# Digital laser printing and sintering of silver nanoparticle inks for the additive manufacturing of micro-conductive patterns on non-planar flexible substrates

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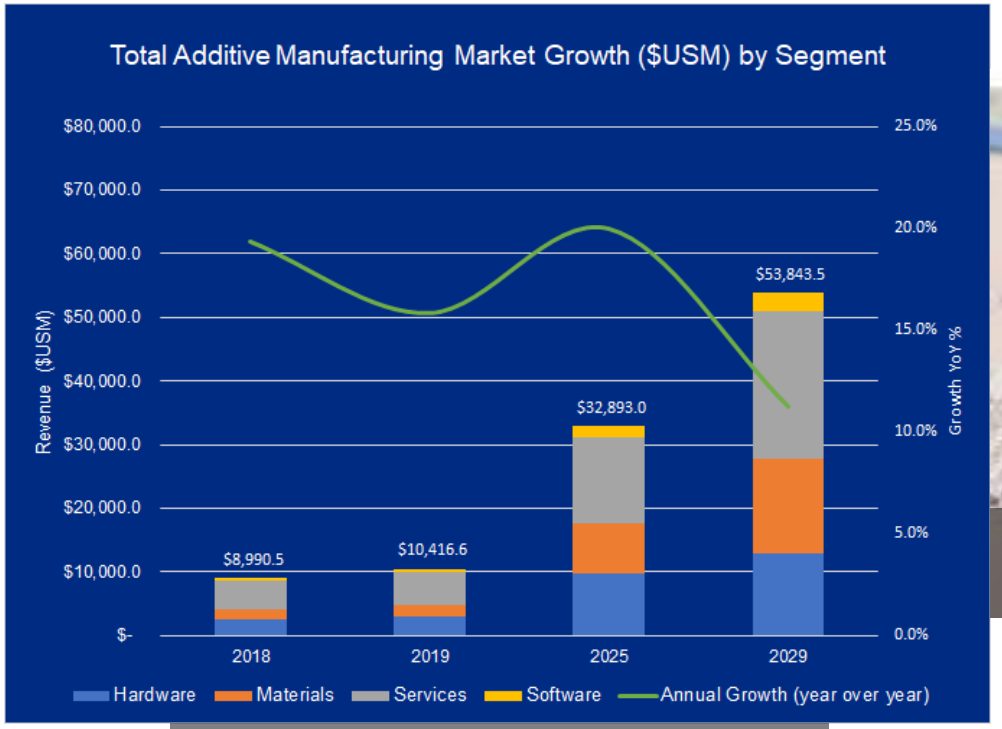
# Additive manufacturing

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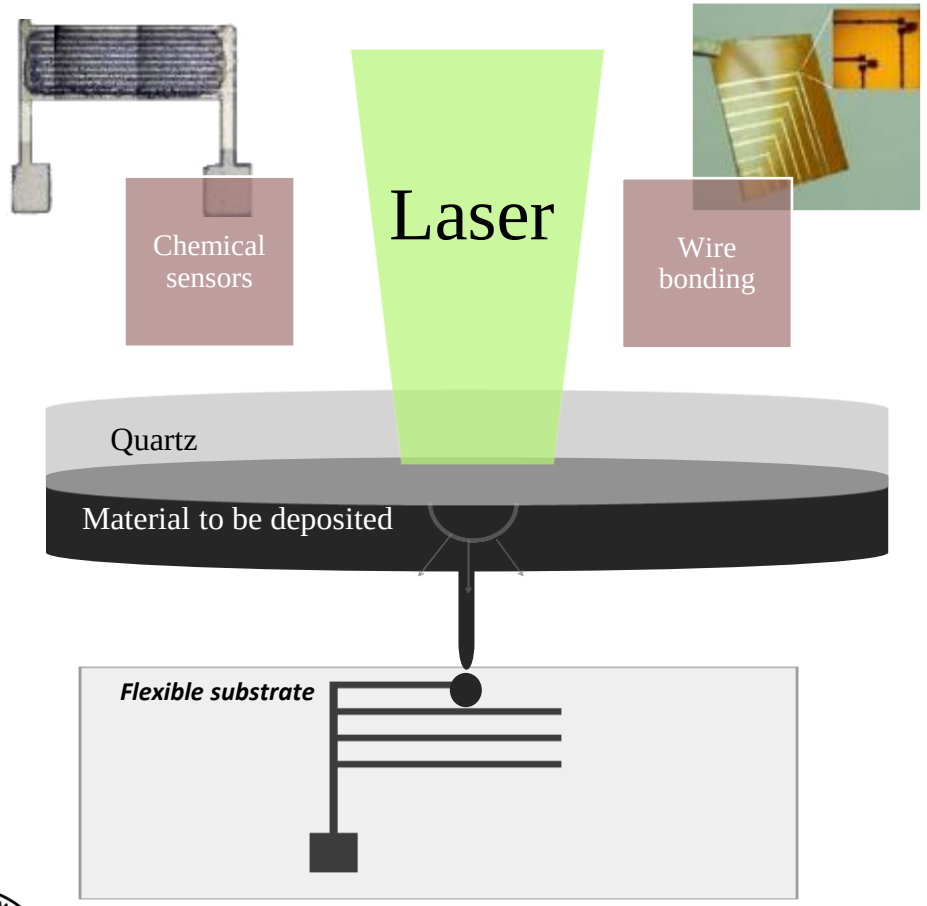
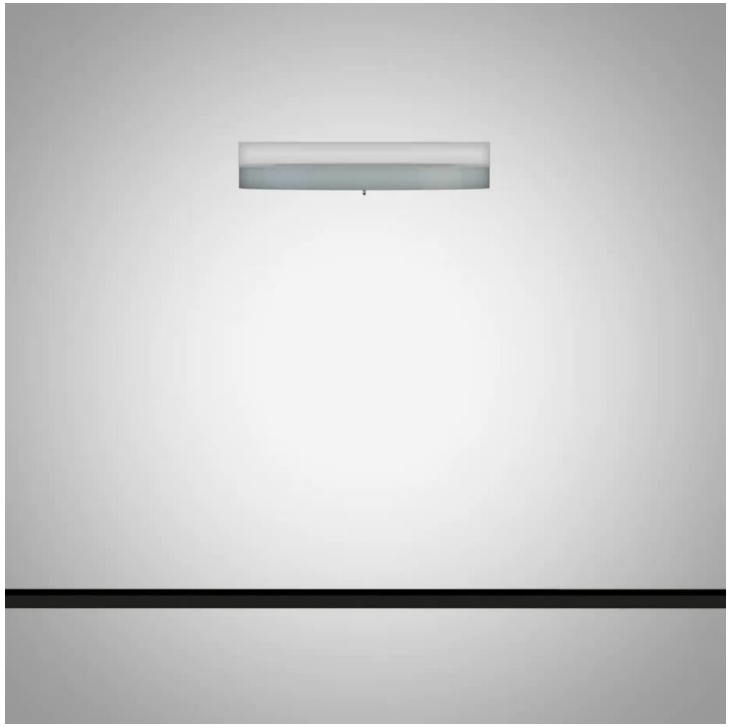
Flexible circuits

