WorldWide ElectroActive Polymers

EAP

(Artificial Muscles) Newsletter

Vol. 13, No. 2 (26th issue) **WW-EAP Newsletter** **December 2011**
http://eap.jpl.nasa.gov

FROM THE EDITOR

Yoseph Bar-Cohen, *yosi@jpl.nasa.gov*
There is increasing number of conferences about biomimetics that are including sessions on the topic of EAP materials. Besides the SPIE's EAPAD Conference that is reaching its 14th year in March 2012, we had for example the recent ASME Congress that included the Biomimetic and Bioinspired Technologies Conference (Topic 7-3), which was held in Denver, CO, from Nov. 14-16, 2011. Also, the 3rd International Conference on Smart Materials and Nanotechnology in Engineering, which was held in Shenzhen, China, which was held Dec. 5-8, 2011. Further details are described in this issue.

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

LIST OF CONTENTS

About the experts

Chunye Xu is now at USTC, China

Chunye Xu is now a Full Professor at the University of Science and Technology (USTC), Hefei, China. Before joining this affiliation, Chunye was a Research Associate Professor at the Center for Intelligent Materials and Systems, Dept. of Mechanical Engineering, University of Washington, Seattle, WA. Chunye has kept an Affiliate Faculty position at the University of Washington. Her research is focused on EAP materials, especially electro-chromic polymers. She has developed various related devices including smart windows, actuators, sensors and self-powered electro-chromic systems Her new. e-mail address is chunye@ustc.edu.cn

Chunye Xu, USTC, China

Tian Bing Xu is IDTechEx award recipient

Tian Bing Xu, NIA

On November 15, Tian Bing Xu, NIA, became the recipient of an IDTechEx award for developing a highly efficient energy harvester. The harvester is based on a hybrid piezoelectric energy harvesting transducer (HYPEHT) invention that was developed by researchers from NIA (Tian Bing Xu), the Advanced Materials & Processing Branch of NASA LaRC (Mia Siochi, Ji Su), North Carolina State University (Xiaoning Jiang), Stony Brook University (Lei Zuo and Wanlu Zhou) and TRS Technologies (Paul Rehrig and Welsey Hackenberge) with support from NASA LaRC.

The HYPEHT is a device that utilizes force-amplification of two types of piezoelectric multilayer elements that couple more mechanical energy, produce more electrical charge, and to yield enhanced energy conversion efficiency. Their tests have shown that the HYPEHT yields 19 times more electrical energy output than an equivalent 31-mode flextensional transducer as well as 2 to 3 orders of magnitude more than an analogous bimorph or sandwich piezoelectric beam. The device has 26% conversion efficiency from mechanical to electrical energy, which is more than 5 times greater than the state-of-the-art piezoelectric transducers.

The HYPEHT can be used with various types of piezoelectric materials including piezoelectric ceramics and polymeric materials. The current experimental verification was based on a PZT ceramic material. However, the developers' theoretical study demonstrated that electroactive polymer-based HYPEHTs have the same advantages as piezoelectric ceramic HYPEHTs [US Patent: 7,394,181 developed in 2005 by Ji Su and Tian-Bing Xu].

Ji Su, NASA LARC

UPCOMING CONFERENCES

2012 EuroEAP Conference

Over the last few years, the field of EAP transducers & artificial muscles has undergone an enormous expansion in basic research, industrial development and commercial exploitation. This expansion has stimulated in Europe the creation of the 'European Scientific Network for Artificial Muscles' (ESNAM), established as a COST Action (www.esnam.eu). The network gathers the most active European research institutes, industrial developers and end users in the EAP field. In an effort to disseminate current advances in this emerging field of science and technology, gathering experts from all over the world, the network organises and supports the EuroEAP conference. The 2nd Intl. Conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles is going to be held at Potsdam, Germany, 29–30 May 2012. This event is a forum for international experts and professionals seeking scientific quality, industrial impact and opportunities of cooperation.
Further information and details at www.euroeap.eu.

2012 SPIE EAPAD Conference

The 14th SPIE's EAPAD conference is going to be held in San Diego, California from March 11 to 15, 2012,. The Chair of this Conference is Yoseph Bar-Cohen, JPL, and the Co-chair Keiichi Kaneto, Kyushu Institute of Technology, Japan. The

Conference Program Committee consists of representatives from 26 countries.

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, methods of processing and characterization of the properties and performance as well as various applications.

A Special Session is being dedicated to the subject of "EAP Actuated Medical and Tactile Devices" and the Session is chaired by John David W. Madden, The Univ. of British Columbia, Canada; and Yahya A. Ismail, University of Nizwa, Sultanate of Oman.

The conference will have two Keynote speakers as follows:

- Jeff Corsiglia, Vice President of Spin Master (http://www.spinmaster.com/), will talk about actuation of toys and potential applications for artificial muscles.
- John Rogers, who is the Lee J. Flory-Founder Chair in Engineering and a Professor at University of Illinois at Urbana/Champaign, will talk about stretchable electronics through soft lithography.

The invited papers are going to be:

Paper 8340-4: “Multi-functional soft smart materials and their applications,” Jinsong Leng, Harbin Institute of Technology (China)

Paper 8340-5: “Actuators, biomedicine, and cell biology,” Edwin W. H. Jager, Linköping Univ. (Sweden)

Paper 8340-16: “Applications of scanned pipette techniques for the highly localized electrochemical fabrication and characterization of conducting polymers,” Jadranka Travas-Sejdic, The Univ. of Auckland (New Zealand)

Paper 8340-17: “Patterning process and actuation in open air of micro-beam actuator based on conducting IPNs,” Cedric Plesse, Univ. de Cergy-Pontoise (France); Alexandre Khaldi, Univ. de Valenciennes et du Hainaut-Cambrésis (France); Ali Maziz, Univ. de Cergy-Pontoise (France); Caroline Soyer, Univ. de Valenciennes et du Hainaut-Cambrésis (France); Claude Chevrot, Dominique Teyssie, Frederic Vidal, Univ. de Cergy-Pontoise (France); Eric Cattan, Univ. de Valenciennes et du Hainaut-Cambrésis (France)

Paper 8340-28: “Giant torsional actuation from carbon nanotube yarns,” Javad Foroughi, Geoffrey M. Spinks, Gordon Wallace, Univ. of Wollongong (Australia); Jiyoung Oh, Mikhail E. Kozlov, Shaoli Fang, The Univ. of Texas at Dallas (United States); John D. Madden, Univ. of British Columbia (Canada); Tissaphern Mirfakhrai, Stanford Univ. (United States); Min Kyoon Shin, Seon Jeong Kim, Hanyang Univ. (Korea, Republic of); Ray H. Baughman, The Univ. of Texas at Dallas (United States)

