NANOSPAIN 2008
Braga (Portugal) April 14-18, 2008
NanoIberian Conference

Electroactive β-PVDF Polymer as Fluidic Acoustic Mixer for Lab-on-a-Chip Applications

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Summary

Motivation and Objectives

The Biological Microsystem Advantages

Lab-On-a-Chip Concept

Lab-On-a-Chip Design and Fabrication

Experimental Results

Conclusions

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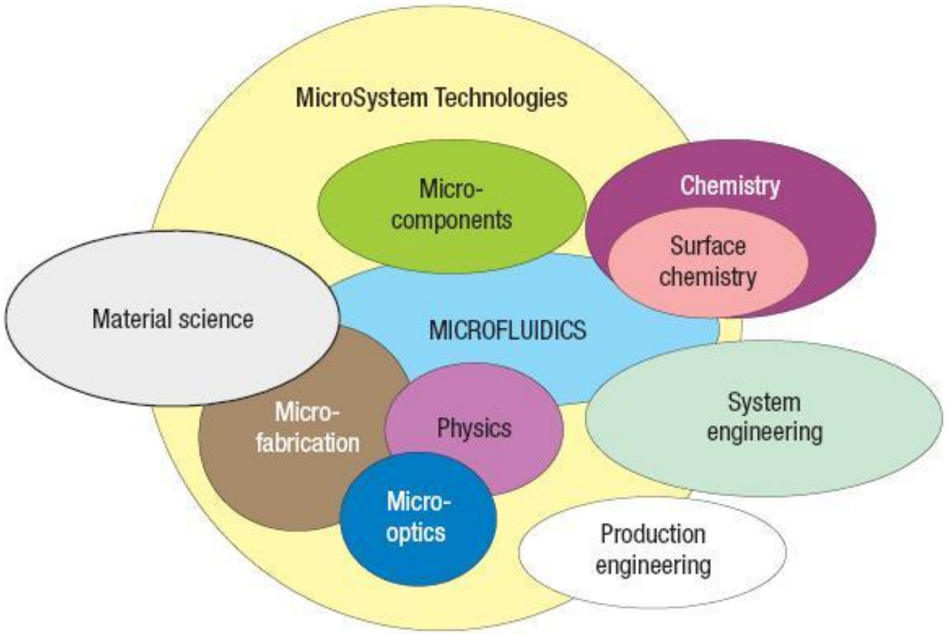
Microfluidics:

- Laminar flow regime (no turbulent mixing);
- Surface tension, surface charge become important.



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Current clinical analysis systems disadvantages:

- Costs;
- Mistake in logistics;
- Delayed results.

Symptoms → Medical → Analysis (Lab) → Results → Therapy

- Two steps removed
- Decreased of the response time and cost
- Easily applicable in developing country
- Developed country: point-of-care, speed, cost

De Melo. 2007. World lab-on-chip congress

The Biological Microsystems Advanteges

- **Small components**
  - Reduced weight (portable) and size (implantable, integratable);
  - Reduced energy consumption.

- **Fabrication**
  - Reduced price (disposable).

- **Small amount of samples/reagents**
  - Reduced consumption of (expensive/limited) chemicals;
  - Reduced production of (toxic) waste;
  - Accurate dosing;

- **Complex systems**
  - Integration of sensors, parallel process, automation.

- **Device performance**
  - Scaling law for new effects and better:
  - Increased heat exchange;
  - Fast mass transport (rapid analysis).

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Main Objective:

- Lab-on-a-chip with fluidic acoustic microagitation to quantify the concentration of the molecules in biological fluids.

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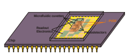
Why lab-on-chip?

- Miniaturization can speed up the reaction;

- Hundreds of assays can be performed simultaneously, saving considerable time and effort;



