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Power Generation Using Magnetotactic Bacteria

[1] Swarup R. lanjewar, [2] Seema D. Pawar, [3] Aarzoo R. Jais, [4] G.H. Agrawal, [5] A. Sudha
[1][2][3] Student, [4] [5] Prof
[1][2][3][4][5] Electrical Department, KDK College Of Ennginneering Nagpur, India

***Abstract*: -- Magnetotactic bacteria (MTB) have the unique ability to generate electricity, it has magnetic particles surrounded by a biomembrane to form the magnetosome organelle. Magnetotactic bacteria have the magnetic properties which can be used in several biotechnological applications. Magnetotactic bacteria (MTB) have biomineralized intracellular nanoparticles of magnetite (magnetosomes). This unique characteristic of MTB can be used to generate electricity by means of Faraday's Law of Electromagnetic Induction. This paper discusses the possibility that MTB can potentially be used to convert mechanical energy into electrical energy, using the principle of Electromagnetic Induction.**

***Keywords*— Magnetotactic bacteria, magnetosomes, electricity, electromagnetic induction, Faraday`s law.**

I. INTRODUCTION

The purpose of this research is to determine whether magnetised Magnetotactic Bacteria can be used to generate electricity. Magnetotactic bacteria (MTB) biomineralize intracellular nanoparticles of magnetite (magnetosomes). However, these bacteria swim towards oxic-anoxic transition zones or according to geomagnetic fields in order to maintain optimal growth conditions [2]. These two characteristics of MTB (magnetisable magnetosomes and movement) are used to generate electricity by means of Faraday`s law of electromagnetic induction [3]. MTB were separated from fresh water with a magnet. The MTB isolate were cultivated in homemade and laboratory prepared growth mediums. Light, transmission electron (TEM) and scanning electron (SEM) microscopy as well as electron diffraction spectroscopy (EDS) were performed. A magnetising tube (responsible for magnetised magnetosomes) was built. The MTB`s natural movement were simulated and kept constant with a peristaltic pump. An induction tube with copper windings was built. The magnetised MTB moved through the induction tube and electricity was generated with Faraday`s law of electromagnetic induction. the micrographs indicated unique characteristics of MTB. The scanning electron microscopy indicated magnetosomes and the electron diffraction spectroscopy indicated iron inclusions.

II. ULTRASTRUCTURE OF MAGNETOTACTIC BACTERIA

Magnetotactic bacteria (or MTB) are a polyphyletic group of bacteria was discovered by Richard P. Blakemore in 1975, they orient along the magnetic fielde lines of Earth's magnetic field [1]. To perform this task MTB has organelles called magnetosomes, that contain magnetic particles as shown in fig. 1. The biological phenomenon of microorganisms tending to move with respect of earth's magnetic polarity is known as magnetotaxis. In contrast to the magnetoception of animals, these bacteria contains fixed magnets that forces these bacterias into alignment—even the cells which are dead align, just like a compass needle.

Biology

Several different morphologies (shapes) of MTB exist, differing in number, layout and pattern of the bacterial magnetic particles (BMPs) all they contain. The MTB's can be subdivided into two categories, firstly they produce particles of magnetite (Fe_3O_4) and secondly greigite (Fe_3S_4), although some species are capable of producing both. Magnetite possesses a magnetic moment three times that of greigite [1].

Magnetite-producing magnetotactic bacteria are usually found in an oxic-anoxic transition zone (OATZ), the transition zone between oxygen-rich and oxygen-starved water or sediment[4]. Many of these organisms are able to survive only in environments with very limited oxygen, and some of them can exist only in completely anaerobic environments. It has been analysed that the evolutionary advantage of possessing a system of magnetosomes is linked to the ability of efficiently navigating within the zone of sharp chemical gradients by simplifying a potential three-dimensional search for various favourable conditions to a single dimension[4].The ability of these magnetotactic bacteria to produce mgnetic particles are in the form of chains[1].