Paper 8340-29: “Ionic EAP transducers with amorphous nanoporous carbon electrodes,” Friedrich Kaasik, Janno Torop, Inga Põldsalu, Indrek Must, Alvo Aabloo, Univ. of Tartu (Estonia)

Paper 8340-36: “Compliant electrodes for large strain actuation,” Sungryul Yun, Qibing Pei, Univ. of California, Los Angeles (United States)

Paper 8340-49: “Electroactive polymer based force sensor for robotic fingertip tactile sensing,” Baek-chul Kim, Hogyun Won, Y. Lee, Jae-Do Nam, Hyungpil Moon, Hyouk Ryeol Choi, Ja Choon Koo, Sungkyunkwan Univ. (Korea, Republic of)

Paper 8340-53: “Macro-, micro-, and nano-actuators based on liquid crystal elastomers: a bottom-up molecular design,” Patrick Keller, Min-Hui Li, Institute Curie (France)

On Sunday, March 11, 2012, a course is going to be 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. For further information see http://spie.org/x12234.xml

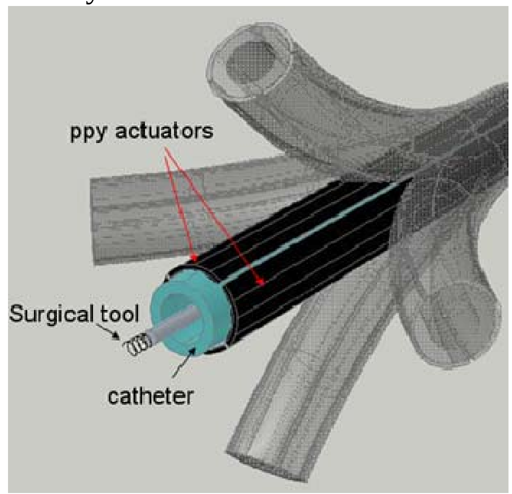
The EAP-in-Action Session will be held on Monday, March 12, 2012. This Session provides a spotlight on EAP materials, their capability, and their potential for smart structures. New materials and applications are continuing to emerge and this is a great opportunity for the attendees to see state-of-the-art 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 he first Human/EAP-Robot Armwrestling Contest was held in 2005. We are going to have 7 research and industry presenters from 5 countries demonstrating their latest EAP actuators and devices including the following:

Australia and Canada

1. John D.W. Madden (University of British Columbia) and Geoffrey M. Spunks (University of Wollongong) will present "**Carbon Nanotube Torsional Muscles"**

This demo will consist of a rapid rotation of a plastic paddle in air driven by carbon nanotube yarn. The torsional muscle operates with part of the yarn immersed in a liquid electrolyte that is electrochemically charged by application of a small voltage. The charging of the yarn causes the yarn to partially untwist and produce rotation of the attached paddle. Discharging the yarn causes it to re-twist. The demonstration will illustrate the very rapid and large rotations achievable in these simple actuator systems.

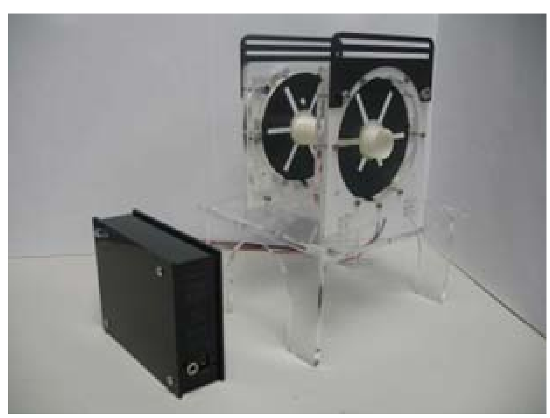
2, U.N. Rana, K. Lee, T. Shoa, S. Nafici, **G.M. Spinks**, V.X.D. Yang and **J.D.W. Madden will present a "Steerable Catheter**". A catheter is coated with polypyrrole, and patterned to enable tip deflection. This catheter is intended to enable navigation and imaging within the neuro-vascular system.



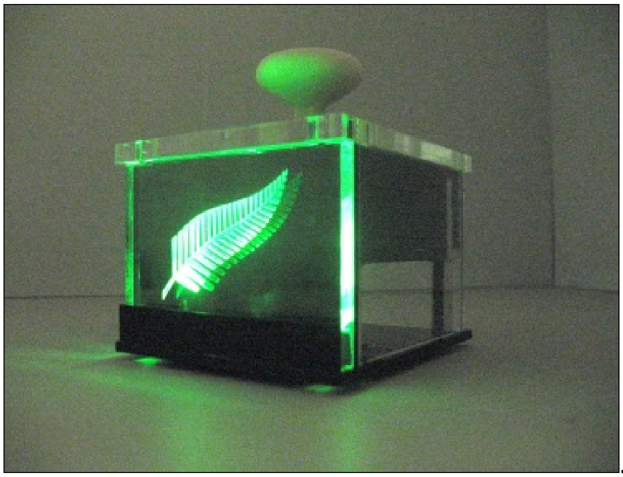
New Zealand

3. **Iain Anderson**, Emilio Calius, Todd Gisby, Andrew Lo, Thomas McKay, Ben O'Brien Biomimetics Laboratory, Auckland Bioengineering Institute, Auckland, New Zealand, will present **Dielectric elastomer (DE) technology** for self-sensing, portable energy harvesting and product development. This showcase will include the following demonstrations.

a. Cyber-proprioception and cyber-pain: Like natural muscles, DE-based artificial muscles can now provide in real time both positional feedback (cyber-proprioception) and condition-monitoring information (cyber-pain). These capabilities, essential for the control and performance of soft machines, will be demonstrated using the lab's Self-Sensing Unit coupled to a DE actuator.



b. A hand-held dielectric elastomer generator: DE can be used to extract useful low voltage power from human movement. This will be demonstrated using a device that can be held in one hand

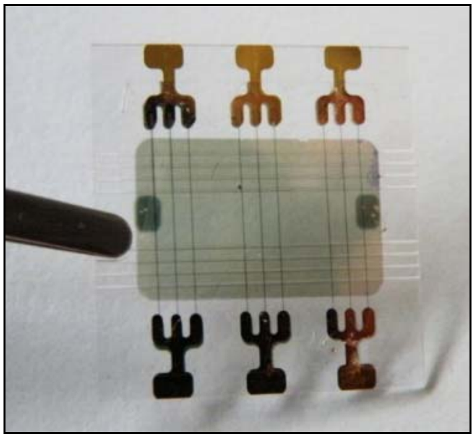


.

