



LIFT of high viscosity silver paste for new metallization methods in photovoltaic and flexible electronics industry

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Hub of Application Laboratories for Equipment Assessment
in Laser Based Manufacturing





1. Introduction: metallization for solar cells
2. Metallization using LIFT
3. Application to flexible photovoltaic devices
4. Summary & Acknowledgements



Front-side Metallization: key process for enhancing efficiency in a cost effective way

Metallization comprises different steps:

1. Pre-metallization processes

- Patterning of dielectric layer
- Developing metal seed layers



Front-side Metallization: key process for enhancing efficiency in a cost effective way

Metallization comprises different steps:

1. Pre-metallization processes
2. Metallization
 - Transference of the conductive material

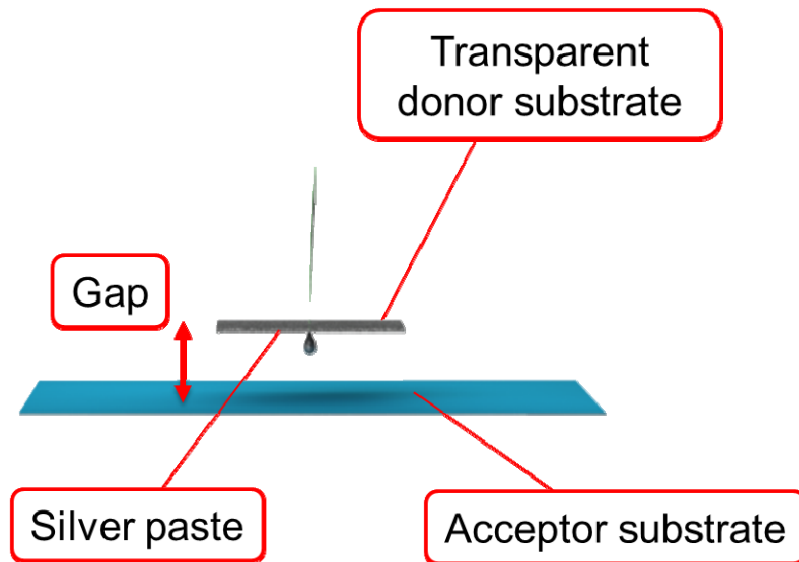


Front-side Metallization: key process for enhancing efficiency in a cost effective way

Metallization comprises different steps:

1. Pre-metallization processes
2. Metallization
3. Curing, sintering and firing

*Metallization using
Laser Induced Forward Transfer (LIFT)*

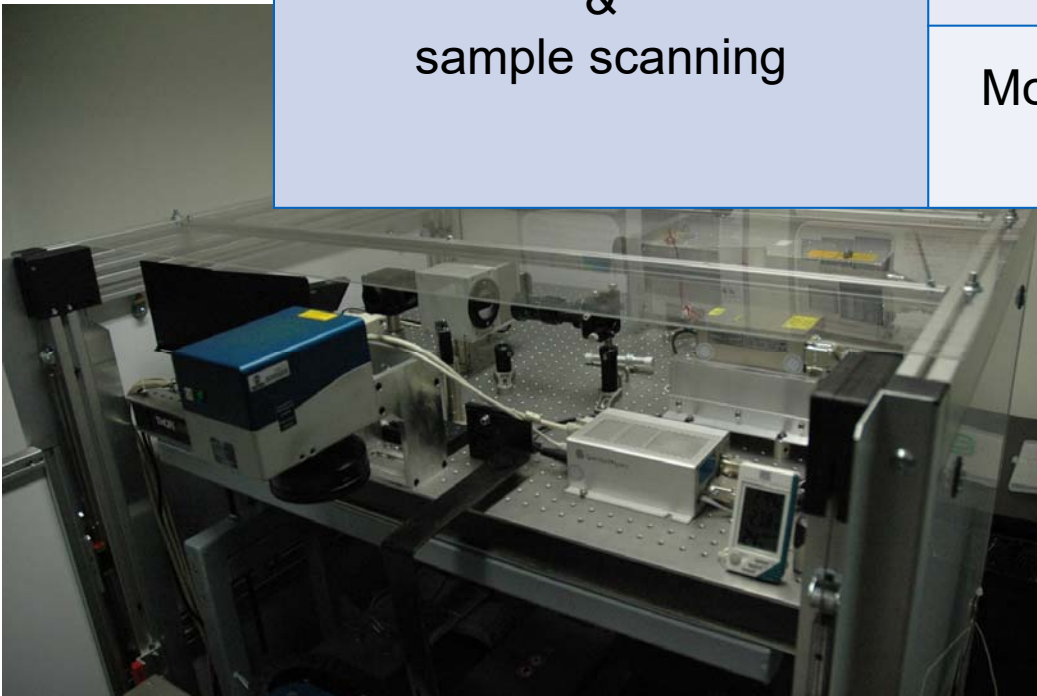
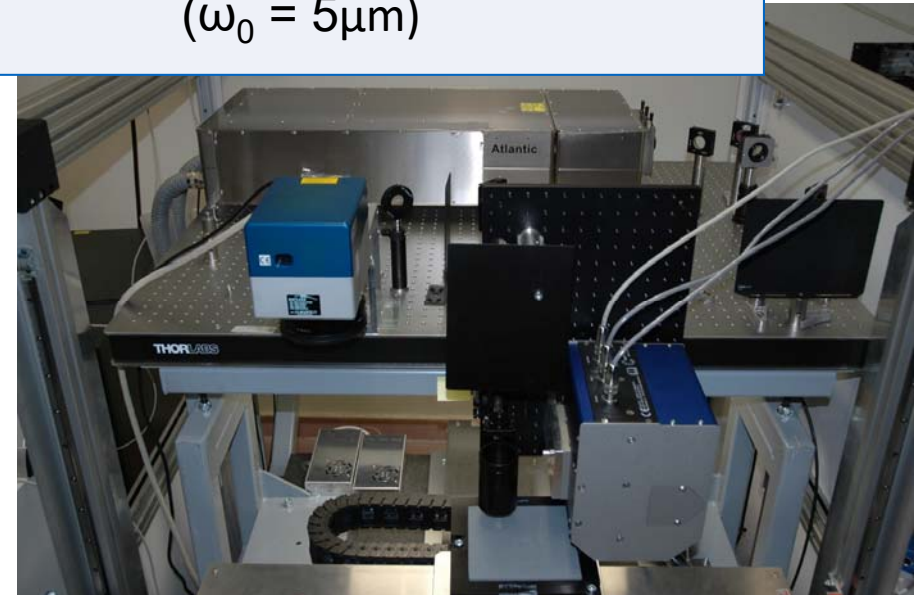


