Nanomotors as Drug Delivery Vehicles

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Nanomotors are emerging miniaturized machines that can convert chemical or external energy into mechanical motion. Mobility and directionality of nanomachines creates new opportunities in mobile sensors, self-assembled complex nanoarchitectures, and advanced forms of micro- and nano- electronics. During the past decade, significant progress has been made on designing nano-motors as intelligent biomedical platforms for targeted drug transport. While drug delivery systems have evolved since 1952[1], traditional carriers rely on the body fluid circulation and, therefore, lack adequate and targeted penetration of the drug in the desired tissue or lesion. The advent of nanomachines offers a new option in drug transport, as they can be fuel-driven – also called catalytic nanomotors – or propelled by exogenous stimuli (magnetic or electric field, ultrasound, and light) towards the area of interest with high efficiency. Such propulsion mechanisms are also used to attain the therapeutic cargo release in certain locations in the body, improving drug targeting. Considering the toxicity of fuels, catalytic nanomotors are mainly limited to on-chip proof of concept studies. The first nanoscale platform for drug-delivery was reported by D. Kagan and his team[3], who managed to precisely deliver an anticancer drug, encapsulated in a magnetic copolymer (PLGA), by a flexible Ni-Ag alloy catalytic nanomotor (Fig.1). The Ni segment was able to pick up the copolymer by interacting with its magnetic microparticles. His research was fundamental in the field of cancer-targeted delivery by demonstrating that the strong propelling force provided by the nanoshuttles can potentially facilitate the tissue penetration of drug carriers. Furthermore, it emphasized the need of fuel-free nanomotors for this purpose.

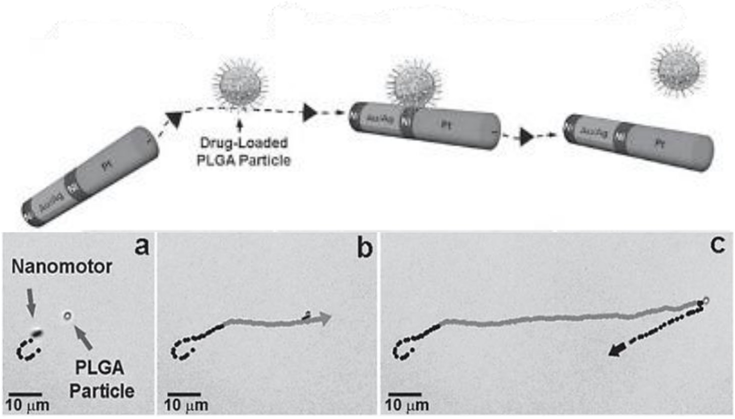

Figure 1. Top: Load, transfer and release of a drug loaded PLGA particle by a catalytic Ni-Ag nanowire motor. Bottom: Optical microscopy images of an en-route PLGA particle pick-up by the nanomotor. (a) movement towards magnetic cargo; (b) dynamic load, and transport ; (c) release.[3]

To date, numerous attempts were made, both from the same team[4] and other researchers[5],[6], to fabricate fuel-free nanomotors. In a recent study[6], they were able to create hybrid nanodevices mimicking the eel's motion for targeted and spatially controlled drug delivery. Said study, expanded on the understanding of the propulsion mechanisms, whilst at the same time, providing a design which offered desired competencies in motion and directionality(Fig. 2). However, the main issue with synthetic devices is the in vivo compatibility. Most of the nanomotors reported are composed of inorganic materials, which limit in vivo research at the cellular level.

Currently, biological hybrid nanomotors ap-pear more promising as an alternative to artificial nanodevices[7], featuring advantages toward in vivo, targeted and personalized therapies, such as durable coating to assist the protection of the therapeutic cargo during its transport, and -most significantly- biocompatibility[8]. Despite the great advances on the field of drug delivery via nanomotors, more research is required in order to overcome the current challenges, giving emphasis on seeking the golden line between our insight on artificial devices and biocompatible materials. Bio-hybrid systems are expected to provide a new and unique approach for rapidly and effectively delivering drugs or drug carriers to predetermined destinations in a target-specific manner, and eventually being able to bear satisfactory characteristics to pass in vivo trials.

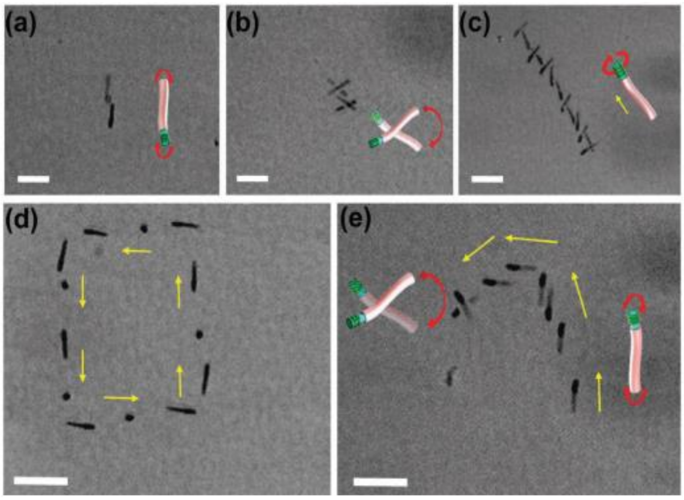

Figure 2. Swimming behavior of hybrid nanoeels. (a) Surface-walking; (b) wobbling; (c) corkscrewing motion; (d) controlled motion on a predefined trajectory; (e) transition from a surface-walking swimming mode to a wobbling motion upon changing the parameters of magnetic fields. All scale bars are 15 μm. [6]

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