



Laser printing and curing/sintering of silver paste lines for solar cell metallization

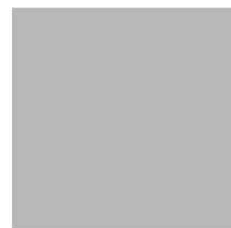
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Hub of Application Laboratories for Equipment Assessment
in Laser Based Manufacturing





1. Introduction: metallization for solar cells
2. Experimental setup
3. Metallization using LIFT
4. Laser curing / sintering
5. Summary
6. 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

All-laser based process



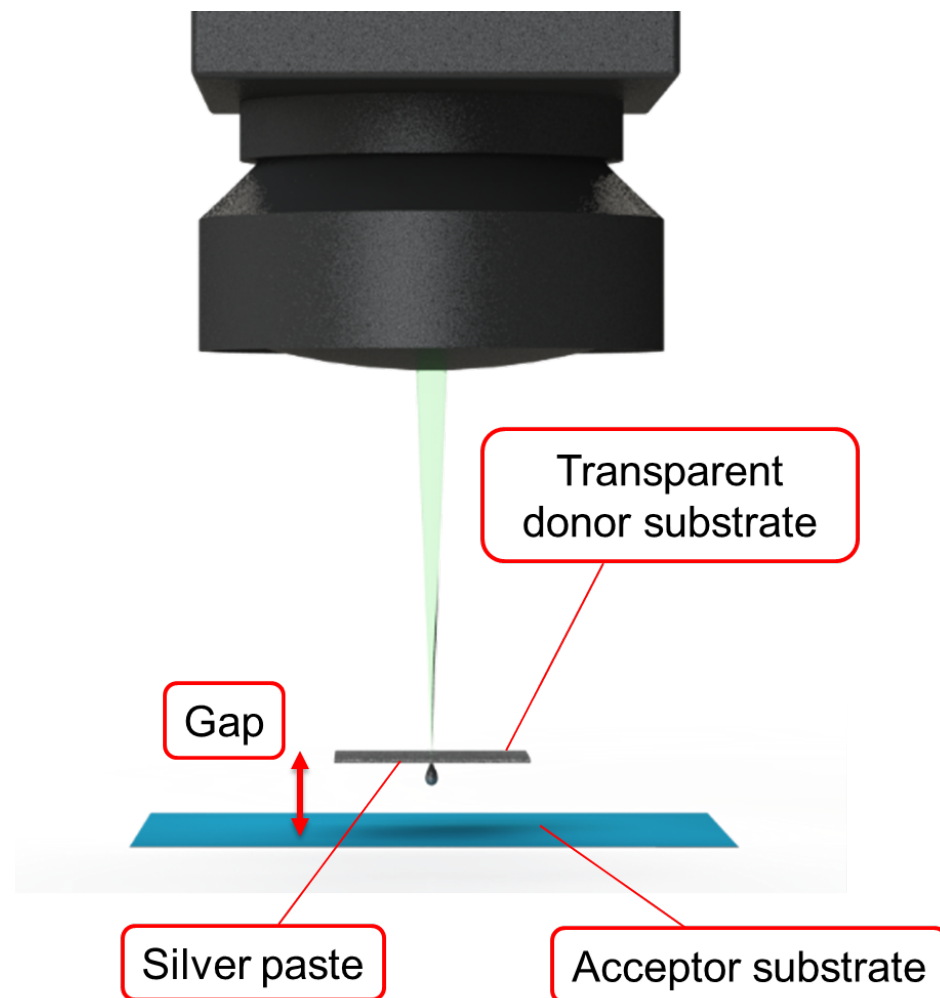
	Metallization	Curing & sintering
Technique	Laser-Induce Forward Transfer (LIFT)	CW Laser local heating



	Metallization	Curing & sintering
Technique	Laser-Induce Forward Transfer (LIFT)	CW Laser local heating
Laser source	<p>Spectra Physics Explorer</p> <ul style="list-style-type: none">▪ DPSS▪ Nd:YVO4 emitting 532 nm▪ Pulse duration 15 ns▪ 20 - 150 KHz	<p>Spectra Physics Millenia</p> <ul style="list-style-type: none">▪ DPSS▪ Nd:YVO4 emitting 532 nm▪ CW, power up to 20W
Optical path	<ul style="list-style-type: none">▪ Optical attenuator▪ Optical Scanner (ScanLab HurryScan)▪ F-Theta Lens, focal 250 mm▪ Focused beam diameter ~20 μm	



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



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

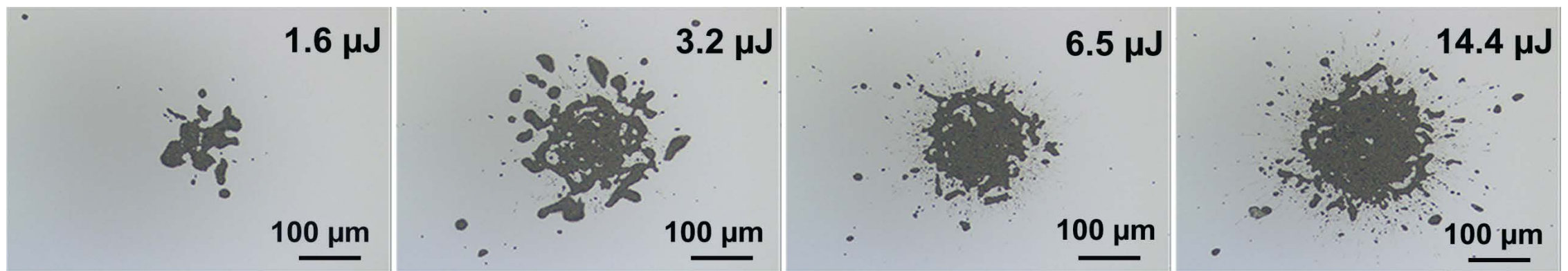


Process parameterization

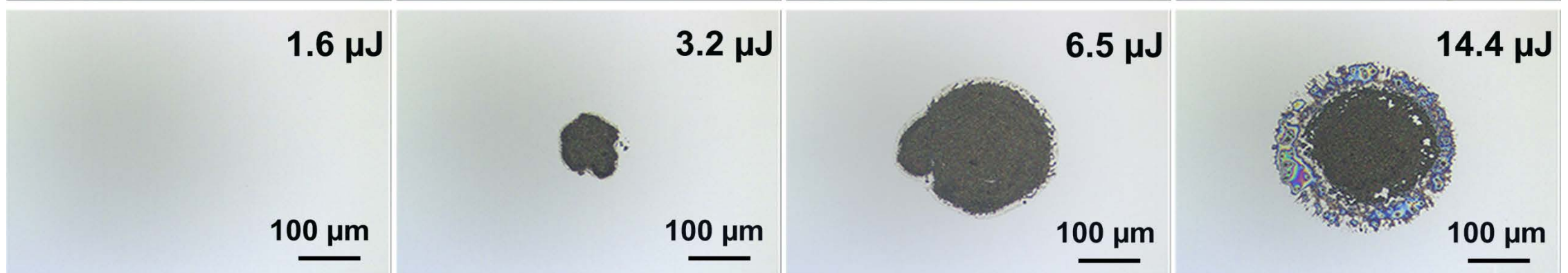
- Deposition of paste voxels using single laser pulses