Glass(1000 μm)
Silver paste (30-80 μm)
Kapton tapes(50 μm)
Silicon Substrate (520 μm)

- Commercial screen printing Ag paste (DuPont PV17F)
- Deposition onto donor substrate using a blade coater (RK PrintCoat Instruments). Layer thickness: 30 – 80 μm .
- Basic LIFT configuration (no intermediate absorbing layer or assisting liquid matrix).
Gap distance: 25 – 50 μm .



Laser source ($\lambda = 532 \text{ nm}$)	ns-pulsed Spectra Physics Explorer
	ps-pulsed EKSPLA Atlantic
Beam focusing & sample scanning	Optical galvo scanner with f-theta lens ($\omega_0 = 15 \mu\text{m}$)
	Motorized XY stage with fix focal lens ($\omega_0 = 5 \mu\text{m}$)





DuPont PV17F

- Commercial screen printing Ag paste
- Provides excellent efficiency
- Reliable soldered adhesion
- Low lay down
- Rapid dry
- Very fast firing

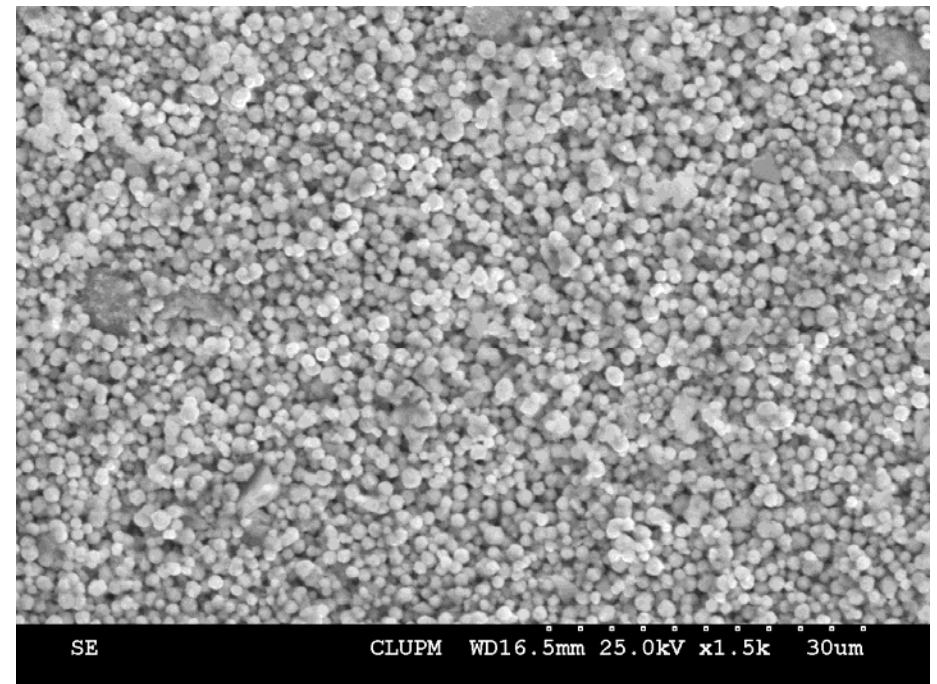


Non-newtonian, pseudoplastic,
thixotropic fluids

Viscosity $250 \pm 30 \text{ Pa}\cdot\text{s}$

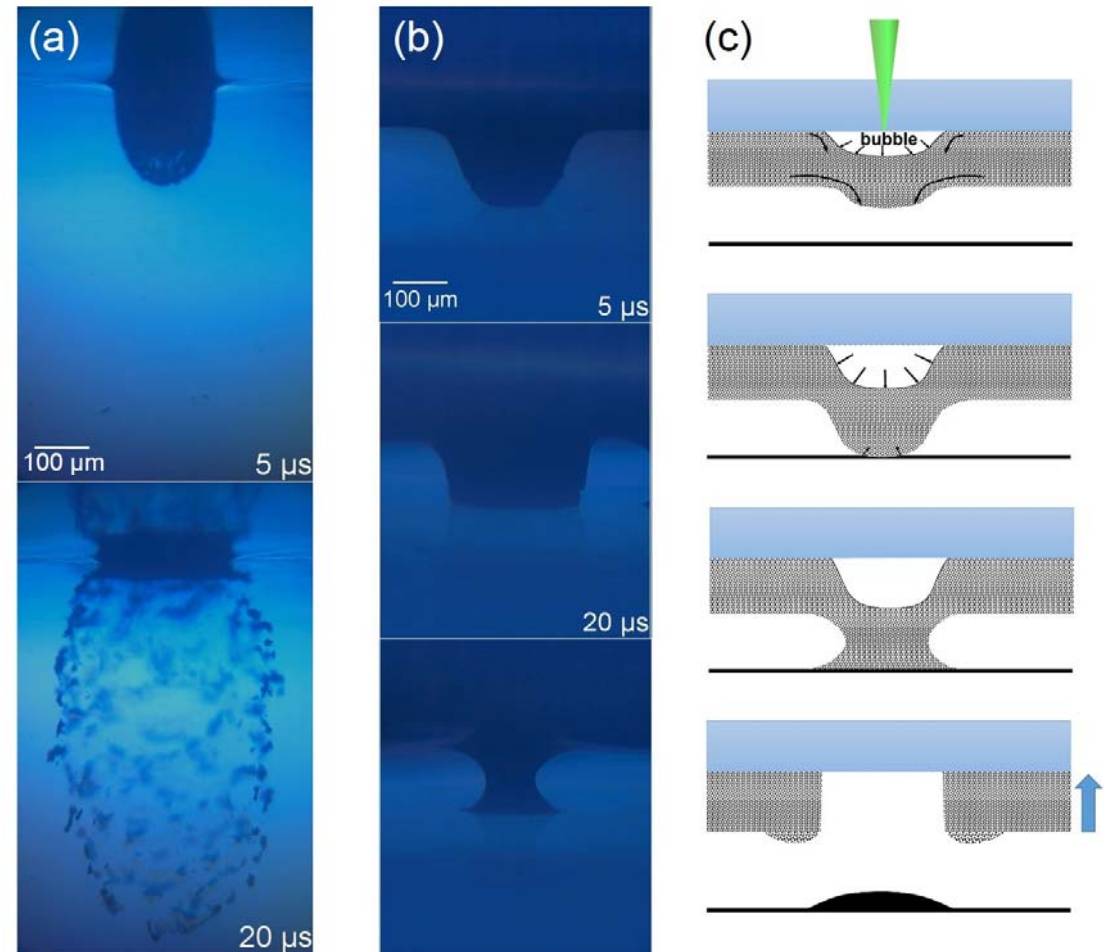
Ag particles size: $1\text{-}5 \mu\text{m}$

Solid Content @750°C: 91.0 %



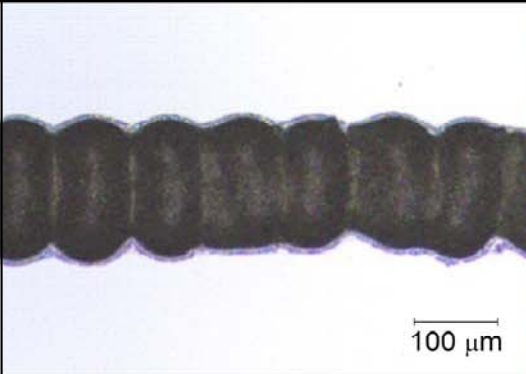
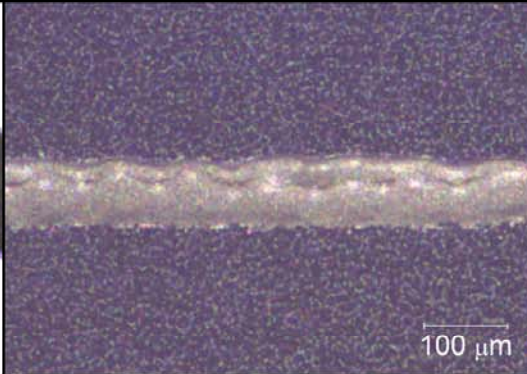
High viscosity paste transfer mechanisms

