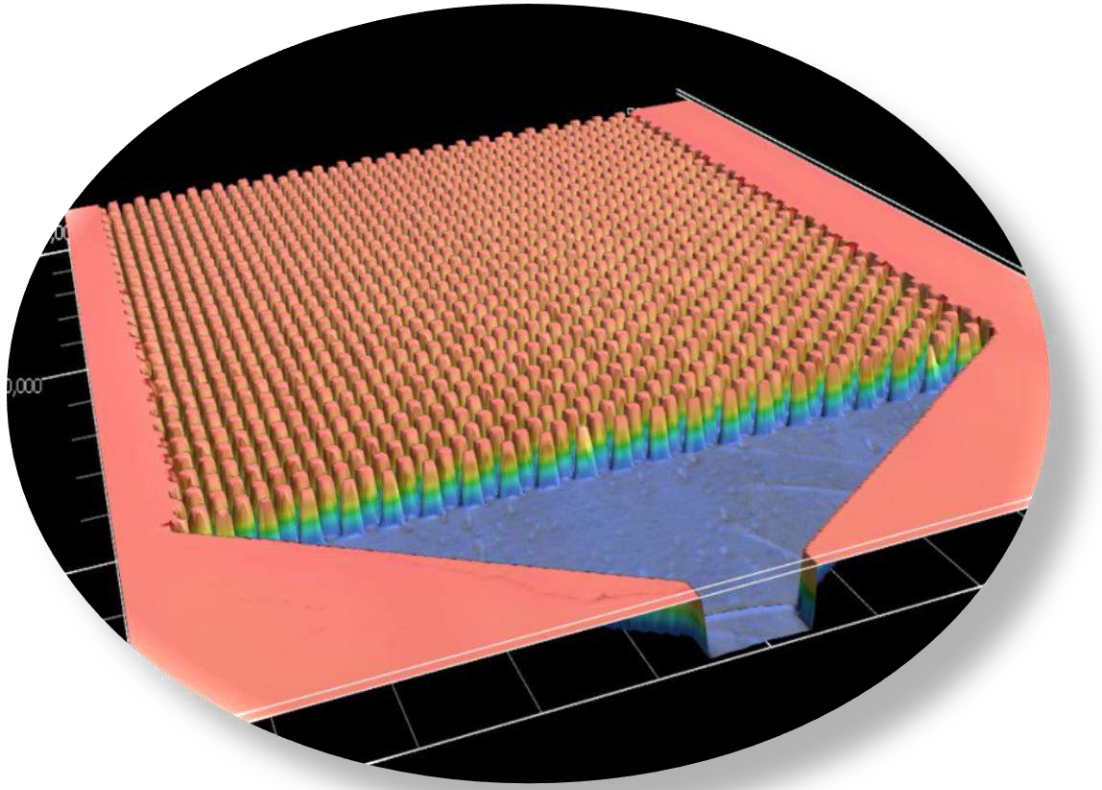
Microfluidic chip with embedded 3D microelements

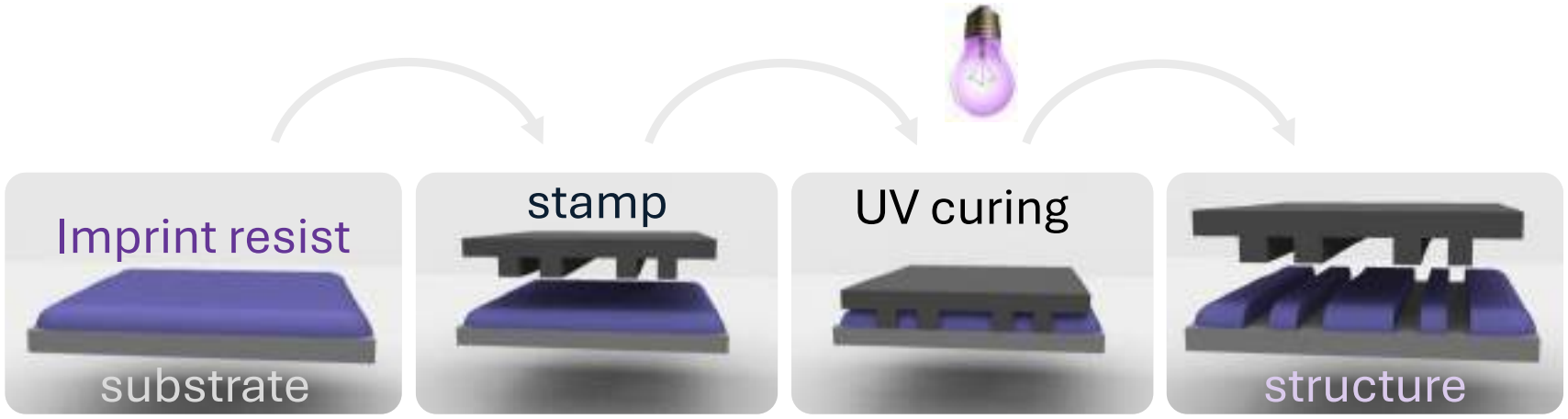


Anja Haase

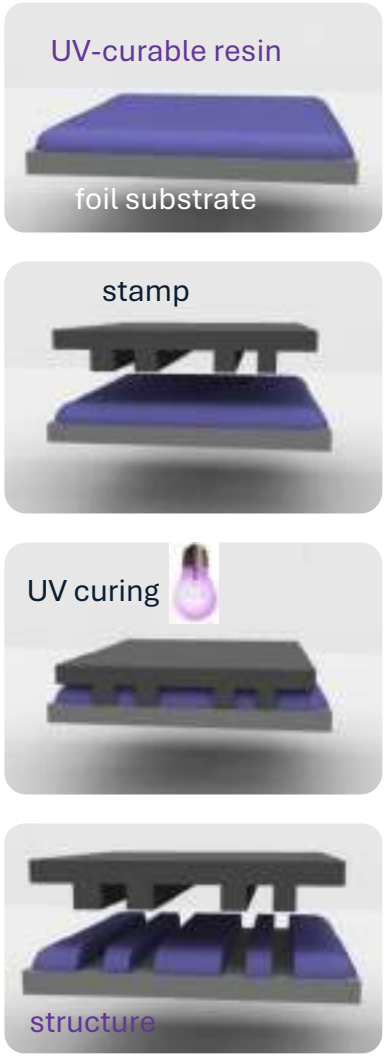
JOANNEUM RESEARCH MATERIALS

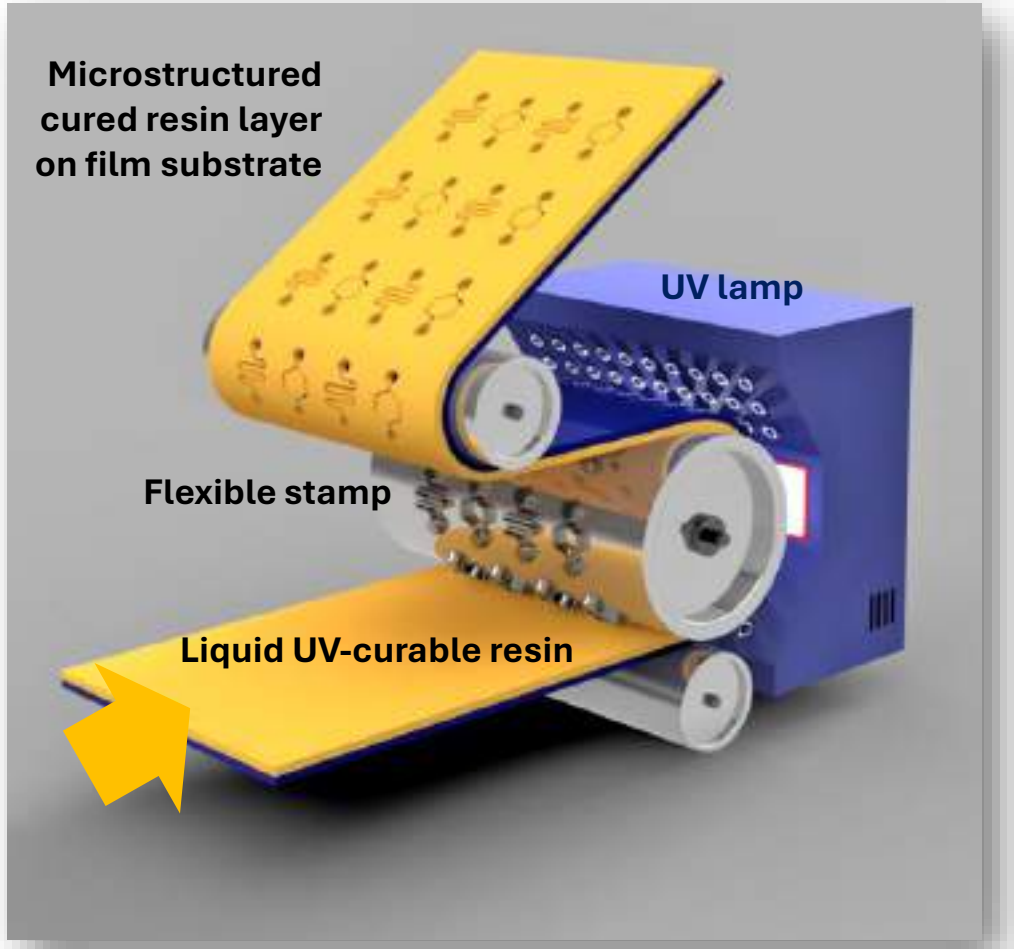
Micro- and Nano Imprint Lithography

- Very simple method for replication of micro- and nanostructures
- Curing process either with UV light or temperature
- Very flexible with respect to geometries, sizes, and forms
- Lateral resolution independent on optical wavelength



