cell cut, edge view

CONCLUSION

The C60 and the Swarovski-type solar cells cutting into circular and square solar cell were investigated on SYNOVA LDS 300.
This machine is based on the MicroJet® technology and combines the advantages of a high energy pulsed fiber laser with a hair-thin water jet. While the laser is used for material ablation, the water jet is used for guiding the laser light, cooling the edges and preventing particle contamination, advantages that are essential for scribing and cutting of solar cells with high quality.

The absorption properties of the silicon lead us to use the green source to optimize the cold ablation effect.
So, a green laser source (wavelength: 532 nm; pulse width: 28 ns) was used to cut through C-60 cells according to the Anonymous pattern.
We used different cutting parameters to get the best edge isolation and so to reduce the quantity of generated shunts.

The tests show that:

- It has been possible to optimize the efficiency of small devices (high resistance under a low illumination) thanks to laser and process set of parameters.
- The expectation in terms of final resistance has been reached.
- The best process time for the full design is close to 3 min 20 sec.
- The results seem to be stable and repeatable.

We are open to further discuss your needs regarding:

- The fixture system in order to keep a constant ablation rate during the process.
- The cleaning.

We thank you for your interest in our technology and we hope our results meet your requirements.
Our sales agent will contact you soon to obtain a feedback about the analysis of these results and to discuss with you the further steps.