Microfluidic Stickers

Alexandra Homsy
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

Why microfluidics?

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

![Image showing wet and dry etching with isotropic and anisotropic categories]
Fabrication: cleanroom

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

- Chip-to world interface

  Leakage if:

  bad bonding / or interconnection
Advantages:
» Highly reproducible fabrication process
» Known surface chemistry
» No absorption 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

<table>
<thead>
<tr>
<th>Comparison</th>
<th>PDMS</th>
<th>NOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical resistance against organic solvents</td>
<td>No</td>
<td>Yes (most)</td>
</tr>
<tr>
<td>Gas permeability</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Bonding to glass, itself, etc..</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Curing time</td>
<td>10 min to 2 days</td>
<td>10–20 min</td>
</tr>
<tr>
<td>Biocompatibility</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Duration of surface modification</td>
<td>½ day</td>
<td>2 months and more</td>
</tr>
<tr>
<td>Commercially available</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
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
Fig. 4: Dynamic wetting behavior analysis on NOA81 surface with 1wt% of APTES in its bulk. The advancing ($\theta_a$) and receding ($\theta_r$) 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.

Philip Wägli, Alexandra Homsy, Nico F. de Rooij, Accepted for oral presentation at Eurosensors 2010 conference
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 amaran) in a hydrophilic microfluidic channel. (B) Water-in-oil droplet generation: Saliva (colored with amaran) 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 \( \lambda_{ex}=470\text{nm} \)), 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 \( \lambda_{ex}=546\text{nm} \)), 20 days after chip fabrication. The grey region around each plot represents the standard deviation of the measurement.

Philip Wägli, Blaise Guélat, Alexandra Homsy, Nico F. de Rooij, accepted for poster at micro-TAS 2010 conference
NOA: Fluorescent spectra

Figure 3: Evolution of fluorescent emission spectrum of NOA81 (excitation at $\lambda_{ex}=470$nm); 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, $\lambda_{ex}=540$ nm, $\lambda_{em}=625$ 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.

Philip Wägli, Blaise Guélat, Alexandra Hornsy, Nico F. de Rooij, accepted for poster at micro-TAS 2010 conference
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…
Summary

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