Roll-to-Roll- Micro- and Nanoimprinting







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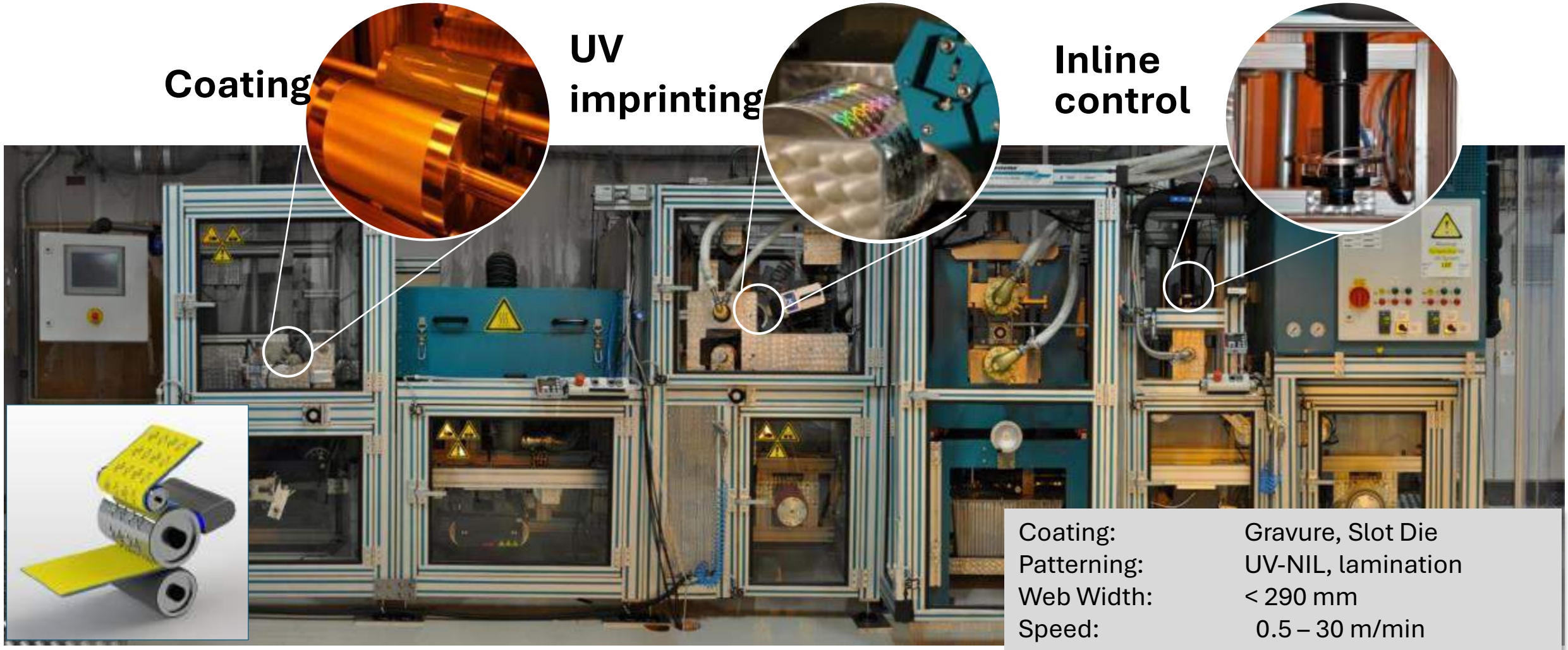


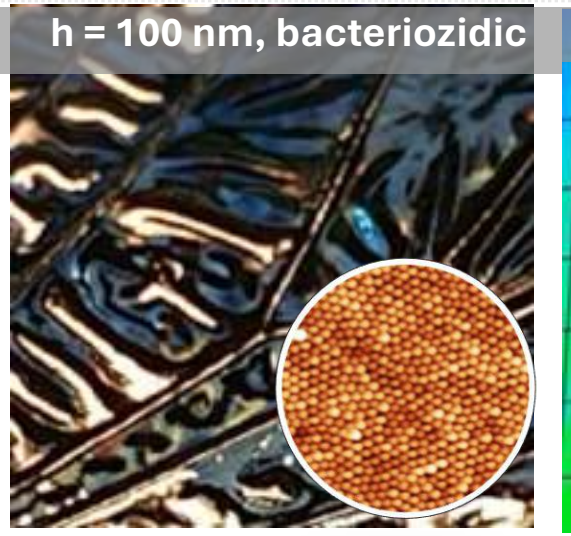
Coating:	Gravure, Slot Die
Patterning:	UV-NIL, lamination
Web Width:	< 290 mm
Speed:	0.5 – 30 m/min

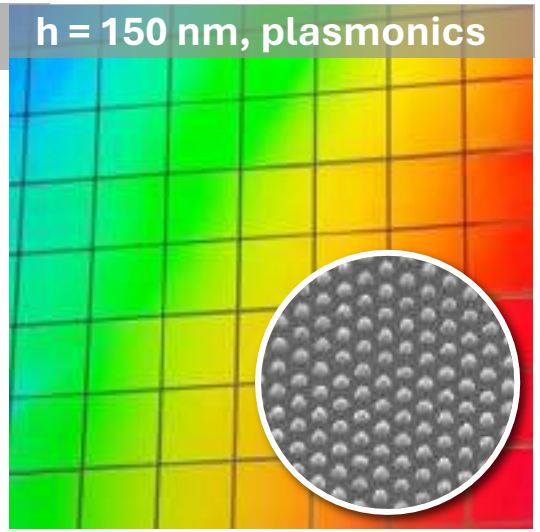
In-line camera, wet thickness control

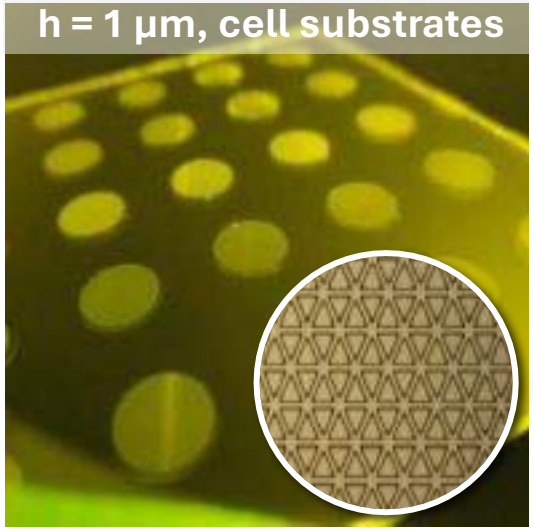
M. Leitgeb, D. Nees, B. Stadlober et al. ACS Nano 2016

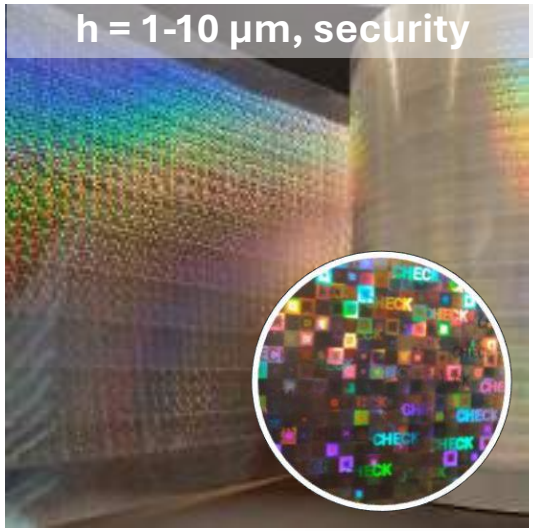
Application examples of nano and micro imprinting

