A REVIEW ON SUPPLY OF POWER TO NANOROBOTS USED IN NANOMEDICINE

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ABSTRACT

Nano technology has vast applications such as microscopic robots or travel inside the body to deliver drug or do micro surgery. One major requirement to carry out such activity is power. Here in my paper, I have studied the possible sources of power supply from within the body and supply from outside the body, their merits and demerits. I have studied the various factors and different situations that can influence the power requirements.

KEYWORDS: *Fiber based nanogenerators, piezoelectric effect, thermoelectric generator, microbial fuel cells, electrogenic bacteria.*

I. INTRODUCTION

A nanorobot is a tiny machine designed to perform a specific task. Its dimension is in nano scale i.e. a few nano meters (nm) or less, where $1nm=10^{-9}$ meters. Nano robots are designed to perform at atomic or molecular level.

The major application is in medical industry known as nanomedicine. There is a vast area of applications such as chemotherapy, pacemakers, biochips, insulin pumps, nebulizers, needleless injectors, hearing aids, medical flow sensors, blood pressure sensors, glucose monitoring, drug delivery systems.... and many more.

One major requirement for nanorobots is a possible power source. It needs the power supply to move to the site of operation, to perform its functions at the site, at last after finishing, to exit from the body. There are various possibilities discussed below. The total paper is divided into two categories power source from within the body and from a source external to the body. Power source from within the body is divided into two main categories as self contained power supply and power from blood stream. Under each topic all the possible sources are studied. Similarly from a source external to the body is also divided into two major categories as using a physical connection and having no physical connection. Under these categories all the possibilities with their merits and demerits are studied.

II. SELF CONTAINED POWER SUPPLY

In this category we will see all the possibilities from where the nanorobots can get the power by itself. Each nanorobot should contain a power source within itself so that it can carry out its work smoothly. Various possibilities are discussed below.

2.1. Chemical Batteries

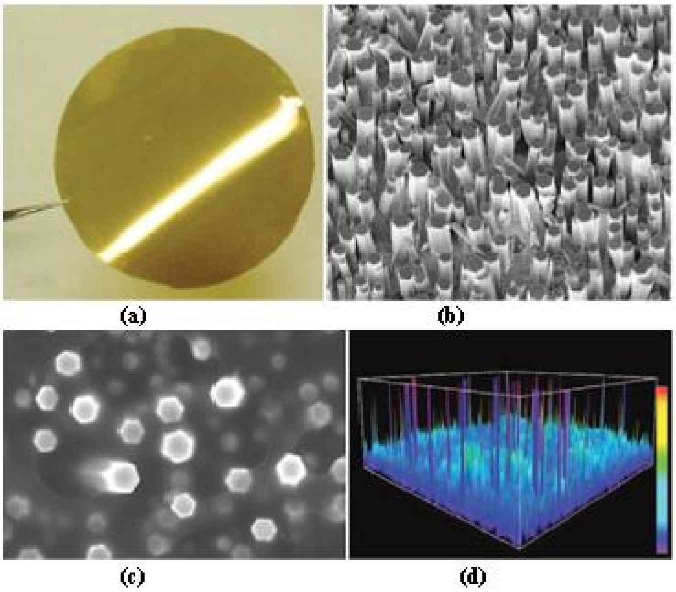

Figure 1: (a) Optical image of the polymer substrate on which aligned ZnO nanowires had been grown. (b) SEM image of the as-synthesized ZnO nanowires by a chemical approach. (c) SEM image of the as-synthesized ZnO nanowires on a patterned substrate. (d) Electric energy can be generated and electric output can be achieved.[1]

We can simply carry a chemical battery directly on board. We can use conventional chemical batteries. The main disadvantage is its size. The ratio between power and size tells us we will not get the required power with this small size.

