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PHOTONIC CURING OF CONDUCTIVE SILVER INKS AND GLUES FOR IN-MOLD ELECTRONICS ON POLYCARBONATE AND BIO-BASED BIODEGRADABLE POLYLACTIC ACID FILMS

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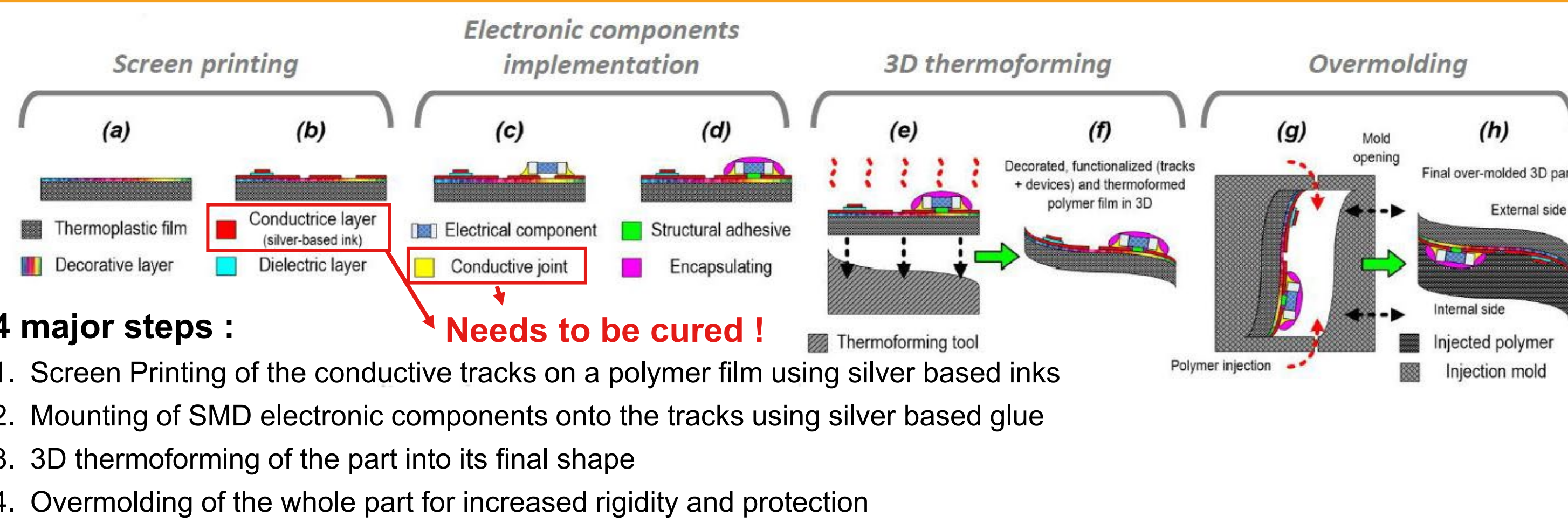
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Projet ANR-22-CE05-0015-03 AMBRE : Antenne Multifonctionnelle Biosourcée pour la récupération d'Énergie

INTRODUCTION

- In-Mold Electronics is a new manufacturing process allowing the production of electronic parts on a 3D polymer part by screen-printing the electronics directly on the surface of the polymer, using conductive silver-filled inks. It allows for production of lighter and simpler components compared to traditional electronics + housing assemblies.
- This process a few drawbacks, notably that those inks have a higher resistivity than the bulk copper used in traditional PCB, and that during the manufacturing, they need to be thermally cured in ovens in order to evaporate the solvents they contain and improve their conductivity. This process is long and only usable on high-temperature resistant substrates such as polycarbonate.
- In the AMBRE project, we want to use the IME process on a bio-based and biodegradable polymer substrate : Polylactic Acid (PLA). This polymer cannot stand the high curing temperatures needed for the IME process, thus we propose to use the Photonic Curing technology to cure the inks on this substrate.