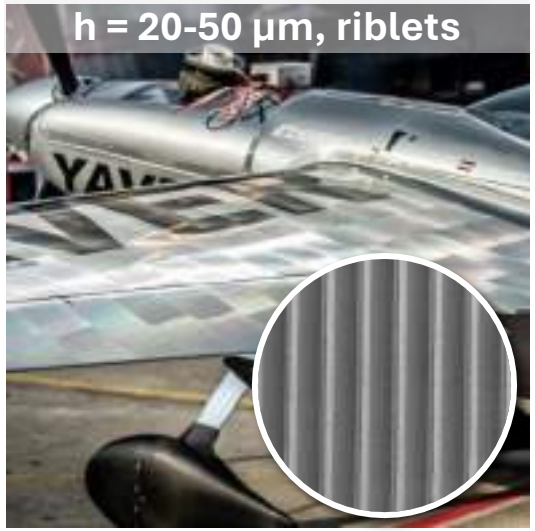
Structures range from 100nm to 200µm

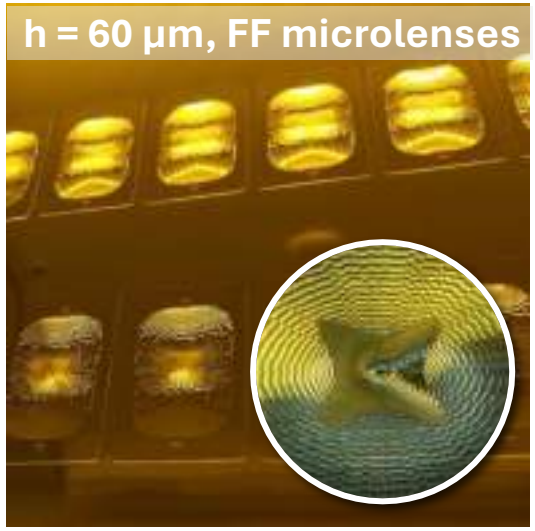


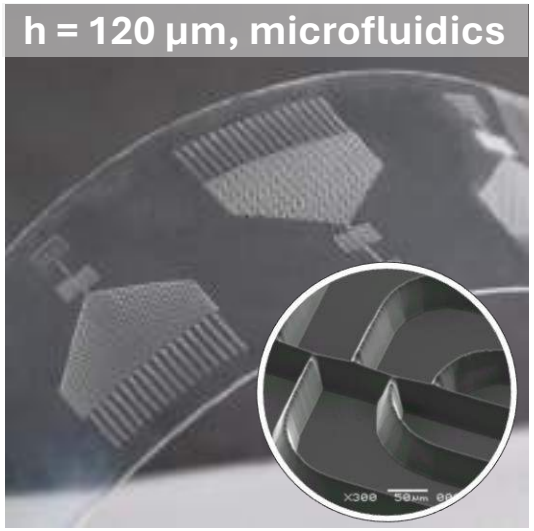


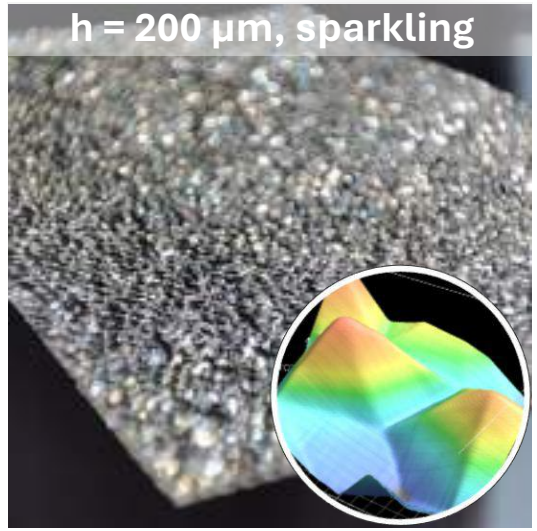




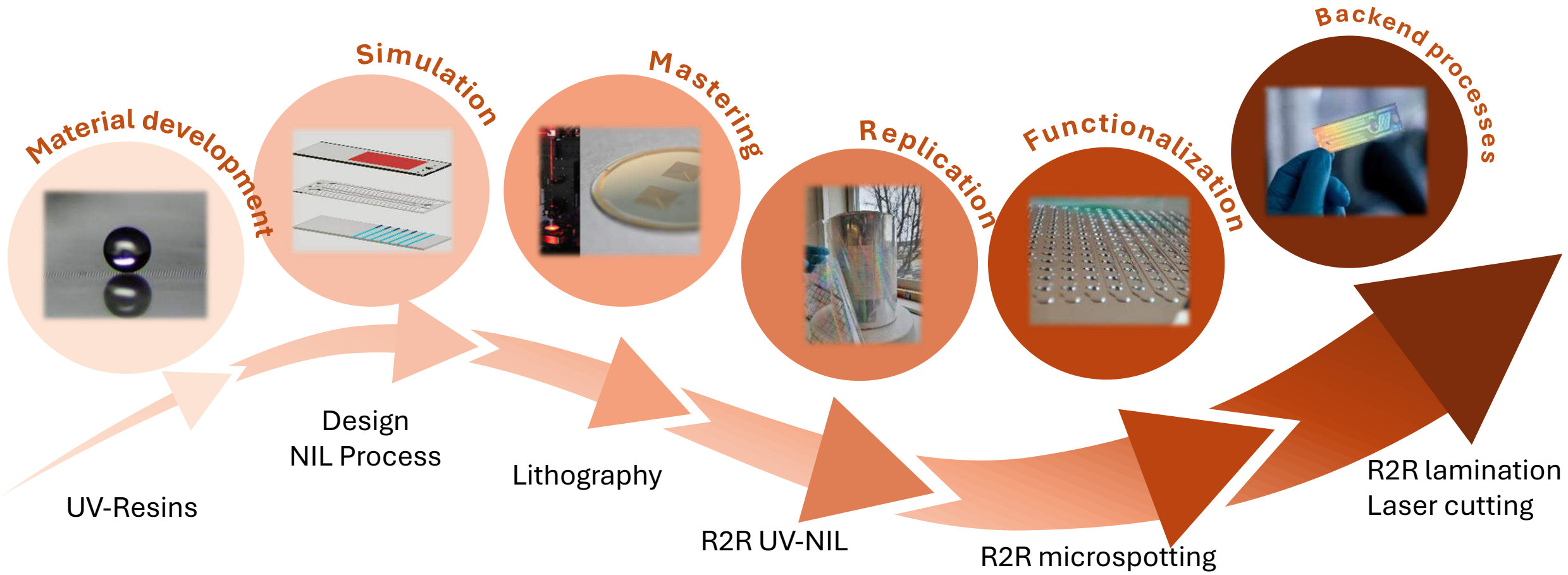






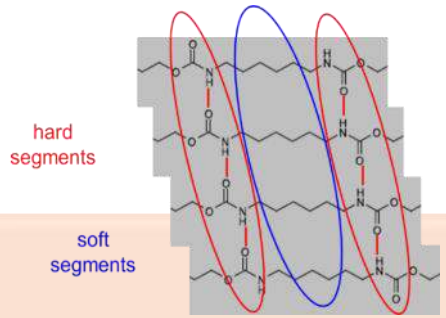


Microfluidics @ JR - Competences in the Value Chain



Material development - NILcure® Product Line

- Customized polymer matrix and additives
- Biobased UV curable resin product line
- Low cytotoxicity & low leakage of components
- Water soluble resins for lift-off processes (VOC free)
- Residual free imprinting (avoiding etching process)
- Self-replicability
- Resistant against UV radiation and weathering

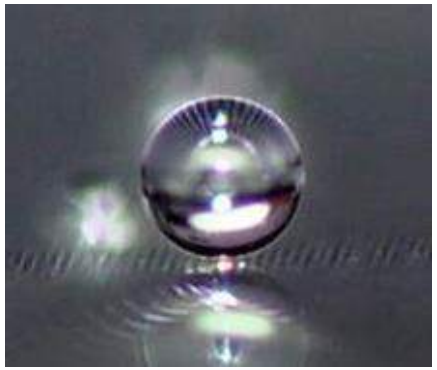


Property tuneable	from	to
Young's Modulus Elongation	5 MPa 100 %	1000 MPa 5 %
Surface energy	15 mN/m	70 mN/m
Refractive Index @589nm	1.4	1.8
Viscosity	10 mPas	10 Pas

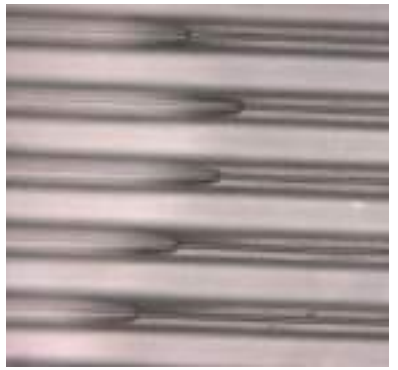
bio NILcure

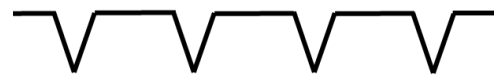
NILcure

Material development - Wetting Control

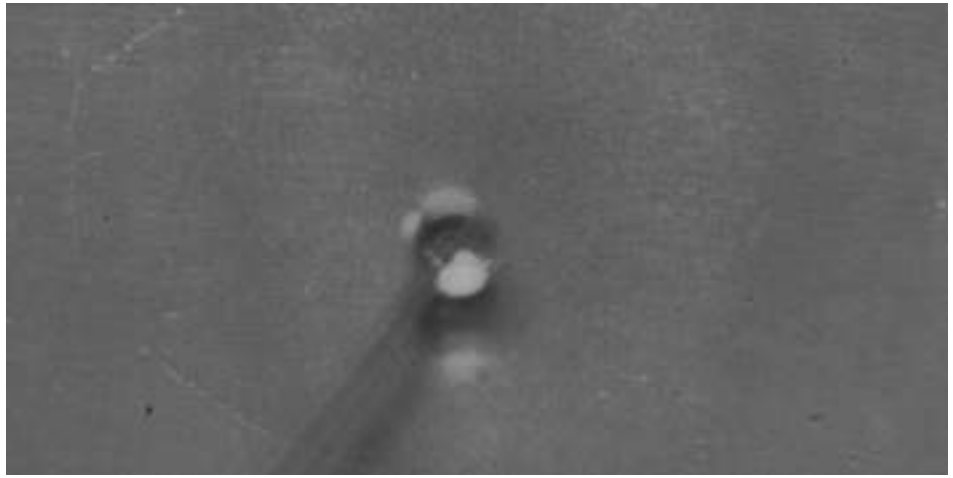






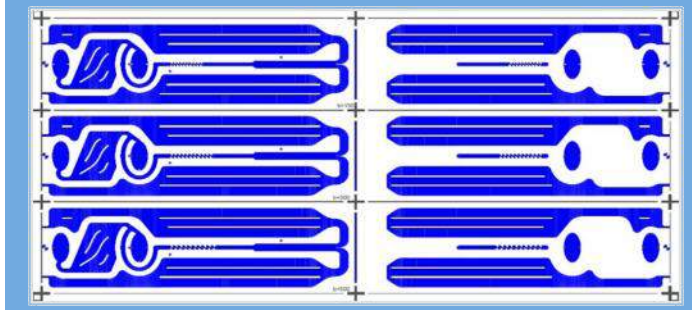
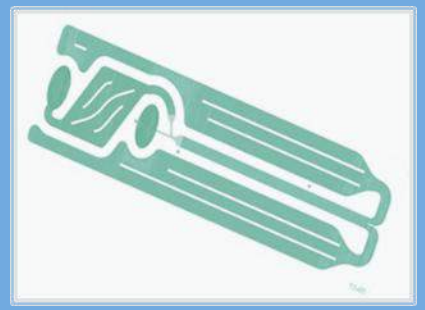
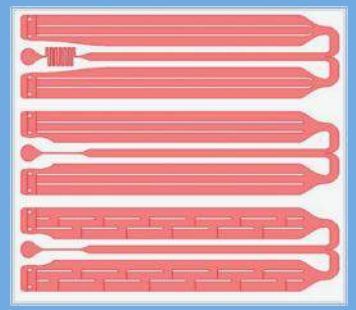


