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ARTIFICIAL CILIA FOR MICROPARTICLE MANIPULATION AND ANTI-FOULING

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Motivation and Aim

The (bio-)fouling of surfaces submerged in liquid forms a serious problem for many applications. One inspiration to address this issue is the use of cilia which are oscillating micro-hairs found in nature, and which are very effective in particle manipulation. Thus we aim to develop engineered analogues of cilia – magnetically actuated artificial cilia (MAAC) for particle manipulation and anti-fouling. We have fabricated MAAC using a home-built roll-pulling setup. The MAAC perform a synchronized tilted conical movement when actuated by a rotating magnet underneath, generating substantial fluid flow which is an important first step towards manipulating surrounding particles and creating anti-fouling.

Background

(Bio-)fouling (Bio-)fouling occurs in many applications including biomedical and microfluidic devices, micro- to macroscale sensors and marine devices. It inhibits their normal functioning and leads to enormous economic losses.

Cilia

In nature, cilia are very effective in manipulating surrounding particles [1].

Simulation-base evidence

Since biological cilia are so effective in manipulating particles, researchers propose the use of cilia to create anti-fouling surfaces. Numerical simulations on repelling particles away from ciliated surface have been done by the group of Balazs and coworkers [2].

Figure 3: Numerical simulation of microparticle manipulation using cilia: (a) a model of active cilia; (b) a model of passive cilia.

Figure 1: Biofouling on the hull of a ship and of submerged marine constructions.

Figure 2: Cilia in: (a) the trachea propelling mucus out of the human body [2]; (b) micro-organisms capturing food into their mouth [3]; (c) in the fallopian tube where they transport the fertilized ovum to the uterus [4].

Experiments

Roll Pulling Process of MAAC

We have fabricated MAAC using a novel out-of-cleanroom, cost-effective and potentially large-scale roll-pulling method. The MAAC made in this way can perform a synchronized tilted conical movement under the actuation of an external rotating magnet. An actuation movie can be found on https://youtu.be/qnqh435wHo8.

Figure 4: (a) Schematic of the roll-pulling setup; (b) Photo of the home-built set-up; (c) Microscopic picture of MAAC made with the roll-pulling setup using micropillars of 150 μm in diameter.

Results

We can produce MAAC with lengths of 250, 200 and 150 μm using micropillars with diameters 150, 125 and 100 μm respectively. The length and aspect ratio can be adjusted by varying the gap between the roll and the substrate, and the diameter of the micropillars. What’s more, the geometrical configuration of the MAAC can be set by controlling the arrangement of the roll’s micropillars. Fig. 5d shows the fluid flow generation property of MAAC.

Figure 5: Microscopic pictures of MAAC: (a) MAAC fabricated with micropillars of 100 μm diameter; (b) MAAC fabricated with 125 μm diameter micropillars; (c) MAAC fabricated with 150 μm diameter micropillars; and (d) the fluid flow generation property of MAAC made by pillars of diameter 150 μm.

Outlooks

Characterize the capability of MAAC in manipulating particles, including sticky and non-sticky, soft and hard, passive and active particles.

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References