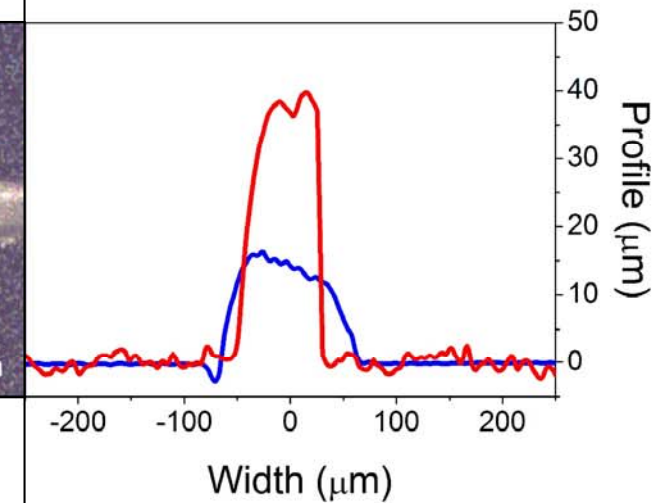
- Morphology of the transferred voxel depends on laser fluence (F), donor film thickness (h) and gap distance (d)
- Voxels transferred using large F consist of non-continuous clusters of paste (cluster-dot transfer)
- F just larger than the transfer threshold allows printing single dots of paste with large aspect ratio (concrete-dot transfer)
- **Effect of the substrate:** formation of a continuous pillar between donor and acceptor





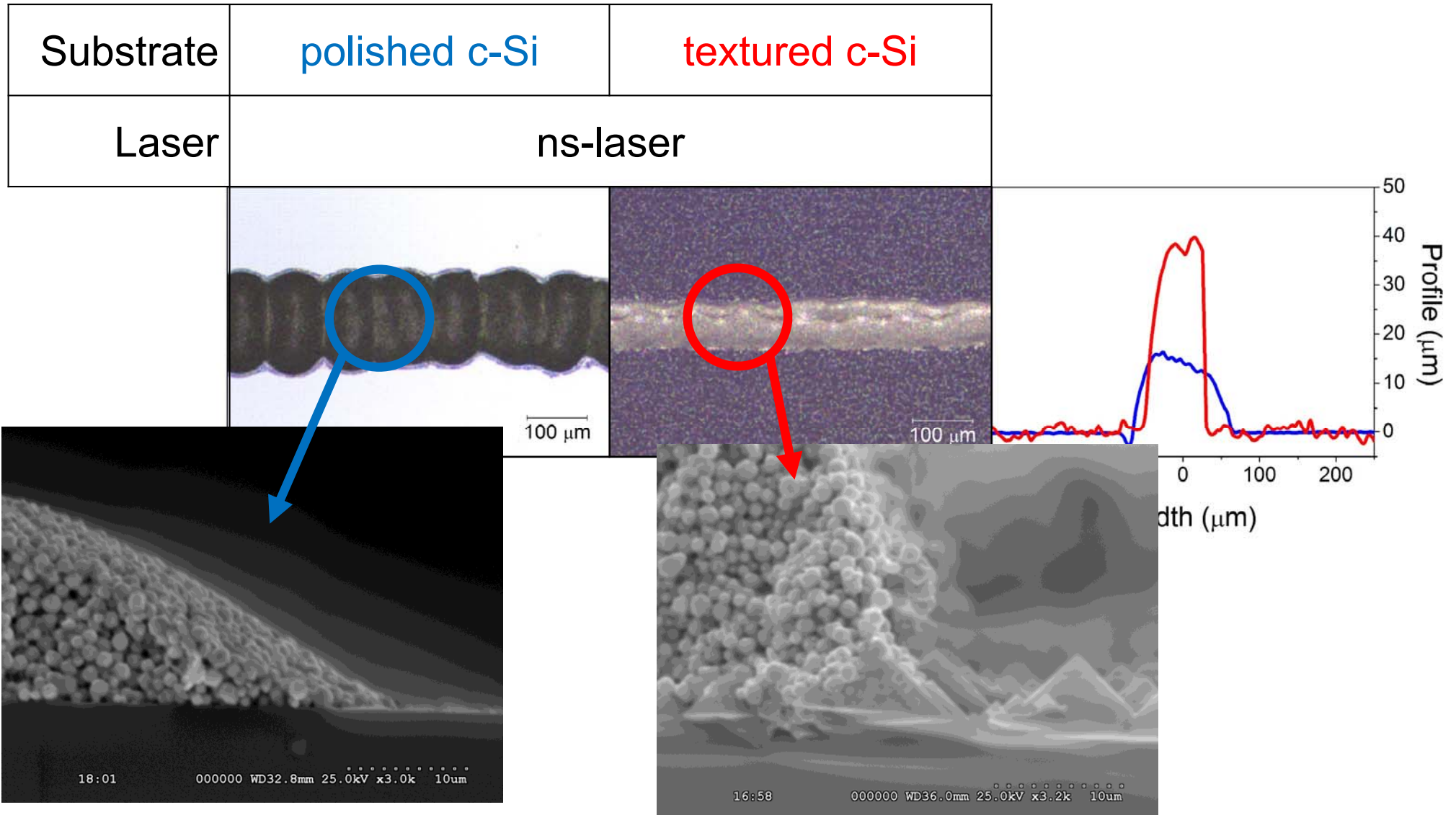
Printing of lines

Substrate	polished c-Si	textured c-Si
Laser	ns-laser	
		
		<p>$E_p = 13 \mu\text{J}$ $\omega_0 = 15 \mu\text{m}$ Rep Rate = 20 kHz $v = 1800 \text{ mm/s}$ $h = 50 \mu\text{m}$ $d = 50 \mu\text{m}$</p>



