Optimization of the Herringbone Type Micromixer
Using Numerical Modelling and Validation By Measurements

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Abstract
One of the key features of Lab-On-a-Chip devices is sample preparation which includes the dilution and complete mixing of the analyte with reagents or adequate buffer solutions. The mixing possibilities are limited on microscale, since turbulent flow cannot occur due to dominant viscous forces. Chaotic advection can be considered as an ideal mixing method in microfluidic channels as the flows are laminar. Laminar Flow interface of COMSOL Multiphysics® was used to solve the velocity field of the micromixer to characterise fluid flow properties. Mixing by diffusion along the channel was modelled with Transport of Diluted Species interface. To avoid numerical diffusion and high computational cost we used the Particle Tracing Module to observe mixing at the level of particles. To optimize the mixing efficiency we conducted a parametric sweep on the thickness of the ridges. Modelled herringbone structures were fabricated in polydimethylsiloxane (PDMS) using multilayer technology and measured with dark field microscopy. Results agreed well with the measurement. Furthermore an optimal herringbone structure was proposed for integration into a bioanalytical system.

Concentration based model and particle based model
Mixing can be modelled well with concentration distribution. However, in the case of low available mesh resolution (due to high computational cost) numeric diffusion may be an issue. Modelling particles instead of concentration gives a better overall picture of the mixing. If we color the particles based on their initial position across the channel we can visualise particle displacement relative to each other.

Flow characterisation
Herringbone structures act as anisotropic fluid resistances causing secondary (transversal) flow.

Optimization
A parametric sweep on the number of herringbones per cycle, their width and the number of mixing cycles was conducted. Modelling shows that mixing is more efficient with wider herringbones. More mixing cycles are more efficient than more herringbones in one cycle.

Conclusion
- Flow properties and mixing of the herringbone mixer were characterised by numeric modelling using the Laminar Flow, Transport of Diluted Species and Particle tracing physics of COMSOL Multiphysics.
- Concentration-based and particle-based approaches were compared.
- Further investigation of the Herringbone mixer was made using parametric sweep on the herringbone width and the number of herringbones per mixing cycle.
- The modelled mixers were realised and measured model results were validated.

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