Laser Induced Forward Transfer: a Digital Additive Manufacturing solution for electronics processing and packaging

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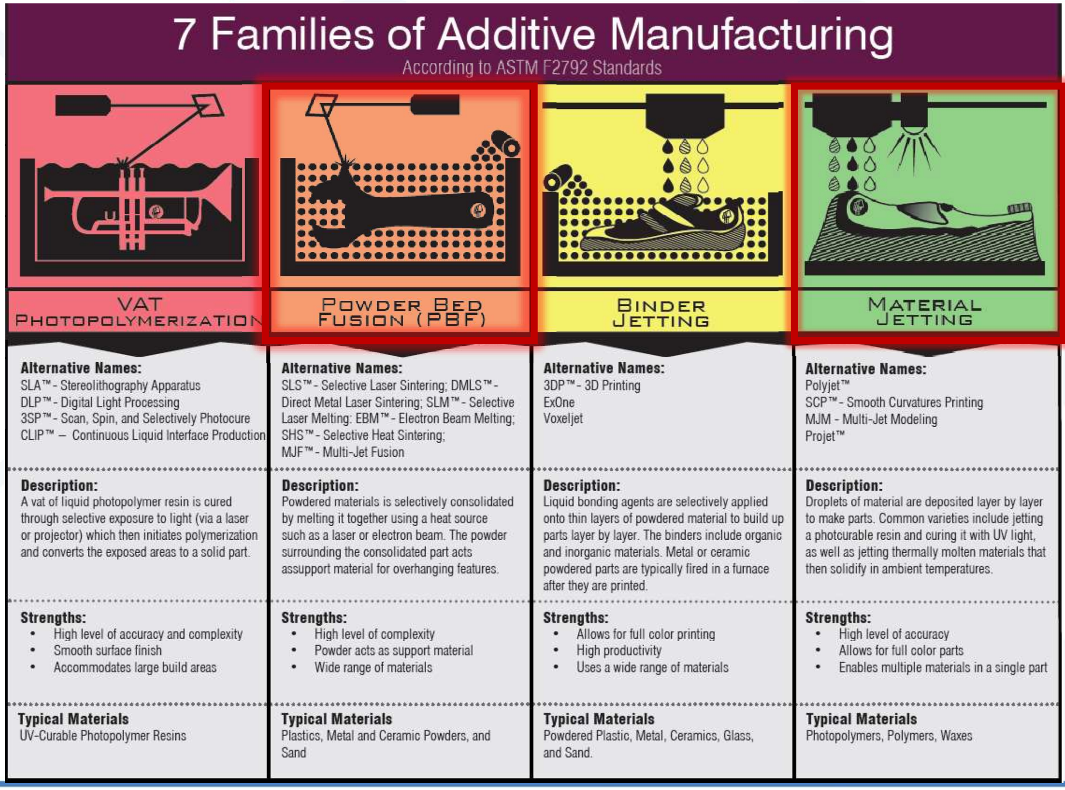
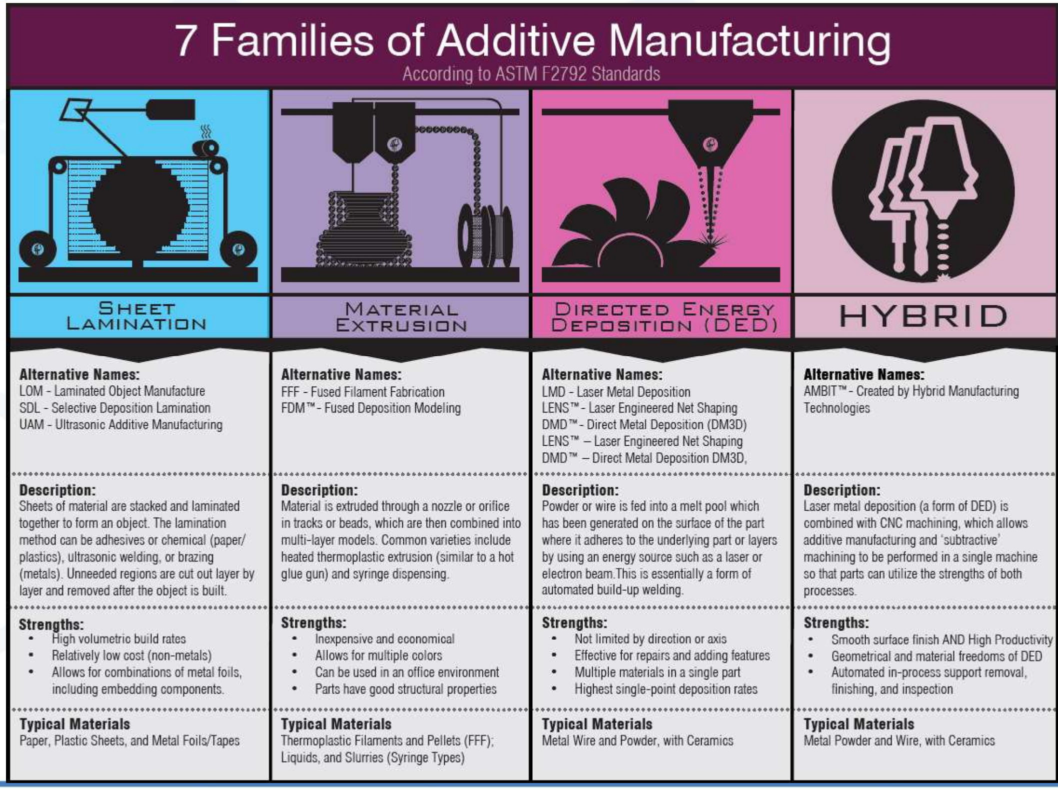
National Technical University of Athens
June 28 2022, Grenoble

AM families according to the American Society for Testing and Material (ASTM)





Digital Additive Manufacturing

Material Jetting "Drop on demand":

an additive manufacturing process in which droplets of build material are selectively deposited