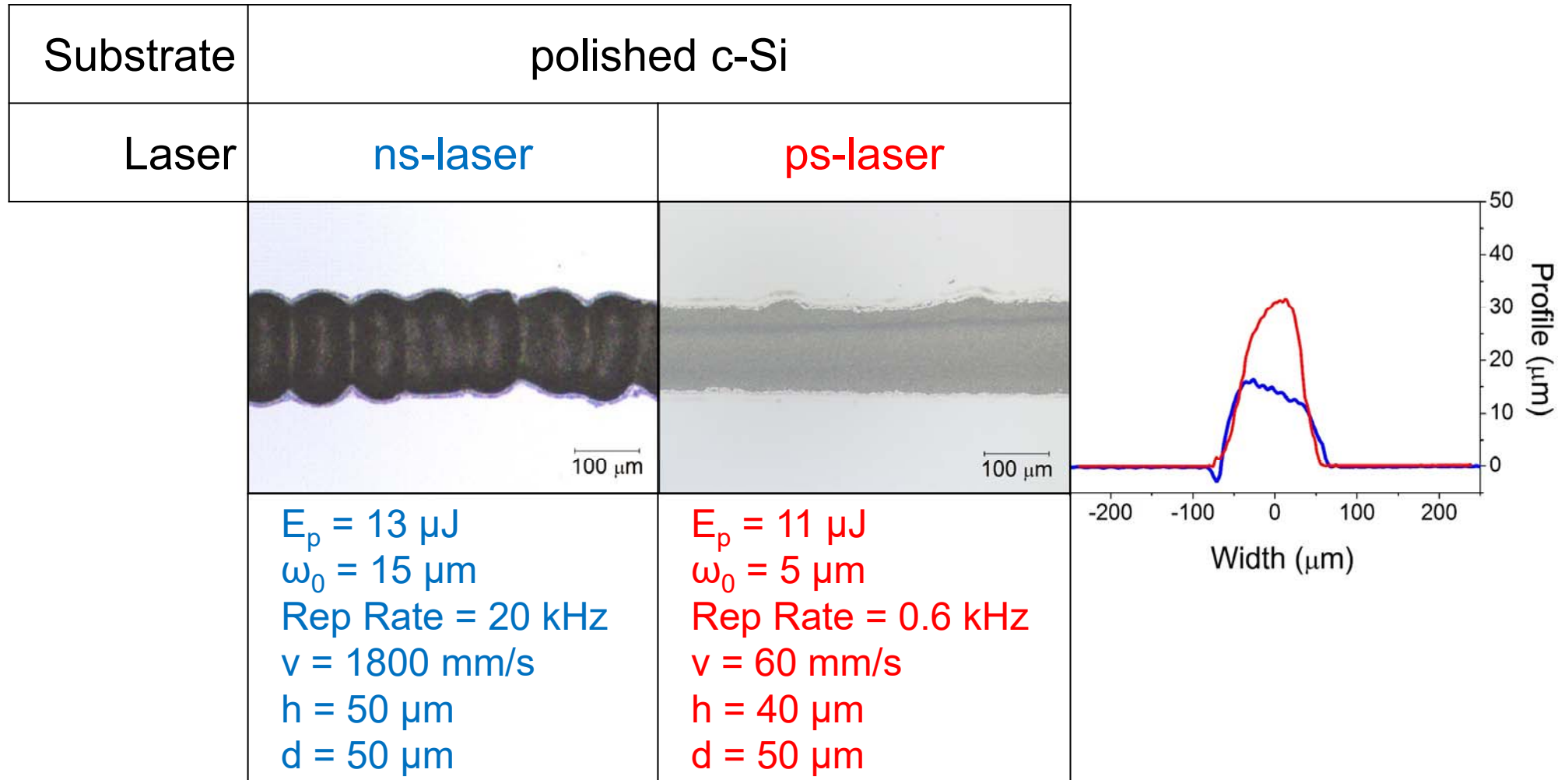


Printing of lines





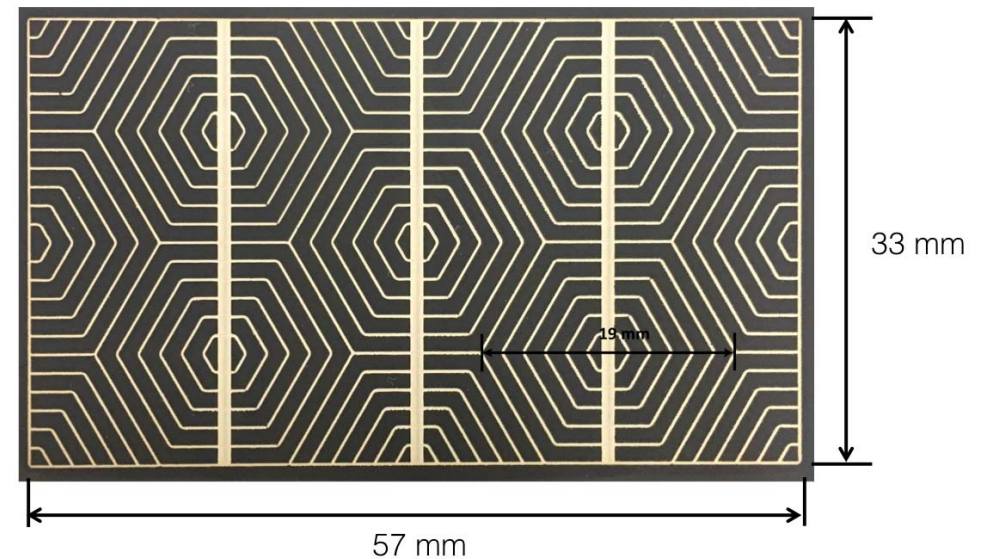
Printing of lines





Printing of lines: design flexibility

- Optical scanners allows fast processing and flexible design to print large areas.
