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Some experimental micromagnetomechanical manipulators which are inspirited by the magnetic bacteria

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CHRONICLE

We dedicate the 1-2/2015 number of Bulletin to the young members of the Excellency Centre for Training in Scientific Research of the Youngs which are pupils of the "Tudor Vianu" National College of Informatics and the ICHB.

The papers represent the research scientific preoccupations of a new series of the members of Excellency Centre.

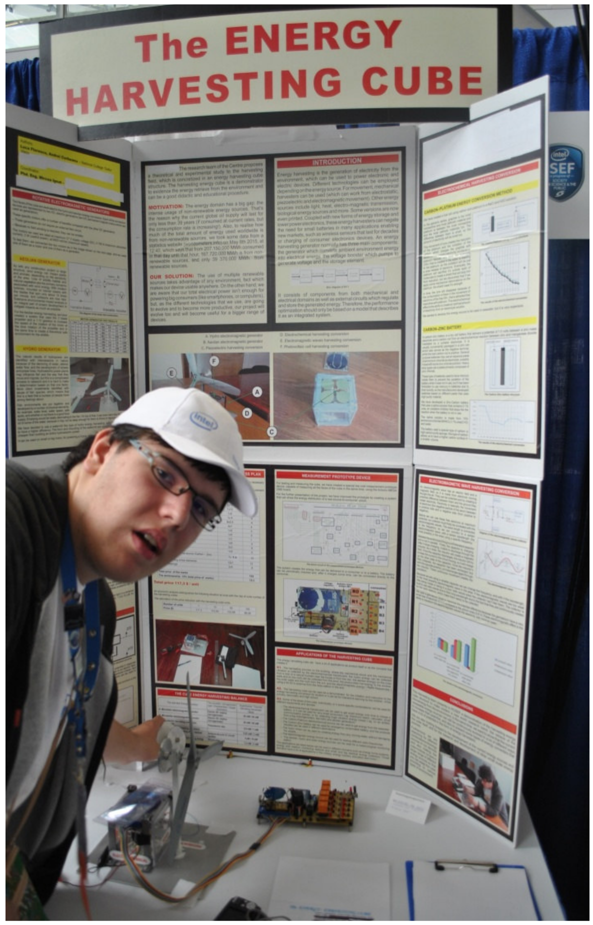
Also, we present different images of the research competitions: INFOMATRIX 2015 (Bucharest - Romania), INTEL-ISEF 2015 (Pittsburg - USA) and ROSEF 2015 (Suceava - Romania).

Editor in Chief

Mircea Ignat

Excellency Centre for Training in Scientific Research of the Youngs – images

Supper (to the Excalibur) with the first generation of the Excellency Centre: Cristian Dragomir, Andrei Pangratie, Alexandru Glonţaru, Ştefan Iov, Matei Sarivan, Raluca Turcu



Andrei Corbeanu, member of the Energy Harvesting Cube team
Participant to the ISEF, Pittsburg, June 2015, Olympiad

The representatives of the new generation: Ionuț Costin, Elena Feng Yuan (Gold medal to the ROSEF 2015 competition), Ana Maria Tudorache, Miruna Ojoga (Gold medal to the INFOMATRIX International Olympiad 2015), with Prof.Wilhelm Kappel - General Manager of INCDIE ICPE-CA and Dr. Eng. Mircea Ignat - the chief of the Excellency Centre

Image of the time ROSEF 2015 competition (Suceava – Romania, June 2015) with the jury to the stand of the Magnetic Bacteria team (Elena Yuan, Ionuţ Costin - Gold medals)

The reception of the Science prize for the research activity of the Excellency Centre (through the coordinator Mircea Ignat), to the Romania Cultural Gala (March 2015)

Contents

Reviews
Ioan I. Ardelean……………………...…………………………………………………….. 11

Magnetic Bacteria
Elena FengYuan, Ionut Cristian Costin ………………………………………………… 15

Applications of microwires
Maria Velicu, Eugen Manta, Andrei Dan Corbeanu ……..……………………………… 23

Short Introduction on the magnetostrictive motor
Mircea Ignat, Alexandru Dalea………………………………………………………...... 29

Medical Rehabilitation - Sensors and monitoring
Ana-Maria Tudorache, Miruna Alexandra Ojoga……………………………………….. 35

Nanomicrobiology - Physiological and Environmental Characteristics 2014, Barton L.E., D. A. and Xu H., Springer (Eds.), Springer, Dordrecht, Heidelberg, London, New York, ISBN 978-1-4939-1666-5, 184 p, 67 figures (28 in colours)

This interesting book is focused on some ultrastructural components of prokaryotic cell, either belonging to Domain Bacteria or to Domain Archaea, as well as on metal nanoparticles formation during metabolism and nanostructures involved in bacterial glinding motility. When it comes to ultrastructural components of prokaryotic cell special emphasis is focused on S-layer in *Bacteria* and *Archaea*, magnetosomes in magnetotactic bacteria as well as on other ultrastructural components: carboxysomes, nanowires, molecular motors (flagellum, ATP-ase, DNA packing, and translocation of proteins across membranes by secretion systems) and outer membrane vesicles. The opening chapter concerns some of the controversies related to the reports on nanobacteria and their possible geochemical and biomedical significances. The book ends with an Index making the trip easier within this volume. The contributors are well known scientists in their field under the leading authority of truly famous scientists acting as Editors. The chapters are written very clearly, from microbiological point of view and from nanotechnological point of view as well, having a very generous bibliography and useful illustrations. The book Nanomicrobiology seems to me to be a useful working instrument for young growing students and scientists, as well as for senior ones interested to either Microbiology or nanotechnology, or to both of them. In this respect, the editors' hope that the book "*should stimulate scientists and others interested in nanotechnology research to adapt some of these principles to their research efforts*" in my opinion is sustained by the content of this volume.

Ioan I. Ardelean

Bio-Inspired Nanotechnology - From Surface Analysis to Applications, Knecht M., Walsh R., Tiffany R. (Eds.) 2014, Springer, Dordrecht, Heidelberg, London, New York, VIII, 314 p. 172 illus., 108 illus. in colour

The book is a true multidisciplinary one, covering chemistry, physics, surface science, structural and molecular biology, genetics, materials science, computational modelling and informatics. This book is focused on screening, selection, characterization, and exploitation of peptides capable of recognizing and binding inorganic materials. The main audience, according to the vision of editors, should be the scientist or scholar who is new to the research area, nanomaterials engineers, bioengineers, chemists, biologists, physicists, and medical researchers. Accordingly, the first chapters are good introductory ones (Peptide - Nanoparticle Strategies, Interactions, and Challenges; Fundamentals of Peptide - Materials Interfaces; Experimental Characterization of Peptide – Surface Interactions; Interfacial Structure Determination). The following chapters are focused and dedicated methodologies and applications in the field of bio-inspired nanotechnologies (Understanding Biomineral Growth and Assembly for Engineering Novel Green Nanomaterials; Understanding Molecular Recognition on Metallic and Oxidic Nanostructures from a Perspective of Computer Simulation and Theory; Bio-Inspired Nanocatalysis; Addressable Biological Functionalization of Inorganics: Materials-Selective Fusion Proteins in Bio-nanotechnology; Environmental Interactions of Geo- and Bio-Macromolecules with Nanomaterials; Mimicking Biomineral Systems). Each chapter has a very reach bibliography as well as clear and helpful illustrations further contributing to this book which, as a whole, is a valuable scientific product.

Ioan I. Ardelean

Sustainable Bioenergy Production: An Integrated Approach, 2013, Ruppert H., Martin Kappas M., Ibendorf J., Springer, Dordrecht, Heidelberg, London, New York,
ISBN: 978-94-007-6641-9, Springer, 451 p

This interdisciplinary book focuses on the use of agricultural land not only for food or energy conservation but also on ecological, economic and societal impacts of these uses thus opening new trends in Sustainable Bioenergy Production. This book is based on the ongoing research in Germany, and contains 14 chapters wrote by strong professionals. The first chapter is an introductory one to the topic whereas the second focuses on bioenergy villages in Germany and the third is a short review of global bioenergy potentials and their contribution to the world's future energy demand. In the next chapter the biomass potentials in Germany is estimated by means of a modelled Net Primary Productivity (NPP), validated by empirical data. Chapter 5 is focused on modelling site-specific and larger area biomass potentials in Lower Saxony in very good connection with the next two chapters which concern the environmentally sound optimization of bioenergy production. The next 5 chapters deeply present the economic optimization of a heat distribution network relying on wood and crops and the socially acceptable optimization of bioenergy production, including scientifically knowledge of farmers' opinions. The last two chapters (13 and 14) focuses again of environmental issues with special emphasis on organic and inorganic emissions during the burning of wood and straw in heat systems as well as on the opportunity to grow energy plants on soil contaminated with heavy metals. The contributors to this book are very well known professionals in their fields, working in Germany. Each contribution and the book as a whole give to the reader the strong feeling of an excellent scientific text but also the deep concern for something very well done, both theoretically and practically. Each chapter has the relevant bibliography, and the book contains also a reach and useful index. In my opinion, this book is a very nice example to be followed for other scientific topics which aim to improve the quality of human life communities, in harmony with Planet Earth.

Ioan I. Ardelean

Nanotechnology for Water Treatment and Purification, 2014, Hu. A., Apblett A., (Eds.) Springer International Publishing ISBN 978-3-319-06577-9, 373p

This book is volume 22 in the Series Lecture Notes in Nanoscale Science and Technology, contains 10 interesting chapters which are written by 24 very well known scientist working in Canada (15), USA (7) and PR China (2). This interdisciplinary book is indeed written for a broad audience of municipal water managers, engineers, researchers, and, last but not least, policymakers, all active in wastewater and drinking water treatment, describing the latest progress in the application of nanotechnology for water treatment and purification. The introductory chapter is a very good and comprehensive one concerning fundamentals on adsorption, membrane filtration, and advanced oxidation processes for water treatment. The following 8 chapters are devoted to specific nanomaterials (TiO_2 nanowires; nanofiber membranes; fullerenes and carbon nano-onions; graphene; magnetically recyclable nanomaterials; magnetic activated carbons) for dedicated applications (membrane filtration; photocatalytic degradation of perfluorooctanoic acid; environmental and sensor applications; water treatment; removal of 4, 6-dinitro-*o*- cresol, congo red dye, and decane and disinfection of by-product formation). The last chapter concerns nanotechnology in contemporary mine water. The book has a comprehensive index. Each chapter is written very clear, having good and useful illustrations and rich references. In my opinion, the book Nanotechnology for Water Treatment and Purification is not only an excellent scientific lecture but also a working instrument to be found on the laboratory bench of the scientists and on the *bureau* of responsible policymakers active in wastewater and drinking water treatment.

Ioan I. Ardelean

Magnetic Bacteria

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Abstract - Controlled assembly of magnetic nanoparticles was demonstrated by manipulating magnetotactic bacteria in a fluid with microelectromagnets. Magnetotactic bacteria synthesize a chain of magnetic nanoparticles inside their bodies. Microelectromagnets, consisting of multiple layers of lithographically patterned conductors, generate versatile magnetic fields on micrometer length scales, allowing sophisticated control of magnetotactic bacteria inside a microfluidic chamber. A single bacterium was stably trapped and its orientation was controlled; multiple groups of bacteria were assembled in a fluid. After positioning the bacteria, their cellular membranes were removed by cell lysis, leaving a chain and a ring of magnetic nanoparticles on a substrate.

Index Terms – Magnetic nanoparticles, magnetotactic bacteria, microbiology, bacterial cultures, magnetosomes, bionic applications.

I. INTRODUCTION

The first description of magnetotactic bacteria appeared in 1963 in a publication of the Microbiology Institute of the University of Pavia written by Salvatore Bellini. While observing bog sediments under his microscope, he noticed a group of bacteria that evidently oriented themselves in a unique direction. [1]

It has been known for some time that some bacteria, known as magnetotactic bacteria, contain chains of magnetic crystals that are thought to be used for navigation. The ability to find your way is as important for a bacteria as it is for a human being since if you can't find a food source, whether the supermarket in town, or organic debris in sediment, then you are likely to starve. Whilst humans can use maps or satnav in order to find their way, bacteria face a significant challenge in locating food sources within the microscopic world of sediments. Magnetic crystals, known as magnetosomes, usually consisting of the iron oxide mineral magnetite can however act as microscopic compasses that allow bacteria to sense direction.

Scientists have had a long-standing problem with bacteria magnetosome compasses - the magnetite crystals in some bacteria are just too small to be used as magnets [1]. Magnetism in minerals such as magnetite is ferromagnetic, as such small magnetic minerals behave like bar magnets, that is, a dipole having a north and south pole. The magnetization in magnetosome crystals is uniform – termed single domain - and behaves like a compass needle in response to the earth's magnetic field. The problem for bacteria is that the magnetization in the very smallest crystals of magnetite is not stable due the thermal vibrations and effectively loses its magnetism easily. These small crystals are said to display superparamagnetic behaviour, and no longer behaves like a magnetic compass needle.

