# WorldWide ElectroActive Polymers


# EAP (Artificial Muscles) Newsletter

**Vol. 12, No. 2 (24th issue)** **WW-EAP Newsletter** **Dec. 2010**

http://eap.jpl.nasa.gov


## FROM THE EDITOR

***Yoseph Bar-Cohen,*** *yosi@jpl.nasa.gov*

The applications of EAP are continuing to grow and we increasingly seeing the potential of emergence of commercial products with a large market. The fact that we already have major industries stepping into the field is quite encouraging. The recent acquisition of Artificial Muscles Inc. (AMI) by Bayer MaterialScience LLC is a wonderful step in this direction and an important milestone for the field.

It is interesting to note that there is a growing formation of regional EAP groups and the example of the European Scientific Network for Artificial Muscles (ESNAM) was reported in the previous issue of this Newsletter. Another is the Indian Society of Electroactive Polymers that has been holding biennial conferences since 2004 and its latest is covered in this issue of the Newsletter.

Energy harvesting has a worldwide significance in terms of the impact on our Climate Change and the need for green forms of renewable energy sources. To bring attention to this important topic, special sessions of the 2011 EAPAD Conference are going to cover the progress in this field. This SPIE conference is going to be held on March 7-10, 2010, in San Diego, California. In addition, in this Conference there are going to be special sessions from authors who are members of ESNAM and information about their recent development is reported in this Newsletter. In addition, we are going to have an all day course on EAP as well as another exciting EAP-in-Action Session.

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## 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

## Kick-off of the European Scientific Network for Artificial Muscles

*Federico Carpi, University of Pisa, Italy*
*f.carpi@centropiaggio.unipi.it*

Over the last couple of years, a core group of leading European research institutes and industries in the EAP field has been forming an informal network called 'European Scientific Network for Artificial Muscles (ESNAM)'. Today, this network consists of 37 Member Institutions from 17 European Countries (www.esnam.eu) and **Figure 1** presents their geographical distribution.

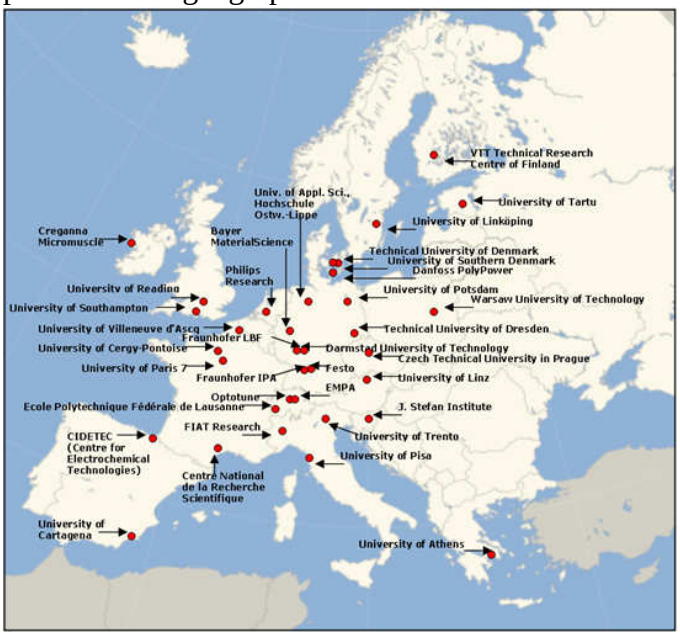


**Figure 1**: The informal ESNAM network.

ESNAM is primarily aimed at fostering scientific and technological advancement of transducers and artificial muscles based on EAPs as smart materials for electromechanical transduction (actuation, sensing and energy harvesting).

In recognition of the significance of this effort, the European Science Foundation has recently approved a COST Action grant for ESNAM. The kick-off meeting of the ESNAM COST Action has been held on December 8, 2010, in Brussels, Belgium.

During the meeting, the ESNAM members have taken, among others, the following two important decisions.

In consideration of the fast growing size of the EAP community and the potential impact of the EAP technologies, the network is going to establish a European Society for EAP transducers and artificial muscles (EuroEAP Society). This Society will be open to members from all over the world.

Moreover, the Society will organize a periodic international conference in the field (EuroEAP Conference). While details have still to be defined, the first edition is planned to be held during the summer of 2011.