- Inkjet printing
- Aerosol Printing
- Laser Printing

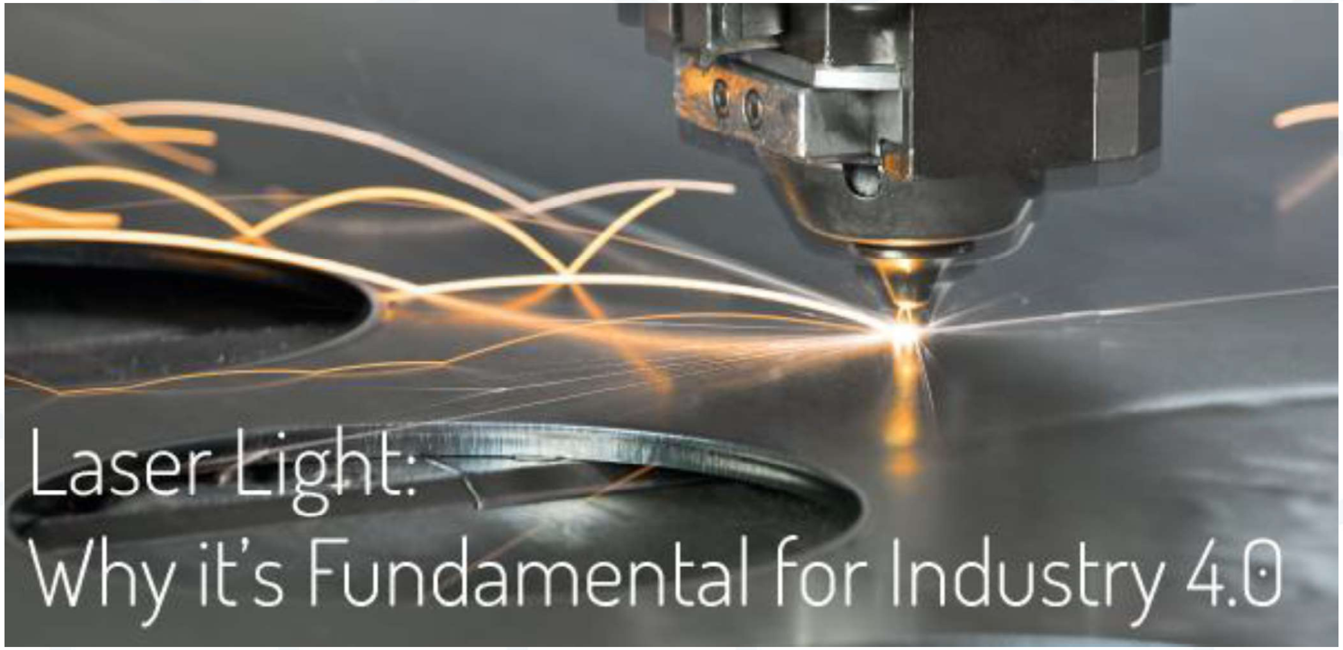
Powder Bed Fusion:

An additive manufacturing process in which thermal energy selectively fuses regions of a powder bed

- Direct Metal Laser sintering
- Multi-Jet fusion
- Electron Beam Melting
- Selective Laser Sintering

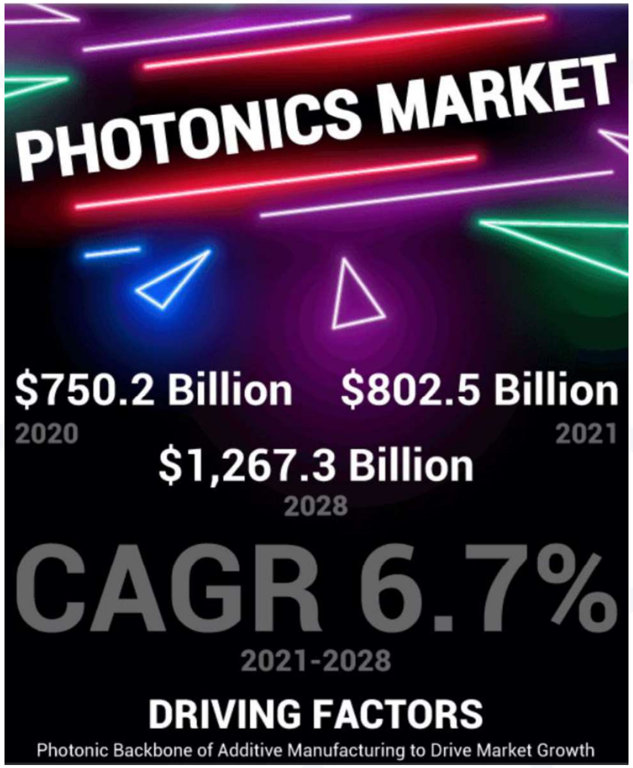
Why is laser additive manufacturing a key-enabler for Industry

"Europe's age of light!
How photonics will power growth and innovation"
Photonics 21 Strategic Roadmap 2021–27

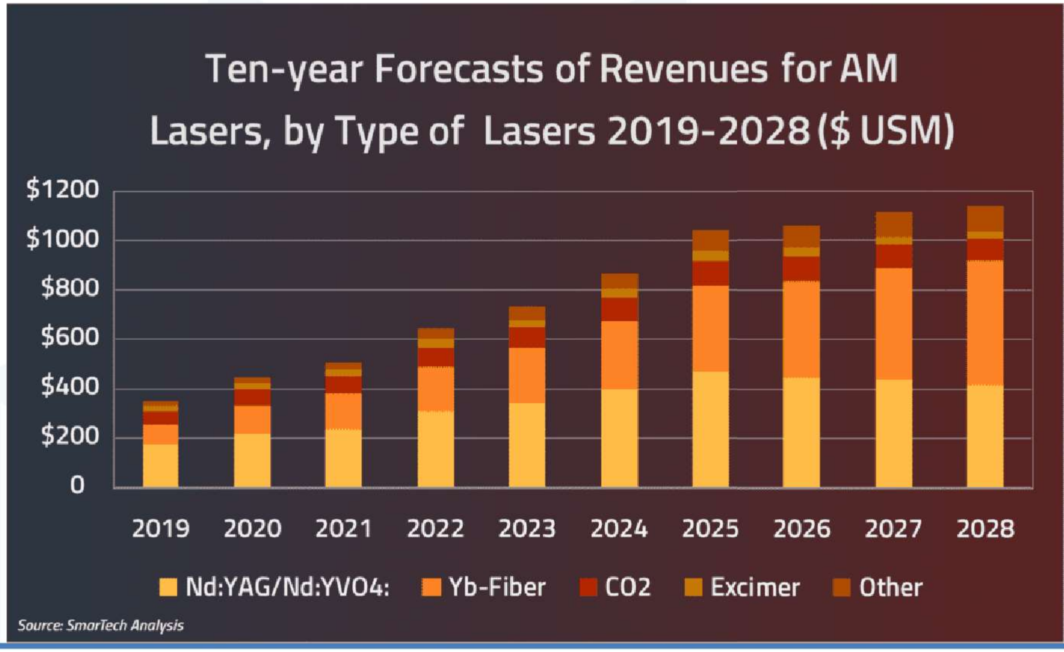


"Photonic technology is the bedrock of additive manufacturing"
Laser Focus World, Sep. 21 2021

