

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

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Ingenious micromixing systems have been developed in order to overcome the limitations of mixing microflows in microfluidic devices reaching a complete and effective mixing in short times. Several approaches have been tried. MEMS (Micro Electro Mechanical Systems) based devices have been used, such as microvalves and micropumps [1]. However, these systems increase the cost of the system, the complexity of the control system and are difficult to integrate in a single-chip. Other approaches rely in long or complex channels topologies, that can be difficult to microfabricate and can involve long mixing times, especially when the fluids diffusion coefficients are very small [2]. A different approach can be the use of acoustic waves. They have been used both to promote mixing [3] and to pump [4] fluids. One possible way to achieve these effects, is using a piezoelectric material.

This study aims to the incorporation and validation of the use of a piezoelectric polymer Poly(Vinylidene Fluoride) in its β phase, β -PVDF, in a fully-integrated disposable lab-on-a-chip for point-of-care testing and monitoring of biochemical parameters in biological fluids (Figure 1). With the deposition of the polymer underneath the microfluidics structures, acoustic microagitation can be obtained through electrical actuation, which leads to the enhancement of mixing and reaction time without moving parts.

PVDF is a semi-crystalline polymer with large scientific and technological interest due to its electroactive properties. It shows an excellent combination of processability, mechanical stress, chemical agent resistance, lightness, moldability, low-cost production and chemical inertness. It is flexible, it has a low density (1.97g/cm^3) and it is easily produced into a thin-film. This polymer presents an unusual polymorphism in this class of materials, showing four different crystalline phases. The β -phase is the one which shows better properties to be applied in sensors, actuators and transducers, due to its higher piezo-, pyro- and ferroelectric properties [5]. Moreover, it can be easily processed in submicron size allowing integration in lab-on-chip systems.

Before the lab-on-a-chip device fabrication shown in Figure 1, preliminary experiments using regular cuvettes, with β -PVDF and its corresponding aluminum electrodes deposited on the external walls, were performed in order to validate the theoretical idea and to explore the effect of the thickness and area of the electroactive polymer on the acoustic microagitation process as well as the efficiency of the mixing. Tests were performed using two different β -PVDF thicknesses ($28\ \mu\text{m}$ and $110\ \mu\text{m}$) both with the same area ($2.4\ \text{cm}^2$) and using two different areas ($2.4\ \text{cm}^2$ and $0.6\ \text{cm}^2$) for the same thickness ($28\ \mu\text{m}$).

The evaluation of the mixing process was carried out using the Sigma Diagnostic kit (InfinityTM Uric Acid Reagent) and a standard of urine with $15\ \text{mg/dL}$ of uric acid concentration (Sigma, 2006). Optical absorption spectrophotometry (Unicam Helios Gamma&Deta) is used as the analytical technique. The above reagent reacts with the sample of urine containing uric acid in a 50:1 ratio and produces a pink color with maximum absorption at $495\ \text{nm}$. The microagitation was set using sinusoidal signals of $3.3\ \text{V}$ amplitude with $1\ \text{kHz}$ frequency applied to the electrical contacts of the β -PVDF. The evolution of the reaction was studied up to a maximum absorbance of $0.535\ \text{a. u.}$, which is the absorbance

value of the completed mixture. All the curves (Figure 2) show similar behavior, being the main difference the time at which the total mixture is completed. This time is related directly with the reaction velocity represented by the slope of the curves. As an analysis of the results presented on Figure 2, it can be observed that faster mixtures occur when the acoustic microagitation is implemented, both with the 28 μm and 110 μm film thickness, regardless of the areas. Moreover, the mixing time is shorter in the case of films with smaller thickness: 257 s for the 28 μm β -PVDF with an area of 2.4 cm^2 and 304 s for the 100 μm β -PVDF with the same area. Furthermore, the mixing time is larger for the smaller area of the polymer: 257 s for the 28 μm β -PVDF with an area of 2.4 cm^2 and 352 s for the same thickness and with an area of 0.6 cm^2 .

To evaluate more qualitatively the mixing performance, an experiment was prepared in order to visualize the mixture. Two cuvettes were set for the chemical reaction between a solution of Sodium Hydroxide, Sucrose and Potassium Permanganate. In one of the cuvettes, microagitation was performed using sinusoidal signals of 10 V amplitude, with 15 MHz frequency on the β -PVDF transducer. Figure 3 shows the mixing differences between both cuvettes: with the application of acoustic microagitation the complete reaction time was improved in 93%. As a next step, submicron thin polymer film will be directly deposited within the lab-on-a-chip presented in Figure 1.

Acknowledgements:

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Figures:

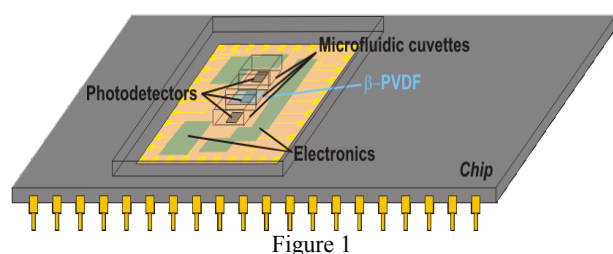


Figure 1

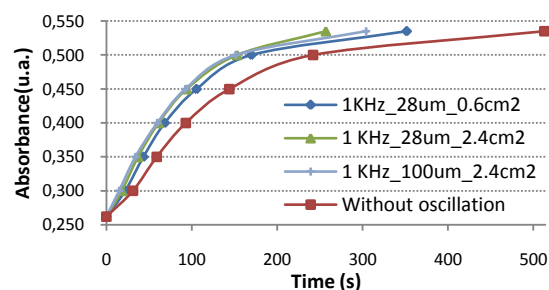


Figure 2



Figure 3