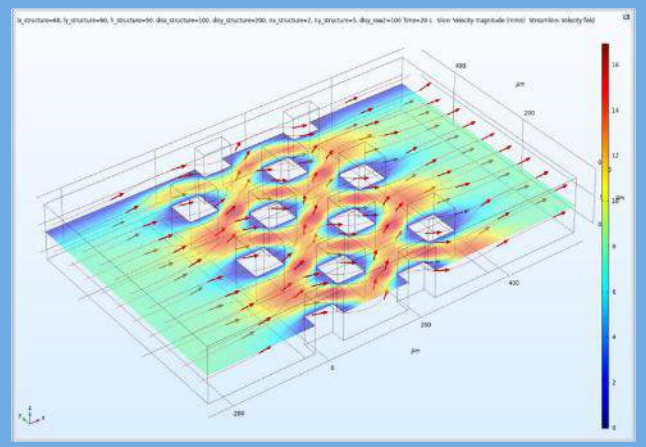
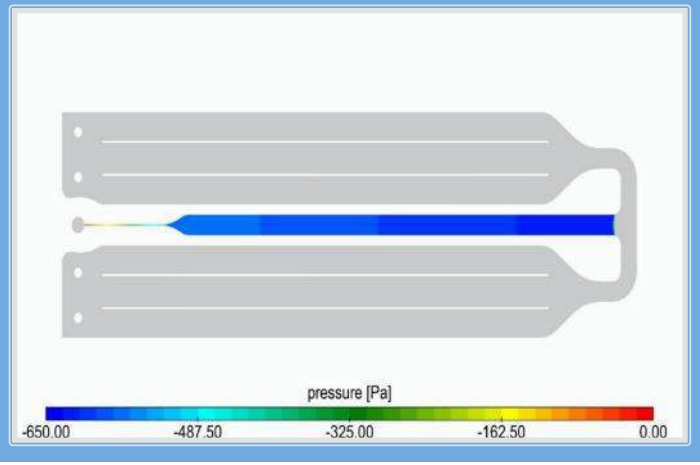


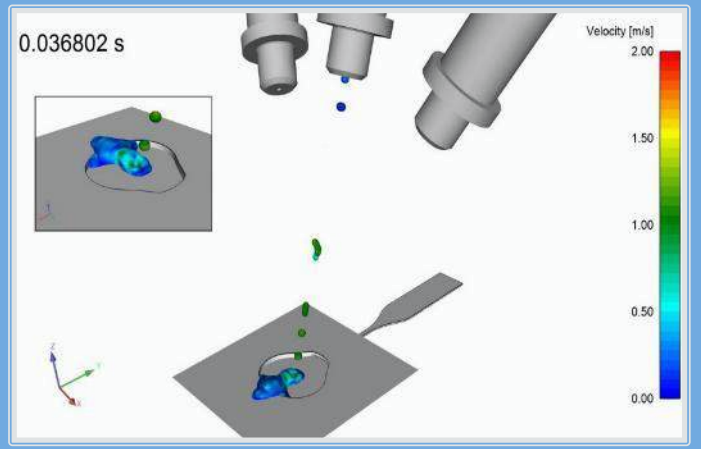


Design & Simulation

- Design of microfluidic devices
- Simulation of fluidics and reaction kinetics

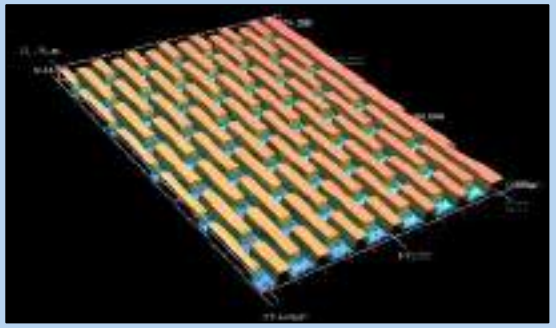






Patterning

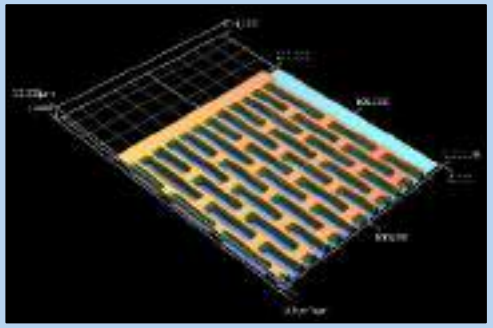
Master

- Photolithography
- Laserlithography
  - Grey scale litho
- Postlaser processing



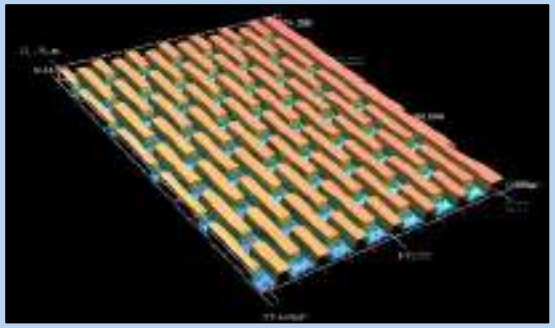
Working stamp

- Polymer working stamp
- Ni working stamp
- Small or large scale



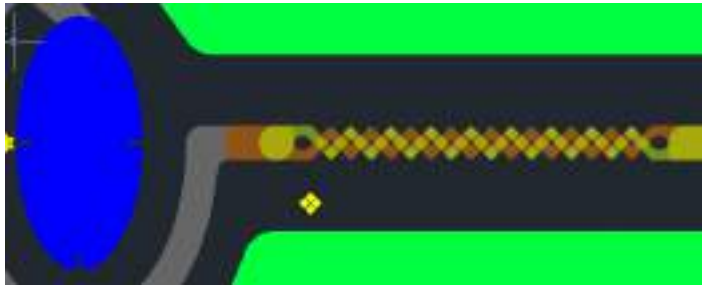
Replication

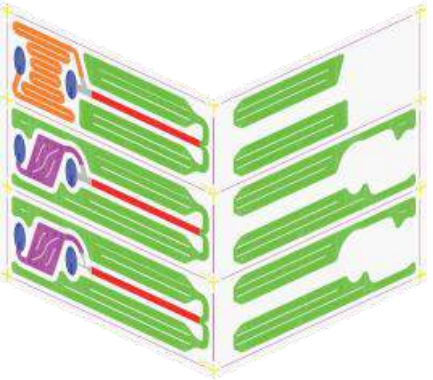
- Manual imprinting
- R2R imprinting



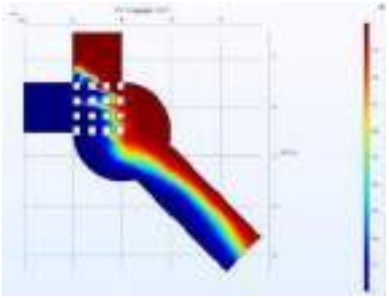
Where do you need additional structures in a microfluidic channel?

- Mixing Zones
  - Herringbone grooves
  - Serpentine channels
- Cell/Particle Manipulation Zones
  - Trapping wells
  - Separation areas
- Sensing & Detection Areas
  - Electrode patterns
  - Nanostructured sensing surfaces
- Flow Splitting & Metering Sections
  - Capillary valves / hydrophobic patches
  - Restriction channels (flow resistors)
  - Passive metering
  - Capillary pumps









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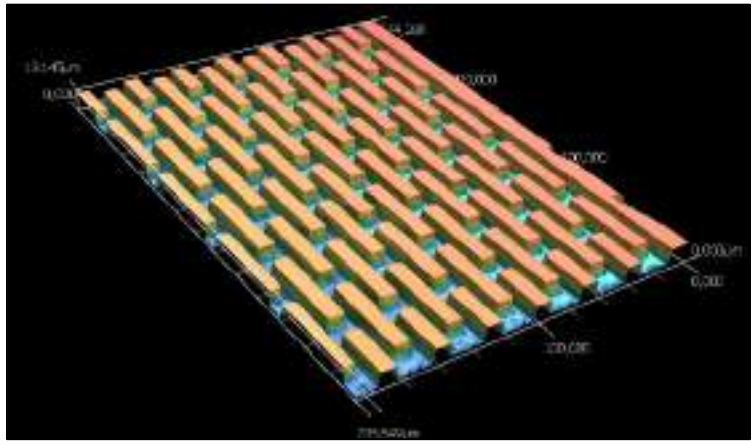



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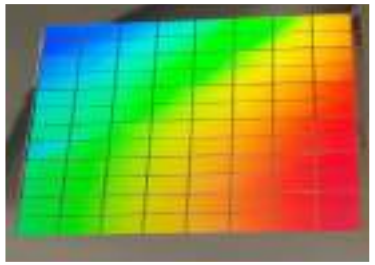