Information on both the EuroEAP Society and the EuroEAP Conference will be released soon. An e-mailing list is in preparation for that purpose.

Those who are interested in being included in the e-mailing list are warmly invited to send a message to the following address: info@euroeap.eu

# CHALLENGES

## ISAS - Institute for Sleep Apnea & Snoring Henry Getty

*Henry Getty, henry.getty@gmail.com*

The main problem of the majority of the people that suffer from Sleep Apnea or its earlier condition snoring is the loss of tone of the strongest muscle in the human body (proportional to size) ***the tongue.***

The medical world agreed that the size, posture and position of the tongue are the main causes for Sleep Apnea and snoring. Therefore, if we can find a way to return the tone to the tongue or to create a good support for the tongue to prevent it from sliding into the airway we could help those millions of people and prevent so many other indirect conditions, illness and diseases. Examples include:

**High Blood pressure:** The oxygen deficiency in the brain, occurred directly due to sleep apnea, causes the brain to command the heart muscle to work harder to receive more blood and to decrees the vessel diameter increasing the pressure. The result of this condition is increased chances for stroke and/or heart attack.

**Diabetes:** Persons suffering from Sleep Apnea do not enjoy peaceful sleep. A study found that, when healthy young men slept only 4 hours a night for 6 nights in a row, their insulin and blood sugar levels mimicked those seen in people who were developing diabetes. If you already have diabetes, a pattern of sleep-deprivation only further contributes to a flux in blood sugars. The result of sleep-deprivation is the increase in insulin resistance and it contributes to diabetes.

**Alzheimer's**: Studies of the brain with MRI made in 40 sleep apnea sufferers, showed mammillary bodies (formations at the base of the brain) that are 20% smaller as compared to those who do not. This finding is similar to the one in patients who are suffering from memory loss due to Alzheimer's and alcoholism. People with sleep apnea develop a significant increase in the number of small silent strokes (or lacunar infarcts). If Sleep Apnea causes lots of mini-strokes over decades a person will end up becoming demented at age 70 -80. Effectively, suffers result in having Alzheimer's.

All the described symptoms are constantly projected on their spouse preventing peaceful sleep from them too. Therefore, these produce the same problems in a person who is not directly suffering from Sleep Apnea.

The desired solution is illustrated in **Figure 2** where a smart artificial tongue driven by EAP will be developed.

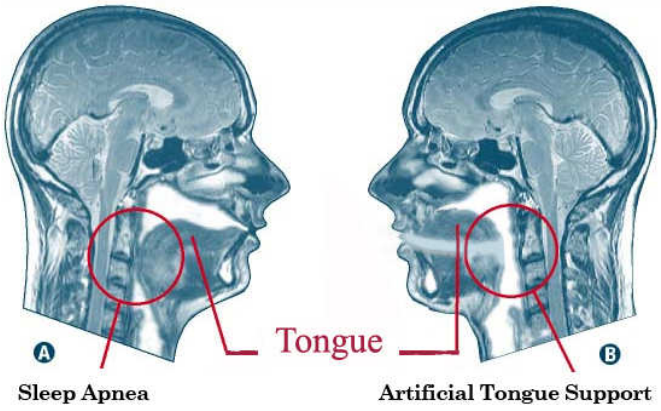


**Figure 2:** Cross section view clarifying the need for smart tongue support for preventing sleep related disorders.

# ABOUT THE EAP COMPANIES

## Artificial Muscle, Inc.

**Artificial Muscle, Inc. is introducing Reflex™ Technology as an innovative solution for the video gaming industry**

*Dirk Schapeler* *Dirk.Schapeler@artificialmuscle.com*

On December 2, 2010, Artificial Muscle Inc. (AMI) announced its Reflex™ Technology solution that enables simulation of real gaming events with high-fidelity vibrational haptic feedback. Using this capability, gamers can experience for example the feel of actual balls rolling in pinball, labyrinth games of realistic vibration of driving, flight simulation games, and many other customized events in games. With complete customizability of output effect almost like a high-fidelity speaker for the sense of touch, Reflex will revolutionize the way that consumer experience games. Reflex has an extremely thin form factor and allows for customized integration. AMI developed a novel controller design that enables Reflex to effectively operate with most existing video games without need for modification. But as game developers create future games, they can also design for Reflex to further enhance functionality.

