Nanobiochemical applications of rolled-up nanomembranes for: From Nanorobotics to Lab-in-a-tube systems

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We will present the recent progress on the fabrication of rolled-up 3D microstructures for nanobiochemical applications, in particular (i) the development of catalytic microjet engines, and (ii) a new bioanalytic microsystem platform, dubbed “Lab-in-a-tube”, for single cell studies

The fabrication of autonomous nanomachines which could one day navigate inside the human body remains a challenging dream in nanotechnology and biomedicine.[1] Over the last few years, there has been increasing interest in the use of chemistry to propel tiny engines in a similar fashion that nature uses biochemistry to power biological motors.[2,3]

There are three main challenges that researchers try to conquer when engineering artificial nanomachines: i) efficient *self-propulsion*; ii) *motion control*; iii) the *development of useful task* such as the transport of cargo in fluid, biosensing and bioseparations in chips.

Rolled-up microtubes[4] containing a Pt catalyst[5] or catalase enzymes[6] in their inner layer can trigger the breakdown of the hydrogen peroxide fuel wherein they are immersed. The hollow structure generates a thrust of oxygen microbubbles in their interior released from one of the tubular openings which in turn propels the microtubes.

Here we will present our recent advances on the controllable manipulation of microjets in microfluidic channels[7] and the transport of different microobjects[8] and biological material such as cells[9] (Figure 1). We performed different methods to wirelessly control the motion and the power of the microjets.[8],[10] In addition, there is a great interest in reducing the toxicity of the fuel used to self-propel artificial nanomachines. Therefore, a method to increase the efficiency on the conversion of chemical into mechanical energy is desired. We employed temperature control to increase the efficiency of the microjet engines while simultaneously reducing the amount of the peroxide fuel. Cytoxicity tests proved the viability of Fibroblast cells in the working solution for about 1 hour.[11] We will also present the scalability of these nanotubular machines down to sub-micron size in diameter (we obtained the World Guinness Record ® for the Smallest man-made jet engine)[12] which can be used as nanotools.

Based on the novel “Lab-in-a-tube” concept,[13] we can design arrays of multifunctional devices for the observation of single cell behavior inside transparent microtubes that can be employed for diverse biological applications (Figure 2).[14] A simple approach to guide the outgrowth of neurons[15] and yeast cells[16] in mi-crotubular confined spaces has been previously reported which paved the way to more advanced studies based on biocompatible microtubular structures such as mitosis time, spindle reorientation and mechanical and chemical stress to mammalian cells.[17] Microtubular structures act both as microreactor chamber for cellular growth and also as optical sensors for studying different phenomena occurring within the cells confined in their interior. The multifunctionality of the “Lab-in-a-tube” platform will be further extended by integrating different modules into a single microtubular unit, bringing up several applications such as optofluidics sensors[18], magnetic biodetection[19] among others.

Figures

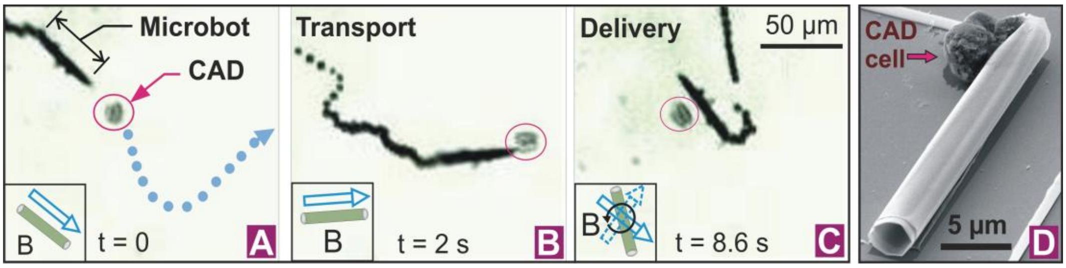

Figure 1. Controlled manipulation and transport (A-C) of CAD cells by using catalytic microbots. The motion of the microbot is aligned by an external magnetic field (schematic insets) provided by a small magnet placed underneath the sample containing the cells and microbots. D) SEM image of Ti/Fe/Pt rolled-up microtubes with CAD cells.

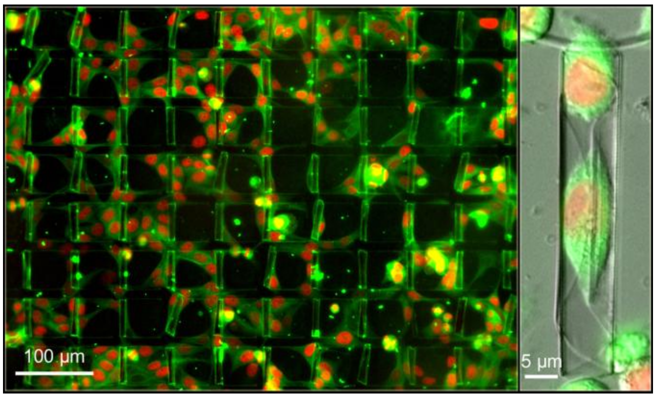

Figure 2. Array of Fibronectin functionalized SiO/SiO_2 microtubes containing dyed HeLa cells. The cells interact with the biocompatible microtubes and they can go inside where they even proliferate.

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