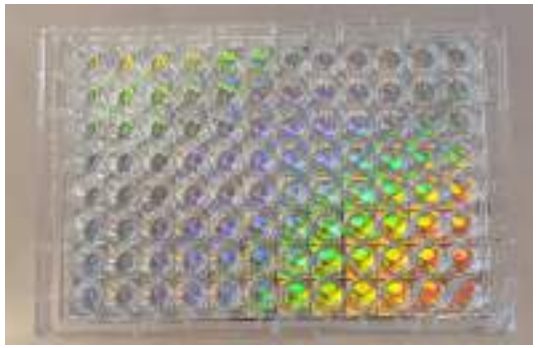

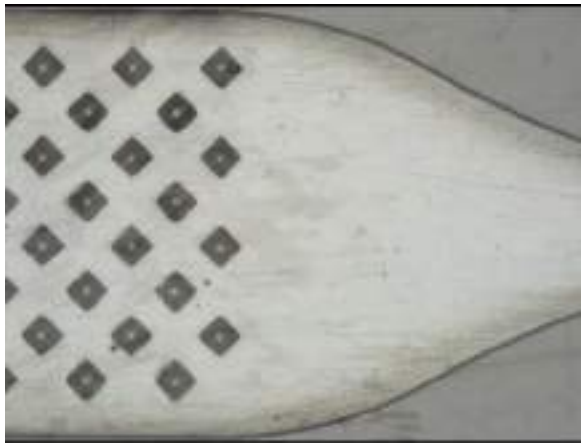

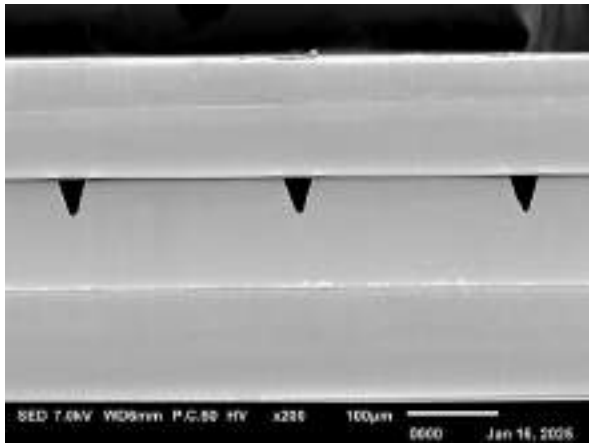

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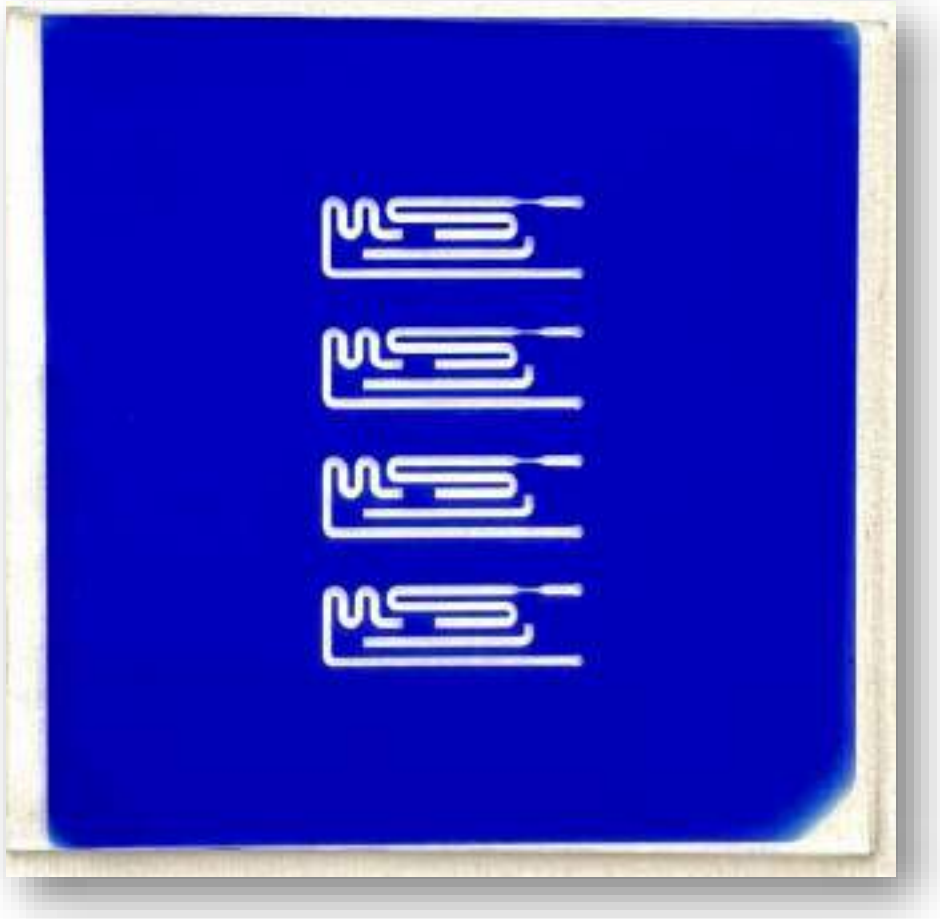

Why coordinated liquid handling in microfluidic circuits?

- Meter an exact volume of sample in a closed system
  - Contamination free
- Especially interesting for blood samples
  - No hematocrit dependency (varying viscosity)
  - Quantitative Analysis
  - Point of care sampling

State-of-the-art- dried blood sampling



Protein saver cards



VAMS Mitra



Capitainer®B



TASSO

- Limited liquid handling capability
- Hematocrit dependency → varying viscosity

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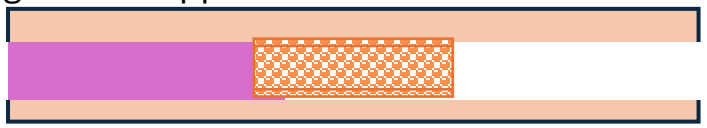
https://www.neoteryx.com/hubfs/Page%20Graphics/Cartridge/2019-cartridge/Mitra-microsampler-capillary-blood-collection-device.png

Geometric Burst Valves (GBV)

- State of the art: Integration Hydrophobic Burst Valves
  - Introduce flow resistance due to change of surface energy
    - Hydrophobic/ superhydrophobic reagents are applied into channel

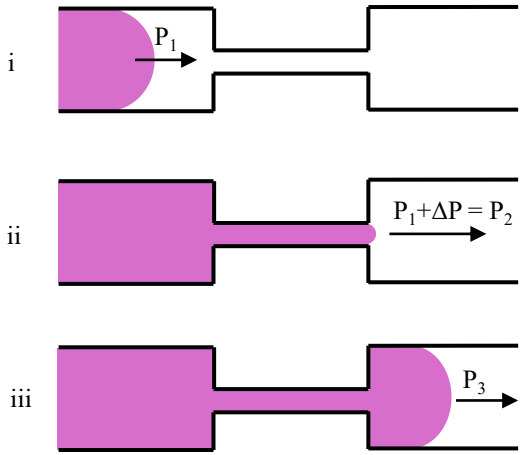


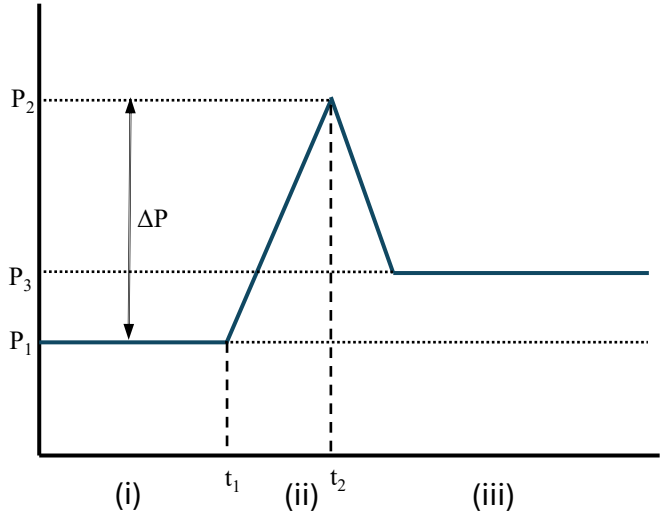
→ Complex coating step

  - Not suitable for high throughput manufacturing,
  - difficult to be precise in positioning and amount

- Other possibility → **Geometric Burst Valves**
  - Burst valves by **changing the geometry of the microfluidic channel**
  - Introduce flow resistance (low surface energie) due to abrupt change in geometry
  - Big advantage: no additional step
  - Can be included in the design

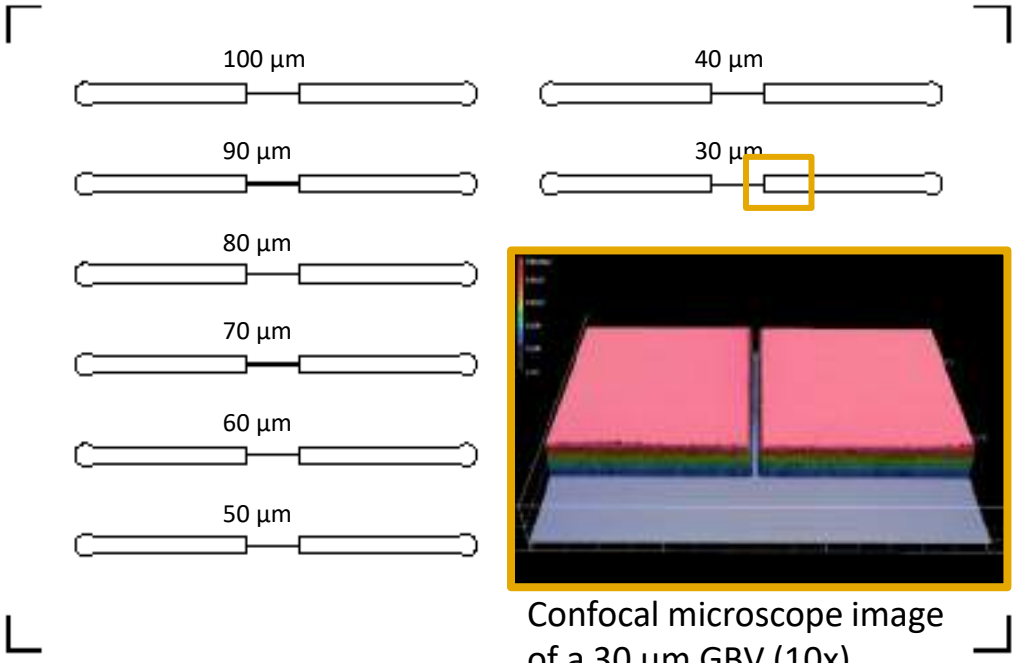






Geometric burst and stop valves characterization

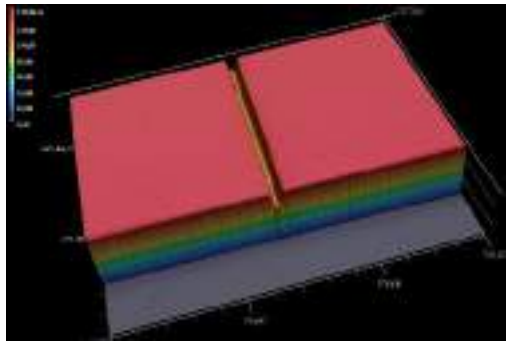
Geometric burst valves (2D) – delays liquid

