

Artificial Cilia: versatile microactuators and –sensors inspired by nature

MSc thesis theme



Background

Cilia are slender microscopic protrusions of biological cells, acting both as actuators and sensors – especially for generating and sensing fluid flow. They can be viewed as micro-hairs, with a typical length between 2 and 15 μm . Cilia are present on most tissues in human bodies and are responsible for numerous biological processes (Fig. 1). They transport cells and particles – e.g. the ovum is guided by cilia in the Fallopian tube, and cilia sweep mucus to clear the windpipe and the lungs. Cilia in the embryonic node drive fluid transport, critical to embryonic development. Cilia can also sense flow, for example in the kidney tubule.

In the Microsystems Research Section, inspired by these biological cilia, we are developing *artificial cilia*, that we use to manipulate fluids and particles on a small scale, for example to create fluid flow in microfluidic devices, to transport particles, to generate micro-mixing, or to sense small forces at the micro-scale. We focus on magnetically actuated artificial cilia, for which we have developed a range of microfabrication techniques (see Fig. 2).

Project topics

Our current artificial cilia can generate a strong microfluid flow, they can manipulate particles, and they can be used for anti-fouling, as shown in Fig. 3. However we have a big research program to develop them further in various directions: we want to make them even smaller, have better control over their shape and motion, and further develop applications towards fully integrated micropumps and micromixers, anti-fouling surfaces, and sensor elements for measuring local flows and forces for example on and around cells and biological tissues.

MSc thesis projects can focus on any of these topics, and may involve design, microfabrication, fluid flow analysis (transport and mixing), mechanical analysis, or even applying artificial cilia to the characterization of cells and tissues.

References

- [1] J.M.J. den Toonder et al., (2018) *Atlas of Cilia Bioengineering and Computing*.
- [2] S. Zhang et al (2018) *Sensors & Actuators*.
- [3] S. Zhang et al. (2018) *Adv. Funct. Mater.*

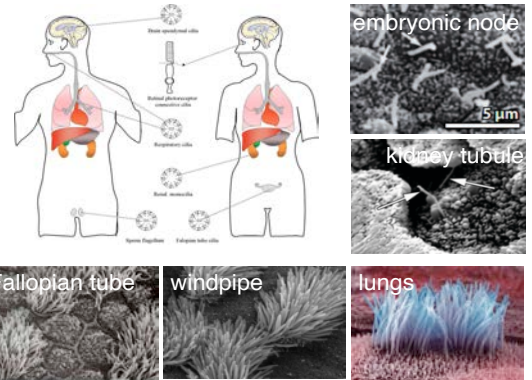


Figure 1: Cilia are microscopic hairlike structures, that function as actuators (for flow generation) or sensors (for shear stress) in many biological systems, including our own body.

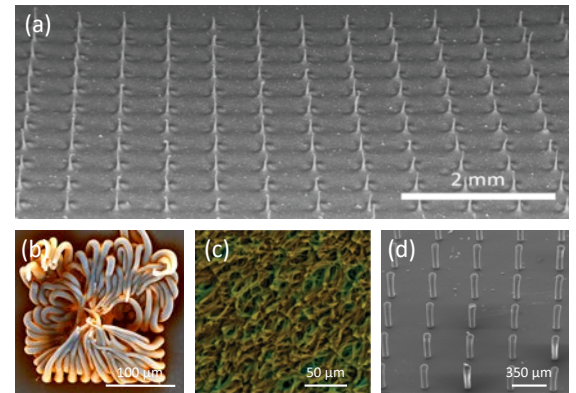


Figure 2: Artificial cilia, magnetically actuated, realized in our lab, made with various microfabrication approaches [1]

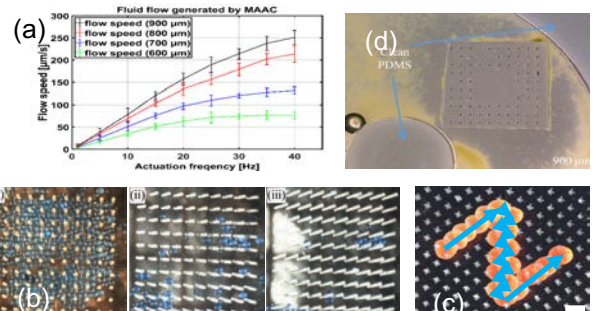


Figure 2: (a) Flow velocities up to hundreds of microns per second can be generated by the artificial cilia. Cilia can also (b) remove particles, (c) controllably transport a particle, (d) create anti-biofouling, preventing algae from attaching to the surface, or removing them. [2,3]