Smart displays

# Laser induced forward transfer (LIFT)



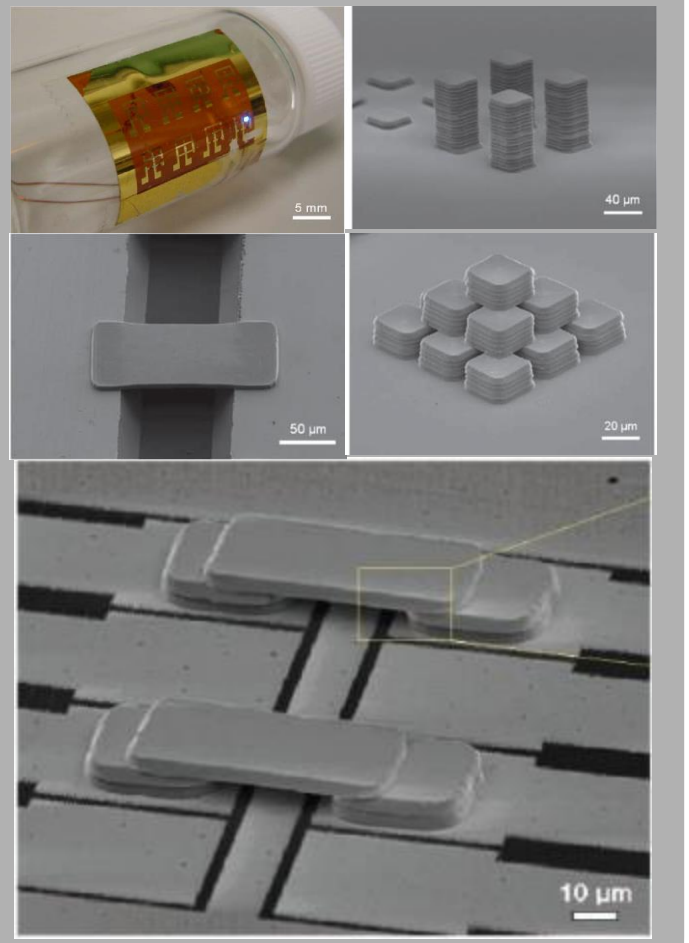

**Donor**



- Printing in solid, liquid phase and 2D materials
- Spatial resolution down to 10 μm for liquid and sub-micron for solid phase
- Printing of inorganic, organic, biological materials

