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A novel passive micromixer suitable for mass production in polymers

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Concept

We present a novel passive micromixer concept that creates direct lamination in a 2D channel. The principle is to make a controlled 90° rotation of the flow cross section followed by a splitting into several channels; the flow in each of these channels is rotated further 90° before recombination as shown in figure 1. The 90° rotation is achieved by patterning the channel bed with grooves as seen in figure 2.

Experimental

The mixer presented has been produced using several microfabrication methods

- Milling of mold insert in aluminium and injection molding in PS
- Direct milling in PMMA and PC
- Laser ablation in PMMA

Fabricated prototype efficiency was analysed using scanning laser confocal microscopy. Two fluorescent dyes, Fluorescein and Rhodamine B, were used. The lamination in one mixing module was investigated using 3D finite element simulations in Comsol Multiphysics. The two fluids are treated as isothermal and incompressible Newtonian fluids following the Navier-Stokes equations.

Results

The lamination of the two fluids in one mixing module is shown in figure 3 demonstrating good agreement between simulated and measured rotation of the fluids in the microdevice. In figure 4 the confocal microscopy images used to evaluate mixing after one to three modules are shown. The standard deviation of the fluorescence intensity from confocal microscopy was used evaluate the mixing efficiency. In figure 5 it can be seen that this value drops to 10% of its initial value after four mixing modules indicating complete mixing.

Conclusions

- The novel mixer shows good lamination of two fluids, achieving complete mixing after four modules. Using the layout in figure 1 this can be realised on only 4 mm x 4 mm.
- Very good agreement is observed between simulations and experiments
- The simple design makes the mixer easy to mass produce using inexpensive materials. This is especially important in applications such as medical diagnostics where cost effective, disposable micromodules are preferably used.

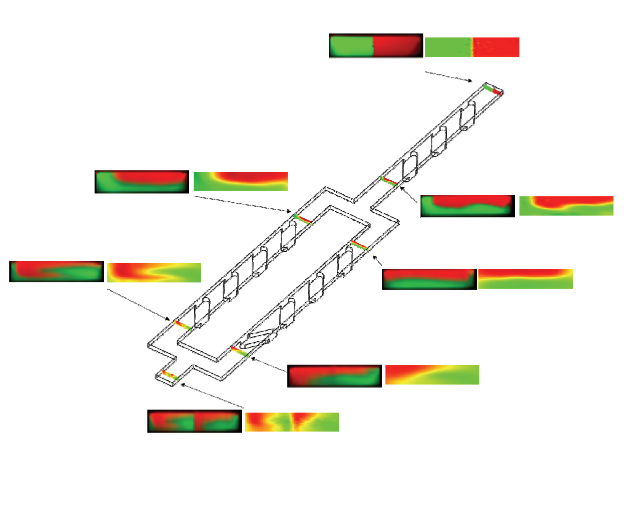

Fig. 3: Simulated and measured concentration distributions within one mixing module

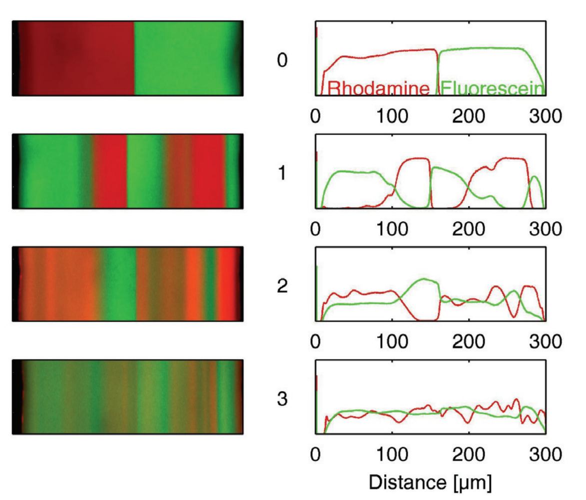

Fig. 4 Left: Confocal microscopy images showing planes at $z = h/2$, where h is the channel depth. The images show the intensity after 0, 1, 2 and 3 full modules. Right: Normalized intensity of the two flourophores measured across the cross sections on the left.

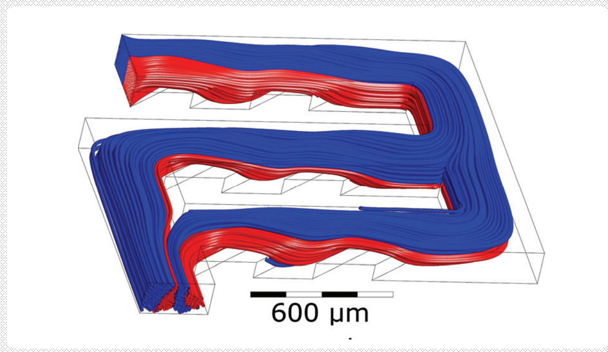

Fig. 1: Simulated flow field in one compact mixing module showing lamination

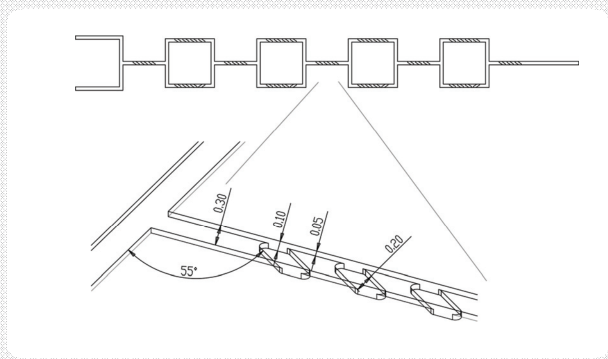

Fig.2: Above: Design showing four mixing modules. Below: Detailed view of the grooves with dimensions indicated [mm].

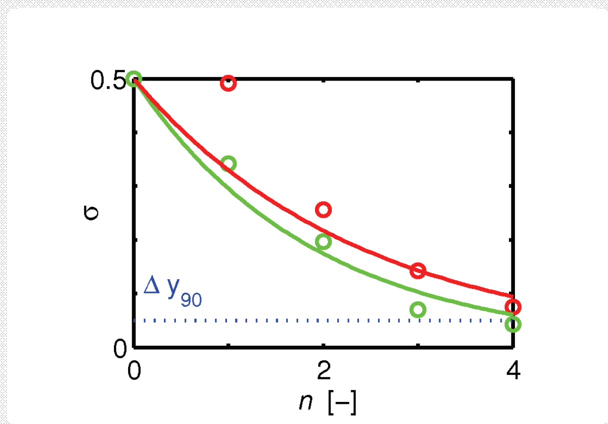

Fig. 5 The standard deviation of the fluorescence intensity at the entrance and after one to four modules. Δy_{90} shows when the standard deviation has fallen to 10% of its initial value, a criteria used in the literature for indicating complete mixing.

Acknowledgements

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