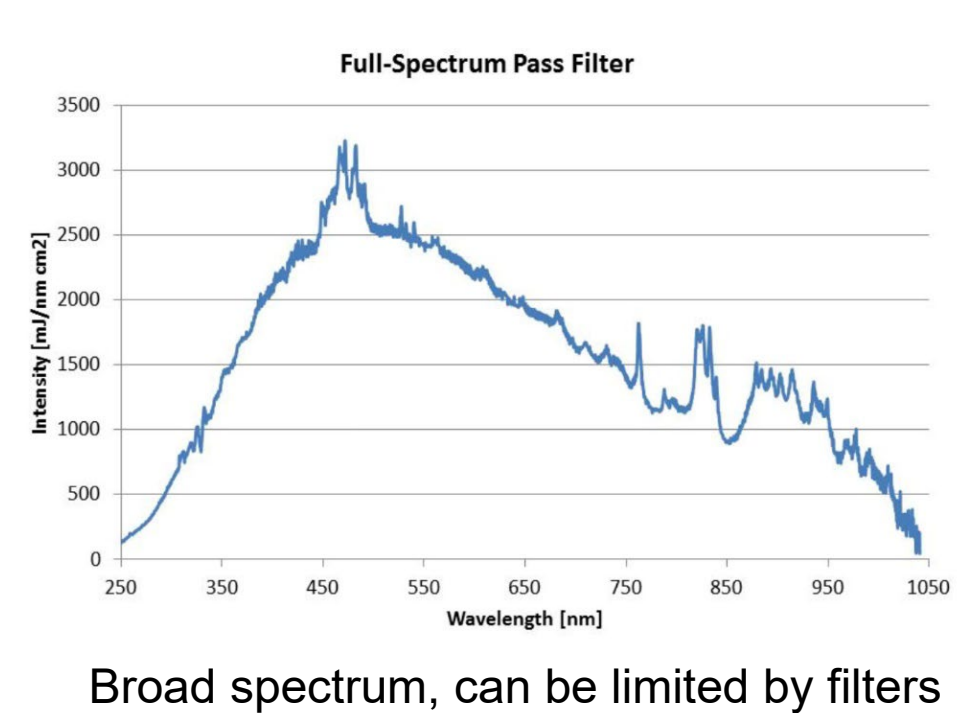
IN-MOLD ELECTRONICS



PHOTONIC CURING



- High-intensity light pulses (Xenon broad spectrum lamp)
- The light is mainly absorbed by the ink/solder paste
- Very short pulses to limit the heating of the polymer substrate (in the millisecond range, 1 μ s increments)
- Depending on the parameters, ink annealing and SMD soldering may be done