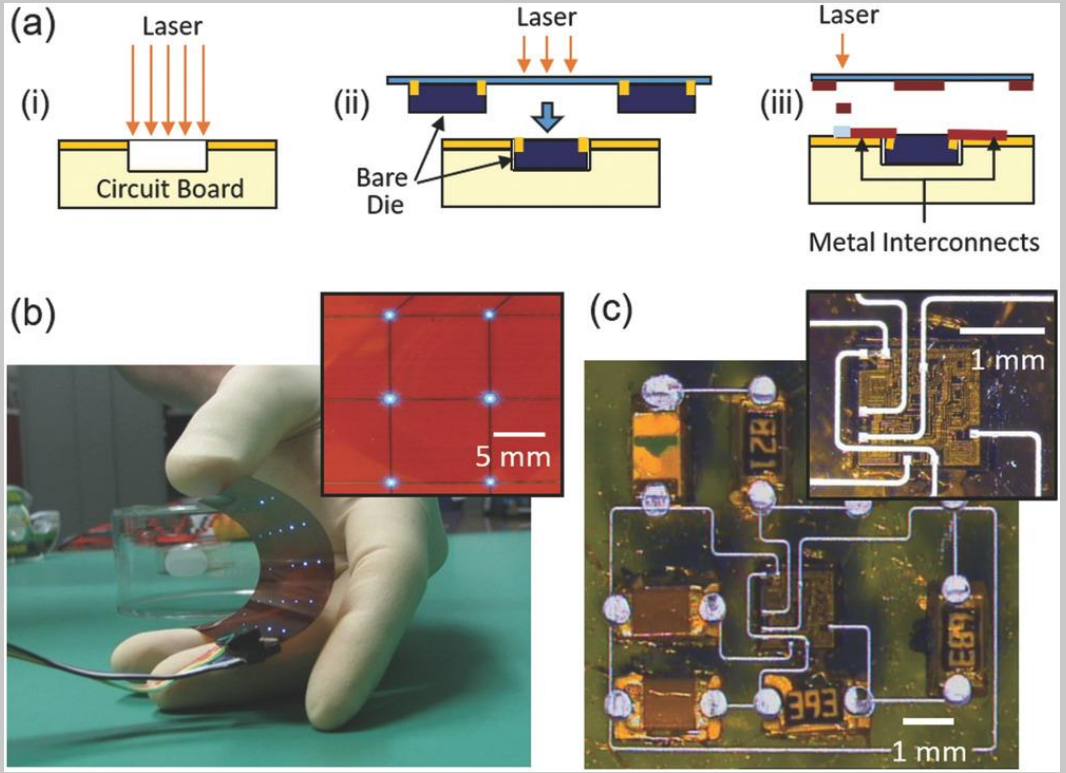
# LIFT applications

## Printing Silver Nanopastes for interconnection bonding of Au pads



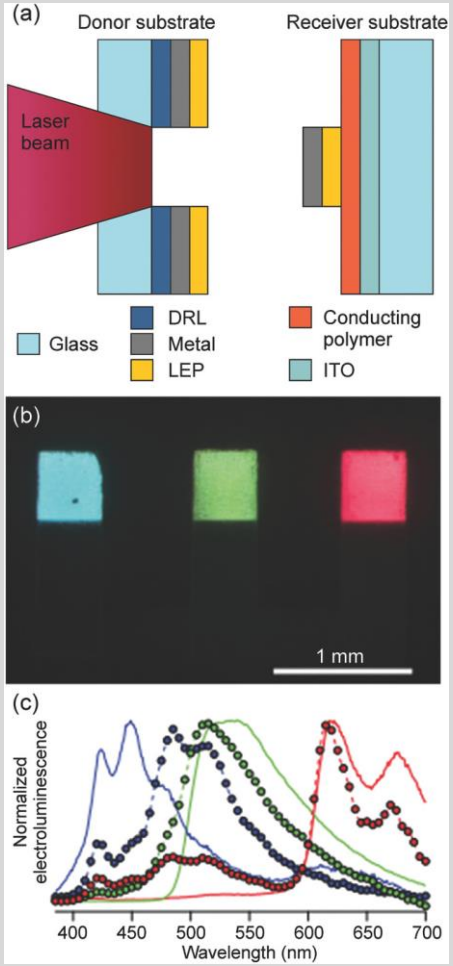

*Wang et al., Adv. Mater., 22, 4462–4466, (2010)*

## Laser mediated embedded electronics




*A. Piqué, R. C. Y. Auyeung, H. Kim, N. A. Charipar, S. A. Mathews, J. Phys. D: Appl. Phys. 2016, 49, 223001.*

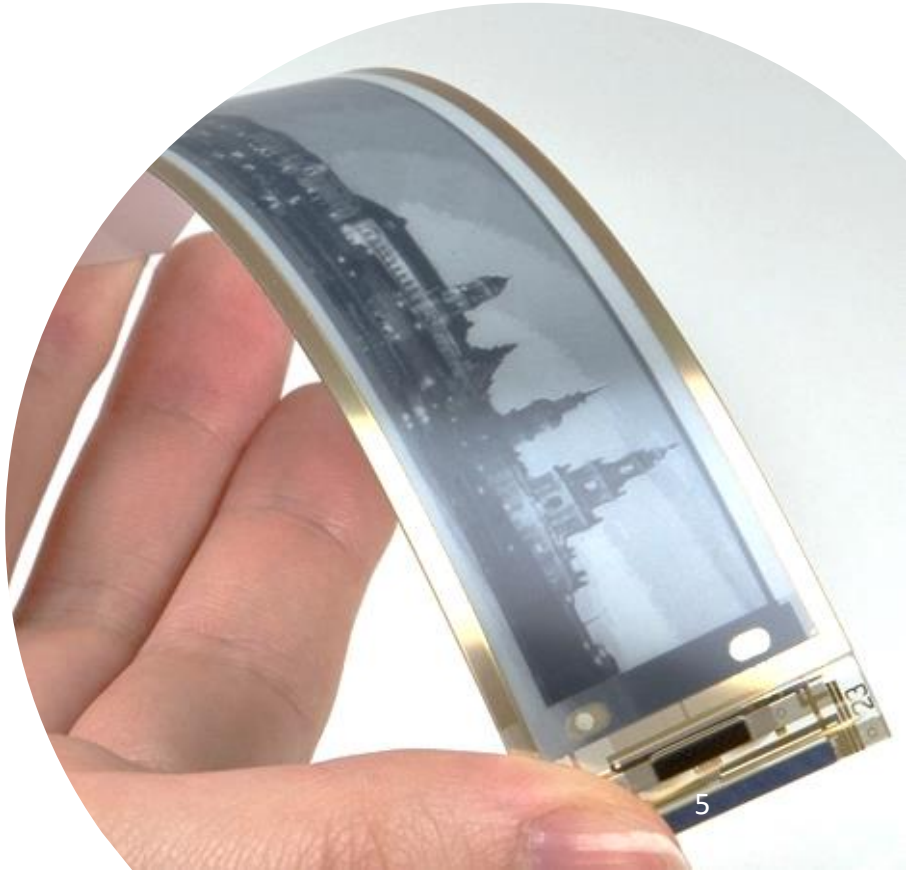
## Single-step laser printing of multistack OLEDs through a DRL