Paste
thickness

30 μm



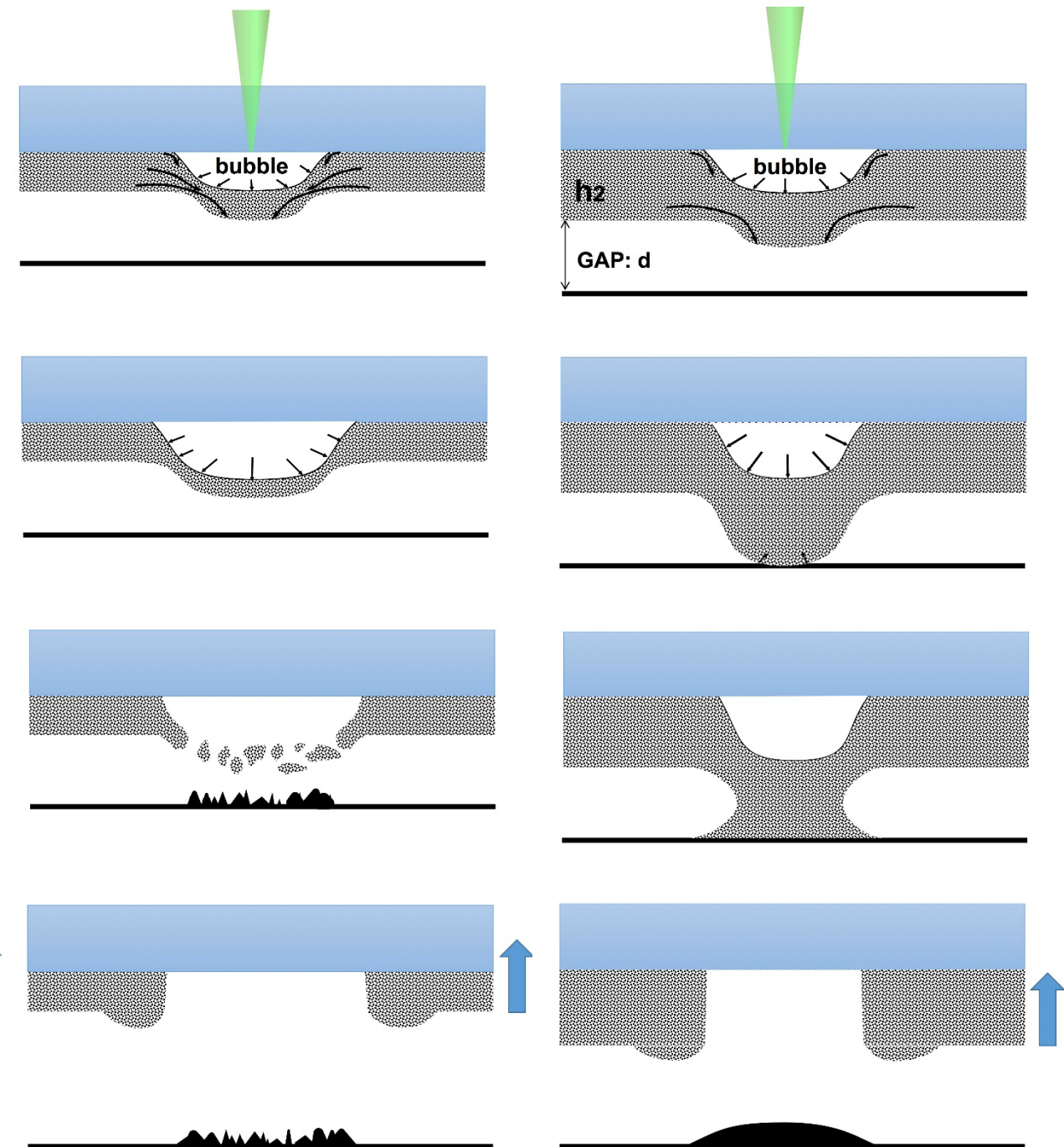
50 μm





Process parameterization

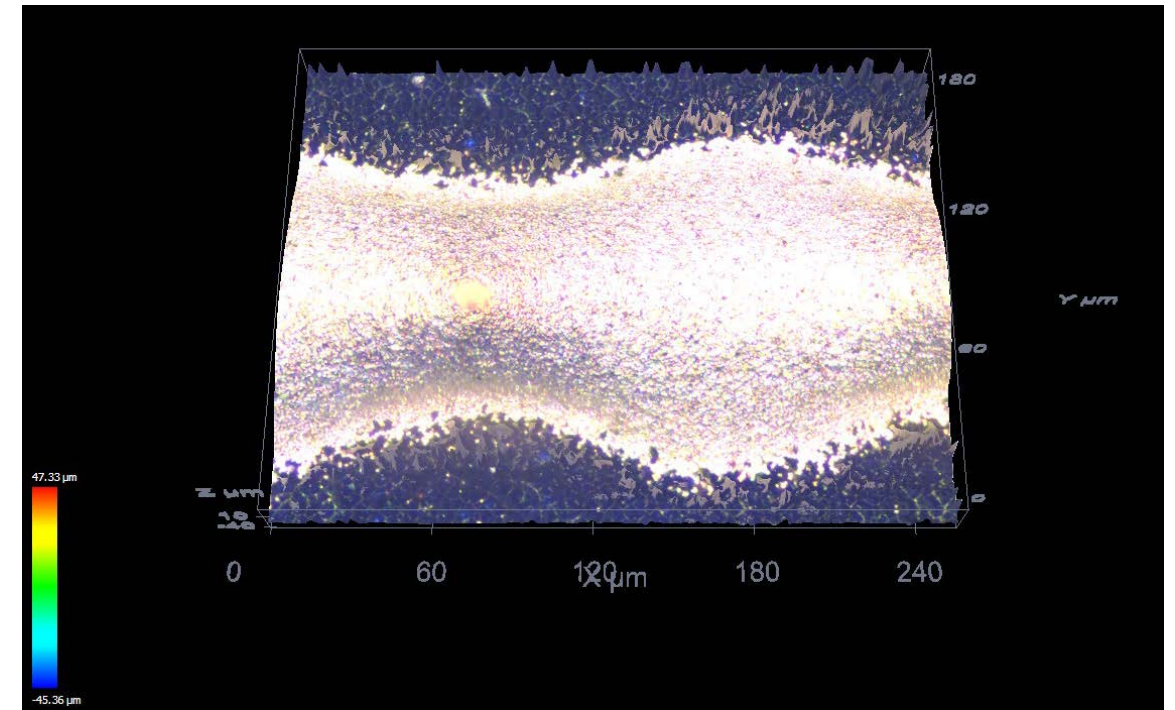