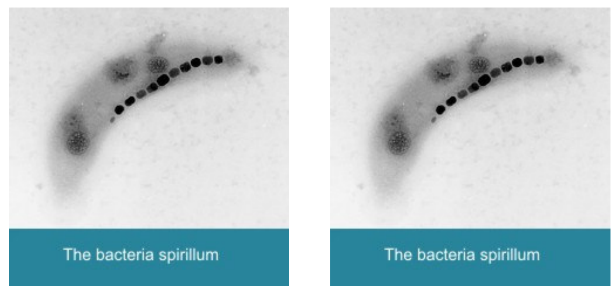


Fig.1. The microstructure of Magnetic bacteria [1]

II. SPECIFIC BIOLOGICAL STUDY OF MAGNETIC BACTERIA

Several different morphologies (shapes) of MTB exist, differing in number, layout and pattern of the bacterial magnetic particles (BMPs) they contain. The MTBs can be subdivided into two categories, according to whether they produce particles of magnetite (Fe3O4) or of greigite (Fe3S4), although some species are capable of producing both. Magnetite possesses a magnetic moment three times that of greigite.

In 1975 Robert Blakemore published his paper on magnetotactic bacteria (MTB).He stated that MTB’s main functional characteristic is magnetotaxis, the orientation along the Earth` s geomagnetic field lines [6]. Magnetotaxis is determined by the presence inside the cell of particles named magnetosomes. These were originally defined as intracellular, magnetic single-domain (SD) crystals of a magnetic iron mineral that are enveloped by a trilaminate strcuture, the magnetosome membrane (MM). In other words, magnetosome consist of magnetic iron mineral particles (the inorganic phase) enclosed within a membrane (the organic phase).

The organic phase (the magnetosome membrane = the magnetosome vesicle), consists in Magentospirillum strains (M.magnetotacticum or M.gryphiswaldense) of a bilayer.

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. Many MTB are able to survive only in environments with very limited oxygen, and some can exist only in completely anaerobic environments. It has been postulated that the evolutionary advantage of possessing a system of magnetosomes is linked to the ability of efficiently navigating within this zone of sharp chemical gradients by simplifying a potential three-dimensional search for more favourable conditions to a single dimension (see the "Magnetism" subsection below for a description of this mechanism). Some types of magnetotactic bacteria can produce magnetite even in anaerobic conditions, usingnitric oxide, nitrate, or sulfate as a final acceptor for electrons. The greigite mineralising MTBs are usually strictly anaerobic. [10]

It has been suggested MTB evolved in the early Proterozoic Era, as the increase in atmospheric oxygen reduced the quantity of dissolved iron in the oceans. Organisms began to store iron in some form, and this intracellular iron was later adapted to form magnetosomes for magnetotaxis. These early MTB may have participated in the formation of the first eukaryotic cells. Biogenic magnetite not too different from that found in magnetotactic bacteria has been also found in higher organisms, from Euglenoid algae totrout. [11] Reports in humans and pigeons are far less advanced. [12]

Magnetotactic bacteria produce their magnetic particles in chains. The magnetic dipole of the cell is therefore the sum of the dipoles of each BMP, which is then sufficient to passively orient the cell and overcome the casual thermal forces found in a water environment. In the presence of more than one chain, the inter-chain repulsive forces will push these structures to the edge of the cell, inducing turgor.

The diversity of MTB is reflected by the high number of different morphotypes found in environmental samples of water or sediment. Commonly observed morphotypes include spherical or ovoid cells (cocci), rod-shaped (bacilli), and spiral bacteria of various dimensions. One of the more distinctive morphotypes is an apparently multicellular bacterium referred to as the many-celled magnetotactic prokaryote (MMP). Regardless of their morphology, all MTB studied so far are motile by means of flagella are Gram-negative bacteria of various phyla: Despite the majority of known species' being proteobacteria, e.g. Magnetospirillum magneticum an alphaproteobacterium, members of various phyla possess the magnetosome gene cluster, such as Candidatus Magnetobacterium bavaricum a Nitrospira. The arrangement of flagella differs and can be polar, bipolar, or in tufts. The first phylogenetic analysis on magnetotactic bacteria using 16SrRNA gene sequence comparisons was performed by P. Eden et al. in 1991.

Another trait that shows considerable diversity is the arrangement of magnetosomes inside the bacterial cell. In the majority of MTB, the magnetosomes are aligned in chains of various lengths and numbers along the cell's long axis, which is magnetically the most efficient orientation. However, dispersed aggregates or clusters of magnetosomes occur in some MTB, usually at one side of the cell, which often corresponds to the site of flagellar insertion. Besides magnetosomes, large inclusion bodies containing elemental sulphur, polyphosphate, or poly-β-hydroxybutyrate are common in MTB.

The most abundant type of MTB occurring in environmental samples, especially sediments, is coccoid cells, possessing two flagellar bundles on a somewhat flattened side. This "bilophotrichous" type of flagellation gave rise to the tentative genus "Bilophococcus"for these bacteria. In contrast, two of the morphologically more conspicuous MTB, regularly observed in natural samples, but never isolated in pure culture, are the MMP and a large rod containing copious amounts of hook-shaped magnetosomes.

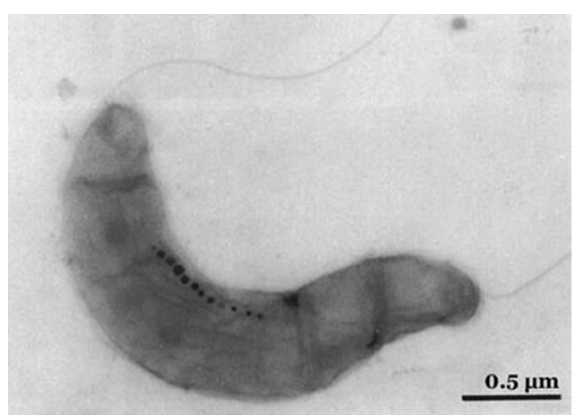


Fig. 2. The main components: magnetosomes and vibriles

III. CHARACTERISTICS OF MAGNETIC BACTERIA

TABLE I. Bibliographical study of the magnetic bacterium characteristics

Characteristics, Parameters	**Specification (Method)**	**References**	**Type of magnetic bacterium**
1. The dimensions of magnetic bacterium	a. Length, (TEM) diameter, average surface;	A. P. Philipse, D. Maas, Langmuir 2002, 18, pp. 9977 - 9984.	*Magnetospillum magnetotacticum*
2. Bacterial cell Fe concentration	a. 1,8 mg/g dry weight;	A. P. Philipse, D. Maas, Langmuir 2002, 18, pp. 9977 - 9984.	*Magnetospillum magnet*
3. The diameter of magnetosome (Spherical model)	a. 38nm (TEM); b. 30 - 39 nm (Xray diffraction); c. ~47,1 nm (TEM);	R. Hergt, R. M. Zeisberger, D. Schuler, W. A. Kaiser, J. of Magnetism and Magnetic Materials, 293 (2005), pp.80-86; A. P. Philipse, D. Maas, Langmuir 2002, 18, pp. 9977 - 9984.	*Magnetospirillum gryphiswaldense* *Magnetospillum magnet*
4. Magnetite Fe concentration	a. 9 mg/g;	A. P. Philipse, D. Maas, Langmuir 2002, 18, pp. 9977 - 9984.	*Magnetospillum magnet*
5. Number of magnetite particles (magnetosomes)	a. 0 – 45;	A. P. Philipse, D. Maas, Langmuir 2002, 18, pp. 9977 - 9984.	*Magnetospillum magnet*
6. Magnetic properties of the cell	a. Remanent magnetization 2,77 nA/m b. Coercitive field 13,8 mT; c. Maximum magnetization 13,4 nA/m; (The vibrating magnetometer)	A. P. Philipse, D. Maas, Langmuir 2002, 18, pp. 9977 - 9984.	*Magnetospillum magnet.*

IV. MAGNETISM

A magnetic material (as magnetic bacteria) is characterized if we know [3], [5] – [7];

- The relation between the magnetizing force (the magnetic field intensity) H and the flux density (the magnetic induction) B, the B(H).
- The hysteresis loops: B(H).

The relation between the magnetic field intensity and the magnetic induction is:

$$B = \mu H \quad (1)$$

where μ - permeability with:

$$\mu = \mu_0 \mu_r \quad (2)$$

where $\mu_0 = 4\pi 10^{-7}[\frac{H}{m}]$, represents the permeability of free space, μ_r represents the relative permeability (is specific of the material), $[\frac{H}{m}] - henry / meter$ in MKS system.

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. Likewise, extremely small magnetic particles do not exhibit signs of magnetization at room temperature; their magnetic force is continuously altered by the thermal motions inherent in their composition. Instead, individual magnetite crystals in MTB are of a size between 35 and 120 nm, that is, large enough to have a magnetic field and at the same time small enough to remain a single magnetic domain.

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 shown that magnetotaxis and aerotaxis work in conjunction in the magnetotactic bacteria. Aerotaxis is the response by which bacteria migrate to an optimal oxygen concentration in an oxygen gradient. It has been shown that, in water droplets, one-way swimming magnetotactic bacteria can reverse their swimming direction and swim backwards under reducing conditions (less than optimal oxygen concentration), as opposed to toxic conditions (greater than optimal oxygen concentration). The behaviour that has been observed in these bacterial strains has been referred to as magneto-aerotaxis.

Two different magneto-aerotactic mechanisms – known as polar and axial – are found in different MTB strains. Some strains that swim persistently in one direction along the magnetic field (either north-seeking [NS] or south-seeking [SS]) – mainly the magnetotactic cocci – are polar magneto-aerotactic. These magnetotactic bacteria will travel along the lines of the earth's magnetic field according to their orientation, but will swerve as a group and reverse direction if exposed to a local, more powerful and oppositely-oriented magnetic field. In this way, they continue to travel in the same magnetic direction, but relative instead to the local field. Those MTB that swim in either direction along magnetic field lines with frequent, spontaneous reversals of swimming direction without turning around – for example, freshwater spirilla – are axial magneto-aerotactic and the distinction between NS and SS does not apply to these bacteria. The magnetic field provides both an axis and a direction of motility for polar magneto-aerotactic bacteria, whereas it only provides an axis of motility for axial types of bacteria. In both cases, magnetotaxis increases the efficiency of aerotaxis in vertical concentration gradients by reducing a three-dimensional search to a single dimension.

V. MICROSCOPIC STUDY

Magnetotactic bacteria (or MTB) are a polyphyletic group of bacteria, discovered by Richard P. Blakemore in 1975, that orient along the magnetic field lines of Earth's magnetic field. To perform this task, these bacteria have organelles called magnetosomes that contain magnetic crystals. The biological phenomenon of microorganisms tending to move in response to the environment's magnetic characteristics is known as magnetotaxis (although this term is misleading in that every other application of the term taxis involves a stimulus-response mechanism). In contrast to the magnetoception of animals, the bacteria contain fixed magnets that force the bacteria into alignment — even dead cells align, just like a compass needle. The alignment is believed to aid these organisms in reaching regions of optimal oxygen concentration. [8]

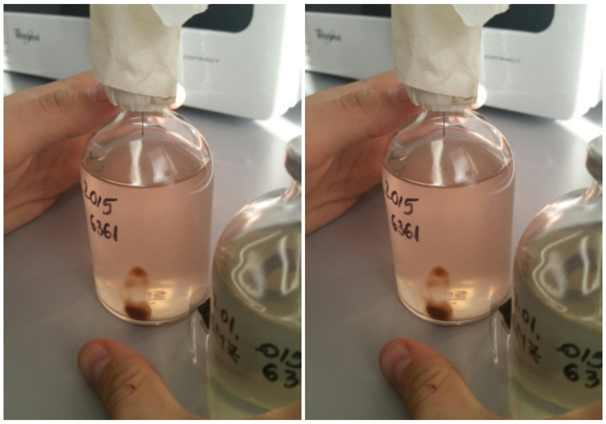


Fig. 3. The magnetic bacteria cultures

Magnetotactic bacteria are put in a nutritive solution such that they could feed themselves and grow in diameter. In the first bottle the group of magnetotactic bacteria is almost at the bottom because they were attracted by the magnet that is sticked on the second bottle.

Microbiology Institute: The magnetotactic bacterial cultures were created on January 29, 2015 and at the time the photos were taken they were 2 weeks old.

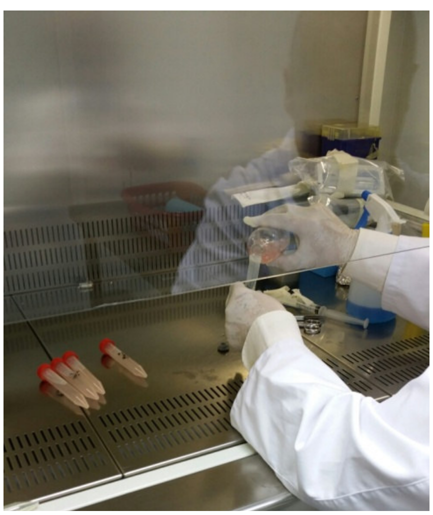


Fig. 4. Handling the cultures

We transferred nutritive solution including bacteria in to 6 sterile tubes using a vertical laminar flow hood mod of 900-1200-1500-1800 FLV which is indicated for handling of various materials in a sterile environment.