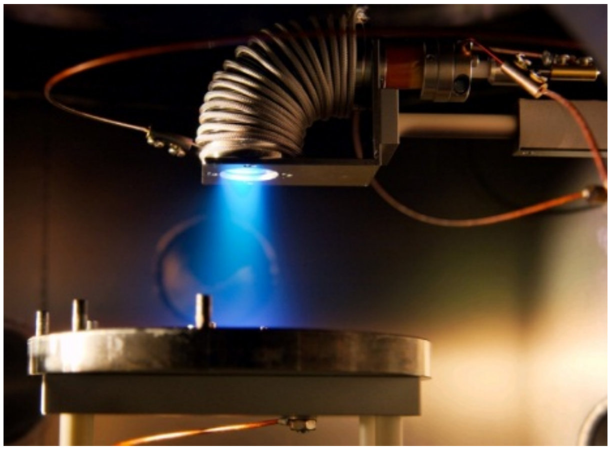
c. The four channel Artificial Muscle Control Unit: This stand-alone portable laboratory instrument simplifies the generation and control of high voltages for artificial muscle research. Features include 4 independent output channels, computer control, battery operation, and safety features that make it suitable for bench-top use.

Switzerland

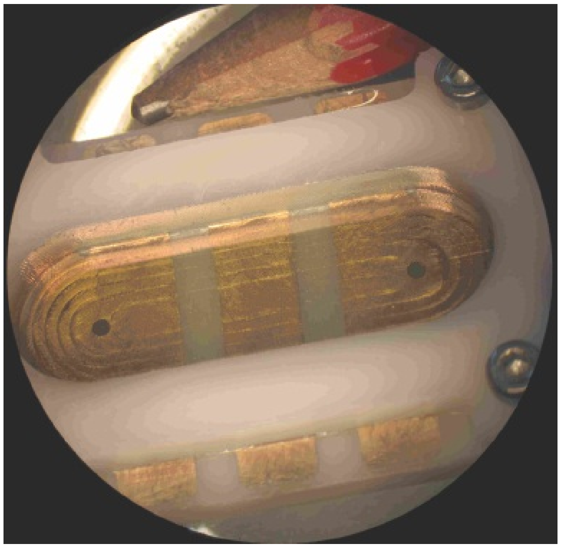
4. S. Rosset, L. Maffli, S. Akbari, B. O'Brien, **Herbert R. Shea,** EPFL-LMTS, Switzerland, "**Miniaturized EAPs based on Ion-implanted compliant electrodes: mm-size pumps, motors, and robots**," Several miniaturized dielectric elastomer devices will be demonstrated. By using metal ion-implantation compliant electrodes can be made with features as small as 50 µm. The developed devices will include micropumps, rolling robots, rotary motors, and cell-stretchers.



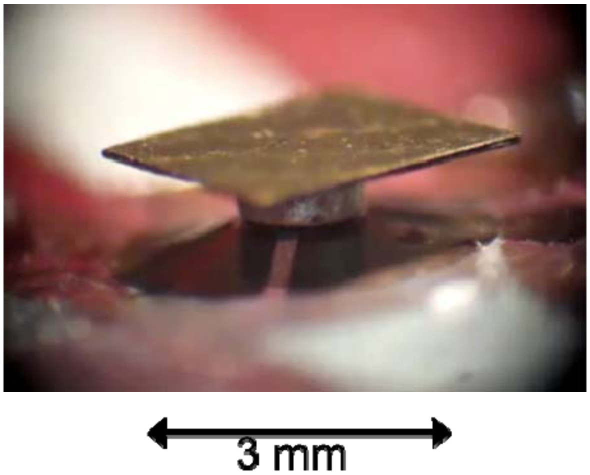
Array of 72 devices on a 2x2 cm2 chips



Inside the ion implanter



Zipping peristaltic pump



2-axis tilting mirror

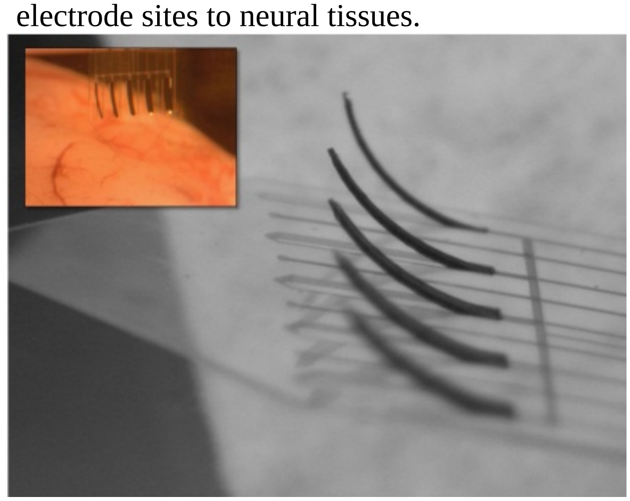
USA

5. **Marcus Rosenthal,** and Andy Cheng, Artificial Muscle, Inc., a Bayer MaterialScience Company, California, "'**Feel the game' with ViviTouch™ Technology".** This demo will include the latest ViviTouch haptic actuators integrated into consumer products for "high definition feel" in Mobile and Gaming applications.

6. Xiaofan Niu, Paul Brochu, Sungryul Yun, Zhibin Yu, Qibing Pei, UCLA, "**Improved bistable electroactive polymers (BSEP) and refreshable Braille display devices,"** This demo is bistable EAP actuators with significantly improved actuation performance, and refreshable Braille display device consisting of 1 to 4x10 cells.

Braille screen fabricated on a plastic sheet.

7. **Eugene Dariush Daneshvar**[1], Elisabeth Smela[2], Daryl Kipke[1]
[1]Department of Biomedical Engineering, University of Michigan, Ann Arbor, MI, USA
[2]Department of Mechanical Engineering, University of Maryland, College Park, MD
"Articulating Neural Interfaces" - Articulating neural interfaces will be demonstrated that can guide the trajectory as well as the proximity of electrode sites to neural tissues.



Articulating Neural Interfaces

Information about the EAPAD 2012 Conference can be found at http://spie.org/app/program/index.cfm?fuseaction=conferencedetail&export_id=x12536&ID=x12233&redir=x12233.xml&conference_id=965764&event_id=959138

RECENT CONFERENCES

ASME Biomimetics Conference

The Biomimetic and Bioinspired Technologies Conference (Topic 7-3), of the ASME 2011 International Mechanical Engineering - Congress & Exposition, was held in Denver, Colorado from November 14 thru 16, 2011. This conference was part of Track #7 - Nanoengineering for Medicine and Biology. The conference was opened with a Plenary Paper presentation by the Editor of this Newsletter, Yoseph Bar-Cohen, JPL, and the title of his talk was "Humanlike Robots - the Biomimetic Ultimate Challenge". This paper was followed by an invited paper presentation by Mark Dorfman, Biomimicry Guild, MT, entitled “Biomimetic green chemistry solutions: Achievements and Outlook”. The second invited paper in this conference was given by Morgan Trexler, John Hopkins University, Baltimore, MD. The paper title was “Correlation of transparency and mechanical strength of nanostructure of vitrified collagen gels for repair of ocular injuries. This paper was coauthored with X. Calderon-Colon. R. McCally and J. Maranchi. Further, this conference included a session about EAP materials (**Figure 1**) that was chaired by Ron Pelrine, SRI International, as well as education, design, robotics and other biomimetics related sessions.

