ELECTROKINETIC MIXERS BASED ON STIMULI-RESPONDING SURFACES

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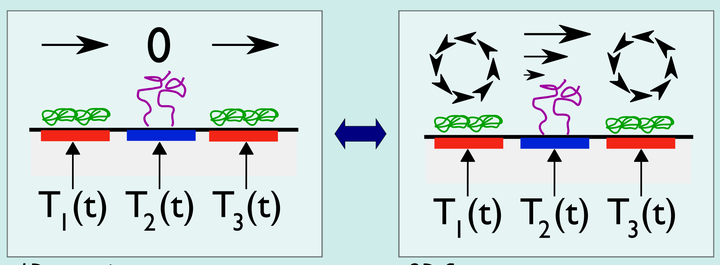
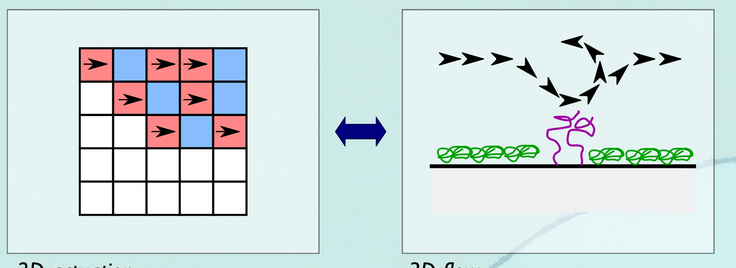
Goal & principle

We report on a novel approach for mixing fluids in microsystems, relying on convective rolls and complex flows caused by on-demand surface actuation.



1D actuation *2D flow*

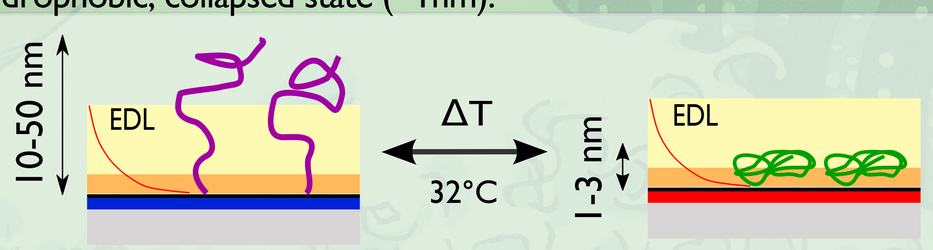
Spatio-temporal control of surfaces properties is achieved through switchable thermo-sensitive polymers grafted on charged surfaces and activated by integrated addressable microheaters.



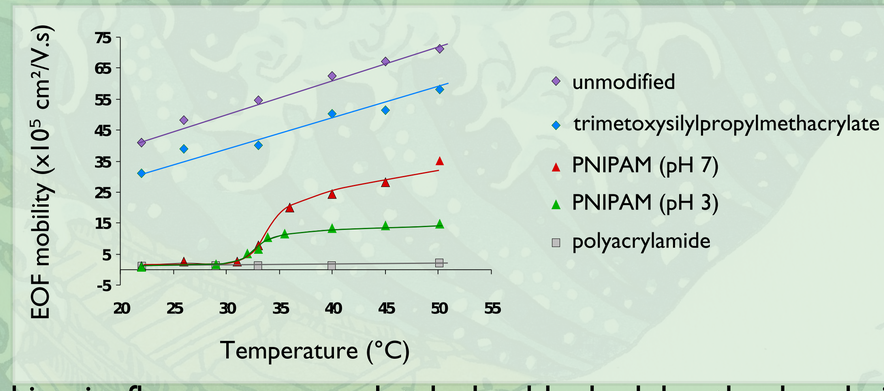
2D actuation *3D flow*

Thermoresponsive polymers

- Surface chemistry: poly(N-isopropylacrylamide) (PNIPAM) grafted via a silane layer
- Reversible switch around 32°C (LCST, lower critical solution temperature) from a hydrophilic, swollen state (~10nm) to a hydrophobic, collapsed state (~1nm).



We can dynamically manipulate the flow-boundary conditions at the nanometer scale within the electrical double layer (EDL). Thus we gain a control over the liquid flow on the microscopic scale.



Electrokinetic flows can completely be blocked by the brush in its swollen state, while they can build up unhindered when the brush is collapsed [1]. We fabricate PNIPAM-coated integrated microheaters to achieve local surface activation and hence generation of complex flows [2].

References

[1] Sudor et al., Spatio-temporal tuning of stimuli-responding surfaces for dynamic control of electro-osmotic flows, µTAS'06, Tokyo, 2006.