After the transfer ended we made a prepared for microscope. First we put the top of the bottle in the flame to sterilize them, then we used a pipette to take a sample and place it on a microscope slide and we used a purple colorant such that the magnetotactic bacteria will distinct one from each other.

After the preparation we put them to a microscope and took several photos (Fig. 5).

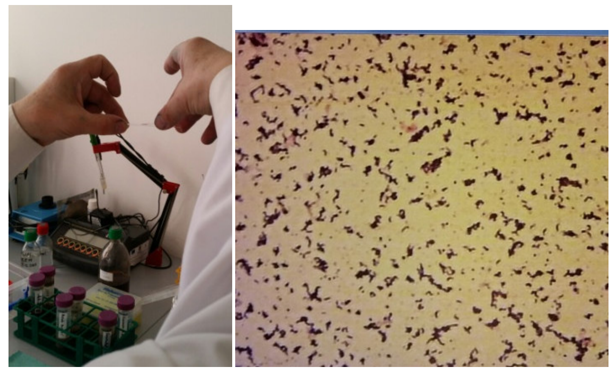
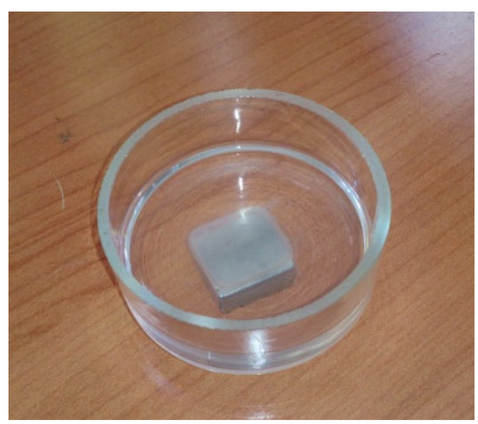
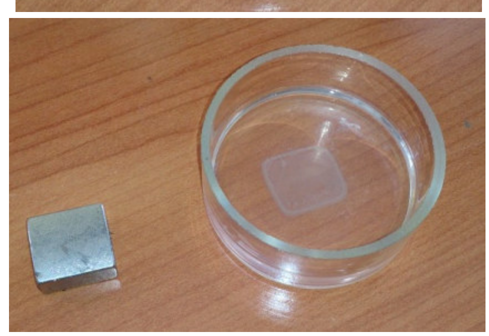


Fig. 5. Microscope slide with sample (left) and sample microscope image (right)

In Fig. 6a and 6b we presented a sedimentation experiment with a magnetic bacteria culture with a permanent magnet which is mounted under this culture. After 24 hours, on the bottom of the crystallizer, magnetic bacteria sedimentation appears.



a)



b)

Fig. 6. The sedimentation experiment

VI. THEORETICAL MODELS

TABLE II. Dimensions used for modeling magnetotactic bacteria.

	Tube diameter	Magnets length	Distance between				Total length
			0-I	I-II	II-III	III-IV	
Magnets	9.82mm	24.37mm	16.48mm	18.74mm	21.64mm	41.54mm	175mm
Iron Fillings	4.4mm	-	-	-	-	-	198mm

Figure 7 shows a geometrical modelling of a magnetotactic bacterium (MTB) using 3 magnets put with different polarity so that they could reject each other and don't allow anything to pass such as water.

Fig. 7. Geometrical modelling of a magnetotactic bacterium using 3 magnets

Figure 8 represents "Snake of life", a geometrical modelling of a magnetotactic bacterium using iron filings.

Fig. 8. Geometrical modelling of a magnetotactic bacterium using iron filings

Figure 9 represents "Dragon baby", a modelling of a MTB using 12 cylindrical magnets with diameter 4mm and length of 10 mm put with different polarity.

Fig. 9. Modelling of a MTB using 12 cylindrical magnets

Figure 10 represents "Flexible dragon", a modelling of a MTB using 5 spherical magnets with 5 mm diameter and 4 pen springs allowing to contract in contact cu a strong magnet field and it helps the model to take a various of shapes.

Fig. 10. Modelling of a MTB using 5 spherical magnets

Figure 11 is an example of how easy "Flexible dragon" can move and enter small places such as the plastic tube.

Fig. 11. Flexible dragon's easy movement

VII. APPLICATIONS OF MAGNETIC BACTERIA MAGNETOSOMES IN NANOMEDICINE

The specific structural characteristic of magnetotactic bacteria (MTB) is the presence inside the cell of particles named magnetosomes which are magnetic nanocrystals. Magnetosomes, with nanometric dimensions, are defined as intracellular, magnetic single domain crystals of a magnetic iron mineral that are enveloped by membranes.

The use of isolated magnetosomes can be a solution for a nanobiological manipulator structure.

The authors propose a biotechnology of formation that is an alternative of typically technological process of nano sized magnetic particles:

- the milling powder method;
- the chemical synthesis method.

It is presented an algorithm to obtain isolated magnetosomes to be used in nanotechnologies:

A. The improvement of the cultivation protocol of magnetotactic bacteria, the source of magnetosomes.

B. The development of different protocols for magnetosomes separation, with our without the organic phase.

C. The sorting out of the magnetosomes by the size.

D. The applications of magnetosomes.

The magnetosome and magnetosome chain microstructure belong to a category of nanomanipulators for nanomedicine applications. The magnetosome nanomanipulators which include the drug are driven to a target - invalid tissue or tumor (see Fig. 13).

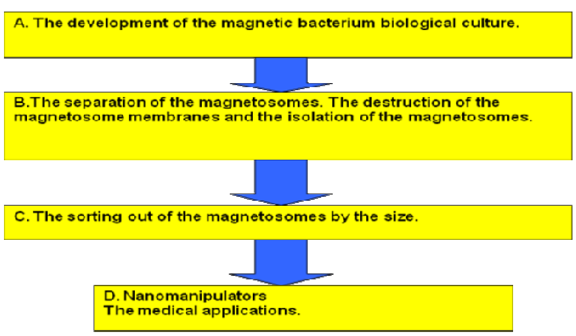


Fig. 12. Diagram of a biotechnology to extract the magnetosome

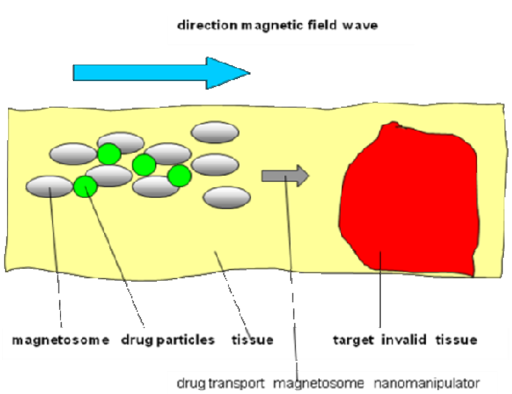


Fig. 13. Drug transportation using magnetosome

In the diagram in Fig. 12 we present a proposal biotechnology specific to extract the magnetosome by the magnetic bacteria and below Fig. 13 a possibility to use this magnetosome for drug transport.

The Bionics Applications

An application by a bionic study is the micromanipulator structure based on the micromechano-magnetic of the magnetic bacteria.

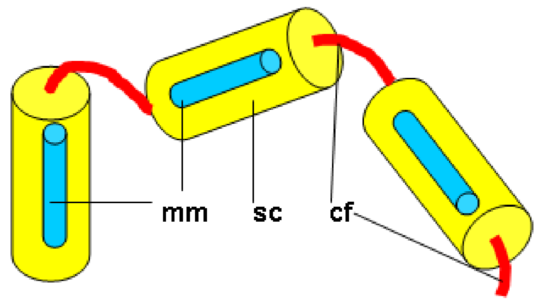


Fig.14. Structure of magnetic micromanipulator: mm - magnetic core, sc - cylindrical support, cf - flexible connection

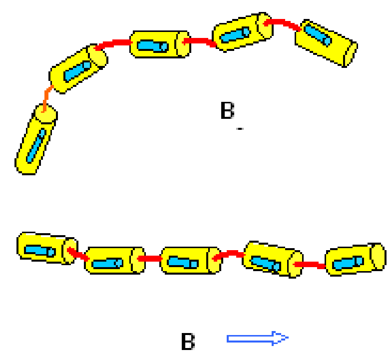


Fig. 15. Magnetic micromanipulator in absence and presence of magnetic fields

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IX. BIOGRAPHIES

Elena Yuan was born, in 2000, in Bucharest. She is a student at The International Computer High School of Bucharest, class of 2016. She has preoccupations in biology and microrobots.

Her merits in scientific competitions include INFOMATRIX 2015, national completion, INFOMATRIX International competition, and ROSEF 2015 competition.

Ionuț Costin was born, in 2000, in Bucharest. He is a student at The International Computer High school of Bucharest, class of 2016. The specific preoccupations are: the microrobots and bionics.

His merits in scientific competitions include INFOMATRIX 2015, national completion, INFOMATRIX International competition and ROSEF 2015 competition.

Applications of Microwires

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Abstract - The research team of the Centre proposes a theoretical and experimental study of micro wires, which is concretized in new manipulation methods and original applications.
We present an efficient method of removing the glass coating using hydrofluoric acid and a mechanism that allows the insertion of a single microwire in a circuit.
The measurements we have made regarding the variation of the temperature with the resistance and of the capacity offer a better understanding of the possible applications.

Index Terms - microwires, glass coating, connectors.

I. INTRODUCTION

Microwires were initially developed for inductance applications, but the capacitance and resistance measurements we have made lead to the conclusion that microwires are suitable materials for small and precise measuring instruments.

Because of their small diameter, microwires show a quick rise in temperature when current passes through them. Microwires also present an exceptional flexibility. These proprieties make microwires useful for thermal clothing (clothes that are embroidered with microwires and connected to a battery).

The glass coating of microwires makes them extremely resistant to strongly corrosive media such as concentrated acids. Normally metals would react with acids and could not be used to analyze the physical proprieties of acidic solutions. We developed a capacitor that uses microwires as the capacitor's plates. It can be used to precisely determine the permittivity of the solution.

II. PRODUCING METHOD

The microwires we used were prepared through the Taylor-Ulitovsky method. This method uses a glass tube in which a metal or alloy rod was inserted. One end of the tube is placed next to a field of high frequency induction. The electromagnetic field melts the metal forming a drop. The glass tube that is in contact with the molten metal softens, forming a mantle that covers the drop. In certain operating regimes, this melted mass trains, forming microwires that are collected on spools.

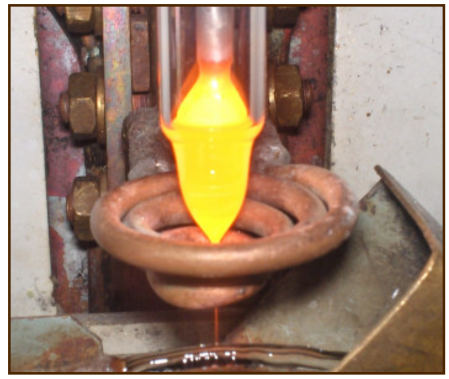

Fig. 1. Aspects from melting and obtain microwires

Metals that can be used to produce microwires include copper, silver, gold, platinum, iridium and various alloy compositions. We used copper and iron-boron-silicon for the experiments.

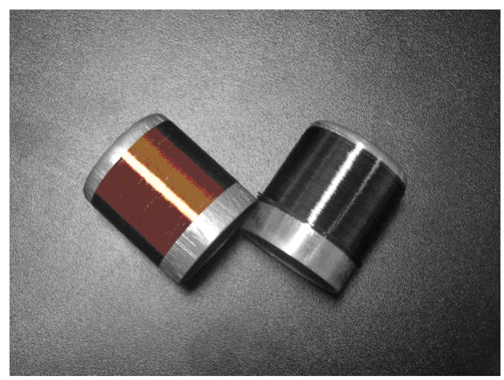

Fig. 2. Microwires obtain at INCDIE ICPE-CA

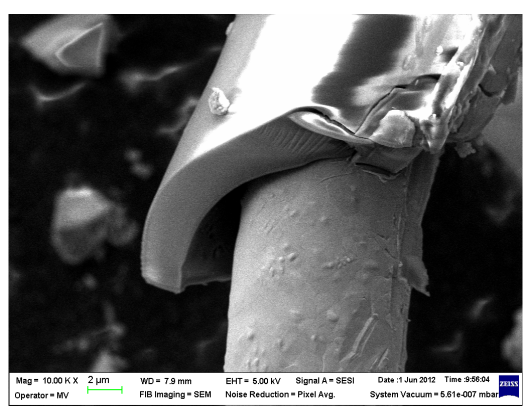

Fig. 3a. SEM photography of glass-coated microwire, produced by the Taylor-Ulitovsky method

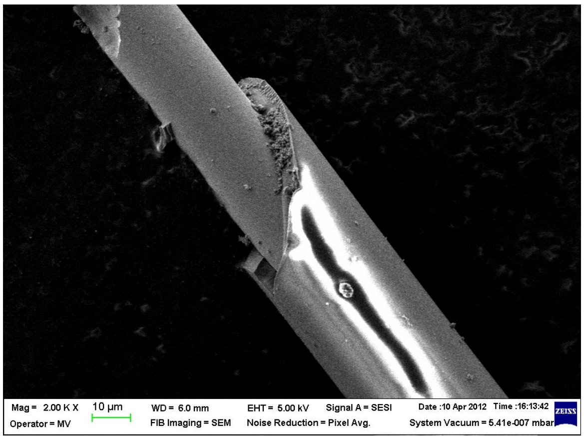

Fig. 3b. SEM photography of glass-coated microwire, produced by the Taylor-Ulitovsky method

III. PROCESSING METHOD

A. Removal of the glass coating

In order to use microwires in electrical circuits, the isolating glass coating must be removed from the ends. The currently used technology in order to do so is mechanical removal using tweezers. This method is time consuming since it can only be performed manually and microwires are hard to manipulate because of their size. To make microwires viable for industrial usage, we came up with a chemical way of partially removing the glass coating.