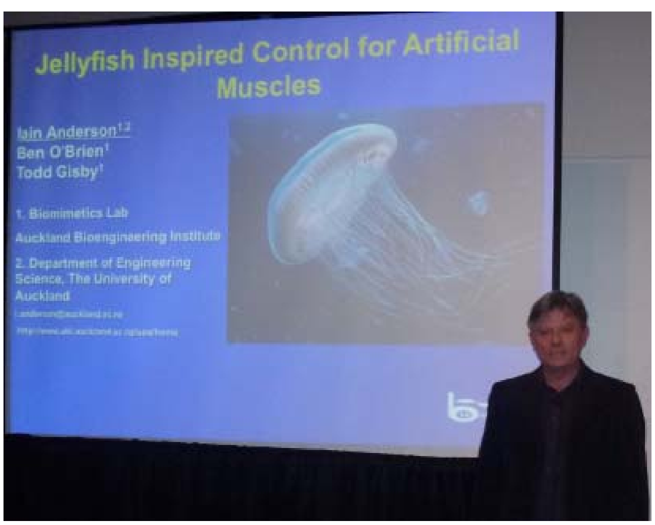


Figure 1: Iain Anderson, New Zealand, presenting his paper about control of EAP at the Biomimetics Conf. of the ASME 2011 International Mechanical Engineering - Congress & Exposition.

SMN2011 conference

The 3rd International Conference on Smart Materials and Nanotechnology in Engineering (SMN 2011), was held at Shenzhen (near Hong Kong), China from December 5 to 8, 2011, http://smartnano.org/smn2011. The conference was Chaired by Jinsong Leng (**Figure 2**), Harbin Institute of Technology, China, and Co-Chaired by Yoseph Bar-Cohen, Jet Propulsion Laboratory/California Institute of Technology, USA; In-Lee, Korea Advanced Institute of Science and Technology (KAIST), Korea; and Jian Lu, City University of Hong Kong, China. Also, the Honorary Chairs were Shanyi Du, Harbin Institute of Technology, China; and Ken P. Chong, National Institute of Standards and Technologies (NIST), USA.

This Conference covered topics related to Sensors and Actuators, Bio-inspired Materials Multifunctional Materials, Nanocomposites, and Structures, Adaptive Materials and Structures, Structural Health Monitoring, Mechanics, Modeling and Applications.

Figure 2: Jinsong Leng, the Chair of the SMN2011, opens the conference.

ADVANCES IN EAP

Auckland Bioengineering Institute, New Zealand

Artificial Muscle Emergent Behavior

Iain Anderson i.anderson@auckland.ac.nz and Ben O'Brien

Emergent behavior, for which the whole is greater than the sum of its parts, is a common theme in nature. Consider the muscle cells of the heart: each is a linear motor and actuator that can be electrically activated by its neighboring muscle cell. Numerous cells assembled together in conjunction with the heart's electrical conduction system and pacemaker can produce orderly contraction of the ventricular wall resulting in the pumping of blood.

We can't yet produce a soft heart but we can emulate aspects of natural soft machines using arrays of artificial muscle devices that can be assembled so as to produce some useful emergent behavior. For instance, we have combined piezoresistive dielectric elastomer switches (DES) coupled to dielectric elastomer actuators (DEA) [1] to produce a fully soft ring oscillator [2], a device formed by an odd number of digital inverters connected into a ring (**Figure 3**).

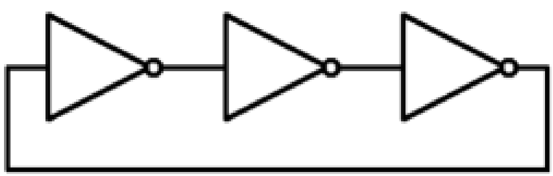


Figure 3: Simple three stage ring oscillator. As the number of inverters is odd the ring is unstable and will oscillate as fast as the components allow.

The device consists of 6 simple subunits each of which includes a DES sandwiched between two DEAs (**Figure 4**).

An equivalent circuit with 6 of these subunits is depicted in **Figure 5**.

Our ring oscillator successfully self-started and formed a stable 1 Hz square wave oscillation. On miniaturization we would expect the device to run much faster. Possible applications include multiphase motors or pumps as each inverter stage can act as an out of phase output. The oscillator can also act as a test bed for new switching and artificial muscle materials. But the real payback will be inclusion in other soft and smart machines composed of many elements that will collectively produce useful emergent behavior.

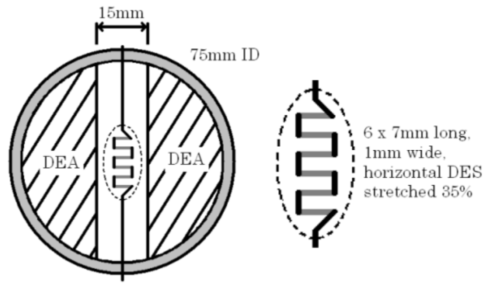


Figure 4: Oscillator Subunit. The two DEA compress the central DES when activated.

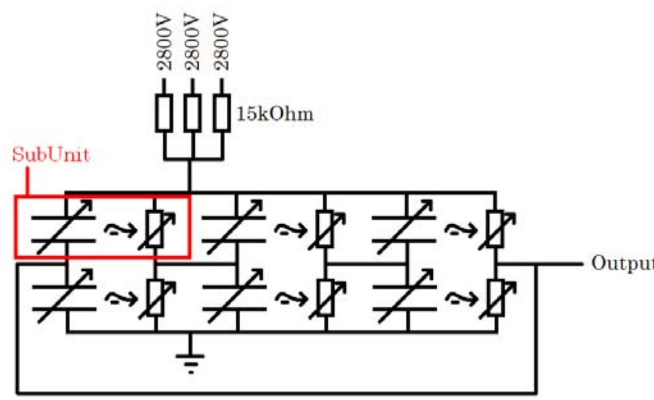


Figure 5: Ring oscillator design. Each pair of subunits forms an inverter, and the three inverters are connected in a ring. A WYE configuration connects three separate channels of the power supply to provide enough current.

