Microfluidic Stickers

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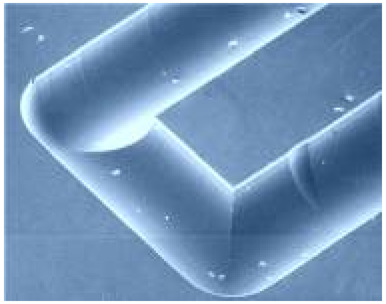
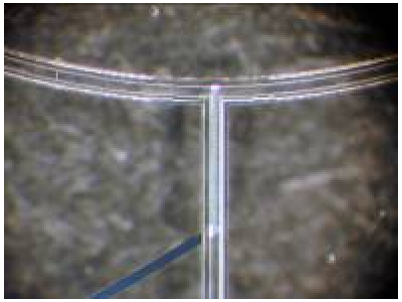
What is microfluidics ?

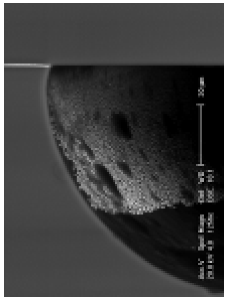
- Definition:

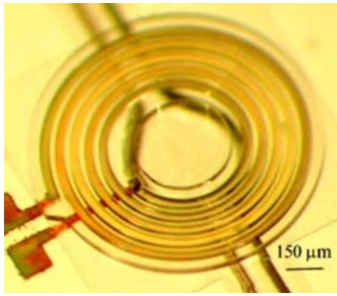
Systems that process or manipulate small (10^{-9} to 10^{-18} liters) amounts of fluids, using channels with dimensions of tens to hundreds of micrometers

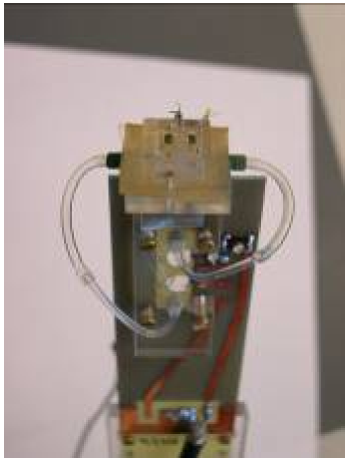
G. Whitesides, Nature, 2006, 442







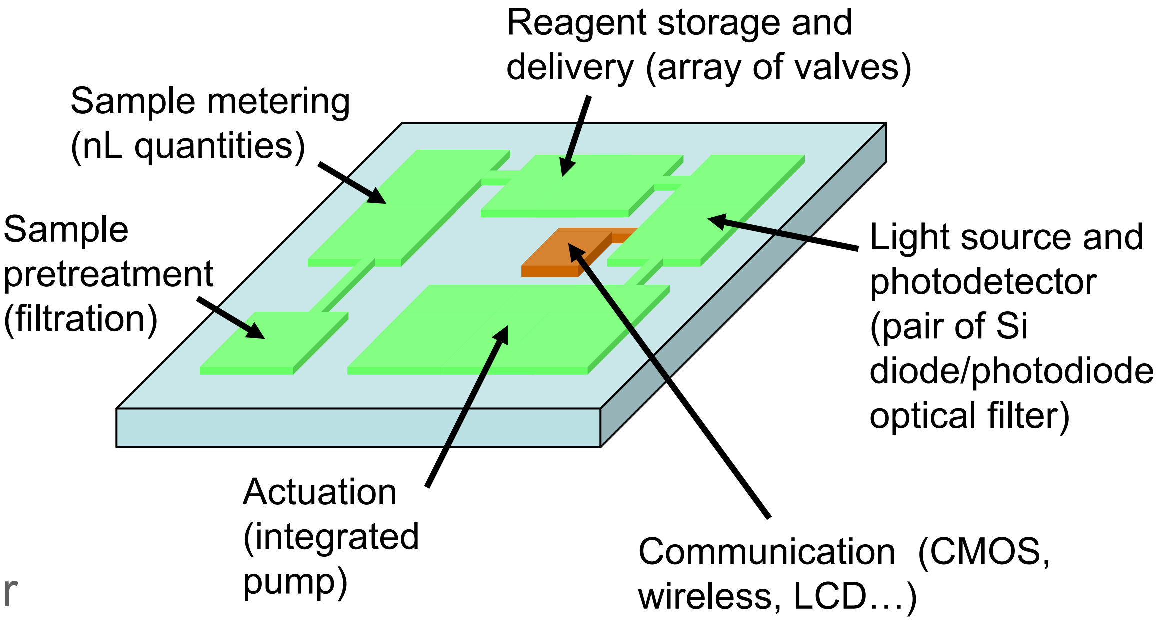




Why microfluidics ?

- Small volumes
- Short reaction times
- Portability
- Low consumption of power
- Parallel operation
- Integration with other miniaturized devices

µTAS or Lab-on-a-Chip


Reagent storage and delivery (array of valves)

Sample metering (nL quantities)

Sample pretreatment (filtration)

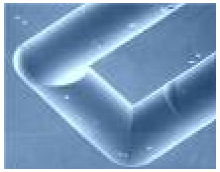
Light source and photodetector (pair of Si diode/photodiode optical filter)

Actuation (integrated pump)

Communication (CMOS, wireless, LCD…)

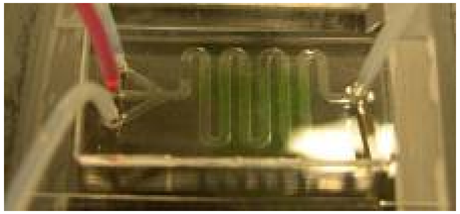
Materials for microfluidic systems

- Pyrex glass
  - *Wet etching (HF, BHF) from 10 nm to 300 µm*
  - *Multi-layer process (integration of electrodes, wafer-wafer alignment)*



- Silicon
  - *Wet and dry etching, surface micromachining*
- SU-8 photoepoxy
  - *Pattern by photolithography*

- PDMS, UV glue
  - *Soft lithography (mould in SU-8 or Silicon)*
  - *Reversible bonding (or irreversible with O2 plasma to oxidize surfaces)*
- Thermoplastics
  - *Pattern by hot embossing, injection molding*



Fabrication

Chronologically, microfabrication techniques evolved to:

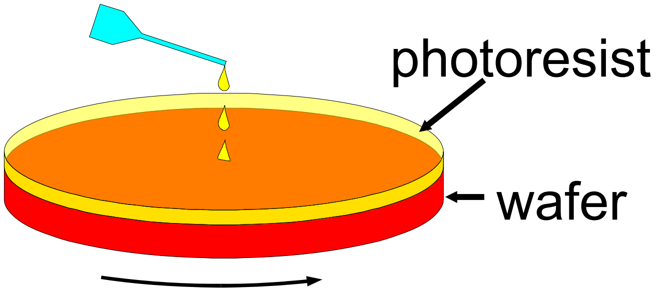
- offer more flexibility in design
- require less technology infrastructure
- become cheaper to produce