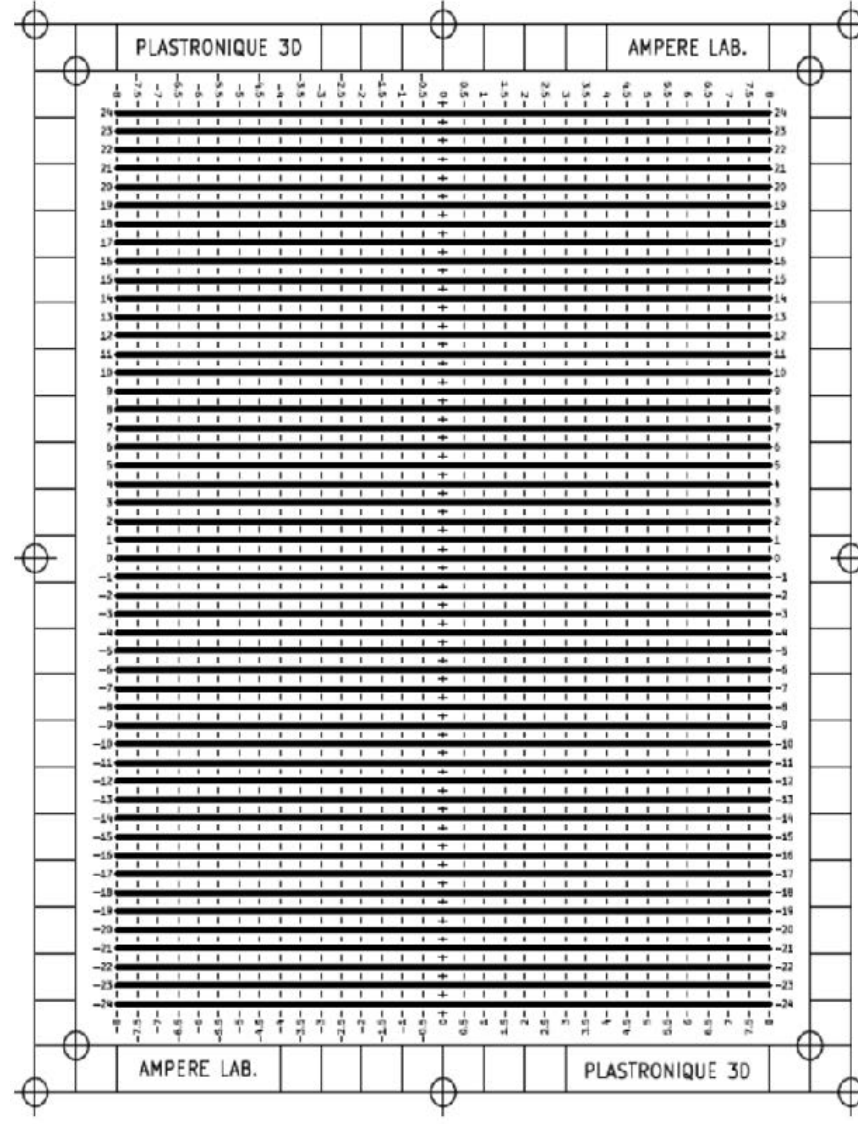


Novacentrix PulseForge Invent Photonic Curing Machine

PHOTONIC CURING TO IMPROVE INK CONDUCTIVITY

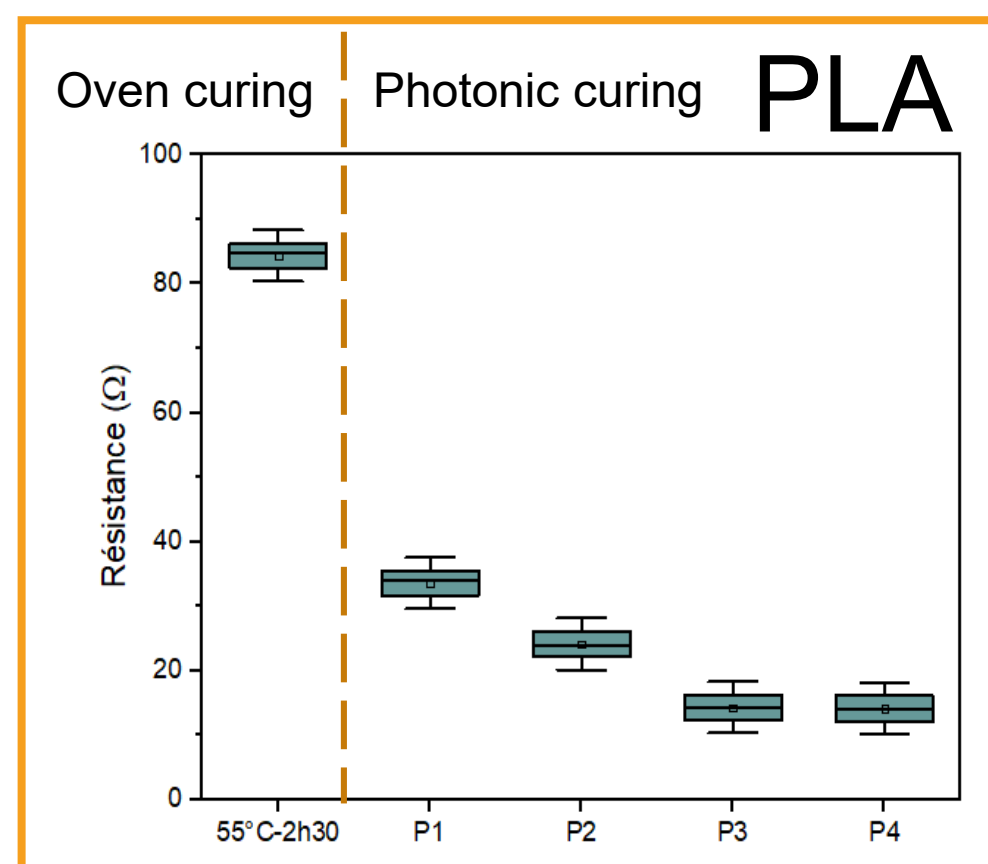
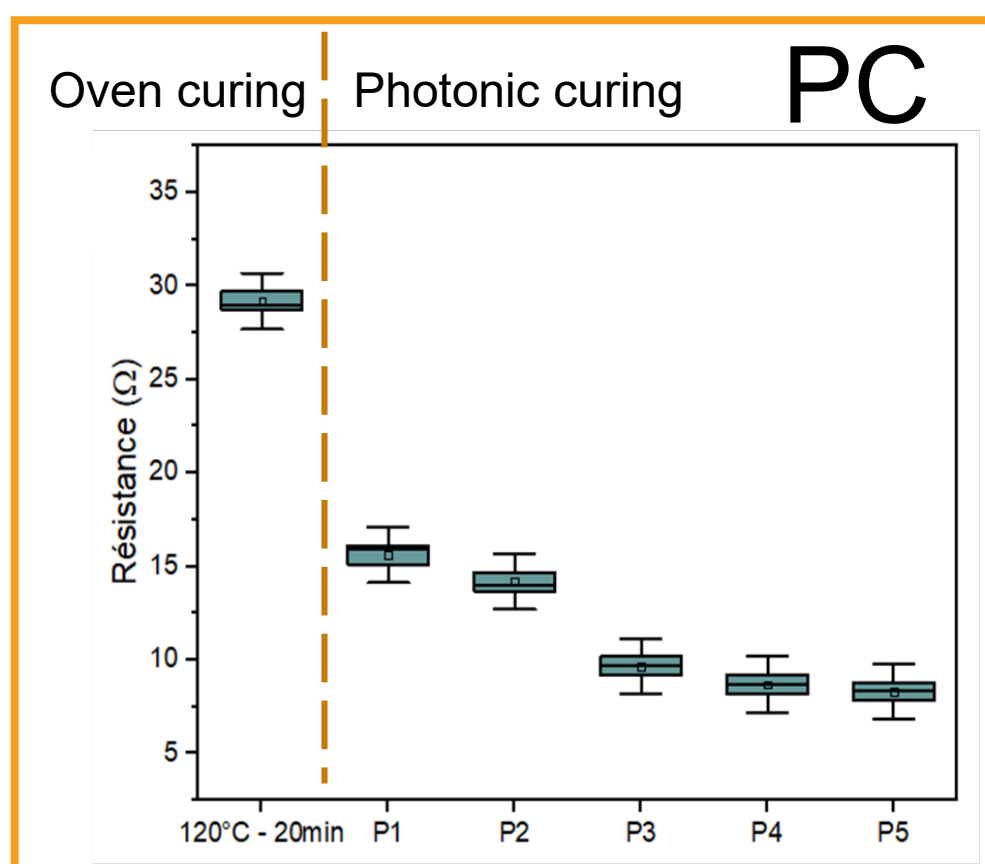
- Resistivity of the tracks depending on the type of curing:

Oven Curing	Configuration	Temperature	Duration	source	
	P0 PC	120°C	20 min	Supplier data	
P0 PLA	55°C	2h30	Previous work [1]		
Photonic Curing	Configuration	Frequency	Pulse duration	Number of pulses	Cycle Time
	P1	1 Hz	1000 μ s	20	20 s
	P2	1 Hz	1000 μ s	40	40 s
	P3	10 Hz	1000 μ s	40	4 s
	P4	20 Hz	1000 μ s	40	2 s
	P5	30 Hz	1000 μ s	40	1,33 s