References

1. O'Brien, B.M., Calius, E. P., Inamura, T., Xie, S. Q., Anderson, I. A., *Dielectric elastomer switches for smart artificial muscles.* Applied Physics A: Materials Science and Processing, 2010. **100**(2): p. 385-389.
2. O'Brien, B., Anderson, I.A., *An artificial muscle ring oscillator.* IEEE/ASME Transactions on Mechatronics, 2011(10.1109/TMECH.2011.2165553).

Compliant Transducer Systems (CTSystems)

CTSystems is a spin-off EMPA

Gabor Kovacs gabor.kovacs@ct-systems.ch
www.ct-systems.ch

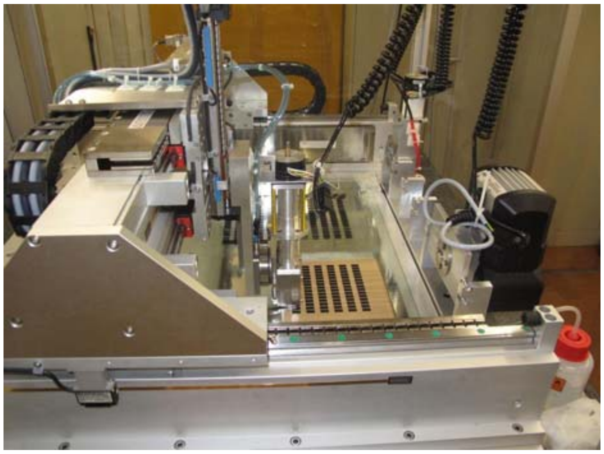


Figure 3: Manufacturing system at the new company, CTSystems, which is a spin-off EMPA

Recently, EMPA has spanned-off a new company called Compliant Transducer Systems (CTSystems). This new company will focus on commercialization of EAP stack actuators and it is intended to fill the current short-come in suppliers of such actuators. For these purpose, EMPA has developed and established a fully automated processing facility for the fabrication of stack actuators that can be used for various applications (**Figure 3)**.

JKU Linz and Harvard University

Harnessing snap-through instability in soft dielectrics to achieve giant voltage-triggered deformation

Christoph Keplinger (ckeplinger@seas.harvard.edu), Tiefeng Li, Richard Baumgartner, Zhigang Suo (suo@seas.harvard.edu) and Siegfried Bauer (sbauer@jku.at)

A soft membrane can be readily stretched many times its initial area by mechanical forces, but achieving such a large deformation by voltage has been difficult. A maximum voltage-induced area expansion of 380% was reported in literature [1], significantly lower than that achievable with mechanical forces. Increasing the voltage across an elastomer membrane can result in an electromechanical instability, known as pull-in or snap-through instability [2]. Such instability often leads to electrical breakdown, causing ultimate failure of the device [3].

As suggested by a recent theory [4], the snap-through instability can be made safe to allow for giant voltage-induced deformation with specially designed soft dielectrics. Here however, we show large deformation comparable to that achievable with mechanical forces triggered electrically using off-the-shelf materials. Our principle of operation enables giant voltage-triggered deformation for any soft dielectric: *place a soft dielectric membrane in a state near the verge of the instability, trigger the snap with a voltage, and avert electrical breakdown by a suitable loading path.*

With a commercially available acrylic elastomer (3M™VHB™4910), we demonstrate voltage-triggered expansion of area by 1692%, well beyond the largest values reported in literature. The large expansion can even be retained after the voltage is switched off:

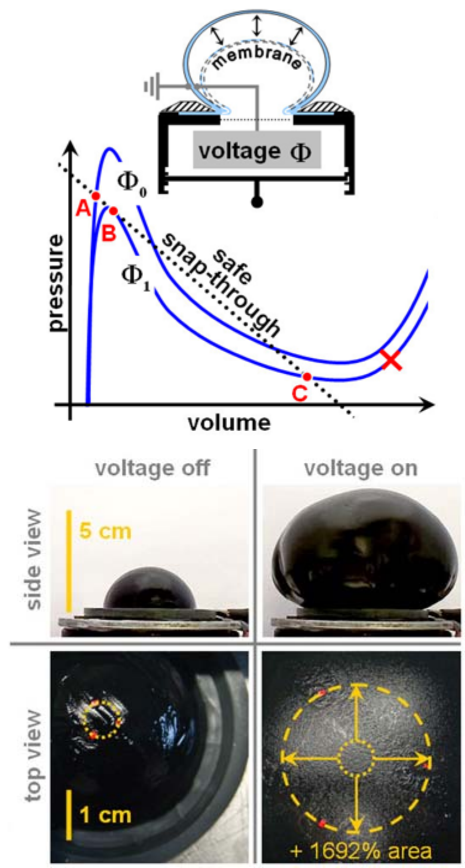


Figure 4: *A soft dielectric membrane was mounted on a chamber of a suitable volume, pressurize the membrane into a state near the verge of the snap-through instability, and apply a voltage to trigger*

the snap without causing electrical breakdown. For a 3MTMVHBTM4910 acrylic membrane we show giant voltage-triggered expansion of area by 1692%, far beyond the largest values reported in the literature.

The paper is now published on the web:

Soft Matter, 2012, Advance Article
DOI: 10.1039/C1SM06736B
http://xlink.rsc.org/?doi=C1SM06736B

References:

[1] P. Brochu and Q. B. Pei, *Macromol. Rapid Commun.*, 2010, **31**, 10.
[2] X. H. Zhao, W. Hong and Z. G. Suo, *Phys. Rev. B: Condens. Matter Mater. Phys.*, 2007, **76**, 134113.
[3] K. H. Stark and C. G. Garton, *Nature*, 1955, **176**, 1225.

North Carolina State University

Enhanced IPMC with Nanostructured Block Ionomers

Pruthesh H. Vargantwar pruthesh@gmail.com

Researchers at North Carolina State University have demonstrated that a uniquely designed multiblock ionomer, selectively solvated by a polar solvent performs as effective ionic polymer-metal composites (IPMCs) [Vargantwar et al., 2012]. These EAP materials are a class of electroactive polymers that function on the principle of ion-transport induced by an electrical stimulus and generate bending moment upon electro-actuation. While conventional IPMCs are prepared from Nafion® and other chemically-related polyelectrolytes, the IPMCs in this reported work are derived from a commercially available poly[p-t-butyl styrene-b-(ethylene-alt-propylene)-b-(styrene-co-styrenesulfonate)-b-(ethylene-alt-propylene)-b-p-t-butyl styrene] pentablock ionomer wherein the midblock is ionic and the endblocks are glassy. Due to the thermodynamic incompatibility among the blocks, these molecules self-organize to form a nanostructure that stabilizes a three-dimensional molecular network.