Lab-On-a-Chip Concept

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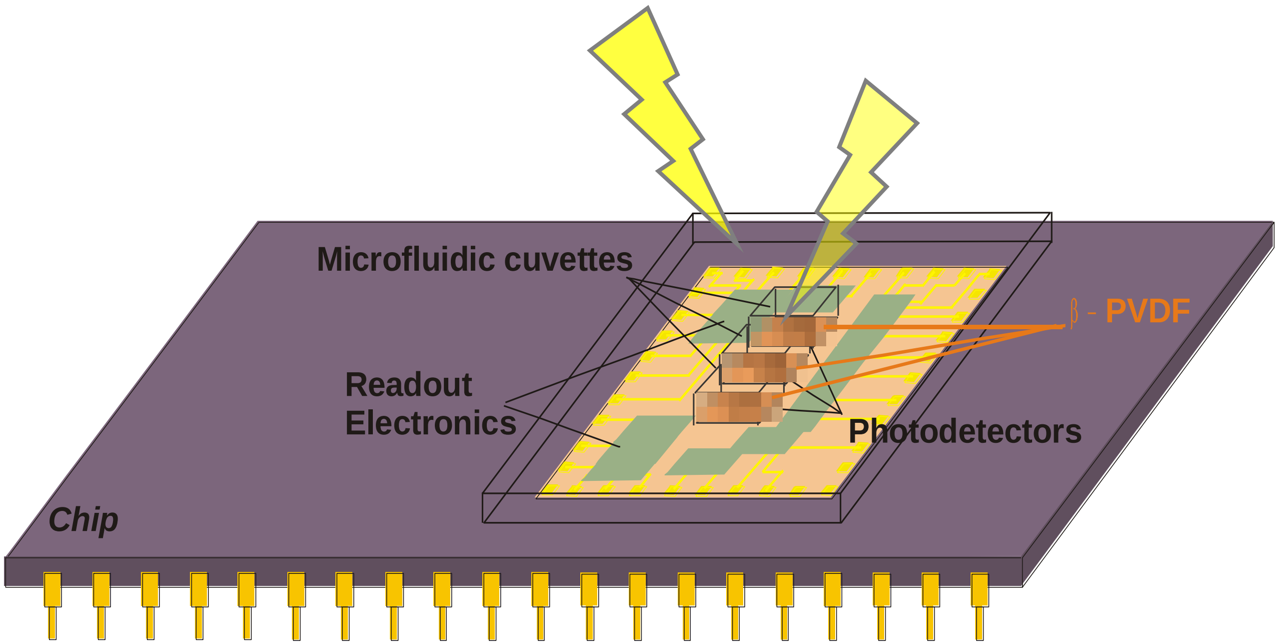