Photonics and Laser AM Market size

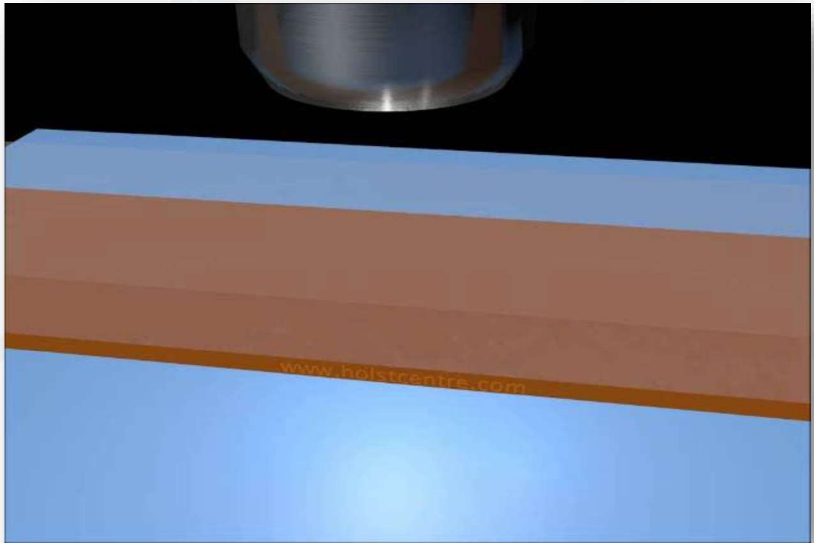


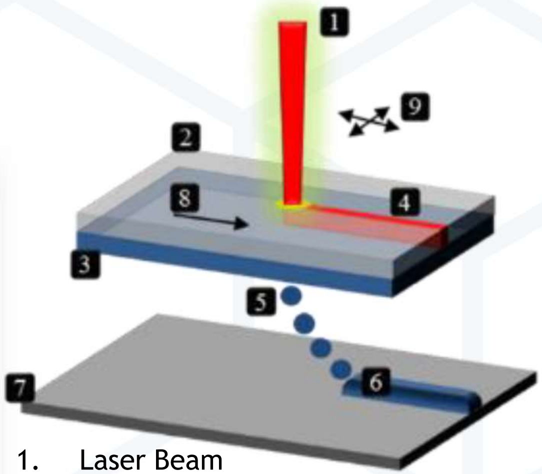
"Photonics technologies are opening up new manufacturing paradigms, such as 3D additive manufacturing, which will secure renewed growth in European manufacturing"
Photonics21 Multiannual Strategic Roadmap 2021–2027



Laser Induced Forward Transfer for the fabrication of metallic micro patterns as components in flexible electronics

LIFT





1. Laser Beam
2. Transparent donor foil
3. Coating of functional ink or paste
4. Path traced by laser beam or donor foil
5. Ejected droplets
6. Printed track
7. Receiver substrate
8. Direction of donor web movement
9. Laser beam scanning

Laser Direct Transfer

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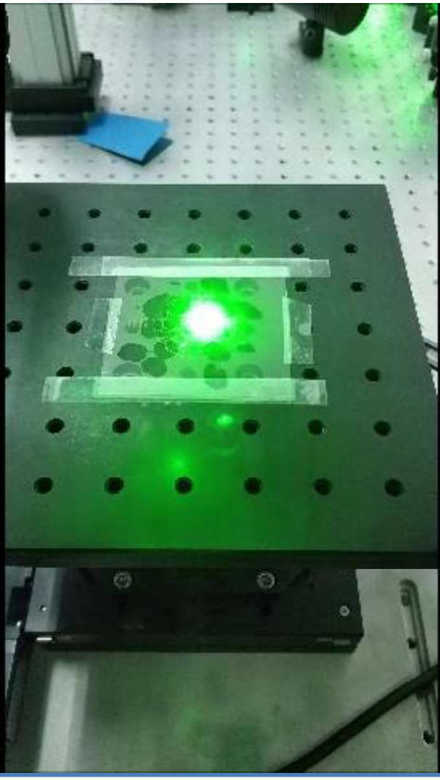
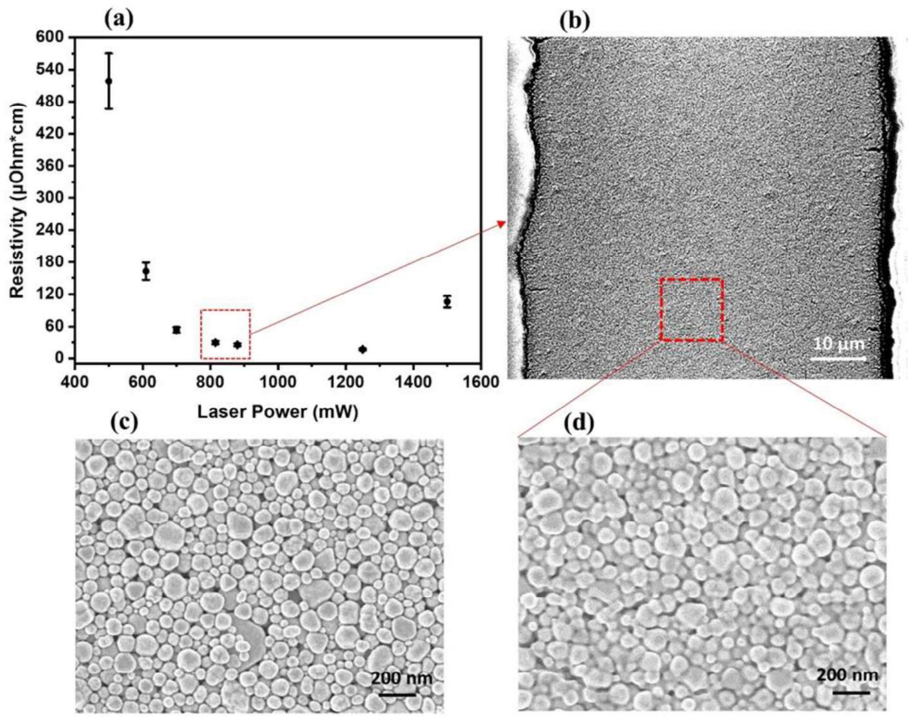
Courtesy of Dr. Gari Arutinov

TNO innovation for life

Selective Laser microSintering: transforming nanoparticle deposits to solid metal tracks



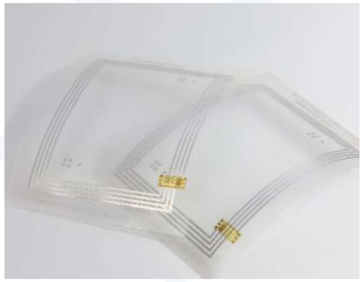


Non-sintered

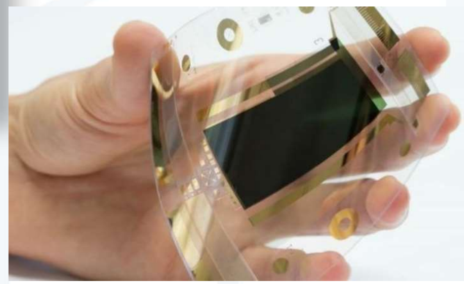
850 mW laser sintered line

Example I: HIgh PERformance Laser-Additive Manufacturing for Industrial electronic applications

