Joint Research Activities (JRA)

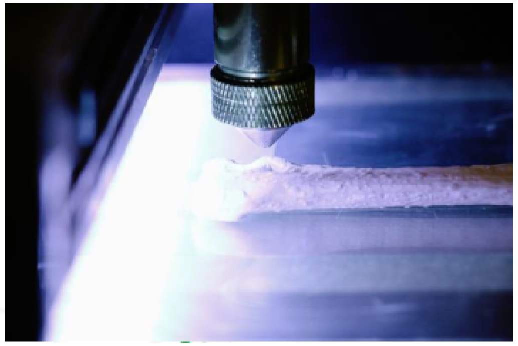
Overview of first activities

Barbara Stadlober, JOANNEUM RESEARCH

Objectives of Joint Research Activities

Transnational activities shall be supported by three cutting edge JRA programmes performed within the consortium to develop new enabling methods and advanced services to be **transferred to the portfolio of the TAs** by the end of the project

- JRA1 – Research on hybrid printing setups with quantitative in-line measurement methods for high precision fabrication of bio-nano systems
- JRA2 – Research on high throughput novel inks/pastes synthesis
- JRA3 – Research on Functional 3D printing for multifunctional smart objects with interactive free-form surfaces



JRA 1

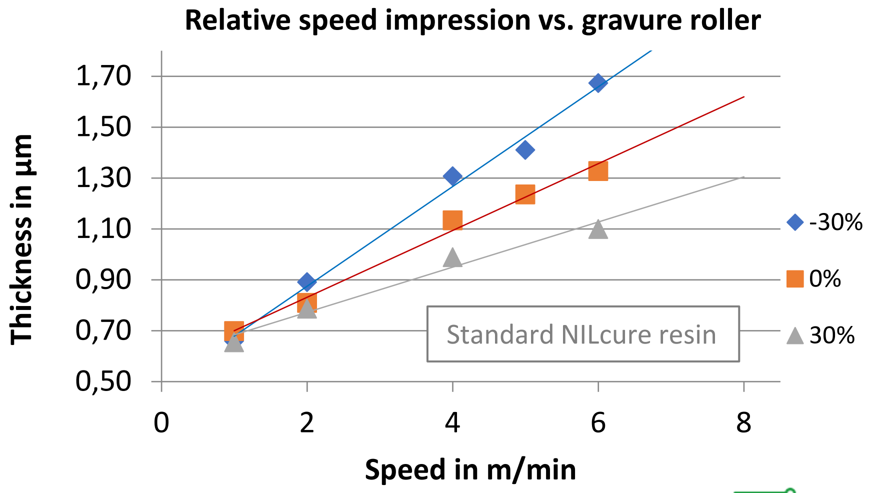
Research on hybrid printing setups with quantitative in-line measurement methods for high precision fabrication of bio-nano systems

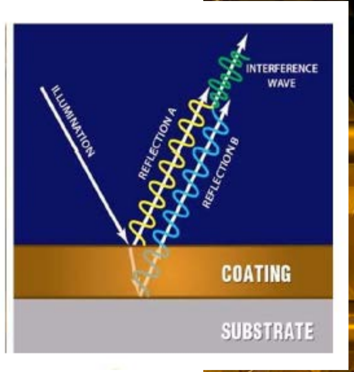
JOR, ICN2, MCL, TUD-IAPP, ALMA

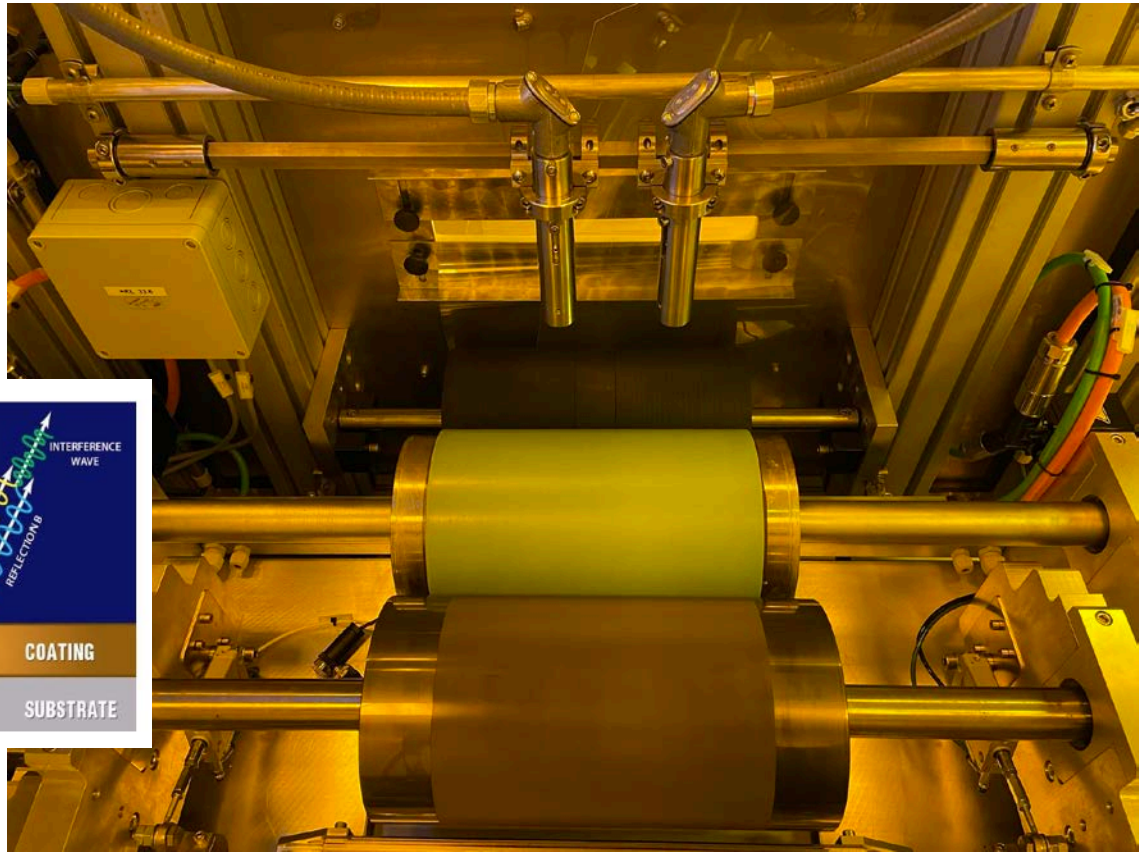
JRA 1-Task 1: In-line inspected hybrid R2R-nanoimprinting / screen / gravure printing pilot line for fabricating enhanced biosensing and bioelectronics components

JOANNEUM RESEARCH MATERIALS

- ✓ **In-line wet thickness measurement:** based on a white light interferometer
  - Thickness monitoring for homogenous coating process
  - Integration right after coating (slot die, gravure)
- ✓ **Specifications:**
  - 200 nm up to 200 µm wet thickness measurement with min. 5 % accuracy
  - Web speed up to 30 m/min
  - Two moveable sensors







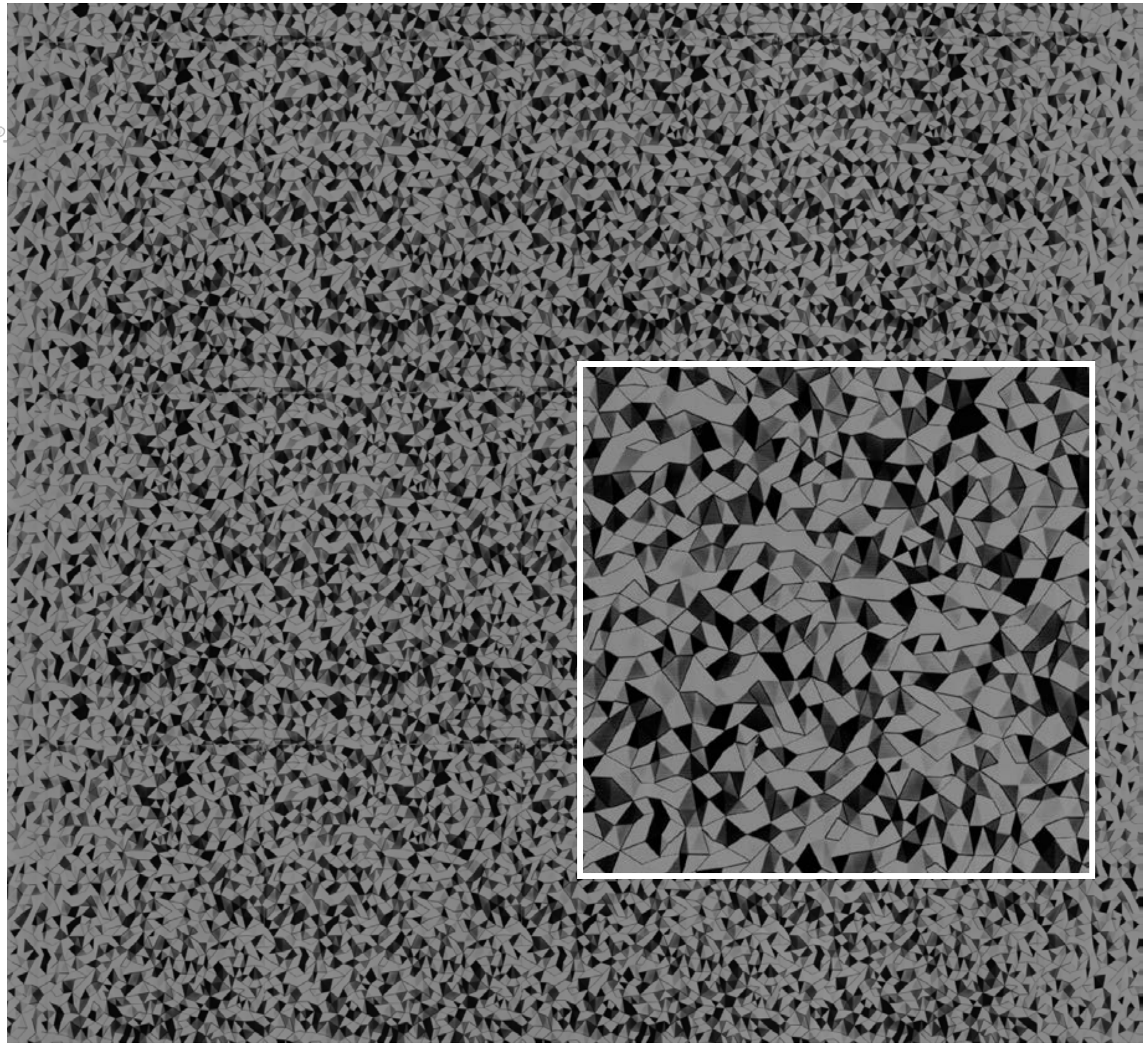
EMERGE
Emerging Printed Electronics Research Infrastructure

