LASER INDUCED FORWARD TRANSFER OF SILVER PASTES FOR PRINTING OF FINGERS IN C-SI CELLS.

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ABSTRACT: The main objective of this work is to adapt the Laser Induced Forward Techniques (LIFT), a well-known laser direct writing technique for material transfer, to define metallic contacts (fingers and busbars) onto c-Si cells. The silver paste (with viscosity around 30-50 kcPs) is applied over a glass substrate using a coater. The thickness of the paste can be control changing the deposit parameters. The glass with the silver paste is set at a controlled gap over the c-Si cell. A solid state pulsed laser (532 nm) is focused at the glass/silver interface producing a droplet of silver that it is transferred to the c-Si cell. A scanner is used to print lines.
The process parameters (silver paste thickness, gap and laser parameters -spot size, pulse energy and overlapping of pulses) are modified and the morphology of the lines is studied using confocal microscopy.
Long lines are printed and the uniformity (in thickness and height) is studied. Some examples of metallization of larger areas (up to 10 cm x 10 cm) are presented.

Keywords: see enclosed list of keywords

1 INTRODUCTION

Laser-induced forward transfer (LIFT) is a direct-write technique capable of printing precise patterns of a variety of materials [1-5],

The LIFT process has some attractive features such as flexibility in choice of inks and a easy setup that has even led to an industrial implementation [6].

LIFT uses laser pulses to push thin disks of a ribbon material from a transparent substrate and deposit them onto an acceptor substrate. The laser beam is focused in the donor substrate/ribbon interface. During the pulse duration, the laser energy is deposited within the laser spot size into the interface, evaporating a little amount of the material and generating the expansion of the remaining material, accelerating the non-evaporated part of the metal film towards the acceptor substrate, see figure 1.

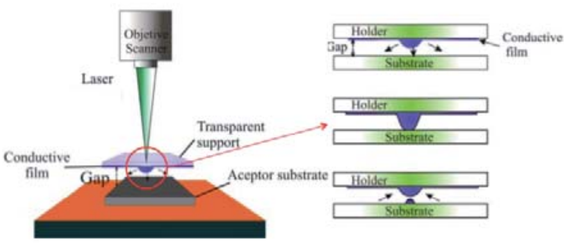

Figure 1: Principle of LIFT process for metalisation of thin-film solar cells.

By translating the donor and acceptor substrates or moving the pulse location with a rotating mirror between pulses, user-defined patterns of high-resolution droplets can be deposited [7].

The LIFT made with ns pulses is a well-known technology to generate structured metallization onto substrates but have not been applied up to the moment to define in a single step the fingers of front contact in a photovoltaics device (though two steps approaches has been developed in the last years [8]).

The aim of solar cell researchers and manufacturers is to find technologies leading to an increase in the efficiencies of solar cells and, at the same time, keep low costs. Procedures capable of making better contacts by improving the aspect ratio, decreasing contact loss and keeping low costs, is one of the goals to reach.

The main objective of this work is to adapt the Laser Induced Forward Techniques (LIFT to define metallic contacts (fingers and busbars) using a silver paste of high viscosity onto c-Si cells that can fulfill these requirements.

In order to achieve this objetive the process parameters (silver paste thickness, gap and laser parameters -spot size, pulse energy and overlapping of pulses) are modified and the morphology of the lines is studied using confocal microscopy.

With the best parameters long lines are printed and the uniformity (in thickness and height) is studied.

Some examples of metallization of larger areas (up to 10 cm x 10 cm) are also presented.

2 LIFT EXPERIMENTAL METHOD

In this point the experimental procedure followed for the LIFT process is presented.

2.1 Paste deposit at the glass

The paste used in these experiments is the Dupont Solamet PV17F. It is a highly conductive silver composition paste provides excellent efficiency, reliable soldered adhesion and low lay down. It is designed for rapid dry and very fast (spike) firing, see table I for its main properties [9].

Table I: Dupont Solament PV17F properties

Viscosity (Brookfield HBT, 10 rpm SC4-14/6R utility cap and spindle, 25ºC)	280 - 400 Pa·s
Solid Content at 750 ºC	89.5 - 91.0 %
Resistivity	<5 mΩ/sq/µm

Although it is designed for screen printing, its excellent electrical and sintering properties makes it a good candidate for LIFT metallization.