Application 1: Laser printed RFID antenna



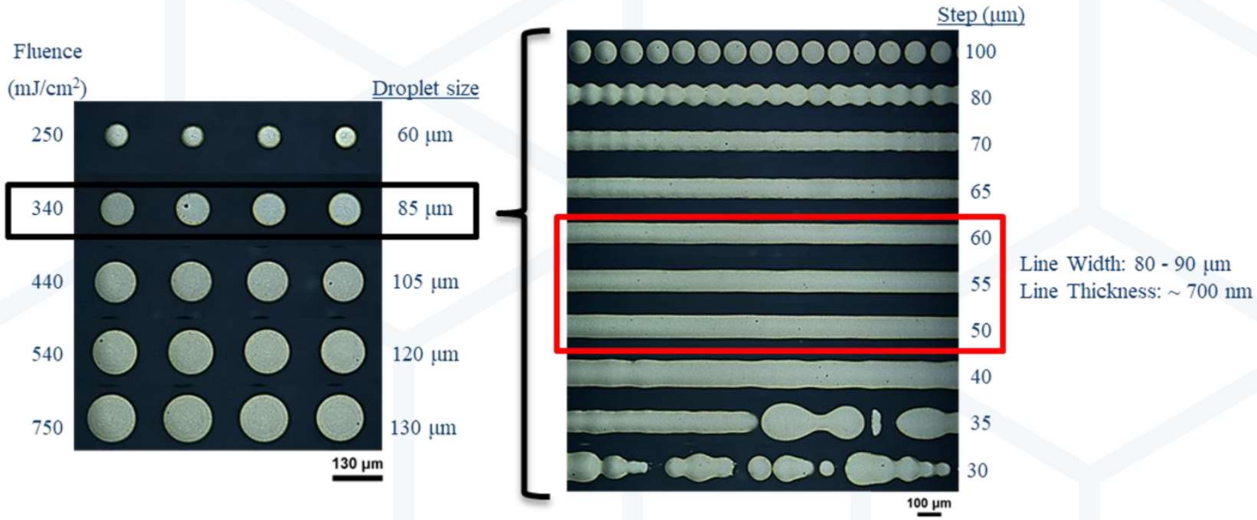
Application 2: Laser printed Fingerprint sensors



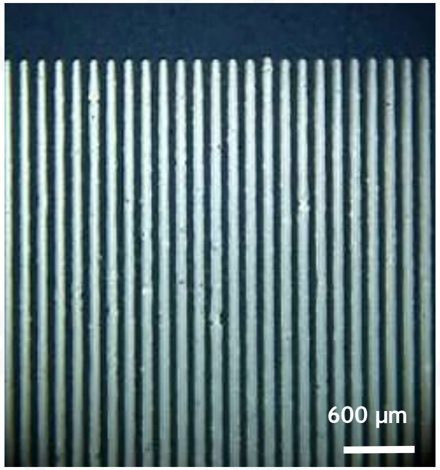
H2020-FOF-13-2017-2019

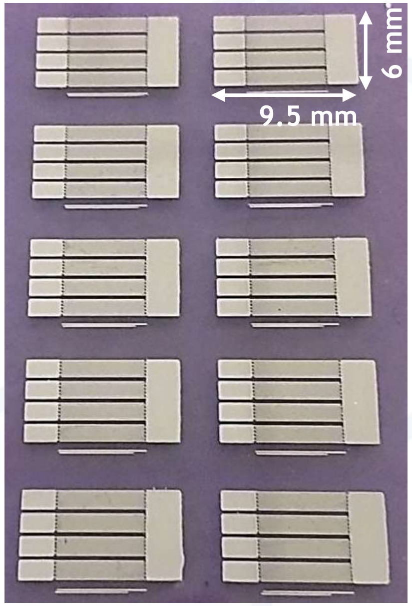
Use case Ia. Laser printed and sintered linear patterns for fingerprint sensors

Laser printing process development



Resulting conductive patterns (fingerprint sensors)



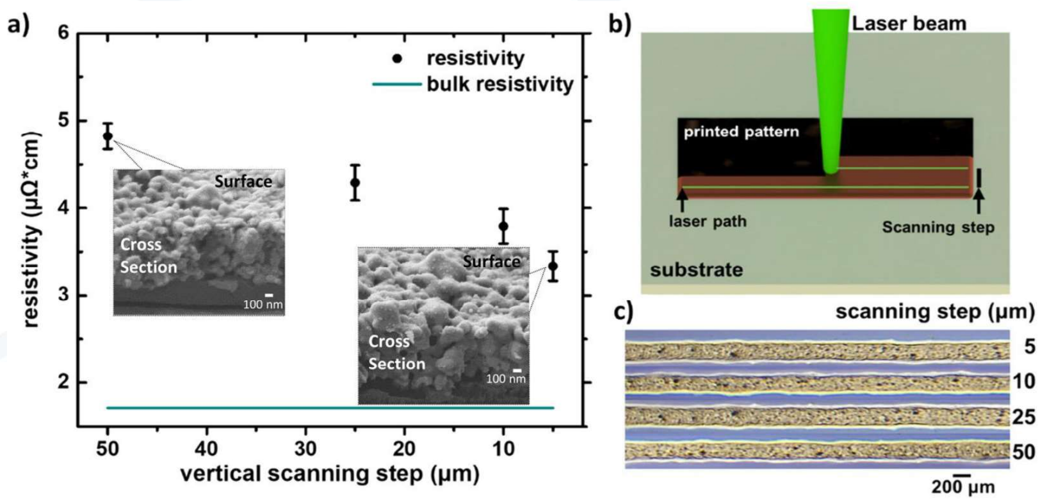


Lines' width ~ 90 µm
Lines' gap ~ 60 µm

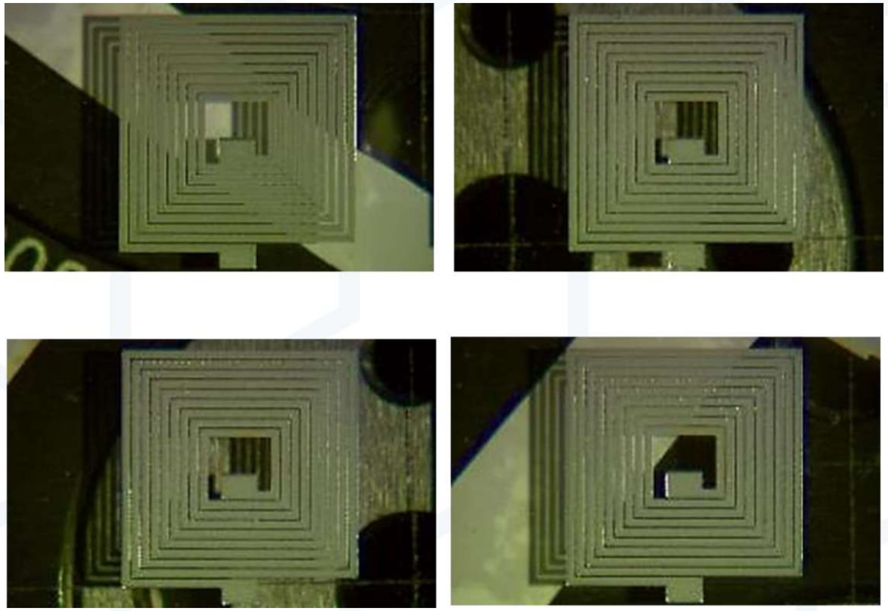
High speed laser printing and sintering of flexible RFID antennas and fingerprint sensors, I. Theodorakos et al., Proc. SPIE 11267, Laser Applications in Microelectronic and Optoelectronic Manufacturing (LAMOM) XXV, 1126709 (11 March 2020)

Use case Ib. Laser printed, low-cost, flexible RFID antennas made of Cu nanoparticles