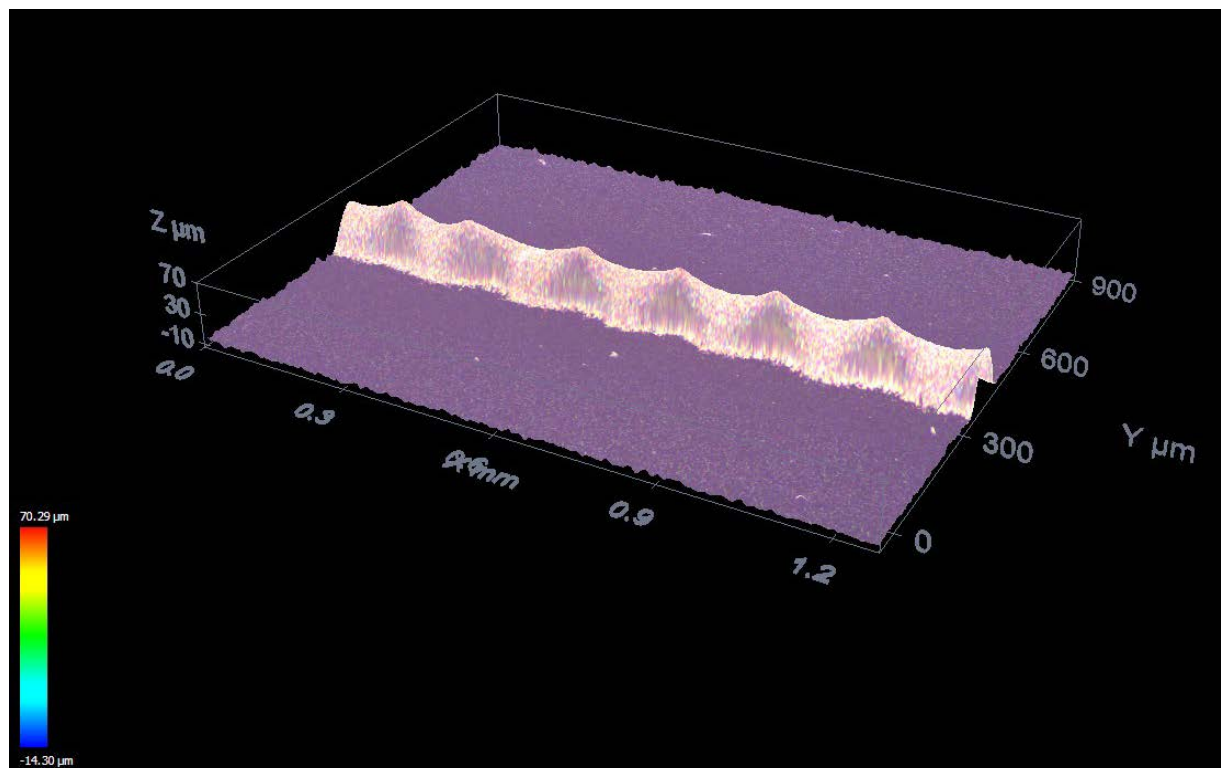
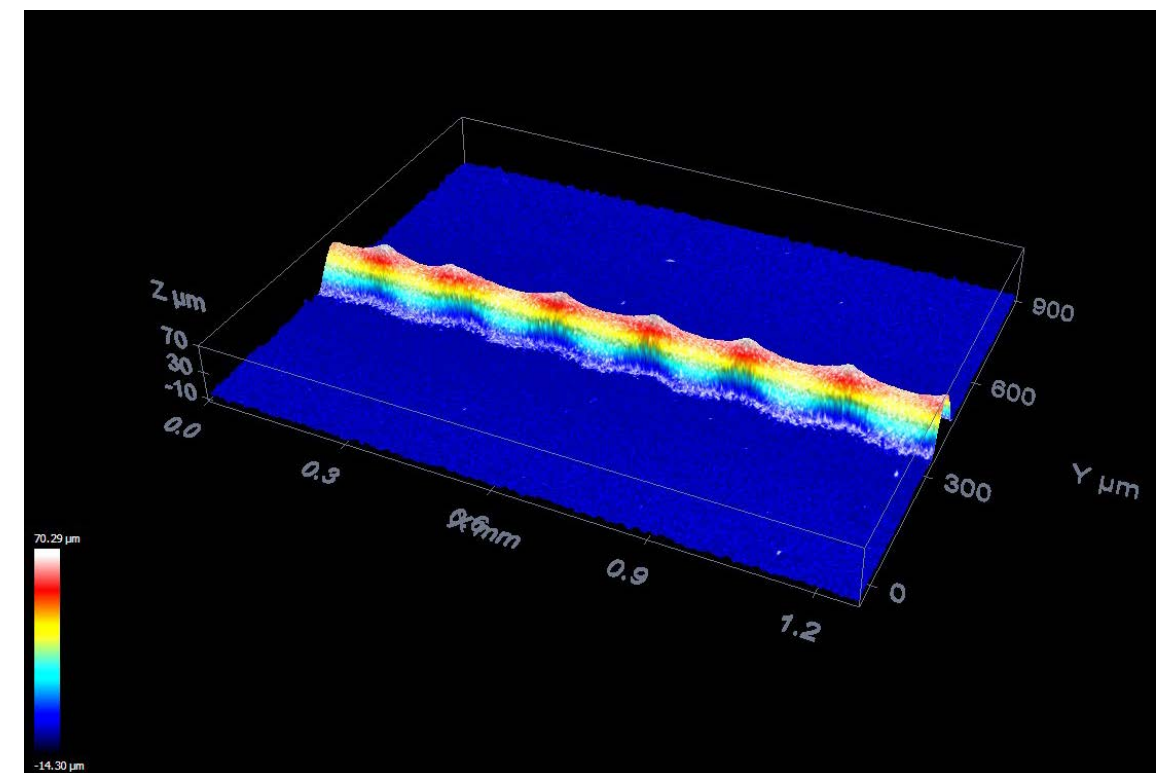
- Deposition of paste voxels using single laser pulses
- Transfer mechanism

