PHYSICAL CHEMISTRY AND SOFT MATTER

WAGENINGEN UR

A Simple Microfluidic Mixer Based on Suspensions

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Aim

Mixing in microfluidic devices is difficult, as flow is laminar. We solve this problem using fluctuations induced by the presence of sheared particles. It was recently shown that particles within a fluid greatly enhance transport properties in sheared non-Brownian suspensions.[1] We use this mechanism to create a highly efficient, *active* microfluidic mixer with a low pressure drop.

Methods

We design and construct a microfluidic chip (Figure 1) with a cylindrical mixing chamber, filled with 30-40% volume of glass particles. A small magnet is added to the chamber to drive the particles. Channel dimensions are chosen such that the glass particles are confined to the chamber. We pump a viscous fluid (η = 58 mPas) in both inlets at equal rates. In one inlet, we add a dye to visualize mixing.

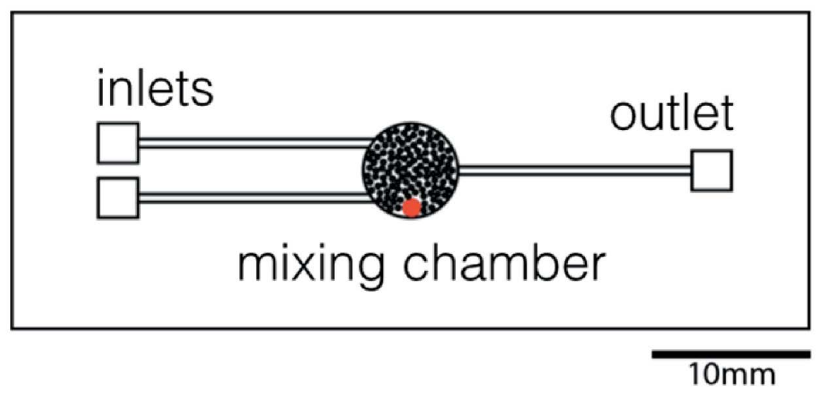

Figure 1: Scheme of the mixer chip.