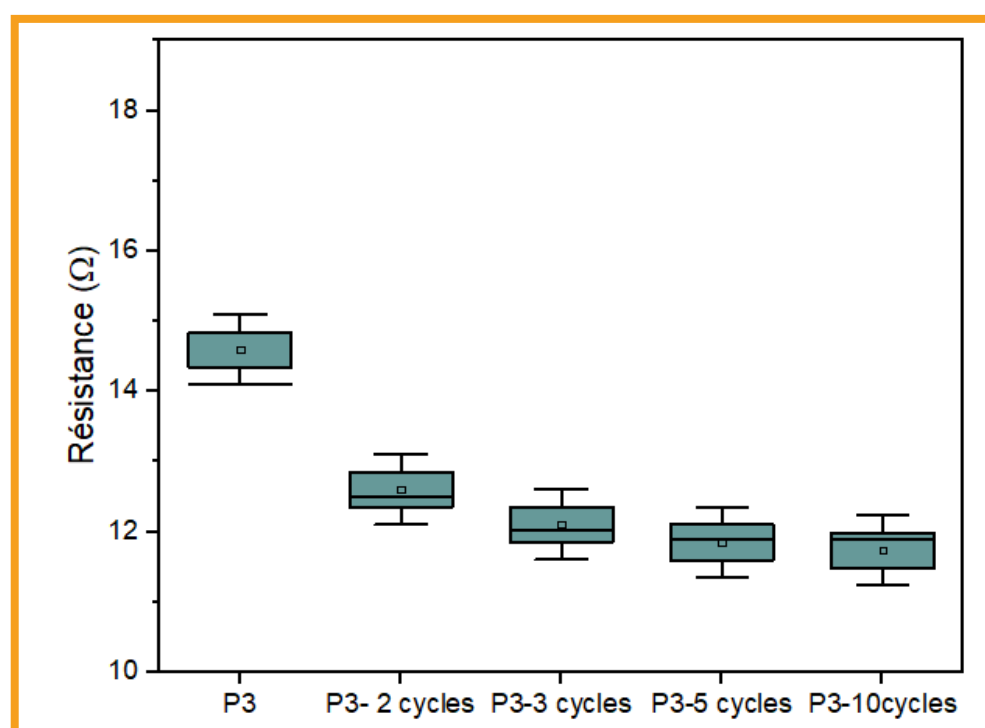


Screen printed pattern for this study: 49 lines, L= 160mm, w = 1 mm

Photonic Curing allows a reduction of 67% of the track resistance on PC substrate, and 82% on PLA substrate, compared to regular oven curing.