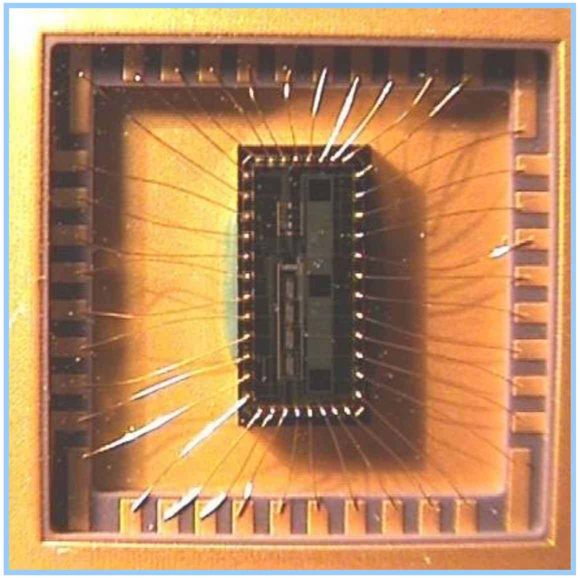

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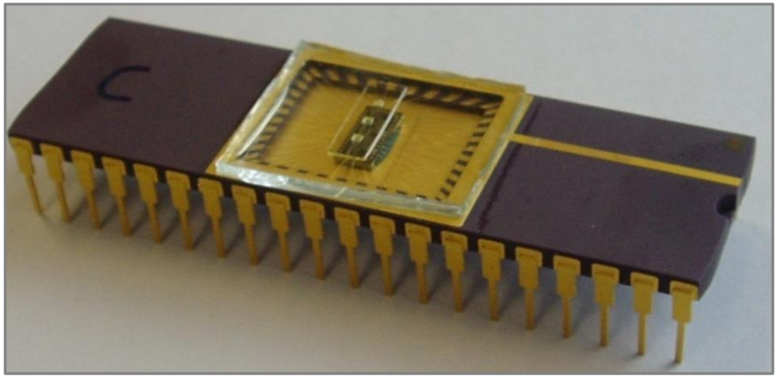
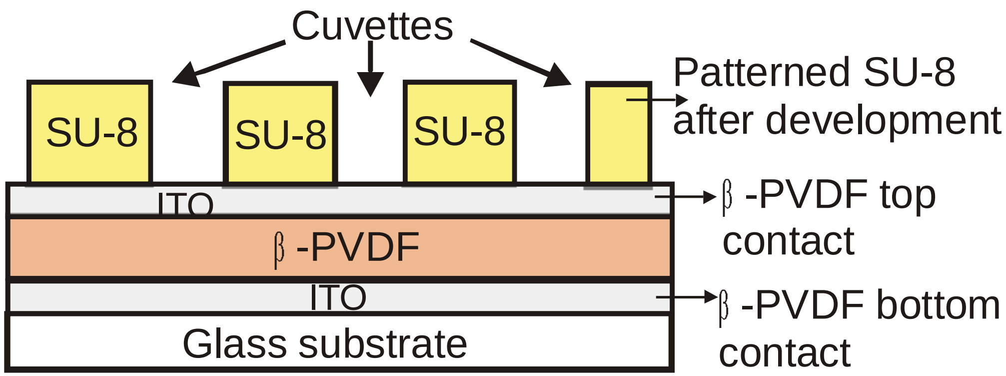
Cuvetes:



- 1) Chemical Reagent;
- 2) Mixture Sample + Reagent;
- 3) Standard Sample.



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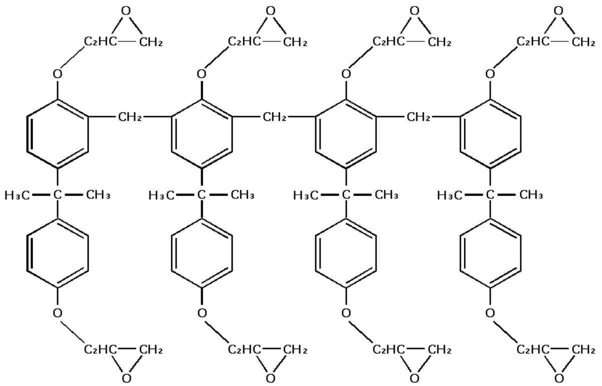
Why using SU-8?



- Low Cost;
- Biocompatible;
- High mechanical strength;
- Good adhesion on many different substrate materials;
- UV lithography semiconductor compatible;
- Very low roughness → suitable for optical absorption measurements.

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Major problems with microscale:

- Miniaturization of biological assays is more complex than just transferring reactions to smaller volume;
- Miniaturization in itself does not help to integrate and automate the tests from the biochemical point of view;
- Lack of turbulence;
- Typical Reynolds < 10 → Diffusion mixing is dominant.

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Solution:

- Induce the microfluidic die by a mechanism that accelerates the mixing and the reaction, preferably with ANY external apparatus, internal moving parts or valves.

Alternating voltage applied to its contacts

↓

Generation of acoustic waves

↓

Fluidic Acoustic Microagitation

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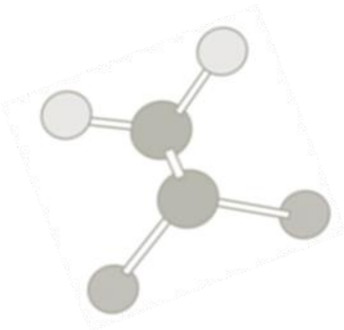
PVDF:



- Semi crystalline polymer;
- Presents four polymorphs (α, β, γ, δ)
- β-phase is the one which shows better proprieties to be applied in sensors, actuators and transducers, due to its higher piezo-, pyro- and ferroelectrics proprieties;
- Show excellent combination of processability, mechanical stress, chemical agent resistance, lightness, moldability, low cost production and chemically inertness;
- More area, more vibration;
- More thickness, less vibration.