JRA 1-Task 1: In-line inspected hybrid R2R-nanoimprinting/screen/ gravure printing pilot line for fabricating enhanced biosensing and bioelectronics components

JOANNEUM RESEARCH MATERIALS

- ✓ **In-line optical inspection for an automatic defect characterization** (on the basis of a fast, high resolution line camera)
  - High resolution line camera for taking images during web movement
  - Evaluation via software to automatically detect predefined errors
- ✓ **Specifications:**
  - Resolution down to 1 µm at several m/min with a field/width of view of around 2 cm
  - High power LED illumination (due to the very fast exposure times)
  - Movement across the web to cover the whole width
  - 1 image per shim length (ca. 63 cm)

Teledyne e2V ELiiXa+



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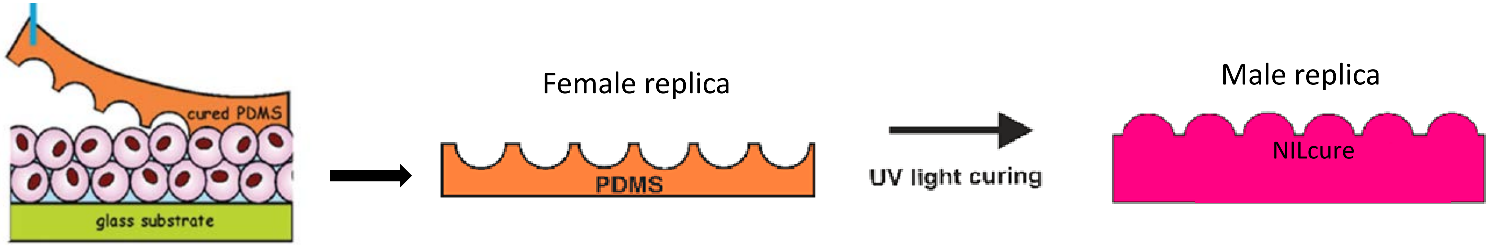
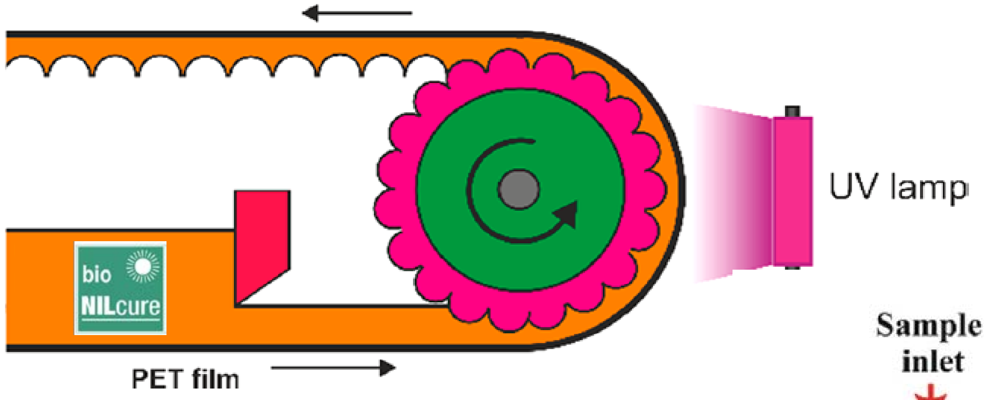
JRA 1-Task 1: In-line inspected hybrid R2R-nanoimprinting / screen / gravure printing pilot line for fabricating enhanced biosensing and bioelectronics components

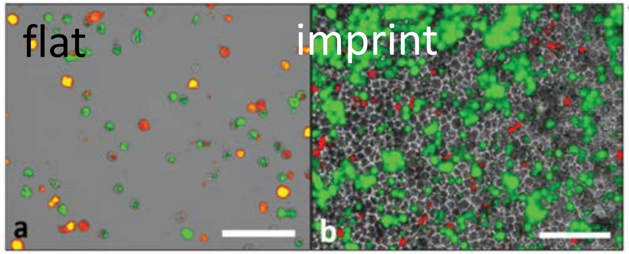
- Testing of the bioimprinting method for the **classification of red blood cells** to **detect** Anaemia. Recognition and classification of shape changes of the RBC as a diagnostic tool, optical detection or impedance change



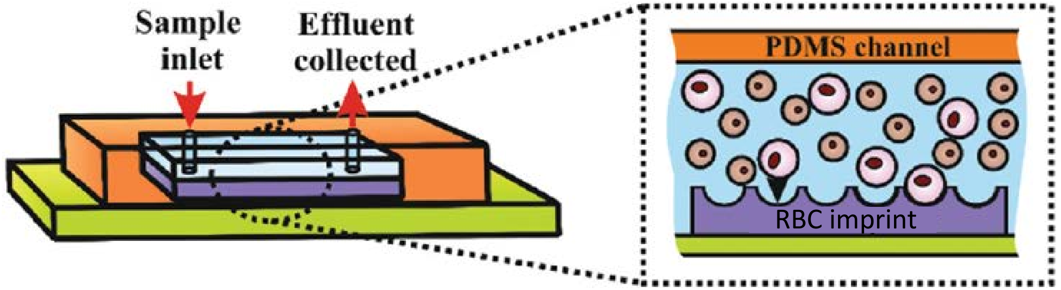
Imprint from blood cells or PS spheres



(Das et al., J. Mater. Chem. B 201)



Discrimination of HL60 (green) from PBMCs (red)



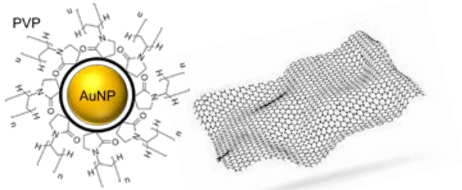
JRA 1-Task 2 : In-line stand-alone disposable, optionally wearable paper-based biosensor

ICN2 EXCELENCIA SEVERO OCHOA
Institut Català de Nanociència i Nanotecnologia

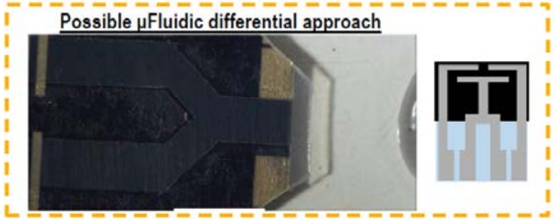
- **Electrochemical aptamer-based (EAB) sensors for detection of COVID-19 proteins fabricated by inkjet printing**

Consumer inkjet printers

+

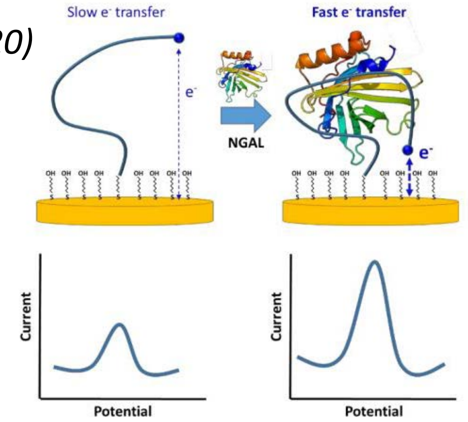


Nanomaterials for enhanced biosensing



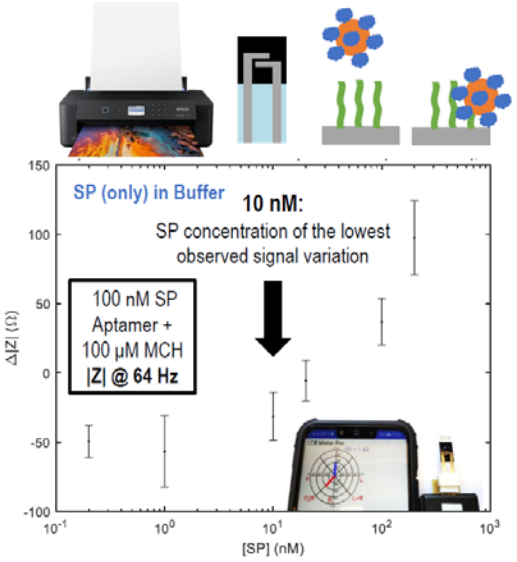
passive microfluidic sampling with 2 channels for differential measurements