The technology is based on a dielectric elastomer EAP. AMI offers two reference designs: a Moving Touch Sensor design and a Battery Shaker design. The Moving Touch Sensor Design provides a direct tactile response to the user by moving the touch surface. Alternatively, the Battery Shaker design uses a Reflex to move the battery as a mass to provide feedback that can be felt in a user's hand.

Artificial Muscle, Inc. (AMI) of Sunnyvale, California, is a wholly owned subsidiary of Bayer MaterialScience LLC. AMI's Reflex™ haptic actuators (see **Figure 3**) allow users to synchronize the sensory experience by adding the sense of touch to devices which previously only provided sound and sight. Reflex™ enables touch screens to create the sensation of authentic tactile feedback, just like a conventional keyboard. This innovative technology is ideal for electronic devices like smart

phones, portable electronics, gaming controllers, touch pads, and other touch interface products.

Bayer MaterialScience LLC which is one of the leading producers of polymers and high-performance plastics in North America. It is part of the global Bayer MaterialScience business with approximately 14,300 employees at 30 production sites around the world and 2009 sales of 7.5 billion Euros. The company manufactures high-tech polymer materials and develops innovative solutions for products used in many areas of daily life. The main segments served are the automotive, electrical and electronics, construction, medical, and sports and leisure industries. Sustainability is central to Bayer MaterialScience LLC's business and is based around the key areas of innovation, product stewardship, excellence in corporate management, social responsibility and respect for the environment.

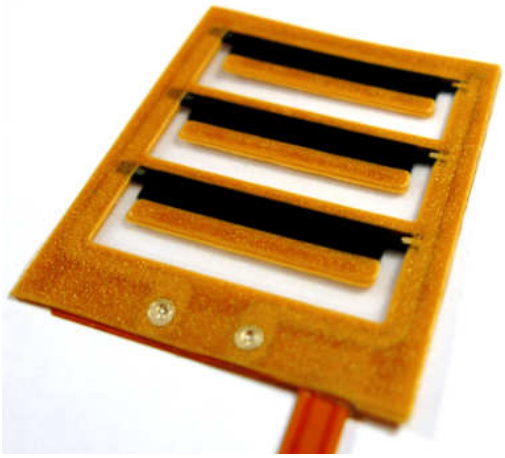

**Figure 3:** AMI's printed EAP actuator for haptic feedback applications

For further information contact Marcus Rosenthal at info2010-usa@artificialmuscle.com or visit www.artificialmuscle.com

# RECENT CONFERENCES

## ICEP-2010, India, Nov 21 – 26, 2010

*Amreesh Chandra rishu_chandra@yahoo.com; achandra@phy.iitkgp.ernet.in*

The 4th ICEP Conference, which is part of the International Conference on Electroactive Polymers: Materials and Devices biennial series, was held on Nov. 21 - 26 at Surajkund, India (www.icep2010.org). The conference was Chaired by Suresh Chandra (**Figure 4**), Amita Chandra and S.A. Hashmi, and the organizing Secretariats were Amreesh Chandra and R. K. Singh. This series of conferences in India started with the first conference at Dalhousie in 2004, followed by ones held at Goa (2006) and Jaipur (2008). This series of conferences is part of the effort of the Indian Society of Electroactive Polymers to create a forum of information exchange between world's leading scientists in the area of EAP and their counterparts in India to discuss current and future research areas. These conferences were highly productive and led to many collaborative interactions. This year was no different! Intense interaction among the participants was its hallmark.