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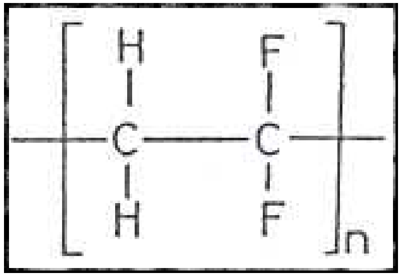
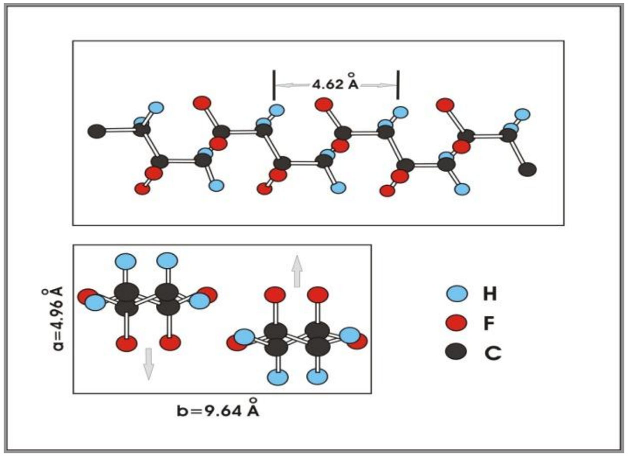
PVDF:

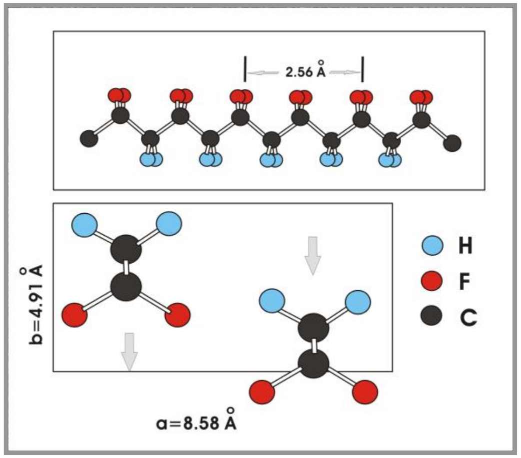
Monomer



α-PVDF



β-PVDF



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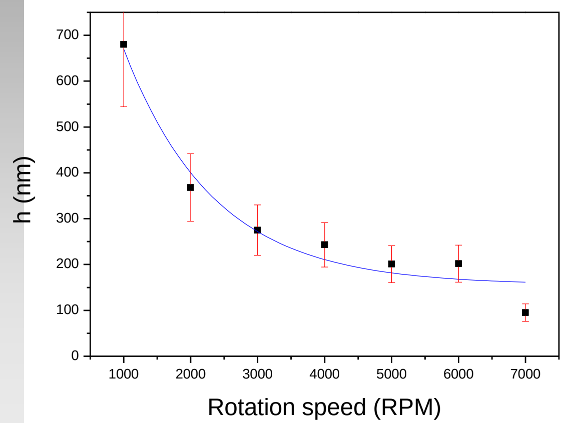
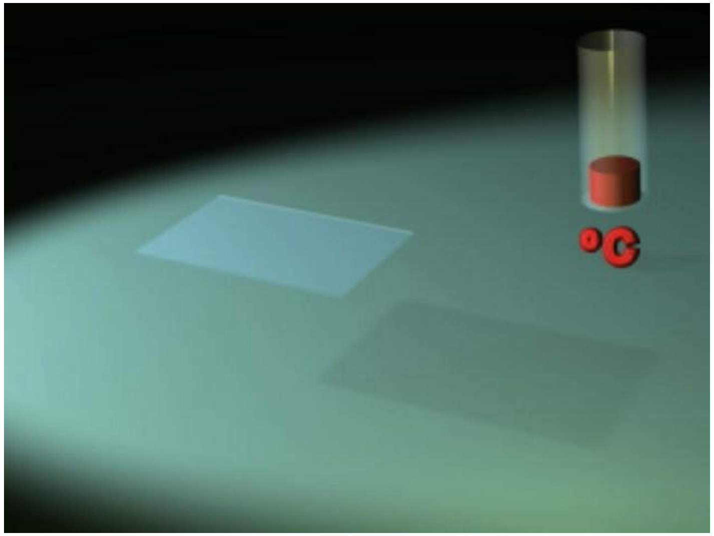
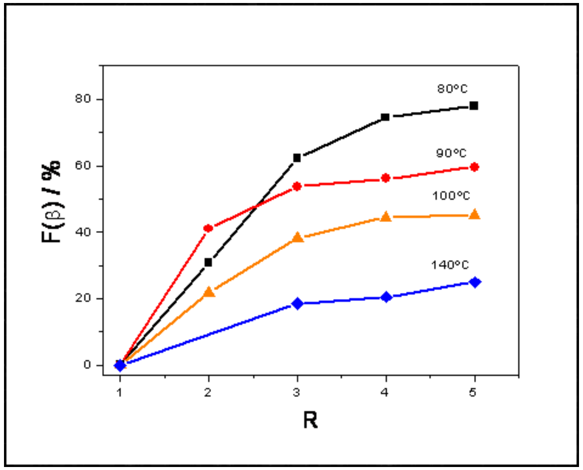
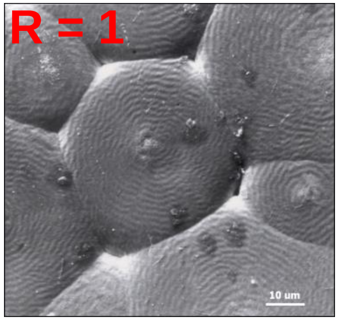
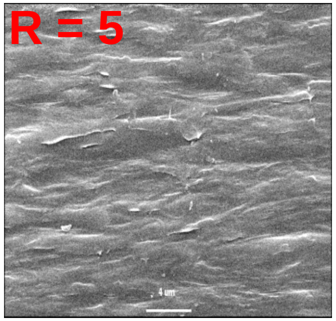
PVDF α-β Phase transition:











