Design and Fabrication of Microfluidic Mixer for Three Orders of Magnitude of Dilution

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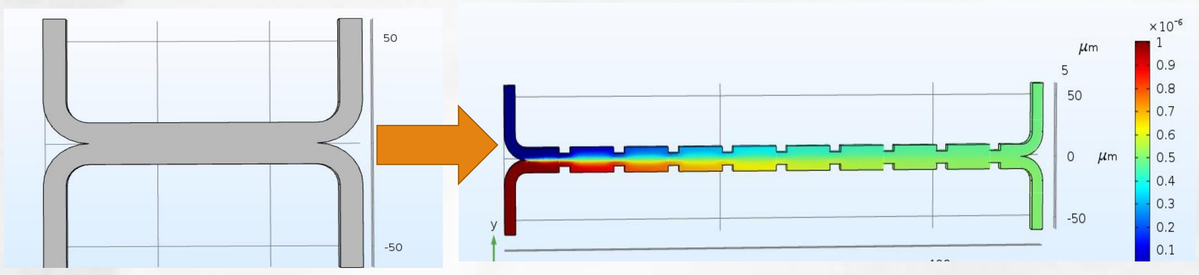
Abstract

Manual serial dilutions of low concentration samples may hinder the assessment of electronics-based biosensors due to the requirement of good sampling accuracy. For this reason, we design a PDMS based microfluidic mixing device, which achieves dilution by multiple orders of magnitude of protein samples with buffer. The microfluidic device is H shaped diffusive mixer with two inlets and two outlets, simple to integrate with the sensing units such as Electrolyte Gated Organic Field Effect Transistors (EGOFETs). The mixing principle of the device is based on controlled diffusion, since the species in the microfluidic path are in laminar flow regime. To increase the mixing efficiency, rectangular shaped obstacles are designed on the wall of the microfluidic channel. These obstacles cause a change in the velocity field and concentration, increasing the interfacial contact area between two fluid streams. As a result, the diffusion occurs on a perturbed flow pattern and the mixing efficiency increases. Experimental results are shown employing 3D printer and replica molding fabrication processes. The dilution rates of the samples are validated with the UV absorption spectra.

Design and Simulation

H-shaped micro-cell designed for controlled diffusive mixing

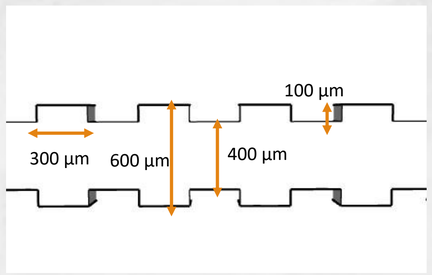


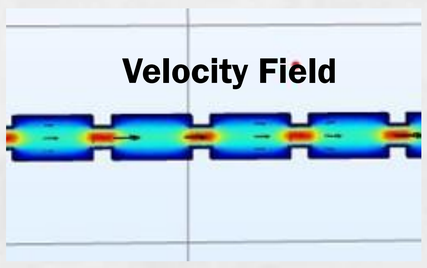
H-shaped micro-cell design from COMSOL Application Library is used as base for our design. The device has two inlets and two outlets. One inlet is for the buffer and the other one for the mother solution such as biological samples. These two species will mix completely and achieve the half of the initial concentration at each outlet. Since the dimension of channel is in the micrometer range, the flow regime is laminar. In the laminar flow, there is no turbulence. The species do flow parallel and do not mix together. Only mixing occurs by cause of diffusion of molecules across the interface between the fluids. COMSOL Multiphysics Software program are used for the simulations, specially the computational fluid dynamics (CFD) module.

Diffusion

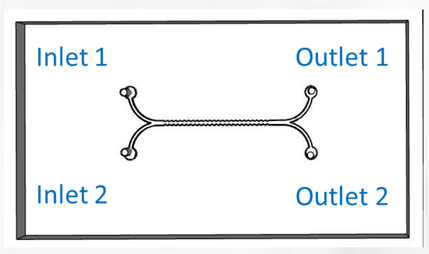
Diffusion drives a net flux of particles from high to low concentration and it stops as it reaches the equilibrium. In addition to diffusion, the convection also contribute to the flux due to bulk fluid motion. However, convection cannot lead to efficient mixing between layers of fluid, since the main component is along the flow streamline. A transversal component to the fluid flow is needed, which allows broadening contact area.