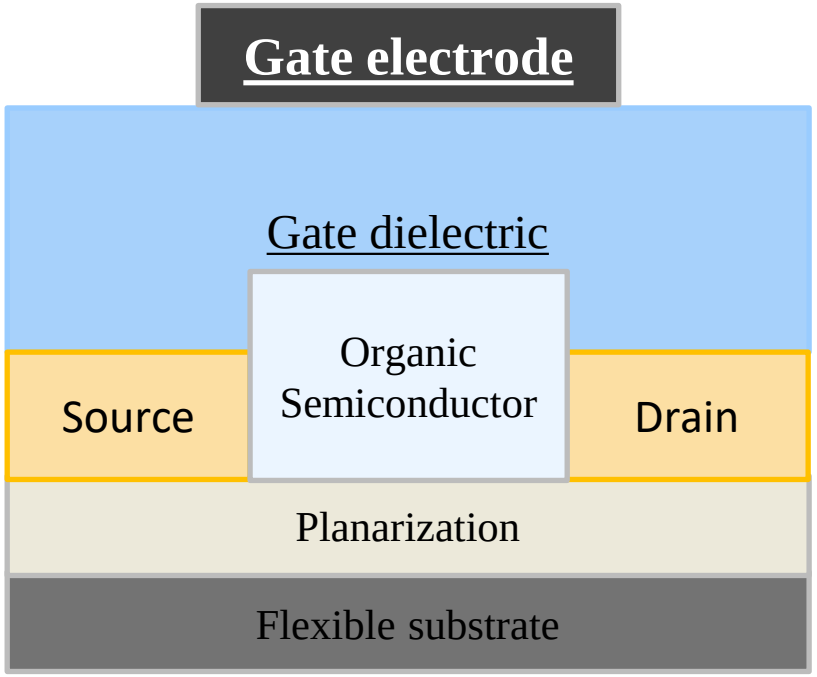

*J. Shaw-Stewart, T. Lippert, M. Nagel, F. Nüesch, A. Wokaun, Appl. Phys. Lett. 2012, 100, 203303*

# Organic thin film transistor displays

- Lightweight
- Simple fabrication methods
- Inexpensive
- Flexible
- Durability



# Organic thin film transistor (OTFT)




**OTFT stack schematic representation**

- Photolithography masks to be designed and ordered
- Not fully compatible with complex non-planar patterned substrates due to waviness
- Gate dielectric thermally sensitive (Tg < 120$^{o}$C)

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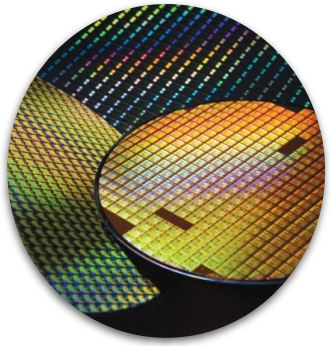
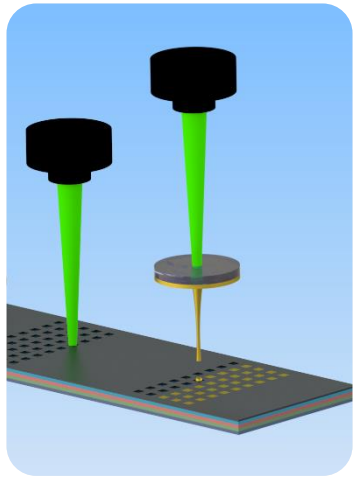
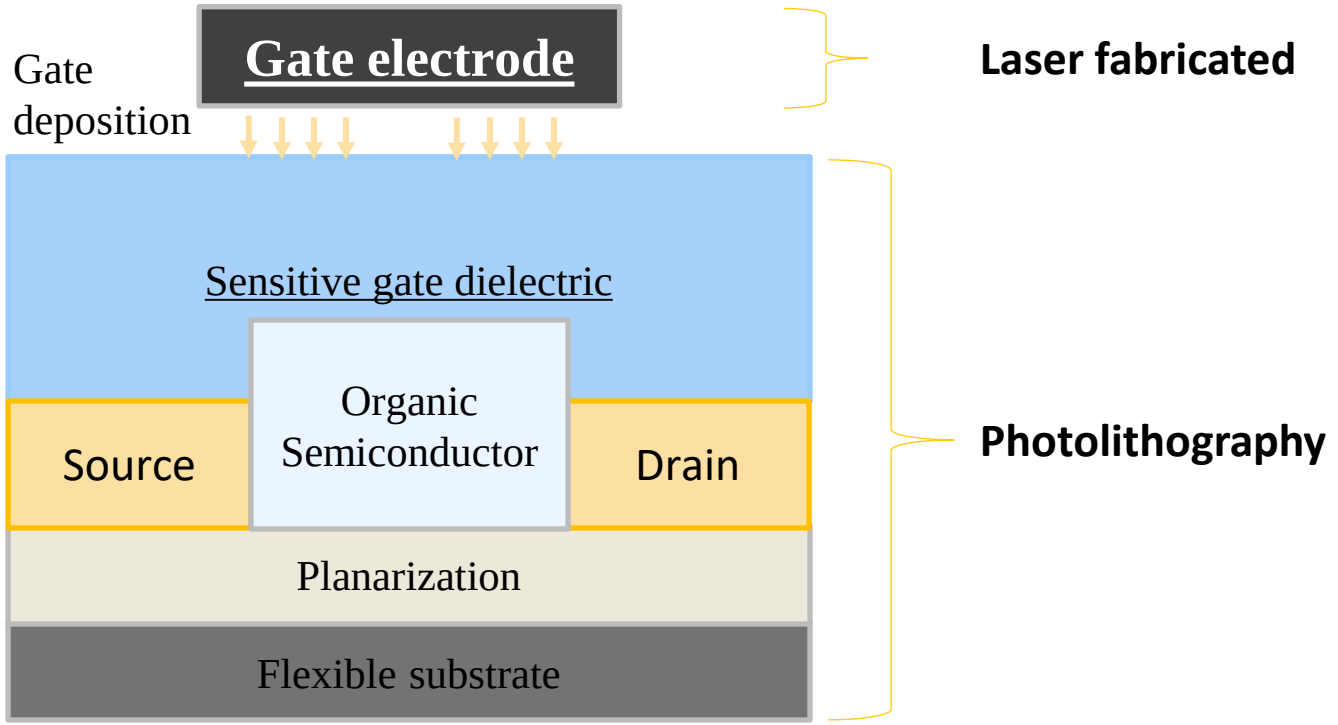
# LIFT & photolithography for OTFTs