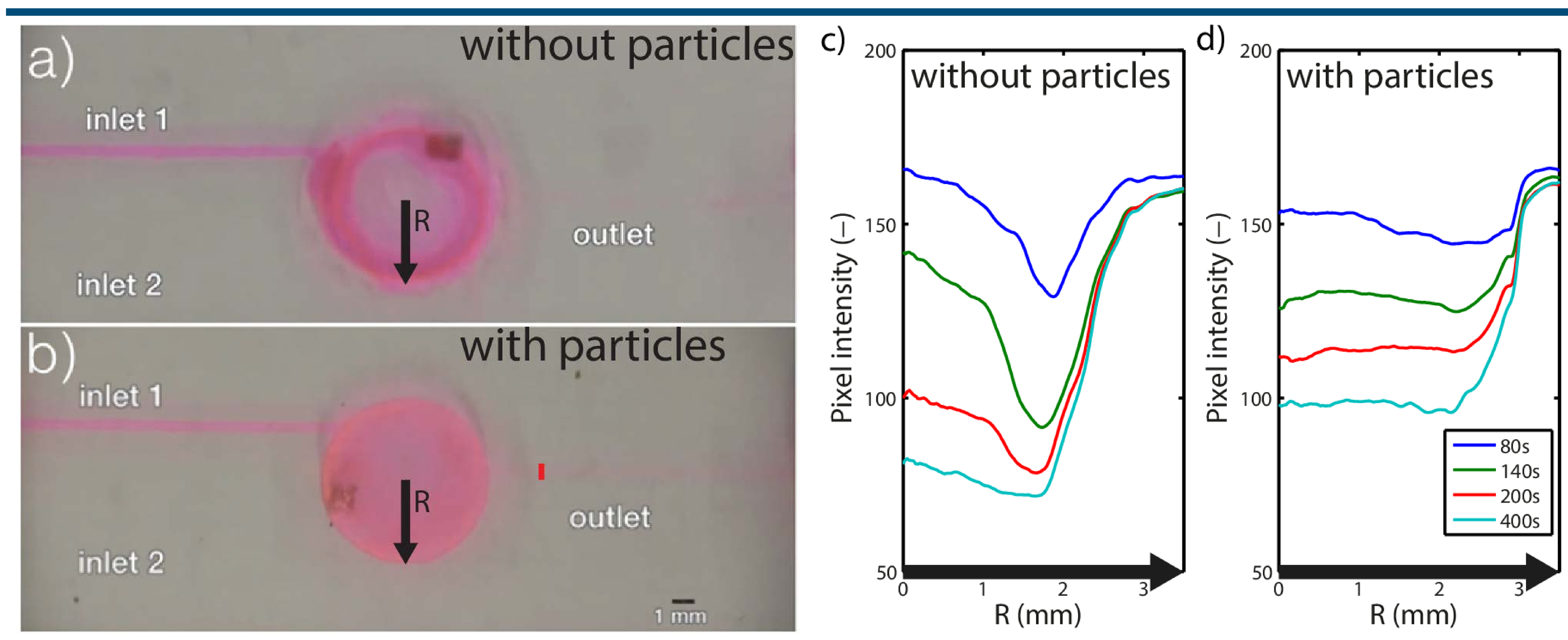

Figure 2: (a) Mixing chip without particles and (b) with particles, after 45s of operation.
(c) Radial intensity profiles of the mixing chamber without particles and (d) with particles.

Dye Distribution in Mixing Chamber

In Figure 2a-b we show two mixers after 45s of operation. In both cases, the rate at which the magnet performs circular motion is set at 0.5 Hz. Clearly, the dye is not homogeneously distributed in the mixer without particles. In Figure 2c-d we show the corresponding radial intensity profiles of the mixing chamber. The legend applies to both (c) and (d). Indeed, for the mixer with particles the dye is **more homogeneously distributed**. Thus, the added **particles strongly enhance the mixing capability** of a single magnet.

Mixing efficiency: Effect of driving rate

To evaluate mixing efficiency, we monitor intensity fluctuations in the outlet channel in the steady state. We measure the standard deviation σ of 45 pixels at different driving rates of the magnet. When the rate is set to zero, no mixing occurs (Figure 3a) and the standard deviation is maximized (σ_{max}). We define the mixing efficiency as $\alpha = 1 - \frac{\sigma}{\sigma_{max}}$.[2] The mixing efficiency is plotted as a function of driving rate in Figure 3b. The mixing efficiency is already **maximized at very low driving rates.**

