

WorldWide ElectroActive Polymers



EAP

(Artificial Muscles) Newsletter

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FROM THE EDITOR

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Since the field of Electroactive Polymers (EAP) is part of the larger field of biomimetics, increasingly this Newsletter is including inputs related to Biomimetics, Bio-inspired, Bionics, Biomimicry and other terms that are used to describe biologically inspired or mimicked technologies.

As mentioned in the previous issue, there is significant number of conferences and journals that are dedicated to the biomimetics. The SPIE Symposium on Smart Structures has added a related conference and in 2013 we had the third one held. As part of this conference, there has been the participation of employees from the biomimetic program at the San Diego Zoo and this year a python snake was shown during their Plenary Paper presentation in March this year, an owl was shown and described (**Figure 1**).

GENERAL NEWS

The WW-EAP Webhub <http://eap.jpl.nasa.gov> is continually being updated with information regarding the EAP activity worldwide. This Webhub is a link of the JPL's NDEAA Webhub of the Advanced Technologies Group having the address: <http://ndeaa.jpl.nasa.gov>



Figure 1: A python snake was shown during the plenary presentation Education Department of the San Diego Zoo about biomimetics during the 2013 Smart Structures Symposium.

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BIOMIMETICS AND ROBOTICS JOURNALS

International Journal of Advanced Robotic Systems - Humanoid Robotics

Natalia Reinic reinic@intechopen.com

The International Journal of Advanced Robotic Systems has initiated the inclusion of Humanoid Robotics as a dedicated topic starting at the end of June. This journal publishes peer-reviewed articles covering all aspects of robotics research and it is ISI-indexed Open Access journal. Between 2010 and 2013, its ISI-index has grown from 0.326 to 0.821.



The submissions are open on an ongoing basis and the scope of the topic of Humanoid Robotics includes:

- Humanoids and Humanlike robots
- Exoskeletons and prosthetics
- Humanoid Perception, Cognition and Recognition
- Humanoids related Ethics

The Editor-in-Chief for Humanoid Robotics is Yoseph Bar-Cohen who is also the editor of this Newsletter. The Associate Editors of this topic are: Bram Vanderborght, Vrije Universiteit Brussel, Belgium; Liliana Rogozea, Transilvania University of Brasov, Romania; John-John Cabibihan, National University of Singapore, Singapore; and Lorenzo Natale, The Italian Institute of Technology, Italy.

Submission of related research papers needs to be done via <http://www.editorialmanager.com/ijars/>

To view the complete list of topics covered by the International Journal of Advanced Robotic Systems, can be done thru the journal homepage address http://www.intechopen.com/journals/author/international_journal_of_advanced_robotic_systems/about

UPCOMING CONFERENCES

2014 SPIE EAPAD Conference

The 16th SPIE's EAPAD conference is going to be held March 9-13, 2014, in San Diego, California. This Conference will be chaired by Yoseph Bar-Cohen, JPL, and Co-chaired by Siegfried Bauer, Johannes Kepler University Austria. The Conference Program Committee is consisted of representatives from 26 countries. The call for abstracts has been issued and can be found at www.spie.org/eap. The submittal of abstracts is due on August 26, 2013.

The papers will focus on issues that help transitioning EAP to practical use thru better understanding of the principles responsible for the electro-mechanical behavior, improved materials, analytical modeling, fabrication and processing methods, characterization of the properties and performance as well as various applications.

At the EAPAD 2014, the Keynote Speaker is going to be Robert Shepherd, Cornell University and he will cover the subject of "Soft Robotics: A Review and Progress towards Faster and Higher Torque Actuators". Also, a Special Sessions is planned entitled "Electroding Materials and Systems", and it is going to be chaired by Qibing Pei, Univ. of California, Los Angeles and Pawel Zylka, Wroclaw Univ. of Technology, Poland.

As in past years, a course will be given on Sunday, March 9, and the EAP-in-Action Session will be held on Monday, March 10, 2014.

SMN 2013 Conference

From July 10 to 12, 2013, the 4th International Conference on Smart Materials and Nanotechnology in Engineering (SMN) is going to be held at Gold Coast, Australia. The conference is chaired by Jinsong Leng, Harbin Instituted of Technology, China; and Jayantha Epaarachchi, University of Southern Queensland, Australia. The

conference will focus on smart materials and structure, and nanotechnology for different engineering applications ranging from nano-structural and biosensor systems to large scale structures, including smart wind turbine technology and solar energy systems for space vehicles. The conference is seeking to address the growing interest in designing materials with multi-functionality in the form of smart structures. These include magnetically-changed materials, "memory" molecules that return to their original form, and materials that generate an electric charge when pressed, twisted, or warped. Smart structures that are incorporated with sensor system can be used for aerospace, civil and mechanical engineering and other applications. Since the last decade, a significant growth took place in the development of miniature structures and systems, particularly on micro and nano electromechanical systems (MEMS and NEMs). Also, integrated biosensor systems have opened new page in the era of smart materials and nanotechnology.

Information about this conference is available at: <http://www.a-tech.hk/SMN%202013/index.html>

BAMN2013 Conference

The 7th World Congress on Biomimetics, Artificial Muscles and Nano-Bio (BAMN2013) is going to be held on August 26-30, 2013, at Jeju Island, South Korea. This is a biannual conference that is held at different countries all over the world. The island Jeju is a UNESCO Heritage of Nature and one of New 7 Wonders of Nature (<http://www.n7w.com>).

The aim of this congress is to offer high-level lectures, extensive discussions and communications covering the state of the art on biomimetics, artificial muscles, and nano- & bio-materials including potential applications to industrial, biomedical and robotic fields. This conference is a platform for a dialogue between researchers from different areas including chemistry, physics, biology, medicine, engineering, robotics, etc.