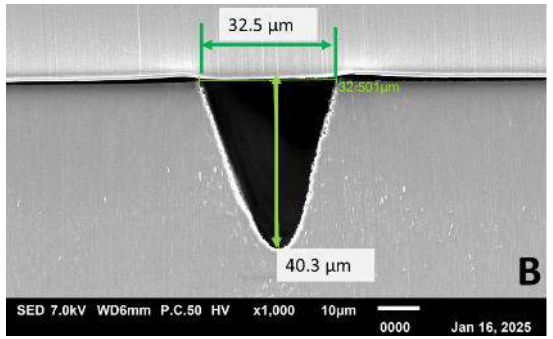


Confocal microscope image of a 30 µm GBV (10x)

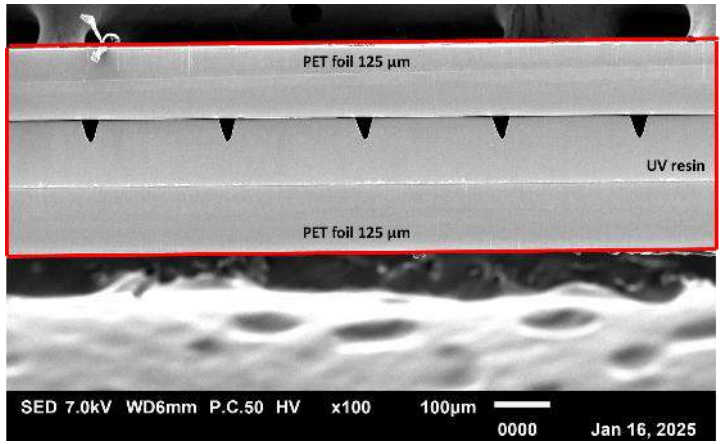
Geometric Burst Valves structures were realized during photolithography with dry film resist (height 120 µm)

Geometric stop valves (3D) – stops liquid, permeable to air



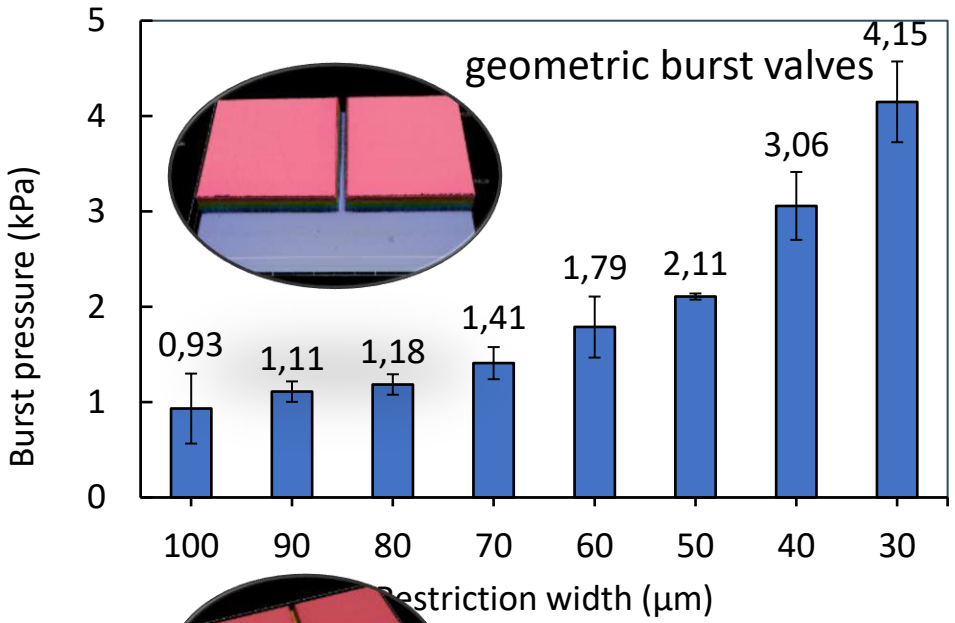


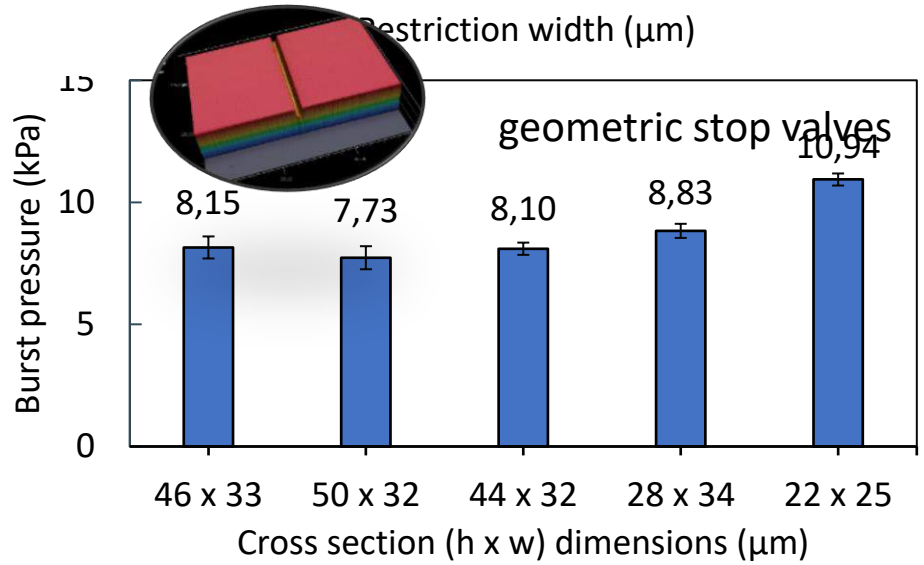
Confocal microscope image of a GSV (10x)

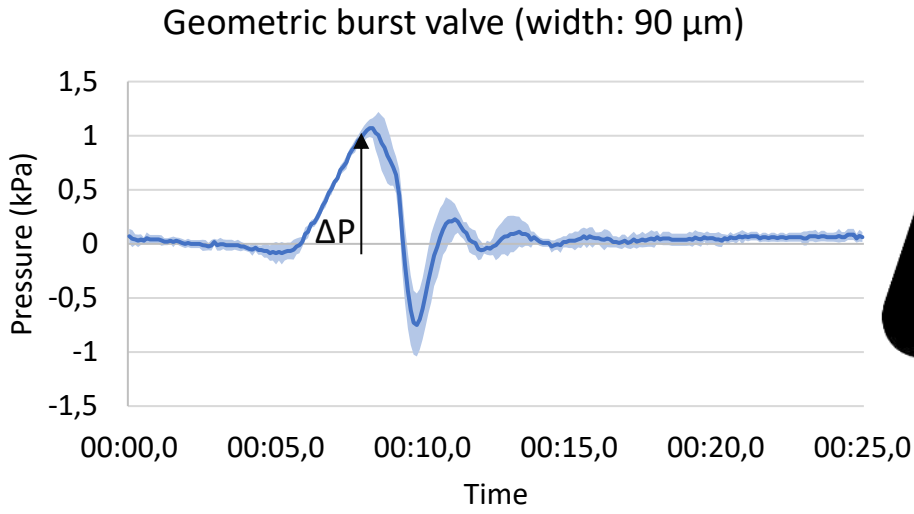


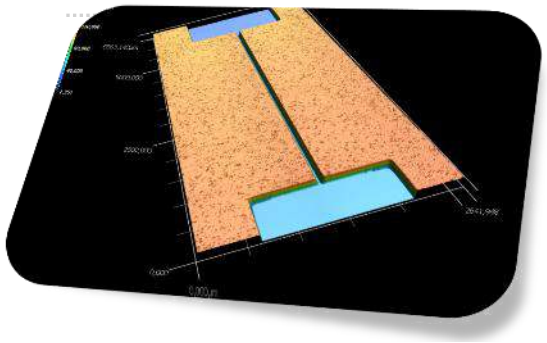
Geometric Stop Valves were ablated into the master by a Femtosecond Laser - combination of photolithography and laser engraving