- Wet etching in Pyrex glass, thermal bonding (also in Silicon)
- Wet/Dry etching in silicon to produce shapes replicated in polymers
- Soft lithography (layout produced in thick photoresist and replicated in polymer)
- Hot embossing (PMMA…) and injection molding

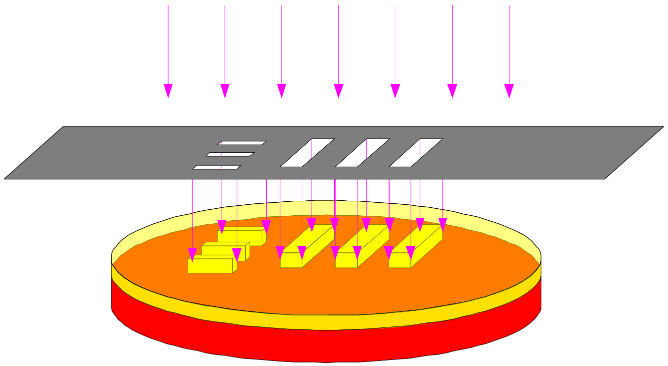
Fabrication: cleanroom

- Standard lithography in cleanroom

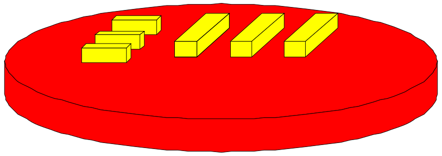
(1) resist deposition by spin-coating



(2) optical lithography



(3) development



Fabrication: cleanroom

- Standard etching in the cleanroom

Wet etching

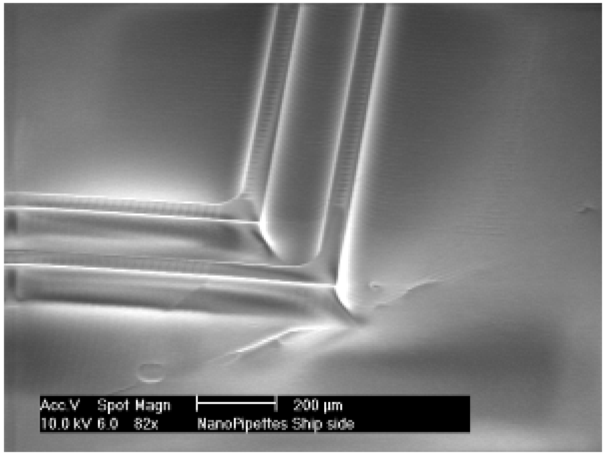
Dry etching

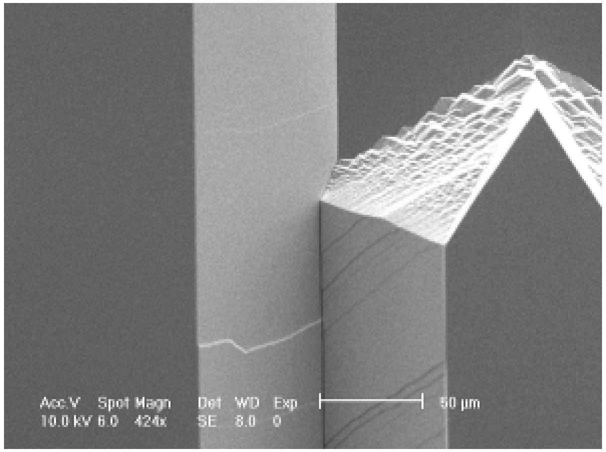
isotropic

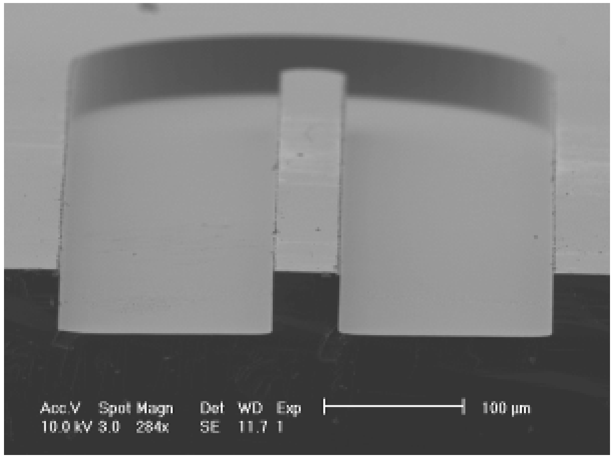
anisotropic

isotropic

vertical



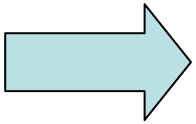




Fabrication: cleanroom

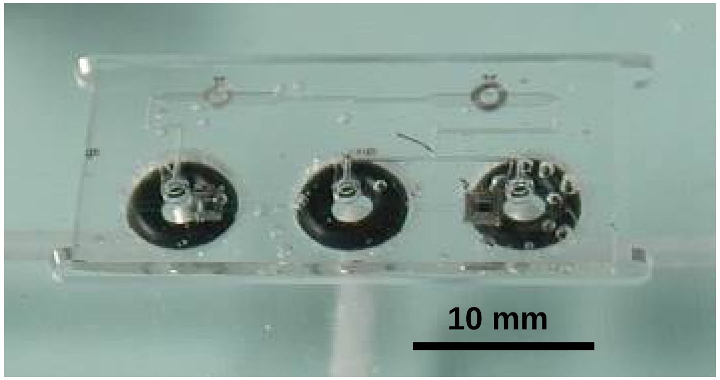
- Chip sealing: Anodic bonding or Fusion bonding in the cleanroom