One of the few substances that react with silicon dioxide is hydrofluoric acid. The equation of the global reaction that takes place is SiO_2 + 4HF --> SiF_4 + $2H_2O$.

In order to use this propriety of glass in order to remove the isolating shell of microwires we have developed a process. The scheme of this process is given below:

The portion of the micro wire that needs to be de-isolated is carefully immersed into a solution of hydrofluoric acid. The reaction occurs in about 5 minutes. Bubbles of SiF4 (a gaseous compound) can be observed on the wire.

The operation is repeated with the other end of the micro wire.

The micro wire is dried and physical analysis can be performed in order to determine if the procedure was successful. The internal resistance of the micro wire can now be measured with a multimeter. If the reaction has taken place, the resistance will be of about 200 ohms.

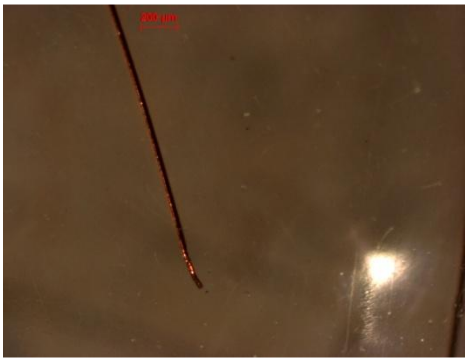

Fig. 4. ZEISS STEMI 2000-C photography of a physically de isolated copper micro wire

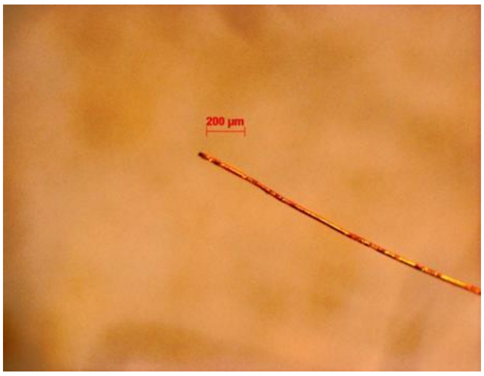

Fig. 5. ZEISS STEMI 2000-C photography of a chemically de isolated copper micro wire

As it can be observed from the photographs taken with the microscope (magnified 50 times), the chemical process was much more effective, and all the glass was removed. Unfortunately, when we tried to apply the same process to iron micro wires, the metal alloy was corroded. Hydrofluoric acid is a weak acid that does not attack metals with low reactivity such as iron or copper and it doesn't react with boron. On the other hand, silicon yields silicon fluorine and hydrogen. Because of this, this method can only be applied for copper micro wires since the structure of the iron micro wire is destroyed when immersed in acid.

In order to make the physical process of de isolation more effective, we used Kocher pence for easy maneuvering of the wire and then proceeded to remove the glass using pincers. Iron micro wires are more resistant to physical shocks and therefore they don't break during the process.

B. Integration in electric circuits

One of the greatest problems of microwires is the difficulty of maneuvering them. Adding a single microwire in a circuit was a difficult process because of their size and fragility. Alligator clips or hook connectors are not efficient because they destroy the microwire. The new type of connector we developed is based on an even distribution of the force that holds them (a magnetic force), thus maintaining the structure of the wire intact.

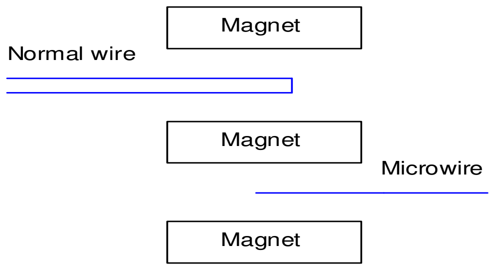

Fig. 6. The scheme of a magnetic connector

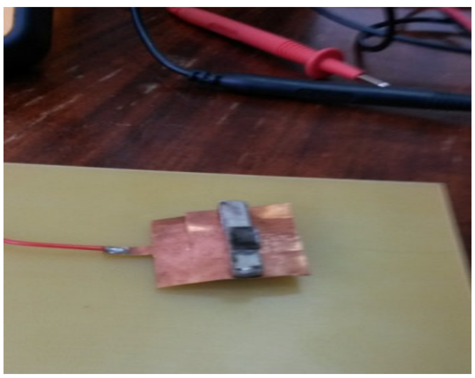

Fig. 7. A magnetic connector

IV. THEORETICAL ASPECTS AND APPLICATIONS

A changing distribution of the glass appears because of the roughness of the metallic core, the micro technologic conditions, and because glass is a heterogeneous material. Thus, there appears a micromechanical stress distribution on the glass shell (presented in Fig. 8a and Fig. 8b). This stress can be better understood as a micromechanical pressure distributed radially and longitudinally along the microwire.

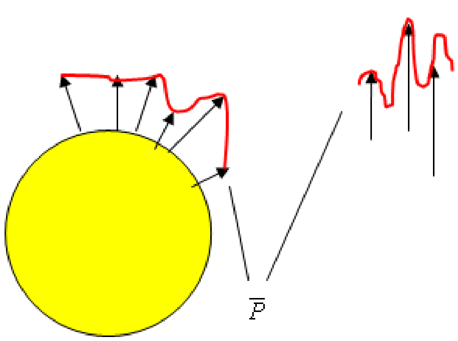

Fig. 8a and 8b. Micromechanical stress distribution on the glass shell

A. Inductance

One of the main applications of microwires is based on their inductance. In order to measure the inductive proprieties of microwires, we built micro coils. These can be used in inductive micro sensors, micro transformers and relays.

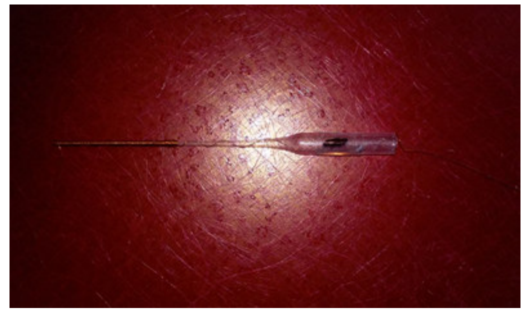

Fig. 9. Inductance realized with a microwire with a diameter of 8 micrometers and 170 turns which is realized on a capillary pipette (with a diameter of 0.8mm).

When we measured the inductance (with an ESCORT 132 A LRC bridge), the value of inductance was to 1 kHz and to 120 Hz. Then we introduce a micro core with 5 Fe-B-Si microwires (5microns/wire) and the inductances became to 1 kHz and to 120 Hz which a significant values for micro sensor applications.

Based on this data, microwires can be used to measure small electro-magnetic fields (micro sensors), to precisely determine electromagnetic fields, to create micro motors with better coil insulation and to make discrete electrical components (micro relay, magnetic switch, micro transformer).

B. Capacitance

Capacitance is the ability of a body to store an electrical charge. Any object that can be electrically charged exhibits capacitance. A common form of energy storage device is a parallel-plate capacitor where the capacitance is directly proportional to the surface area of the conductor plates (in our case, the surface of the microwires) and inversely proportional to the separation distance between them.

Due to the material of the plates, the number of instruments that allow measurements under certain conditions is limited. Even if the capacitance is an important characteristic of acidic liquids, there are only a few ways of measuring the pH of those solutions. Because microwires are made of metal wires covered in glass, we can measure the capacitance (Fig. 10) of different acidic substances as the metal is protected and cannot be corroded.

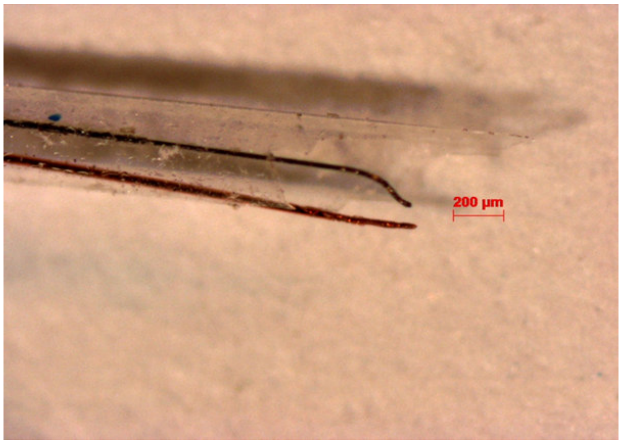

Fig. 9. Microcapacitor made of microwires

In order to test them, we used the above mentioned connectors, but because of their construction the connectors themselves had a capacitance of 28.8 pF. The way we build the connector placed the microwire capacitor in parallel with the capacitor created by the magnets.

$$C_{total} = C_1 + C_2 + \dots + C_n \quad (1)$$

Firstly we measure the capacitance between the two microwires in air, to find the base capacitance. For two 17 cm wires, we measured a capacitance of 42.8 pF, which means that the wires themselves have a capacitance of 14 pF. After finding the base capacitance we measured it in various liquids.

The scheme of the created circuit is represented in Fig 11. The meanings of the notations are given below:

- - the capacity of the microwire inside the glass pipette;
- - the capacity of the connectors;
- - the capacity of the medium which we measured;
- - the parasite capacitance;
- - the capacitance of the uncovered microwire;
- R - the resistance of the connections, measured in ohms.

If we know the capacitance it is possible to determine the material permittivity of the medium.

Possible applications based on this property of microwires include precision measurement the capacitance of different liquids and measurements of the pH of different fluids.

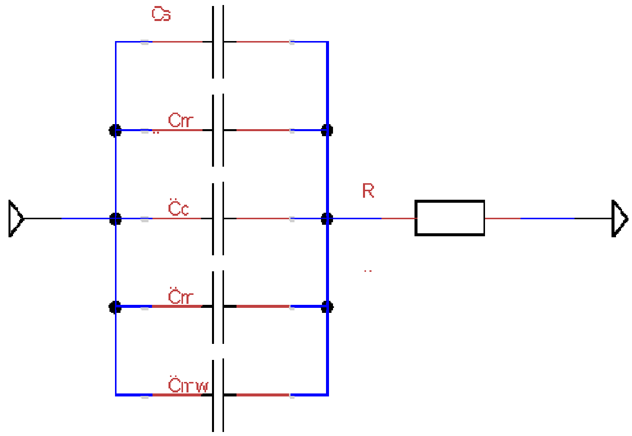

Fig. 11. Equivalent scheme of the circuit

C. Electrical resistance

We observed that microwires easily change their resistance over temperature. For the further testing of this propriety we made a textile sample by embroidering a 10 X 10 cm material with microwires.

Then we tested the resistance and the temperature of the microwire in the material over time.

In Fig.12 are presented two thermal evolutions of a textile sample which was weaved with a microwires conductor to the following parameters:

1) Voltage U = 102 V; current I = 10 mA;
2) Voltage U = 200 V; current I = 15 mA.

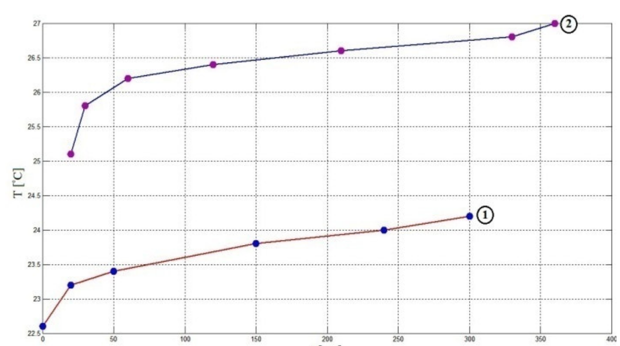

Fig 12. Graphic of the thermal evolution of a microwire textile

Based on this property, microwires can be made to create high precision temperature sensors with fast reaction to change and materials with controlled heat.

D. Mechanical resistance

Microwires have a very small mechanical resistance, due to the materials they are made of, and due to their small size. Microwires have a limited variation in length, and they break after passing it.

For those properties, an application in structure breakpoint sensors can be created.

In order to determine the variation of the length we made more mechanical resistance measurements.

The determined Young's modulus for the copper microwires is approximately 1650 N/cm^2 and for the iron-boron-silicon 1970 N/cm^2.