Good results have been achieved (see next section) but a thinner could be used to modify the rheological behavior of the paste and its transference properties in order to optimize the use of this pastes for LIFT metallization.

The transparent donor substrate used in the parameterization experiments is a square glass of 5 cm x 5 cm with a thickness of 1.9 mm. In order to show the metallization of larger areas the same glass is used with a larger area.

The silver paste is applied over the glass substrate using a coater. The coated used in this experiment is the Control Coater model 101 from RK PrintCoat Instruments Ltd, see figure 2.

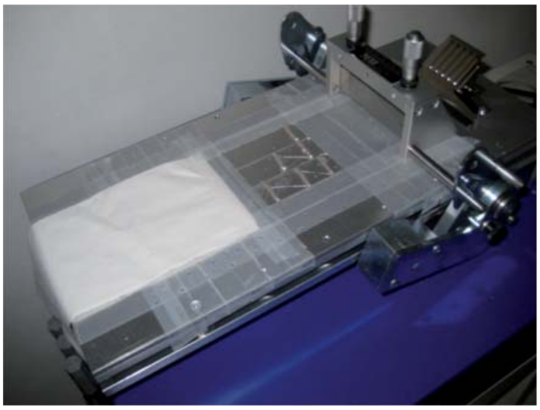

Figure 2: Control Coater model 101 from RK PrintCoat Instruments Ltd at UPM.

The thickness of the paste can be control changing the deposit parameters. The coating parameters are adjusted to get a thickness of 50-100 µm of silver paste.

Predeposit process is critical and it is difficult to control and reproduce. Predeposit inhomogeneities affect transference.

2.2 LIFT process

The metallization is done using the previously coated sample over a c-Si (non-textured) sample that acts as acceptor substrate.

The glass with the silver paste has to be set at a controlled gap over the substrate. Two Kapton tapes are stuck on the two sides of the glass slide, see figure 3.

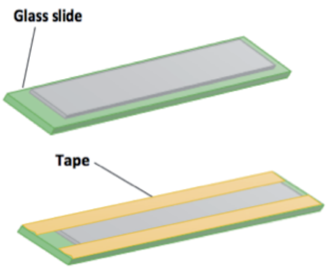

Figure 3: Diagram of the method used for fixing the gap using kapton tape.

These tapes are used to set the gap between the silver paste and the substrate surface. The gap distance is controlled using tape of different thickness or using several layers of tape.

Different gap distances have been used for the parameterization of the process.

The LIFT process is done following three steps, see figure 4.

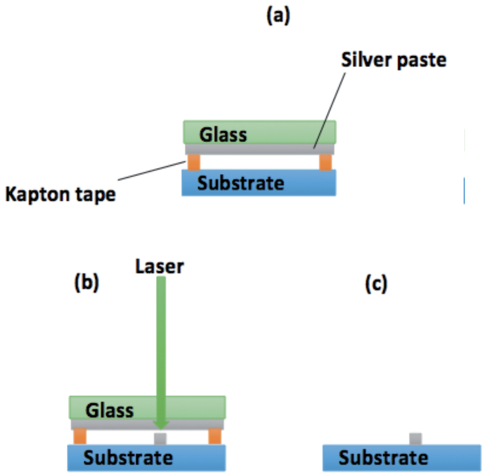

Figure 4: Diagram of the LIFT process.

First, after the preparation of the silver paste sample, the glass side is placed upside down with the silver paste side on the top of the solar cell substrate, figure 4a.

Then a pulsed Nd:YVO_4 laser with wavelength of 532 nm is applied at the glass/silver paste interface generating a gas at high pressure that pushes both materials and transfers the silver paste locally to the surface of the solar cell (acceptor substrate) and forms the finger lines, figure 4b. A scanner is used to print lines overlapping different laser pulses. Figure 5 shows the laser station used in these experiments and table II its main features.

Figure 5: Laser station for LIFT processes at UPM.

Afterwards the glass side with tapes is removed leaving only the transferred lines on the substrate, figure 4c.

To study the best parameters of the LIFT process to achieve a good metallic line, all process parameters are fixed and are changed one by one until the best results are obtained. Table III Shows the parameters used in this study. Moreover these parameters should also be industrially viable, that means that high processing velocities are required.