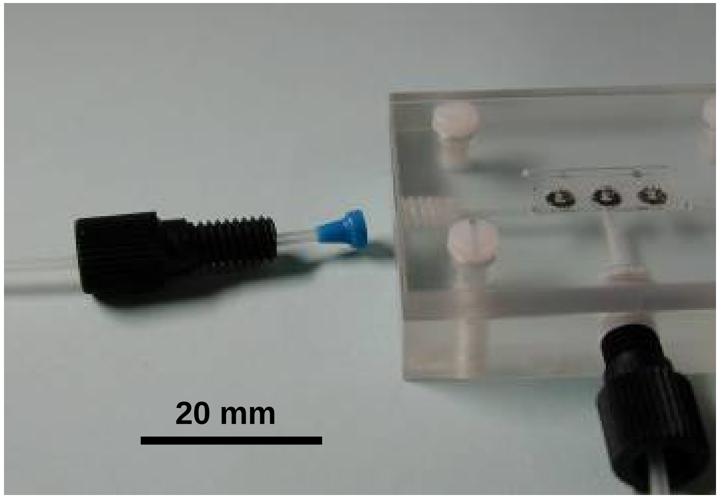
- Chip-to world interface



Leakage if:

bad bonding / or interconnection





Fabrication: cleanroom

- Advantages:
  - » Highly reproducible fabrication process
  - » Known surface chemistry
  - » No absorbtion of chemicals
  - » Strong bonding

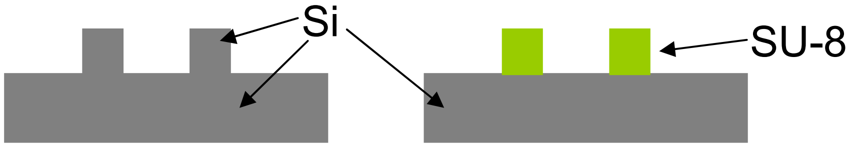
- Disadvantages:
  - » Time consuming
  - » Expensive: only few devices per wafer
  - » Needs a cleanroom to fabricate the chips
  - » Not really disposable

Fabrication: Soft lithography

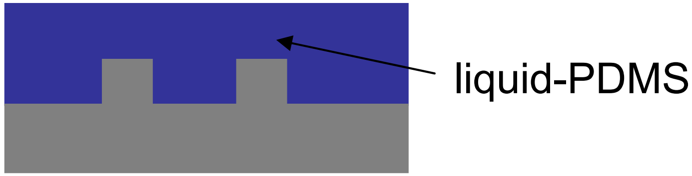
- Chip microfabrication in any lab
- Only need 1-2 days to fabricate a chip + interface
- Most popular material: PDMS
- Another emerging material: Norland Optical Adhesives, the « microfludic stickers »

Fabrication: PDMS Soft lithography

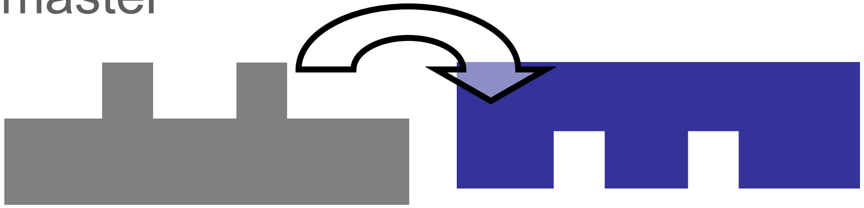
- Cleanroom: Dry etching of master (or thick photoresist lithography)



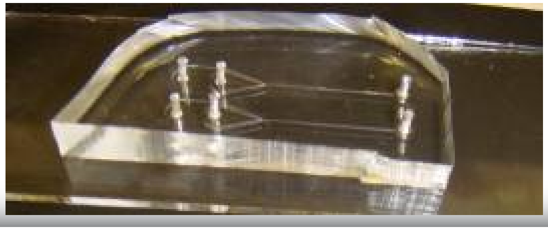
- Lab: Pre-PDMS poured over the master, polymerization



- Lab: PDMS peeled-off from the master



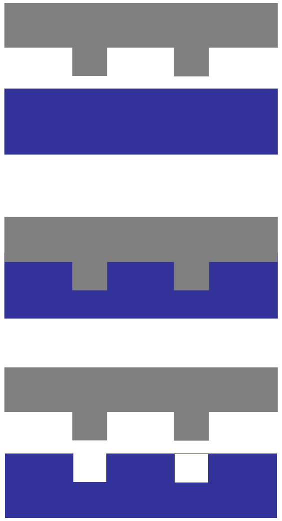
- Lab: Bonding (irreversible with O2 plasma treatment)



Fabrication: Mass production

- Microfluidic chips are big → expensive microfabrication
- Alternative → volume production in low cost plastic

  (hot embossing, injection molding)



PDMS vs NOA

	PDMS	NOA
Chemical resistance against organic solvents	No	Yes (most)
Gas permeability	Yes	No
Bonding to glass, itself, etc..	Yes	Yes
Curing time	10 min to 2 days	10–20 min
Biocompatibility	Yes	Yes
Duration of surface modification	½ day	2 months and more
Commercialy available	Yes	Yes

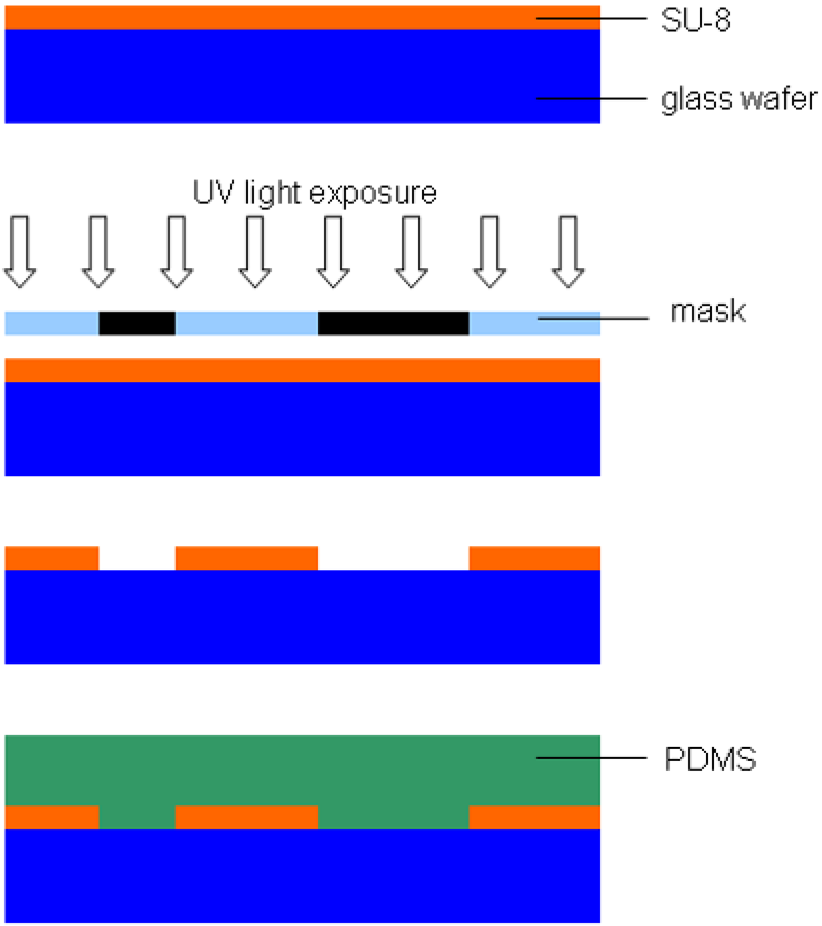
Why NOA ?