**Photolithography** **Laser Printing + Laser sintering**





**Flexible & Wearable electronics**

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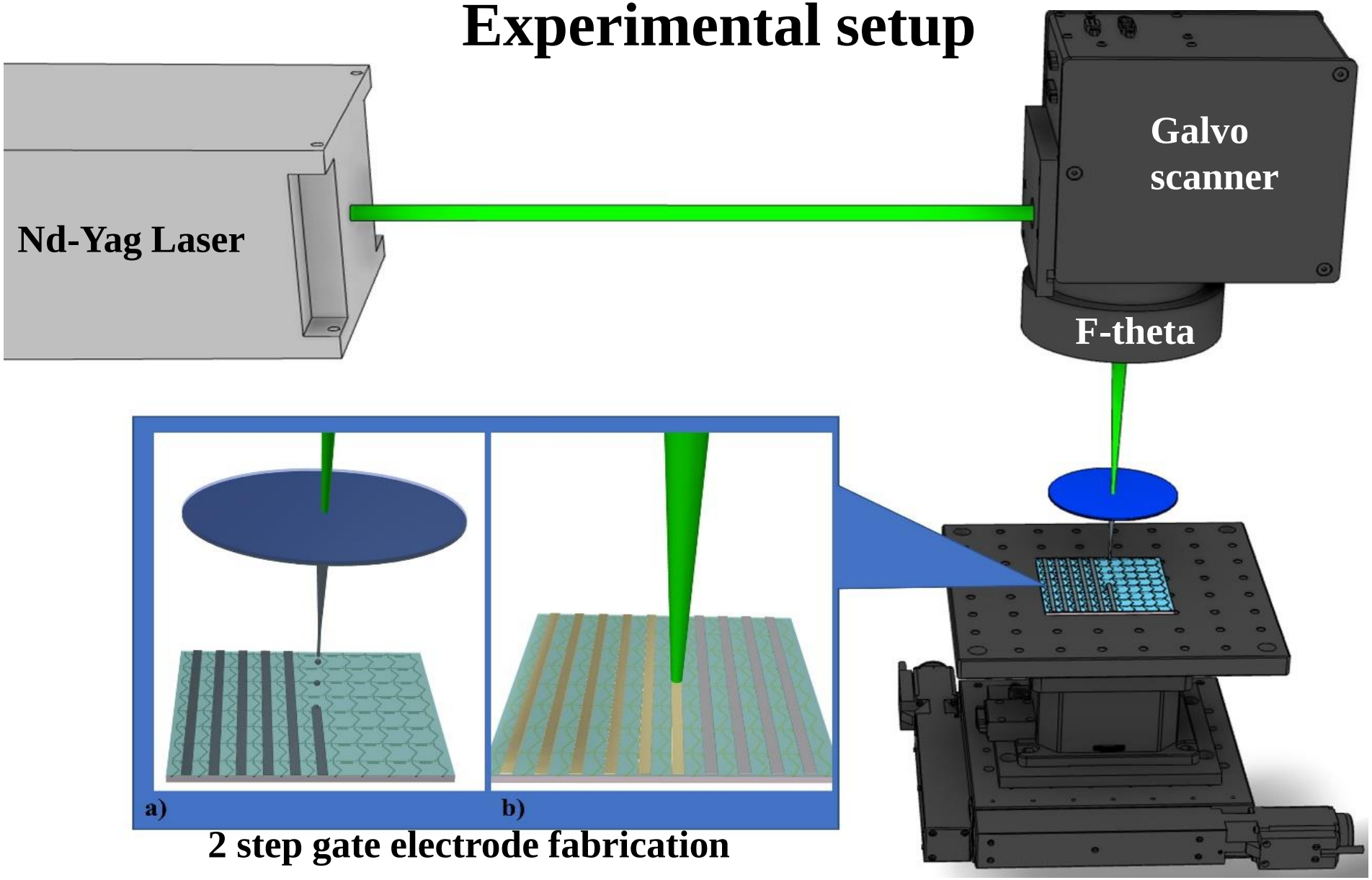
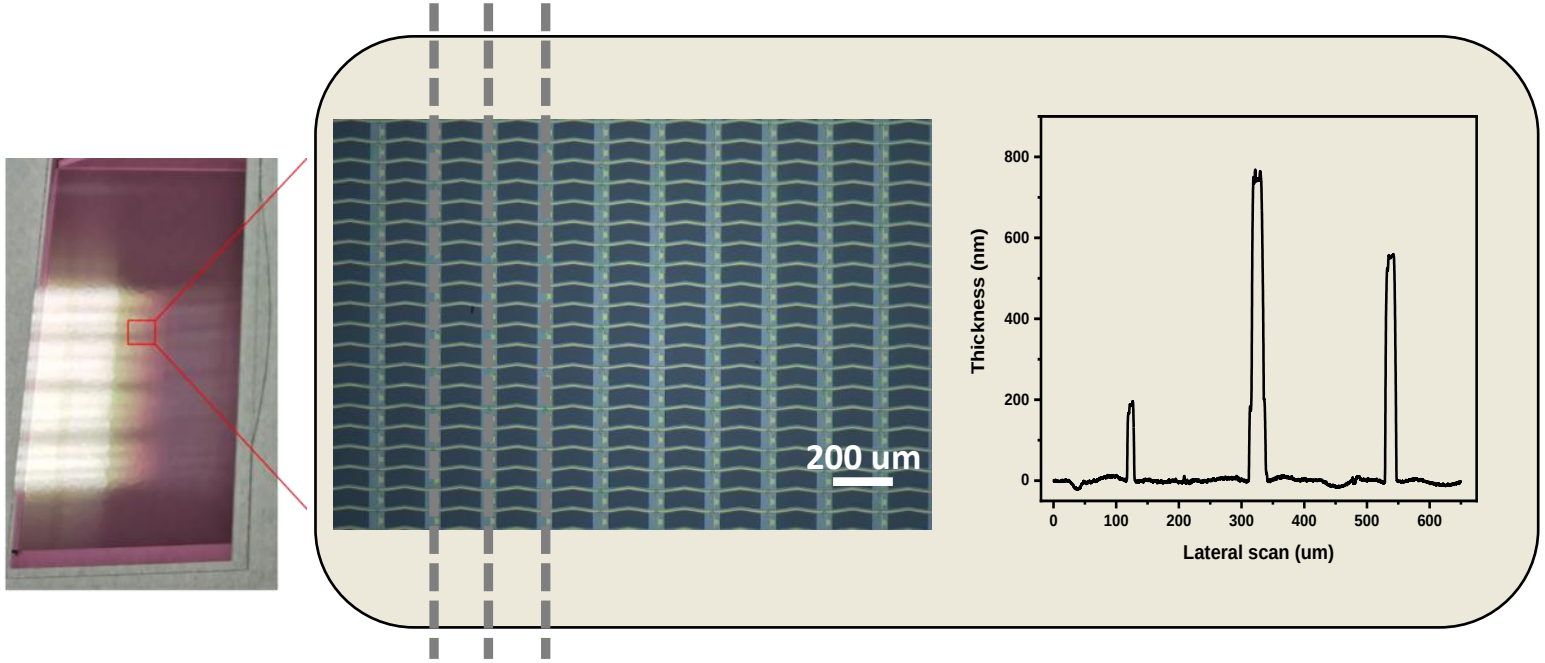
# Experimental setup