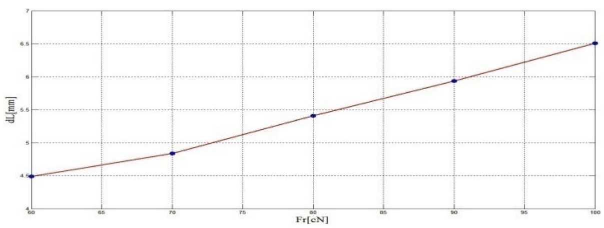

Fig. 13. Graphic of length variation with force

V. ACKNOWLEDGMENT

The authors gratefully acknowledge the contributions of Mircea Ignat for his work on this document.

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VII. BIOGRAPHIES

Velicu Maria was born on September 6th, 1998 in Bucharest. She is a student at The International Computer High School of Bucharest, class of 2016.

Her merits in scientific competitions include the second and third place in the National Chemistry Olympiad and being a part of Romanian's team for science and chemistry Olympiads several times.

Dr. Manta Eugen, was born at January 12th, 1982. Current position: Engineer for Technological Development (IDT III), PhD., Adv. Materials Dept., INCDIE ICPE-CA. He is member of professional associations: Romanian Society of Magnetic Materials (2006), Romanian Society of Materials „Teodor Segarceanu" (2006).

Corbeanu Dan Andrei was born in Bucharest on May 16, 1998. He attends from the 6th to the 8th grade to the International Computer Highschool of Bucharest, and currently is the pupil of the "Tudor Vianu" National College. Along these years, he participated to various international project competitions and Olympiads in the field of science in America, Holland and Romania, where he gain various prizes.

Short Introduction on the Magnetostrictive Motor

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Abstract - The paper presents general aspects of a new unconventional micromotor: the magnetostrictive motor. Are presented: theoretical aspects, functional principle and the main electromechanical aspects.

Index Terms – Magnetostriction, magnetostrictive motor, magnetostrictive actuator, micromechanical contact.

I. INTRODUCTION

The magnetostriction is defined as the dependence of the state of strain (dimensions) of a ferromagnetic sample on the direction and extent of its magnetization.

In discussing the effect of a unidirectional stress it is convenient to divide materials into two classes [1], which have:

- Positive magnetostriction – where the magnetization is increased by tension and the material expands when magnetized;
- Negative magnetostriction – where the magnetization is decreased by tension and the material contracts when magnetized.

The main equations of the magnetostrictive effects are [1], [2], [3]:

$$\begin{aligned} \overline{\overline{S}}_i &= \overline{\overline{s}}^H_{ij}\overline{\overline{T}}_j + \overline{\overline{d}}_{ni}\overline{H}_n \\ \overline{B}_m &= \overline{\overline{d}}_{mj}\overline{\overline{T}}_j + \overline{\overline{\mu}}^T_{mn}\overline{H}_n \end{aligned} \qquad (1)$$

where:

$\overline{\overline{S}}$ - the longitudinal deformation tensor;

$\overline{\overline{T}}$ - the mechanical stress tensor;

$\overline{\overline{s}}^H$ - the electromechanic compliance tensor to a constant magnetic intensity field;

$\overline{\overline{d}}$ - the magnetostriction ratio tensor;

$\overline{\overline{\mu}}$ - the magnetic permeability tensor to a constant mechanical stress.

Among the magnetostrictive applications (there are many magnetostriction effects: longitudinal, volume effects, radial, Young modulus variation, etc.) [1], [2], [3], [4]: sensors, actuators, harvesting microgenerators, an interesting application is represented by the magnetostriction motor [5], [6], [7], [8].

A general functionally algorithm of the magnetostrictive motor is presented in Fig. 1, and in Fig. 2 a simple sketch of the functional structure.

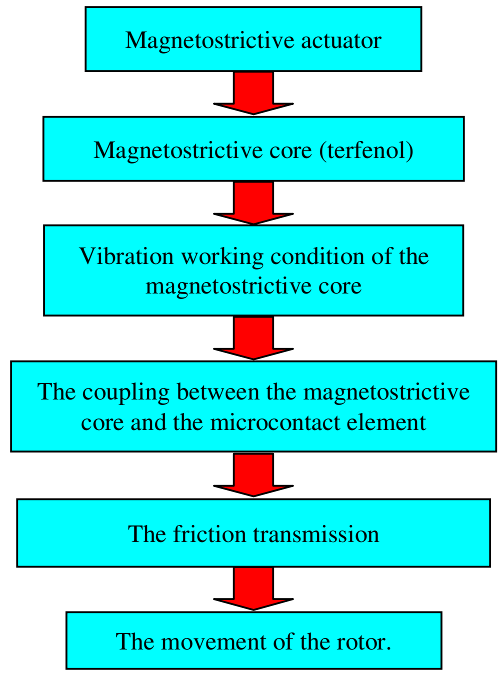

Fig. 1. The functional mode

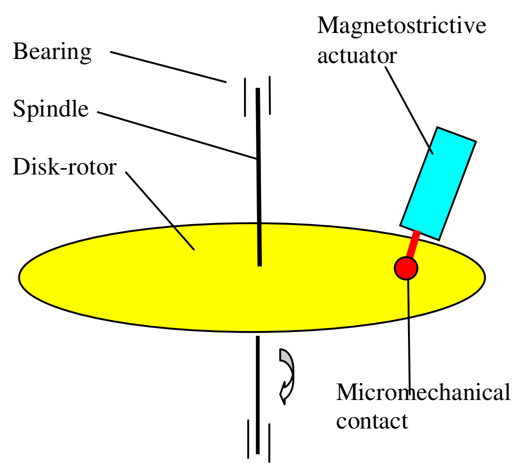

Fig. 2. A simple functional structure

The magnetostrictive actuator (which is fed with AC voltage) generates the mechanical vibrations which are transmitted to a disk rotor through the micromechanical contact. In this way a mechanical torque appears.

II. A MECHANICAL ANALYSIS

In Fig. 3 is presented the micromechanical contact structure where the main guide mark is the flexible friction element, and in Fig. 4 are presented the components of the active force (P) of the magnetostrictive actuator, where α is the angle between the actuator and the disk rotor plane. For a good efficiency of this motor, is necessary to mount the actuator inclined to a certain angle.

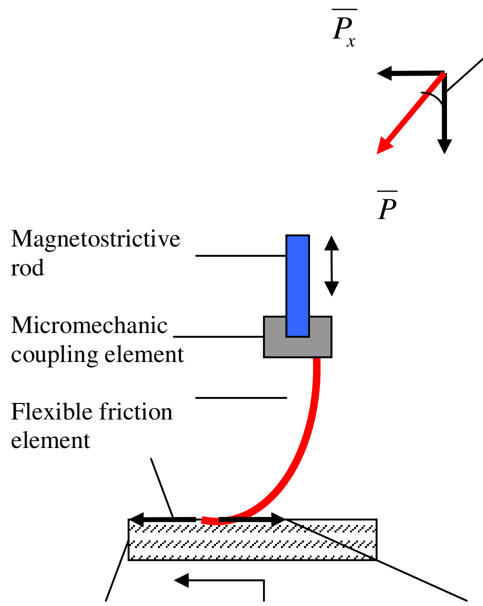

Fig. 3. The micromechanical contact structure

The active force, which is generated by magnetostrictive actuator, has the form:

$$P = P_0 \sin(\omega T + \varphi) \tag{2}$$

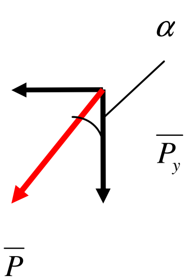

Fig. 4. The force system of the magnetostrictive actuator

The static model of the disk rotor is presented in Fig. 5.

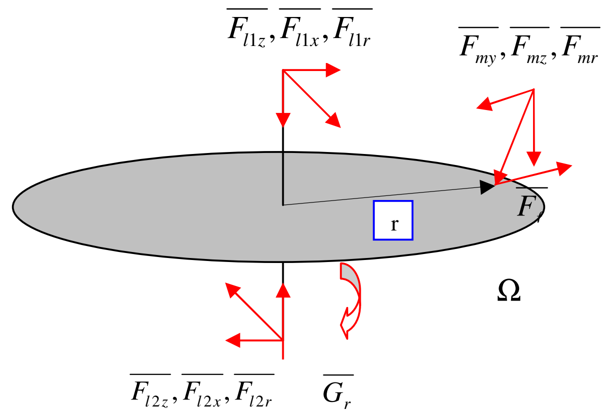

Fig. 5. The static micromechanical model of the rotor

The equations of the static representation are:

$$\overline{F_{l1r}} + \overline{F_{l2r}} + \overline{F_{mr}} = 0 \tag{3}$$

$$(Ox)\ \overline{F_{l1x}} + \overline{F_{l2x}} = 0 \tag{4}$$

$$(Oy)\ \overline{F_{my}} > \overline{F_f} \tag{5}$$

$$(Oz)\ \overline{F_{l1z}} + \overline{F_{l2z}} + \overline{F_{mz}} = 0 \tag{6}$$

where:

$\overline{F_{l1r}}$, $\overline{F_{l1x}}$, $\overline{F_{l1z}}$ - the components of the upper microbearing;

$\overline{F_{l2r}}$, $\overline{F_{l2x}}$, $\overline{F_{l2z}}$ - the components of the lower microbearing;

F_f - the main friction force;

r - the radius where is realized the micromechanical contact.

III. THE MICROMECHANICAL EQUIVALENT SCHEME

The diagram of the equivalent micromechanic contact is presented in Fig. 6, and in Table 1 the elastic and damping (or viscous) ratios of the equivalent diagram described [7], [8].

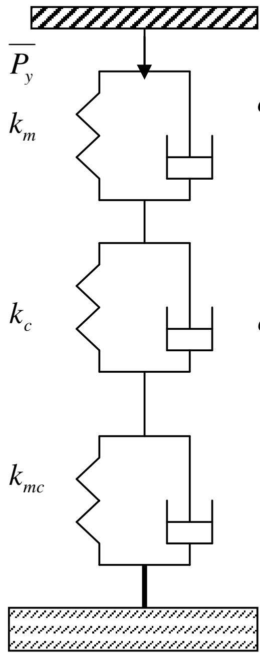

Fig. 6. The equivalent scheme of the micromechanical contact

TABLE I. The elastic and damping ratio of equivalent diagram.

Guide mark	Spring rate	Damping rate	Mass
The magnetostrictive rod	k_m	c_m	m_m
The microme-chanical coupling	k_c	c_c	m_c
The contact element	k_{mc}	c_{mc}	m_{mc}

Together with the equation (2) is possible to describe the dynamic behaviour in micromechanical contact (and the transmission of the vibrations):

$$m_m \frac{d^2 y}{dt^2} + c_m \frac{dy}{dt} + k_m y = P_y \quad (7)$$

$$m_c \frac{d^2 y}{dt^2} + c_c \frac{dy}{dt} + k_c y = 0 \quad (8)$$

$$m_{mc} \frac{d^2 y}{dt^2} + c_{mc} \frac{dy}{dt} + k_{mc} y = 0 \quad (9)$$

The solution of the first equation is [9], [10]:

$$y_m = e^{-\xi_m p_m t}(A\cos p_{1m}t + B\sin p_{1m}t) + y_0 \sin(\omega t - \theta_m) \quad (10)$$

and it can be generalized also for equations (8) and (9).

The micromechanical pressure on the contact has an ellipsoidal distribution [10], [11].

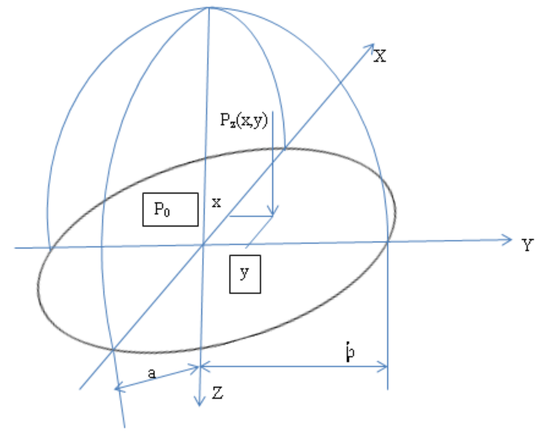

Fig. 7. The contact pressure distribution

The analytical relation of the x, y distribution is [10]:

$$p(x, y) = \frac{3P_y}{2\pi ab}\sqrt{1 - \frac{x^2}{a^2} - \frac{y^2}{b^2}} = p_0\sqrt{1 - \frac{x^2}{a^2} - \frac{y^2}{b^2}} \quad (11)$$

IV. DESIGN ASPECTS

The main element of the magnetostrictive motor is the actuator.

The structure of the magnetostrictive actuator has the following elements (see Fig. 8):

- The magnetostrictive rod (by Terfenol [1], [2], [3], [14]);
- The permanent magnet necessary for the magnetic bias [1], [2], [3];
- The coil;
- The ferromagnetic circuit.

The design of magnetic circuit includes [2], [3], [5], [6]:

- the magnetic reluctance:

$$R_i = \frac{H_i l_i}{\Phi_i}[A/Wb] \quad (12)$$

where: $H_i[A/m]$ - the magnetic intensity field on the magnetic segment i, $l_i[m]$ - the length of the magnetic segment, $\Phi_i[Wb]$ - the magnetic flux.