Table II: Laser processing station main features for LIFT processes.

Spectra Physics Explorer	
DPSS Nd:YVO4	532 nm
Pulse duration FWHM	14 ns
Frequency	20 -150 kHz
Power	2 W @ 50 kHz
Energy attenuator	
Scanner	120 mm x 120 mm

Table III: Process parameters used in the experiments.

Wavelength (nm)	532
Pulse duration FWHM (ns)	14
Frequency (kHz)	20
Power (W)	0.2 – 0.8
Energy per pulse (µJ)	10 - 40
Spot size (µm)	22
Silver paste thickness (µm)	50 - 100
Gap (µm)	15 - 100
Speed (m/s)	0.05 - 2

2.3 LIFT metallization lines

After doing the LIFT process for every parameterization study the morphology of the lines is studied using confocal microscopy (Leica DCM 3D). The main parameters to check are the width and height of the line and line continuity.

Figure 6 shows confocal images and profiles of different LIFT lines printed with the same process parameters. These lines have been obtained with the best parameters at high speeds 2 m/s, fully compatible with industrial requirements.

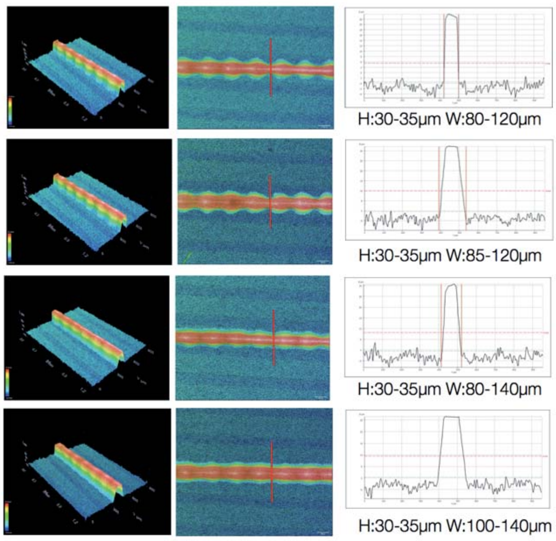

Figure 6: Different LIFT lines profiles obtained with these process parameters: Paste thickness: 80 µm; Gap: 50 µm; Power: 0.29 W; Frequency: 20 kHz; Speed: 2.0 m/s.

High aspect ratio lines (width: 80-140 µm height: 30-35 µm) without discontinuities can be obtained with this approach.

The parameterization has shown that laser power, paste thickness and gap distance are key factors to get a good printed line.

In these experiments paste deterioration (due to solvent evaporation) has been observed. To avoid this problem the use of the proper thinner and viscosity measurements before every set of experiments is needed.

2.4 LIFT metallization of front grids on c-Si cells.

LIFT metallization can be used to print the front grid without the need of a screen. This allows the printing of different grids just changing the program for the scanner giving a great process flexibility.

Figure 7 shows the possibilities of this technique with two different grids for different size cells done with the same parameters and different programs.

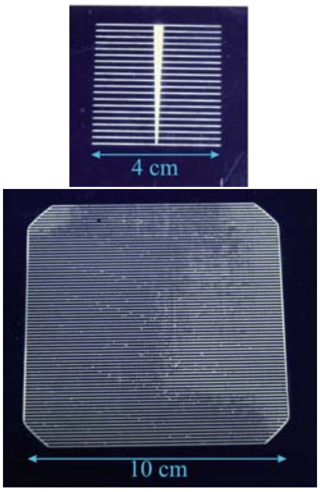

Figure 7: Different front grids printed with LIFT on a c-Si cell.

5 CONCLUSIONS

With an appropriate process parameterization (laser pulse energies around 20 µJ) at high speeds (2 m/s), it is possible to transfer high volume per pulse (30 pL) and high aspect ratio lines (height of 30-35 µm and width of 100 µm).

Transference of continuous lines has been proved possible making possible the metallization of c-Si cells of up to 10 cm x 10 cm

Paste deterioration (due to solvent evaporation) is observed.

The use of the proper thinner and viscosity measurements before every set of experiments is needed.

Predeposit process is critical and it is difficult to control and reproduce. Predeposit inhomogeneities affect transference.

The laser power, the paste thickness and the paste-substrate gap are identified as key variables in the process.

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