The IPMCs are fabricated by solvent casting of the ionomer, followed by repeated deposition of Pt electrodes. Unlike IPMCs derived from Nafion®, the present IPMCs can be dimensionally customized due to their facile sample preparation. The pentablock ionomer is capable of enormous solvent uptake, and, upon actuation, the performance of the resulting IPMCs is at least comparable or superior to conventional IPMCs. Electrode fabrication is considered critical because of the intimate polymer/electrode interface that can be achieved. An unexpected bending characteristic noted in this work is that the actuation direction can be changed on the basis of the solvent used.

Reference

P. H. Vargantwar, K. E. Roskov, T. K. Ghosh, R. J. Spontak, "Enhanced Biomimetic Performance of Ionic Polymer–Metal Composite Actuators Prepared with Nanostructured Block Ionomers," Macromolecular Rapid Communications Journal, Wiley,: DOI: 10.1002/marc.201100535 (2012)

Penn State University

Compact core-free tubular actuators based on the electrostrictive PVDF terpolymers and their applications for Refreshable Braille displays

Christopher D. Rahn cdrahn@engr.psu.edu *, and Q. M. Zhang* qxz1@psu.edu

A research team at Penn State University, led by Christopher Rahn and Qiming Zhang, has developed and demonstrated an electrostrictive PVDF terpolymer based Refreshable Braille display, which is suitable for the development of a full page Braille and graphic display. Even though single line Refreshable Braille displays have been available for several decades, the lack of small diameter actuators which can fit into confined vertical spaces to move pins made it a great challenge to have portable full page Braille displays. The electrostrictive PVDF based terpolymer can potentially provide high strain and actuation force under modest electric fields that are required for this application. Under an NIH grant, the research team developed core-free tubular actuators from uniaxially stretched films of 6 µm thick, laminated into bilayers, and rolled into 3 cm long and 1.8 mm diameter tubes. Experimental tests of these actuators demonstrated significant strains of up to 4%. Under a field of 100 MV/m, the tubular actuators generate a displacement ~ 1 mm and a force of 2 N (**Figure 5**).

A novel Braille cell was designed and fabricated using six of these actuators to form a 3 × 2 Braille cell (see **Figure 6**). Such cells can be easily arranged for full page Braille and graphic displays. The high force capability, large strain (and displacement) with fast response speed, and compact size of these core-free actuators based on the electrostrictive PVDF based terpolymer are also suitable for robotics and other smart structure applications.

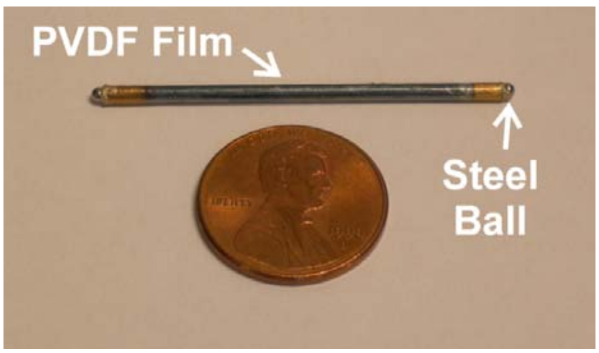


Figure 5: Example of electrostrictive PVDF terpolymer core-free tube actuator that generates 1 mm displacement at the tip with more than 1 N force.

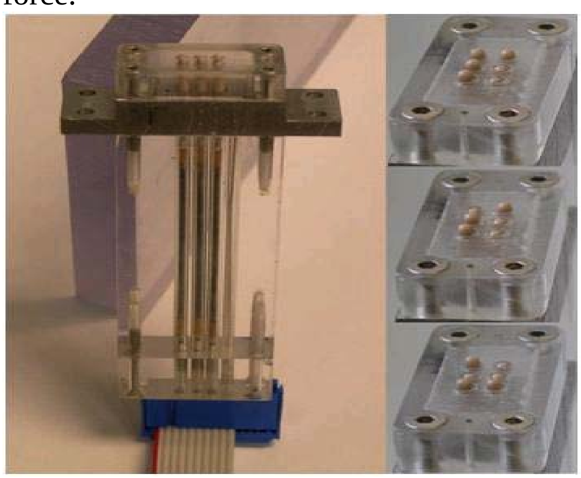


Figure 6: (Left) A Braille cell with 6 EAP pins which are about 3 cm long and 1.8 mm in diameter; (right) Braille pin movements when voltages are applied to different Braille pin actuators.

<u>NOTE FROM THE EDITOR</u>: An extensive review of the EAP-based Refreshable Braille displays that were developed so-far and the requirements for such devices can be found at:

Y. Bar-Cohen, "Refreshable Braille Displays (RBDs) Actuated by Electroactive Polymers (EAP)," Chapter 7 in Y. Bar-Cohen (Ed.), *Biomimetics: Nature-Based Innovation*, ISBN: 9781439834763, ISBN 10: 1439834768, CRC Press, Taylor & Francis Group, Boca Raton, Florida (Sept. 2011).

SynapTech

Braille – first product venture

Eugene Daneshvar
Eugene.Daneshvar@synaptech.co

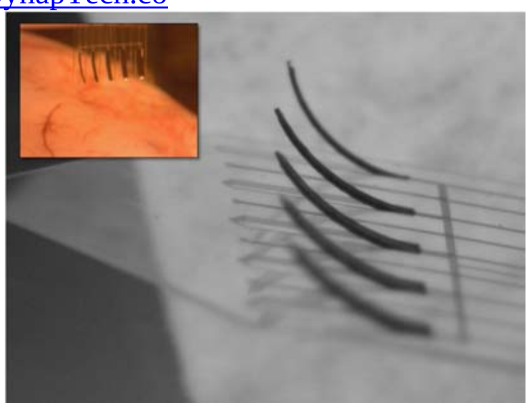
Advances in neural interface technologies to treat movement, sensory, or neurologic disorders range across a wide array of applications. Commercially-available stimulation therapies, such as cochlear implants to restore hearing and deep brain stimulation devices to treat a variety of disorders including Parkinson's disease, have been widely successful for decades. Currently entering the market, retinal prosthetics are devices intended to restore vision in disorders caused by photoreceptor loss. Such disorders include age-related macular degeneration and retinitis pigmentosa whose patient populations are increasing.

Direct retinal stimulation, using a grid of electrode sites as digital pixels, convert camera images to restore a perception of vision for the blind. However, increasing the pixel density while maintaining contrast is a dynamic challenge. This therapy is currently restricted since the available electrodes do not conform to the exact contour of the retinal layers. Gaps between the electrode sites and the retina necessitate greater therapeutic stimulation potentials which result in reduced visual acuity.