- the magnetic reactance (because of the AC working condition of the actuator):

$$X_i = \frac{2p_f G_f}{\omega \Phi_i^2}[A/Wb] \quad (13)$$

where: $p_f[W/kg]$ - the specific losses on the i subdomain, $G_f[kg]$ - the mass of subdomain (segment) i, $\omega = 2\pi f$, with $f[Hz]$ - frequency.

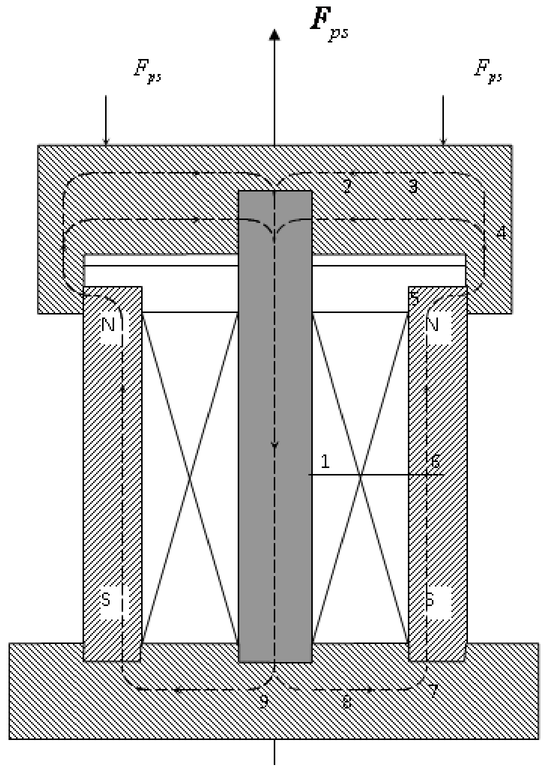

Fig. 8. The magnetostrictive actuator

The flux is:

$$\Phi_i = \frac{\sqrt{2}U}{N\omega}[Wb] \tag{14}$$

where $U[V]$ - voltage, N - the number of turns in coil.

In Fig. 9 is shown the characteristic of flux vs. turns, for an actuator which was realised to the Microelectromechanical Department of INCDIE.

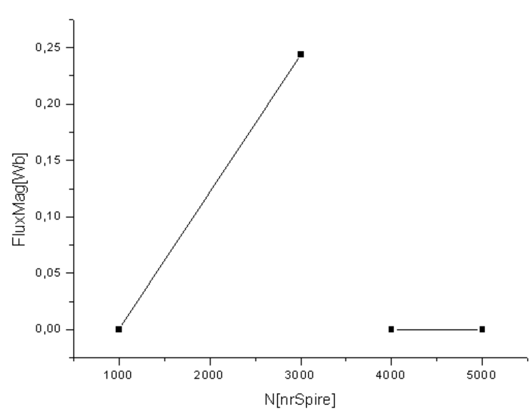

Fig. 9. The characteristic flux vs. the number of turns

An important parameter of the actuator is:

$$\lambda_s = \frac{\Delta l}{l} \tag{15}$$

where $l, \Delta l$ - are the initial length of the magnetostrictive rod and the expansion of the rod to the magnetic stress [3], [14], with:

1000 ppm < λ_s < 4000 ppm;

20 μm < Δl < 400 μm.

The mechanical properties of the Terfenol D ($Tb_{0,27}Dy_{0,75}Fe_2$) are showed in Table 2 [3], [14].

TABLE 2. Mechanical properties of Terfenol D.

Density	9250 kg/m^3
Young modulus	23-35 GPa
Mechanical traction	28 MPa
Mechanical compression	700 MPa
Relative permeability	3-10

The permanent magnets are in general AlNiCo magnets.

The force of the actuator is:

$$\overline{F} = \overline{n}\frac{B^2 A}{2\mu_0} \tag{16}$$

where A is the rod section.

A material ratio in design is magnetostrictive ratio (for specific coupling module 33):

$$k_{33}^2 = \frac{d_{33}^2}{s_{33}^H \mu_{33}^T} \tag{17}$$

Specific ratios of Terfenol ($Tb_{0,27}Dy_{0,75}Fe_2$) (see the rod in Fig. 10):

$$\begin{aligned} &H_0 = 100[\frac{kA}{m}],\\ &T_0 = 40[MPa],\\ &s_{33}^H = 4{,}3\cdot 10^{-11}[\frac{1}{Pa}],\\ &\mu_{33}^T = 3{,}8\,\mu_0,\\ &d_{33} = 9{,}6\cdot 10^{-9}\left[\frac{m}{A}\right],\\ &k_{33} = 67\%. \end{aligned} \tag{18}$$

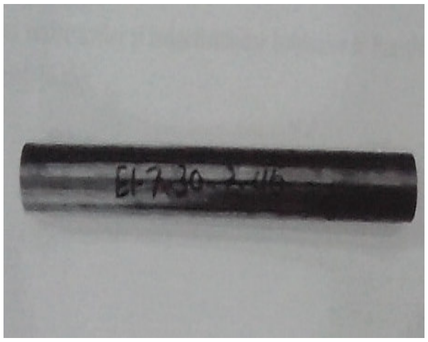

Fig. 10. The magnetostrictive rod

The force valuation is possible with the relation:

$$F_{act} = \left| -T_0 A \right| \qquad (19)$$

with A - the section of the magnetostrictive rod.

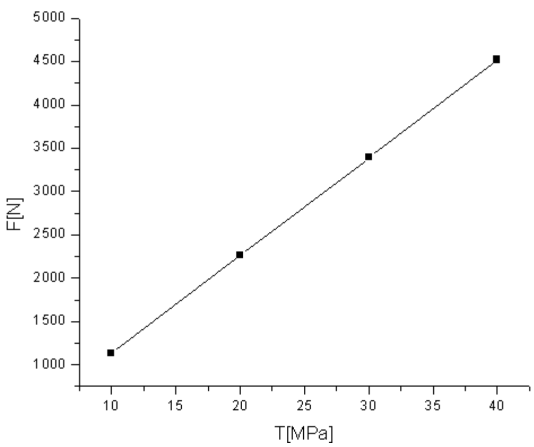

Fig. 11. The estimation of characteristic force

V. SOME STRUCTURES OF THE MAGNETOSTRICTIVE MOTOR

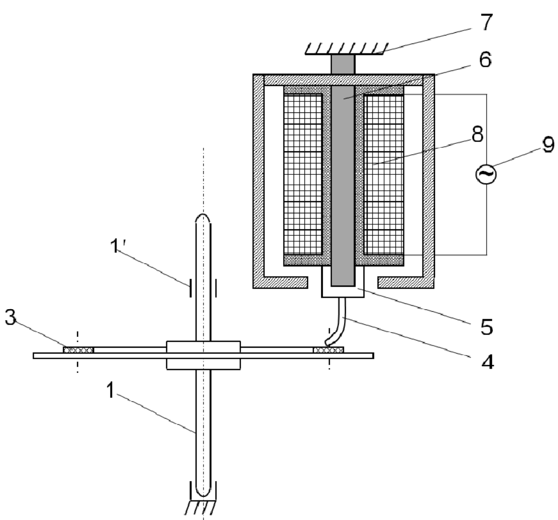

Fig. 12. The motor with a single actuator

There are two main divisions of the magnetostrictive motors:

I. With single or many actuators which drive the rotor (Fig. 12);
II. With many actuators with phase difference which drive the spindle of the motor (Fig. 13, 14).

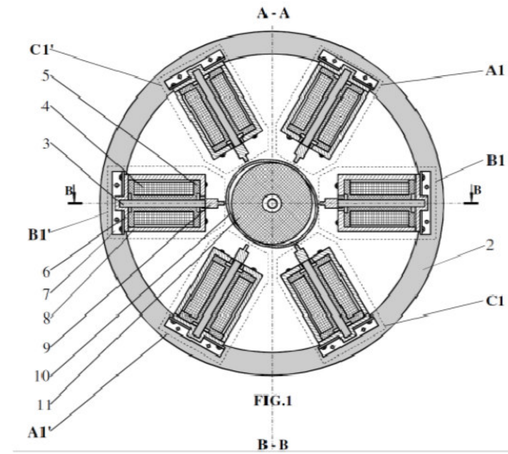

Fig. 13. The motor with many phase difference actuators

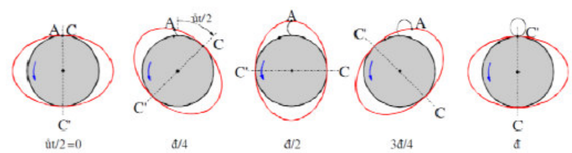

Fig. 14. The diagram of the drive of the motor with phase difference

Fig. 15. The functional motor

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VI. BIOGRAPHIES

Mircea Ignat was born in Bucharest on March 4, 1953. He graduated at 1977 and he received PhD. degrees in electrical engineering from Polytechnic University of Bucharest in 1999.

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The research preoccupation include: the unconventional applications of the piezoelectric and magnetostrictive effects.

Medical Rehabilitation
- Sensors and monitoring -

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Abstract - This paper presents a solution proposed in monitoring the process of patients caring out medical rehabilitation procedures. The authors present different aspects: the theoretical aspects and experiments, the practical experiments, the technological aspects (the piezoelectric sensors, the silicone rubber, the “double-glove”) and studies regarding medical rehabilitation.

Index Terms - sensors, medical rehabilitation, piezoceramics.

I. INTRODUCTION

Rehabilitation is a treatment or treatments designed to facilitate the process of recovery from injury [1], illness or diseases to as normal a condition as possible.

***Rehabilitation (rehab) [rē'habil'itā'shən]*:**

1) Etymology: L, *re* + *habitalas*;

2) The return of a function after illness or injury, usually understood to occur with the help of specialized medical professionals (e.g. physical therapist, occupational therapists) (Segen’s Medical Dictionary. 2012 Farlex, Inc. All rights reserved.)

A. Objective

The objective of rehabilitation is to restore some or all of the patient’s physical, sensory and mental capabilities that were lost due to injury, illness or diseases. Rehabilitation includes assisting the patient to compensate for deficits that cannot be reversed medically. It is prescribed after many types of injury, illness or diseases including: amputations, arthritis, cancer, cardiac diseases, neurological problems, orthopedic injuries, stroke, traumatic brain injuries or spinal cord injuries.

A. Loss of Muscular Force - Causes [2]

1. **Syndrome of long-term immobilization:**
   - appears at patients with polytraumatisms, in a coma or with fractures that were immobilized in a cast;
   - the muscular force is lost progressively because of the lack of joint movement (muscular sideration).
2. **Syndrome of upper neuron:**
   - It affects the central nervous system (central cortex and the spinal cord);
   - It occurs due to strokes, cerebral tumours, traumatic brain injuries or vertebra - medullar traumas;
   - The clinical expression of this disease is the motor deficit:
     - hemiparesis (stroke, cerebral tumours);
     - tetraparesis & paraparesis (TBI, VMT).
   - In acute and post acute state, the motor deficit is flask (flask paraparesis) when the patient can't move the affected limb active, only passive. In this stage, muscular force has the value 0 or 1[1] (value that can oscillate between 0 and 5 in the table of muscular force);
   - After some time, spasticity[2] is installed and the muscular force is beginning to rise, the patient can make active assisted movements, active movements and active with resistance movements.
3. **Syndrome of peripheral neuron:**
   - There exists a traumatic injury or of other nature (toxic) of an peripheral nerve
   - The specific symptoms are loss of muscular force, alteration of sensibility(tactile, thermal) with the apparition of muscular hypotrophy
   - In contrast to the lesions of upper motor neuron, these paralyses are flask, spasticity does not occur in this case.

II. TECHNOLOGICAL ASPECTS

A. Silicone Rubber

The product is a bicomponent (A+B), and it

---

[1] Table of muscular force:
0 - no contraction;
1 - there exists muscular fasciculation, but no muscle contraction;
2 - there exists movement, but not anti-gravitational;
3 - there exists anti-gravitational movement;
4 - there exists contraction against a medium resistance;
5 - normal contraction force.

[2] Spasticity is a muscle control disorder that is characterized by tight or stiff muscle and an inability to control those muscled.

hardens at room temperature; it has fluid consistence, which strengthens by adding the catalyst (Y), according to the polycondensation process.

It contains compounds with anti-slip properties, which make the product very flexible, being indicated while creating fine-drown details. The main qualities of these rubbers are medium stiffness and a great tearing endurance.

Due to its low harshness (10 Shore A), Globalsil AL/10 is ideal for manufacturing matrix, in which will later on be poured synthetic resins (polyester, epoxy, polyurethane, etc.). After complete drying, it can be peeled off from the object on which it was applied.

Globalsil AL/20 with medium harshness (20 Shore A), holds very good mechanical properties, being appropriate for manufacturing molds or statues, decorative items for gardens, wood imitations, ornaments, decorative candles, different prototypes, etc. Also, it is successfully used in archaeology or palaeontology.

Globalsil AL/40, with a medium-high harshness (40 Shore A), is perfect for manufacturing big molds.