SLS of Cu nanoparticle inks

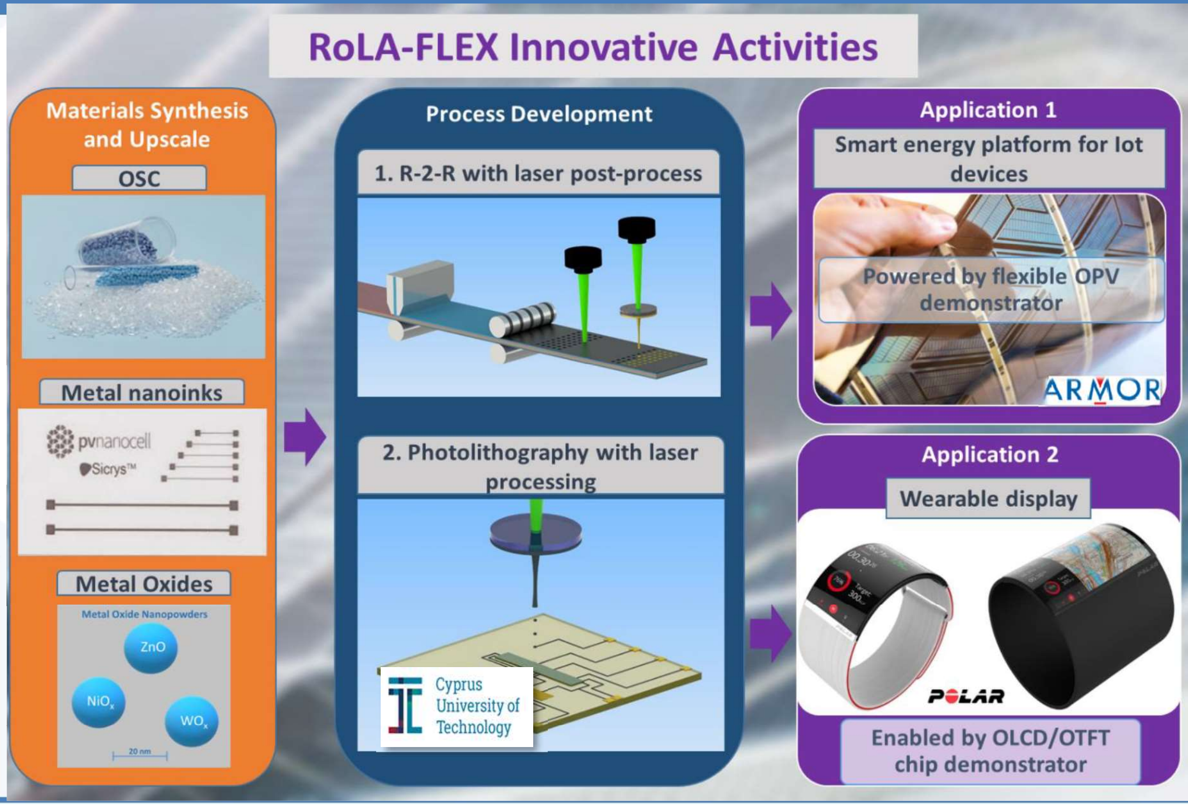


Resulting conductive patterns (RFIDs)



"Copper micro-electrode fabrication using laser printing and laser sintering processes for on-chip antennas on flexible integrated circuits", O. Koritsoglou et al. , Opt. Mater. Express 9, 3046-3058, (2019),

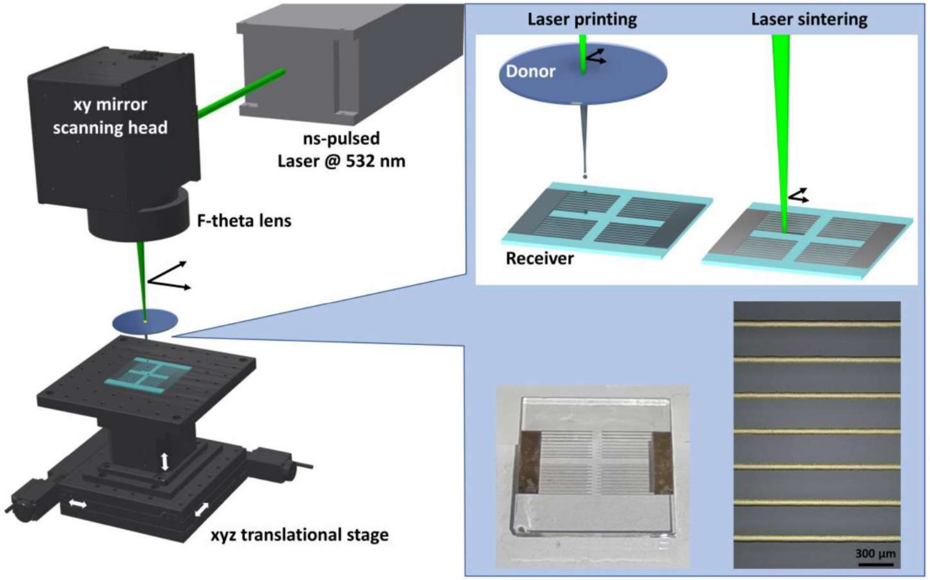
Example II: Roll-2-Roll and Photolithography post-processed with LAser digital technology for FLEXible photovoltaics and wearable displays



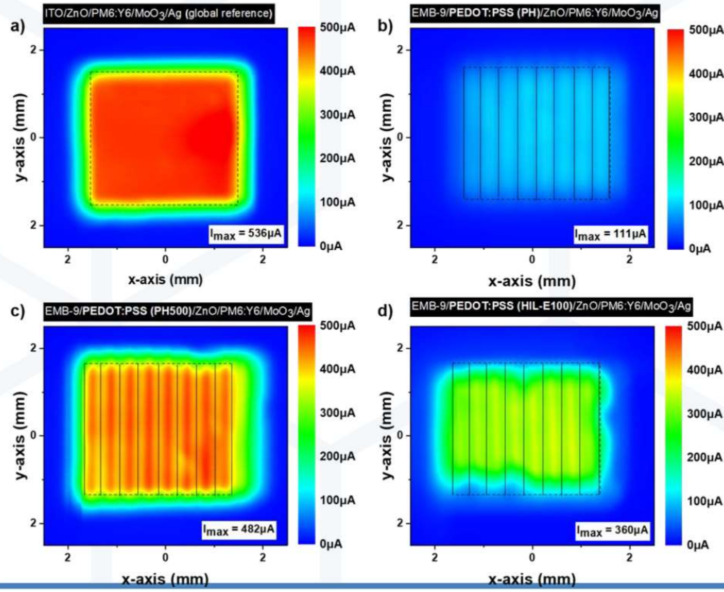
01/05/2020-30/10/2023
Topic: H2020-DT-NMBP-18-2019 (IA)

Use case IIa. Flexible, ITO-free OPVs

Laser printing and laser sintering of metal grids as transparent and conductive electrodes of OPVs