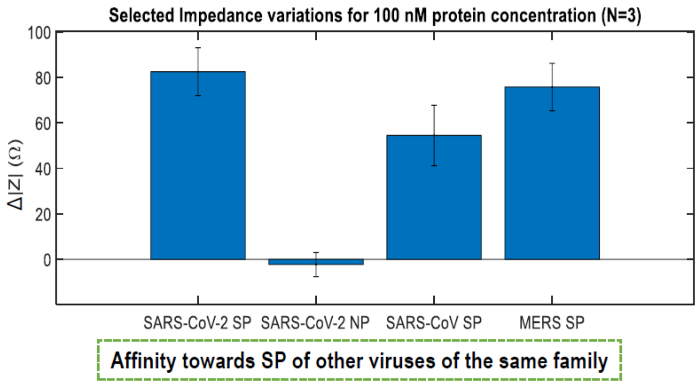
EAB principle
(Parolo, ACS Sensors 2020)



1. EAB with Ag NPs

Thiolated Aptamer-based, impedance read-out via interdigitated Ag electrodes, MCH immobilization, tested in buffers with artificial saliva

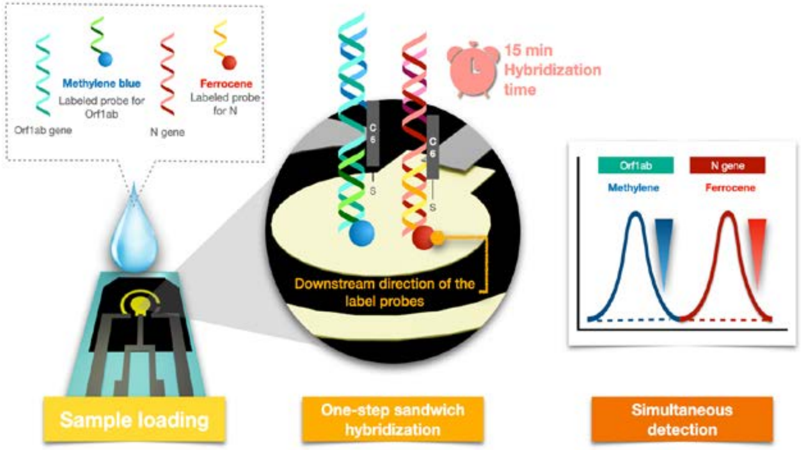




2. EAB with Au electrodes

chemically sintered Au electrode, square-wave voltametric read-out, detection of spike protein and two other RNA sequences (N- gene, Orf1ab) of SARS-COV 2 by methylene- and ferrocene- labelled aptamer probes.

(Idili, ACS Sensors 2021)



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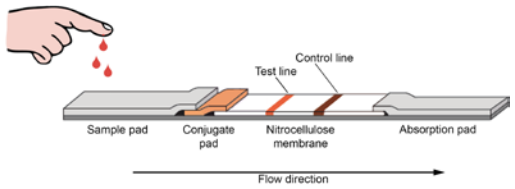
JRA 1-Task 2 : In-line stand-alone disposable, optionally wearable paper-based biosensor

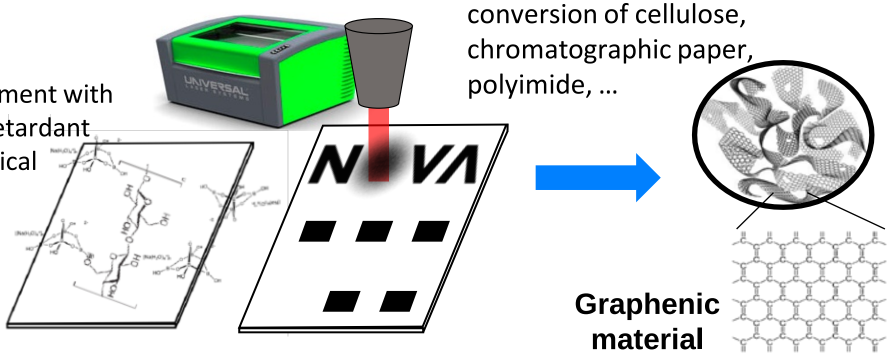


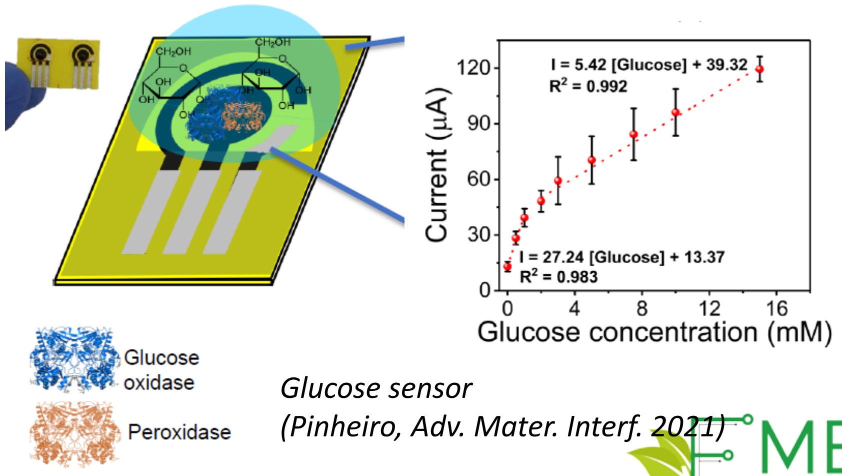
- **Lateral flow strip biosensors produced with laser ablation: Laser-induced graphene (LIG) fabrication**

✓ *UNINOVA master student starts at ICN2 in March.*

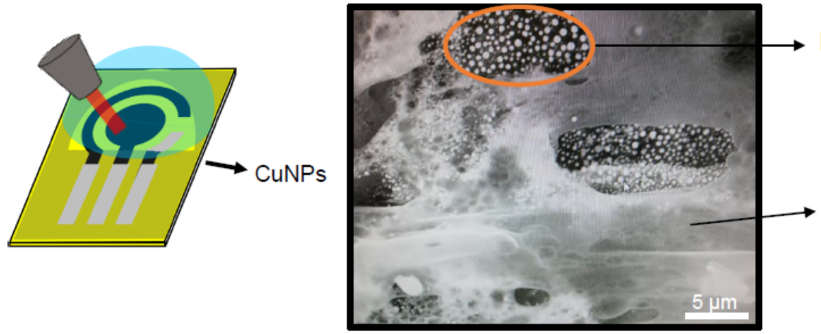
Treatment with fire retardant chemical

Photothermal,- chemical conversion of cellulose, chromatographic paper, polyimide, …

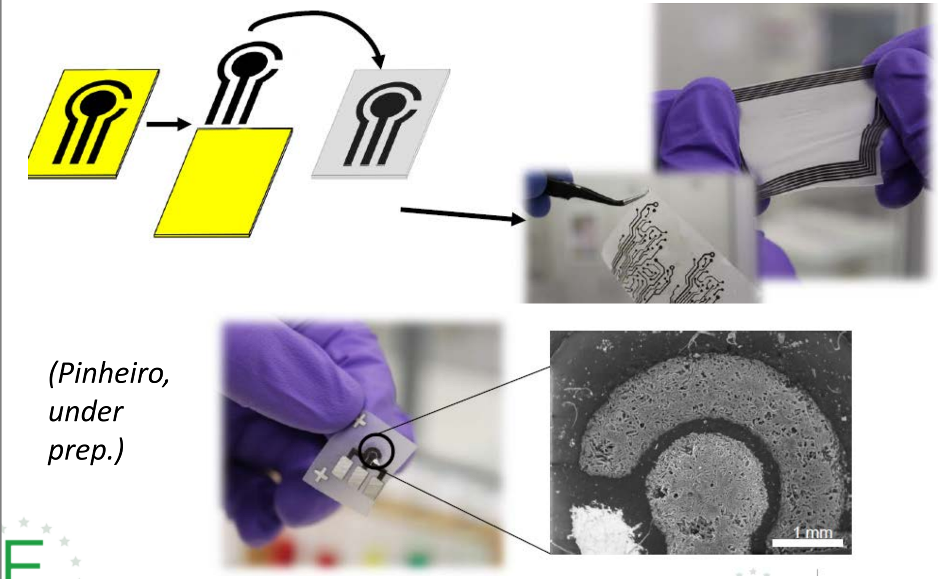




Glucose sensor (Pinheiro, Adv. Mater. Interf. 2021)

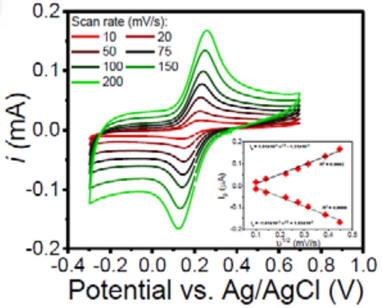


One-step synthesis of LIG-CuNP composites: catalytic activity towards glucose oxidase



Lift-off & transfer to skin-friendly substrates like TPU

(Pinheiro, under prep.)