The Conference is chaired by Il-Kwon Oh, Korea Advanced Institute of Science and Technology (KAIST), Korea. Information about this conference is provided at <http://www.bamn2013.org>.

RECENT CONFERENCES

2013 SPIE EAPAD Conference

The 15th SPIE's EAPAD conference was held March 11-14, 2013, in San Diego, California. This Conference has been chaired by Yoseph Bar-Cohen, JPL, and Co-chaired by Siegfried Bauer, Johannes Kepler University Austria. The Conference Program Committee consisted of representatives from 28 countries.

The papers focused on issues that help transitioning EAP to practical use thru better understanding of the principles responsible for the electro-mechanical behavior, improved materials, analytical modeling, fabrication and processing methods, characterization of the properties and performance as well as various applications.

The Keynote Speaker has been Larry Howell, Brigham Young University (**Figure 2**), and he reviewed the subject of Compliant Mechanisms and showed examples.



Figure 2: Larry L Howell, BYU, the Keynote speaker at the EAPAD 2013.

A Special Session was dedicated to the subject of "Electro-chemo-mechanical Actuators and Mechano-chemo-electrical Sensors". The Session will be Chaired by Toribio Fernández Otero, Univ. Politécnica de Cartagena (Spain); and Qibing Pei, Univ. of California, Los Angeles (United States).

The invited papers are going to be:

- 8687-2 - Márcio D. Lima, The Univ. of Texas at Dallas (United States); Na Li, The Univ. of Texas at Dallas (United States) and Nankai Univ. (China); Mônica J. Andrade, Shaoli Fang, Jiyoung Oh, The Univ. of Texas at Dallas (United States); Geoffrey M. Spinks, Univ. of Wollongong (Australia); Mikhail E. Kozlov, Carter S. Haines, Dongseok Suh, The Univ. of Texas at Dallas (United States); Javad Foroughi, Univ. of Wollongong (Australia); Seon-Jeong Kim, Hanyang Univ. (Korea, Republic of); Yongsheng Chen, Nankai Univ. (China); Taylor Ware, The Univ. of Texas at Dallas (United States); Min Kyoon Shin, Hanyang Univ. (Korea, Republic of); Leonardo D. Machado, Univ. Estadual de Campinas (Brazil); Alexandre F. Fonseca, Univ. Estadual de São Paulo (Brazil); John D. Madden, The Univ. of British Columbia (Canada); Walter E. Voit, The Univ. of Texas at Dallas (United States); Douglas S. Galvão, Univ. Estadual de Campinas (Brazil); Ray H. Baughman, The Univ. of Texas at Dallas (**Figure 3**), “High-performance electrolyte-free torsional and tensile carbon nanotube hybrid muscles”
- Paper 8687-4 - Toribio Fernández Otero, Jose G. Martinez, Univ. Politécnica de Cartagena (Spain), “Reactive actuators and sensors integrated in one device: mimicking brain-muscles feedback communication.
- Paper 8687-8 - Yonas T. Tadesse, The Univ. of Texas at Dallas, “Electroactive polymer and shape-memory alloy actuators in biomimetics and humanoids”.
- 8687-27 - Herbert R. Shea, Ecole Polytechnique Fédérale de Lausanne (Switzerland), “Fast, miniaturized, and manufacturable μm - to cm-scale dielectric elastomer actuators”
- 8687-46 - Kinji Asaka, Ken Mukai, Takushi Sugino, National Institute of Advanced Industrial Science and Technology (Japan); Hyacinthe Randriamahazaka, Univ. Paris 7 - Denis Diderot (France); Toribio Fernández Otero, Univ. Politécnica de Cartagena (Spain), “Electrochemistry of electromechanical actuators based on carbon nanotubes and ionic liquids”
- 8687-48 - Maurizio Bisio, Alberto Ansaldo, Davide Ricci, Istituto Italiano di Tecnologia (Italy), “Improving dry carbon nanotube actuators by chemical modifications, material hybridization, and proper engineering”
- 8687-64 – Elisabeth Smela, Deepa Sritharan, Univ. of Maryland, College Park, “Stable electroosmotically driven Nastic actuators”



Figure 3: Ray H. Baughman, the Univ. of Texas at Dallas, United States

On Sunday, March 10, 2013, a half-day course has been given overviewing the field of EAP covering the state of the art, challenges and potentials. The two groups of polymer materials will be described, namely those that involve ionic mechanisms (Ionic EAP), and field activated materials (Electronic EAP). The lead instructor is Yoseph Bar-Cohen, JPL, the topic of ionic EAP will be taught by Qibing Pei, professor of materials science and engineering, University of California, Los Angeles (UCLA) and the topic of ionic EAP materials will be covered by John D. W. Madden who is an Assistant Professor of Electrical & Computer Engineering at the University of British Columbia, Vancouver, Canada.

The EAP-in-Action Session was held on Monday, March 11, 2013. This Session provides a spotlight on EAP materials, their capability, and their potential for smart structures. New materials and applications are continuing to emerge and this is a great opportunity for the attendees to see state-of-the-art demonstrations of the unique capabilities of EAP as possible actuators-of-choice. This

Session offers a forum for interaction between developers and potential users as well as a "hands-on" experience with this emerging technology. It was during this session that the first Human/EAP-Robot Armwrestling Contest was held in 2005. 7 research and industry presenters from 4 countries demonstrated their latest EAP actuators and devices including the following:

Japan

"Smart Push Button with Shape Memory Gel" was presented by Hidemitsu Furukawa, Jin Gong, Soft and Wet Matter Engineering Laboratory (SWEL), Yamagata University, Japan (**Figure 4**). A smart push button that is designed using shape memory gel as a contact disc has been shown. This push button has the similar small size as a toy block, and its on/off switch can be smartly controlled by temperature.



