Opinion

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Medical Nano Robots for Precise Drug Delivery through Targeted Transport

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Description

The flexible and helical swimmers introduced represent examples from the class of mechanical swimmers that rely on external fields for actuation. Chemical swimmers, on the other hand, exploit chemical energy from their local environments for self-propulsion. These include self-phoretic Janus particles or nanowires that generate local solute concentration gradients (for self-diffusiophoresis) or local electrical potential gradients (for self-electrophoresis) due to asymmetries in surface activity. In addition to phoretic locomotion, chemical reactions can generate bubbles to propel the particle by recoil forces. Since the propulsion mechanism is not phoretic, these bubble-propelled particles have more roust propulsion performance even in the presence of dissolved salts, an advantage over phoretic swimmers for biomedical applications. Recent efforts have also taken a hybrid approach by combining multiple artificial propulsion mechanisms or integrating artificial and biological systems (biohybrid swimmers). It should be noticed that in addition to the microswimmers, rolling and crawling-like surface surfacemediated locomotion have been utilized both in synthetic and biohybrid microrobots. All these propulsion strategies, together with other novel designs, form a diverse spectrum of candidates for equipping biomedical micro/nanorobots with robust locomotive capabilities.

Fabrication of Micro Robots

The advances of computer chip technology, it is now possible to make diodes well below the scale of microns, and molecular diodes only two to three nanometers in length have long been synthesized chemically. It may thus become possible to make microscopic scalpels that consist of propulsion, steering and sensing components patterned onto tiny silicon chips. One can imagine driving diode-powered scalpels wirelessly and remotely with radio-frequency electric fields, which are not absorbed by the body. Ultimately, these microscalpels might be delivered with a very fine needle and piloted to their destination by remote control. Scientists (and science-fiction writers) have contemplated nanomachines at least since 1959, when physicist Richard Feynman considered the limits of scale for machines and information storage systems in a forward-looking lecture entitled “Plenty of Room at the Bottom.” He pointed out that the laws of physics are valid down to the length scale of molecules. There is, therefore, no reason, apart from the obvious challenges of making them, that one should be prohibited from constructing vehicles or even the factories to mass-produce nanomachines from atomically precise molecular parts.

In the intervening decades, Feynman’s lecture has continued to inspire research in nanotechnology. Meanwhile the prevailing view of the living cell has shifted from a soup pot of enzymes carrying out metabolic reactions to a ticking Swiss watch of mechanically linked nanometers. Thus, in many ways, cells are the molecular factories that Feynman envisioned. Investigators have learned a good deal about how to make nonbiological motors inspired by those of biology, but there is still much to learn about the principles of catalyzed movement on this length scale. No doubt future work will find as yet unimagined ways to exploit such knowledge in biomedicine, energy conversion, chemidon foleycal synthesis and other fields.

Nano Robots and Nems

Nano robots, Nano machines, and other Nano systems discussed in this paper are objects with overall sizes on the order of a few micrometers or less in all three spatial directions, and which are assemblies of nanoscopic components with individual dimensions 1–100 nm. Medical Nano devices traveling in the human body for therapeutic purposes have captured the public’s imagination at least since the times of the movie Fantastic Voyage (Twentieth Century Fox, winner of the 1966 Oscar for best visual effects). Order-of-magnitude feasibility calculations indicate that nanorobots are not physically impossible. They would be extremely useful not only in the medical field but also in applications such as: 1) monitoring and interacting with harmful microorganisms in the air or in water and 2) building intelligent surfaces with a controllable (programmable) structure, for example, with variable roughness and friction. However, artificial Nano robots do not exist today, primarily because of the difficulties in building the necessary nanostructures. The only extant nanorobotics systems are biological, and provide an existence proof that such systems are indeed feasible. Nanorobotics and, more generally, NEMS research involves design (which often is biologically inspired), prototyping, fabrication, programming, and applications such as biomedical nanotechnology.

Robotics at any scale involves sensing, control, actuation and propulsion, power, communications, interfacing, and programming and coordination. In the following sections we discuss some of these issues, with an emphasis on actuation, which is a fundamental requirement for robotics. (We use the terms “machine,” “motor,” and “actuator” as synonymous in this paper. We will often look toward biology, for instance to microorganisms such as bacteria, to see how nature has solved some of the problems that Nano robots will encounter.

At small scales, locomotion is governed by low Reynolds numbers and Brownian motion, thus the primary consideration for designing micro/nanorobots relies on developing engines that are continuously “turn-on” and generate enough force to overcome the drag forces from the environment. Therefore, the design and fabrication of small-scale robots are driven by the need for active materials that can continuously convert diverse energy sources into locomotion. For example, chemically propelled micro robots require the asymmetric distribution of catalytic material to generate directional motion, magnetically propelled micro motors use magnetic materials to induce rotation of a micro engineered structures and ultrasound propelled motors employ a structure with density asymmetries to generate pressure gradients that enable their locomotion. The first generation of micro/Nano engines for small scale robotics relied on simple fabrication procedures and geometries. These early Nano robots were fabricated by electrochemically reducing metallic correspondent salts inside Nano/micro symmetrical pores. The advantage of this highly explored fabrication method is the large scale production (>100 0000 structures per batch), and the ability to intercalate different electroactive materials (metals, polymers, semiconductors) and designs (hollow tubes, porous wires) in the same construct. Another bottom-up strategy is self-assembly. This includes layer by layer assembly of sequentially charged materials, generating self-organized polymers to create bowl shape stomatoyces filled in their interior with catalytic materials, and connecting colloids to make engineered structures and magnetic links. The use of thin-film coatings over templates to generate asymmetric coated structures has also been explored for micro/Nano engine fabrication. For example, Janus micro motors were built by adding a catalytic thin film layer over half of a microsphere using e-beam or sputtering deposition. On the other hand, atomic layer deposition-based coatings (parylene, titanium oxide, silicon oxide) were used to cover most of the reactive surface except for a small opening, thus reducing the exposed reactive area.