- Resistant to organic solvents
- Surface modification is stable
- Same microfluidic design can be either:
  - Microfabricated (2-4 months turnaround)
  - Tested by NOA rapid prototyping with only one designed wafer fabricated in the cleanroom (1-2 weeks turnaround)

NOA: Fabrication

- Master fabrication in two steps

A: microfabrication in the cleanroom



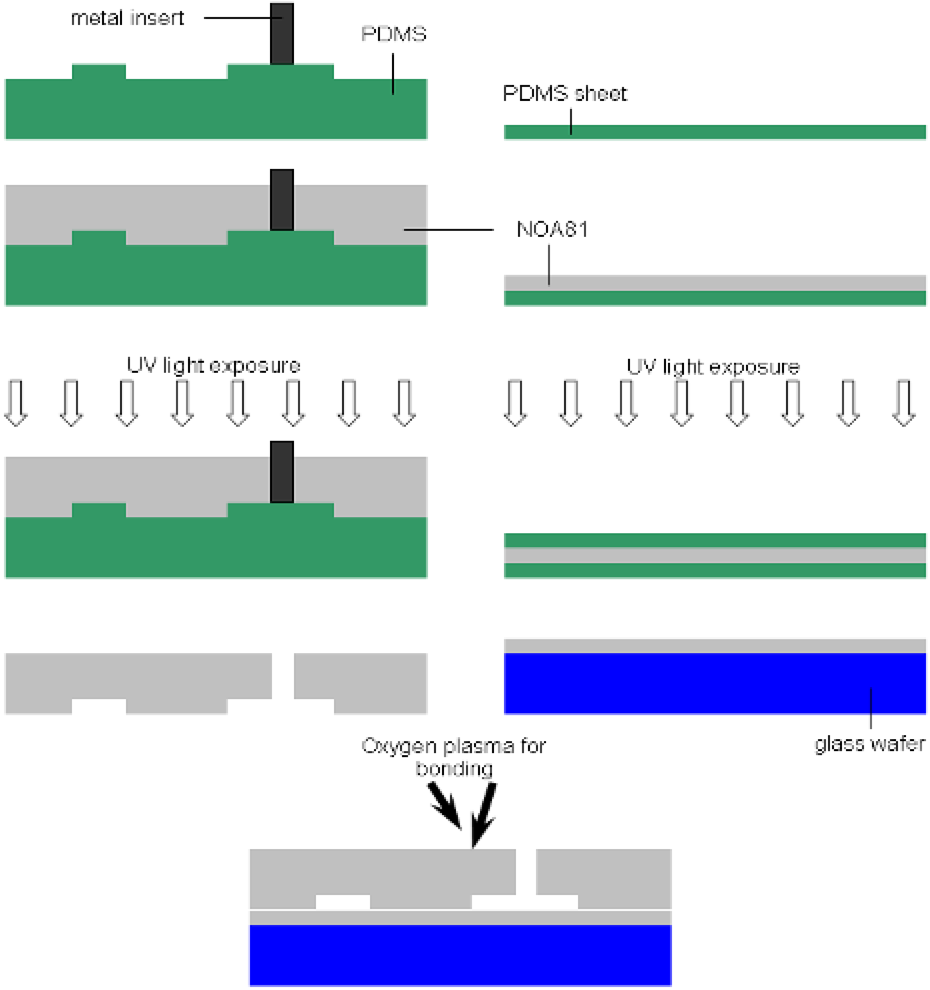
B: PDMS molding

NOA: Fabrication

- Soft lithography on PDMS master

Same basic procedure as

PDMS soft lithography

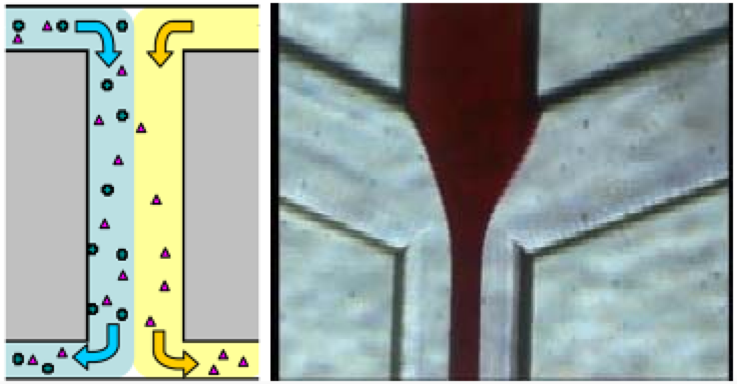


NOA: Nano-Tera Project IrSens

- Microfluidic System for Near- and Mid-Infrared Analysis of Human Saliva

- Goal: build an integrated optofluidic system for cocaine detection by IR-spectroscopy

- Microfluidics for liquid handling at the interface between light excitation and detection



NOA: Chemical resistance

- Tested different organic solvents
- Chloroform, ethyl acetate, n-pentane, n-hexane, n-heptane, cyclohexane
- Bonding area was attacked fast by chloroform
- Bonding area attacked after some time (>4h) with ethyl acetate

NOA: Surface properties

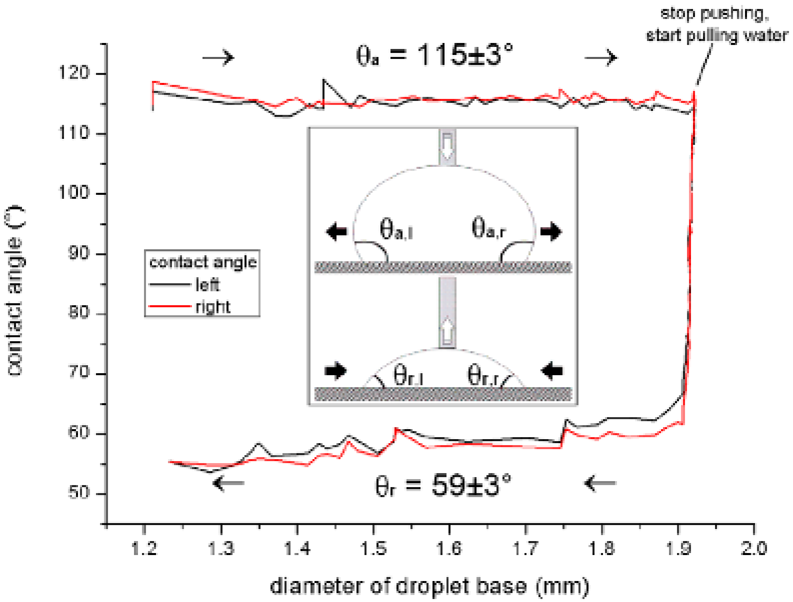


Fig. 4: Dynamic wetting behavior analysis on NOA81 surface with 1wt% of APTES in its bulk. The advancing (θ_a) and receding (θ_r) contact angle was measured on the left and right side of the water droplet.