Figure 4: Hidemitsu Furukawa and his team Soft and Wet Matter Engineering Laboratory (SWEL), Yamagata University, Japan, presented smart push button with shape memory gel.

New Zealand

"Dielectric elastomer (DE) technology for self-sensing, portable energy harvesting and product development" has been presented by Iain Anderson, Andrew Lo, and Daniel Xu, Biomimetics Laboratory, Auckland, New Zealand (**Figure 5**). Their demo included:

1. 8 channel capacitive sensing unit Multi-degree-of-freedom robots that could one day mimic the octopus that require multi-degree-of-freedom sensing. A device was demonstrated using the latest in-house developed sensing electronics to provide multi-degree-of-freedom sensing. This sensing unit can simultaneously capture the capacitance of 8 independent sensors.

2. A hand-held dielectric elastomer generator was presented that includes some new developments in artificial muscle portable energy harvesting.
3. A four channel Artificial Muscle Control Unit (www.biomimeticslab.com) was presented. This stand-alone portable lab instrument simplifies the generation and control of high voltages for artificial muscle research. It features include 4 independent output channels, computer control, battery operation, and safety features that make it suitable for bench-top use.
4. A Self-Sensing Unit that gets real-time sensory feedback from your artificial muscles was demonstrated. It characterizes new EAP materials and is being developed as a new product at the Biomimetics Lab.
5. A high voltage surprise was also demonstrated.

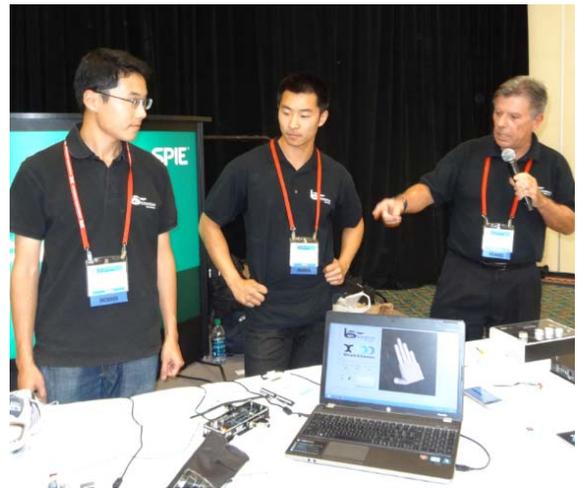


Figure 5: Ho Cheong (Andrew) Lo; Daniel Xu; and Iain Anderson, U. of Auckland, New Zealand

Switzerland

"High-speed silicone DEAs" has been presented by S. Rosset, L. Maffli, S. Akbari, J. Shintake, S. Araromi, A. Poulin, and H. Shea, EPFL, Switzerland (**Figure 6**). This presentation included dielectric elastomer actuators at the scales of μm - to cm. This capability became possible using silicone membranes and silicone-carbon electrodes that operate at speeds up to several kHz, limited by device resonance frequency. Applications range from soft robotics to tissue engineering.



Figure 6: J. Shintake, L. Maffli, H. Shea, and S. Rosset, EPFL, Switzerland (from left to right)

USA

- “ViviTouch Audio: Take the Power of Live Music Anywhere”, was presented by Roger Hitchcock, Director of Power Supply and Systems Engineering and Michael Lipton, Mechanical Engineer, ViviTouch, a Bayer MaterialScience Brand in Sunnyvale, California (**Figure 7**). This demo showcased how ViviTouch actuators are now applying EAP technology in a brand new way to the portable headphone category.



Figure 7: Roger Hitchcock, Director of Power Supply and Systems Engineering and Michael Lipton, Mechanical Engineer, ViviTouch, a Bayer MaterialScience Brand in Sunnyvale, California

- “Torsional and Tensile Carbon Nanotube Hybrid Yarn Muscles” will be presented by Marcio Lima, Na Li, Monica Jung de Andrade, Carter S. Haines, Ray H. Baughman, NanoTech Institute, University of Texas at Dallas (**Figure 8**).

Electrolyte-free carbon nanotube based artificial muscles have been designed to provide fast torsional and tensile actuation. As recently published in the journal Science [Lima et al, 2012], these muscles can spin a rotor at an average 11,500

revolutions/minute (20 times higher than previously demonstrated for an artificial muscle) and provide up to 27.9 kW/kg of mechanical power density during muscle contraction (85 times higher than for natural skeletal muscle). More than a million cycles of tensile and torsional actuation have been performed without a significant loss of performance. These actuators can operate from cryogenic temperatures to 2500°C.

Demonstrations include torsional rotors and contractile muscles exemplifying large stroke and high rate performance. Ref: M. D. Lima, N. Li, M. Jung de Andrade, S. Fang, J. Oh, G. M. Spinks, M. E. Kozlov, C. S. Haines, D. Suh, J. Foroughi, S. J. Kim, Y. Chen, T. Ware, M. K. Shin, L. D. Machado, A. F. Fonseca, J. D. W. Madden, W. E. Voit, D. S. Galvão, R. H. Baughman, “Electrically, Chemically, and Photonically Powered Torsional and Tensile Actuation of Hybrid Carbon Nanotube Yarn Muscles”, Science (2012)



Figure 8: Na Li, Marco Lima, and Monica De Andrade, UT of Dallas.

- “Bistable electroactive polymers (BSEP) and refreshable Braille display devices”, will be presented by Xiaofan Niu, Xinguo Yang, Paul Brochu, Hristiyan Stoyanov, Sungryul Yun, Zhibin Yu, and Qibing Pei, Department of Materials Science and Engineering, University of California, Los Angeles (**Figure 9**). A new bistable electroactive polymer has been developed via a prestrain-free synthesis. The actuation stability has been significantly improved. High-performance bistable electroactive polymer actuators and a refreshable Braille display device will be demonstrated.