To increase the interface area, we introduced shapes or so called obstacles on the walls of microfluidic device. These obstacles cause decreasing of the cross section area, so species have bigger contact area between them. Additionally, they are responsible for generating a transverse component to the flow. This act Is called chaotic advection. As a result, diffusion and mixing efficiency increase. If we don't have these obstacles, diffusion requires a long time and long device path.





Fabrication of the Microfluidic Device

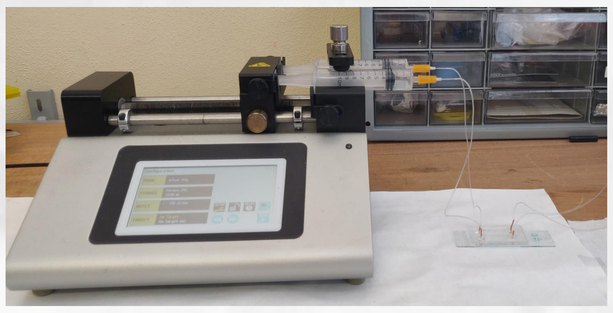


Design made SketchUp

3D printed Master

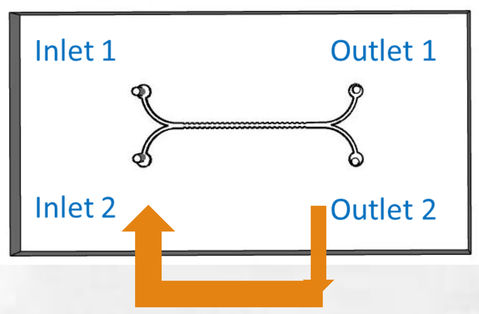
Replica Moulding with PDMS with connectors

Experimental Set-up with Syringe Pump:

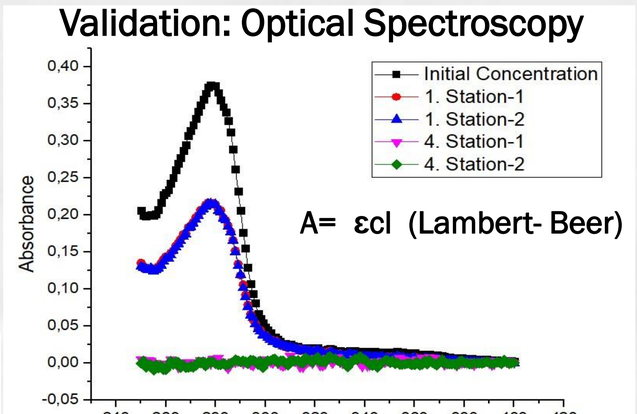


Flowrate	20 µl/min
Device Length	25 mm
Device Height	0.5 mm
Inlet 1	Buffer like PBS or Water
Inlet 2	PBS with Protein

Serial Dilution



Initial Concentration	1.Cycle	4. Cycle
8.5 µM	~ 4.6 µM	~ 0.9 µM



The mixer achieves every time fifty -fifty mixing, which means that we get half of the initial concentration. In order to achieve multiple orders of dilution, we did create a closed loop feedback microfluidics. We connected the outlet 2 with inlet 1. With every cycle, we get half of initial concentration. According to the calculations, we reach one order at 4th cycle, two orders at 8th cycle and three orders at 12th cycle. To validate the results, the optical spectroscopy is used. The protein concentration at the outlet is calculated with Absorbance level.

Conclusions

- ✓ Mixing is only depend on diffusion since the flow regime is laminar.
- ✓ To increase the mixing efficiency, the geometry of the device is optimized.
- ✓ By putting the shapes or so called obstacles on the microfluidic device wall, the mixing efficiency is increased.
- ✓ Serial dilution is achieved with one level fluid architecture.

Future Perspectives

- ❑ Optimization of the device with additional reservoirs
- ❑ Automatization of the microfluidic device
- ❑ Integration of the sensing unit such as EGOFET with device

Acknowledgements

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