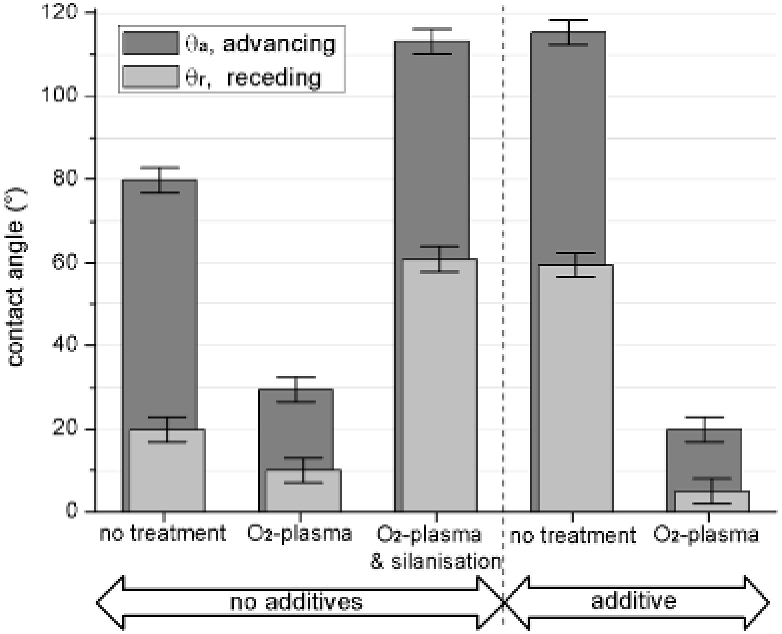


Fig. 5: Overview of dynamic wetting behavior of water on differently treated NOA81 surfaces. As additive APTES was mixed in the uncured polymer.

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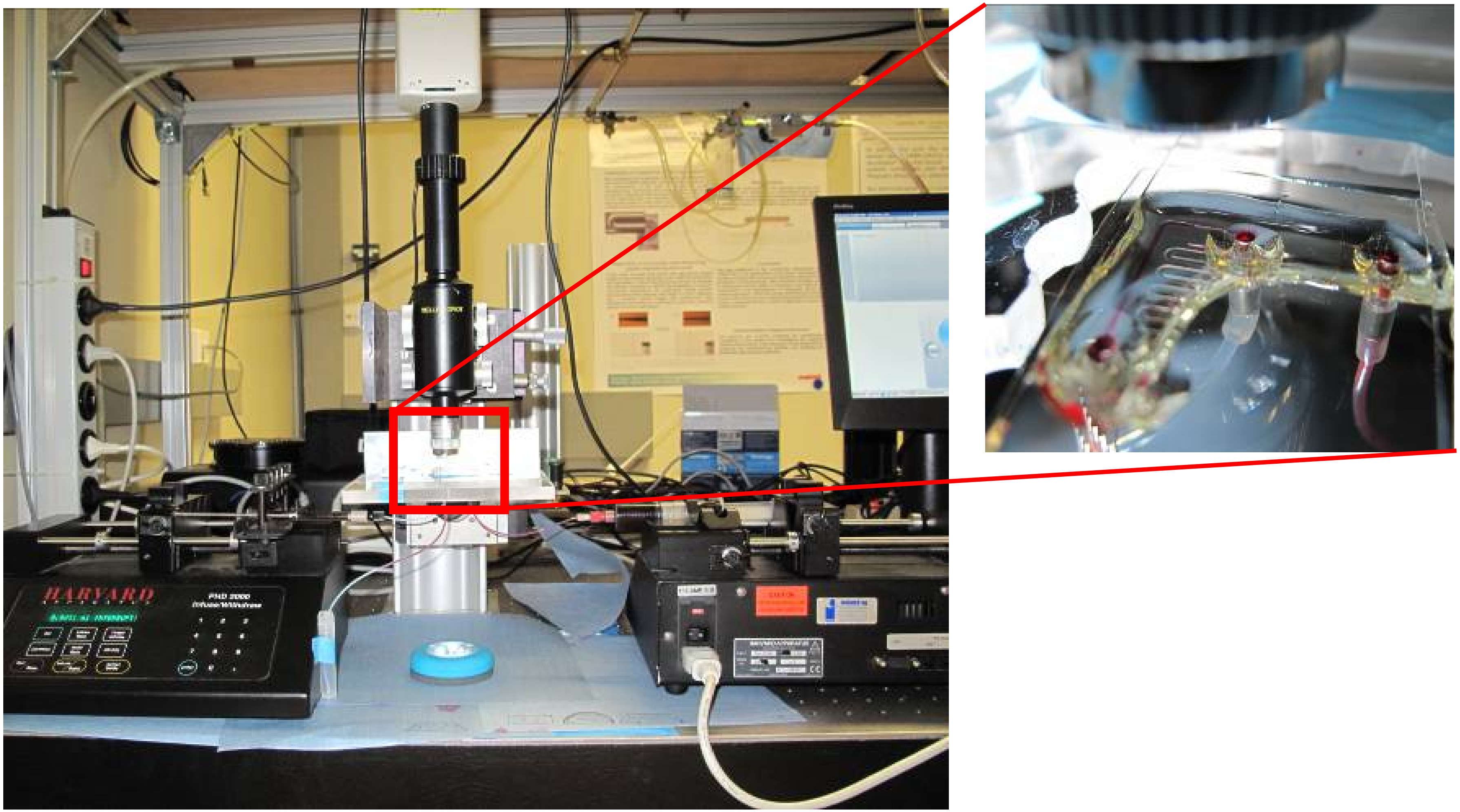
NOA: Droplet generation