Figure 9: Wei (Maggie) Hu, Qibing Pei, and David McCoul, UCLA (from left to right).

- “Electrically Driven Mechanochemical Actuators” was demonstrated by Lenore Rasmussen, Ras Labs, LLC, Picatinny Arsenal, NJ (**Figure 10**). The demo uses carbon infused contractile EAP and was made to an electrically driven mechano-chemical actuators. Driven by 50 V or less, the demonstrated actuator was shown to rotational in push-pull motions with minimal generation of heat or noise.



Figure 10: Lenore Rasmussen, Ras Labs, LLC, Picatinny Arsenal, NJ.

EuroEAP 2013 conference

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EuroEAP 2013, the 3rd international conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles was held in Zurich,

Switzerland, on June 25-26, 2013 (www.euroeap.eu/conference). The conference has been chaired by Gabor Kovacs, from the EMPA, and was organized by the European Scientific Network for Artificial Muscles (ESNAM) (www.esnam.eu). The conference was open to participants from any country worldwide. Following the consolidated scheme adopted in the previous Conference, each speaker was deliver a short oral presentation followed by a poster presentation.

The invited speakers in the EuroEAP 2013 were: Ilkwon Oh (Korea Advanced Institute of Science and Technology), Kwang Kim (University of Nevada, Las Vegas, USA), H. Okuzaki (University of Yamanashi, Takeda, Japan), Richard Spontak (North Carolina State University, USA), Florian Habrard (Empa), Xiaofan Niu (UCLA, USA), Christoph Keplinger (Harvard University, USA) and Adrian Koh (National University of Singapore, Singapore).

ADVANCES IN EAP

Aerospace Engineering-Propulsion

DEA Compressor: Response Time

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Response time has been the most important challenge that has been faced by the author since he started to design and model novel DEA compressor [1]. As the compressor is designed to serve in gas turbine engines, it needs to provide a steady airflow. It means a frequency of inflation/depletion about 50 Hz or more is needed.

With regard to this fact that most of the studies have been focused on DEA potentials as artificial muscles, their response time to electric field has not been a crucial factor to study. As a result, the author had to find a reliable data to draw out this specification such that it can be used in computer modeling. Reference [2] has provided good measurements for this important factor that can be considered in this study. Additionally, more recent studies like [3] have presented a formula to measure this factor (see **Figure 11**).

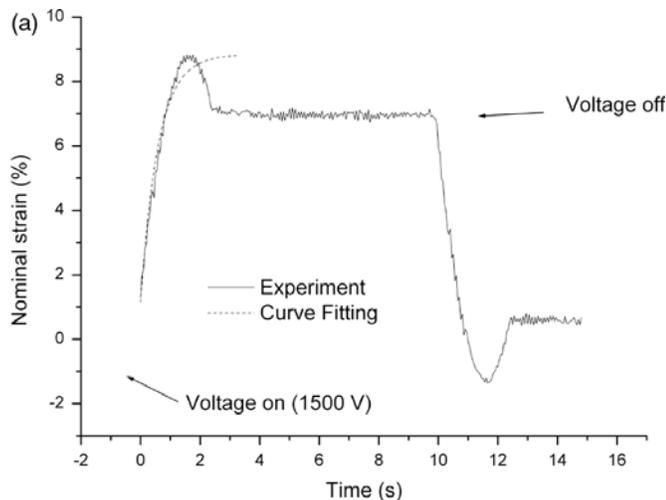


Figure 11: time response for silicone DC 3481 (see [3])

Moreover, modeling this compressor by ANSYS needs a good knowledge about different functions of this huge software. The standard package provided by ANSYS that has capability to model dielectric elastomer actuators is Multiphysics. However, to reach intended performance, one needs to find the best way to define particular part and specification, and then it is another challenge in this project.

Currently, response time is being formulated and is being used in ANSYS code base file and is modeled to determine the parts acceptably, so that deformation after/before applying electric field can be simulated, and the needed data would be available for analysis.

References

1. Babak Aryana, "Implementing DEA to create a novel type of compressor", *Materials Science and Engineering C* 30 (2010) 42–49
2. R. Kornbluh, R. Pelrine, Q. Pei, S. Oh, J. Josef, in: Y. Bar-Cohen (Ed.), *Electroactive polymer actuators and device*, Proc. SPIE, 3987, 2000, p. 51.
3. SilvainMichel, Xuequn Q Zhang, Michael Wissler, Christiane Lowe, Gabor Kovacs, "A comparison between silicone and acrylic elastomers as dielectric materials in electroactive polymer actuators", in Wiley Interscience: 18 December 2009.

Bayer's ViviTouch®

Major headphone brands announce EAP based headphones at E3 tradeshow

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During this year's E3 expo in Los Angeles, California, two headphone brands announced new headphone models using ViviTouch® 4D Sound technology, developed by Bayer. ViviTouch® 4D Sound changes how you hear, not what you hear, producing rich, full-bodied sound that you can actually feel, just like you were experiencing live. Able Planet (ableplanet.com), expert in Audiology and Speech Languages Sciences, will initially develop a line of gaming and home theater headphones, as well as, communication and hearing health devices. Mad Catz® (madcatz.com), a global provider of innovative interactive entertainment products, announced the F.R.E.Q. 4D Gaming Headset for Windows® PC and Smart Devices. Both brands will be launching headphones by the end of this year.