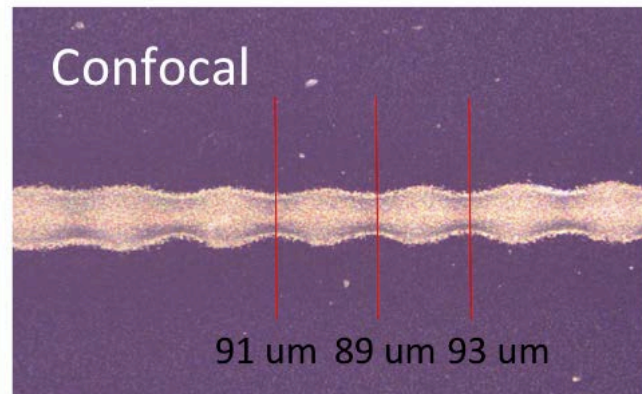
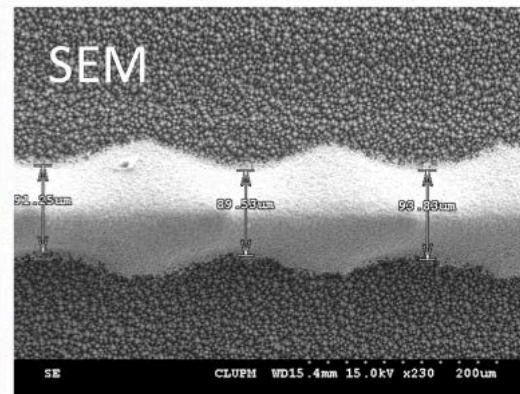
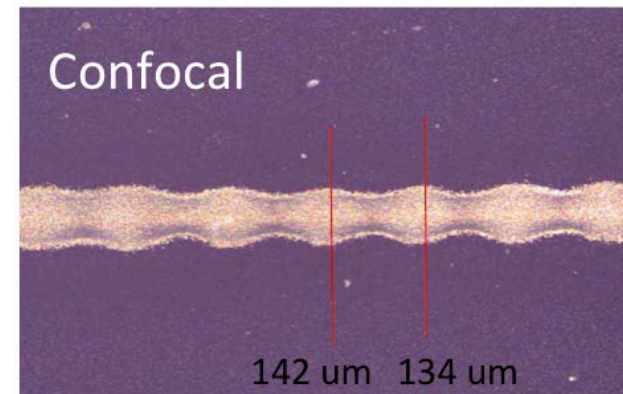
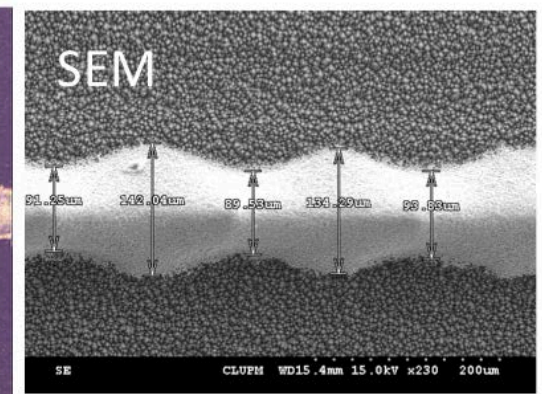
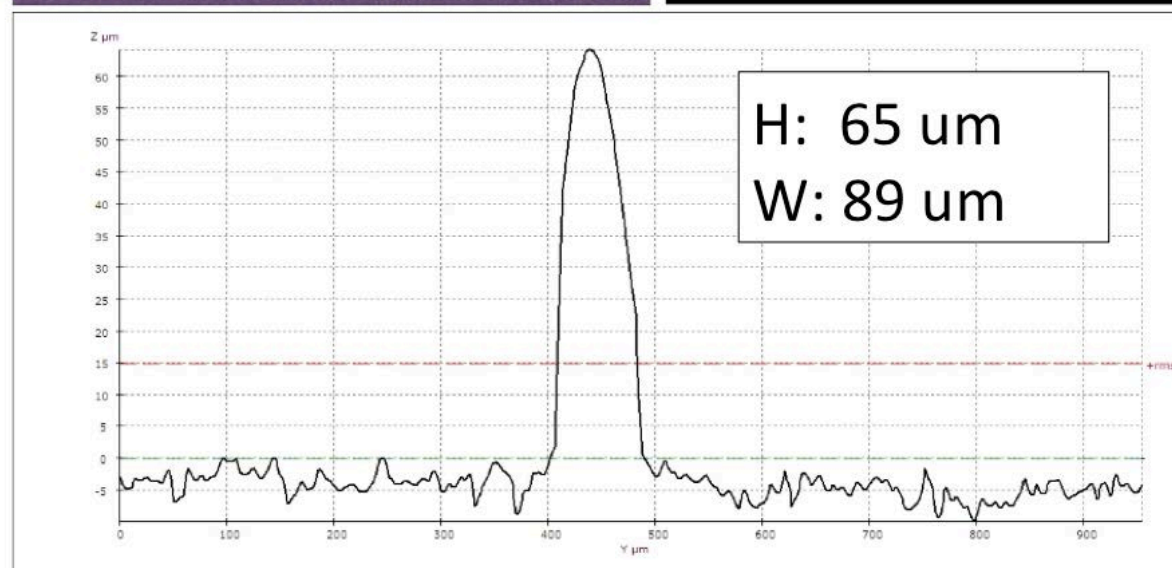
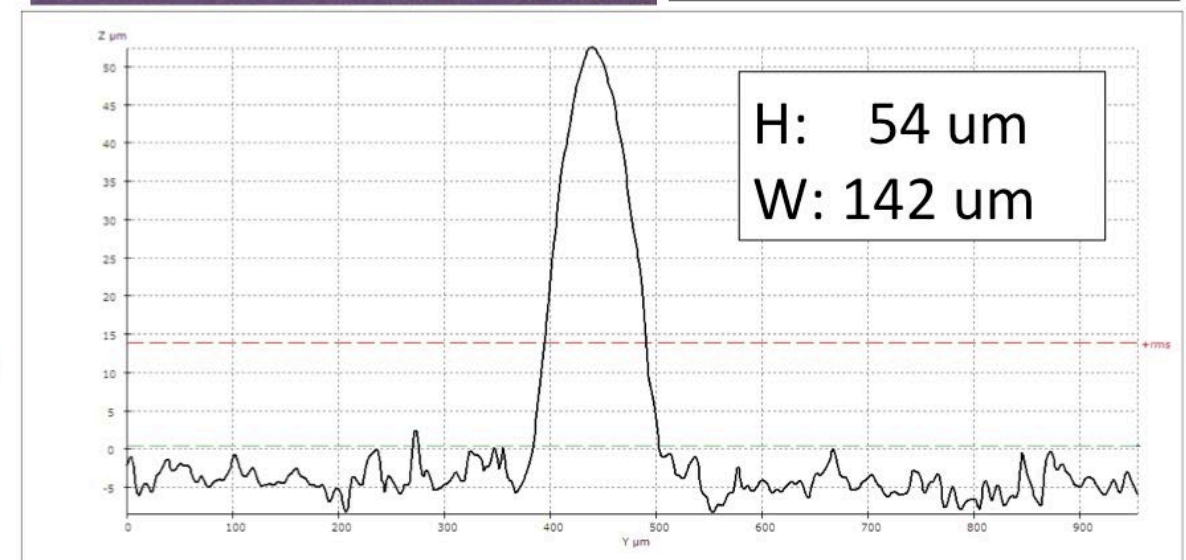




Printing of lines using LIFT

- Optical scanner at 2 m/s
- Larger thickness ($80\text{ }\mu\text{m}$) and pulse energy ($14.5\text{ }\mu\text{J}$)