- Very versatile, allowing any freeform design for the solar cells personalization.
- Application in Building integrated PV.



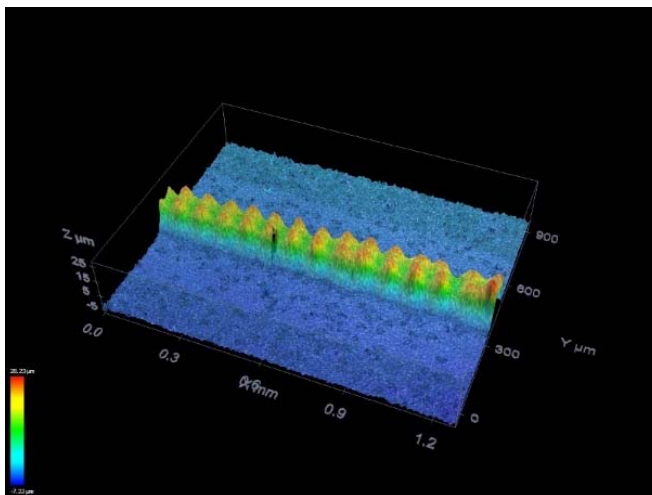
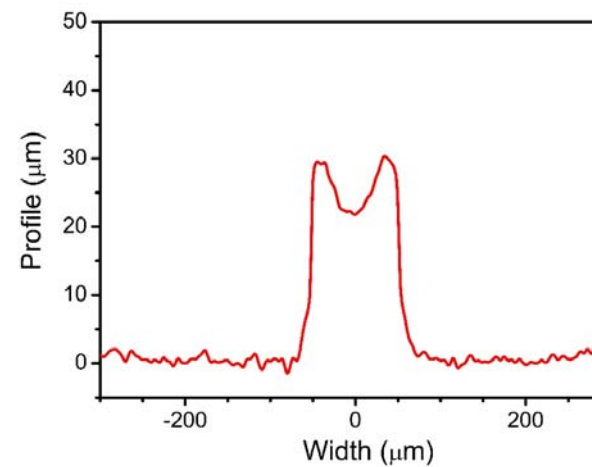


Proof of concept: full metallization of a CIGS solar cell on steel flex substrate