µ-fluidic Chip & Measurement Setup



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NOA: Droplet generation

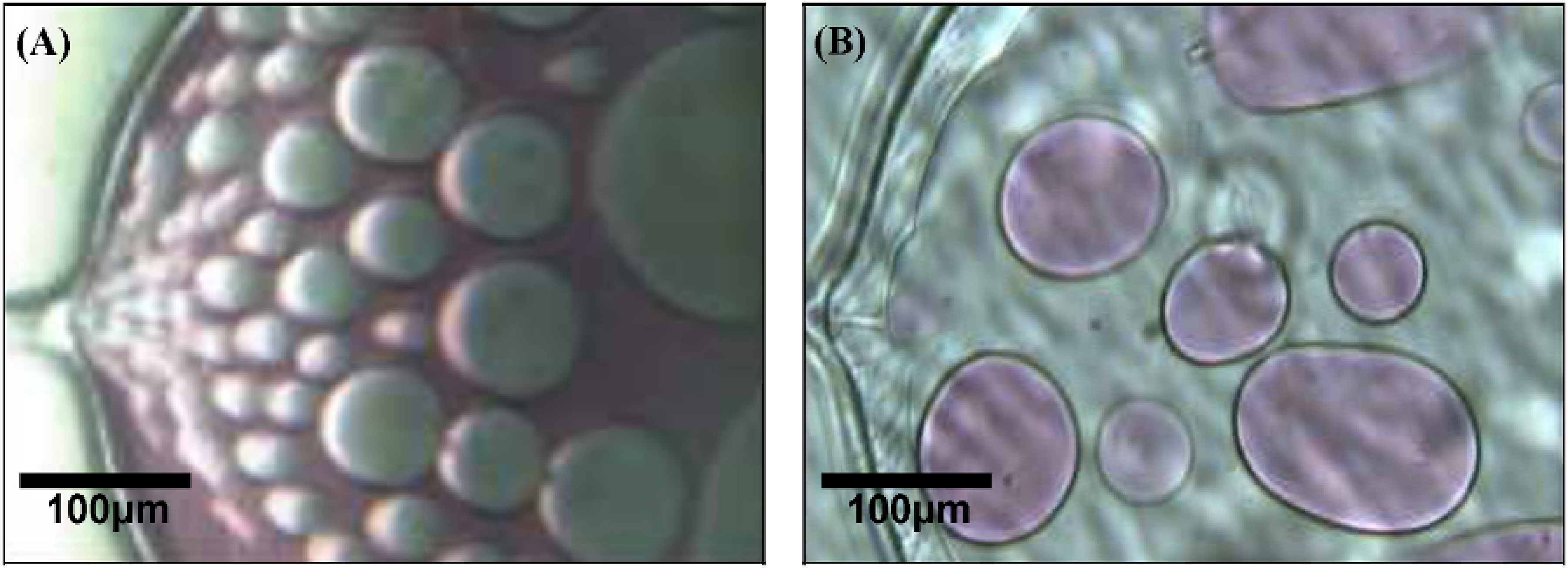

Fig. 6: (A) Oil-in-water droplet generation: Ethylacetate droplets generated in saliva (colored with amarant) in a hydrophilic microfluidic channel. (B) Water-in-oil droplet generation: Saliva (colored with amarant) droplets generated in ethylacetate in a hydrophobic microfluidic channel.

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NOA: Fluorescent spectra

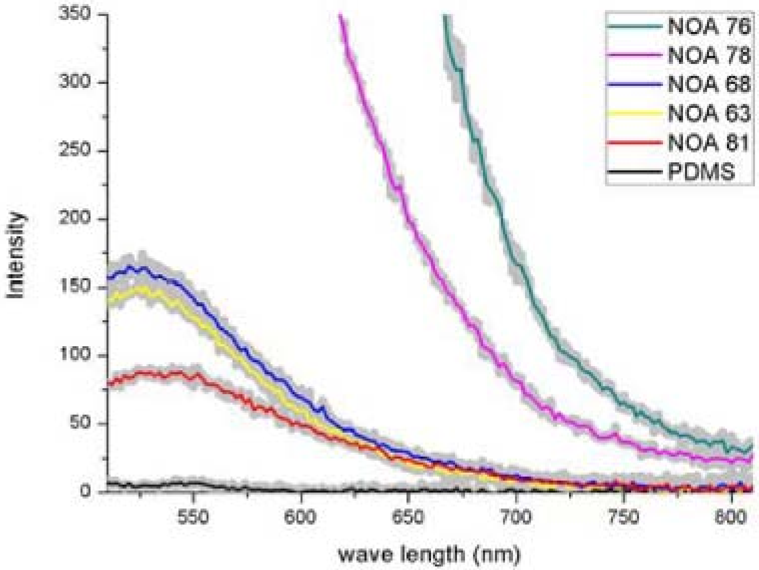

Figure 1: Comparison of fluorescent emission spectra of different NOAs and PDMS (excitation at λ_{ex}=470nm), 20 days after chip fabrication. The grey region around each plot represents the standard deviation of the measurement.

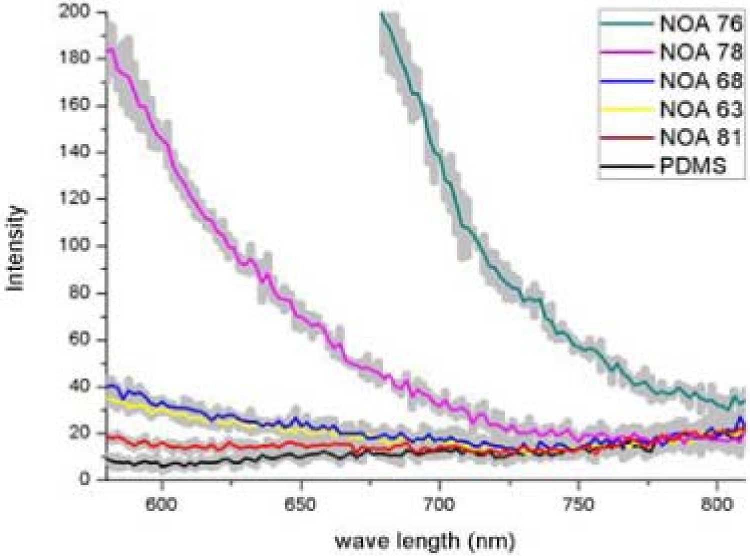

Figure 2: Comparison of fluorescent emission spectra of different NOAs and PDMS (excitation at λ_{ex}=546nm), 20 days after chip fabrication. The grey region around each plot represents the standard deviation of the measurement.