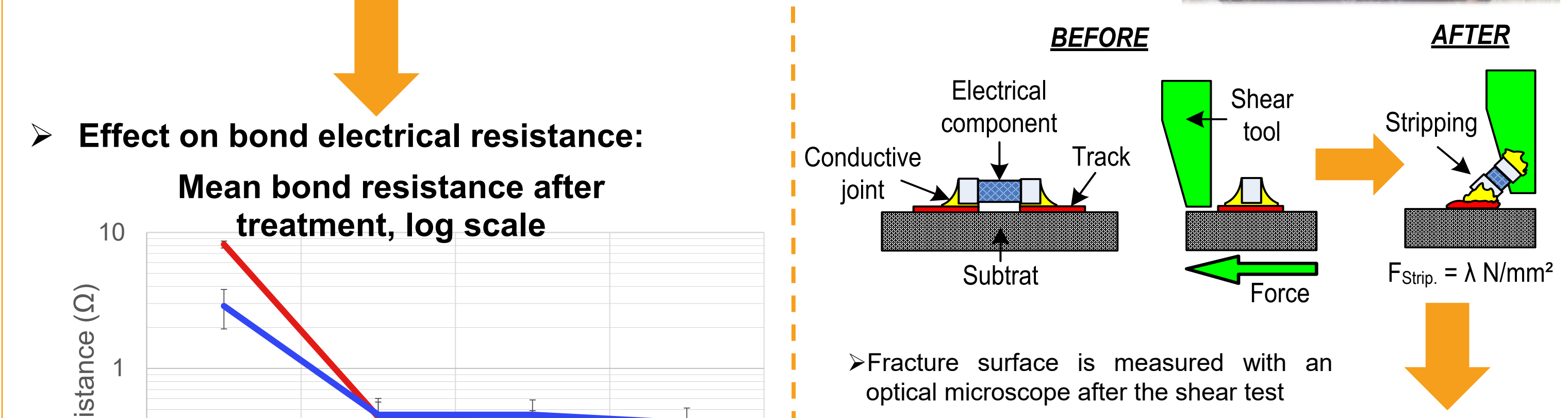
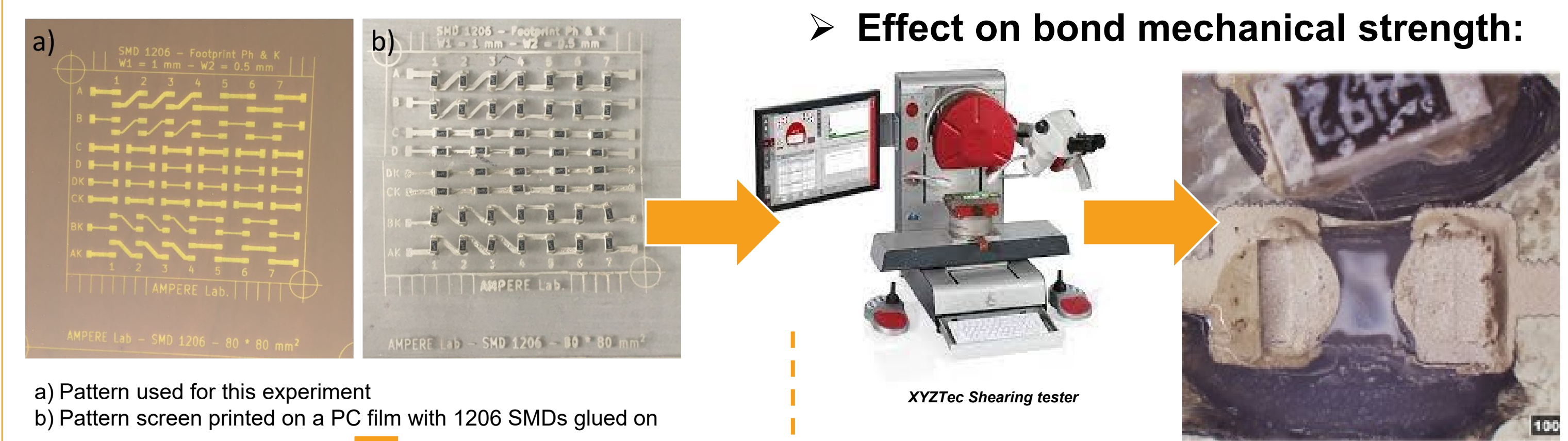
- Effect of repeated curing:



Multiple Photonic Curing cycles allow to further reduce track resistance by 20%, while increasing the process time by only a few seconds.

Configuration	Average track resistance	Comment
P3	14,5 Ω	Reference
2x P3	12,5 Ω	
3x P3	12,1 Ω	
5x P3	11,8 Ω	
10x P3	12 Ω	Damage to many tracks

PHOTONIC CURING TO IMPROVE GLUE BONDS



	Reference (thermal curing)	oven-cured ink, photonic-cured glue	photonic-cured glue only	photonic-cured glue only, two cycles
PLA	8,163	0,4405	0,3955	0,309
PC	2,879	0,4565	0,456	0,3985