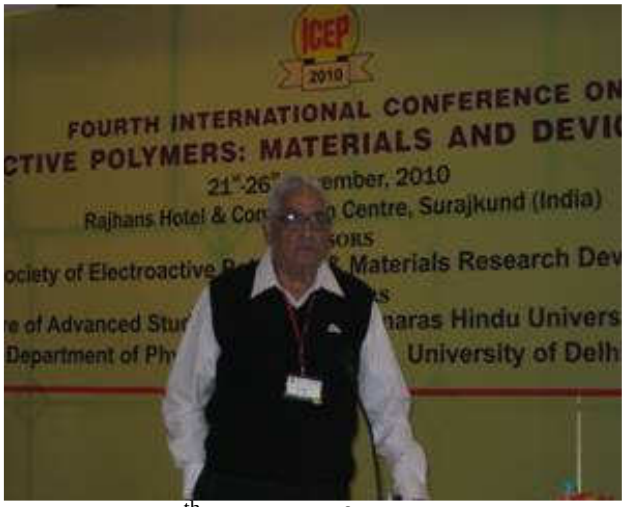


**Figure 4:** The 4th ICEP Conference Chair, Suresh Chandra.

The conference was attended by more than 100 participants from more than 12 countries and it included 2 Plenary, 25 Invited, 20 Oral and nearly 50 Poster presentations. The conference started with an introduction by Suresh Chandra, President, Indian Society of EAP. Chandra gave details of some of the recent work which are being carried out in India in the field of EAP. The technical sessions of the conference started with a plenary lecture by Yoseph Bar-Cohen (USA). Bar-Cohen gave a comprehensive overview about the recent trends in the field of EAP and the future in-store for such polymers.


One of the areas of application of EAP materials is the field of organic light emitting diodes and organic photo-voltaics. The recent trend in this area was vibrantly discussed by eminent speakers like Karl Leo (Germany), Frederic Lacquai (Germany), S.C.J. Meskers (Netherlands), H.M. Upadhyaya (U.K.) and many others. The development and recent achievements in the field of polymer electrolytes was presented by leading scientists in this area such as Michael Armand (France), Dieter Neher (Germany), B. Kumar (USA), Daniel Brandell (Sweden) and Martin Aeschlimann (Germany). The preparation and studies of polymer composites for application in devices hold tremendous promise. This field was discussed in the invited papers by Gal de Botton (Israel), D. Fink (Mexico), Amreesh Chandra (India), Klaus Raetzke (Germany), and Laylay Chua (Singapore). The theoretical studies and simulation aspects in these polymers was excellently presented in the plenary talk by Kurt Kremer (Germany) and invited papers by R.K.Singh, Amita Chandra/ Sangeeta Rawat, S.A.Hashmi/ G.P. Pandey, M.P. Singh and other members of the team led by Suresh Chandra (India). Many leading groups from different parts of India also presented their work which highlighted the intense activity in the area of EAP in India. The fast developing field of biopolymers, ionic liquids and their application in medical diagnostics was discussed by Tony Killard (Ireland) (see **Figure 5**), Yosi Diamond (Israel) and Maria Forsyth (Australia).

**Figure 5:** Tony Killard presenting an invited paper on biopolymers.

In the series of oral presentations in every session of the conference many young Indian scientists and researchers presented their recent work. They also presented their work during the poster session of the conference. To promote excellence amongst young researchers, the conference gives Young Scientists Awards for the best posters to researchers below the age of 35 years. This year the first three prizes were given to Jatin Khera (India), Sujeet Chaurasia (India) and T.I.T. Kudim (Malaysia) for their excellent presentation and defense of the work they presented.

In addition to the technical presentations, the participants were given a feel of the local culture of India during a full day excursion trip to several important tourist sites in Delhi. The trip was organized by the organizing committee of the conference. Also, in the reception of the Conference a cultural show was made including blowing fire from a dancer mouth (**Figure 6**).

The 5th International Conference on EAP Materials and Devices is scheduled to be held in 2012. The first circular for this conference will be published in November. 2011.

**Figure 6:** Part of the cultural show during the reception of the ICEP-2010 that was held in Surujkund, India (Courtesy of Tunku Ishak Al-Irsyad, Malaysia).

# UPCOMING CONFERENCES

## 2011 SPIE EAPAD Conference

The 13th SPIE's EAPAD conference is going to be held from March 6 - 10, 2011, in San Diego, California. This Conference will be chaired by Yoseph Bar-Cohen, JPL, and Co-chaired by Federico Carpi, University of Pisa, Italy. The Conference Program Committee consisted of representatives from 24 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.