A. Preparation and Usage of the Blend in the Embedment Process

Fig. 1. The piezo sensors before being embedded

Before mixing the two components, it is well-recommended to stir in each of them (separately), in order to be sure they are homogenized (decantation might possibly occur if the product is kept in its package for a longer period of time)

After weighting the base and the catalyst (in the specified proportions mentioned on the data sheet) – the maximum allowed deviation being 1 gram – you will mix them using circular slow motions (to prevent air bubbles from being formed) (Fig. 2).

The mixing must be done in a clean container, of appropriate capacity, for a few minutes. Afterwards, the blend will be moved into another container and re-homogenized for a few seconds, this ensuring the perfectly done mix of the catalyst, which might still remain on the sides or on the bottom of the first container.

The wires are added on each side of the micro-sensors, one on the upper side and the other on the lower side. After the silicone rubber is ready to be used, the sensors with the wires attached are placed in the matrix, the wires being pulled outside through the special holes made in the matrix (Fig. 3).

Fig. 2. Technological sequence on the formation of the silicone rubber solution

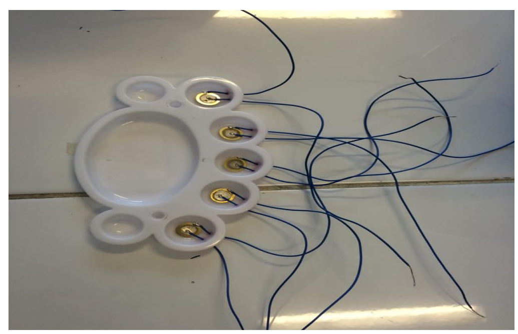


Fig. 3. Microsensors with planar geometry inside the matrix and their connexions kept outside

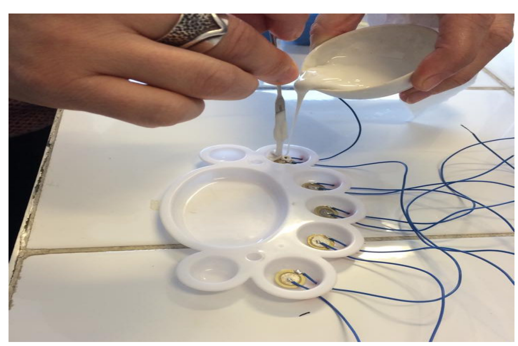


Fig. 4. Pouring the silicone rubber solution into the plastic matrix, over the sensors

The two mixed components will then be

carefully poured in the matrix, avoiding air bubble formation, (Fig. 4) then the finishes will be made (Fig. 5). The optimum strengthening of Globalsil rubbers occurs at temperatures between 10 and 350°C. Chemical-mechanical properties of the product are reached after 48 hours, so the matrix will not be moved in this time (Fig. 6). When the time passed, the micro-sensors embedded in silicon rubber will loosen from the matrix (Fig. 7).

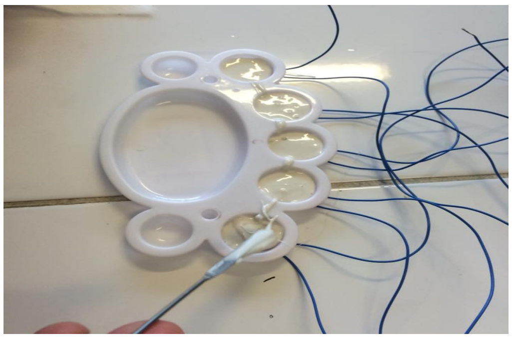


Fig. 5. Finishing the details of each space with microsensors after pouring the silicon rubber

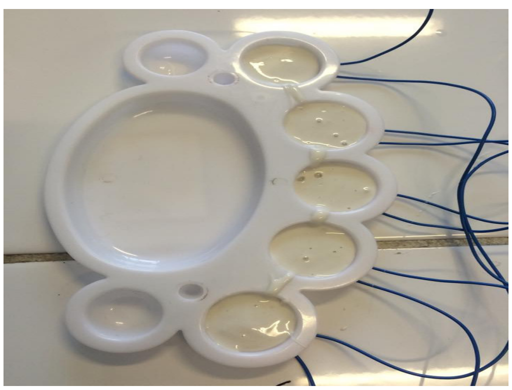


Fig. 6. Matrix with all the spaces filled with silicon rubber solution

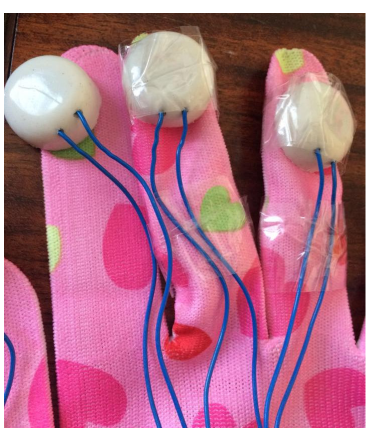
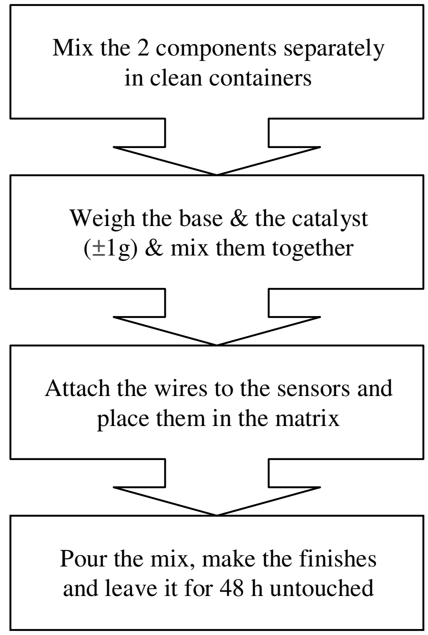


Fig. 7. Sensors embedded in silicon rubber



C. Creating the Evaluation Glove Technology

BRAINSTORMING IDEAS:

- Cotton glove (inner) + plastic/rubber gardening glove (outer);
- Disposable surgical glove (inner) + rubber gardening glove (outer);
- Fixing the embedded sensors on the inner glove with super-glue;
- Fixing the sensors on the inner glove with scotch tape;
- Attaching the wires with scotch tape on the glove;
- Sticking the inner glove inside the outer one.

The first attempt in realizing this double glove was sticking together two gloves, with the sensors fixed between them. The starting point was choosing a disposable surgical glove on which the embedded sensors were going to be glued with super-glue. This disposable glove with the embedded sensors and the wires attached to it was going to be placed inside the gardening glove and then glued together.

THE PROBLEMS OF THE FIRST IDEA:

- Because of the chemical properties of the silicone rubber in which the sensors have been embedded, the chemical properties of the surgical glove and those of the super glue, the three elements of our project were not compatible, making the embedded sensors loosen from the glove (Fig. 8).

HOW WE SOLVED THIS?

We replaced the super-glue with scotch tape, wrapping each finger of the glove, with the sensor fixed on it, in scotch tape (Fig. 9 & 10).

- The disposable surgical gloves are made (of course) to be disposable, which means that after being used once, you are supposed to throw them away. We thought this is not mandatory and choose them as our inner material because of their elasticity and how the moulded on the hand. After putting them on and taking them off a couple of times, the rubber they are made from started to tighten, making them impossible to wear. Another problem was that by putting them on-taking them off, being disposable, little holes started to appear.

HOW WE SOLVED THIS?

We replaced the disposable surgical gloves with cotton gloves, which were made to be used multiple times. In the end, this proved to be a better idea, because the putting on-taking off process is much easier now and also the ripping risk is lower.

With the new replacements, the second attempt in realizing the double glove seemed to be more successful. The idea of having two gloves stuck together, with the sensors fixed between them was still a plausible one, so it became our new starting point. We had 2 options:
1) Sensors stuck on the cotton glove with super-glue;
2) Sensors wrapped in scotch tape around each finger.

The problem of 1st option:

The chemical properties of the silicone rubber in which the sensors have been embedded, the chemical properties of the surgical glove and those of the super glue were still incompatible, making the sensors once again to loosen from the glove.

How we solved this?

There was not really much to solve, because the problem seemed to come from the silicon rubber, so we had to come up with another idea. This is how the 2nd idea appeared, so we tried it.

For now on, this second option of the second idea proved to be the best. The sensors were wrapped in scotch tape around each finger. And the inner glove was supposed to be placed and glued inside the outer one, creating the "double glove". All the wires are fixed together on a plastic element, creating the contact between any possible measuring devices used; this plastic component is placed on the wrist, and is also fixed on the glove (Fig. 11).

Fig. 8. Disposable surgical glove with the sensors glued on it with super glue

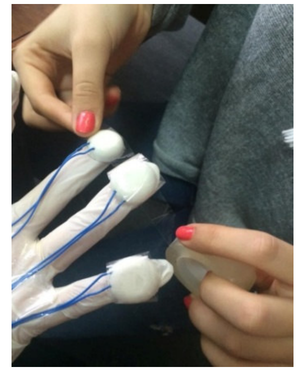


Fig. 9. The process of wrapping the sensors in scotch tape around each finger

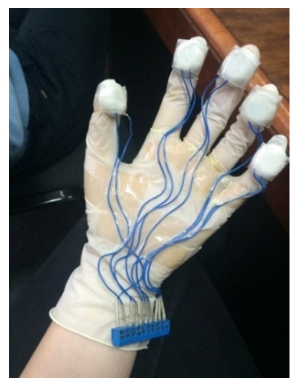


Fig. 10. Disposable surgical glove with the sensors wrapped in scotch tape around each finger

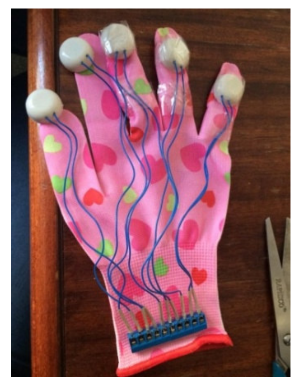


Fig. 11. Cotton glove with some of the embedded sensors and some of wires wrapped in scotch tape

The problems of 2nd option:

- The embedded sensors have wires attached to them, which were not glued in any way to the glove, making them mix together, this leading to a high breaking risk because of their fragility;

How we solved this?

We wrapped the wires in scotch tape at the bottom of each finger, but it didn't seem to be enough, so we applied another piece of scotch tape on the palm, sticking all the wires together.

- At this moment, if we are to glue the inner and the outer glove, the results of the tests might not be totally correct. By gluing them, you are not able to properly place the sensors on the ball of your fingers, because in the putting on process, the sensors might slightly.

How we solved this?

For now on the gloves are not glued together, but put on separately. Firstly you put on and arrange the inner glove, which has the sensors and the wires attached, then carefully cover it with the outer glove which protects the embedded sensors and makes the test exercises easier to be done.

III. EXPERIMENTAL RESULTS

The experiments presented in Tables 1-6 were performed in order to understand the characteristics of the piezoelectric sensors and to measure pressure, voltage or force in different cases. They were mainly performed with the sensors not being attached to the glove, except Table 4 and 5, where the objective of the experiments was to understand the way medical rehabilitation exercises are performed.

TABLE 1. The measuring devices used for the following experiments

INSTRUMENT	BRAND	RESOLUTION	MAX. VAL.
Micropalpator	Iamada (Japan)	2 µm	0-5 mm
Micro-dynamometer	Iamada (Japan)	0.01 kgf	0-1 kgf
Dynamometer	Iamada (Japan)	2 N	

In the following table are shown the results of one of our experiments in which we wanted show the electric tension versus downforce.

TABLE 2. Electric tension versus downforce

d (mm)	F (kgf)
0,004	0
0.343	0.02
0.603	0.05
1.117	0.10
1.906	0.18
2.685	0.25
5.130	0.50
2.675	0.25
1.904	0.18
1.115	0.10
0.607	0.05
0.340	0.02
0.004	0

For the following experiment we used a dynamometer and an oscilloscope. We connected the wires of one sensor to the oscilloscope then pressed with 0.1 – 0.9 kgf on the sensor in order to see the voltage

TABLE 3. Constant applied force on the sensor

FORCE [kgf]	VOLTAGE [V]
0.1	1
0.2	1.5
0.3	2
0.4	2.5
0.5; 0.6; 0.7	3
0.8; 0.9	3.5

For next experiment we used the oscilloscope and a Piezoelectric sensor embedded in silicone rubber. The wires of the sensor were attached at the oscilloscope and each of us pressed on the sensor with each finger, in order to see the pressure we exert on the sensor.

TABLE 4. Constant applied force on the sensor

ANA-MARIA (right hand)	
FINGER	***PRESSURE***
Thumb (1)	20
Index finger (2)	25
Middle finger (3)	25
Ring finger (4)	20
Little finger (5)	30
MIRUNA (right hand)	
Thumb (1)	25
Index finger (2)	25
Middle finger (3)	30
Ring finger(4)	35
Little finger (5)	35

TABLE 5. Experimental matrix system

FORCE (kgf)	SENSOR 1 (V)	SENSOR 2 (mV)
0.1	1	50
0.2	2	100
0.3	3	150
0.5 - 0,6	4	200
0.7 - 0.9	4.5	250

For the following experiment were used the sensor-attached glove and the oscilloscope. The objective was to measure the output voltage while holding different objects or while pressing different bodies.