SynapTech specializes in design, fabrication, and development of articulating microelectrode arrays that have controllable elements to position the neural probes and electrode sites in optimal proximity to the targeted neurons using Electroactive Polymer (EAP) technology. ***Braille***, SynapTech's articulating retinal electrode will enable precise integration of the electrode with the retina, permitting minimal stimulating potentials, greater electrode density and enhanced visual acuity.

SynapTech's articulating neural interface technology can guide the trajectory as well as the proximity of the electrode sites to the neural tissue. SynapTech plans to integrate this actuating technology with other neural interfaces such as cochlear implants, peripheral nerve cuffs, ECoG arrays as well as implantable cortical microelectrodes for stimulation therapy and neural recording. SynapTech recently won $20k of pre-seed funding and is actively seeking partners to develop these respective areas.

Further information can be obtained from www.SynapTech.co



Articulating Neural Interfaces

University of Pisa, Italy

Bioinspired tunable lens made of dielectric elastomer actuators

Federico Carpi f.carpi@centropiaggio.unipi.it, Gabriele Frediani and Danilo De Rossi

Optical lenses with tunable focus are needed in several fields of application, such as consumer electronics, medical diagnostics and optical communications. To address this need, lenses made of 'smart' materials able to respond to mechanical, magnetic, optical, thermal, chemical, electrical or electrochemical stimuli are intensively studied. Dielectric elastomer actuators are well recognized to have a significant potential as a smart material technology for new devices with electrically-tunable optical properties [1].

Here, we report on an electrically tunable lens made of dielectric elastomer actuators. The optical device is inspired to the architecture of the crystalline lens and ciliary muscle of the human eye. It consists of a fluid-filled elastomeric lens integrated with an annular elastomeric actuator working as an artificial muscle.

Upon electrical activation, the artificial muscle deforms the lens, so that a relative variation of focal length comparable to that of the human lens can be achieved (**Figure 7 and 8**). The device combines optical performance with compact size, low weight, fast and silent operation, shock tolerance, no overheating, low power consumption, and possibility of implementation with inexpensive off-the-shelf elastomers. Results show that combing bioinspired design with the unique properties of dielectric elastomers as artificial muscle transducers has the potential to open new perspectives on tunable optics.

For details, interested readers are referred to a paper just published [2]. The paper has gained the inside cover of the journal issue (**Figure 9**).

References

[1] F. Carpi, S. Bauer, D. De Rossi, "Stretching dielectric elastomer performance", *Science*, Vol. 330, pp. 1759-1761, 2010.

[2] F. Carpi, G. Frediani, S. Turco, D. De Rossi, "Bioinspired tunable lens with muscle-like electroactive elastomers", *Advanced Functional Materials*, Vol. 21, pp. 4152–4158, 2011.

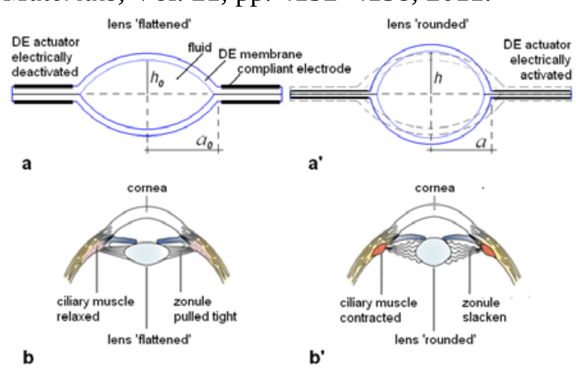


Figure 7: Functional analogy between the bioinspired lens and the human lens. a,b, Schematic sectional views (not in scale) of the two systems in the rest state. a',b', Corresponding views in an activation state. The annular DE actuator works as an artificial muscle, functionally analogous to the combined ciliary muscle and zonule; it radially stretches and relaxes the lens, so as to change the radius of curvature.

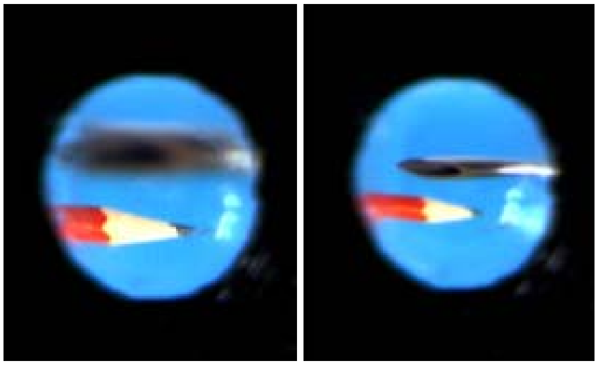


Figure 8: The bioinspired tunable lens in action. Electrically controlled focalization of a pencil and a syringe needle, respectively located 10 and 3 cm far from the lens.

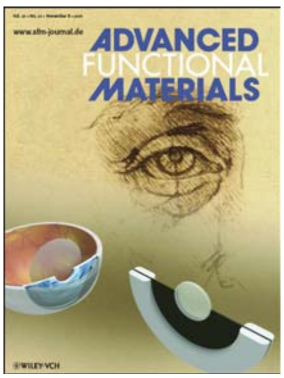
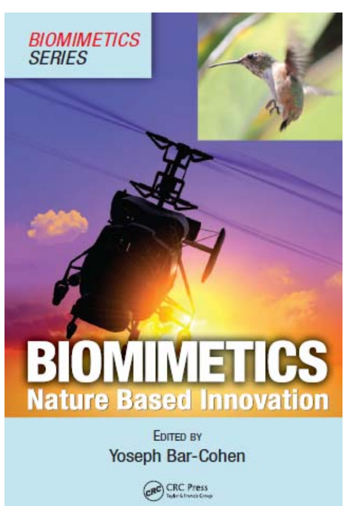


Figure 9: Inside cover of Advanced Functional Materials, Vol. 21, 2011, highlighting the paper by Carpi et al.

NEW BOOKS

Biomimetics – Nature Inspired Innovation

Yoseph Bar-Cohen (Editor)



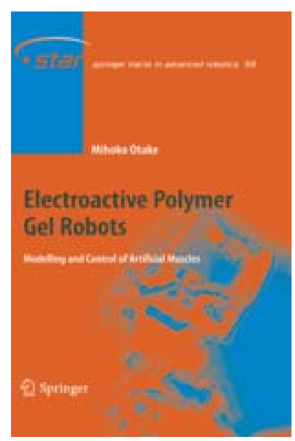
This Edited book was published by CRC Press in September 2011 is part of the new book Series on Biomimetics for which Y. Bar-Cohen is also the editor.