The keynote speaker is going to be Thomas Sugar (**Figure 7**), and the title of his talk is Title: "Walking with Springs". Thomas is a faculty member in the Department of Mechanical and Aerospace Engineering and the Department of Engineering at Arizona State University. He majored in business and mechanical engineering for his Bachelor degree and mechanical engineering for his Doctoral degree all from the University of Pennsylvania. In industry, he worked as a project engineer for W. L. Gore and Associates. His research focuses on compliant wearable robots using tunable springs. He is developing robotic orthoses and prostheses for rehabilitation and mobility. His current research projects include SPARKy, Spring Ankle with Regenerative Kinetics, and PAFO, a powered ankle foot orthosis for stroke rehabilitation.

**Figure 7:** The 2011 EAPAD Conference Keynote Speaker, Thomas Sugar, Arizona State University.

The invited papers in this conference are:

- Siegfried G. Bauer, Johannes Kepler Univ. Linz (Austria), "Dielectric elastomers: from the beginning of modern science to applications in actuators and energy harvesters."
- Roy D. Kornbluh, Ron Pelrine, Harsha Prahlad, Annjoe Wong-Foy, Brian McCoy, Susan Kim, and Joseph Eckerle, SRI International (United States), "From boots to buoys: promises and challenges of dielectric elastomer energy harvesting."
- Zhigang Suo, Harvard Univ. (United States), "Maximal energy that can be converted by a dielectric elastomer generator."
- Guggi Kofod, Hristiyan Stoyanov, Matthias Kollosche, Sebastian Risse, Hülya Ragusch, Denis N. McCarthy, Dmitry Rychkov, Mario Dansachmüller, and Remi Waché, Univ. Potsdam (Germany), "Molecular level materials design for improvements of actuation properties of dielectric elastomer actuators."
- Frederic Vidal, Cédric Plesse, Univ. de Cergy-Pontoise (France); Alexandre Khaldi, Univ. de Valenciennes et du Hainaut-Cambrésis (France); Nicolas Festin, Brain Vision Systems (France); Eric Cattan, Univ. de Valenciennes et du Hainaut-Cambrésis (France); Patrick Pirim, Brain Vision Systems (France); Dominique Teyssié, and Claude Chevrot, Univ. de Cergy-Pontoise (France), "Conducting IPNs based electrochemical actuators: from chemistry towards devices ."
- Herbert R. Shea, Ecole Polytechnique Fédérale de Lausanne (Switzerland), "Miniaturized EAPs with compliant electrodes fabricated by ion implantation."
- Edwin W. H. Jager, Linköping Univ. (Sweden), "Actuators, biomedicine, and cellbiology."
- Iain A. Anderson, Tony C. Tse, Tokushu Inamura, Benjamin M. O'Brien, Auckland Bioengineering Institute (New Zealand); Thomas G. McKay, The Univ. of Auckland (New Zealand); and Todd A. Gisby, Auckland Bioengineering Institute (New Zealand), "Flexi-drive: a soft artificial muscle motor."

Also, we are going to have three Special Sessions on "**Energy Harvesting using EAP**". The concern about green forms of producing energy is continually increasing and the recent accident in the Gulf of Mexico with thousands of gallons of oil leaking into the environment makes this need even more urgent.

In addition, we are going to have 4 special sessions from members of the European Scientific Network for Artificial Muscles (ENAM) where one of them is part of the sessions on Energy harvesting.

As in past years, an EAPAD course will be given on Sunday, March 6, 2011, and the EAP-in-Action will be held on Monday, March 7, 2011.

The EAPAD course will provide an overview of the field of EAP covering the state of the art, challenges and potential. 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, Univ. 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

On Monday, March 7, 2011, we are planning to hold the EAP-in-Action Session. This Session is continues to provide a spotlight on Electroactive 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 8 research and industry presenters demonstrating their latest EAP actuators and devices including:

Lone Ivang, Danfoss PolyPower A/S, **Denmark**: PolyPower® DEAP energy harvesting system – The demonstration will include a medium scale DEAP energy harvesting system comprised of control and monitor electronics, PolyPower DEAP generator elements, and mechanical energy source. Also, "Constant charge, constant voltage, and constant electric field" energy conversion cycles will be demonstrated.

