Novel 3d Printed Capacity and pH Buffer Sensor

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Abstract

This work presents a novel 3D-printed micromixer capable to not only measure pH also molarity of the buffer. Buffer molarity control is especially sensitive in biological processes[1]. The design takes advantage of the diffusion of the solutions (buffers) and analyzes interaction area and the color change experienced by bromocresol purple (pH indicator). The performance of the proposed solution was evaluated in three different buffer molarities (0.1, 0.5 and 1.0 M) with three different pH values (6.0, 7.0 and 8.0). The microfluidic channel was designed for a Reynolds number of 1, therefore the diffusion was occurring progressively from the inlet to the outlet. Molarity measurements were done at the intersection of the inlets, while pH measurement (that required complete mixture) was done at the outlet. The results showed that not only the current setup is successful at measuring the buffer molarity and pH, but also the fabrication method is more rapid and flexible in creating microfluidic devices.

Methodology

The microfluidic device shown in Figure 1 (a) and (b) was manufactured using a 3d printer based on Digital Light Projection Technique (DLP) [1] . Briefly, the geometry from Figure 1 is modeled in 3D using @Solidworks software and exported to *.slt format to be introduced to the @MiiCraft Plus printer.

The channel's height is also set to 500 μm and the top layer to 300 μm to ensure that the channel is fully sealed and the chip is printed uniformly.

The pH indicator is Bromocresol purple (5′,5″-dibromo-o-cresolsulfophthalein), @sigma Aldrich. (4-(2-hydroxyethyl)-1-pi-perazineethanesulfonic acid) HEPES, from @Sigma Aldrich, was used as buffer at different molarities and pH [28].

During the assay the main channel injects the Bromocresol and the buffers are injected into the device, through lateral channels. The injection is done by another syringe pumps (kdScientific 410-CE- @kdScientific, Holliston, MA, US).

Conclusions

According to the results, the DLP 3D printed microfluidic mixers can be employed as a flexible process to manufacture pH and molarity buffer sensor. The use of 3D printed microfluidics provides portability to pH measures and the opportunity to control the buffer capacity measuring its molarity/concentration. In the current study HEPES buffer of 3 different concentrations were evaluated showing clearly that BCP advanced further into the lateral channels when the concentration was increasing. In the same magnification scale, BCP penetrated up to 39 pixels in buffers with 0.1 M of HEPES, see Figure 2. Whereas, the indicator marked a 147 pixels advance for the buffers with 1.0 M of HEPES, showing a 2.77 times increase in the diffusion width, while the inlets' discharges were kept constant. Besides, pH measurement, which required a homogeneous mixing, was achieved as well at the outlet of the mixer, See FIGURE 3. This study showed that the 3D printed device could be successfully employed in order to detect buffers in the pH range of 6.0 up to 8.0 as the investigation showed a 21.7% mean blue color difference between buffers with pH 6.0 and 7.0. Although, a 11.2% difference between the buffers with pH 7.0 and 8.0 was reported, but the analysis showed a 35.3% change when buffers with pH 8.0 and 6.0 were compared. Furthermore, the assay showed that the setup could be used as a self-referencing sensor, when two unknown solutions are being injected into the lateral channels. The results showed that, not only the 3D printed device reproduced the numerically predicted trend, but also it provided 76.3% of homogeneity, which is only 1.3% off the numerically predicted efficiency.

References

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[2] P. Mehrdel, S. Karimi, J. Farré-Lladós, and J. Casals-Terré, "Novel variable radius spiral-shaped micromixer: From numerical analysis to experimental validation," *Micromachines*, vol. 9, no. 11, 2018.

Figures

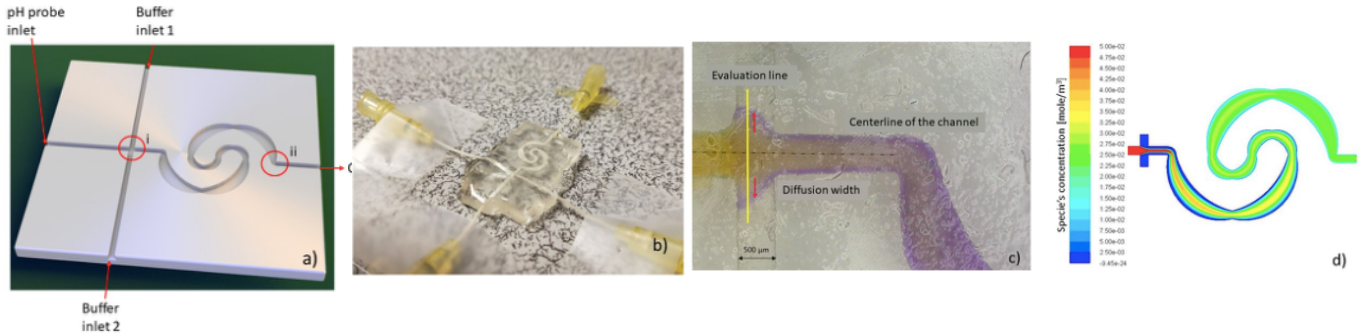

Figure 1. a) shows a 3D view of the investigated device, inlets and measurement zones. i) illustrates the buffer measurement zone and ii) displays the pH measurement zone. b) Inlets, outlet and the channel of the 3D printed device is shown. c) Displays the diffusion phenomena at the intersection of the inlets. The evaluation line, where the buffer diffusion is measured over, is also displayed. d) Shows the numerical simulation of diffusion in one loop mixer with 10% expansion parts, assuming that 0.05 M of a specie is injected into a device while the fluids flow at Re=1.0.