This new book contains 20 chapters and they are 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 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

Electroactive Polymer Gel Robots

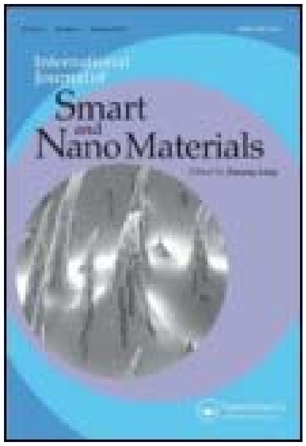
***Mihoko Otake** otake@race.u-tokyo.ac.jp*



The book covers the use of EAP gels for robotics. The use of gel based electroactive polymers is described for muscular-like actuation for deformable robots. It covers the topic from modeling and design to the development, control and experimental testing. Various methods are proposed for describing the shapes and motions of EAP-gel based systems. The results of the reported modeling are demonstrated for beam-shaped gels curling around an object and starfish-shaped gel robots turning over.

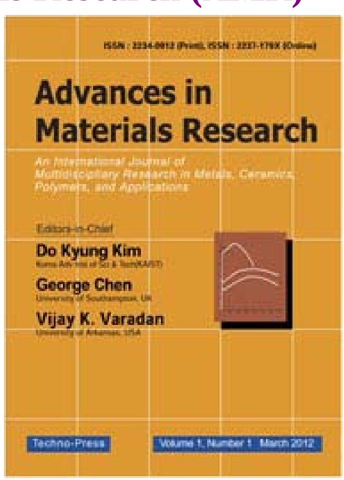
SMART MATERIALS JOURNALS

International Journal of Smart and Nano Materials



The International Journal of Smart and Nano Materials is published by the Taylor and Francis and it is entering its 3rd year since it started as a quarterly journal. The journal is intended to publish advances related to smart materials and structures as well as nano materials. Its central aim is to publish original results, critical reviews, technical discussion and book reviews related to this compelling research field: smart and nano materials, and their applications. Published papers are providing cutting edge information and instructive research guidance, encouraging more scientists to make their contribution to this dynamic research field. Further information about this journal can be found at http://www.tandf.co.uk/journals/TSNM and papers can be sent to the Editor-in-Chief Jinsong Leng at ijsnm@hit.edu.cn

Advances in Materials Research (AMR)



The Advances in Materials Research (AMR) is an International Journal that is aimed at opening a new access to information about the current advances in interdisciplinary materials research and providing an excellent publication channel for the global community of materials research. The areas covered by AMR journal include the interdisciplinary research in Metals, Ceramics and Polymers with applications in Electrical, Biochemical Materials, and Nano Structural Materials.

Papers to this journal can be submitted to Soomin Kim technop1@chol.com and further information about the journal can be found at http://www.techno-press.org/?journal=amr&subpage=1

UPCOMING EVENTS

Date	Conference/Symposium
March 11 -15, 2012	14th EAPAD Conf., SPIE's Smart Structures & Materials and NDE Symposia, San Diego, CA., For information contact: Rob Whitner, SPIE, mikes@SPIE.org Website: http://www.spie.org//eap
March 21–22, 2012	Smart Systems Integration 2012, the 6th International Conference & Exhibition on Integration Issues of Miniaturized Systems - MEMS, NEMS, ICs and Electronic Components, Zurich, Switzerland. For information contact Inga Schalenbach or Liane Preuß at smart@mesago.com Website: www.smartsystemsintegration.com
May, 2012	2nd international conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles (EuroEAP 2012) to be held at Potsdam, Germany, and chaired by Reimund Gerhard from the University of Potsdam. Website: www.euroeap.eu For information contact Federico Carpi f.carpi@centropiaggio.unipi.it
June 10-14, 2012	4th International Conference on Smart Materials Structures and Systems, CIMTEC2012, Montecatini Terme, Italy. For information contact: Pietro Vincenzini, www.cimtec-congress.org
Nov. 4-9, 2012	5th International Conference on Electroactive Polymers: Materials and Devices (ICEP-2012), Banaras Hindo University, Varanasi, India. For information contact Suresh Chandra sureshchandra_bhu@yahoo.co.in

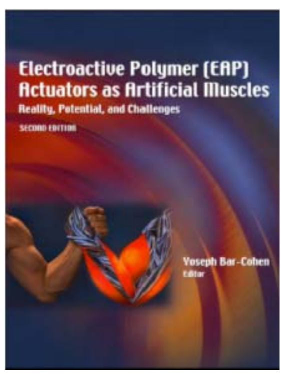
EAP ARCHIVES

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://ndeaa.jpl.nasa.gov/nasa-nde/lommas/eap/WW-EAP-Newsletter.html
Recipe: http://ndeaa.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-recipe.htm
EAP Companies: http://ndeaa.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-material-n-products.htm
Armwrestling Challenge: http://ndeaa.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-armwrestling.htm
Books and Proceedings: http://ndeaa.jpl.nasa.gov/nasa-nde/yosi/yosi-books.htm

2nd Edition of the book on EAP

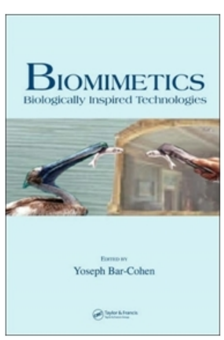
Y. Bar-Cohen (Editor)



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

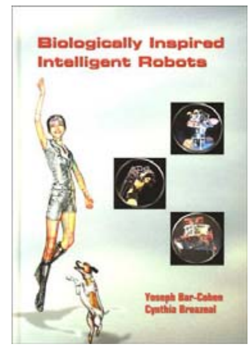
Y. Bar-Cohen (Editor)
http://ndeaa.jpl.nasa.gov/nasa-nde/yosi/yosi-books.htm



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://ndeaa.jpl.nasa.gov/ndeaa-pub/Biomimetics/Biologically-Inspired-Technology.pdf

Biologically Inspired Intelligent Robots

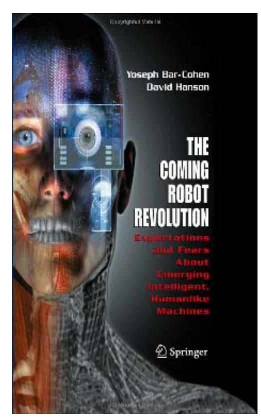
Y. Bar-Cohen and C. Breazeal (Editors)



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.

Happy New Year

WorldWide Electroactive Polymers (EAP) Newsletter

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

All communications should be addressed to:
Yoseph Bar-Cohen, Ph.D.,
JPL, M.S. 67-119, 4800 Oak Grove Dr., Pasadena, CA 91109-8099
Phone: (818)-354-2610 or E-mail: yosi@jpl.nasa.gov
Web: http://ndeaa.jpl.nasa.gov