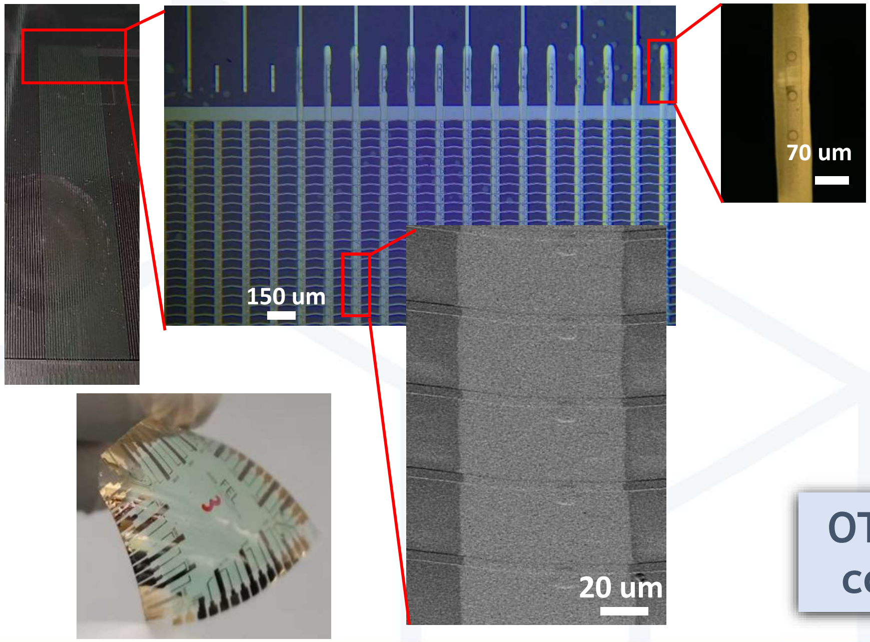
Photocurrent mapping of resulting inverted OPV devices



S. Pozov *et al*. "Highly Efficient Indium Tin Oxide-Free Inverted Organic Photovoltaics using Laser Induced Forward Transfer Silver Nanoparticle Embedded Metal Grids, accepted for publication, ACS Appl. Electron. Mater. 2022"

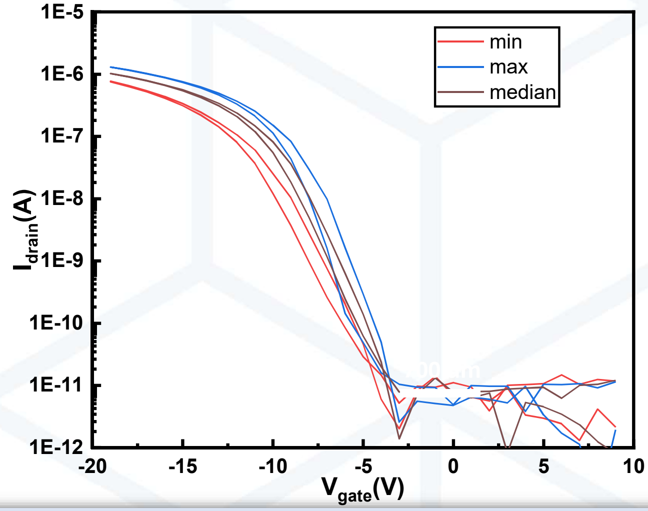
Use case IIb. Conformal laser printing & sintering for OTFT gate electrodes

Resulting gate electrode lines

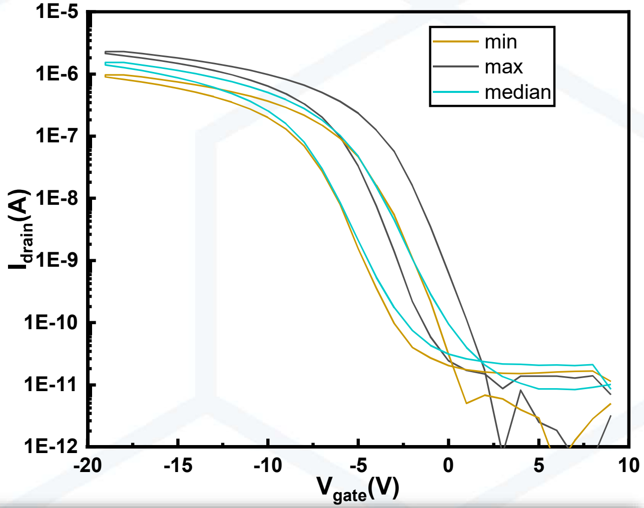


Performance evaluation comparison

Devices with LIFT printed gate



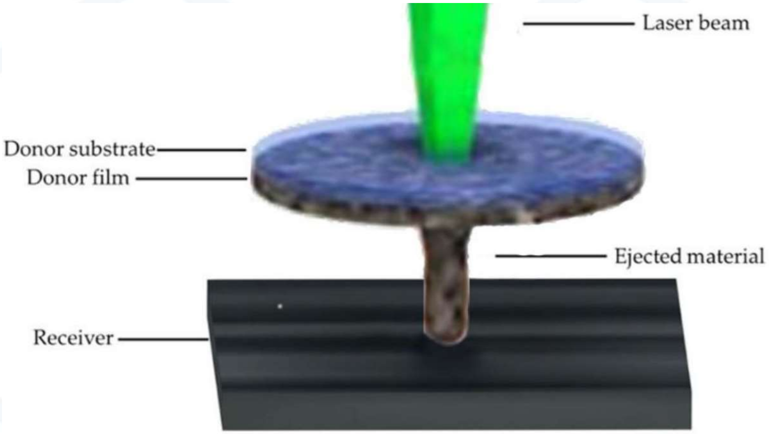
Devices with sputtering deposited gate



OTFTs with LIFT printed and laser-sintered gate electrodes exhibited comparable performance with respect to standard fabrication steps

SYN-LASER: Assembly and wire-bonding of electronic circuits using laser printing processes

SYN-LASER aims at the development of new processes for the assembly and the wire bonding of electronic circuits with digital laser printing and sintering technology, in order to integrate them into industrial processes of packaging and production of electronic circuits.



The project has been co-financed by the European Regional Development Fund of the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE with budget 857.679,30 € (project code:T1EDK-00814)

PLiN Nanotechnology S.A.

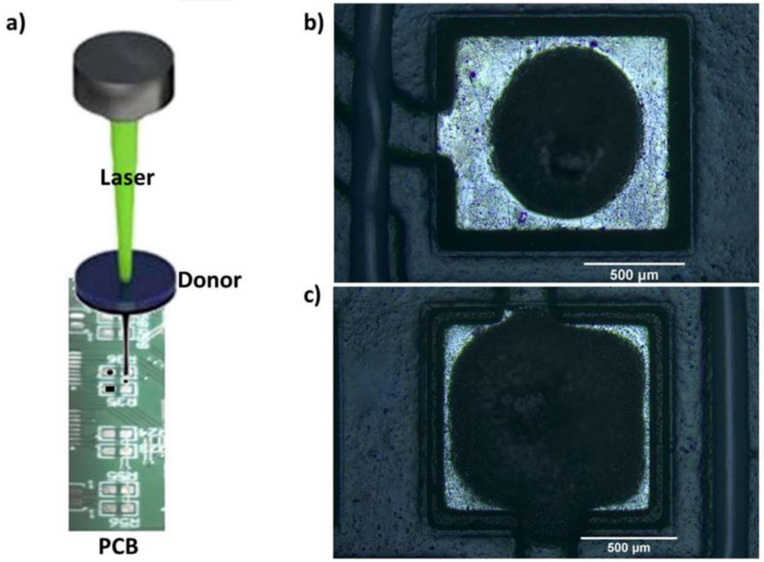
National Technical University of Athens

Prisma Electronics S.A.