2.2. Flexible power generator built on polymer substrate [8][1]

Highly aligned ZnO NW (Nano Wires)s have been grown using chemical synthesis. Figure 1(a) shows optical images of a large polymer substrate on which ZnO NW arrays were grown, which are clearly revealed by scanning electron microscopy image (Figure 1(b)). To improve the adhesion of the substrate with the NWs, a thin layer of polymer can be spanned onto the substrate after the growth, so that the roots of the NWs are partially embedded (Figure 1(c)). Electric energy can be generated using the designed experiment and electric output of ~10 40 mV has been achieved (Figure 1(d)). The piezoelectric power generators using ZnO NWs arrays on flexible plastic substrate might be able to harvest energy from the environment such as body movement (e.g., gestures, respiration, or locomotion).

The ceramic or semiconductor substrates used for growing ZnO NWs are hard, brittle and cannot be used in the areas that require a foldable or flexible power source, such as implantable biosensors in muscles or joints, and power generator built in walking shoes.

Two advantages may be offered by this approach. One is the cost-effective, large-scale solution approach used to grow ZnO NW arrays at a temperature lower than 80 °C. The other is the large-degree of choice of flexible plastic substrates used for growing aligned ZnO NW arrays, which could play an important role in the flexible and portable electronics.

2.3. Fiber-based nanogenerators

The design of the nanogenreator is based on the mechanism of utilizing zigzag electrode, but we have replaced the zigzag electrode by an array of metal wires, as shown in Figure 2(a). By brushing the metal nanowire arrays across the ZnO nanowire arrays, the metal wires act like an array of AFM tips that induce the mechanical deformation to the ZnO nanowires and collect the charges. A unique advantage for ZnO nanowire arrays is that they can be grown at 80 °C on substrates of any shape and any materials. In reality, the metal nanowire arrays were made by metal coating of ZnO nanowire arrays grown on Kevlar fiber (Figure 2(b)). The metal to be coated is required to form a Schottky contact with ZnO. Entangling the two fibers, one coated with Au and one without coating, sets the principle of the fiber-based nanogenerator (Figure 2(c)). A cycled relative sliding between the two fibers produces output current owing to the deflection and bending of the ZnO nanowires (Figure 2(d)). This is the fiber-based nanogenerator , with potential for harvesting energy from body movement, muscle stretching, light wind, and vibration.[1]

2.4. High voltage capacitors

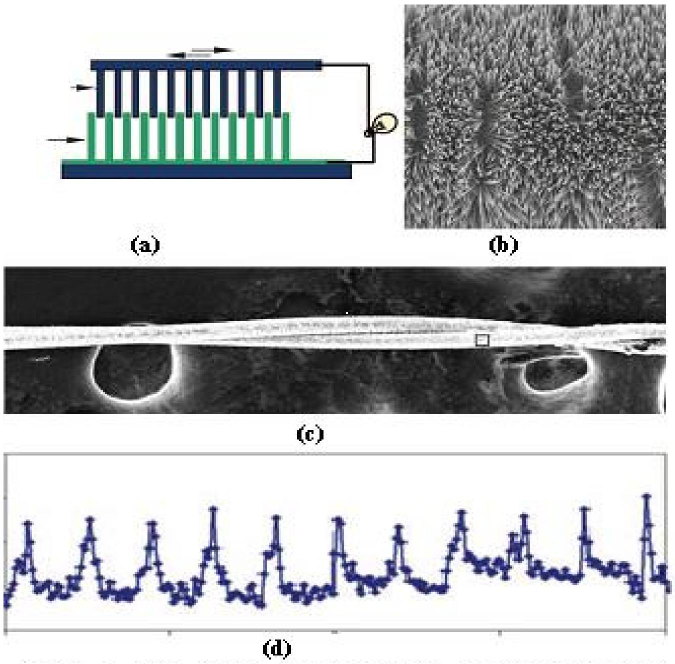

Figure 2: The design and mechanism of the fiber-based nanogenerator as driven by a low-frequency, external vibration/friction/pulling force. (a) Schematic model of the naonogenerator. (b) Aligned ZnO nanowore arrays grown on surfaces of a fiber. (c) An SEM image of a pair of entangled fibers. The Au-coated NWs ar the top serve as the conductive "tips" that deflect/bend the NWs at the bottom, a piezoelectric semiconduction couple process generates electric current. (d) Electric current generated by repeatedly sliding the two fibers.[1]

We know capacitors can store power and use gradually. But here the same problem exists. The ratio between power and size does matter. We will not get sufficient power in the limited size.