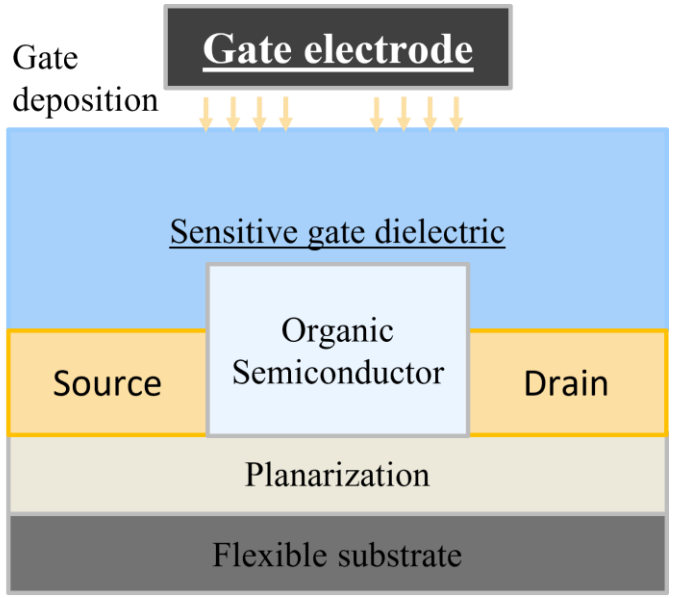



2 step gate electrode fabrication

# Non-planar substrates

**Complex non-planar multilayered OTFT backplane with to be-fabricated gate electrodes (Top view)**

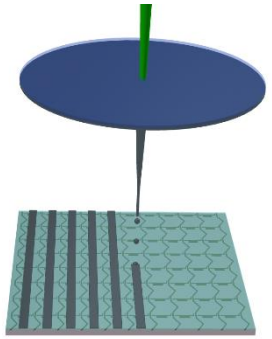


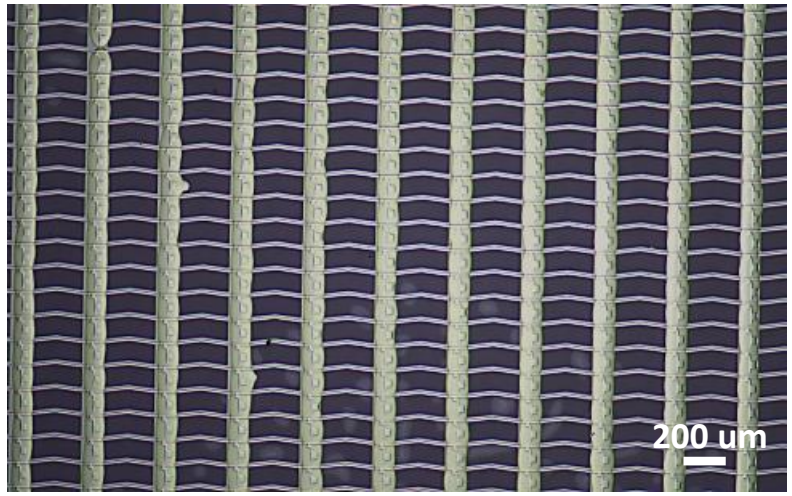

**Underlying structures affect the gate dielectric's morphology**

# Gate electrode printing

Laser printing

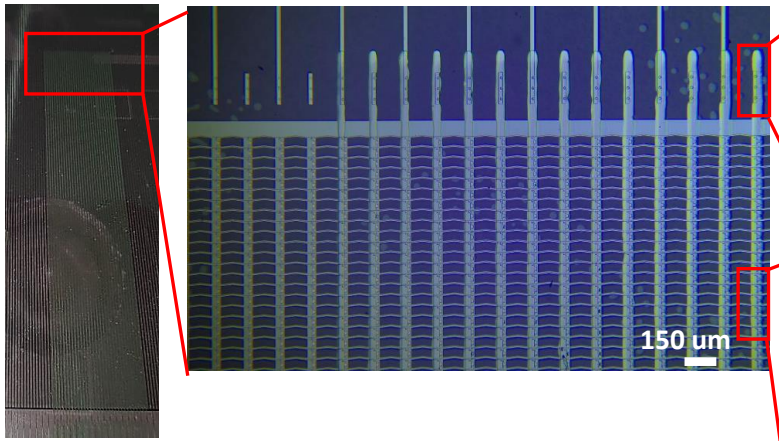


**Pitch 100 µm**

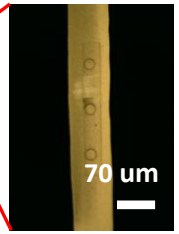



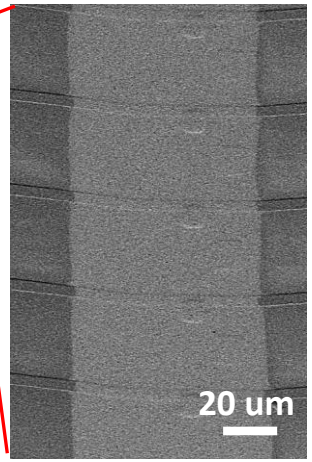

- < 500 nm height
- < 80 um width
- cm long lines printable on planar and non-planar substrates