JRA 2

Research on high throughput novel inks/pastes synthesis

WUT, UNOVA, HMU, FZJ-HPG, ICN2, MCL, TUD

EXCELENCIA SEVERO OCHOA

JRA 2-Task1 : High throughput Hansen Solubility Parameters determination

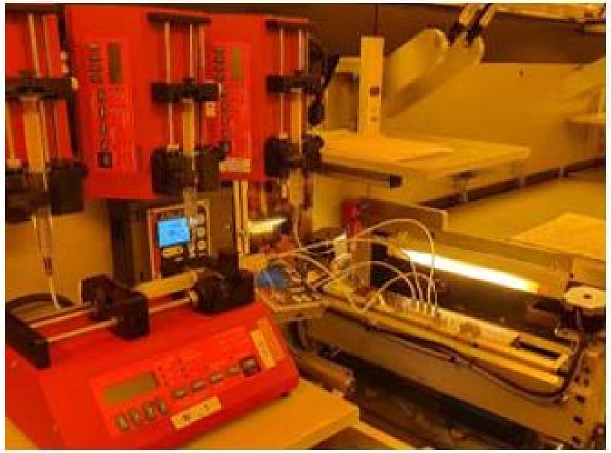
- High throughput measurement for the HSP with a minimum amount of material, with the goal of simplifying the ink development procedure and bringing new inks to the market, automatization is based on liquid handling robots

Printing material	Nature - Form	Concentration	Volume
Alumina ink	Solution: aluminum nitrate and urea dissolved in solvent	0.2 M	10 mL (more if needed)
Zinc oxide ink	Solution: zinc nitrate and urea dissolved in solvent	0.2 M	10 mL (more if needed)
Tin oxide ink	Solution: tin chloride and urea dissolved in solvent	0.2 M	10 mL (more if needed)
Zinc-tin-oxide ink	Solution: zinc nitrate, tin chloride and urea dissolved in solvent	0.2 M	10 mL (more if needed)
Graphene oxide ink (GO)	Suspension: water, ethylene glycol, N-methyl-2-pyrrolidone, dimethylformamide, γ-butyrolactone	0.02-2 mg/mL (depending on initial concentration and solvent)	Normally 10/ 20 mL
Reduced graphene oxide (RGO)	Suspension: dichlorobenzene, acetylacetone, N-methyl-2-pyrrolidone, dimethylformamide, γ-butyrolactone	~0.01-1 mg/mL (Depending on initial concentration and solvent)	Normally 10/ 20 mL
Potassium-treated graphene oxide (KGO1)	Suspension: water	≈1 mg/mL	Normally 10/ 20 mL
Potassium-treated graphene oxide (KGO2)	Suspension: water	≈1 mg/mL	Normally 10/ 20 mL
Potassium-treated graphene oxide (KGO3)	Suspension: water	≈1 mg/mL	Normally 10/ 20 mL

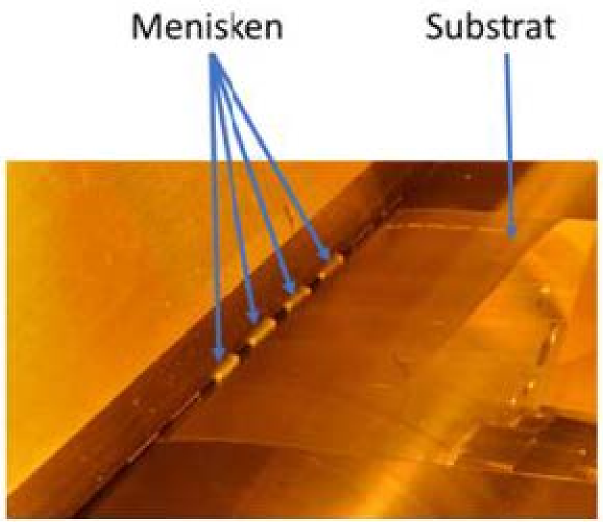
JRA 2 –Task 2 : Development of a multi-nozzle slot-die coating head for advanced ink formulation

- Improvement of solar cell printing process by implementing new materials and developed a multi-nozzle slot die coating head. The developed multi-nozzle head consists of separate, individually pumped channels.

30 cm wide slot-die head in stainless steel with 13 individual inlets and 13 individual channels.



4 syringes connected to four inlets for printing of SnO_2 NP ink in butanol with diff. concentrations as ETL on flex cond. substrate



Calc. Dry Film Thickness [nm]	V_{oc} (V)	FF (%)	PCE (%)
1.4	0.38	42	1.2
6.3	0.62	51	3.2
12.6	0.70	58	3.4
22	0.70	62	3.9

Performance of OPVs (P3HT:o-IDTBR 1:1, PEDOT:PSS, Ag NW) fabricated from the ETL stripes

JRA 3

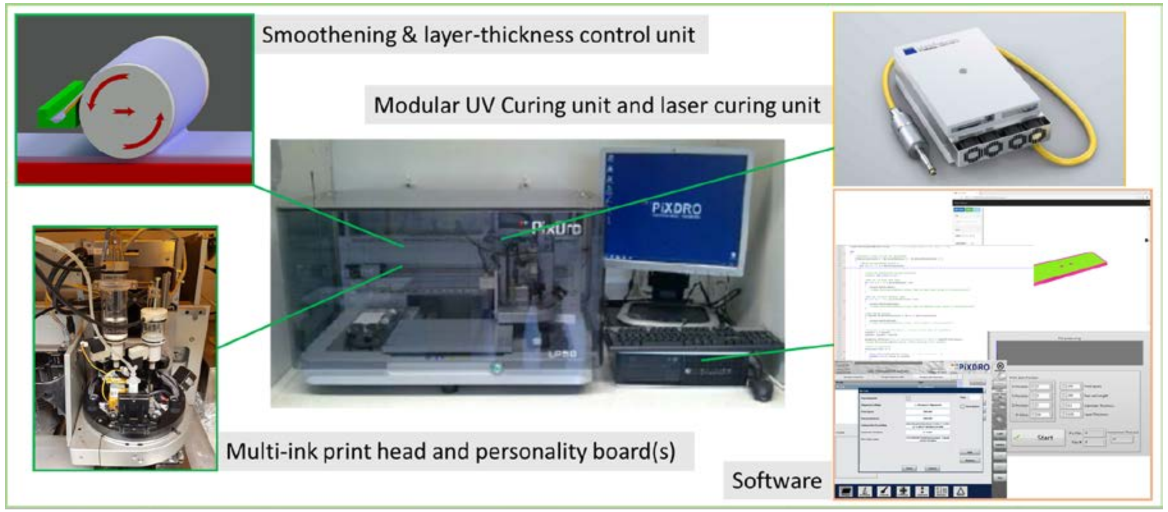
Research on functional 3D printing for multifunctional smart objects with interactive free-form surfaces

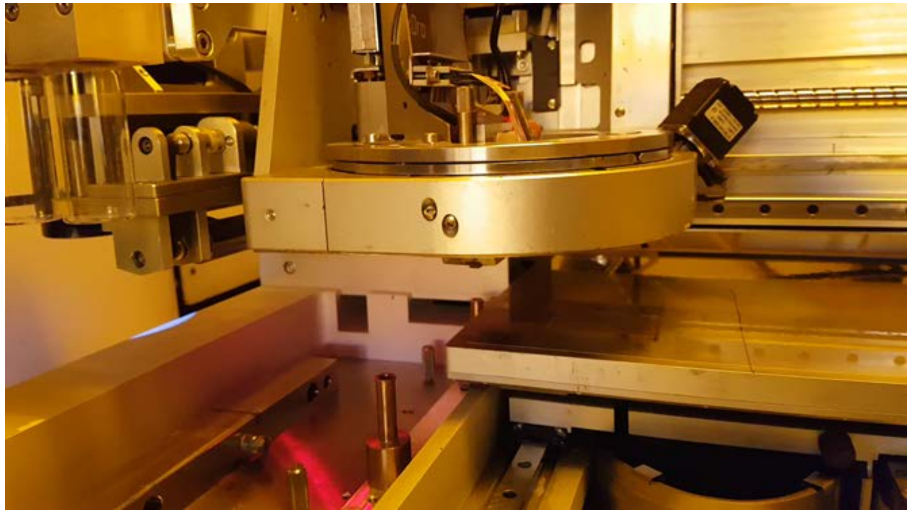
JR, WUT, FZJ-HPG, ICN2

JRA3 - Task 1: Design and fabricate a smart functional 3D printed object with embedded functionalities

JOANNEUM RESEARCH MATERIALS
Politechnika Warszawska
JÜLICH FORSCHUNGSZENTRUM

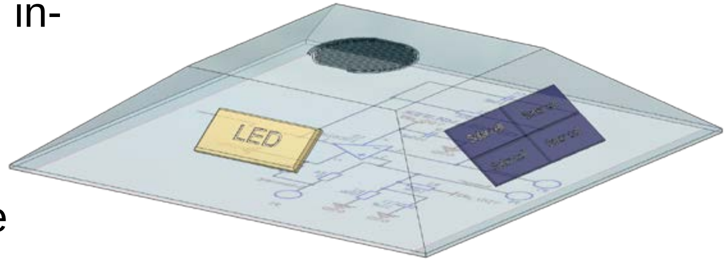
Upgrade of the PIXDRO LP50 inkjet printing platform to allow for heterogeneous (= multimaterial) 3D printing of smart objects

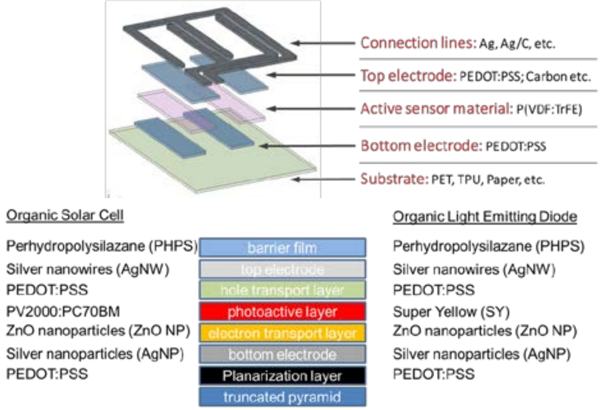




Integrate piezoelectric and conductive layers on the 3D printed smart object to generate a touch sensitive surface

- Printing an embedded circuit into the volume of an in-situ 3D-printed truncated pyramid (JOR);
- Print the LED or solar cell on the sidewall of the truncated pyramid (FZJ);
- Print the PyzoFlex® based pressure sensor on the upper base of the truncated pyramid (WUT).



