Review article

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NANOSWIMMERS- A ADVANCE TOOL FOR MEDICAL APPLICATION

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ABSTRACT

Nanoswimmers are the device attached with nanomotor which is worked under the principle of bacterial flagella motion. The nanoswimmers are specially designed device for biomedical field. Various areas of medicine, including targeted drug delivery, precision nanosurgery, biopsy, cell sorting, or diagnostic assays, would benefit from recent developments of efficient fuel-free and fuel-driven nano/Nanoscale machines. In this review article we discussed fabrication of nanoswimmers and biomedical application. These nanorobots could be the future tool in the bio medical field specially surgery and target drug delivery for most of the complicated diseases.

Keywords: Nanoswimmers, Flagella, Nanorobots.

INTRODUCTION

The motion of natural and synthetic nanoscale objects had been developed fundamentally to stimulated substantial research activity.In future patient treated with nanorobots and could become standard practice to deliver drug specifically to parts of the body affected by disease. But injecting drug-loaded nanocarriers might not always be enough to get them where they need to go. Now scientists are report the development of new nanoswimmers that can move easily through body fluids to target the particular part of body or cell.Small robots could have many benefits for patients. For example, they could be programmed to specifically kill the cancer cells, which would lower the risk of complications, reduce the need for invasive surgery and lead to faster recoveries. It’s ainteresting field of study with early-stage models currently in development in laboratories. But one of the challenges to making these robots work well is getting them to move through body fluids, which are like molasses to something as small as a nanorobot [1].

The researchers strung together three links in a chain about as long as a silk fiber is wide. One segment was a polymer, and two were magnetic, metallic nanowires. They put the tiny devices in a fluid even thicker than blood. And when they applied an oscillating magnetic field, the nanoswimmer moved in an S-like, undulatory motion at the speed of nearly one body length per second. The magnetic field also can direct the swimmers to reach targets.

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Design of Nanoswimmers:

Nanoswimmers in literature are presented as the candidates of minimal-invasive surgery tools to handle high precision therapeutic operations such as retina repair. Based on movement on bacteria and spermatozoa, and via some macro and Nano-scale experiments, propulsion mechanisms of natural nanoswimmer are established as viable actuation means for motile autonomous swimming Nano robots. Propulsion mechanisms of bacteria and spermatozoa are based on wave propagation carried out by slender tail structures actuated by nano-scale motors. The motivation of this work is to identify the role of hydrodynamic interactions between body and tail on the effective drag force and rigid-body kinematics of bacteria species, and to present modelling tools that improve the predictability of swimming action of bacteria, which are to be incorporated in cybernetic nano-robotic [2].

In nature, bacteria such as *E. coli* swim in viscous fluids by rotating flagella in a helical wave to propel them. Inspired by this flagellar propulsion method, magnetic Nano-/nanoswimmers with helical shapes have been fabricated by different methods such as glancing angle deposition (GLAD), self-rolling techniques, 3D lithography, and biotemplate methods[3].

Fabrication of artificial bacterial Nanorobots:

When engineering bacterial Nanorobots, it would be very difficult to replicate the molecular motor design of bacteria. The use of rotating magnetic fields to externally power the nanorobots removes the need for an on-board motor and bearing between the helical tail and the body. Instead, the focus lies on the challenging fabrication of three-dimensional helix structures at the nanoscale. Three methods for the fabrication of helical structures of nanoswimmers will be produced based on nanometer-scale robots in a controllable and repeatable manner. What they have in common is that they produce nanorobots that have a helical shape mimicking the bacterial flagella, which is why bacterial nanorobots are often referred to as ABFs. The other common design parameter is the use of magnetic material in some form or another, which is essential for the magnetic actuation [4].

Self-scrolling method:

The self-scrolling technique was the first method to capable of controllable batch fabrication of bacterial nanorobots. The technique is based on a thin film deposition onto a sacrificial layer using molecular beam epitaxy. Structures are patterned with lithography and a subsequent reactive ion etching (RIE) step. After removing the sacrificial layer, the remaining thin film structures roll up due to internal stresses in the material. The rolling direction is preferred along the h001i direction of the wafer. By choosing the alignment angle between the rolling direction and the ribbon pattern, the helicity angle can be chosen precisely. The radius of the helix is controlled by the thickness of the thin-film layer. Common materials are Silicon (Si) or Gallium arsenide(GaAs) composites, which are not magnetic [5]. A magnetic material, for example nickel, is therefore deposited at one end of the ribbon before the self-scrolling step. Using soft magnetic material requires the shape of the magnetic material to be designed such that it has an easy axis of magnetization perpendicular to the helical axis.

GLAD method:

The glancing angle deposition (GLAD) uses vacuum deposition onto a substrate at an oblique angle combined with a controlled motion of the stage holding the substrate. In standard thin film deposition, the atoms strike the surface at an angle of 90˚. If the substrate is tilted, the atoms agglomerate at nucleation sites, and the material is only deposited along the “line-of-sight” resulting in gaps between the nucleation sites and in pillars growing in the direction of the vapour flow. By a slow and steady rotation of the stage, these pillars are grown into helical shapes. This method results in very densely packed batch fabrication of helical swimmers. Similar to the self-scrolling ABFs, a magnetic material has to be deposited onto the GLAD grown helices in a second step. This is performed by first releasing the structures by sonication and evaporating cobalt on the helices laid flat on a surface. Unlike the self-scrolled ABFs that have magnetic material only at one end and with a defined shape, the GLAD grown helices have a magnetic film along the whole structure [6]. For magnetic actuation, the magnetization has to be perpendicular to the helical axis, which is achieved by permanently magnetizing the cobalt in the last fabrication step.

