# Global mixing in micro-channels and cavities by magnetically actuated particles

Technische Universiteit Eindhoven University of Technology

# Global mixing in micro-channels and cavities by magnetically actuated particles

Y. Gao,
M. A. Hulsen,
J. M. J. den Toonder

Materials Technology Institute, Department of Mechanical Engineering, Eindhoven University of Technology, The Netherlands

## Introduction

A biosensor is an instrument that can rapidly measure the concentration of biological molecules or cells of interest in biofluids such as blood and saliva. The drive to realize such biosensors leads to the development of lab-on-a-chip systems. In these systems mass transport is dominated by diffusion, which is prohibitory slow. Two key processes that need to be mastered are: mixing (Fig. 1(b)) and target catching (Fig. 1(c)). Here, we propose the use of magnetic beads coated with an activated surface, and actuated by a magnetic field to control both process.

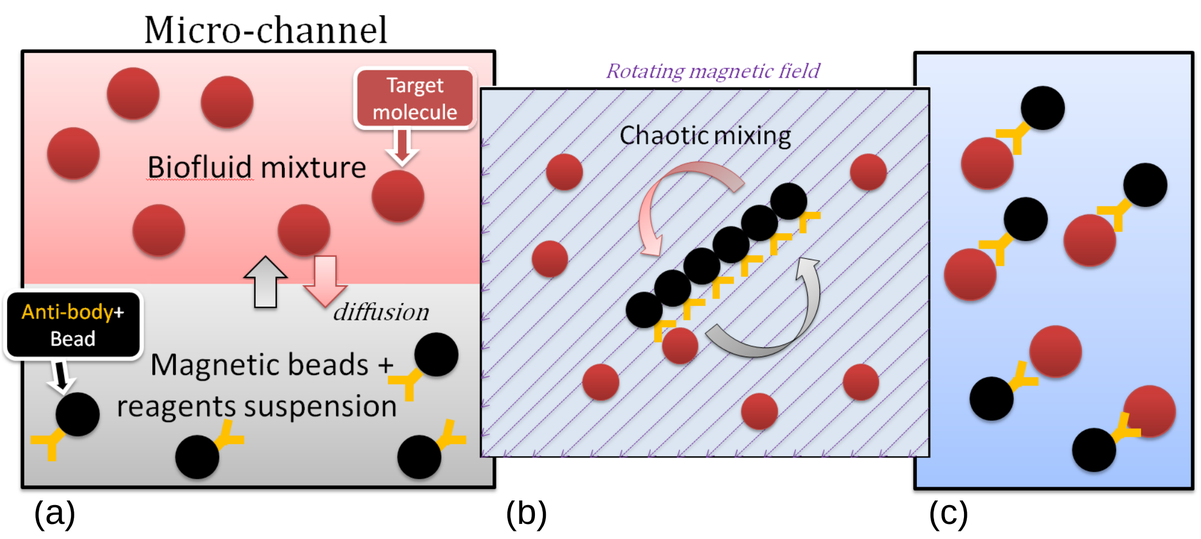


**Fig. 1** *Conceptual diagram of a magneto-active lab-on-a-chip system. (a) Laminar flow between the biofluid and reagents. (b) The mixing of fluid with reagents. (c) The catching and transportation of target material.*

## Objective

The development of optimized magnetic actuation protocols to achieve global mixing processes in micro-channels and sensor cavities.

## Methods

Advanced numerical simulations and microfluidic experiments will be conducted to investigate the possibilities of achieving global mixing flows in micro-channels and cavities. To this end, a 3D finite element model will be set up and microfluidic experiments will be carried out to validate the numerical model.

## Preliminary results

2D computer simulations of suspended super-paramagnetic beads, confined in a circular geometry with the presence of a rotating homogenous magnetic field have been done by Kang et al (Fig. 2) [1]. Kang concluded that the motion of the chain, fluid flow and mixing are significantly influenced by the Mason number, the ratio between the viscous and magnetic forces. Specifically, the intermediate Mason numbers, which are characterized with the alternating topological changes of the chain (break-up and reformation, Fig. 2(b)), are the key mechanisms for chaotic mixing.

