Flow Characterization of a Liquid Micromixer

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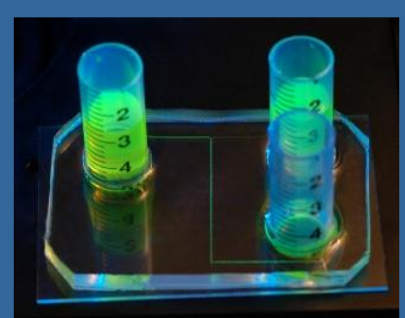
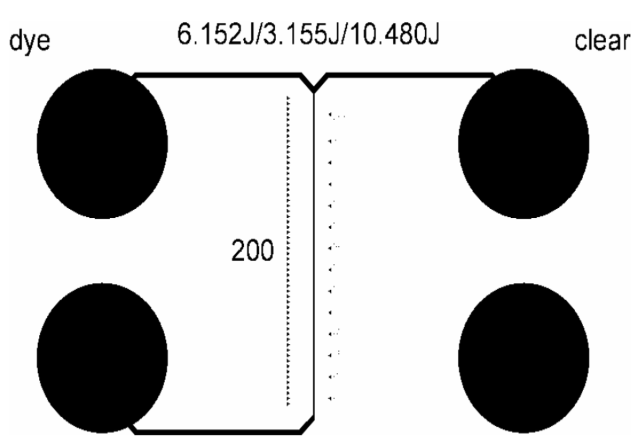


Abstract: Measurements of fluid velocity and diffusion coefficient were performed in a channel of a microfluidic mixer. Both are shown to be in good agreement with theory, with $U_{max(meas)}$=1.78±0.11 mm/s [c.f. $U_{max(theory)}$=1.84]; and $D_{meas}=1.5\times10^{-6}$ cm^2/s [c.f. $D_{theory} = 2\times10^{-6}$ cm^2/s].

Introduction

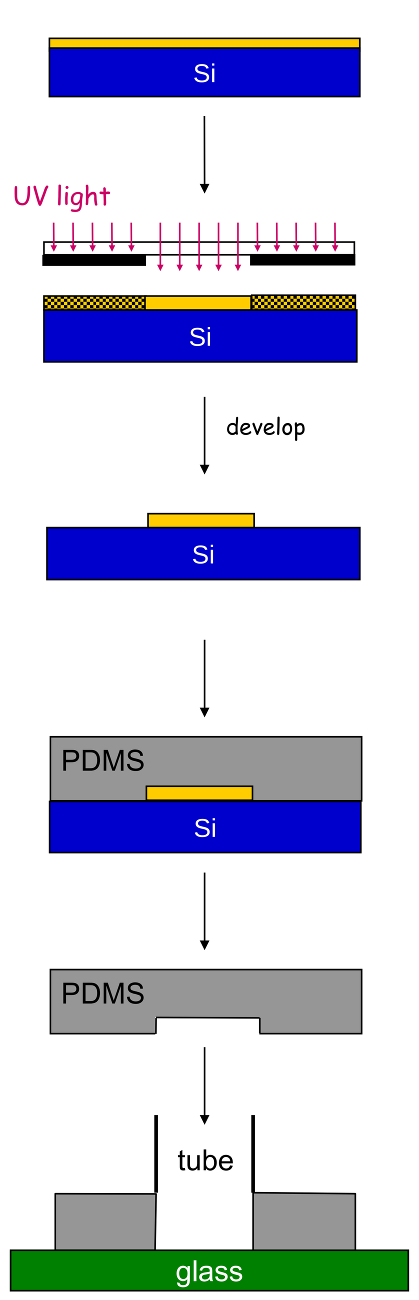
A microfluidic device was created in order to mix the contents of two reservoirs through a 200um-wide, 30mm-long diffusion channel.



LEFT: Device mask for the micromixer. The top two reservoirs are connected to the bottom, output reservoir through a long, narrow channel.

The operation of the micromixer was visually inspected via an optical microscope. The flow velocity and the diffusion coefficients were in good agreement with predicted values.

Fabrication



Spin on 50-micron thick SU-8 film.

Prepare master template by contact photolithography.

Develop with PM-acetate and silanize to discourage bonding with PDMS.

Pour PDMS on master wafer. Al rods define the reservoir locations.

Remove PDMS mold.

Place on glass slide and bond with ashing. Insert tube into reservoirs.

Fluid Velocity

Theory

• Assume laminar flow, for which:

$$\Delta P = \frac{12\eta L}{WH^3}\cdot Q$$

Q: flow rate
η: viscosity
L,W,H: channel dimensions

• Maximum fluid velocity is:

