

Research Highlights

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Artificial cilia

The commonly utilised microfluidic devices are planar microchips made from polymers. Fluids are pumped through a micro-channel network of a specific design, and control of flow velocity and volumes is performed by external devices that are connected to the microchip, *e.g.* syringe pumps, electrodes and voltage generators. The integration of actuating components on the chip usually comes with additional – and often elaborate – fabrication processes. In past years, some effort was made to find materials that undergo reversible shape deformations on an applied stimulus such as heat, light and chemical environment. However, the solutions presented so far are often difficult to miniaturise to the microscale. In a recent publication, Dutch researchers from Eindhoven University of Technology present a new approach to produce optically addressable microactuators. The host matrix for the microactuators is a composition of liquid crystals functionalised with acrylates or methacrylates. This material can be structured by means of inkjet printing. Importantly,

self-organisation of the rod-like monomeric units is exploited to create a liquid crystalline film with anisotropic properties, *i.e.*, a splayed orientation of the monomers dictates the bending direction. In other words, the motion of the film is independent of the direction of the stimulus, which is here the direction of the incoming light. To obtain the light-induced change of the liquid-crystalline polymer, two photoisomerising azo-compounds are added that absorb ultraviolet or visible light, respectively. *Cis-trans*-isomerisation of the azo-compounds results in a change of the molecular order of the matrix, thereby causing a macroscopic shape change. Based on this method, the researchers produced microactuators with a shape mimicking natural cilia, similar to those found on microorganisms (Fig. 1). Within each actuator, two subunits are created by adding a different azo-compound. Hence, the subunits are individually addressable just by changing the wavelength of incoming light. The bending of the microactuators is thereby similar to the motion of natural cilia, and have the potential to create flow and mixing in wet environments. Since only

a few processing steps are required for the production, and remote and simple addressing of the microreactors is possible, the method is particularly useful to integrate actuating components into microchip devices.

Ion mobility spectrometry at high electric fields

Ion mobility spectrometry (IMS) is an analytical method that is routinely used in the detection of explosives and hazardous material and, additionally, is employed for more general chemical, biological and environmental analyses. In a recent work Shvartsburg *et al.* presented the development of a microchip for conducting ultrafast differential IMS, *i.e.* the chip facilitates filtering of ions within 20 μs .²

In IMS, ion species are separated based on their transport properties in an inert buffer gas. Both the density of the gas and the applied electrical field determines thereby the mobility of the ion. In differential or field asymmetric waveform IMS, ions are filtered when they are exposed to a time-dependent electrical field with