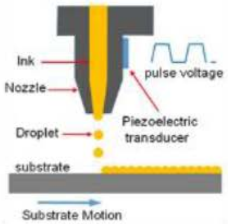


JR3 - Task 2: Combined ink-jet and aerosol jet printing unit for high resolution 2D and 3D printing

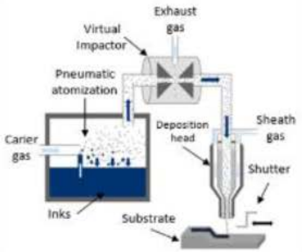
Development of a combined inkjet & aerosol jet unit for direct –to-shape 3D printing

Inkjet-printed organic solar cells on surfaces with different inclinations

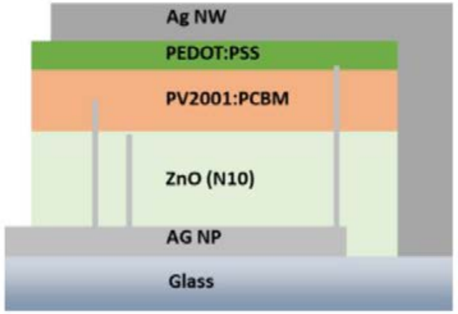
5-Axes-CNC system

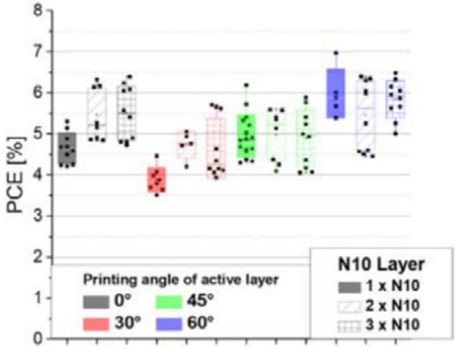


Ink Jet



Aerosol Jet

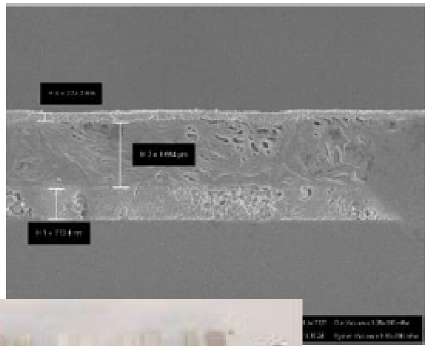


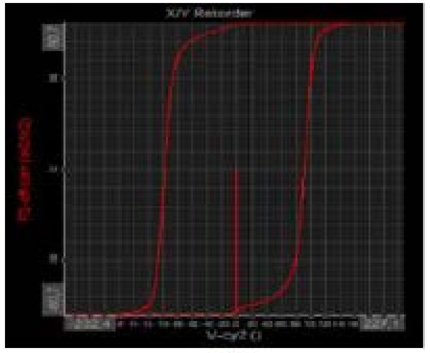


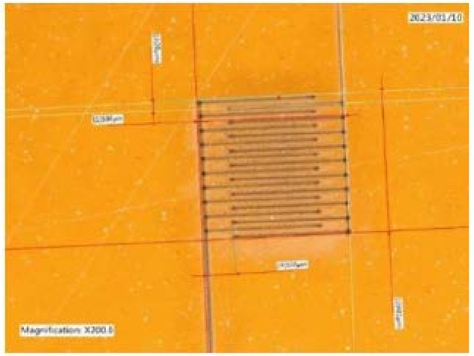
Development of piezoelectric inks for the Inkjet/aerosol jet printing unit and integration with conductive layers to define a touch-sensitive curved surface

1st P(VDF-TrFE) inkjet ink

- Spontaneous NP formation in special aromatic solvent
- Nanoparticle-dispersed ink with high loading: 50 g/L
- Scalable to 4L per batch
- IJP at 6 kHz
- 1 Layer → 1.3 µm
- Many carrier liquids







Implementing P(VDF-TrFE) polymer ink from JOR to the aerosol jet printing system → Polymer based ink in Isophorone (1:1), pneumatic atomizer used

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Politechnika Warszawska
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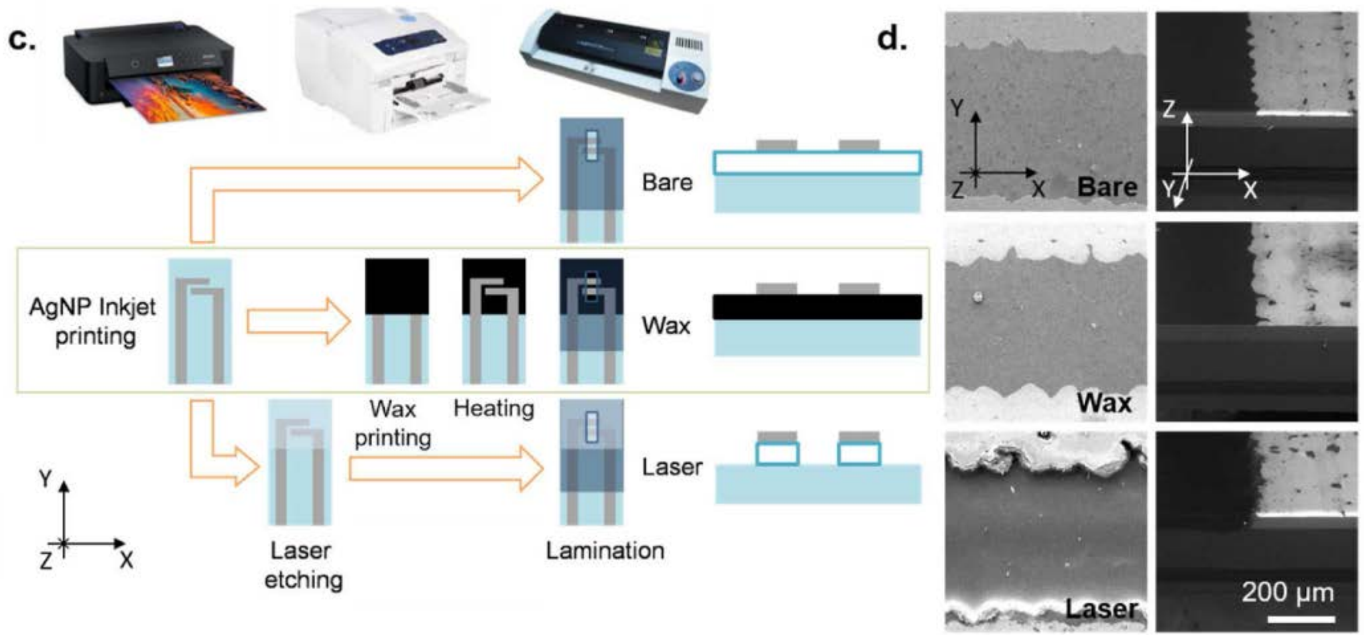
JR3 - Task 2 : Combined ink-jet and aerosol jet printing unit for high resolution 2D and 3D printing

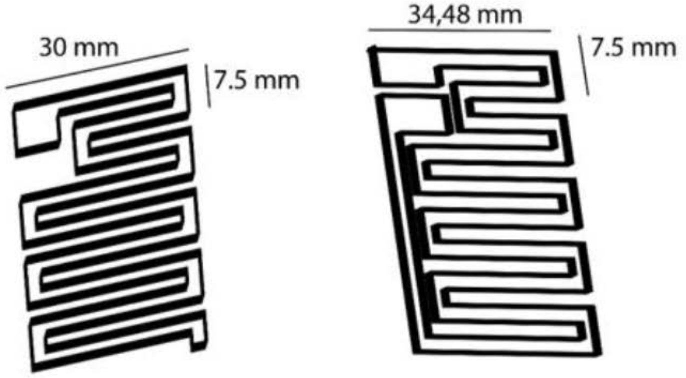
Application of 2D & 3D printing for biosensor sampling platforms (design & fabrication)

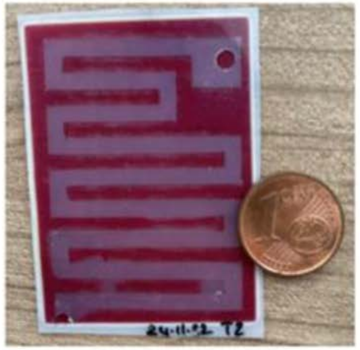
- Passivation of absorbing coatings to repel water penetration for electrochemical measurements on inkjet-printed electrodes.