Aristotle University of Thessaloniki

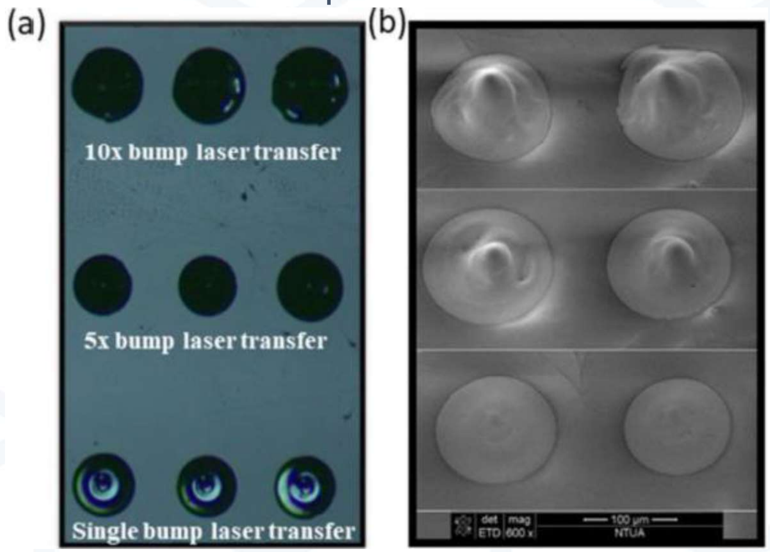
Use case III: – assembly of microelectronic components using laser printing of solder paste

Printing and shaping of solder paste on PCB pads via LIFT



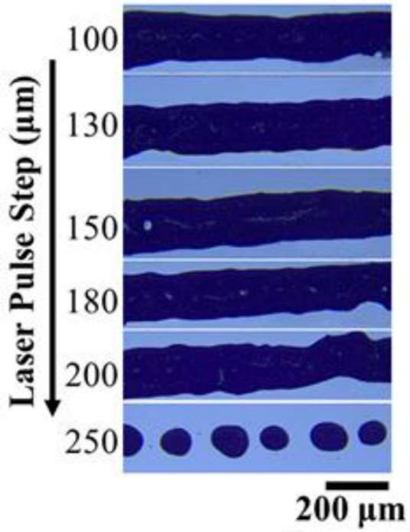
F. Zacharatos, M. Makrygianni and I. Zergioti, / IEEE Journal of Selected Topics in Quantum Electronics, vol. 27, no. 6, pp. 1-8, (2021)

Vertical stacking of Ag paste bumps via LIFT



Eco-Friendly Lead-Free Solder Paste Printing via Laser-Induced Forward Transfer for the Assembly of Ultra-Fine Pitch Electronic Components, M. Makrygianni *et. al*, Materials, 14, 3353, (2021)

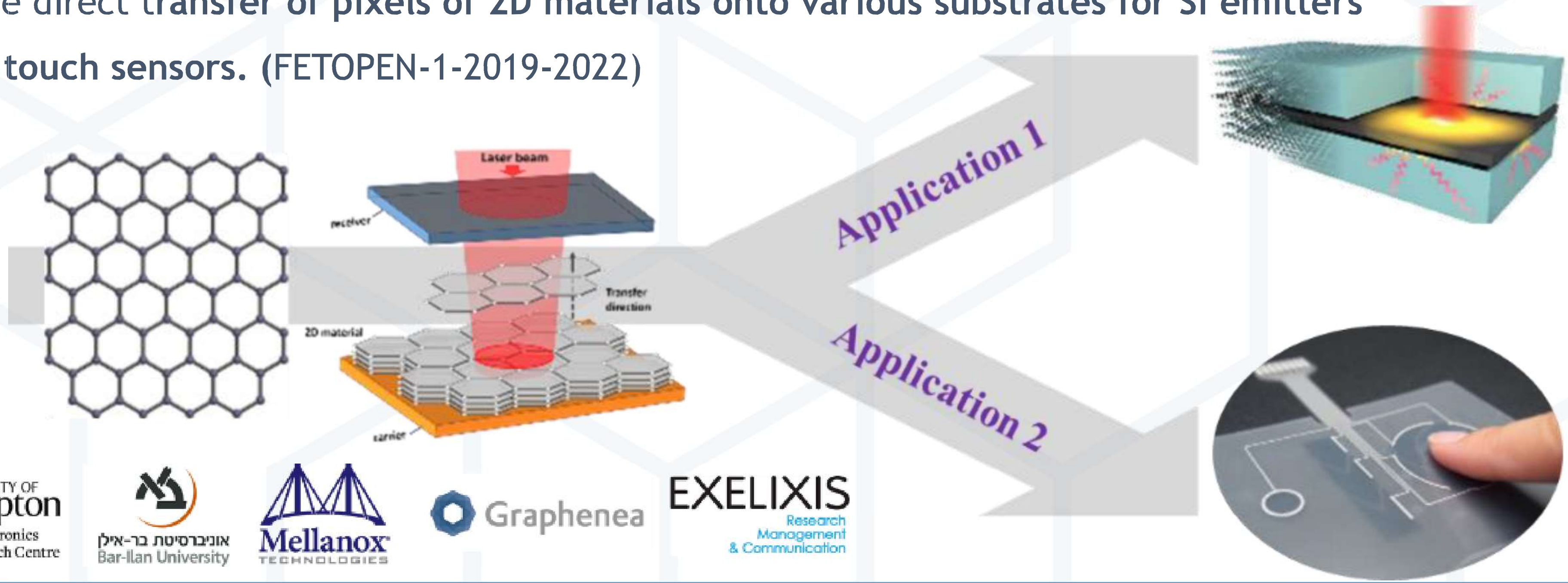
Linear patterns of solder paste via LIFT



M. Makrygianni, E. Margariti, K. Andritsos, D. Reppas, F. Zacharatos *et al.* / JLMN, vol. 15, no. 3 (2020)

Example IV: Laser EnAbled TransFer of 2D Materials: "LEAF-2D"

Introduction of Laser Direct Transfer processes (LIFT, LIBT) as a novel nano-manufacturing platform for the direct t**ransfer of pixels of 2D materials onto various substrates for Si emitters and Graphene touch sensors.** (FETOPEN-1-2019-2022)



