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Novel Smart Concepts for Designing Swimming Soft Microrobots

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Abstract

The development of mobile un-tethered microscale robots could revolutionize the future of medicine, since they can be conceived to move in micro-structured liquid environments, such as in inaccessible districts of the human body for performing *in vivo* diagnosis and therapy. However, power supply and actuation are still open issues in microrobotics, because of the lack of power sources and actuators at these scales. Considering the amazing levels of functionality exhibited by microorganisms, bioinspiration is an attractive approach to address the development of innovative solutions. The demonstration of efficient methods for building, powering and steering microscale robots are thus the first crucial steps towards such advanced systems.

Keywords: Microrobot; Propulsion; Actuation; Power supply

1. Introduction

In the development of mobile un-tethered microrobots, the core issues to deal with are: 1) what kind of motion is most suited to the target working environment (propulsion); 2) how can this motion be implemented (actuation); and, 3) what kind of energy source can be exploited (power supply). Nowadays the most pursued approach consists in facing all these issues through the direct wireless propulsion of microrobots by means of controlled magnetic fields [1]. Such an approach leads to a dramatic simplification of the design and fabrication of microrobots to the detriment of the complexity of the external steering systems, which could require cumbersome hardware. Here the possibilities to modify the microrobot architecture, for implementing features additional to propulsion, are very limited. Hence, our objective is to investigate novel approaches to obtain "smart" microrobots with intrinsic passive and/or active properties. In this route swimming capabilities, self-propulsion and energetic autonomy based on bioinspiration is a key strategy since Nature presents excellent winning solutions at the microscale [2] (Fig. 1).

2. Preliminary Results

Recently [3], we faced the issue related to the movement in delicate liquid-filled anatomical districts (e.g. in the CNS). At first, the design and the choice of materials were such that passive properties of interest could be implemented in the body structure. The microrobots had a near-spherical alginate hydrogel structure, containing a tailored concentration of dodecane. This way, neutral buoyancy in water and softness were obtained and external gravity compensation strategies

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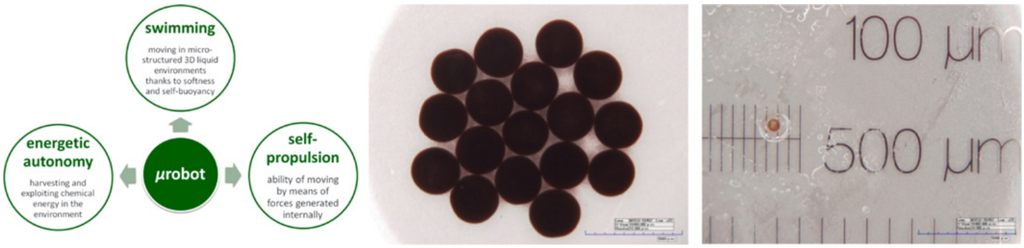

Fig. 1. (a) Schematic of the innovative microrobotic scenario; (b) mm-sized microrobots; (c) microrobots scaled down to ∼500 μm.

can be avoided by setting the microrobots density. In order to investigate the way different reactions to external stimuli can be implemented in the microrobots, two types of magnetic behaviour (paramagnetic and ferromagnetic) were achieved by means of diverse distributions of iron oxide nanoparticles within the polymeric body. The millimetre-sized microrobots were propelled in water at speeds of about 1 mm/s by applying an 8 mT uniform magnetic field for magnetization and a 400 mT/m uniform magnetic field gradient for pulling. The fabrication method allows scaling of the microrobots down to a few hundred micrometers in diameter; currently, the achieved propulsion speeds are of about one body-length per second.

3. Conclusions

Future mobile microrobots will be autonomous, able to navigate in the human body, spontaneously reacting to specific environmental conditions exploiting environmental chemical energy. Development of soft and self-buoyant magnetic microrobots able to swim in liquid environments represents the first step towards development of smart microrobots for human body application.

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