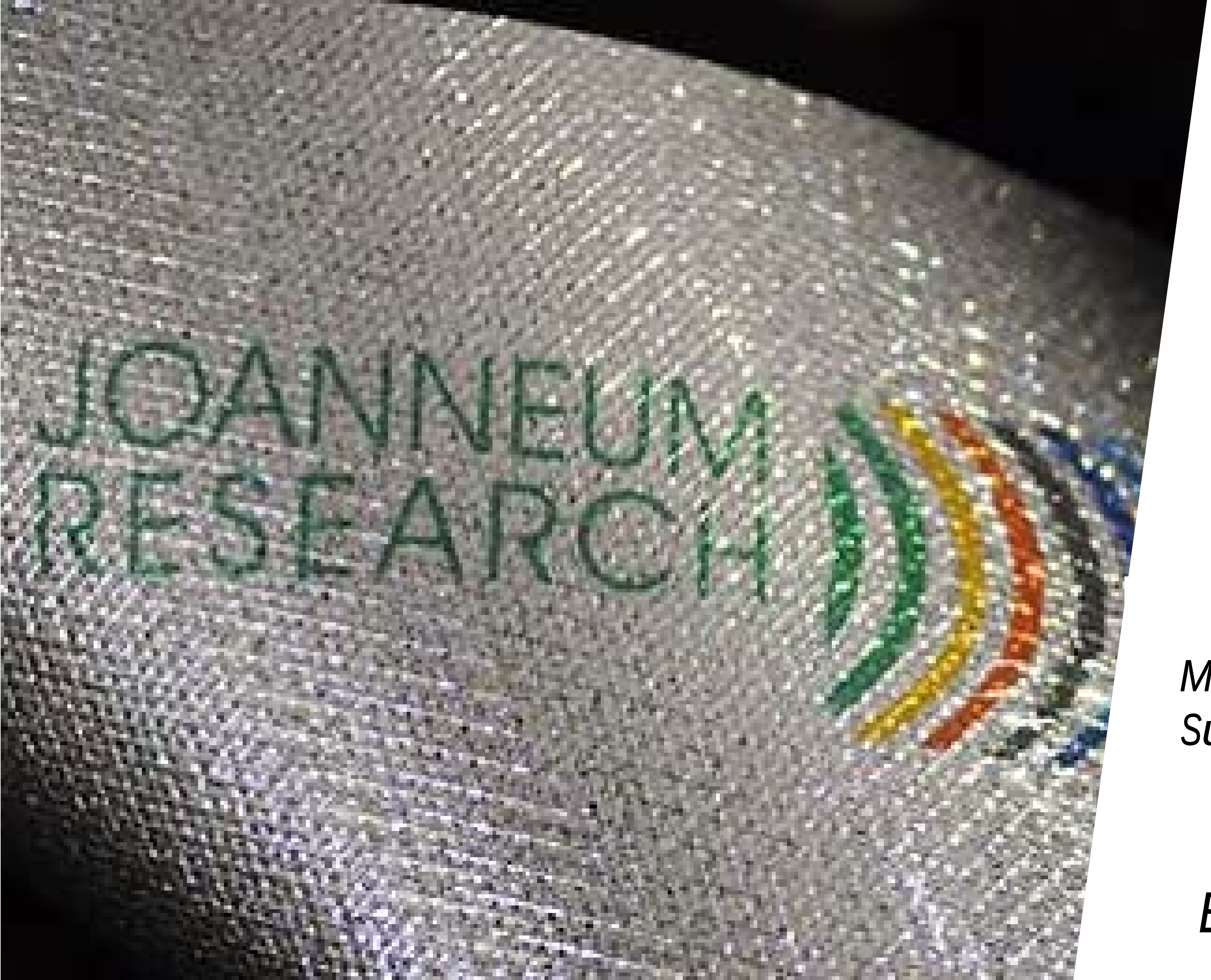
Sinter-free inkjet printing of silver electrodes with consumer printers on appropriate coated substrates. Fabrication of the bare electrodes without any passivation of the coating, with wax passivation (infiltration), and with laser ablation