Fingers



Busbars



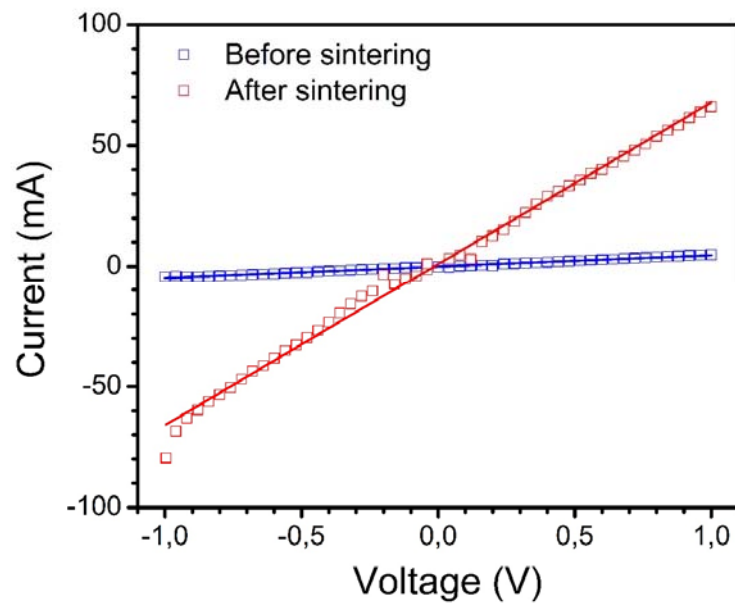


Electrical properties

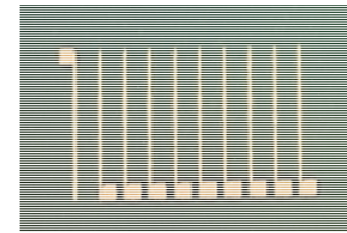
Fingers



Busbars



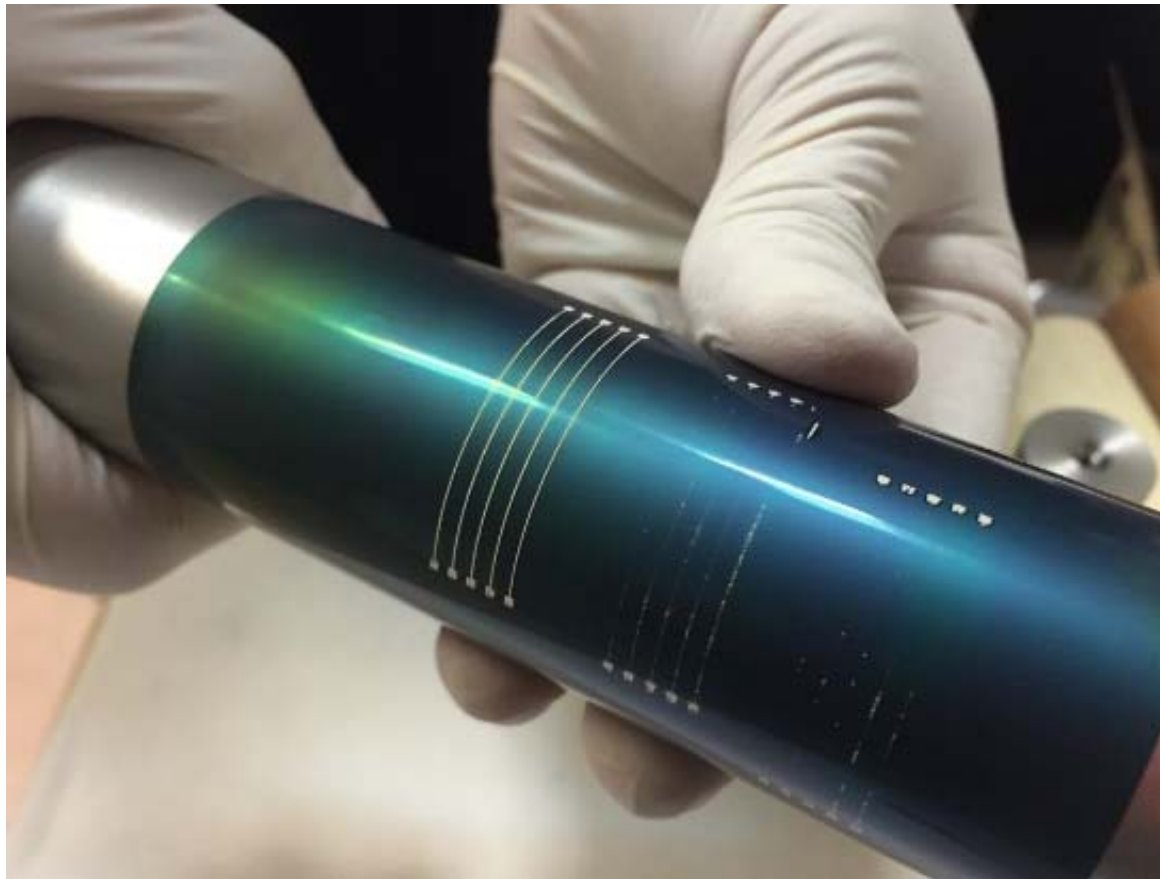
TLM test



Resistivity	40 $\mu\Omega\cdot\text{cm}$
Specific contact resistance	50 $\text{m}\Omega\cdot\text{cm}^2$