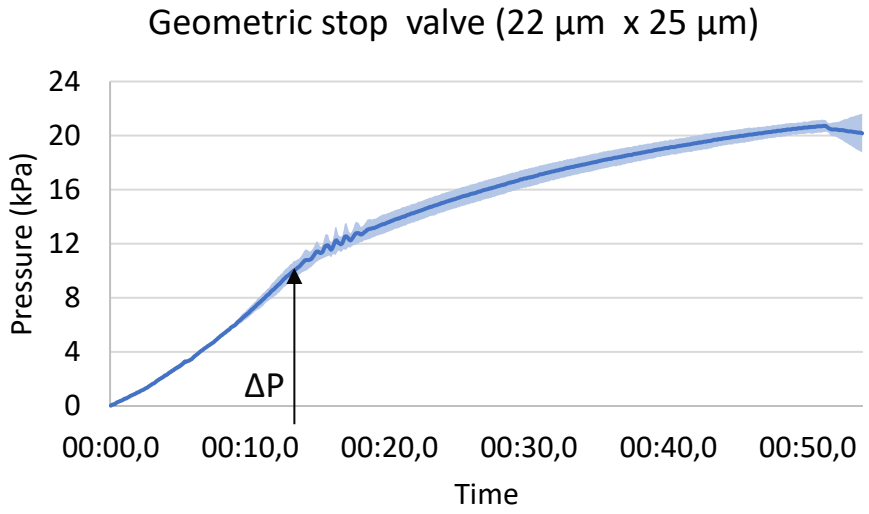
Burst pressure of geometric burst and stop valves