- 2D/3D printed microfluidics





Biadhesive-tape based microfluidic channel structure

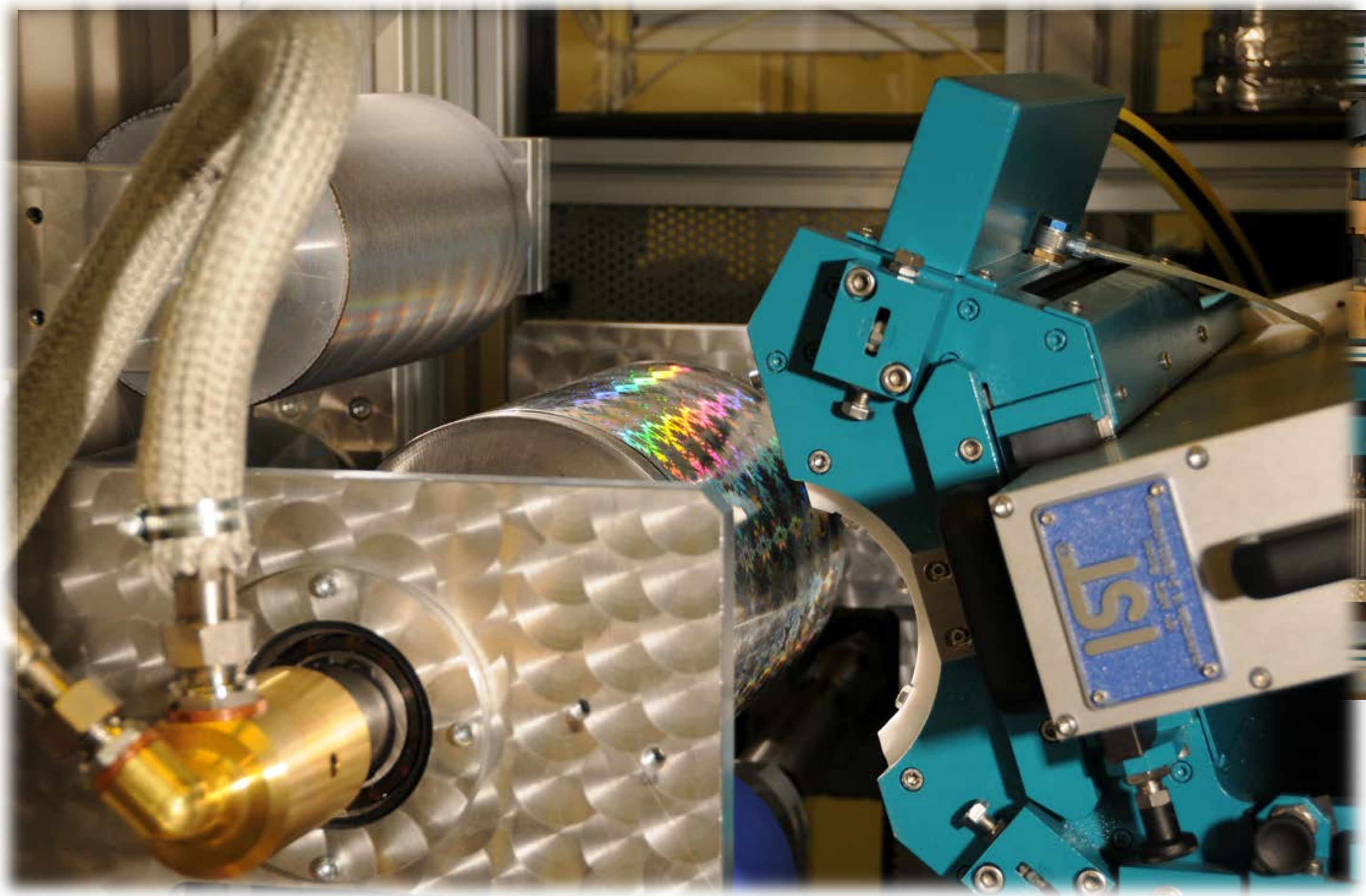


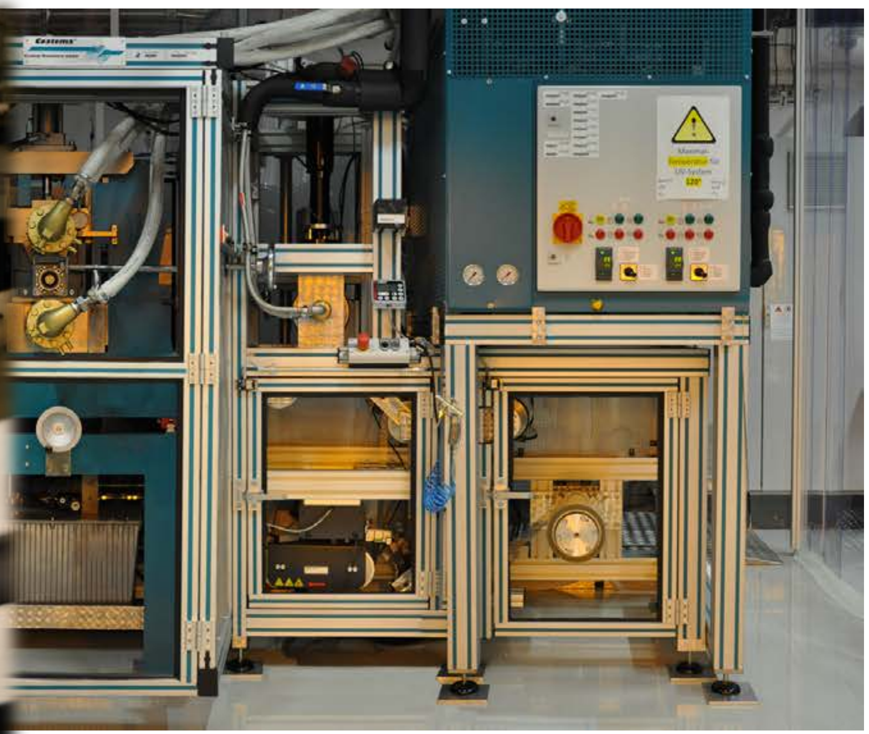
JOANNEUM RESEARCH MATERIALS

MATERIALS - Institute for Surface Technologies and Photonics

Barbara Stadlober

R2R-Nanoimprint Pilot Line @ JR

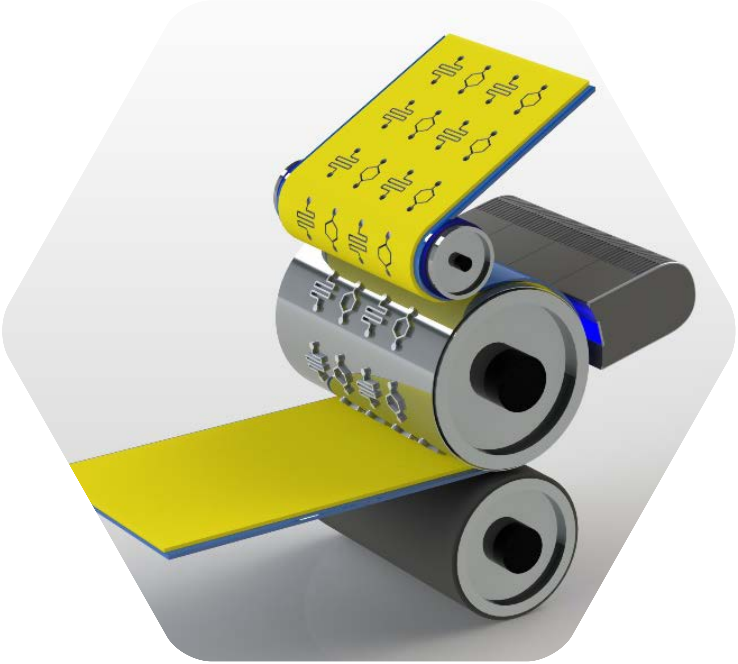




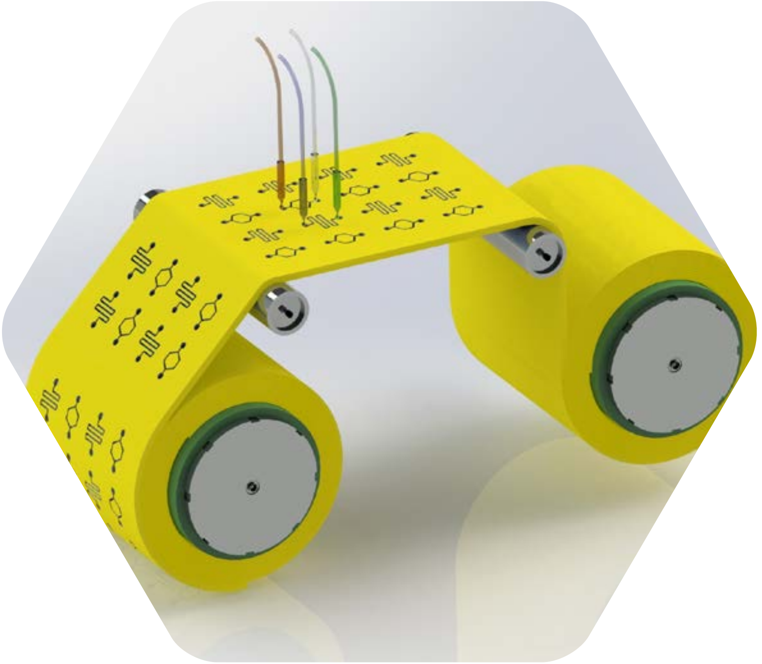
Coating:	Gravure, Slot Die
Patterning:	UV-NIL, *Hot Embossing*
Web Width:	< 290 mm
Speed:	0.5 – 30 m/min