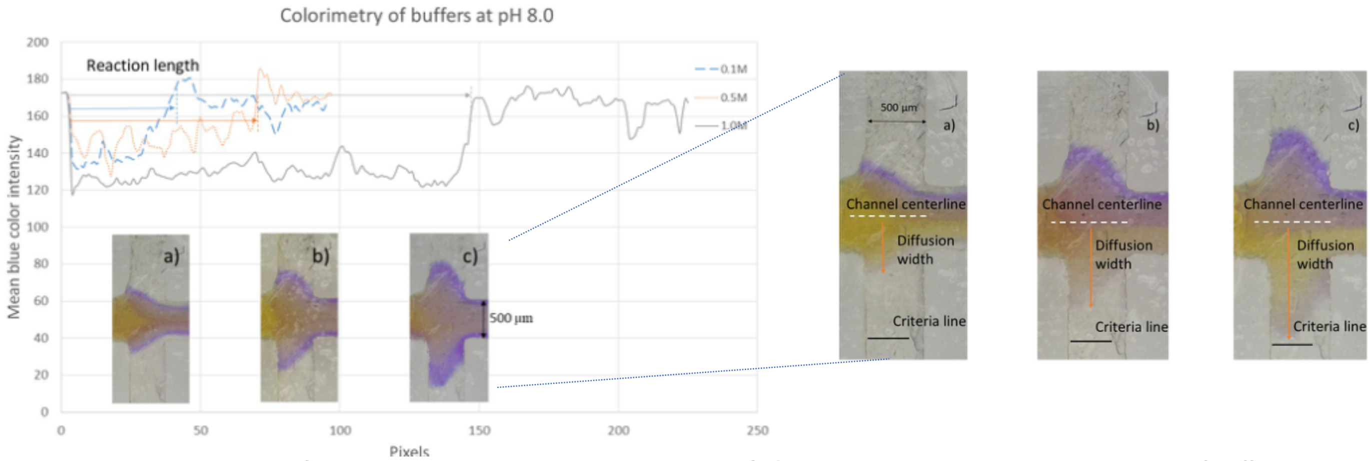

Figure 2. displays the length of reaction at pH 8.0. This level is beyond BCP's capacity to demonstrate the alkalinity of buffers and the color change and reaction lengths are at their maximum. Reactions of BCP and buffers with 0.1, 0.5 and 1.0 M of HEPES are represented in pictures (a), (b) and (c), respectively. Lateral (a), (b) (c) shows the reaction of BCP and buffers with different pH levels at the intersection of the inlets. The upper inlet was dedicated to the buffers with pH 8.0 and through the bottom inlet, the buffer with pH 6.0 was injected. Pictures (a), (b) and (c) show the reaction of buffers with 0.1, 0.5 and 1.0 M of HEPES, respectively.

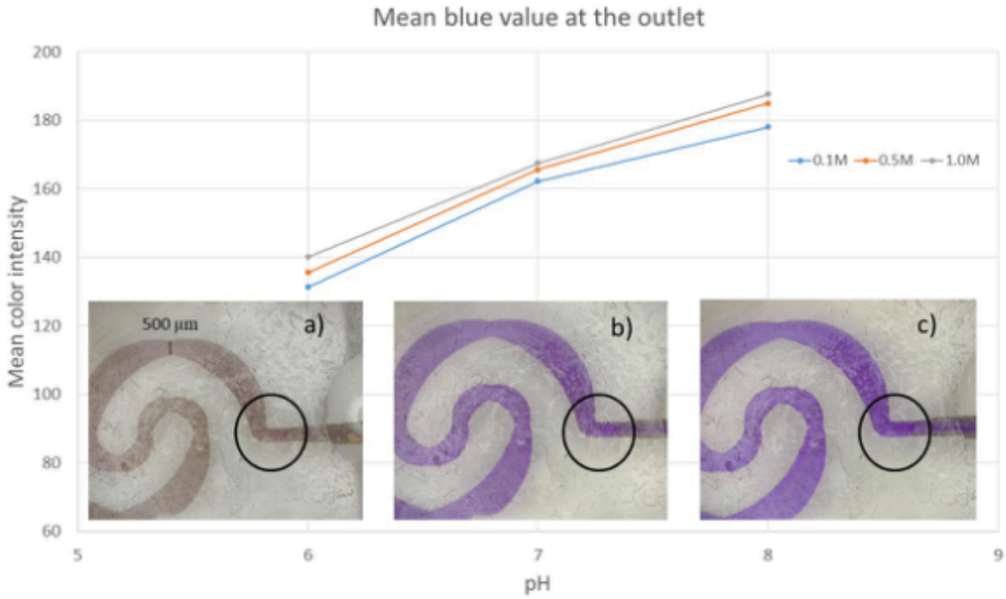

Figure 3. shows the analysis of the mixture of the BCP and the buffers at the outlet. The transition of color in the range of pH 6.0 to 7.0 is quite obvious, but for the range of pH 7.0 to 8.0 further investigation and accurate measurements are necessary. Pictures (a), (b) and (c) show the final mixture of the BCP and buffers with 0.5 M of HEPES at pH 6.0, 7.0 and 8.0, respectively