Nature-inspired active mixing in a microchannel

Citation for published version (APA):

Document status and date:
Published: 01/01/2006

Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:
• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license above, please follow below link for the End User Agreement:
www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:
openaccess@tue.nl
providing details and we will investigate your claim.

Download date: 05. Jun. 2024
NATURE-INSPIRED ACTIVE MIXING IN A MICROCHANNEL
V.V. Khatavkar,1 P.D. Anderson,1 H.E.H. Meijer,1 J.M.J. den Toonder1,2

1 Materials Technology, Dutch Polymer Institute, Eindhoven University of Technology, 2 Philips Research Laboratories, Eindhoven

Introduction
Many applications of microfluidics require efficient mixing of two or more liquids. Mixing at the microscale usually occurs through a rather slow diffusion process due to inherent laminar flow conditions. To speed-up mixing, numerous novel passive and active micromixers are currently being developed.1 We propose a new promising configuration for an active micromixer consisting of an array of individually addressable artificial cilia in the form of micro-actuators covering the channel wall, and that can be actuated by external means field. This concept is inspired by the motion of flagellated and ciliated microorganisms such as shown in figure 1.

Objective
To design and develop a novel active micromixer - inspired by nature - for microfluidics applications.

Modeling
To assess the feasibility of the proposed concept, we carried out numerical simulations of one- and two-micro-actuator configurations, as shown in figure 2, using a fictitious domain method based fluid-structure interaction model.4

![Figure 2. Schematic representation of single (left) and double (right) micro-actuator configurations in a microchannel studied.](image)

The overall modeling strategy is as shown in figure 3 below.

![Figure 3. The overall modeling strategy.](image)

Two micro-actuator batch micromixer
As shown in figure 4, with a proper actuation scheme, two micro-actuators can indeed induce effective mixing by chaotic advection.

![Figure 4. Mixing patterns obtained with two different actuation schemes showing “good” (left) and “no” (right) mixing are superimposed on flow streamlines (colored lines).](image)

The dependency of mixing efficiency, measured in terms of the length stretch, on the actuation scheme and shown in figure 5, is less critical so long as its value is near the optimum value of 90°.

![Figure 5. Quantification of mixing efficiency shown in figure 4 (left) is used to generate a phase diagram (right) where the optimal actuation scheme can be readily identified.](image)

For optimal mixing, figure 6 suggests that the two micro-actuators should be placed as close to each other as possible, obviously taking care to avoid their collision, and they should preferably be actuated 90° out of phase.

![Figure 6. Mixing quality as a function of spacing (D) between the two micro-actuators having a length (L) of 20 μm.](image)

Furthermore, for micro-actuators smaller than 20% of the channel height, the mixing effectiveness is higher when they are arranged on the same wall. However, as shown in figure 7, increasing the micro-actuator length improves the effectiveness of an opposite wall micro-actuator arrangement.

![Figure 7. Improvement in mixing with an increase in the length (L) of micro-actuators for an opposite wall arrangement of the two micro-actuators.](image)

Conclusions
• Nature-inspired cilia-like micro-actuators integrated in a microfluidic channel gives effective mixing by chaotic advection.
• With a well chosen geometrical arrangement and actuation scheme, mixing can even be obtained with only two micro-actuators.

References