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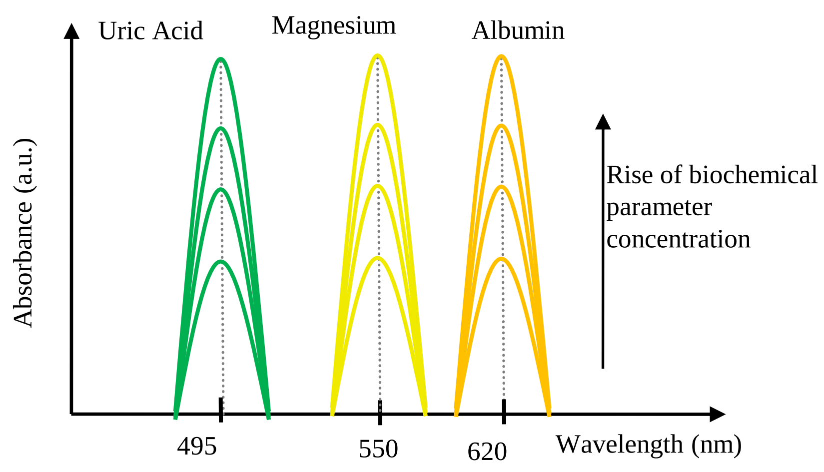
Evaluation of the mixing process based in the incorporation of piezoelectric β-PVDF polymer:

- Sinusoidal signal at 5V amplitude at various frequencies;
- Standards of urine with 30 mg/dl of uric acid concentration;
- Ratio Reagent/Urine → 50/1.



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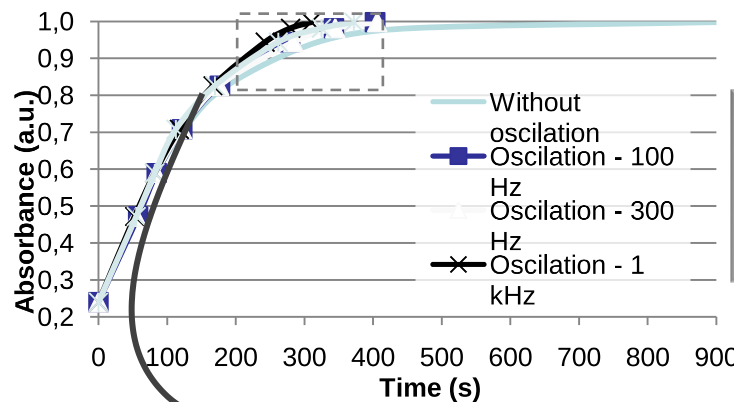
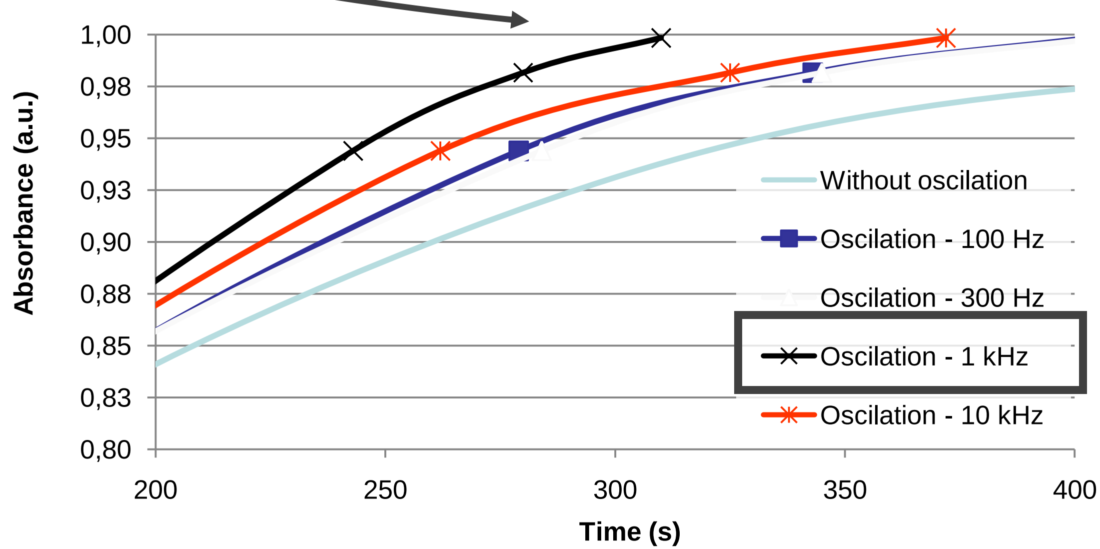
Complete and homogeneous mixing :