TABLE 6. Holding objects

OBJECT	OUTPUT [V]
With the thumb	2
With the table	3
Parallelepipedic object	3
Cylindrical object	2
Ruler	6

IV. MORE EXPERIMENTAL RESULTS

The experiments presented in Tables 7-10 were performed using the sensor-glove at the National Medical Rehabilitation Institute with 4 patients with different traumatisms. The objective was to measure the clamping force between the thumb and all the other fingers and the pressure applied on the thumb by each finger.

TABLE 7. Male, 59 years old, stroke, right hand

FINGER	TENSION [V]
Thumb (1) on…	
Index finger (2)	1
Middle finger (3)	1
Ring finger (4)	2
Little finger (5)	1
Index finger on thumb (2 on 1)	0
Middle finger on thumb (3 on 1)	2
Ring finger on thumb (4 on 1)	1.5
Little finger on thumb (5 on 1)	1

TABLE 8. Female, 67 years old, stroke, right hand

Finger	Tension [mV]
Thumb (1) on…	
Index finger (2)	800
Middle finger (3)	400
Ring finger (4)	600
Little finger (5)	100
Index finger on thumb (2 on 1)	0
Middle finger on thumb(3 on 1)	600
Ring finger on thumb (4 on 1)	400
Little finger on thumb (5 on 1)	0

TABLE 9. Male, 57 years old, vertebra-medullar traumatism, right hand

Finger	Tension [mV]
Thumb (1) on…	
Index finger (2)	800
Middle finger (3)	400
Ring finger (4)	600
Little finger (5)	100
Index finger on thumb (2 on 1)	0
Middle finger on thumb(3 on 1)	600
Ring finger on thumb (4 on 1)	400
Little finger on thumb (5 on 1)	0

TABLE 10. Male, 33 years old, vertebro-medullar traumatism, right hand

Finger	Tension [mV]
Thumb (1) on…	
Index finger (2)	800
Middle finger (3)	400
Ring finger (4)	600
Little finger (5)	100
Index finger on thumb (2 on 1)	0
Middle finger on thumb(3 on 1)	600
Ring finger on thumb (4 on 1)	400
Little finger on thumb (5 on 1)	0

V. CONCLUSIONS

The objective of the project is to monitor the progress of the patients who are caring out medical rehabilitation procedures. The solution proposed for this monitoring activity being our sensor-glove. The project is still in testing and development phase, several changes and improvements will be performed in the future.

VI. ACKNOWLEDGMENT

Thanks to Dr. Eng. Mircea Ignat - the coordinator of the team and of the project, Mrs. Gabriela Hristea for embedding the sensors in silicone rubber, Lecturer Dr. Florina Ojoga for the medical advice and access at The Medical Rehabilitation Institute to work with the patients and Mr. Dorin Petrescu for the mechanical work.

VII. REFERENCES

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[2] Ch. Vaughan, Davis B. O'Connor, "*Dynamics of Human Gait*", Kiboho Publishers, Cape Town, South Africa, 1995.

VIII. BIOGRAPHIES

Ana-Maria Tudorache is born in Bucharest on October 6th, 1999. She studies at ICHB since 2010 and is now in the 10th grade. She is a member of the Excellency Center for Young Olympics at ICPE-CA since November 2014, being involved in the Medical Rehabilitation-Sensors and Monitoring Project, coordinated by Dr. Eng. Mircea Ignat, project that was well recognized - Gold Medal at InfoMatrix National and International Phases. She is interested in research and medical engineering, thinking about a future in the field.

Miruna Alexandra Ojoga is born in Bucharest on January 9th, 2000. She studies at ICHB since 2012 and is now in the 10th grade. She came at the Excellency Center for Young Olympics at ICPE-CA in November 2014 and since then she was involved in the Medical Rehabilitation-Sensors and Monitoring Project, coordinated by Dr.Eng.Mircea Ignat, project that was well recognized-Gold Medal at InfoMatrix National and International Phases. She is interested in research and wants to continue by studying medicine.

Preparation of a Formatted Technical Paper for the Bulletin of Micro and Nanoelectrotechnologies

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Abstract - This document is itself an example of the desired layout (inclusive of this abstract) and can be used as a template. The document contains information regarding desktop publishing format, type sizes, and typefaces. Style rules are provided that explain how to handle equations, units, figures, tables, abbreviations, and acronyms. Sections are also devoted to the preparation of acknowledgments, references, and authors' biographies. The abstract is limited to 150 words and cannot contain equations, figures, tables, or references. It should concisely state what was done, how it was done, principal results, and their significance.

Index Terms - The author shall provide up to 10 keywords (in alphabetical order) to help identify the major topics of the paper and to be enough referenced.

I. INTRODUCTION

This document provides an example of the desired layout for a published MNE technical paper and can be used as a Microsoft Word template. It contains information regarding desktop publishing format, type sizes, and typefaces. Style rules are provided that explain how to handle equations, units, figures, tables, abbreviations, and acronyms. Sections are also devoted to the preparation of acknowledgments, references, and authors' biographies.

II. TECHNICALWORK PREPARATION

Please use automatic language check for your spelling. Additionally, be sure your sentences are complete and that there is continuity within your paragraphs. Check the numbering of your graphics (figures and tables) and make sure that all appropriate references are included.

A. Template

This document may be used as a template for preparing your technical paper. When you open the file, select "Page Layout" from the "View" menu (View | Page Layout), which allows you to see the footnotes. You may then type over sections of the document, cut and paste into it (Edit | Paste Special | Unformatted Text), and/or use markup styles. The pull-down style menu is at the left of the Formatting Toolbar at the top of your Word window (for example, the style at this point in the document is "Text"). Highlight a section that you want to designate with a certain style, then select the appropriate name on the style menu.

B. Format

If you choose not to use this document as a template, prepare your technical work in single-spaced, double-column format, on paper A4 (21x29.7 centimeters). Set top, bottom margins and right margins to 15 millimeters and left margins to about 20 millimeters. Do not violate margins (i.e., text, tables, figures, and equations may not extend into the margins).

C. Typefaces and Sizes

Please use a Times New Roman font. (See your software's "Help" section if you do not know how to embed fonts.) Table I is a sample of the appropriate type sizes and styles to use.

TABLE I. Table name will be written in Times New Roman font.

Micromotor Code	b [mm]	a [mm]	h [mm]	Material
MPR33	33	25	20	PZT 5
MPR27	27	18	9	PZT 5
MPR15	16	10	10	PZT 5

D. Section Headings

A primary section heading is enumerated by a Roman numeral followed by a period and is centred above the text.

A primary heading should be in capital letters and bolded. The standard text format is considered times new roman 12.

The paper title should be in times new roman 20 uppercase and lowercase letters, not all uppercase.

Author name is set to times new roman 12, institution and contact address (E-mail) are set to times new roman 10.

Financial support should be acknowledged below the author name and institution. Example: This work was supported in part by the U.K. Department of Defence under Grant TX123.

A secondary section heading is enumerated by a capital letter followed by a period and is flush left above the section. The first letter of each important starting word is capitalized and the heading is bolded and italicized.

Tertiary and quaternary sections are accepted only in special cases, so usually must be avoided in order to keep a clear article structure. If required, a tertiary and quaternary section heading must be italicized and enumerated by adding an Arabic numeral after each letter.

E. Figures and Tables

Figure axis labels are often a source of confusion. Try to use words rather than symbols. As an example, write the quantity "Torque," or "Torque, *M*," not just "*M*." Put units in parentheses. Do not label axes only with units. As in Fig. 1, write "Torque (cNm)" not just "(cNm)". Do not label axes with a ratio of quantities and units. For example, write "Current (A)," not "Current/A." Figure labels should be legible, approximately 10-point type.

Large figures and tables may span both columns, but may not extend into the page margins. Figure captions should be below the figures; table captions should be above the tables. Do not put captions in "text boxes" linked to the figures. Do not put borders around your figures.

All figures and tables must be in place in the text centered and written with times new roman 10. Use the abbreviation "Fig. 1" in sentence and for each figure name. Each table must be defined as „TABLE I", with capital letters and roman numbers.

Digitize your tables and figures. To insert images in Word, use: Insert | Picture | From File.

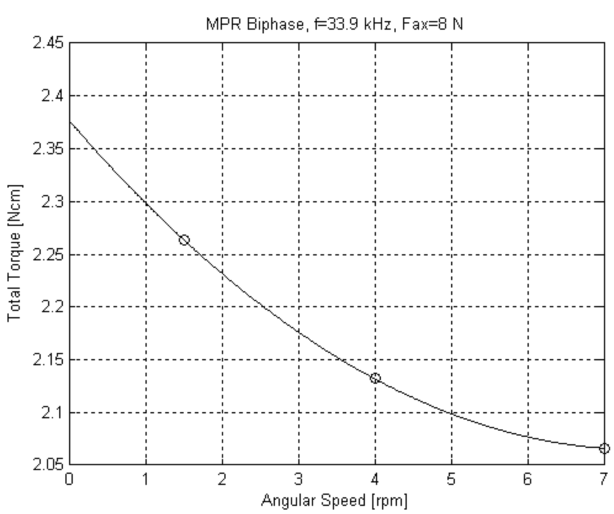

Fig. 1. Total torque function of angular speed. (Note that "Fig." is abbreviated and there is a space after the figure number)

F. Numbering

Please number reference citations consecutively in square brackets [1]. The sentence punctuation follows the brackets [2]. Multiple references [2], [3] are each numbered with separate brackets [1]-[3]. Refer simply to the reference number, as in [3]. Do not use "Ref. [3]" or "reference [3]" except at the beginning of a sentence: "Reference [3] shows….".

Number footnotes separately with superscripts (Insert | Footnote). Place the actual footnote at the bottom of the column in which it is cited. Do not put footnotes in the reference list. Use letters for table footnotes.

Check that all figures and tables are numbered correctly. Use Arabic numerals for figures and Roman numerals for tables.

Appendix figures and tables should be numbered consecutively with the figures and tables appearing in the rest of the paper. They should not have their own numbering system.

G. Units

Metric units are preferred in light of their global readership and the inherent convenience of these units in many fields. In particular, the use of the International System of Units ("Système International d'Unités" or SI Units) is advocated. This system includes a subsystem of units based on the meter, kilogram, second, and ampere (MKSA). British units may be used as secondary units (in parentheses). An exception is when British units are used as identifiers in trade, such as 3.5-inch disk drive.

H. Abbreviations and Acronyms

Define less common abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Standard abbreviations such as SI, CGS, AC, DC, and *rms* do not have to be defined. Do not use abbreviations in the title unless they are unavoidable.

I. Math and Equations

Use either the Microsoft Equation Editor or the *MathType* commercial add-on for MS Word for all math objects in your paper (Insert | Object | Create New | Microsoft Equation *or* MathType Equation). "Float over text" should *not* be selected.

To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize symbols for quantities and variables. Use a long dash for a minus sign or after the definition of constants and variables. Use parentheses to avoid ambiguities in denominators.

The number of each equation must be consecutively added in parentheses and arranged at the right margin, as in (1). Be sure that the symbols in your equation have been defined before the equation appears or immediately following.

Don't use "Eq. (1)" abbreviation instead of "equation (1)", in a sentence.

$$L_m = \frac{m}{A^2} \tag{1}$$

with m - mechanical mass, A - force factor, L_m - electromechanical inductance.

III. ACKNOWLEDGMENT

The following is an example of an acknowledgment.

The authors gratefully acknowledge the contributions of Mircea Ignat and Puflea Ioan for their work on the original version of this document.

IV. APPENDIX

Appendixes, if needed, appear before the acknowledgment.

V. REFERENCES

References are important to the reader; therefore, each citation must be complete and correct. There is no editorial check on references, only the format Times new roman 10 must be considered.

[1] Satanobu J., Lee D.K, Nakamura K., Ueha S., "*Improvement of the Longitudinal Vibration System for the Hybrid Transducer Ultrasonic Motor*", IEEE Trans. On Ultrasonic ferroelectrics and Frequency Control, vol. 47, no. 1, January 2000, pp. 216-220.

[2] Morita T., Yoshida R., Okamoto Y., Kurosawa M., "*A Smooth Impact Rotation Motor Using a Multi-Layered Torsional Piezoelectric Actuator*", IEEE Trans. On Ultrasonic ferroelectrics and Frequency Control, vol. 46, no. 6, November 1999, pp. 1439-1446.

VI. BIOGRAPHIES

A technical biography for each author must be included. It should begin with the author's name (as it appears in the byline). Please do try to finish the two last columns on the last page at the same height. The following is an example of the text of a technical biography:

Mircea Ignat was born in Bucharest on March 4, 1953. He graduated at 1977 and he received PhD. degrees in electrical engineering from Polytechnic University of Bucharest in 1999.

His employment experience included the National Institute for Research and Development in Electrical Engineering ICPE-CA, Dep. of Electrical Micromachines Research and he is the head of Electromechanics Department.

The research preoccupation include: the synchronous generators and the high speed electric machines. He is member of IEEE.