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NOA: Fluorescent spectra

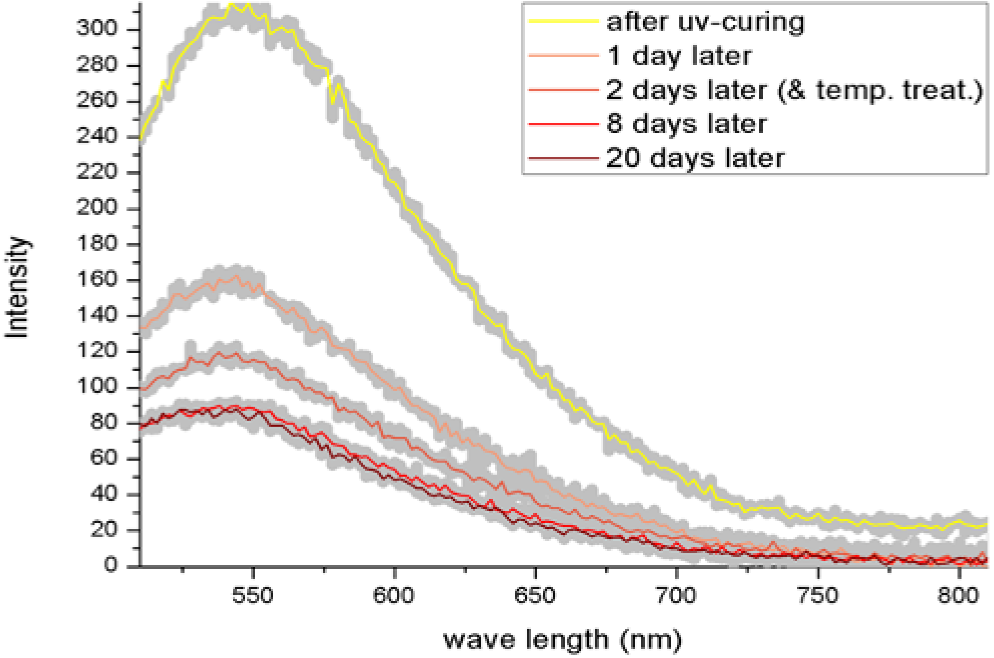

Figure 3: Evolution of fluorescent emission spectrum of NOA81 (excitation at λ_{ex}=470nm); directly after the UV-curing, 1 day after the fabrication, 2 days later and after a temperature treatment of 60°C for 2h, 8 and 20 days later. The intensity is decreasing and stable 8 days after the fabrication. The grey region around each plot represents the standard deviation of the measurement.

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Applications: Capillary electrophoresis

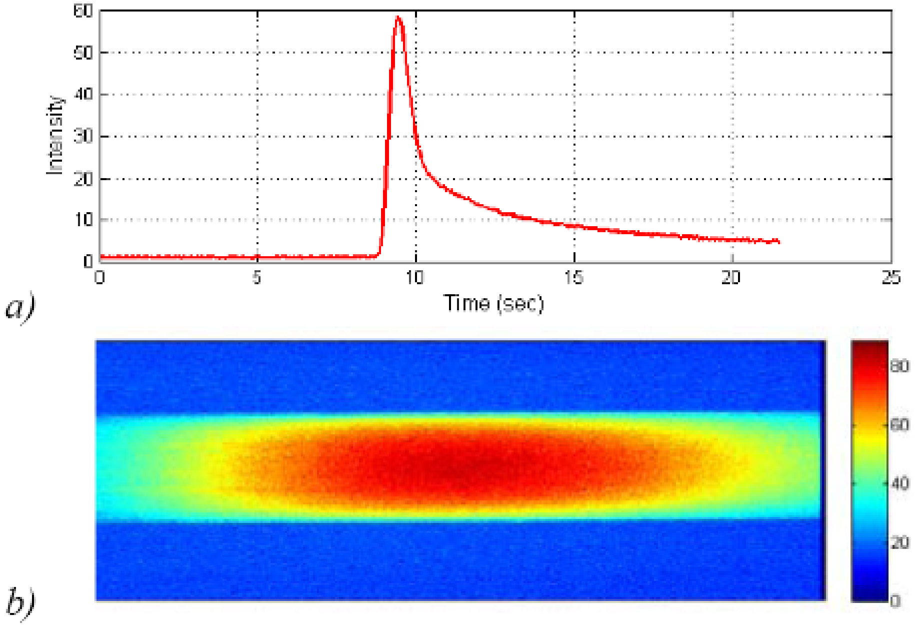

Figure 5: Capillary electrophoresis injection of a sample of Rhodamine B (141 µM, λ_{ex}=540 nm,λ_{em}= 625 nm) with 20 mM sodium tetraborate pH 9.0 as running buffer. An electrical field of 220 V/cm was applied along the NOA separation channel (17 mm). a) Intensity measurement of a well defined plug over time, 10 mm away from the channel intersection; b) Intensity picture of a Rhodamine B plug captured by the CCD camera.

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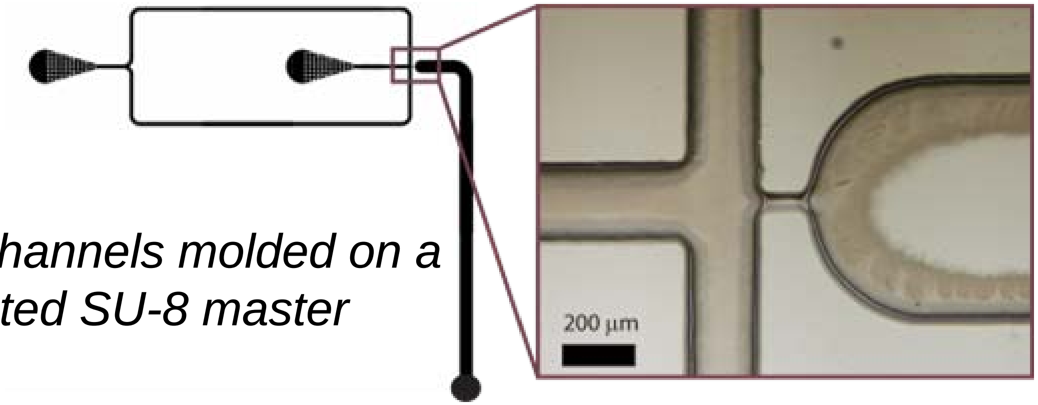
Applications: bead generation

- Monodisperse biodegradable polymer (PLGA) microparticles
- Control of size dispersion
- PLGA Diluted in ethyl acetate and sprayed into aqueous phase