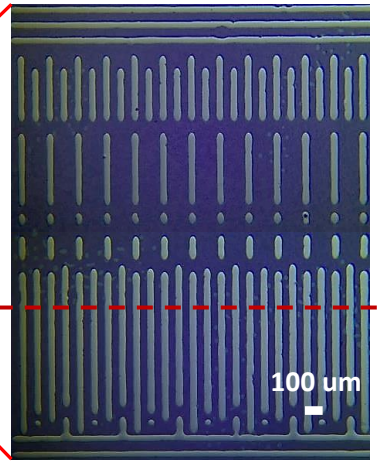
# Gate electrode printing and sintering

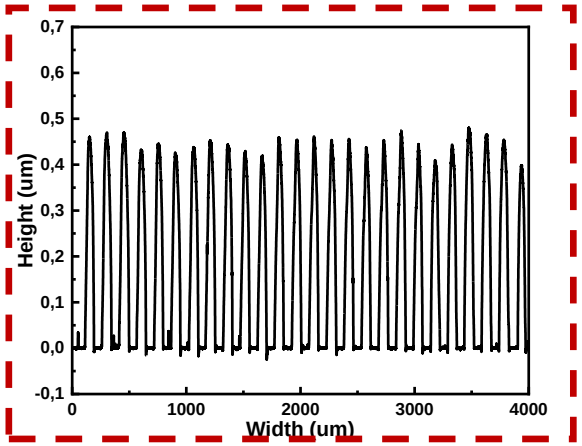





**Gate lines for pixel active area**

- Laser printed and sintered conductive lines on planar and non-planar substrates exhibiting 400 nm conformity
- Reliable large scale printed integrated gate drivers
- Resistivity values < 25 μOhm*cm

**Integrated gate drivers for flexible bezel-less display**

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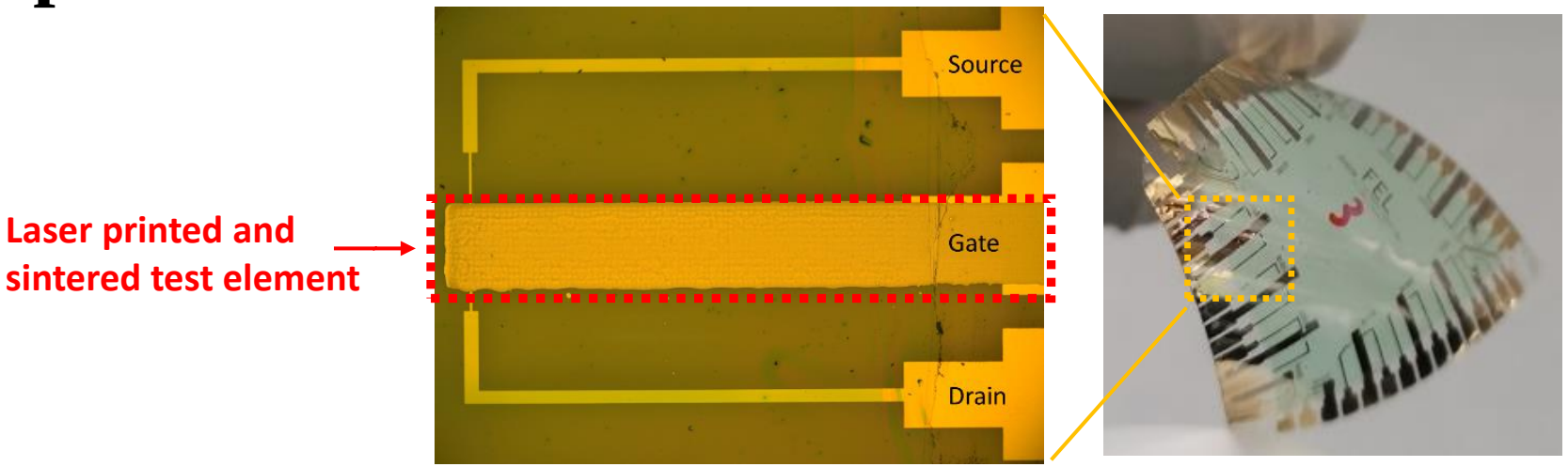
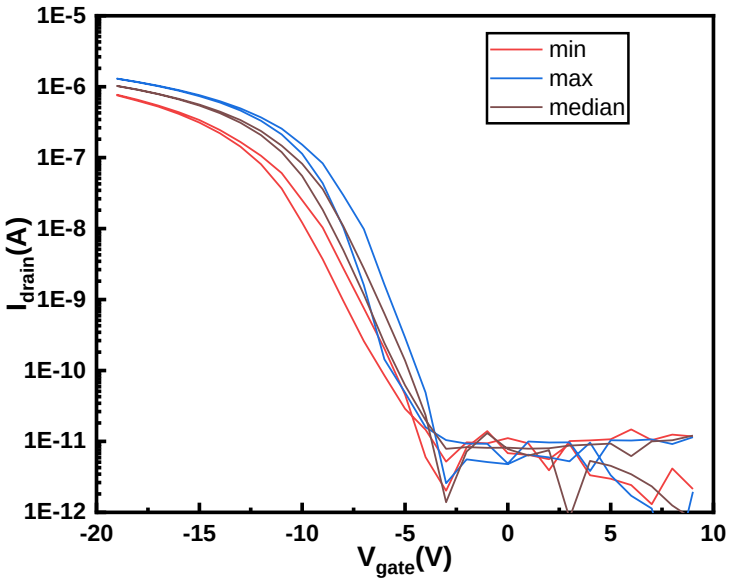
# Flexible Organic TFT for Full HD Organic LCD – performance evaluation