3D lithography method:

The previous methods used fabrication techniques designed for 2D structures in such a way that the 3-dimensional helices could be created. In recent years, commercial machines have become available that allow 3D lithographic patterning of photosensitive polymers. A 2-photon polymerization occurs at the focal point of the laser and, combined with a motorized stage, true 3D structures can be achieved with high flexibility in terms of shapes and sizes. A major drawback is the fact that it is not a batch fabrication process. Also, the combination of multiple materials and compatibility with other fabrication methods remain a challenge. One way to circumvent an additional step of magnetic material deposition is to use a magnetic particle polymer composite [7]. Nanostructures have successfully been written using ferromagnetic particles embedded in the photocurable polymer. One possibility is to permanently magnetize the particles in the polymer perpendicular to the helical structures.

Fig: Artificial bacterial flagella like nanoswimmers

Artificial bacterial flagella (ABFs) are one type of magnetic helical Nanoswimmers with helical shapes and magnetic materials. ABFs can perform 3D navigation in a controllable fashion with Nanometer precision in liquid using low-strength rotating magnetic fields translating rotational movement to translational motion in a screw-like fashion. This flagellar propulsive method has been proposed as a promising approach for in vivo applications [8].

Advantages:

- Deliver drugs to targeted locations in the body
- Move biological material through medical diagnostic devices
- Mix fluid streams in medical diagnostic devices
- Enhance reaction rates

Application:

Artificial nanoswimmers arecurrently an interesting research field due to their various potential medical applications, ranging from modern biomedical applications such as minimally invasive surgery and targeted therapy, manipulation of nano-objects, to environmental applications such as decontamination and toxicity screening. Nanoswimmers with different propulsion mechanisms have been developed. The use of magnetic fields to power nanoswimmers has gained particular interest, especially in biomedical applications, since the magnetic fields can penetrate through the human body allowing wireless control of these tiny devices without harming cells and tissues.

Gene therapy is a medical treatment in which DNA is used as a therapeutic drug that is delivered into a patient's cells to treat diseases such as inherited disorders and cancers. During the process the nucleic acids must be delivered to the defect cells, transfected into the cells, and then express a function to treat a particular disease. Gene delivery carriers, commonly called vectors, have been developed to carry the DNA to improve gene therapy due to the poor efficiency of naked DNA entering cells. Lipoplexes, complexes of cationic lipids and DNA, are one promising tool for nucleic acid delivery to cells, such as for delivering siRNA for gene silencing and plasmid DNA (pDNA) for transfection. The delivery of nucleic acids to targeted cells and tissues remains a challenge [9]. By integrating lipoplexes with mobile Nanorobots such as ABFs as lipoplex carriers, a multifunctional system can be created that can be wirelessly controlled for targeted delivery of DNA to specific areas in hard-to-reach areas, such as in the human body or in lab-on-a-chip environments.

Cancer therapy:

As these robotic agents are very small, it makes sense to use a multitude of them to, for example, increase the amount of drug delivered to a cancer site. A swarm of Nanoswimmers may also be easier to detect because they can emit a stronger signal as a group, for example in the form of fluorescence brightness [10].

Blood clotting:

Nanoswimmers that can penetrate blood and even thicker liquids that exist within the body, something that corkscrews modelled on bacterial flagella have been disappointingly bad at. The tiny devices are made of three connected chains, one made of a polymer and two consisting of nanowires that can be influenced by an external magnetic field to flap in a given direction. This allows the system to control the direction in which the nanoswimmers are moving, so any on-board cargo such as drugs or some sort of nanoparticles can be precisely placed inside a tumor.

Detoxification agent:

For biomedical applications of nanoswimmers were shown to be noncytotoxic after 72 h of incubation with mouse muscle cells, and the functionalization of ABFs with nanosized drug carriers, i.e., liposomes, has been studied. The abilities of controlled release and single-cell targeted delivery with these liposome-functionalized ABFs (f-ABFs) have been demonstrated by capturing a water-soluble drug model molecular (calcein) within liposomes [11].

Nano voyagers:

The nanoswimmers are made of silica and covered in a layer of magnetic coating so that their motion can be controlled from outside by a small and homogeneous rotating magnetic field. Dubbed 'nano voyagers', these tiny swimmers could potentially open doors to a range of biomedical applications in terms of drug delivery. The voyagers would be to use these voyagers for targeted drug delivery and nanosurgery under in-vivo conditions.

One important requirement for a nanomotor to swim in human blood is that the thrust it generates should be big enough to overcome viscous drag due to the thickness and stickiness of blood and resistance offered by blood cells. Secondly, according to Ghosh research, the large concentration of chloride and phosphate ions in blood can eat away the magnetic coating necessitating another protective cover around the nano motor. Finding a suitable second coating that remains stable for several hours, that can be overcame these hurdles by using a 'conformal ferrite' coating over the magnetic nano helices.

CONCLUSION

In the above review of this article, clearly briefing that nanoswimmer tool could be the best choice for drug delivery and surgery in medical field. By understanding and execution of nanomotor biological functionality, i.e., pick-up, transport, and delivery of biologically relevant nanoswimmers, is crucial for myriad future biomedical applications including drug delivery and gene therapy.

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