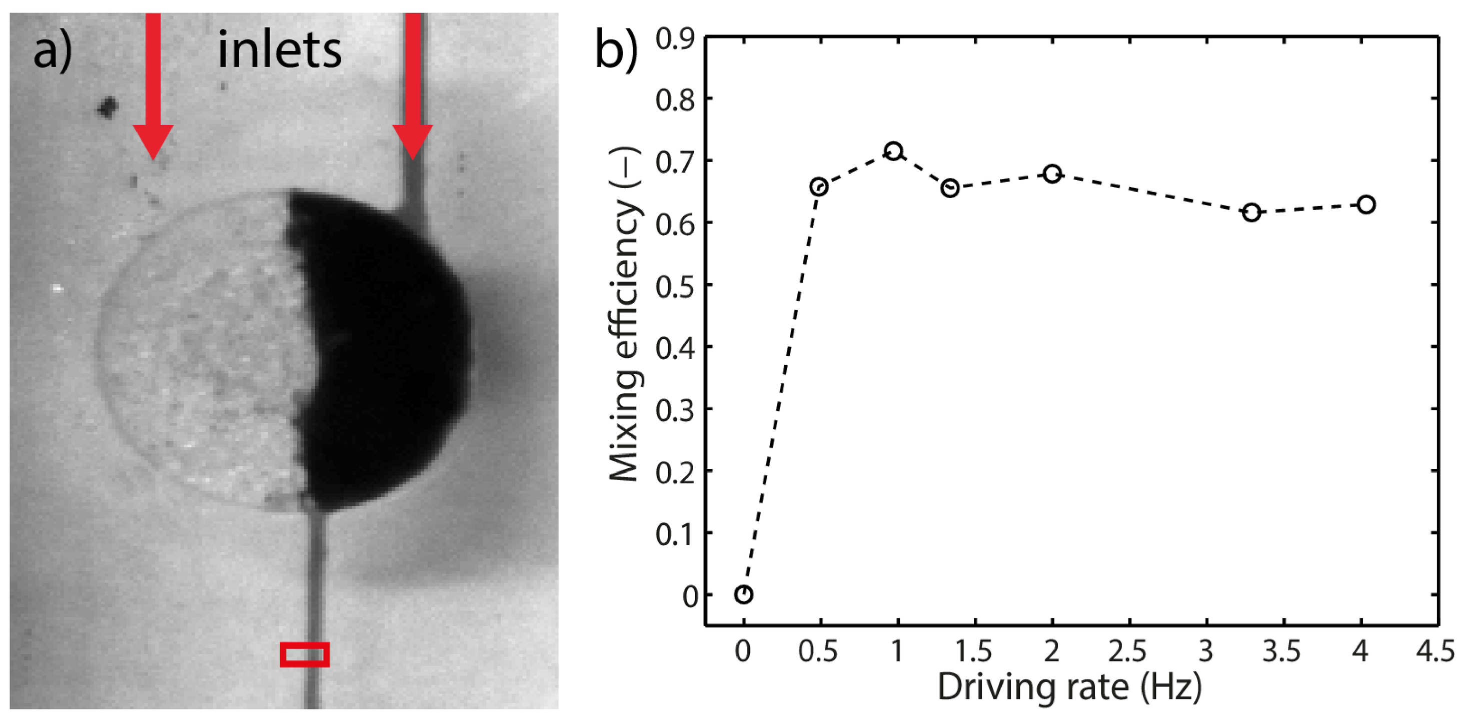

Figure 3: (a) Chip with stationary magnet showing parallel flow.
(b) Mixing efficiency as a function of driving rate.

Pressure Drop

Using Poiseuille's law, the pressure drop across a channel can be calculated[3]. Doing this for a commercially available mixer chip[4] with our experimental parameters results in a pressure drop of about 250 kPa. Neglecting the influence of the mixing chamber, we estimate the pressure drop across our chip as 10 kPa. To verify this result, we simulate the flow in SolidWorks. This results in a pressure drop of 8 kPa (Figure 4a). It can however be reduced about 10x by reducing the in- and outlets to a minimum (Figure 4b).

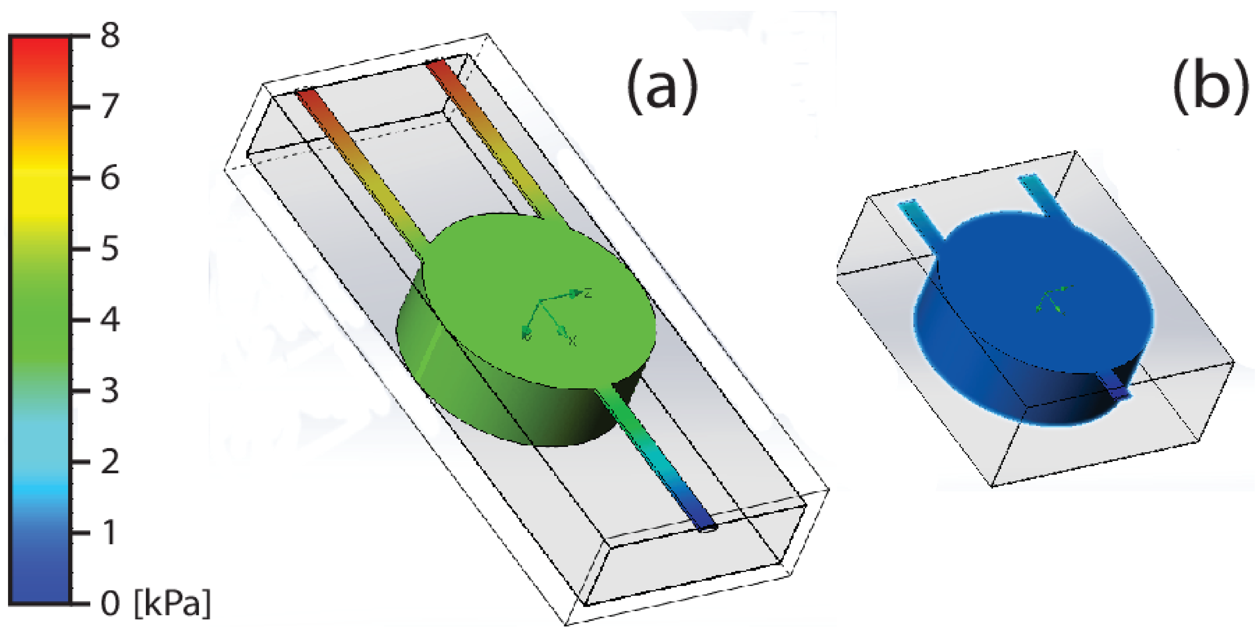

Figure 4: Pressure distribution in a chip with 5 mm (a) and 1 mm (b) in- and outlet channels.

Conclusion

We present a novel microfluidic mixer that is easy to fabricate and simple to use. The mixer features a single mixing chamber in which mixing-enhancing particles are driven by a moving magnet. The mixer is efficient for a range of driving rates and features a low pressure drop. These features make the mixer design compatible with soft chip material, and therefore ideal to incorporate in lab-on-a-chip devices.

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