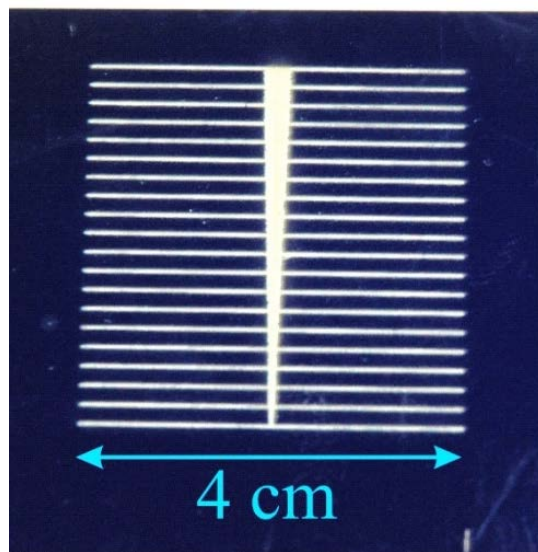
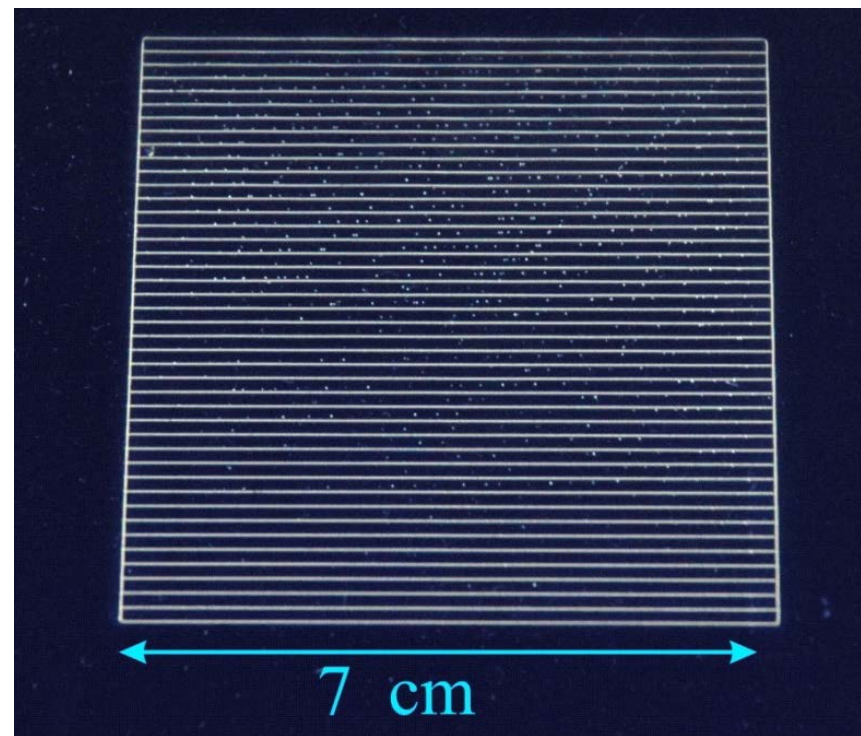
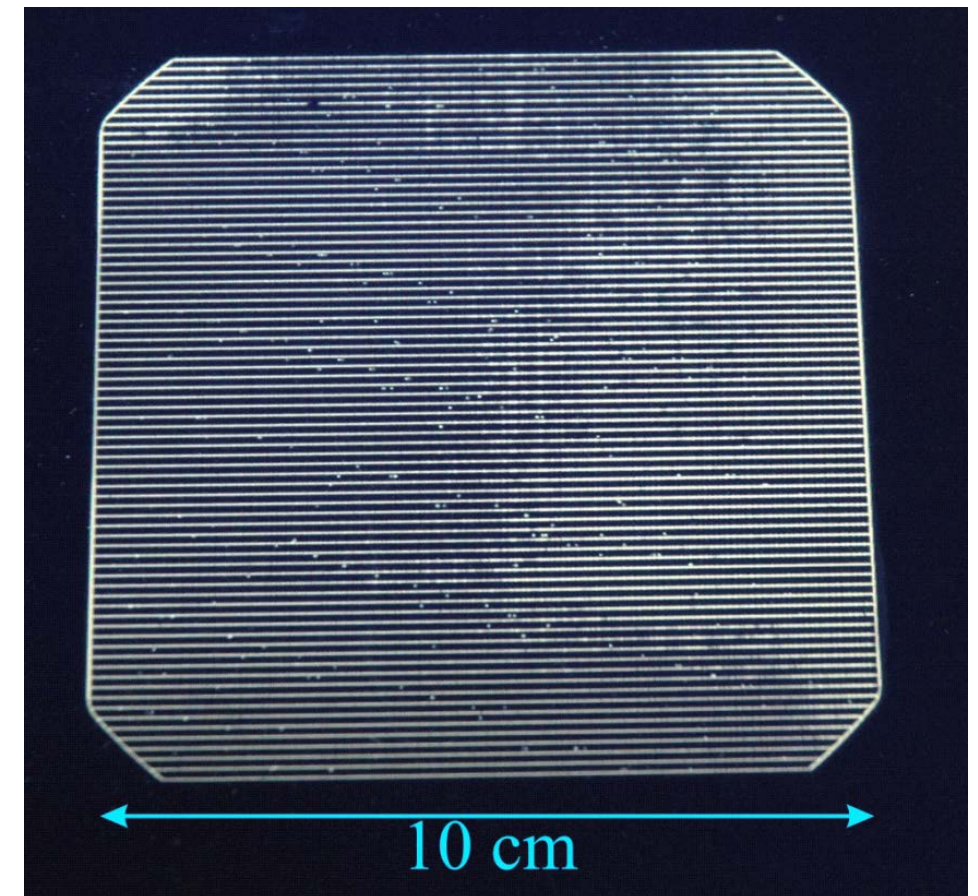


Aspect Ratio $\approx 0.4 - 0.6$
Voxel ≈ 400 pL



Printing of lines using LIFT

- Optical scanners allows fast processing and flexible design to print large areas