- Without agitation → ≈ 15 min at room temperature;
- With manual agitation + 5 min at room temperature;
- Mechanical agitation with macroscopic equipments.

Experimental Results



$$\frac{\mathrm{Time}_{\mathrm{frequency1KHz}}(300s)}{\mathrm{Time}_{\mathrm{Without\ oscillation}}(900s)} = 1/3$$



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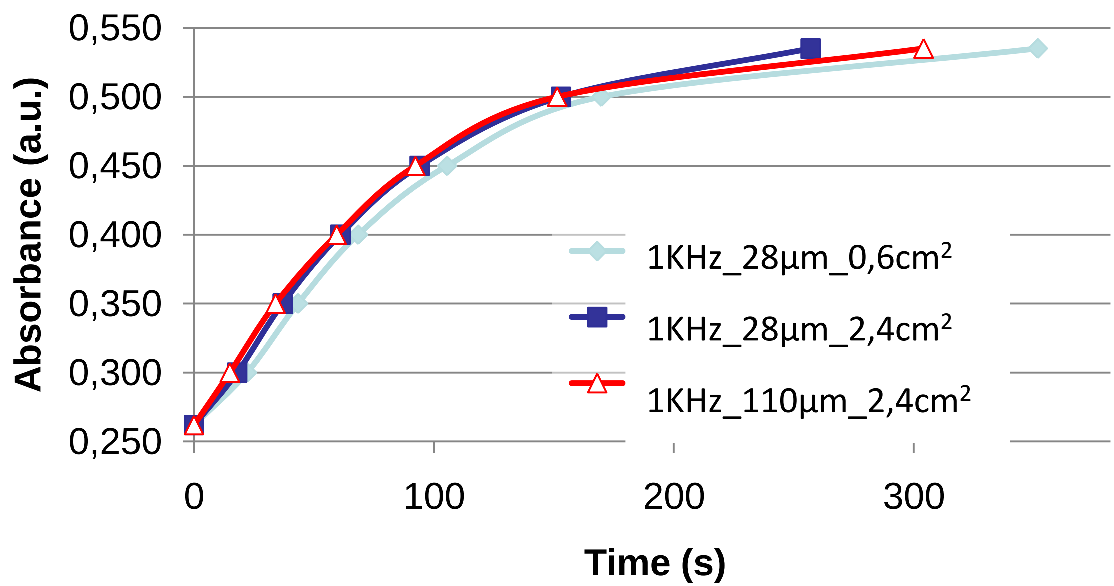
Influence of the thickness and area of the β-PVDF on the fluids reaction velocity :



Area

$$\frac{\text{Time\_28um\_2.4cm}^2(257s)}{\text{Time\_28um\_0.6cm}^2(352s)} = \frac{3}{4}$$

Thickness

$$\frac{\text{Time\_28um\_2.4cm}^2(257s)}{\text{Time\_110um\_2.4cm}^2(304s)} = \frac{5}{6}$$