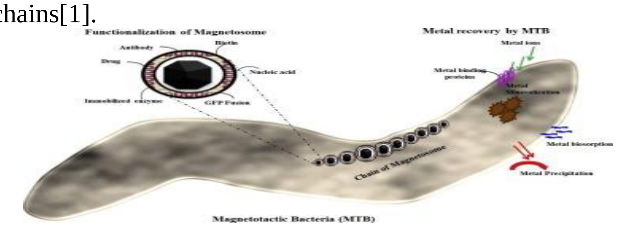

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Fig 1. structure of magnetotactic bacteria.

Magnetism

The physical development of a magnetic crystal is governed by two factors: one is moving to align the magnetic force of the molecules in conjunction with the developing crystal, while the other reduces the magnetic force of the crystal, allowing an attachment of the molecule while experiencing an opposite magnetic force. In nature, this causes the existence of a magnetic domain, surrounding the perimeter of the domain, with a thickness of approximately 150 nm of magnetite, within which the molecules gradually change orientation. For this reason, the iron is not magnetic in the absence of an applied field. Similarly, extremely small magnetic particles do not exhibit the signs of magnetisation at room temperature; their magnetic force is continuously altered by the thermal motions inherent in their composition shown in fig 2. Instead, individual magnetite crystals present in MTB are of a size between 35 and 120 nm, which is, large enough to have a magnetic field and at the same time they are small enough to remain a single magnetic domain.

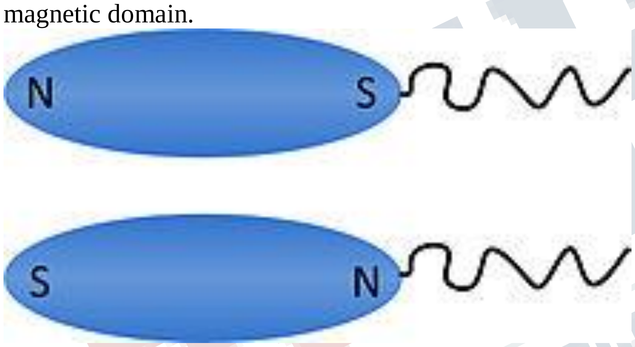

Fig 2. polarisation of MTB

The inclination of the Earth's magnetic field in the two respective hemispheres selects one of the two possible polarities of the magnetotactic cells (with respect to the flagellated pole of the cell), orienting the biomineralisation of the magnetosomes. Various experiments have clearly indicated that magnetotaxis and aerotaxis work in conjunction in the magnetotactic bacteria. Aerotaxis is the response by which bacteria migrate to an optimum level of oxygen concentration in an oxygen gradient. It has been shown that, in the droplets of water molecules one-way swimming magnetotactic bacteria can reverse the direction of their swimming and they starts swimming backward under the reducing conditions (less than optimal oxygen concentration), as opposed to oxic conditions (greater than optimal oxygen concentration). The behaviour which was observed in these bacterial strains has been defined as magneto-aerotaxis.

III. EXPERIMENTAL THEORY

i. Treatment of MTB

Magnetotactic bacteria of diverse morphological types live in marine and freshwater sediments, from these meduims they can be separated by using small permanent magnets. All magnetically responsive cells examined to date (4, 10, 23) have contained one or two intracellular chains of electron-dense, iron-rich particles, each measuring 40 to 100 nm in width. Recently, a helical, heterotrophic, freshwater, magnetotacti bacterium was isolated and designated strain MS-1. This isolate has been characterized and it appears to be a new species of the genus Aquaspirillum by criteria separate from its magnetic properties. Strain MS-1 possesses a single chain of electrondense particles, each approximately 40 nm wide. Results of 57Fe Mossbauer resonance spectroscopy established that iron in magnetotactic cells of strain MS-1 is present primarily as magnetite . A non-magnetotactic variant of this organism (obtained by culturing in a medium with reduced iron content) lacked electron-dense particles and magnetite.

ii.Solenoid Coil

The Solenoid term refers to a coil whose length is substantially greater than its diameter, often wrapped around a metallic core, which produces a uniform magnetic field in a volume of space when an electric current is passed through it. A solenoid is a type of electromagnet when the purpose is to generate a controlled magnetic field. Structure of solenoid coil shown in fig. 4.