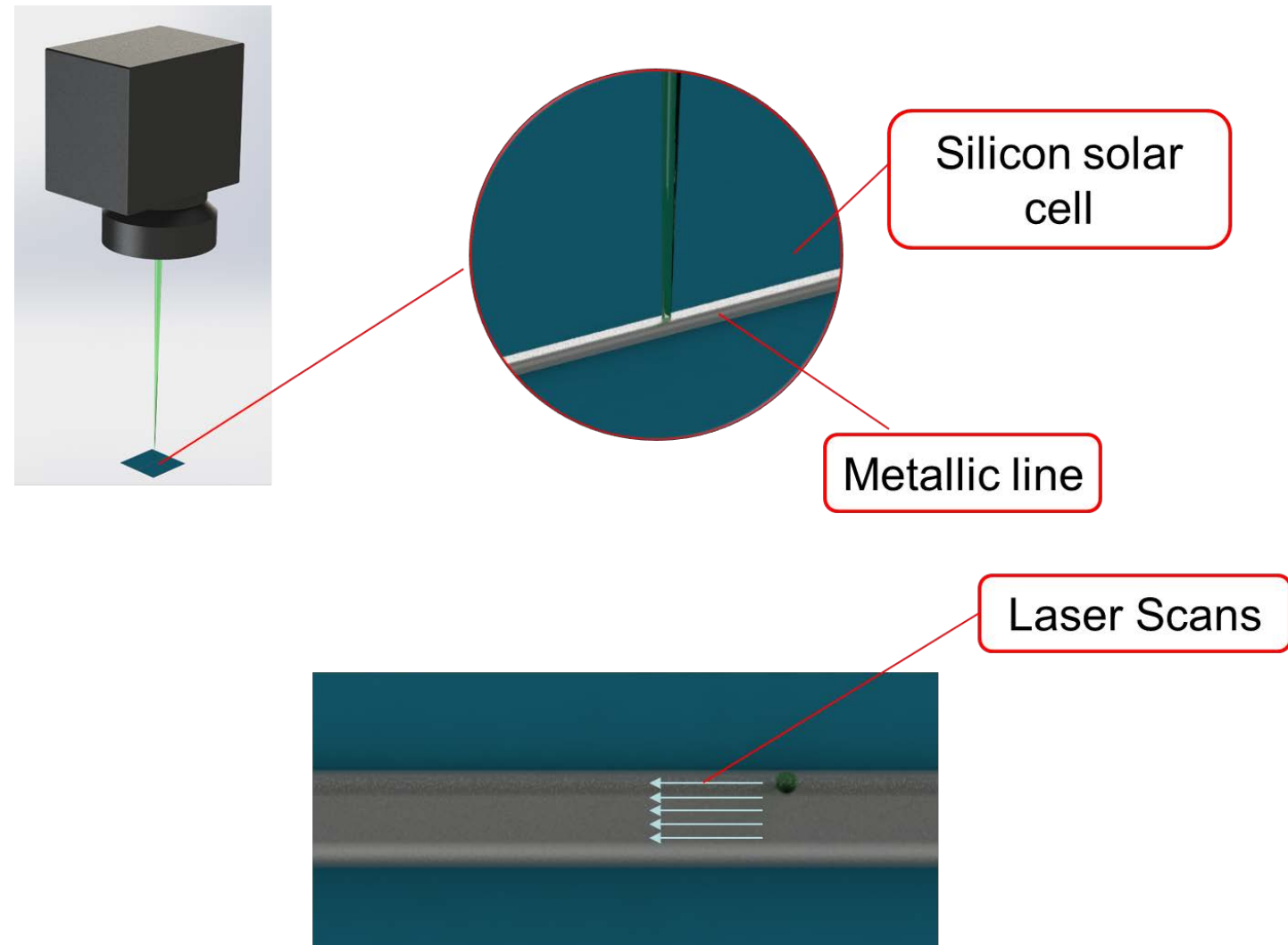




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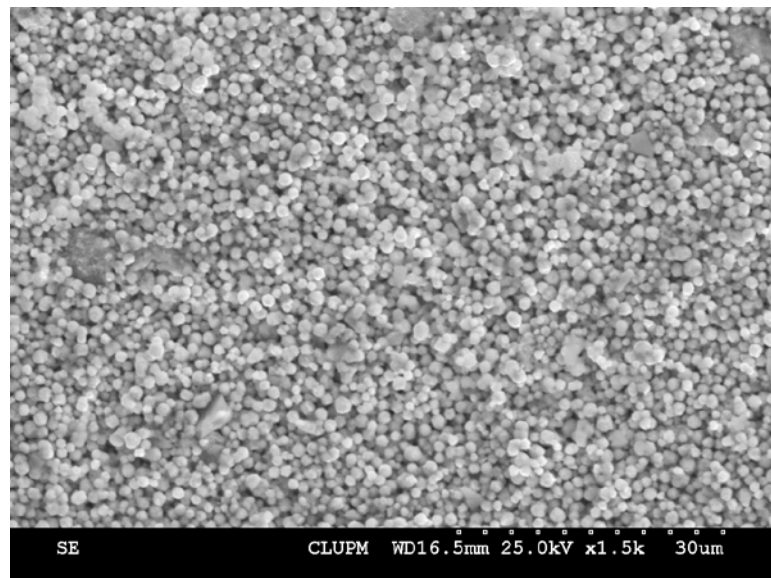
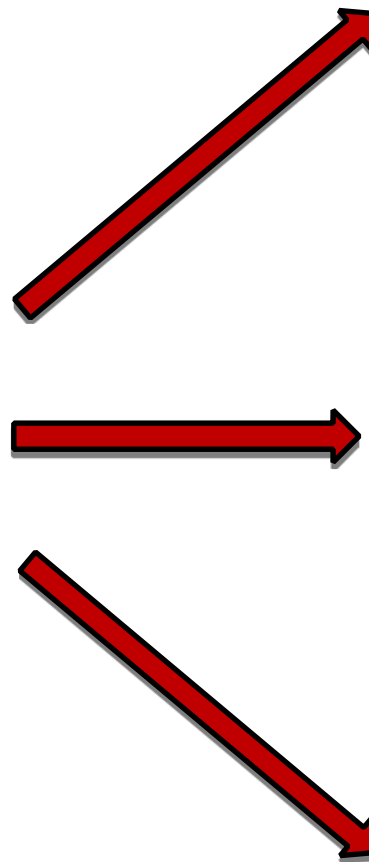
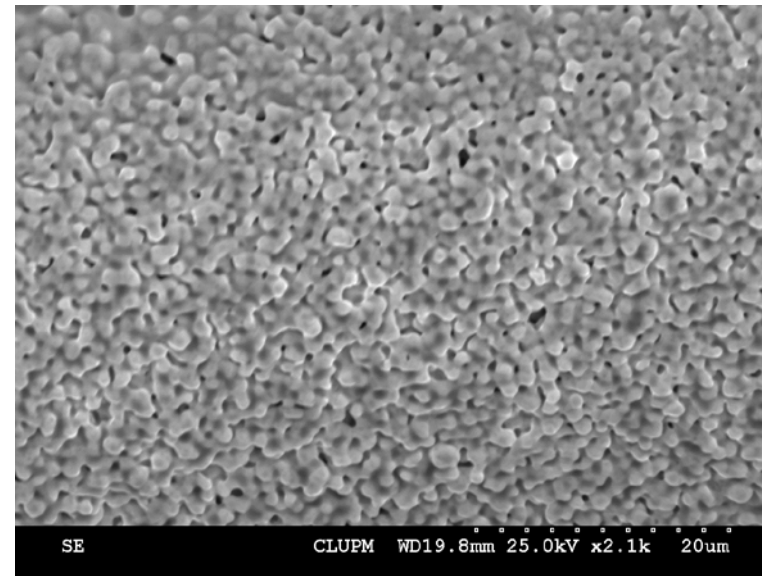


- CW laser heating on lines previously deposited using LIFT
- Laser focused and scanned on the lines
- Several scans have been done for completely cover the surface of the line
- Process parameters: laser power and scan speed
- Morphology and electrical response after treatment

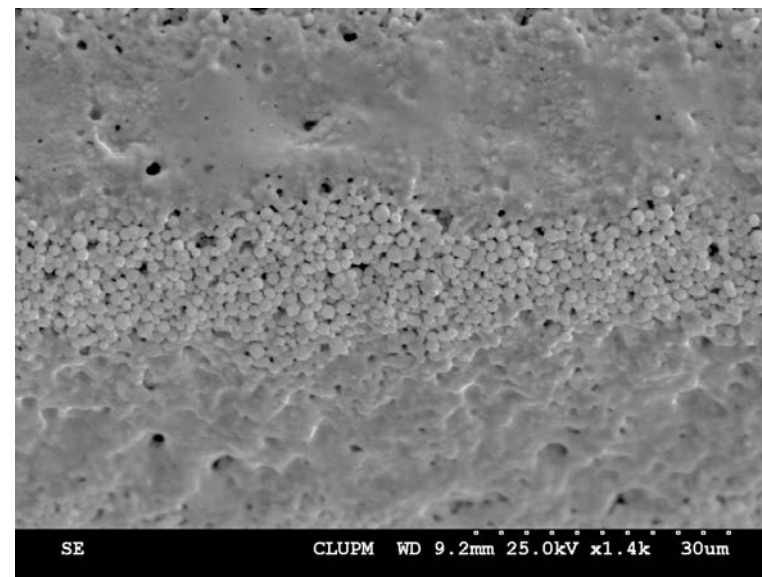




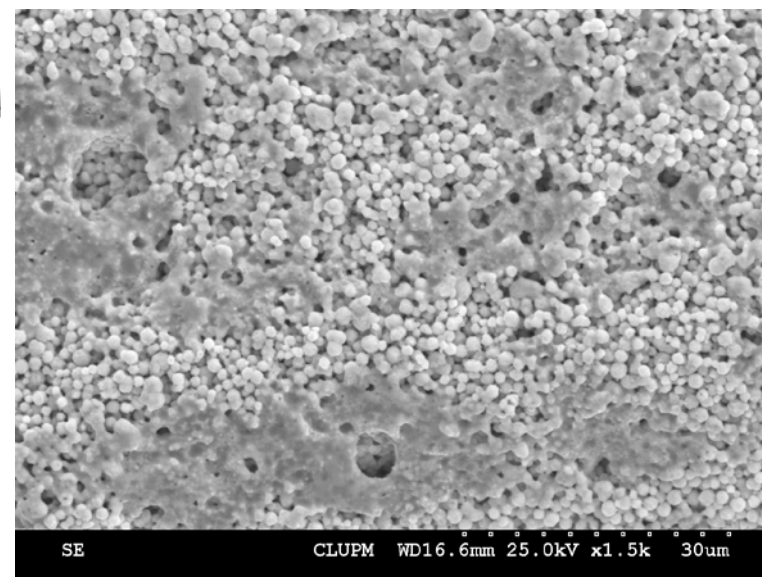
As-deposited
 $\rho = 1.2 \text{ m}\Omega\cdot\text{cm}$