Duke University

Bioinspired Surface with Dynamic Topography for Active Control of Biofouling

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Biofouling, the accumulation of biomolecules, cells, organisms, and their deposits on submerged and implanted surfaces, is a ubiquitous problem across many human endeavors including maritime operations, medicine, food industries, and biotechnology. Existing technologies for preventing and controlling biofouling are generally based on passive surfaces, which do not deform during applications. On the other hand, an enormous number of biological surfaces clean themselves through active deformation and motion. For example, cilia on the surfaces of respiratory tracts constantly sweep out inhaled foreign particles.

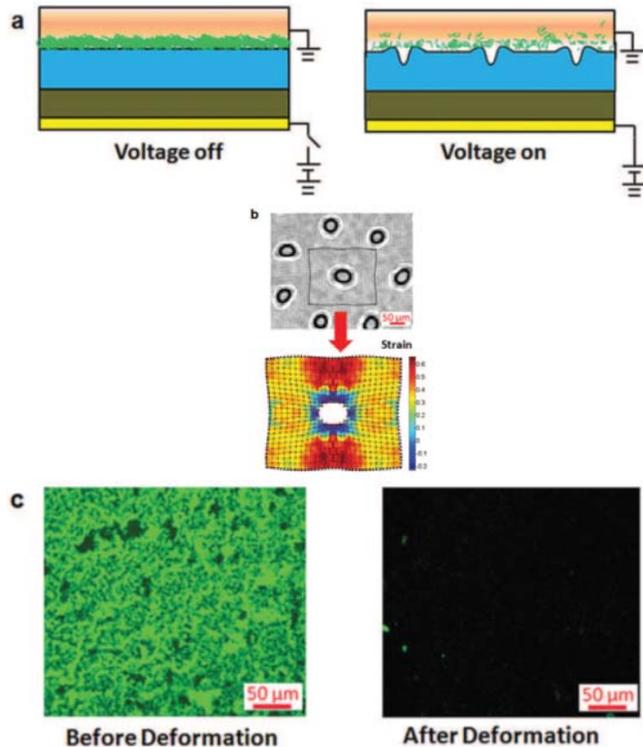


Figure 12: Detachment of bacterial biofilms from dielectric elastomers under voltages. a) Schematic illustration of the laminate structure, actuation mechanism, and the detachment of a bacterial biofilm. b) The applied electric field can induce significant deformation of the elastomer surface as given by the contours of the maximum principal strain. c) The deformation detaches over 95% of a biofilm (*Cobetia Marina*) adhered to the elastomer surface, which is periodically actuated for 200 cycles within 10 minutes.

Inspired by the active biological surfaces found in nature, we at the Soft Active Materials Laboratory, Department of Mechanical Engineering and Materials Science, Duke University, Durham, are developing a dynamic surface based on dielectric elastomers that can actively deform and change its topology in response to applied voltages. We are adhering a layer of a dielectric elastomer on a rigid polymer substrate (**Figure 12a**). Once a voltage

is applied on a metal electrode beneath the substrate, patterns of creases and craters can develop on the surface of the dielectric elastomer (**Figure 12b**) [1, 2]. The deformation and topology variation of the surface can actively detach various types of biofouling adhered on the surface of the dielectric elastomer (**Figure 12c**) [3]. The bioinspired dynamic surface potentially provides a low-cost high-efficiency strategy for biofouling management; and a new application for dielectric elastomers as well.

Reference

1. Qiming Wang, Lin Zhang, Xuanhe Zhao, Creasing to Cratering instability in polymers under ultrahigh electric fields, *Physical Review Letters*, 106, 118301 (2011).
2. Qiming Wang, Mukarram Tahir, Jianfeng Zang, and Xuanhe Zhao, Dynamic Electrostatic Lithography: Multiscale On-demand Patterning on Large-Area Curved Surfaces, *Advanced Materials*, 24, 1947–1951 (2012)
3. Phanindhar Shivapooja, Qiming Wang, Beatriz Orihuela, Daniel Rittschof, Gabriel P. López, Xuanhe Zhao, Bioinspired Surfaces with Dynamic Topography for Active Control of Biofouling, *Advanced Materials*, 25, 1430 (2013)

Johannes Kepler University Linz, Austria Stretch dependence of the electrical breakdown strength and dielectric constant of dielectric elastomers

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Richard Baumgartner, Andreas Tröls

The performance of dielectric elastomer devices is limited by failure mechanisms such as material rupture, loss of tension, electromechanical instability and electrical breakdown. Dielectric breakdown is the ultimate failure mode of any dielectric material - for soft materials the

measurement of the breakdown strength is still challenging. Reported values differ significantly, most likely caused by different experimental conditions employed for breakdown measurements. In a contribution to the international journal "Smart Materials and Structures" [1] we report two experimental configurations for the measurement of the stretch dependence of the electrical breakdown strength of dielectric elastomers (**Figure 13**), and compare the electrical breakdown field for compliant and rigid electrodes on the elastomer. The investigated materials are the acrylic elastomer VHB 4910TM from 3MTM, and the natural rubber (NR) ZruElastTM A1040TM from ZRUNEK rubber technology.

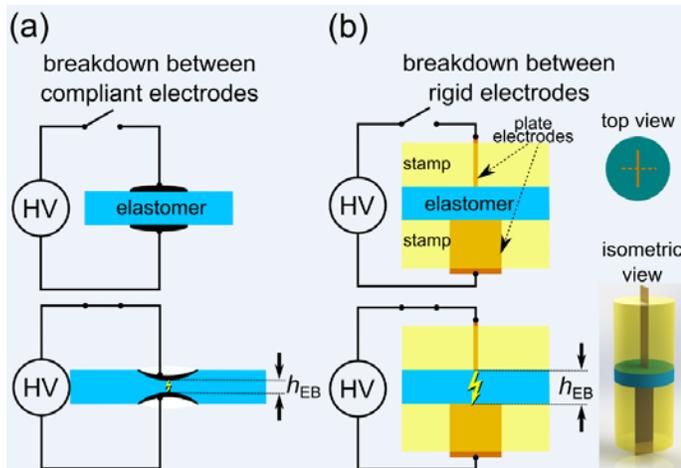


Figure 13: a) Experimental set-up for breakdown measurements with compliant electrodes. (b) Experimental set-up with a mechanically clamped elastomer membrane. The elastomer is clamped between two stamp electrodes, which are arranged perpendicular to each other (top and isometric view). The mechanical clamping between the stamps prevents the elastomer from deforming electromechanically under high voltage.