2.5. Nuclear power source

We can use an on board nuclear power source. We need a very little amount of power so shield given to the amount of fuel involved is easy. We can also use this for tracking the nanorobots because the casing should be hotter than the body temperature. Here there is no chance of running out of power. In a nano scale it is easy to shield and power conversion so it can be done practically. The major problem is to face the social objections to use such material inside the body.

2.6. Thermoelectric generator

Thermoelectric generator relies on the Seebeck Effect, which is about the electric potential observed fl owing between two dissimilar metals that form a junction and are at different temperatures. The voltage produced is proportional to the temperature difference between the two ends. The proportionality constant is known as the Seebeck coefficient, and often referred to as the thermoelectric power or thermo power. This is the physical basis for a thermocouple, which is used often for temperature measurement. Seebeck coefficient of a material characterizes the magnitude of an induced thermoelectric voltage owing to a temperature difference present across the material. An applied temperature difference causes charged carriers in the material, whether they are electrons or holes, to diffuse from the hot side to the cold side, similar to a classical gas that expands when heated. Mobile charged carriers migrating to the cold side leave behind their oppositely charged and immobile nuclei at the hot side thus giving rise to a thermoelectric voltage. Thermoelectrics is one of the most exciting fields in nanotechnology [14]. One dimensional nanomaterials that have a small thermal conductivity but high electrical conductivity, such as Bi and BiTe, are very beneficial for improving the thermal power. Thermoelectric generator usually has a large size because of the requirements of maintaining a higher temperature difference between the two ends of the device.

2.7. Vibration-based energy generation [15]

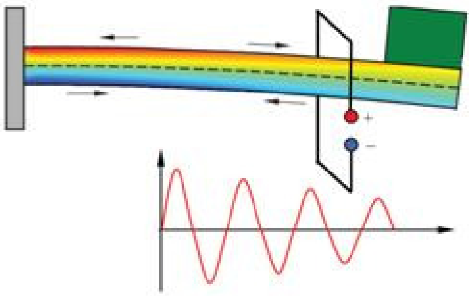

Figure 3:. Schematic diagram showing a piezoelectric vibration based generator for producing AC voltage output[1]

Scientists have built vibration-based generators using three types of electromechanical transducers: electromagnetic, electrostatic, and piezoelectric. The electromagnetic microgenerator utilizes a moving magnet or coil for inducting and alternating electric current in a close circuit. Although some microgenerators have been fabricated at the scale of micro-electromechanical systems (MEMS), the technology tends to produce large structures ranging of 1 75 cm3, exploring vibration ranges from 50 Hz to 5 kHz that induce mechanical oscillations between one-half micrometer and over one millimeter, and producing power from tens of µW to over a kW. A typical piezoelectric vibration-based generator uses a double layered piezoelectric beam with a mass at the end (Figure 3).[1] The principle of this design is based on piezoelectricity, which is the ability of certain crystals to generate a voltage in response to applied mechanical stress. When the gravitation attracts the beam to bend downward, the upper piezoelectric layer is under tensile strain and the lower layer is under compressive strain, resulting in a positive and negative voltage, respectively, across the beam. The mass oscillates back and forth; an alternating voltage would be output. This approach has been the basic principle for converting mechanical vibration energy into electricity for microsystems. This energy generator is reasonably large so that gravitation plays a major role for drive the oscillation of the mass. This design has been one of the major microgenerators for mobile and wireless electronics.