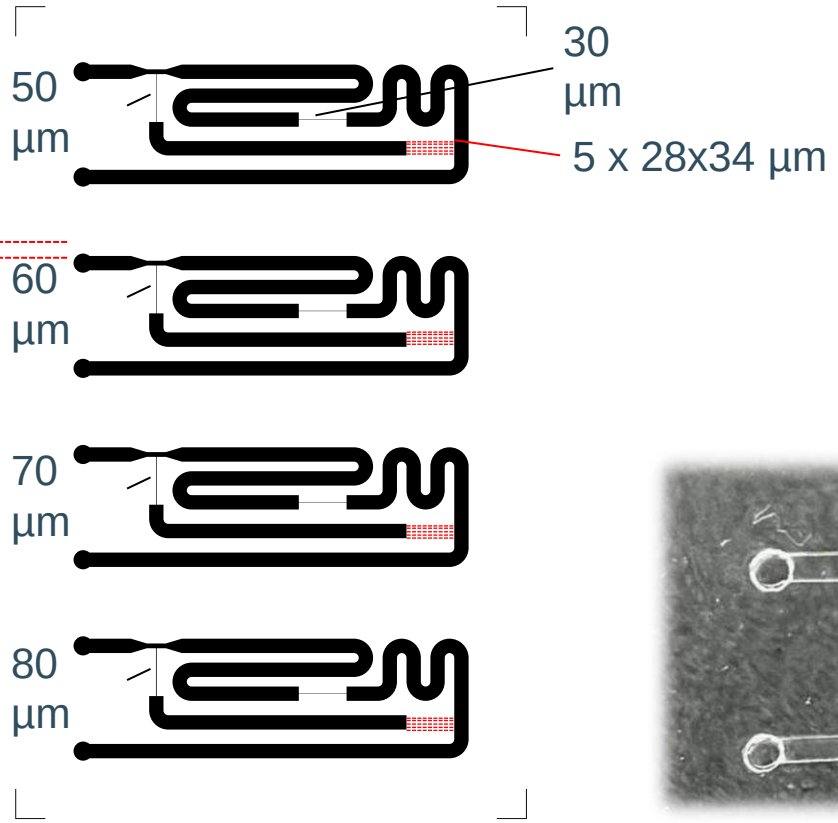


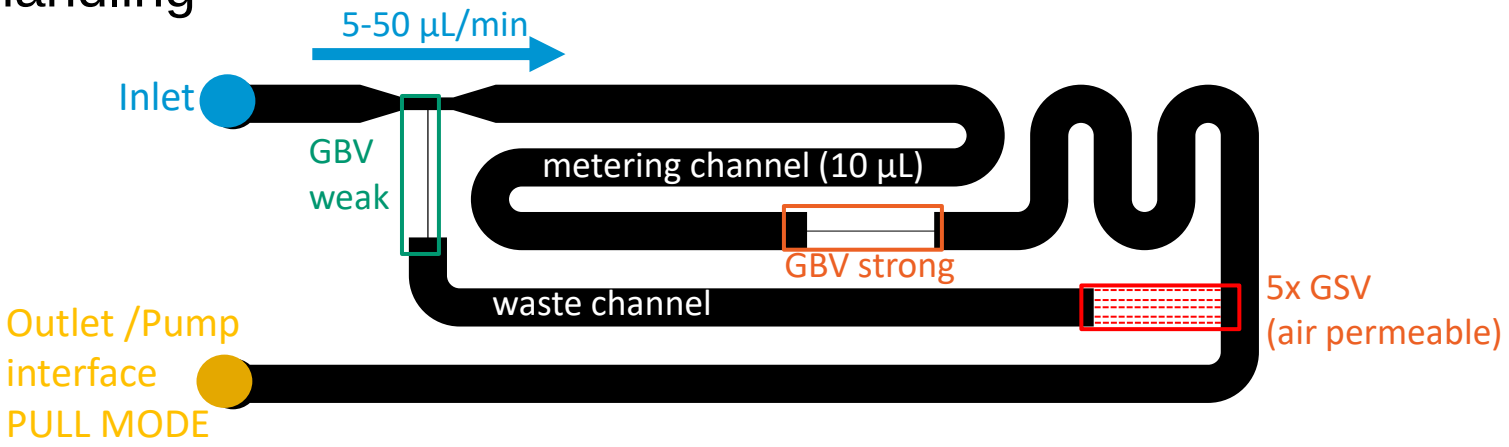


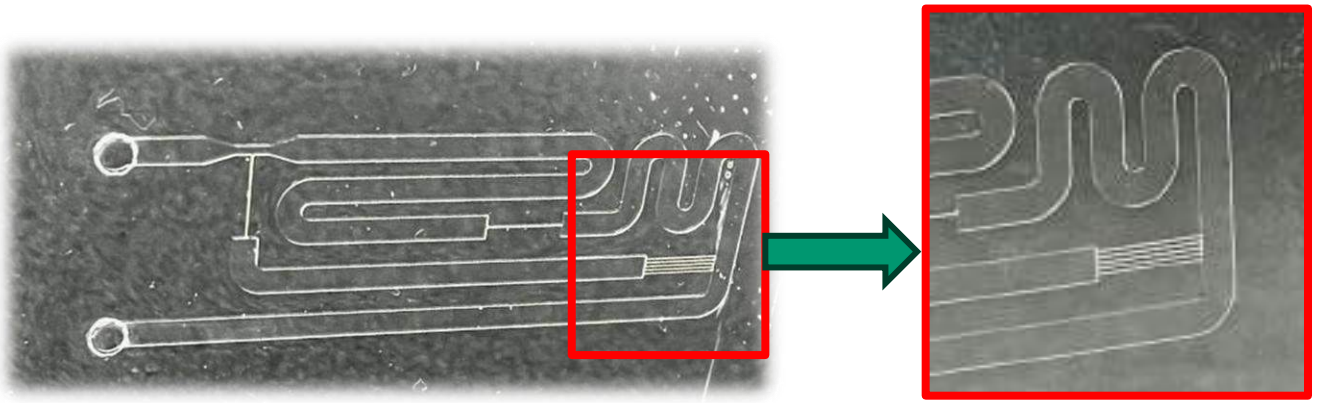


Combination of geometric burst and stop valves

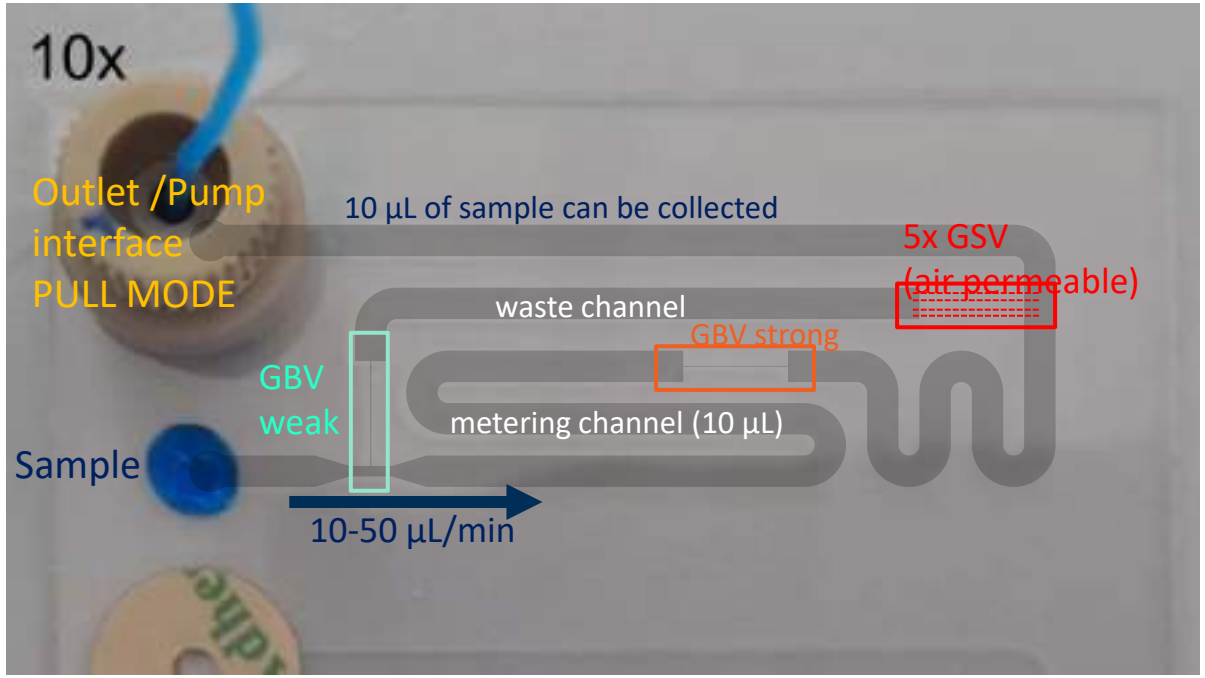
- Enables coordinated liquid handling

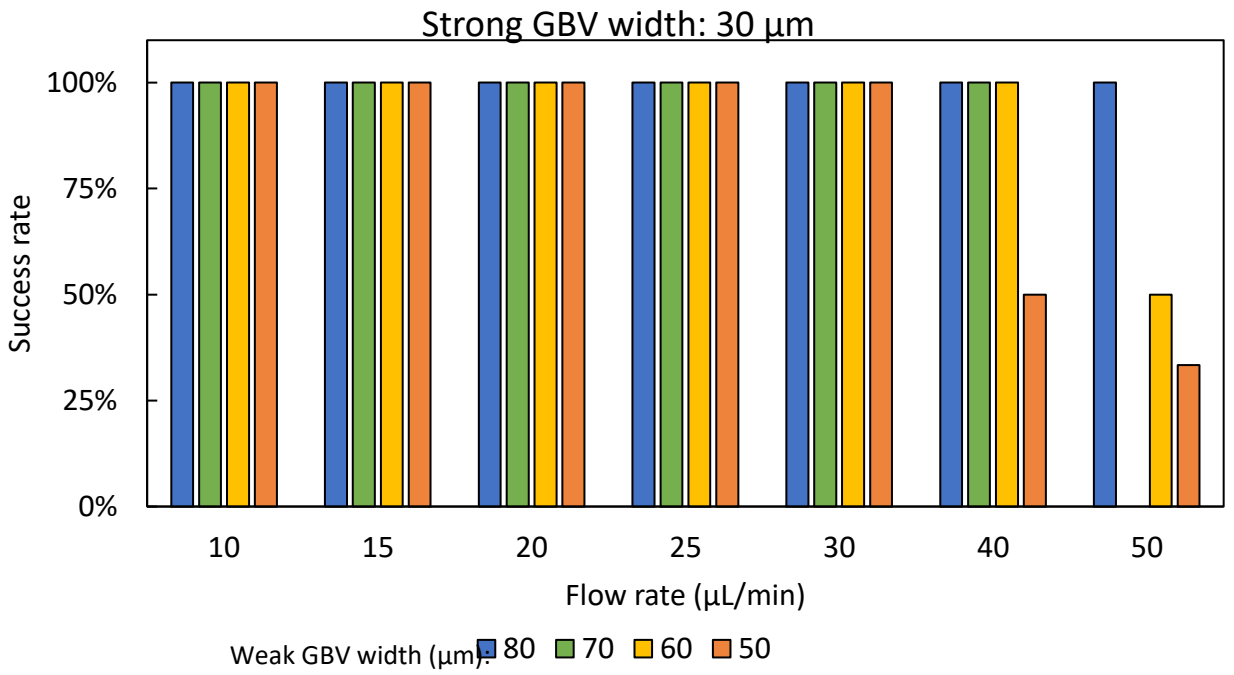






Combination of geometric burst and stop valves



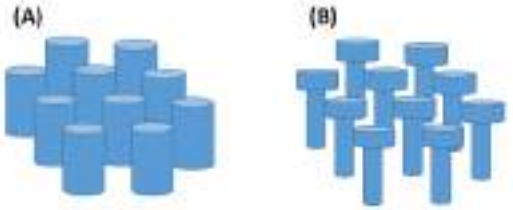


Experimental setup:
Flow rate: 10 – 50 µL/min
Sample: 1:100 blue dye in DI water

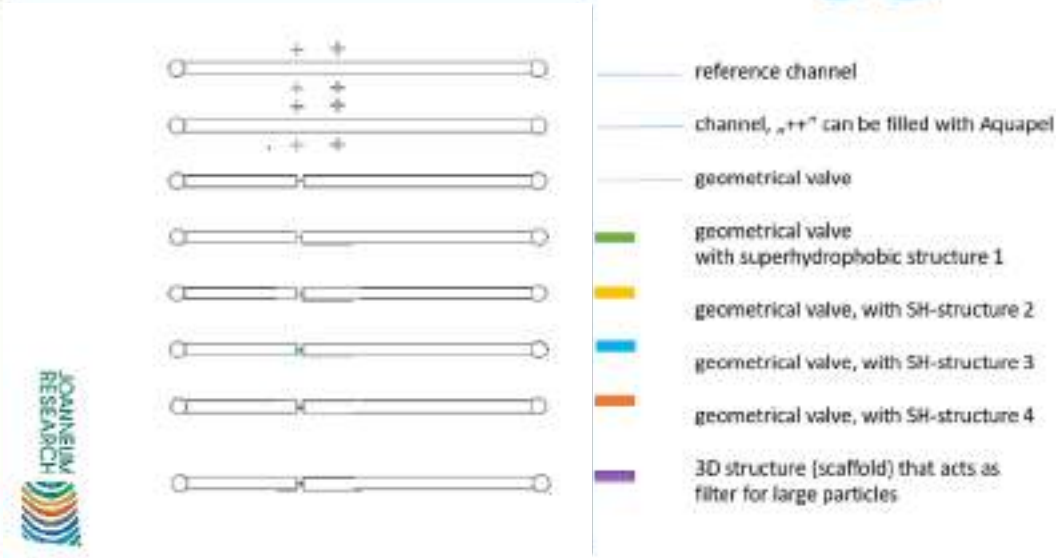
- Combination 30/80 µm had a 100% success rate at 50 µL/min

Microfluidic Chip with embedded 3D Microelement

Design for Lab-on-a-chip channels with functional elements: reference channel, channels with geometric valve and 4 different super hydrophobic (SH) microstructure arrays and one channel with a 3D scaffold

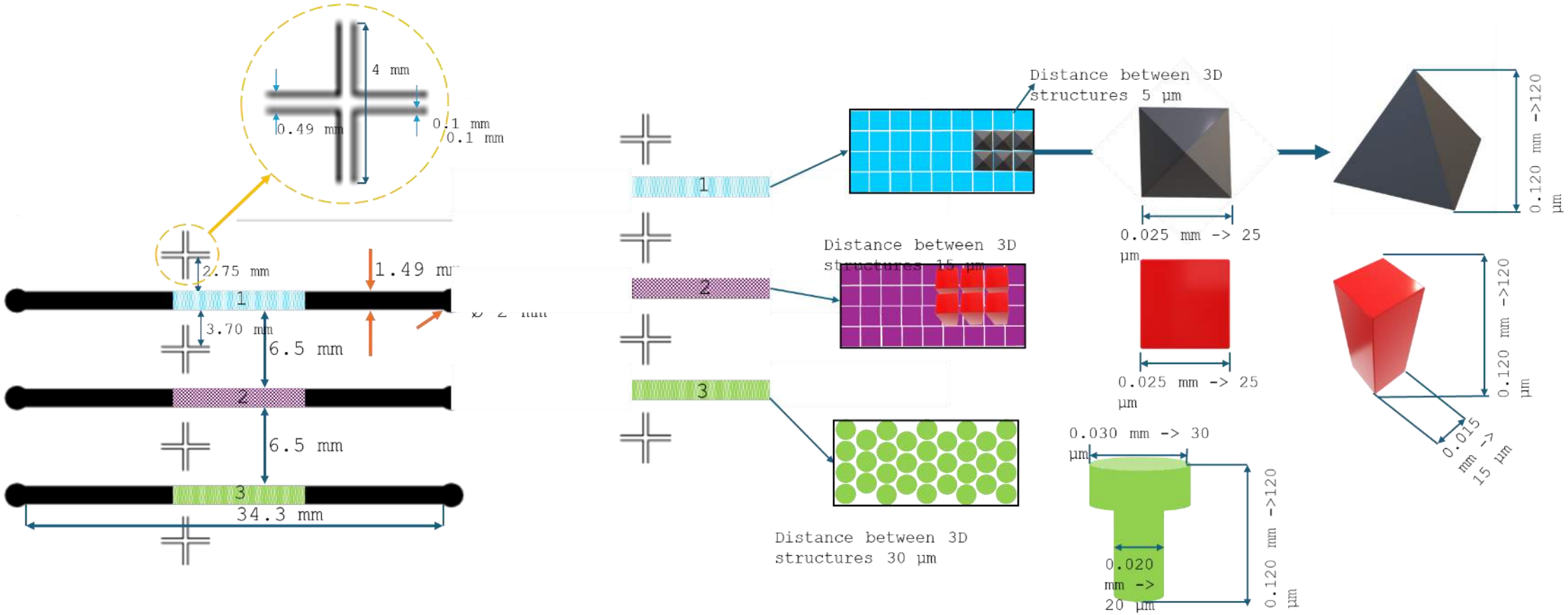


A-pillars, B-pillars with undercut for creating enhanced hydrophobicity in the valves



Channels	**8 channels in total**
Height and size	≥ 120 µm, length = 45 mm, width = 1.5 mm
Features	- 2 reference channels with flat bottom and side walls, one of the channels will be functionalized with a water repelling (hydrophobic) wet coating (Aquapel) - 6 channels have a geometric valve, each - 1 valve contains a 3D scaffold that acts as filter for large particles in the fluid, length, and width of the scaffold <= 300µm, void size <30µm, with of 2PL written scaffold grid line <=20µm, height of the scaffold = channel height - Arrays (size ~ 300x300 µm^2) of 4 different microstructures – pillar (Figure 7A), cone, pillar with undercut (Figure 7B), riblet - are fabricated onto the bottom of valves, height range: 3-20 µm, maximum structure width range: 3-20 µm, structure repetition rate: 1-3 times the maximum structure width, maximum array length in the valve <= 300µm, riblets are designed perpendicular to long channel axis

Use case structure and feature size defined



Thank you for your attention!







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