In the set-up shown in **Figure 13a** compliant electrodes are used. When a voltage is applied in such a configuration the elastomer thins down and in consequence the electric field increases. This positive feedback may cause electromechanical instability and finally breakdown at a thickness h_{EB} , known as Stark Garton breakdown mechanism in literature. In order to suppress the actuation of the

elastomer during the breakdown measurement, we clamp the elastomer between two stamp electrodes, as shown in **Figure 13b**.

Figure 14 shows the comparison of the dielectric strength of NR and VHB. It is observed that the electrode configuration strongly influences the electrical breakdown field strength. The dielectric strength of NR is higher than that of VHB.

The breakdown fields E_{EB} obtained with compliant electrodes (red circles) are lower than those with rigid electrodes in clamped conditions (grey triangles). At high stretch levels the increased stiffness of the elastomer suppresses actuation; the values converge for both electrode configurations. We believe that the breakdown strength measured with rigid electrodes under clamped conditions is close to the material limit, while the lower values with compliant electrodes may be caused by the Stark Garton electromechanical instability breakdown mechanism.

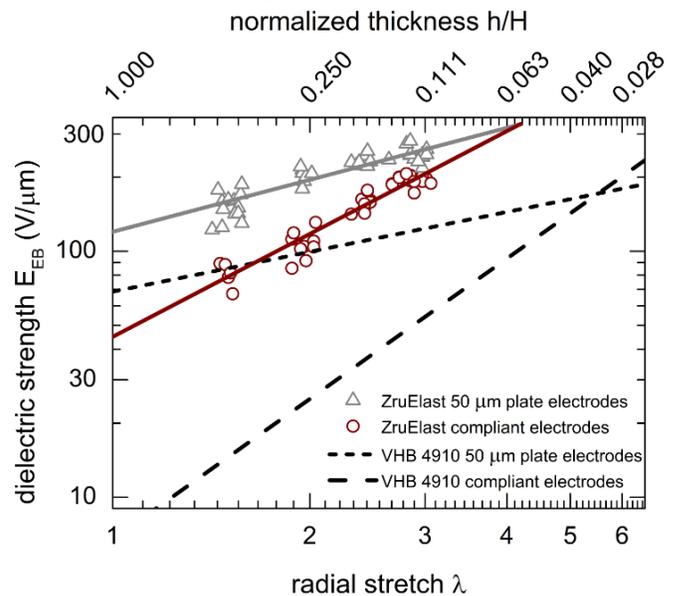


Figure 14: Experimental values for the dielectric strength E_{EB} of natural rubber ZruElastTM A1040TM using compliant and rigid electrode configurations compared to VHB.

Further we compare the stretch dependent dielectric function of the two materials. While the dielectric permittivity of VHB decreases with increasing stretch ratio, the dielectric constant of rubber is insensitive to stretch.

Reference

[1] A. Tröls et al, Smart Mater. Struct. (2013), "Stretch dependence of the electrical breakdown strength and dielectric constant of dielectric elastomers" accepted for publication

University in Prague, Czech Republic, Artificial Bio-inspired Muscle

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Mammalian skeletal muscles are highly optimized systems evolved over more than 600 million years. Depicted motoric element of both natural and artificial muscle cell include the actin A1, A2, and myosin M and N filaments. Movement of the Z plates and the contraction at the bottom of **Figure 15** requires the nanometric heads H to change their angle (tilt) and drag the M and A filaments past one another. Energy is needed for the tilt, which is provided in biological muscle by complex bio-chemical reactions. Artificial skeletal muscle uses a similar structure but the hypothetical primary physical mechanism substitutes for bio-chemical reaction. The tilting of the heads of the artificial muscle results from the simple local conversion of electrostatic repulsion between the negatively charged heads into their attraction by van der Waals forces. The conversion is induced by the transport of positive calcium ions from Z plates along actin filaments to the middle of the motoric element controlled simply by electrical field. The simple physical mechanism enables engineers to bypass the complex bio-chemical reactions.

The principle has been patented in the Russian Federation (2010 Euroasian patent 013443 B1) and in USA (2011 Patent US 7,994,685 B2 Electromechanical Transducer – Artificial Muscle). Large compound systems with high performance can be built from nanomaterials and/or from electro-active polymers using the modular design from the nanometric motoric elements. Medicine can use such actuators for active implants with a low driving voltage comparable to the biological action potentials. The coming nano-electro-mechanical systems (NEMS) can use them.

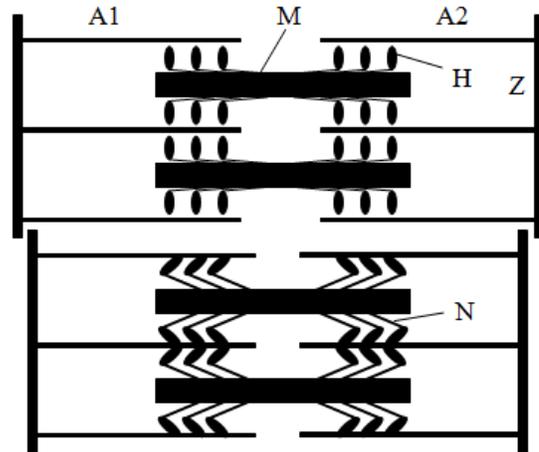


Figure 15: Depicted motoric element of both natural and artificial muscle cell.

