Microfluidic devices: merging technology and biology

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An important recent development within the field of Microsystems has been the emergence of 'wet' microsystems: microfluidic devices with tiny channels and chambers in which fluids can be precisely manipulated and analyzed. Originally based on technologies from the semiconductor industry, microfabrication methods for microfluidics have undergone a transition to cheaper approaches that do not require an expensive cleanroom and that use unconventional materials like elastomers and thermoplastics.

In this lecture, I will show how this development stimulates the exciting merging of engineering sciences and life sciences. On the one hand, fluid manipulation principles found in biology can be adopted and applied in microfluidic devices through 'biomimetic design'. On the other hand, microfluidic devices can be used to control and understand biological processes by studying biomolecules, biological cells, or even miniature models of complex tissue mimicking true-to-nature human organ function [1]. Eventually, this will expand our understanding of health and disease and impact medical diagnosis and therapy.

I will give two specific examples of biomimetic design in microfluidic devices: (1) Artificial cilia for fluid pumping, that mimic biological micro-hairs found in nature, for example on the surface of micro-organisms, en in the inner linings of our airways [2] (Fig. 1). (2) Responsive surfaces that can be used to manipulate liquids, representing dynamic versions of surface topographies found in nature such as on lotus leafs or on shark skin [3]. In addition, to illustrate how microfluidic technology can be used to understand disease biology, I will show our "cancer on a chip" (Fig. 2). In this device, stages of the metastatic cascade that is responsible for tumor spreading, are mimicked by creating, precisely controlling, and systematically varying micro-environments in which tumor cells are grown, to obtain basic understanding of critical micro-environmental factors for metastasis.

[1] Beebe, D.J., Ingber, D.E. & Toonder, J.M.J. den (2013). Organs on Chips 2013. Lab on a Chip, 13(18), 3447-3448.
[2] Wang, Y. (2016). Out-of-cleanroom magnetic artificial cilia. Eindhoven: Technische Universiteit Eindhoven. ISBN 978-94-6259-979-6.
[3] Liu, D., Bastiaansen, C.W.M., Toonder, J.M.J. den & Broer, D.J. (2013). (Photo-) thermally induced formation of dynamic surface topographies in polymer hydrogel networks. Langmuir, 29(18), 5622-5629.

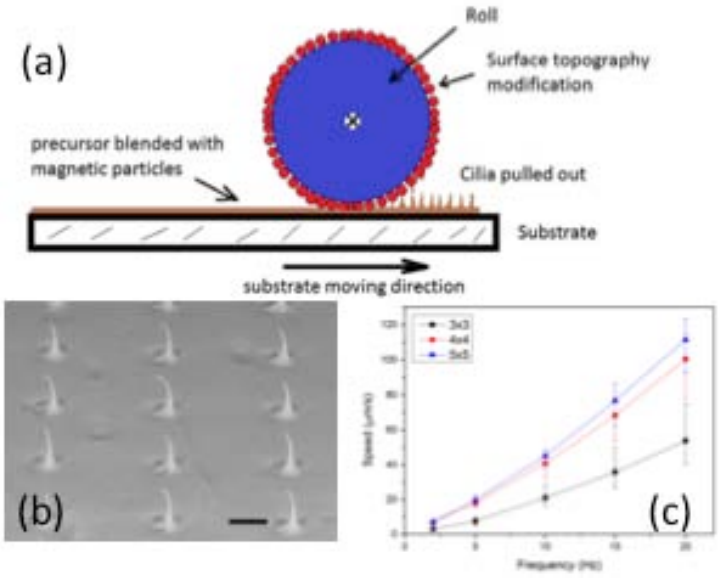

Figure 1: (a) Magnetic micro-actuators (artificial cilia) can be produced on large area surfaces using a roll-pulling process; (b) Artificial cilia made using the roll-pulling process (scale bar 200 µm); (c) the actuated artificial cilia generate substantial flow when integrated in a microfluidic device.

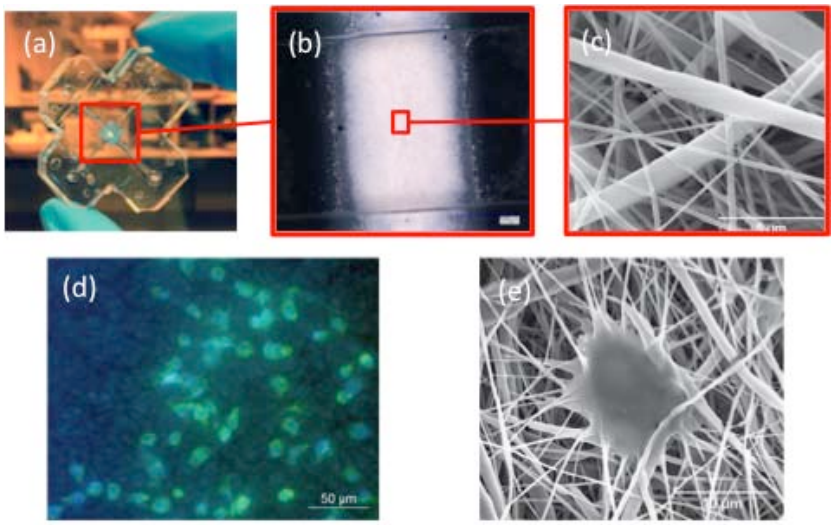

Figure 2:Our breast cancer on a chip. (a) a microfluidic chip, made of PDMS using soft lithography, in which (b) a fibrous ECM, made by electrospinning, is integrated, with (c) a well-controlled nanofibrous structure. The ECM is made of polycaprolactone (PCL), coated with fibronectin. (f) MDA-MB-231 cells cultured in the electrospun ECM. DAPI; blue: green: actin (merged); (g) SEM image of a single MDA-MB-231 cell in the electrospun ECM. (den Toonder et al. unpublished).