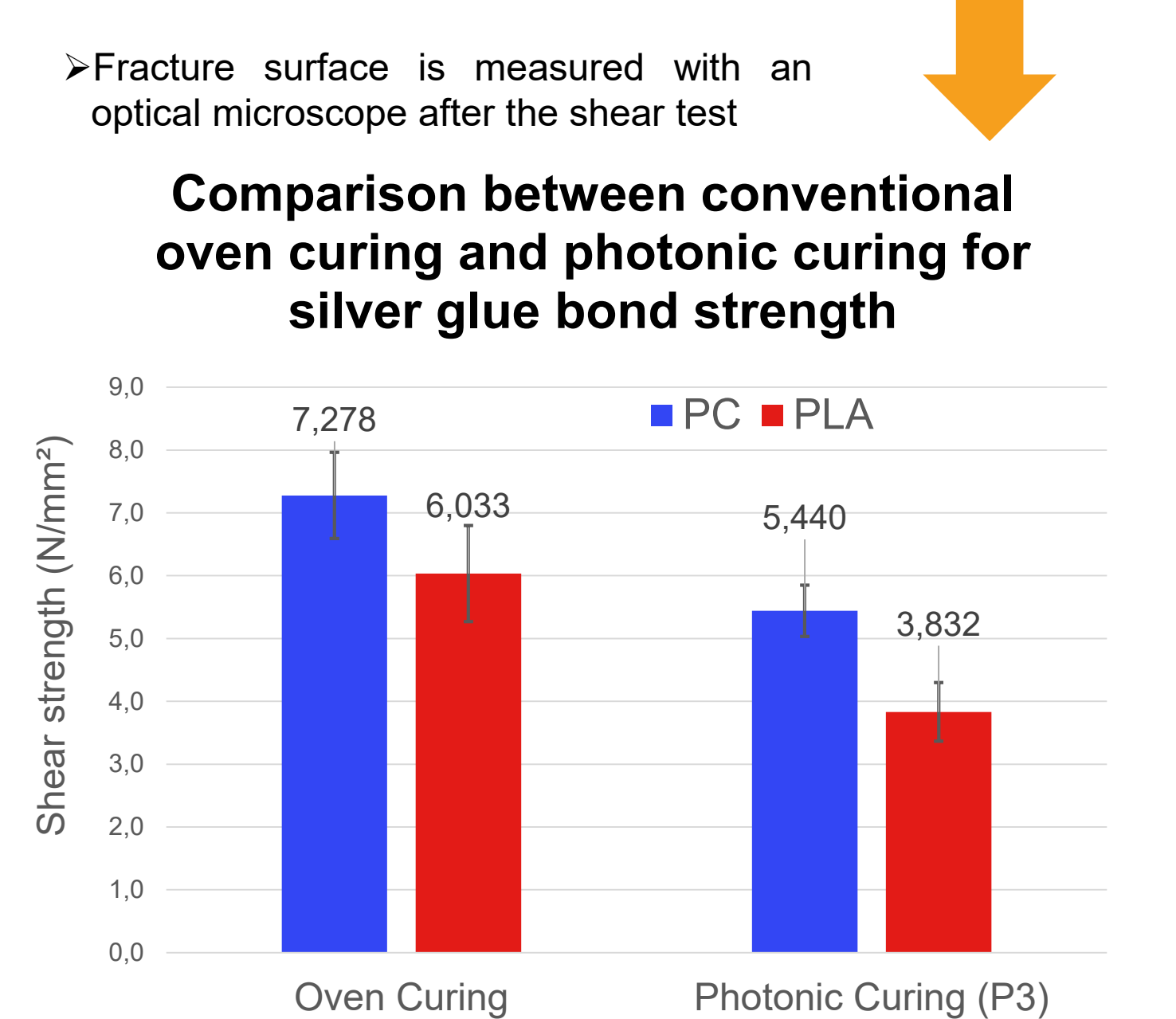
Thermal curing parameters:

- 20 min @ 120°C for PC films (supplier recommended settings)
- 2h30 min @ 55°C for PLA films (based on previous work)

Photonic curing :

- 450V, 1000 μ s, 10Hz, 40 pulses (P3)

Photonic curing of conductive glues improves their conductivity by 86% (PC) to 95% (PLA) depending on the substrate, at the cost of a lowered mechanical strength.



CONCLUSION

- Photonic Curing substantially improves track and bond conductivity compared to regular oven curing.
- It comes at the cost of slightly weaker bond strength: a structural adhesive is still needed to ensure mechanical strength of the whole part.
- Photonic Curing also allows to make IME parts on low-temperature substrates like PLA, with close electrical performance compared to conventional substrates (PC).

	Oven	Photonic (P3)	Change (%)
Ink Curing – resistance (PC)	28 Ω	10 Ω	-67%
Ink Curing – resistance (PLA)	83 Ω	14 Ω	-82%
Glue Curing – bond resistance (PC)	2.9 Ω	0.4 Ω	-86%
Glue Curing – bond resistance (PLA)	8.1 Ω	0.4 Ω	-95%
Glue Curing – bond strength (PC)	7.3 N/mm ²	5.4 N/mm ²	-26%
Glue Curing – bond strength (PLA)	6.0 N/mm ²	3.8 N/mm ²	-36%