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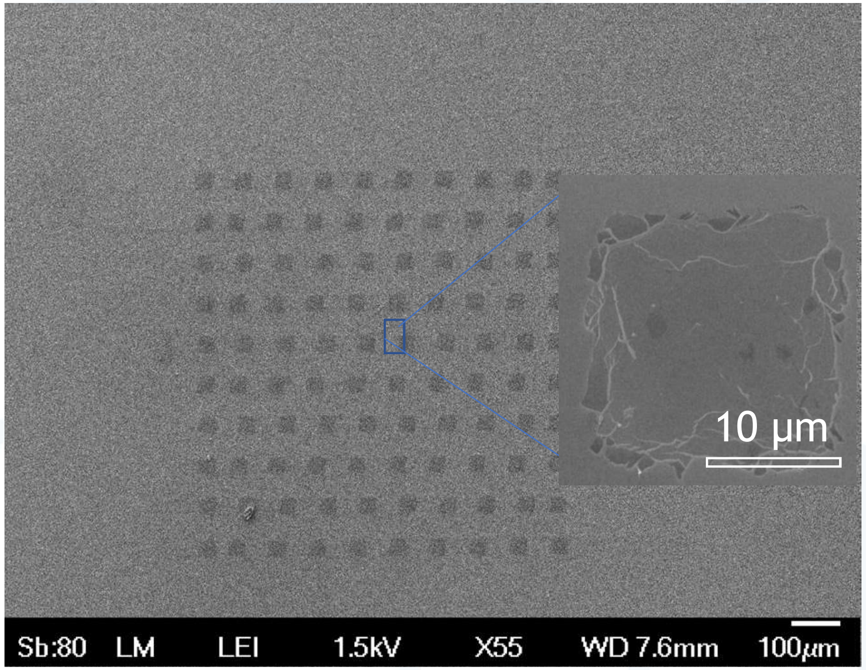
leaf 2D

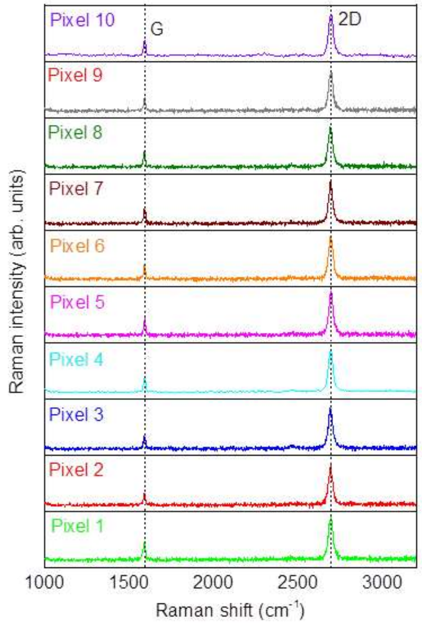
Use case IV: LIFT of single layer graphene pixels

Scanning Electron Microscopy

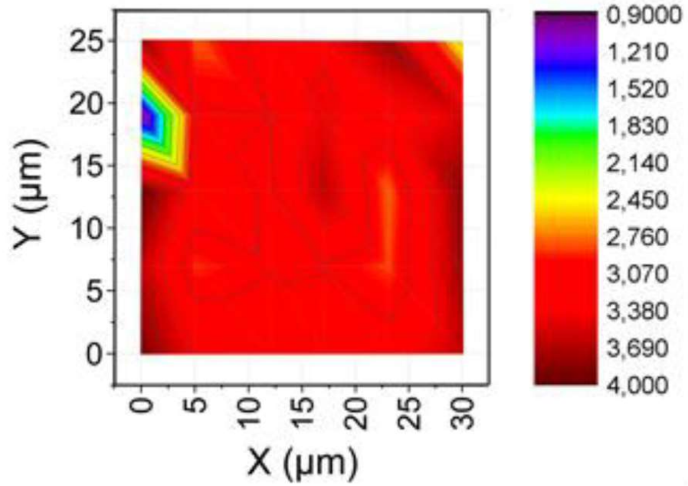


Receiver substrate: SiO_2/Si

Raman spectra of 10 graphene pixels



Raman color mapping of I_{2D}/I_G ratio



I_{2D}/I_G: 3.24±0.57

A direct transfer solution for digital laser printing of CVD graphene", S. Papazoglou *et al.*, in 2D Materials, 8(4), 045017, (2021).

Upscaling example: LASER DIGITAL TRANSFER OF 2D MATERIALS ENABLED PHOTONICS: FROM THE LAB 2 THE FAB
“L2D2” - EIC Transition

IndTech 2022

National Technical University of Athens

Bar-Ilan University

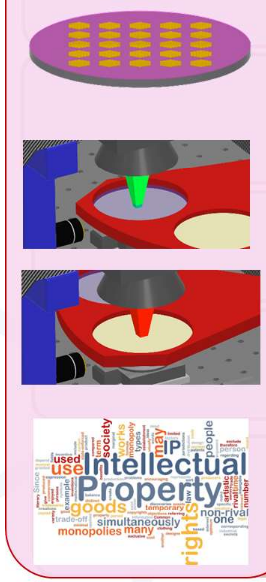
Mellanox Technologies

Graphenea

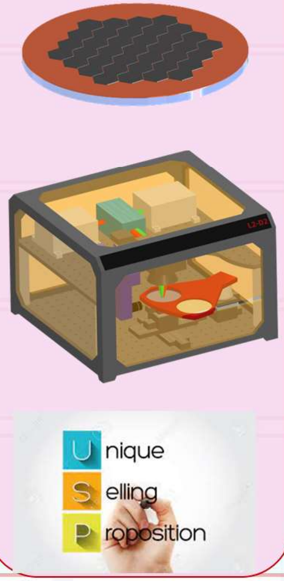
EXELIXIS Research Management & Communication

Within L2D2, we will upscale the laser transfer of intact and pristine Gr and 2D materials pixels in a single step-process, enabling wafer – scale integration and new applications in photonics

Development



Upscaling-Piloting



TRL6 Validation

Graphene and 2DM
High – quality single layer Graphene, $MoTe_2$, WS_2, grown on 8-inch wafers

LDT Process
Laser Digital Transfer upscaling in terms of throughput and yield for 8-inch wafers processing

LDT printing prototype
An automated printing system implementing the LDT process in pre-industrial setting

Chiplets with integrated emitters
On-chip Si emitters enabled by 2DM

Business case
Securing the IP of the LDT technology
Identify the unique selling proposition
Founding of a spinout

Horizon Europe-EIC-2021-Transition-OPEN-01

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Acknowledgments - People

Dimitra Mandala, MSc
Ilias Cheliotis, MSc
Evina Elezoglou, MSc
Kostas Andritsos, PhD
Mado Logotheti, PhD
Maria Chliara, PhD
Christos Katopodis, PhD
Christina Kryou, PhD
Spyros Kanakakis, Engineer
Dr. Ioannis Theodorakos
Dr. Simos Papazoglou,
Dr. Marina Makrygianni
Dr. Filimon Zacharatos
Dr. Marianneza Chatzipetrou
Dr. Chrysa Chandrinou

Prof. D. Tsoukalas
Prod. Y. Raptis
Prof. A. Hatziapostolou

H2020 - FETOPEN-1-2019-2022
Laser-Enabled trAnsFer of 2D materials - "LEAF-2D"

H2020-DT-NMBP-18-2019
Roll-2-Roll and Photolithography post-processed with LAser digital technology for FLEXible photovoltaics and wearable displays- "RoLA-FLEX"

H2020-FOF-13-2017-2019
High Performance Laser-based Additive Manufacturing "HiperLAM"

Thank you!

Questions?