III. POWER FROM BLOOD STREAM

3.1. From body temperature

In this method body heat is used as a power source for our device. Here the device will use the entire body as a power supply. One major problem is body temperature differs in different places of the body. To make a power flow to the device it needs an energy gradient. The nanorobots are mobile devices inside the body, so to fulfill the requirements will be difficult.

3.2. Using electrodes

The nanorobots uses two electrodes mounted on its outside. This will combine with the electrolytes in the blood stream to form a battery. This would result in a low voltage but it is sufficient for our nanorobots. Major disadvantages are it would last until the electrodes were used up. In case of blood clot or arteriosclerosis it may not get the required power. If something is blocked to the electrodes to access bloods then also power cannot be generated. In such situation a backup is needed.

3.3. Fuel cell by burning blood chemicals

This is similar to a battery. In battery power is obtained from current flow between electrodes. In fuel cells we obtain power by causing a chemical reaction to take place at controlled rate. Fuel chemicals will be taken from the blood cells. The main disadvantages are same as using electrodes if the access to the blood is blocked power cannot be generated.

3.4. Microbial fuel cells

Micro-organisms can be used to transform bio convertible substrates directly into electricity, in which the bacterium acts as an anode and the electrons flow from the cathode through a resistor. The catalytic actions of micro-organisms have been used to produce electrical output from the different carbohydrates and complex substrates. The implantable direct glucose fuel cell can produce power output in the range of 50 μW, sufficient to supply a cardiac pacemaker. Animal trials of direct glucose fuel cells have shown durability of 150 days. Both glucose and oxygen are present in the cell and tissue of all eukaryotic organisms, including human beings. Therefore, it is possible to tap into the body's own resources, including the metabolic properties of our cells, to generate enough energy to power an array of clinical devices, including drug delivery systems, diagnostic tools, and human augmentation devices.[16]

3.5. Adenosine tri-phosphate energy converter

Enzymes are proposed as an alternative to powering future nanomechanical devices. Possible nanoscale biological motor enzymes that could be used are inesin, RNA polymerase, myosin, and Adenosine tri-phosphate (ATP) synapse. The motors are fueled by ATP molecule, which consists of adenine, ribose, and three phosphate groups that are linked by covalent bonds. As the first phosphate group is removed, which is signaled by a coenzyme, a large amount of energy is released with the form of a reaction product called adenosine diphosphate (ADP). If a further amount of energy is desirable, the second phosphate group is released to create adenosine monophosphate (AMP). The energy created is made available to be used for chemosynthesis, locomotion (including muscle contraction in animals), and the active transport of ions and molecules across cell membranes. ATP is refueled by the rephosphorylation of ADP and AMP using the chemical energy generated from the oxidation of food. This concept leads to ATP serving as rechargeable batteries inside the human body.[1]

3.6. Electrogenic Bacteria Fuel Bioreactors [17]

MFC technologies use a relatively rare type of bacteria known as electrogenic bacteria, which transfer excess electrons produced by their central metabolism to the cell surface. "Most bacteria use organic compounds as nutrients, oxidizing the carbon source and generating electrons," Qian says. "But most of these bacteria are insulators—they generate electrons but do not release them. They are needed in biosynthetic processes to produce biomass. Electrogenic bacteria have developed unique types of trans membrane proteins that deliver unused electrons to the outside, one by one."

This characteristic makes electrogenic bacteria excellent candidates for use in electricity-generating devices. MFCs use a pair of battery-like terminals (anode and cathode electrodes) connected to an external circuit and an electrolyte solution to conduct electricity. When bacteria physically attach to the anode, electrons generated in the interior of the cell are transferred to an external electrode, producing electrical current.