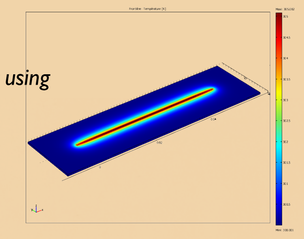
[2] A. Adjari, Electro-osmosis in inhomogeneously charged surfaces, Phys. Rev. Lett., 75, p. 755 (1995)

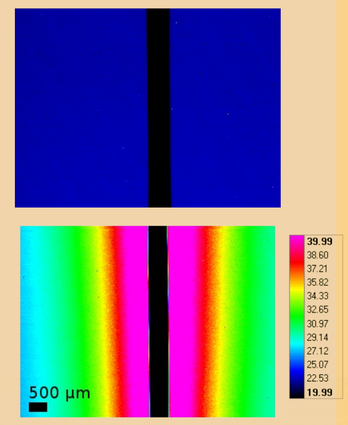
Integrated microheaters

Linear resistive heaters

- 500µm- and 100µm-wide lines
- Ti 1000 Å / Au 8000 Å on pyrex substrates
- PECVD SiO2 as grafting & isolating layer
- LCST reached with a few volts
- Good lateral isolation.

Multiphysics modeling using Comsol

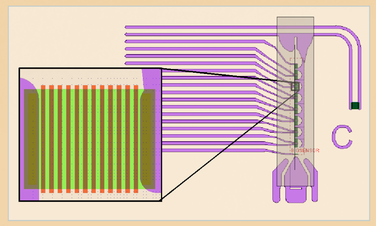




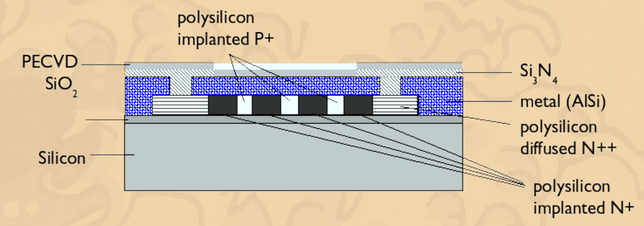
Infrared thermal imaging. Top: 0V, bottom: 4V, 51°C

Polysilicon heater arrays

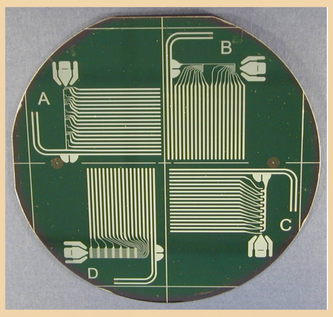
- Combination of non-linear elements (P & N zones) and symmetrical tresholds (NPN / PNP structures)
- 500µm x 500µm heaters composed of 12 alternate 20µm strips of P+ and N+ implanted polySi.
- PECVD SiO2 layer.



Structure of the heaters and close-up on one



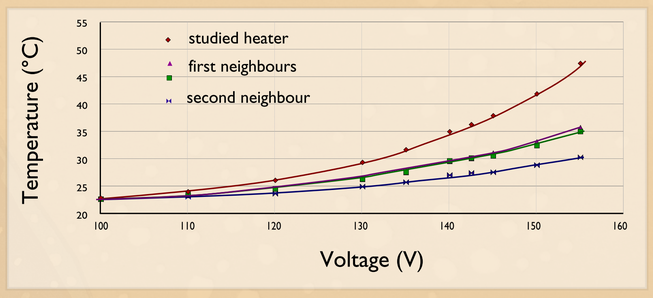
Schematic cross-section of an elementary cell

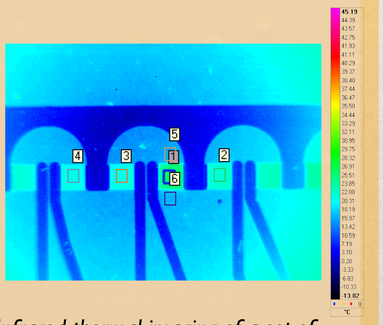


Full wafer with several devices

Thermal & electrical characterization

- Lateral isolation to improve
- High voltage: not embeddable



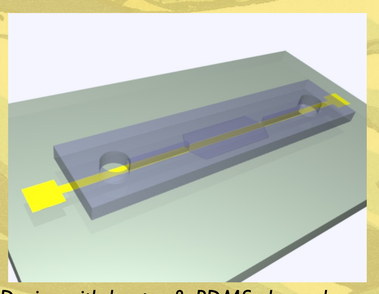


Infrared thermal imaging of a set of microheaters

Addressable heaters allow us to precisely control temperature on individual cells. PECVD SiO2 can be grafted with PNIPAM to switch surface charges and thus provoke complex flows.

Perspectives

- Mixing of liquids in PDMS microchannels (currently under evaluation)
- Developing hybrid PNIPAM-based micro-systems for biochemichal analyses
- Sample desalting & pre-concentration for nanoLC / ESI-MS analysis
- Use of PNIPAM-functionalized beads as carriers of stationary phases



Device with heater & PDMS channel designed to use beads