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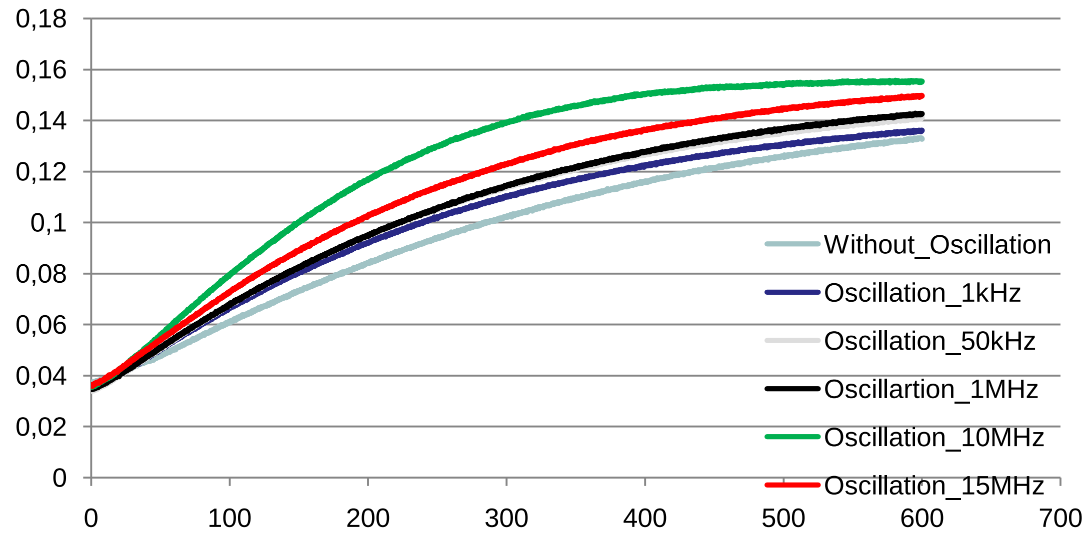
Frequency tests :



	Gain	Fraction
Without agitation	0	
1kHz	12.90%	1/8
50kHz	22.35%	2/9
1MHz	24.90%	1/4
10MHz	56.25%	4/7

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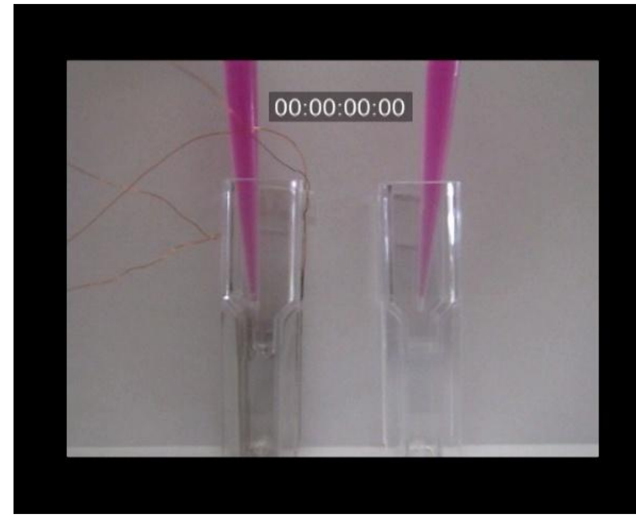
Qualitatively evaluation of the mixing process:



- Reaction between:
  Solution of Sodium Hydroxide,
  Sucrose,
  Potassium Permanganate.

- Sinusoidal signal with 10V amplitude and 15MHz frequency on β-PVDF transducer ;

- Reaction time improved in 93%.

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Conclusions:

- *The incorporation of fluidic acoustic microagitation in a lab-on-a-chip is advantageous when two or more fluids need to be mixed;*
- *Experimental show that, at 1 KHz, the mixing time is reduces to 1/3 of the time needed without agitation;*
- *Experimental results show that the thickness and the area of the polymer affects the mixing time of fluids;*
- *Acoustic microagitation becomes a preferred technology for effective mixing and allows the decreasing of the device sizes.*

Support:

- Portuguese Foundation for Science and Technology (grants PTDC/BIO/70017/2006 and POCI/CTM/59425/2004);

- R&D Algoritmi Centre , from University of Minho, Portugal.

Thanks for your Attention!

More information in:

- http://microlab.dei.uminho.pt/labchip/labchip.htm

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