Most of Qian's research into electron transfer pathways has focused on *Shewanella*, a dissimilatory metal-reducing bacteria considered a model microbe for fundamental research. The bacterium, which she used in the optimized micro-MFC study, is well understood and easy to identify, culture, and manipulate. But for all its great qualities, *Shewanella* is inefficient at generating power because it cannot completely oxidize organic compounds to maximize the energy extraction process.[17]

IV. From A Source External to the Body (using Physical Connection)

Here we need some sort of cable to carry power from outside the body to the nanorobots. The following things to be considered:

- The cable must be thin enough to be fit in every blood vessel where nanorobots can enter.
- The friction from outside should be low enough to allow the wire to move freely inside.
- The cable should not cut the inner side walls of blood vessels.
- It should be flexible enough so that it should not break in between.
- I should be long enough so that it can reach to work site.
- How the power should be transmitted? It can be by electricity or by light as a medium.

4.1. Electricity as a medium

If we use electricity, it needs a return path. i.e. we must deploy a two conductor cable or the body can be used as a return path. This is possible due to small amount of power. Another important aspect is heating of the cable and its surrounding area though blood can do the work of a radiator. Communication can also be made through these cables.

4.2. Light as a medium

It does not require a return path. If power is transmitted using light it can be used directly or can be converted into electricity. We need to consider about the diameter of the cable. A big disadvantage is to convert light to electricity; it should have some on board mechanism to do this. This requires more on board equipment.

V. From A Source External to the Body (with No Physical Connection)

Here some options are given to transmit the power to nanorobots without any sort of physical means.

5.1. Using Microwave

To use microwaves we need an antenna on board of nanorobots. Microwave energy is beamed to the body where it is taken by the antenna inside and converts to electricity. But most of the microwave energy is also absorbed by the body itself. So there is a chance of some damage. Again a large amount of this energy is converted to heat.

5.2. Using Ultrasonic

Ultrasonic can be used same as that of microwave but here heating effect will be less. The chances of damage inside the body will be less. We can use a piezoelectric membrane to receive the signals and convert them into electricity. This membrane can also be used as a communication device.
The nanogenerator was fabricated with vertically aligned zinc oxide nanowire arrays that were placed beneath a zigzag metal electrode with a small gap. The wave drives the electrode up and down to bend and/or vibrate the nanowires. A piezoelectric semiconducting coupling process converts mechanical energy into electricity. The zigzag electrode acts as an array of parallel integrated metal tips that simultaneously and continuously create, collect, and output electricity from all of the nanowires.

5.3. Using Induced Magnetic

The body is surrounded by a magnetic field. This field induces currents within a rotating closed conduction loop in the nanorobots which can be used for power. The frequency of the resulting power is dependent on the rotational speed of the pickup loop, and so alternating the rotational frequency would provide a communications path as well.

VI. RESULT AND DISCUSSION

I have studied various possibilities of power supply to the nanorobot inside the body. It is also seen that due to vary small size of nanorobots energy need also very less. Energy may not be required in the form of electricity it may be any other form also. It is very important that the amount of electricity needed should be controlled so that the tiny parts inside the nanorobot should not be damaged. So controlling the supply of power should be considered as an important part.
Finally, the nanorobot should have a converter to convert to electricity from other form of energy e.g. light or chemical energy. It should also contain a controller to supply a steady amount of electricity to the robot. These parts should be incorporated with the nanorobots. Then the size of the robot should be taken care. Due to the size in nano scale it is too difficult to make these devises, but as chip design technologies are advancing it may be possible in near future.

VII. CONCLUSION

Blood flows throughout the body. So it is easier to move to a particular place along with blood flow. Nanorobots should be designed which can flow through blood stream. The main difficulties lie in dealing with critical organs like brain, heart, kidney … etc. the start and end point should be fixed so that the covering area for nanorobots should be clearly identified. Depending upon the covering area and after finding out its criticalness, then only we can find the feasibility to give the mode of power supply to the device. Again what type of work will be carried out and how much questions will decide how much power needed to the nanorobots to accomplish its task.
So at last it has been studied that various factors such as inside the heart, inside the kidney or inside the brain can influence the power requirement. Different types of power source can be given for different situation for example power source may be different in the muscles but the power source will be different inside the kidney or inside the heart. It may be more difficult when we deal with the nerves of neurons because they work on electricity signals. Further, exact power requirement should be studied before applying any power source.

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