BIOMIMETICS BOOKS

Architecture Follows Nature

Architecture Follows Nature - Biomimetic Principles for Innovative Design

Authored by *Ilaria Mazzoleni* www.imstudio.us
info@imstudio.us in collaboration with Shauna

Price

<http://www.crcpress.com/product/isbn/9781466506077>



The book entitled "Architecture Follows Nature - Biomimetic Principles for Innovative Design" has been published by CRC Press as part of the book series on Biomimetics for which Y. Bar-Cohen is the editor. The homepage of this book series is: http://www.crcpress.com/browse/series/?series_id=2719

This book explores the properties of animal skins as related to the inspiration of architectural envelopes. Mazzoleni proposes that bio-influenced

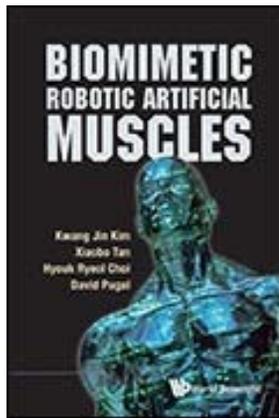
design instill a shift in the way architecture, and design at large, is applied and conceived. Emphasized are the strategies developed by organisms as adaptation to different environments and how they may translate to principles of the built world. To illustrate the methodology, Ilaria Mazzoleni, in collaboration with biologist Shauna Price, draws inspiration from the diversity of animal coverings, referred to broadly as skin, and applies them to the design of building envelopes through a series of twelve case studies. Skin, a complex organ that performs a multitude of functions, namely serves as a link between the body and the environment. Similarly, building envelopes act as interfaces between their inhabitants and external elements.

The book's 264 color pages focus on the opportunity for novel ways to physically and conceptually relate to the environment. Accordingly, it holds an appeal and relevance to biologists, environmentalists, engineers, and designers alike.

Biometric Robotic Artificial Muscles

Authored by Kwang Kim, Xiaobo Tan, Hyouk Ryeol Choi, and David Pugal Kwang.Kim@unlv.edu

A new book entitled "Biometric Robotic Artificial Muscles", ISBN: 978-981-4390-35-4 (hardcover) and ISBN: 978-981-4397-49-0 (ebook), has just been released by World Scientific. It presents a comprehensive up-to-date overview of several types of electroactive materials with a view of using them as biomimetic artificial muscles. The book was coauthored by Kwang Kim (University of Nevada, Las Vegas), Xiaobo Tan (Michigan State University), Hyouk Ryeol Choi (Sungkyunkwan University), and David Pugal (University of Nevada, Reno).



Engineered Biomimicry

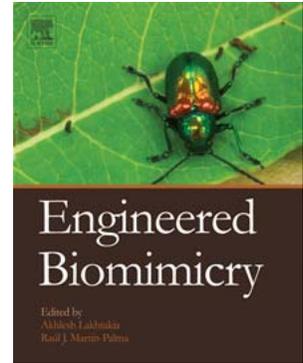
Edited by Akhlesh Lakhtakia axl4@psu.edu and Raúl J. Martín-Palma rauljose.martin@uam.es

On June 5, Elsevier has published the book entitled "Engineered Biomimicry"

ISBN 9780124159952.

The book was written for applied physicists, biophysicists, engineers, bioengineers, and material scientists. The 17

chapters of this book address a slew of topics in the areas of bioinspiration, biomimetics, and bioreplication. Readers will learn to take ideas and concepts from nature, implement them in research, and understand and explain diverse phenomena and functionalities. From bioinspired computing and medical products to biomimetic applications like artificial muscles, MEMS, textiles and vision sensors, the authors explore a wide range of technologies informed by living natural systems.



| Date | Conference/Symposium |
|-------------------------|---|
| July 10 to 12, 2013 | The 4th International Conference on Smart Materials and Nanotechnology in Engineering (SMN) will be held at Gold Coast, Australia. The conference is chaired by Jinsong Leng, Harbin Instituted of Technology, China; and Jayantha A Epaarachchi, University of Southern Queensland, Australia. Information is available at http://www.a-tech.hk/SMN%202013/index.html |
| July 29 to Aug. 2, 2013 | Living Machine 2013, The 2nd International Conference on Biomimetic and Biohybrid Systems, Natural History Museum, London http://csnetwork.eu/livingmachines/conf2013 c/o Gill Ryder, living-machines@sheffield.ac.uk |
| August 26-30, 2013 | The 7th World Congress on Biomimetics, Artificial Muscles and Nano-Bio (BAMN2013) will be held at Jeju Island, South Korea. Information about it is available at http://www.n7w.com . |
| March 9 | 15th EAPAD Conf., SPIE's Smart |

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|----------------|--|
| -13, 2014 | Structures & Materials and NDE Symposia, San Diego, CA., For information contact: Megan Artz megana@spie.org , Website: http://spie.org/app/program/index.cfm?fuseaction=conferencedetail&export_id=x12536&ID=x12233&redir=x12233.xml&conference_id=2028135&event_id=2027121 |
| May 12-15 2014 | IUTAM Symposium on Mechanics of Soft Active Materials (code GA12-13). Chair: Konstantin Volokh, Technion - Israel Institute of Technology. For further information contact cvolokh@technion.ac.il |

EAP ARCHIVES

Information archives and links to various websites worldwide are available on the following (the web addresses below need to be used with no blanks):