- 5.8 W
- 4 mm/s
- Strong sintering
- Lines peel off



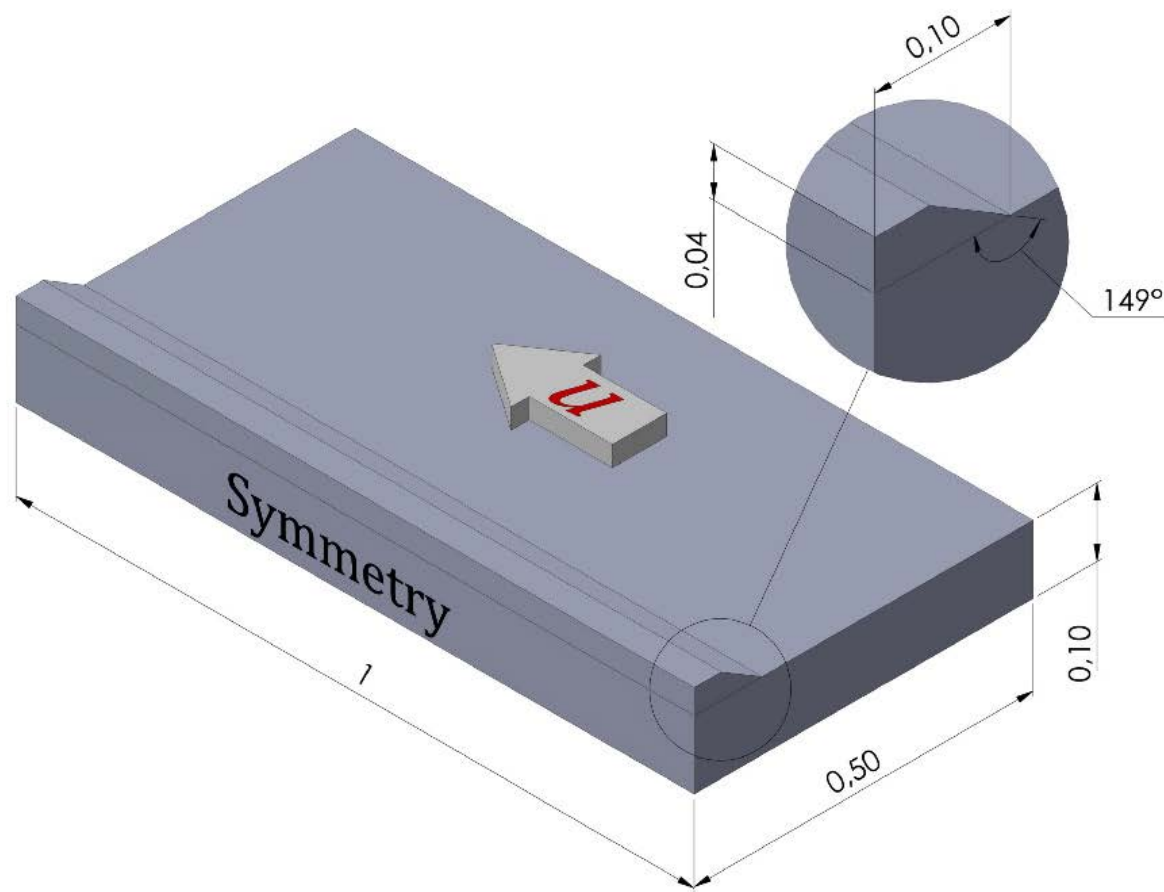
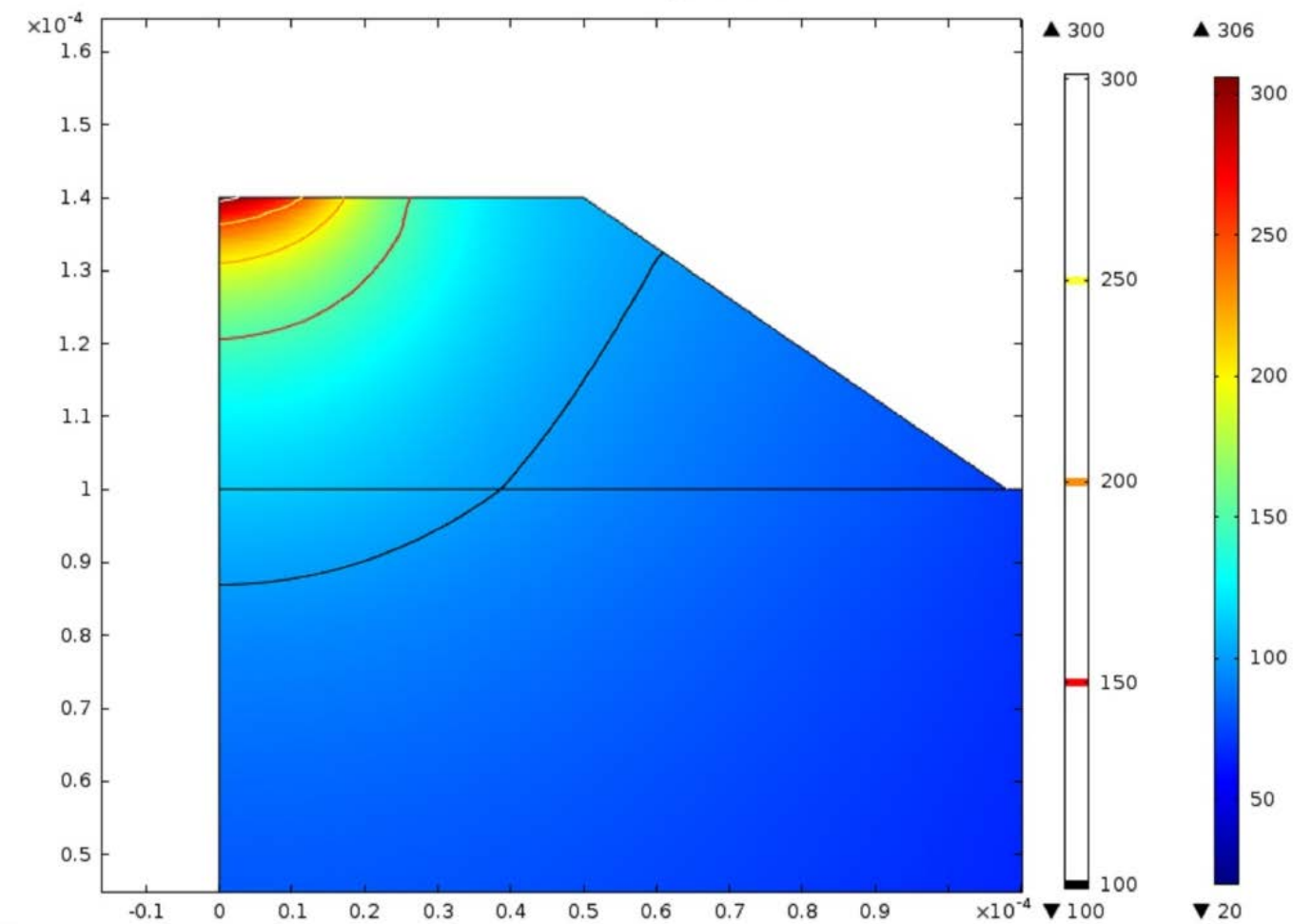
- 4.7 W
- 40 mm/s
- Surface sintering
- Lines peel off



- 2.7 W
- 70 mm/s
- Low sintering
- $\rho = 26 \text{ }\mu\Omega\cdot\text{cm}$



Numerical thermal model for estimating the peak temperature profile





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- 1) LIFT is a promising technique for the metallization of PV devices using commercial screen-printing pastes.
- 2) The transfer mechanisms are strongly determined by the high viscosity of the paste.
- 3) Lines deposited used optimum parameters have good shape and large aspect ratios (≈ 0.5). The volume transferred per pulse (voxel) is quite large (≈ 400 pL).
- 4) There is a small parametric window for laser curing the lines. Using too large laser power or too slow scan speed makes the line to peel off.
- 5) When using optimum parameters, bulk resistivity is reduced two orders of magnitude. Nor the substrate neither the geometry of the line are affected by the laser heating process.
- 6) Optical scanners allows fast processing and flexible design in both LIFT and laser curing. Process can be achieved at high speed giving the possibility to be used in future industrial applications.
- 7) All-laser based metallization processes are possible.