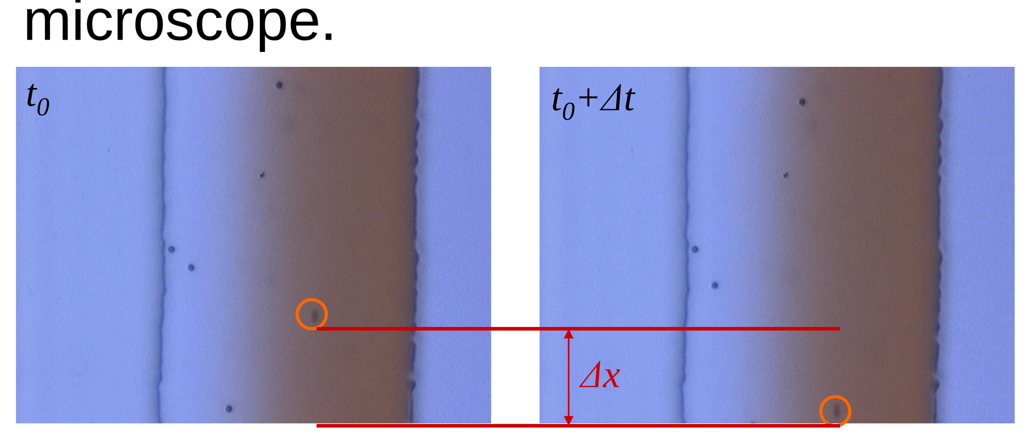
$$U_{max} = \frac{H^2}{8\eta L}\cdot\Delta P$$

Experimental Setup

• Input reservoirs were loaded with 22.5±0.7 mm of water.

• Microbeads were added to each reservoir.

• The motion of the microbeads in the channel was filmed using a PC-based microscope.



ABOVE: By considering two consecutive snapshots of the flow (with known time difference between them) the velocity of particle flow can be determined.

• Pixel values were calibrated by measuring known feature sizes.

• Velocity was measured by analyzing snapshots of the fluid flow, as shown above.

Results

Maximum Fluid Velocity:

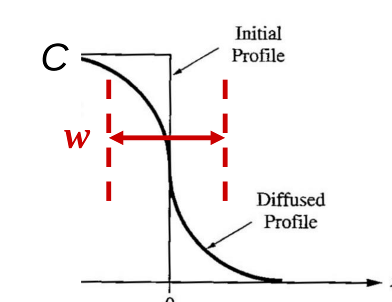
U_{max}=1.78±0.11 mm/s (measured)

U_{max}=1.84 mm/s (theoretical)

Diffusion Coefficient

Theory

•The two fluids mix as they flow down the channel, showing increase in diffusion length scale, *w*.



•Using $U_{avg} = 2/3{*}U_{max}$, and the position along the channel, duration of diffusion is determined.

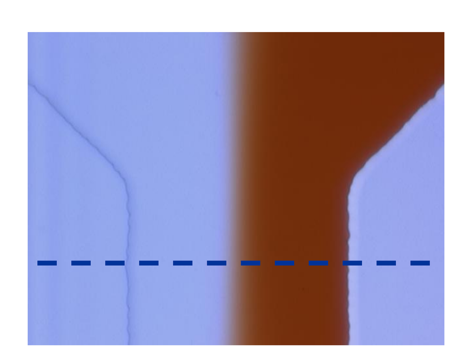
•Diffusion coefficient:

$$D = \frac{w(t)^2}{4\ln 2}\cdot t$$

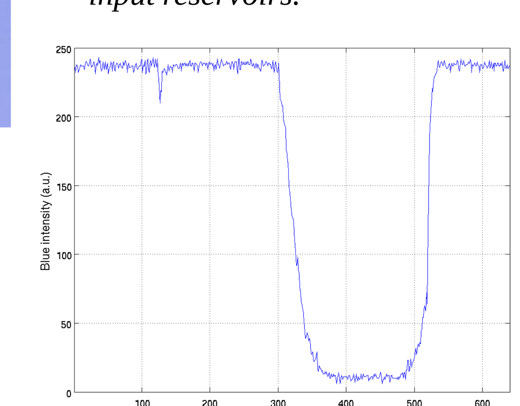
Experimental Setup

• Two reservoirs were filled with water and fine-tuned to have equal heights.

• Red dye was added to one reservoir to track diffusion



LEFT: The boundary between the two fluids was set at the midpoint of the channel by adjusting the heights of the two input reservoirs.



RIGHT: Blue intensity profile across the lateral channel position, at 200 pixels above bottom of image.

•Image analysis technique:

•Filter/smooth profile

•Differentiate the profile

•Measure half-width half-maximum of differential to obtain the diffusion length scale, *w*

Results

Diffusion Coefficient:

$D=1.5\times10^{-6}$ cm^2/s (measured)

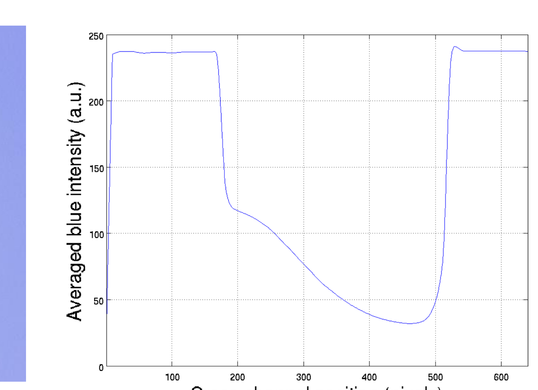
$D\sim2\times10^{-6}$ cm^2/s (theoretical)

Why is the diffusion coefficient lower than expected?

• Theoretical model was based on diffusion into an infinitely sized sample.

• Actual diffusion was constrained by an opposite wall. (See below)

→ restricted diffusion (lower D)



Conclusion

•Microfluidic mixer was fabricated.

•Flow characterization experiments were performed, yielding:

•Fluid velocity

•Diffusion coefficient

•Measurements show good agreement with theory → device behaves as expected.

Acknowledgements

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