Webhub: <http://eap.jpl.nasa.gov>

Newsletter: <http://ndea.jpl.nasa.gov/nasa-nde/lommas/eap/WW-EAP-Newsletter.html>

Recipe: <http://ndea.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-recipe.htm>

EAP Companies: <http://ndea.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-material-n-products.htm>

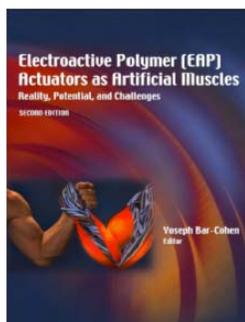
Armresting Challenge:
<http://ndea.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-armresting.htm>

Books and Proceedings:
<http://ndea.jpl.nasa.gov/nasa-nde/yosi/yosi-books.htm>

2nd Edition of the book on EAP

Y. Bar-Cohen (Editor)

In March 2004, the 2nd edition of the “Electroactive Polymer (EAP) Actuators as Artificial Muscles - Reality, Potential and Challenges” was published. This book includes description of the available materials, analytical models, processing techniques, and characterization methods. This book is intent to provide a reference about the subject, tutorial resource, list the



challenges and define a vision for the future direction of this field. Observing the progress that was reported in this field is quite heartwarming, where major milestones are continually being reported.

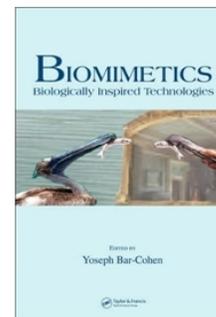
Biomimetics - Biologically Inspired Technologies

Y. Bar-Cohen (Editor)

<http://ndea.jpl.nasa.gov/nasa-nde/yosi/yosi-books.htm>

This book about Biomimetics review technologies that were inspired by nature and outlook for potential development in biomimetics in the future. This book is intended as a reference comprehensive document, tutorial resource, and set challenges and vision for the future direction of this field. Leading experts (co)authored the 20 chapters of this book and the outline can be seen on

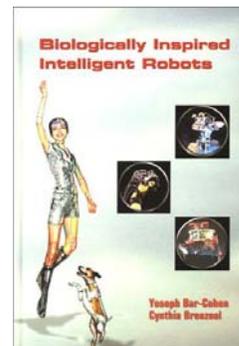
<http://ndea.jpl.nasa.gov/ndea-pub/Biomimetics/Biologically-Inspired-Technology.pdf>



Biologically Inspired Intelligent Robots

Y. Bar-Cohen and C. Breazeal (Editors)

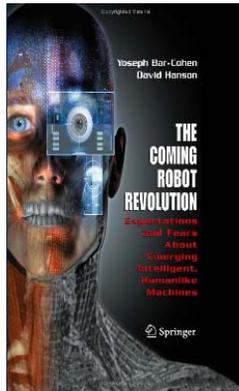
The book that is entitled “Biologically-Inspired Intelligent Robots,” covering the topic of biomimetic robots, was published by SPIE Press in May 2003. There is already extensive heritage of making robots and toys that look and operate similar to human, animals and insects. The emergence of artificial muscles is expected to make such a possibility a closer engineering reality. The topics that are involved with the development of such biomimetic robots are multidisciplinary and they are covered in this book. These topics include: materials, actuators, sensors, structures, control, functionality, intelligence and autonomy.



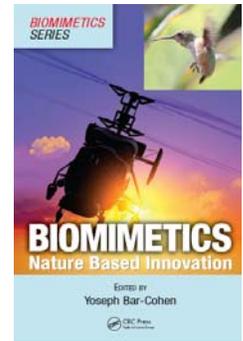
The Coming Robot Revolution - Expectations and Fears about Emerging Intelligent, Humanlike Machines

Yoseph, Bar-Cohen and David Hanson (with futuristic illustrations by Adi Marom), Springer, ISBN: 978-0-387-85348-2, (February 2009)

This book covers the emerging humanlike robots. Generally, in the last few years, there have been enormous advances in robot technology to which EAP can help greatly in making operate more lifelike. Increasingly, humanlike robots are developed for a wide variety of applications. These “smart” lifelike robots are designed to help with household chores, as office workers, to perform tasks in dangerous environments, and to assist in schools and hospitals. In other words, humanlike robots are coming and they may fundamentally change the way we live, even the way we view ourselves.



interdisciplinary education Enhancing Innovation Through Biologically-Inspired Design; Self-reproducing machines and manufacturing processes; Biomimetic products; Biomimetics for medical implants; Application of biomimetics in the design of medical devices; Affective Robotics: Human Motion and Behavioral Inspiration for Safe Cooperation between Humans and Humanoid Assistive Robots; Humanlike robots - capabilities, potentials and challenges; Biomimetic swimmer inspired by the manta ray; Biomimetics and flying technology; The Biomimetic Process in Artistic Creation; and Biomimetics - Reality, Challenges, and Outlook.



Further information is available at: <http://www.crcpress.com/product/isbn/9781439834763>

Biomimetics – Nature Inspired Innovation

Yoseph Bar-Cohen (Editor)

This book contains 20 chapters covering various aspects of the field of biomimetics including Nature as a source for inspiration of innovation; Artificial Senses & Organs; Bio-mimicry at the Cell-Materials Interface; Multiscale modeling of plant cell wall architecture and tissue mechanics for biomimetic applications; Biomimetic composites; EAP actuators as artificial muscles; Refreshable Braille Displays Actuated by EAP; Biological Optics; Biomimicry of the Ultimate Optical Device: Biologically Inspired Design: a tool for



WorldWide Electroactive Polymers (EAP) Newsletter

EDITOR: Yoseph Bar-Cohen, <http://ndea.jpl.nasa.gov/nasa-nde/yosi/yosi.htm>

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