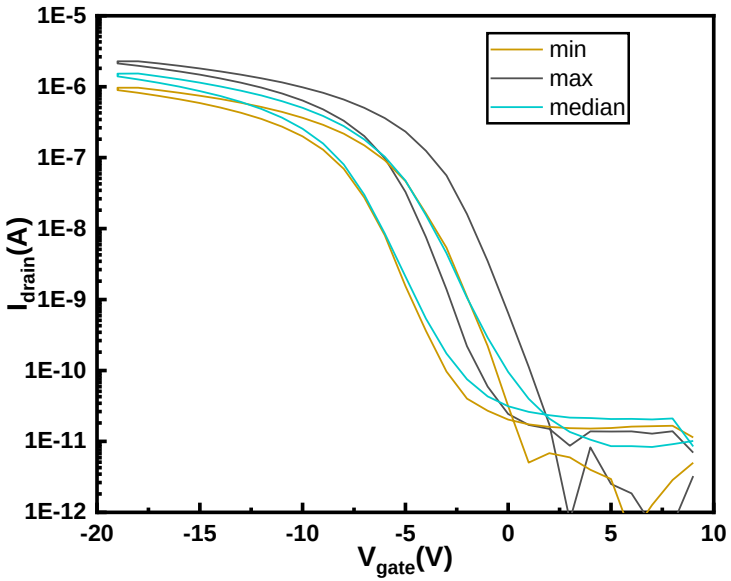
Comparison of LIFT with standard manufacturing techniques




**LIFT printed gate**




**Sputtering deposited gate**

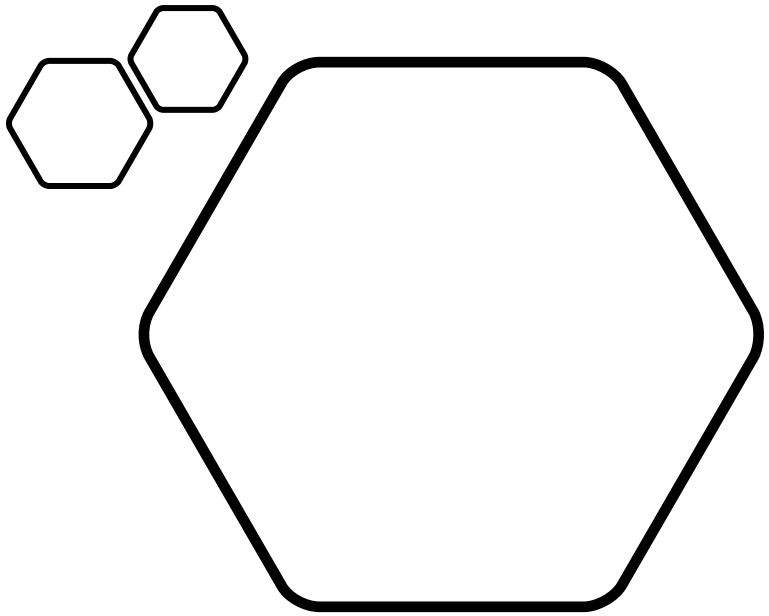



Mobility only decreased by 10% from 1 $cm^2/(V.s)$ (sputtering process) to 0.9 $cm^2/(V.s)$ (laser processing)

- Vth increased by less than 5V
- Ion reduced by less than 50%

# In Conclusion…

- High spatial resolution (400 nm height) and high speed printing (5 m/sec), ideal for 3D processing
- Large area printing on flexible substrates (cm length lines of 400 nm height)
- High throughput and enhanced uniformity (height std < 50 nm) of the printed and sintered samples
- Capability for additive manufacturing on demanding substrates with waviness up to 800 nm
- Fabrication of highly efficient functional devices (device overall performance drop by less than 50%)



# Acknowledgments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- *A. Kabla*
- *S. Melamed*
- *F. de la Vega*
- *Y. Porte*
- *P. Too*

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Call: H2020-NMBP-TR-IND-2019
Start: 01/05/2020-30/4/2023
Duration: 36 months
Topic: DT-NMBP-18-2019 (IA)

# Thank you