Magnetic Actuation of Cilia for Efficient Flow Generation

MSc Thesis Theme

Introduction

Cilia are microscopic hair like structures present almost everywhere in our body, Fig.1(a). They exist in different shapes and forms serving different functions in different parts of our body. In kidneys they act as mechano-sensors, as particle and nutrient transporters in lungs, as chemo and thermo-sensors on almost all eukaryotic cells, as cell transporters in the fallopian tube etc. Transportation happens due to their mechanical beating in a particular manner inducing a flow in the surrounding fluids/ mucus containing cells/ particles/ nutrients. One ingenious way nature has developed to induce a flow in the surrounding fluid is by the asymmetric beating of these micro hair-like structures (cilia) known as tilted conical motion.

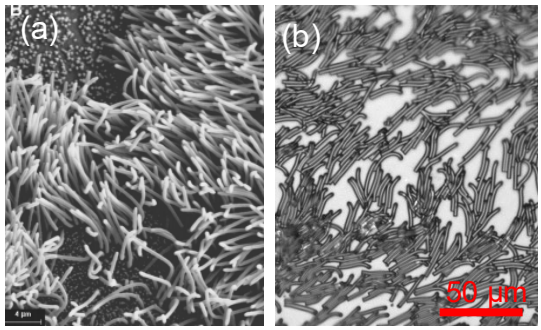

Figure 1: (a) Cilia present in the human Fallopian tubes[1]. (b) Cilia fabricated in the Microfab lab.

Project description

Different methods of fabricating magnetically actuatable cilia using nano and micro magnetic particles have been developed in the Microfab lab at TU/e over the last few years, Fig.1(b). The actuation system requires the placement and rotation of magnet with respect to the cilia structure in a particular configuration as shown in Fig.2. Such a setup rotates the cilia in a manner similar to what is shown in Fig.3, known as tilted conical motion producing a unidirectional flow in the surrounding fluid. Apart from the parameters indicated in Fig.2, the exact path followed by the cilia tip is strongly dependent on the shape of the magnet used. Different shapes would result in different profiles traced by the cilia tip thus affecting the strength of the flow induced thereby, Fig.3.

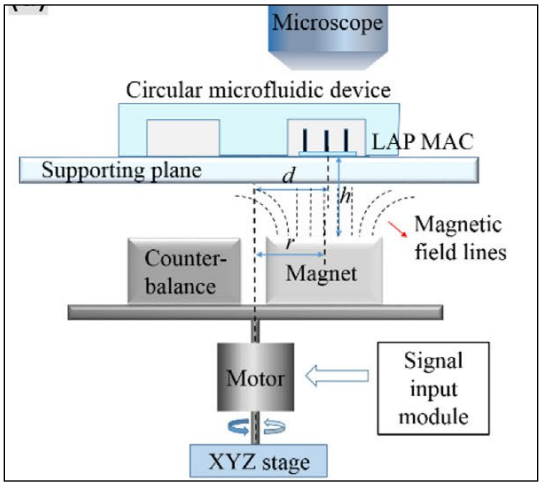

Figure 2: Magnetic actuation system with placement of fabricated cilia in a microfluidic device and magnet position parameters indicated[2].

The project will initially require performing simulation tests to find the actuating magnet shapes with respect to the path followed by the cilia. Next, a microfluidic chip capable of holding cilia of different sizes will be designed, fabricated and experiments will be performed using the profiled magnets to study the fluid flow towards identifying the parameters for efficient flow generation.

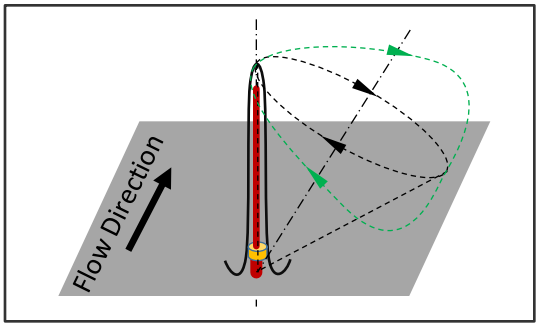

Figure 3: Example of two different paths traced by the cilia actuated by magnets of different shapes. One profile may generate better flow than the other one.

[1] Baczynska, A., et.al., 2007. Morphology of human Fallopian tubes after infection with Mycoplasma genitalium and Mycoplasma hominis—in vitro organ culture study. *Human Reproduction*, *22*(4), pp.968-979.

[2] Zhang, S., Wang, Y., Lavrijsen, R., Onck, P.R. and den Toonder, J.M., 2018. Versatile microfluidic flow generated by moulded magnetic artificial cilia. *Sensors and Actuators B: Chemical*, *263*, pp.614-624.

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