In-line camera, wet thickness control

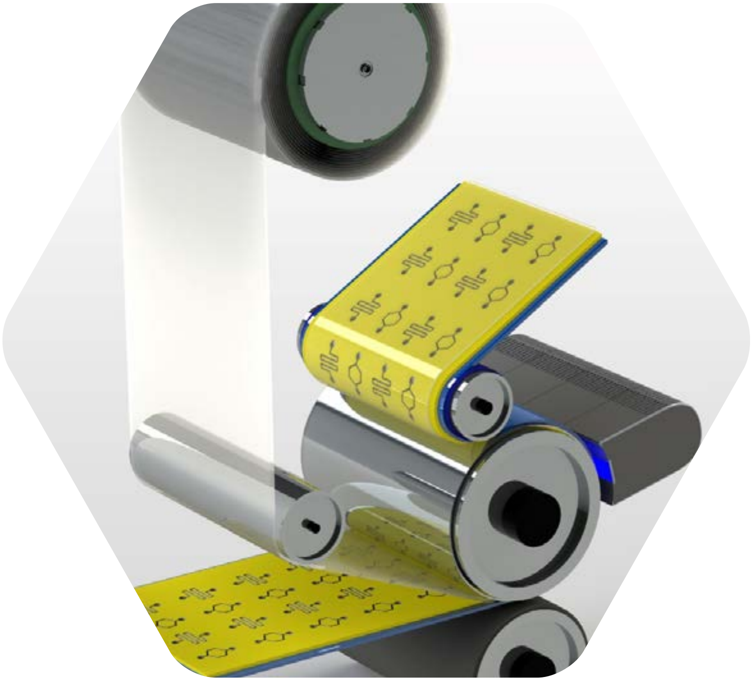
Lab-on-Foil R2R-Pilot Line



UV-Imprinting

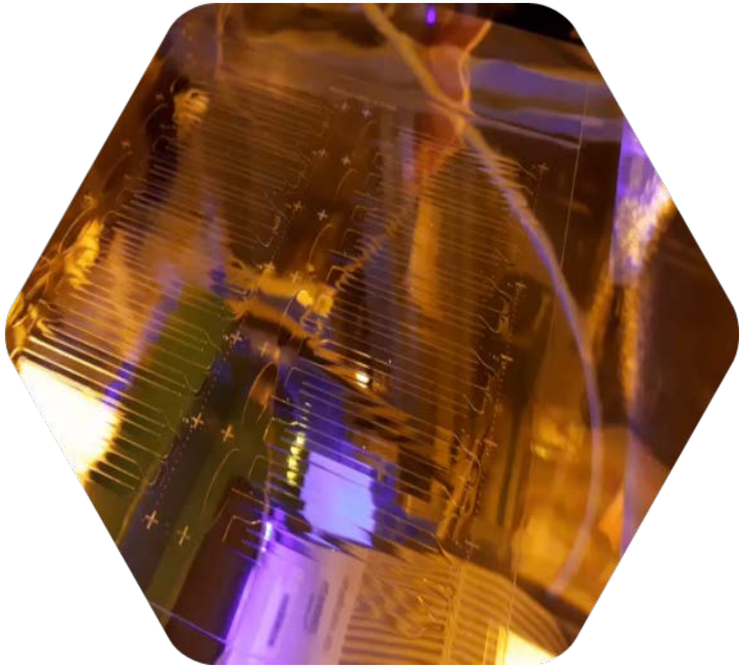


Microarray Spotting of Biomolecules

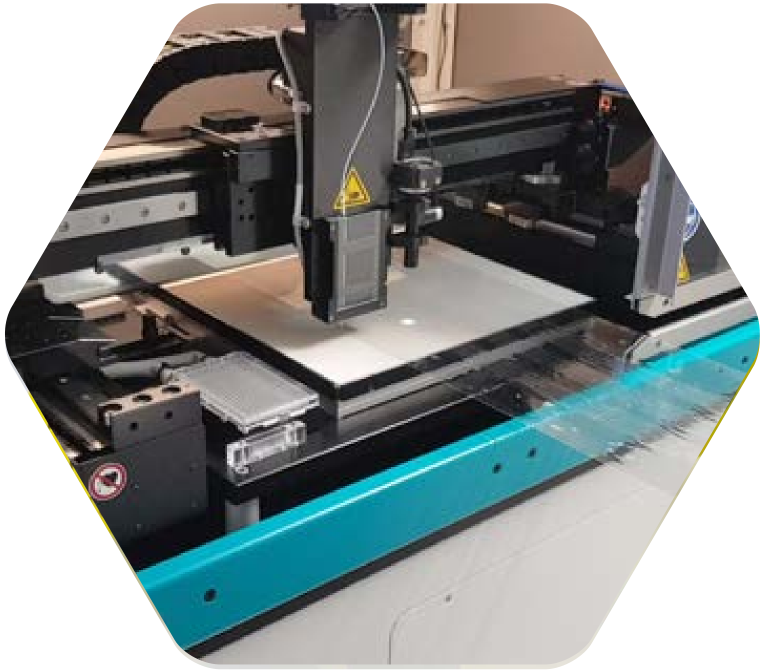


UV Lamination

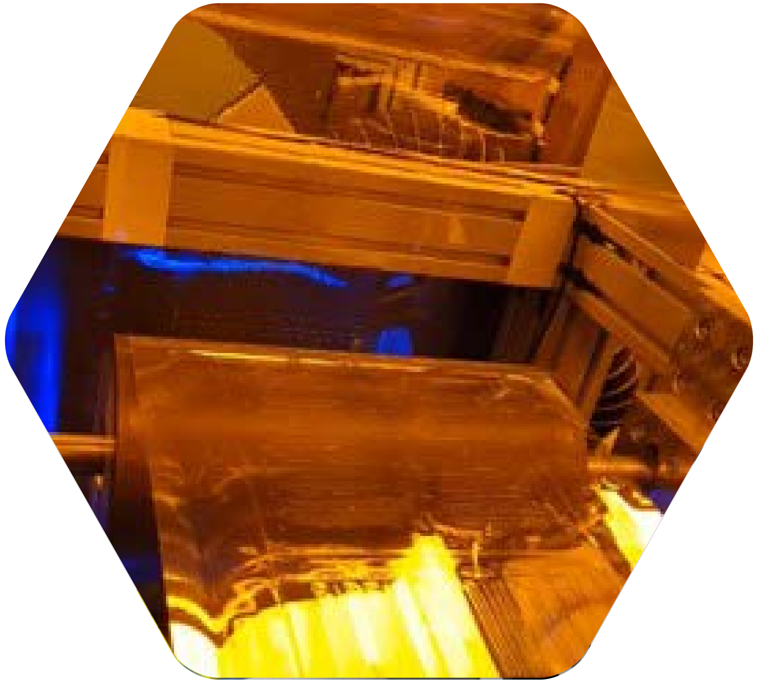
Lab-on-Foil R2R-Pilot Line



UV-Imprinting

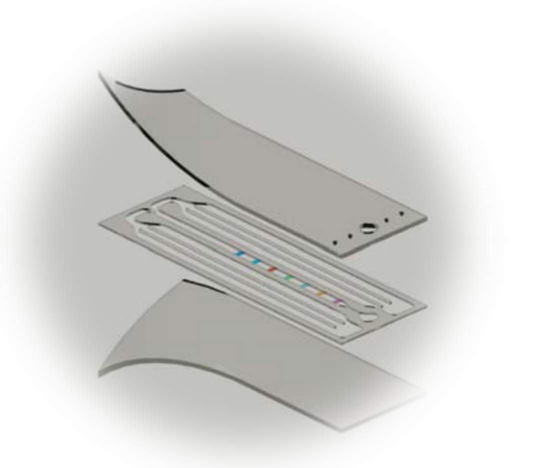


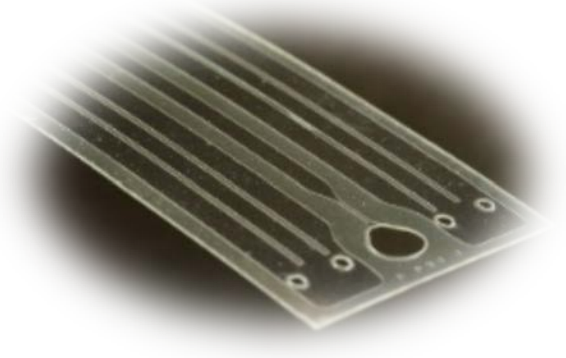
Microarray Spotting of Biomolecules

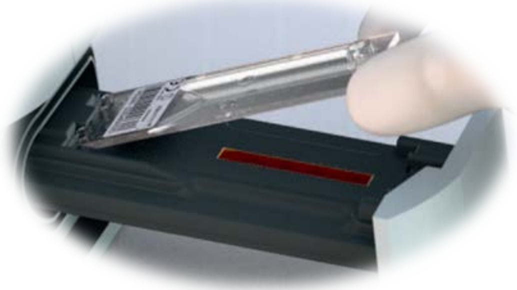


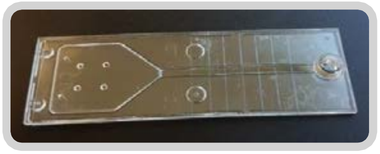
UV Lamination

R2R-based Microfluidics for Lab-on-a-Foil Biosensors

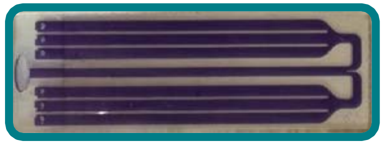




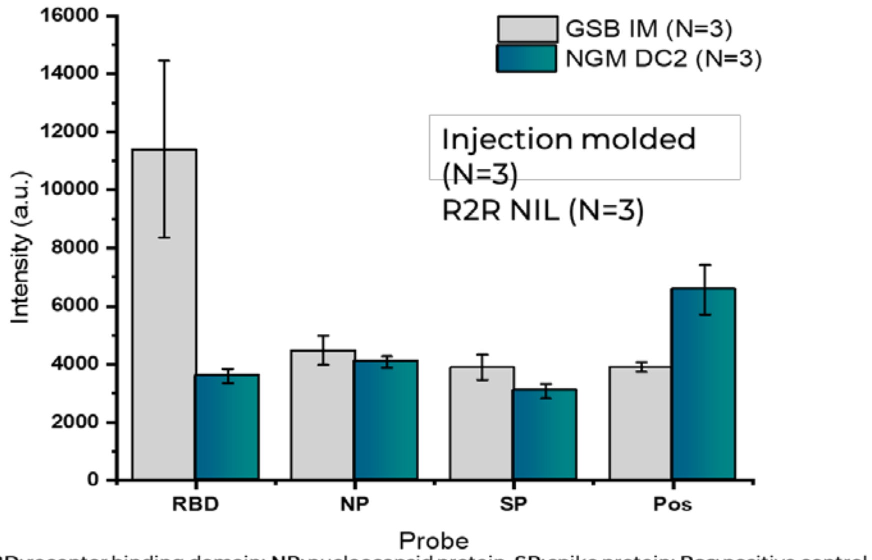




Injection molded chip



R2R-imprinted µF chip

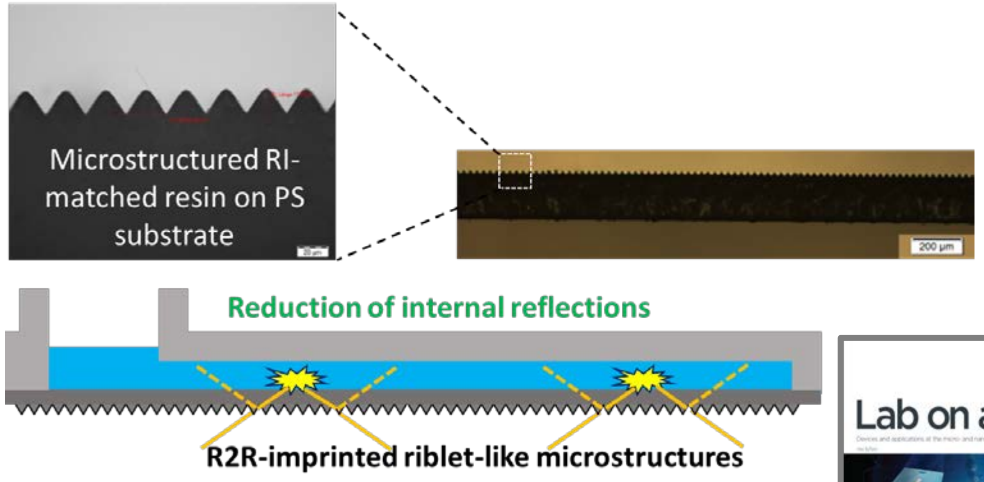


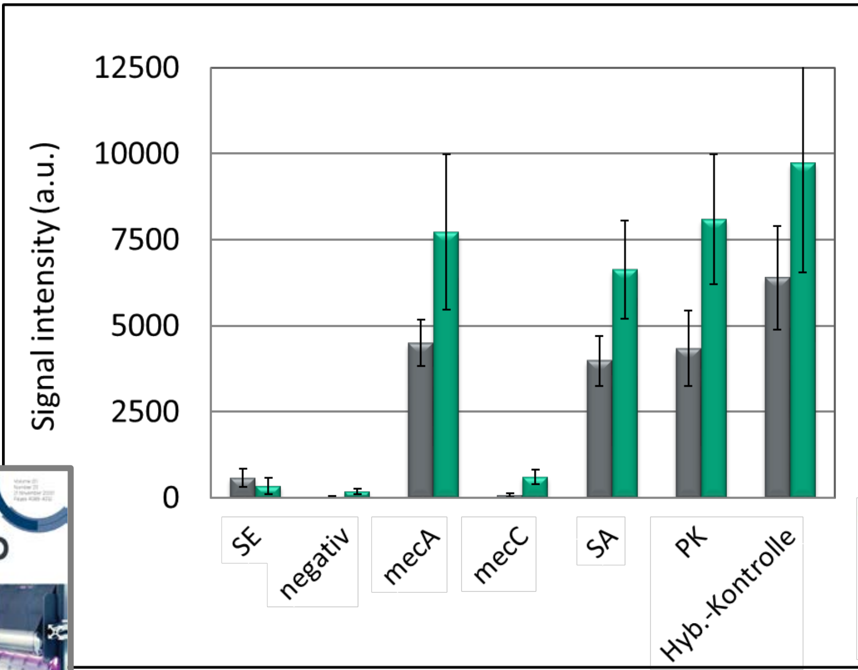
RBD: receptor binding domain; **NP**: nucleocapsid protein, **SP**: spike protein; **Pos**: positive control
*Chips were tested at a different time point in storage

Signals achieved with foil chips are comparable to injection molded chips!

R2R-based Microfluidics for Lab-on-a-Foil Biosensors

R2R-imprinted optical structures for enhanced CL-outcoupling





P. Tören et al., MRS Advances 2021;
P. Tören et al., Lab on Chip 20, 4106 (2020)

Signals achieved with enhanced foil chips are higher than injection molded chips!