NOA microchannels molded on a microfabricated SU-8 master

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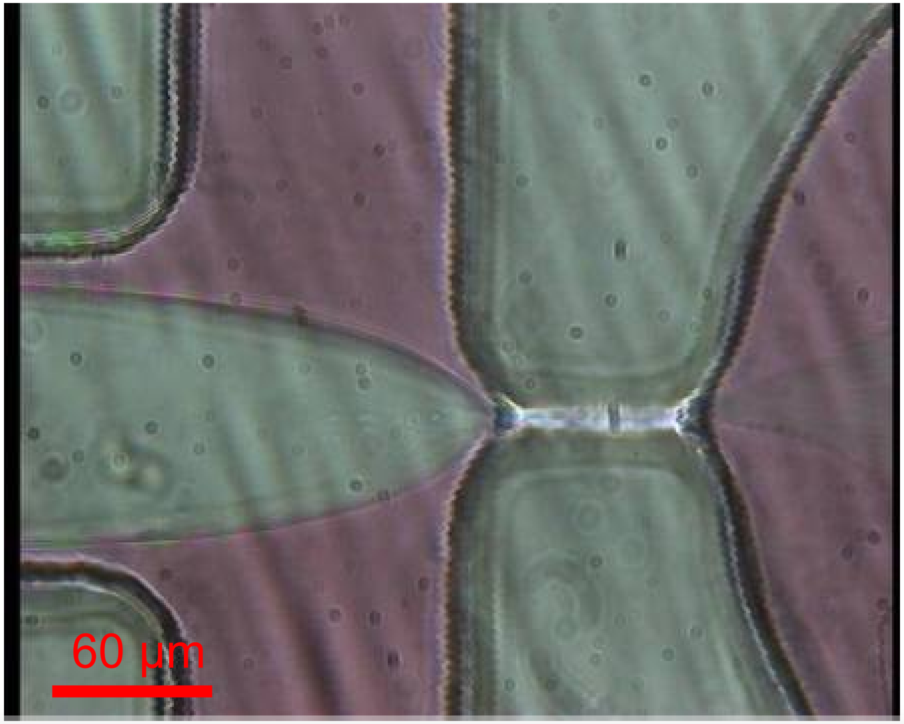
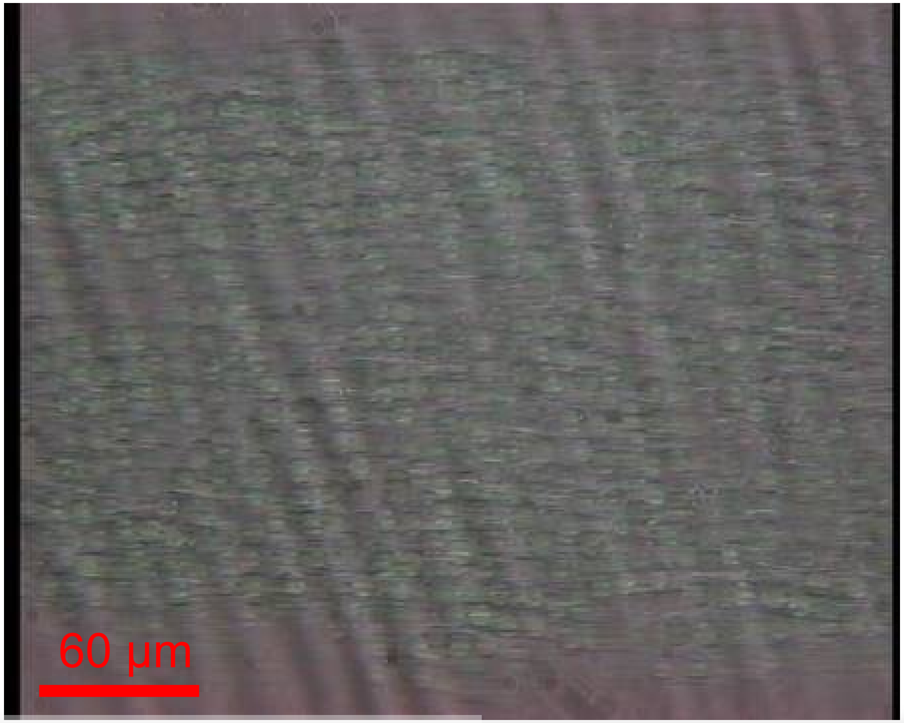
Applications: bead generation

Droplet size & distribution depends on various parameters

- Flow rate ratios
- Width of nozzle
- etc…





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Summary

- Microfluidic stickers well suited for protoyping
- Full polymer properties still need to be investigated
- Compatible with wide range of liquids, stable surface properties
- Easy, fast and cheap to implement

Acknowledgements

Prof. Nico F. de Rooij

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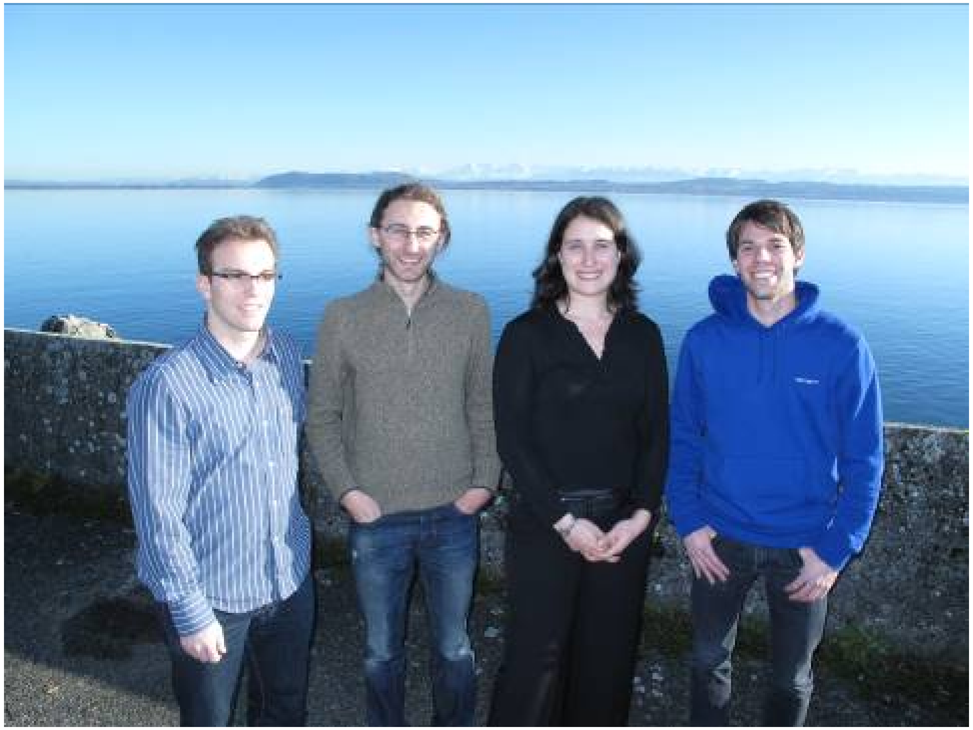
Mr Philip Wägli



Microfluidics Team @ SAMLAB