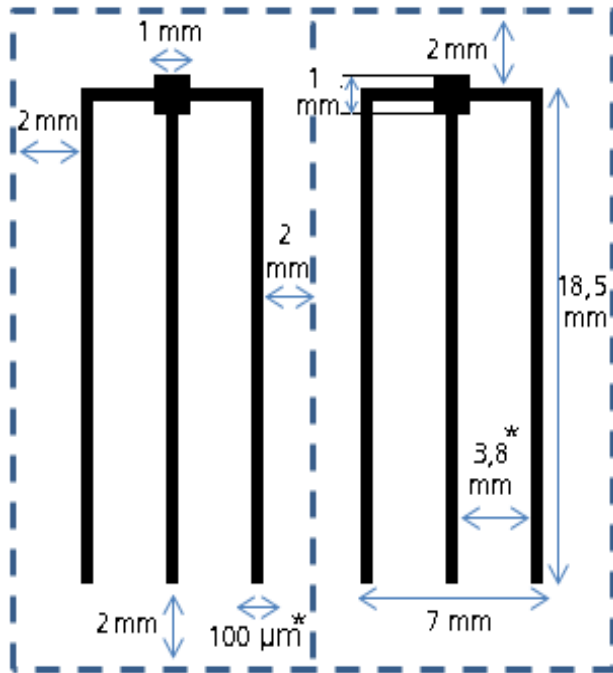
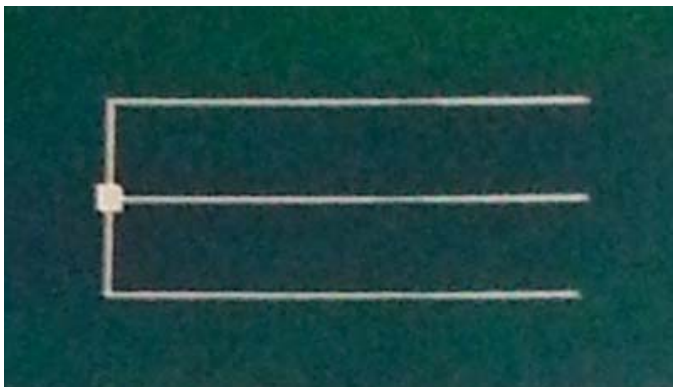
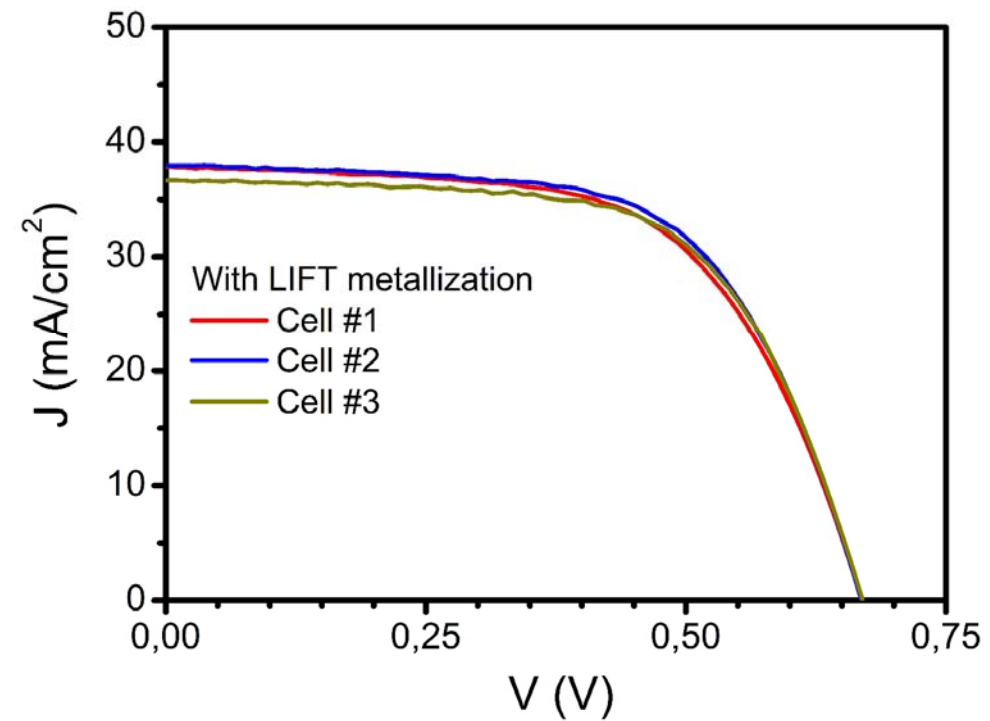
Mechanical properties



Good
adherence after
bending with
radius down to
12 mm



Solar cell performance





- 1) LIFT is a promising technique for the metallization of PV devices using commercial screen-printing Ag pastes.
- 2) The transfer mechanisms are strongly determined by the high viscosity of the paste.
- 3) Lines can be printed using both ns- and ps-lasers by simple overlapping single voxels. Optimum lines have aspect ratios of 0.2 – 0.5.
- 4) There is a strong influence of the roughness of the acceptor substrate on the morphology of the lines.
- 5) Lines can be printed onto flexible PV devices (CIGS on flex steel). Lines are continuous, have low electrical resistance and show good mechanical adherence.
- 6) Flexible CIGS solar cells have been metallized showing appropriate functionality.



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Dankie Gracias
Спасибо شكريا
Merci Takk
Köszönjük Terima kasih
Grazie Dziękujemy Děkojame
Ďakujeme Vielen Dank Paldies
Kiitos Tänname teid 谢谢
Thank You Tak
感謝您 Obrigado Teşekkür Ederiz
감사합니다
Σας ευχαριστούμε ขอบคุณ
Bedankt Děkuje vám
ありがとうございます
Tack