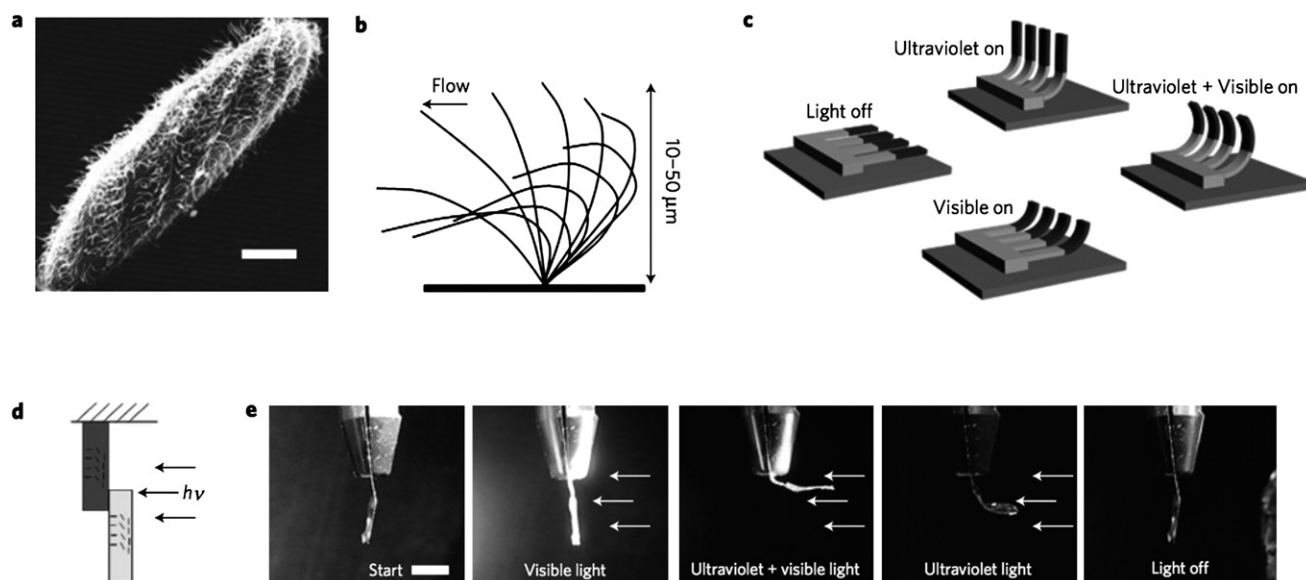


Fig. 1 Fabrication of microactuators inspired by natural cilia. (a, b) Microorganisms such as parametrium (a) use the beating motion of cilia for self-propulsion. (c) Scheme of artificial cilia made of liquid-crystalline polymers. Light-induced changes of the shape results in motion of the microactuators. Since the subunits are responsive to different wavelength of light, they can be individually addressed. (d, e) Scheme and photographs of a single microactuator that is stimulated by ultraviolet and visible light, respectively. (Reprinted by permission from Macmillan Publishers Ltd: *Nature Materials*, ref. 1, copyright 2009).

alternating segments of high and low electrical fields of opposite polarity. The time-dependent electrical field (dispersion field, E_D) is set in a gap between two electrodes, through which ions are pulled by gas flow. The ions drift across the gap, depending on their mobility, until they are neutralised on an electrode. Application of a superimposed so-called compensation field (E_C) sets an offset on this drift and facilitates the determination of two-dimensional maps of E_C vs. E_D , which allows a fuller characterisation of the ionic species. One key to accelerating the separation time in IMS is the increase of the applied dispersion field. However, strong fields usually would cause electrical breakdown for nearly all gases at ambient pressure. In the new microchip with gap sizes of 35 μm it is now possible to establish fields of 61 kV/cm in a N_2 stream, which is 2–3 times higher than in former devices. The gaps are etched through a silicon chip, and the surfaces are electrically connected *via* gold layer deposition. The chip is then mounted on a printed circuit board, and connected to an RF oscillator to apply the high-field dispersion voltage. The chip is integrated with a β -radiation ion source, and a charge collector to detect the filtered ions. The new IMS

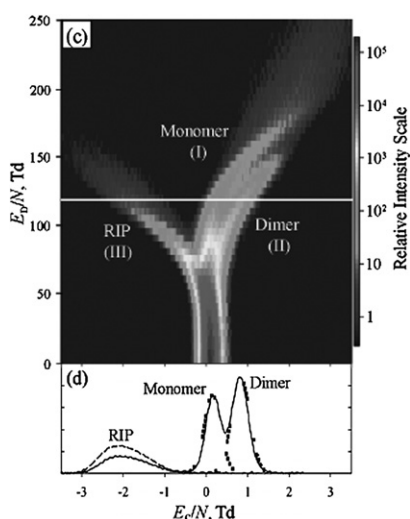


Fig. 2 Separation of ions by ion mobility spectrometry on a microchip. The microchip comprising multiple channels and gaps of 35 μm facilitates high speed separation of ionised species within μs , at extreme electric fields. The two-dimensional map is an example of the analysis of an organophosphorus compound. The β -ionisation of the compound vapour in air produces the monomer, dimer and ubiquitous “reactant ion peak”. (Reprinted with permission from ref. 2. Copyright 2009 American Chemical Society.).

device is characterised using an organophosphorus compound, dimethyl methyl phosphonate (DMMP). By β -ionisation, the protonated monomer, proton-bound dimer and other “reaction ion peak” are produced (Fig. 2). Comparison with former devices reveal that the microdevice has lower resolving power (so far), but accelerates separation times by a factor of 100–10 000. Furthermore, when the detector is not biased, most ions are not captured after separation and hence, subsequent analyses can be performed such as MS, which is currently under development.

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References

- 1 C. L. van Oosten, C. W. M. Bastiansen and D. J. Broer, Printed artificial cilia from liquid-crystal network actuators modularly driven by light, *Nature Mat.*, 2009, DOI: 10.1038/nmat2487.
- 2 A. A. Shvartsburg, R. D. Smith, A. Wilks, A. Koehl, D. Ruiz-Alonso and B. Boyle, Ultrafast Differential Ion Mobility Spectrometry at Extreme Electric Fields in Multichannel microchips, *Anal. Chem.*, 2009, DOI: 10.1021/ac900892u.