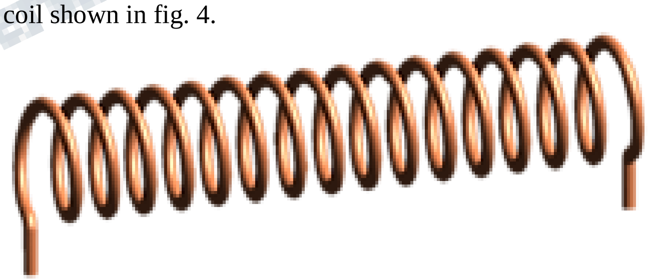

Fig 4. Solenoid coil.

iii. PERISTALTIC PUMP

A Peristaltic pump is a type of positive displacement pump used for pumping a variety of fluids. The fluid is contained within a flexible tube fitted inside a circular pump casing. A rotor with a number of "rollers", "shoes", "wipers", or "lobes" attached to the external circumference of the rotor compresses the flexible tube. As the rotor turns, the part of the tube under compression is pinched closed (or "occludes") thus forcing the fluid to be pumped to move through the tube. Additionally, as the tube opens to its natural state after the passing of the cam ("restitution" or "resilience") fluid flow is induced to the pump. This process is called peristalsis.

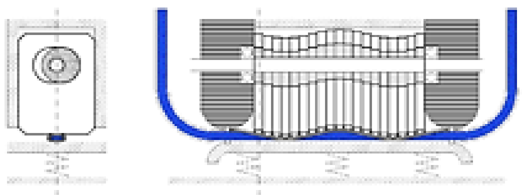

Fig 5. peristaltic Pump.

III. WORKING PRINCIPLE

The experimental setup consisted of a capillary (thin end of a Pasteur pipette) placed between two poles of an electromagnet. Before the pipette was placed between the poles, copper wire (0.1mm diameter and enamelled) was spun around the pipette starting at a distance of 8cm from the tip to create a 3mm X 3mm cylindrical coil (solenoid) around the pipette. The distance between the electromagnet and the solenoid was 0.5cm with solutions passing through the magnetic field first and then the solenoid. The ends of the copper coil were connected to a multimeter. A plastic pipe from the peristaltic pump was connected to the large end of the pipette. The experimental solutions and controls were pumped through the pipette, passing through the magnetic field and coil. Solutions were pumped at a flow rate of 4.4 ml min-1. age measurements were taken every second and the multimeter recorded the average value over each second. With power line frequency synchronisation, the background interferences were suppressed with each measurement. The averages of each second were used to present the results graphically. For representation of the data the same measurements were split into positive and negative values. This was done in order to calculate the alternating current correctly [2].

IV. RESULT

The micrographs indicated unique characteristics of MTB. The scanning electron microscopy indicated magnetosomes and the electron diffraction spectroscopy indicated iron inclusions. At first a current of 0.05ma was generated, but as the MTB multiplied over three days a current of 0.31ma was generated. The hypothesis: "It is possible to generate electricity by using magnetised Magnetotactic Bacteria (MTB) in a Faraday application", proved to be correct. we have successfully shown the possibility to produce energy with MTB and magnetosomes. The fact that an alternating current has been measured can be ascribed to the magnetic nanoparticles passing completely through the solenoid as separate magnetosomes or magnetosome strings. This observation was also reported for the first time by Faraday (1832) in his original study with magnets and we hereby confirm his findings in this study.

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