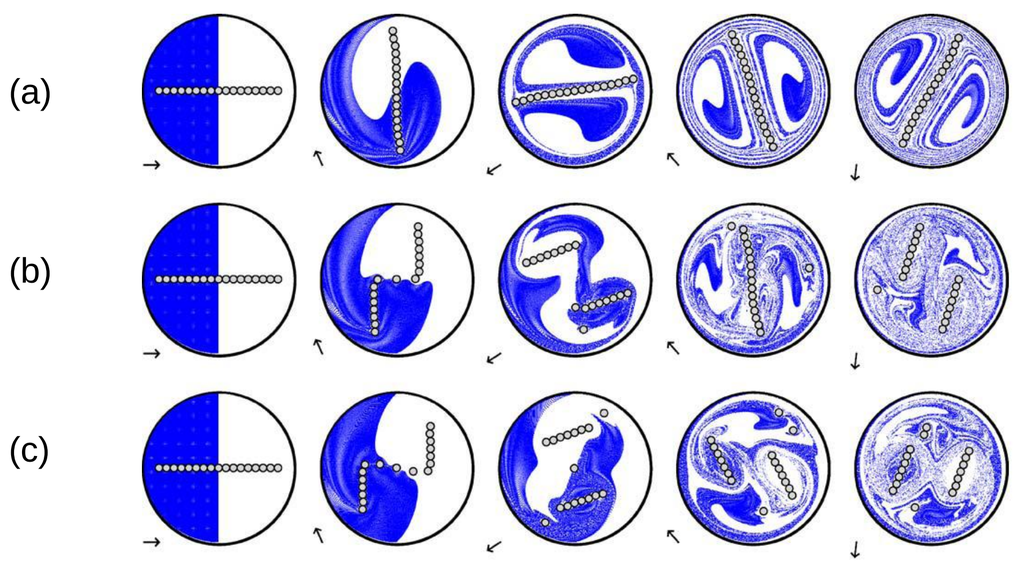


**Fig. 2** *Mixing, chain of beads with initial orientation perpendicular to the different fluid interface, visualized at different Mason numbers (a to c, Ma = {0.001, 0.002, 0.003}). Here, the black arrows indicate the direction of the applied magnetic field. Simulations by Kang et al. [1]*

Microfluidic experiments with a suspension of super-paramagnetic beads in a cylindrical fluid chamber under influence of a rotating homogenous magnetic field (max. 3 mT) were carried out by Bokdam [2]. Fig. 3(b) shows the dynamics of the beads chain at intermediate Mason numbers: break-up and reforming chain rotation.

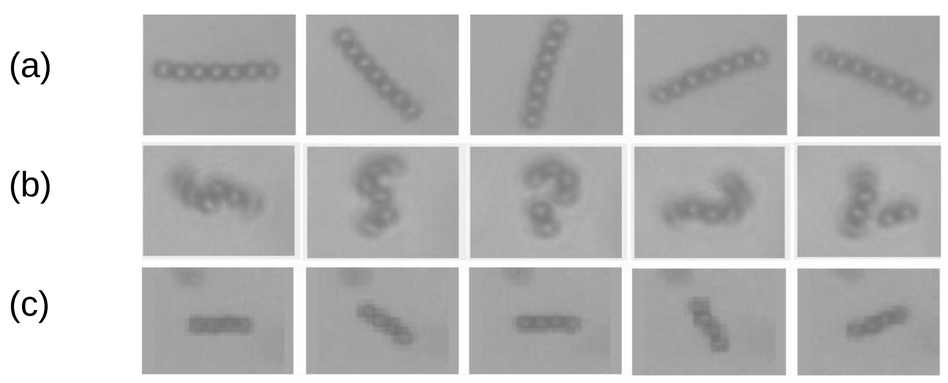


**Fig. 3** *Characteristic chain dynamics visualized at different Mason numbers (a to c, Ma = {0.25, 0.75, 6.8}). The displayed beads are 3 µm Sperotech beads. Results obtained by Bokdam [2].*

## Outlook

Experiments confirmed the simulated chain dynamics at different Mason numbers. Future experiments will consist of flow visualization (dyes) and flow quantification (µ-PIV) to verify effective mixing in the intermediate Mason regime.

**References:**

[1] Kang T. G. , Hulsen M. A. , Toonder J. M. J. DEN, Anderson P. D. , Meijer H. E. H. : *Chaotic mixing induced by a magnetic chain in a rotating magnetic field* (Phys. Rev. E, 2007)

[2] Bokdam M. , Toonder J. M. J. DEN : *super-paramagnetic beads in rotating magnetic fields* (2008)