This work has been supported by the EUROPEAN COMMISSION – APPOLO FP7-2013-NMP-ICT-FOF. 609355 and the Spanish MINECO projects SIMLASPV (ENE2011-23359), HELLO (ENE2013-48629-C4-3-R).



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Assessment in Laser Based Manufacturing



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

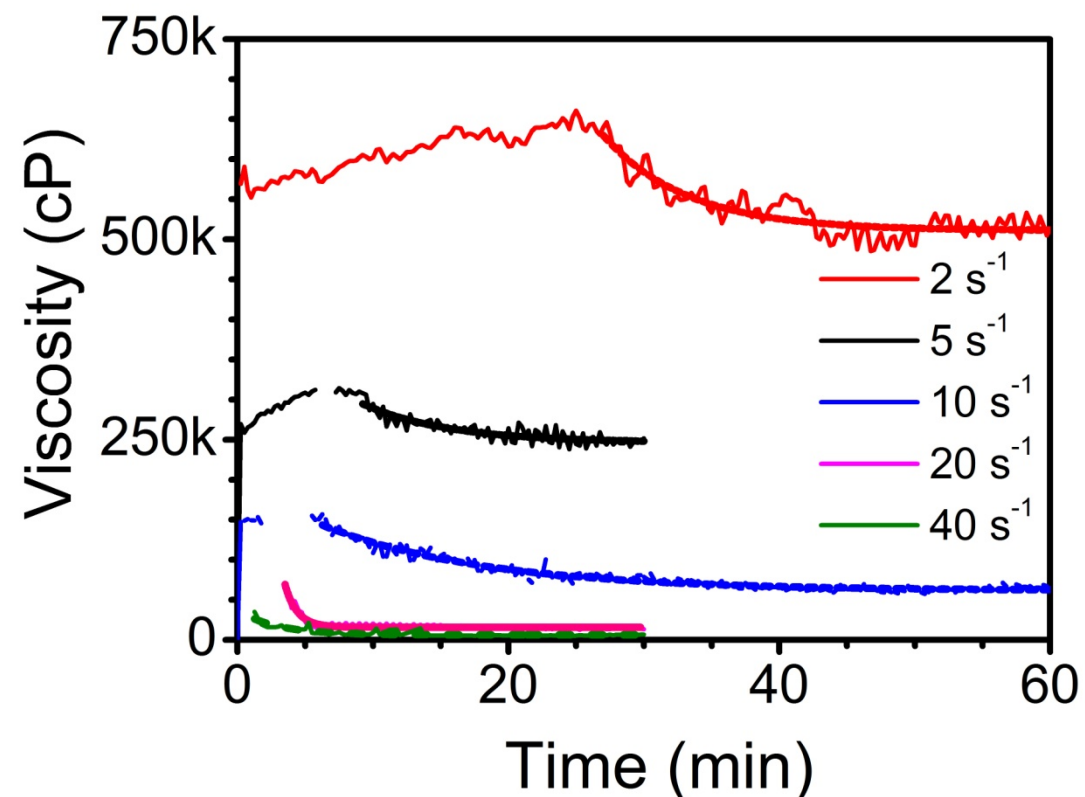
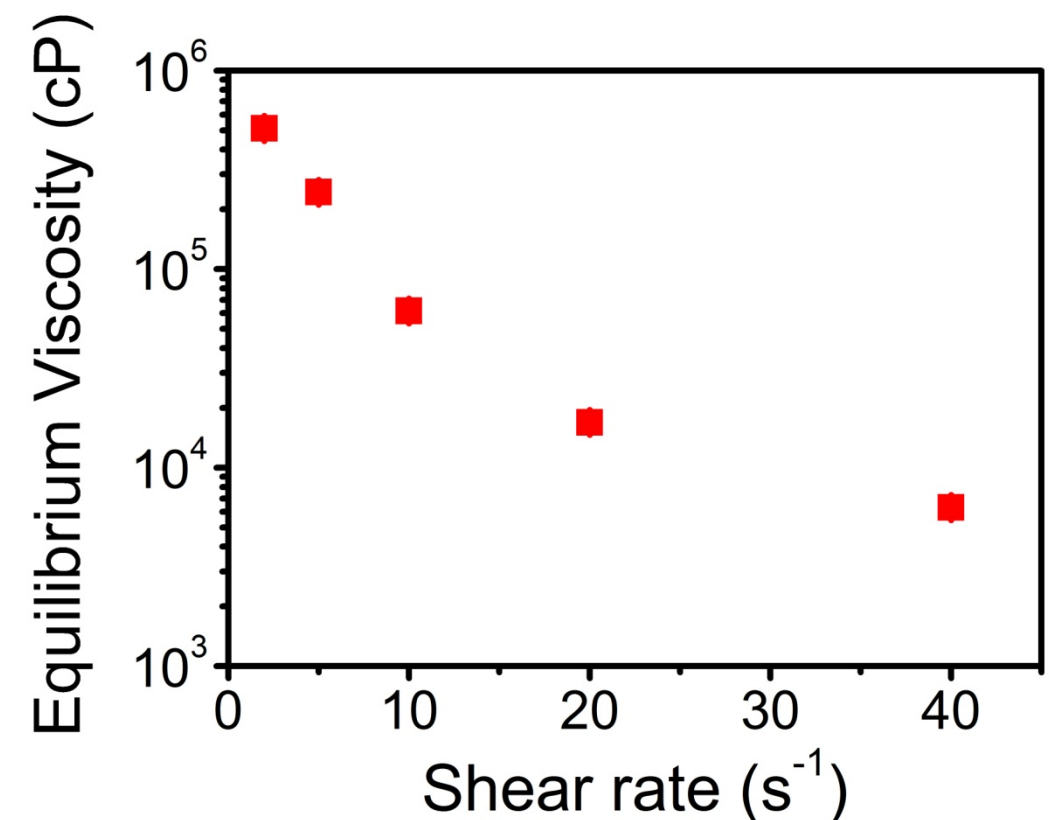


DuPont PV17F

Viscosity (Brookfield HBT, 10 rpm SC4-14/6R utility cap and spindle, 25°C)	280 - 400 Pa·s
Solid Content at 750 °C	89.5 - 91.0 %
Resistivity	< 5 mΩ/sq/μm
Silver grain	1-5 μm
Organic carrier	N,N'-Ethane-1,2-diylbis(decanamide) 12-Hydroxy-N-[2-[1-oxydecyl)amino]ethyl]octadecanamide N,N'-Ethane-1,2- diylbis(12-hydroxyoctadecanamide)
Thinner	9450



Non-newtonian, high-viscosity fluids





Process parameterization

- Deposition of paste voxels using single laser pulses
- Aspect ratio as figure-of-merit