**Figure 8:** PolyPower Energy Harvesting System

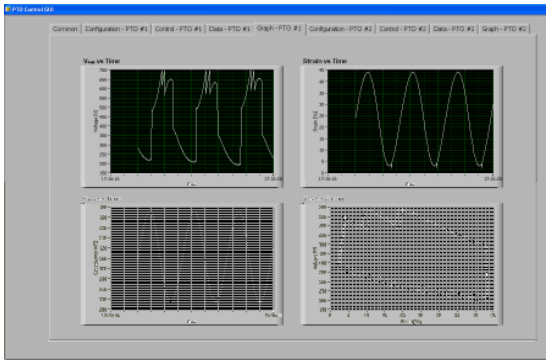

**Figure 9:** Sample display output for constant voltage

P. Lotz[a], M. Matysek[b], H. Hausa, H. Moessingerb, D. Brokken[b], H. F. Schlaak[a]
a. Technische Universität Darmstadt, **Germany**
b. Philips Research, Eindhoven, **The Netherlands**
Handheld haptic user interface with localized tactile feedback – A battery driven bidirectional user interface based on dielectric elastomer transducers will be shown. Its actuator-mode is used to present tactile information (e. g. display device status) while its sensor-mode enables user interaction (e. g. change device status). Energy efficient design and additional wireless communication emphasize the autonomous usability.


**Figure 10:** Handheld haptic user interface with localized tactile feedback

Federico Carpi, University of Pisa, Research Centre "E. Piaggio" **Italy**: Hydrostatically and Granularly coupled dielectric elastomer actuators - Prototype samples of new types of dielectric elastomer actuators (DEAs) will be shown. They are called 'hydrostatically coupled' DEAs and 'granularly coupled' DEAs. In such devices either a fluid or a fine powder is used to transfer forces to a load, without direct contact between the latter and any DEA active element. This solution has specific advantages, including electrical safety and design versatility.

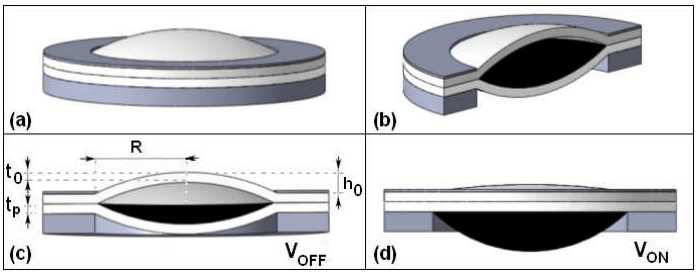


**Figure 11:** Hydrostatically and granularly coupled dielectric elastomer actuators

Iain Anderson Emilio Calius, Todd Gisby, Andrew Lo, Thomas McKay, Ben O'Brien, and Tony Tse, The Biomimetics Lab of the Auckland Bioengineering Institute, **New Zealand:** "Artificial Muscles in Aotearoa" - Dielectric elastomer (DE) technology demonstration will be made including bio-inspired DE self-sensing and logic circuits as follows:

1) A capacitive, high specific torque rotary motor - Sequential actuation of electroded zones on the thin dielectric elastomer membrane produces an

orbiting motion in a gear at the centre of the membrane that contacts and turns a rotor.

2) A four channel artificial muscle controller unit - A stand-alone portable laboratory tool simplifies the generation and control of high voltages for artificial muscle research. The unit features include 4 channel computer controlled output and battery operation.
3) A portable dielectric elastomer generator - A portable and autonomous generator technology will be demonstrated.

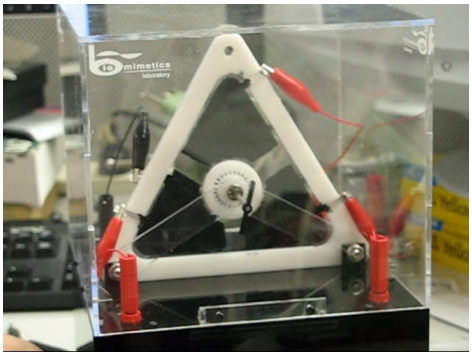

**Figure 12:** Rotary motor


**Figure 13:** 4-channel controller

**Figure 14:** Portable generator

**USA**

Marcus Rosenthal, Artificial Muscle, Inc., a Bayer MaterialScience Company: Reflex Haptic Actuators integrated into Consumer Products – Demos will be made showing the latest Reflex actuators integrated in products for high fidelity haptic feedback in Mobile and Gaming applications

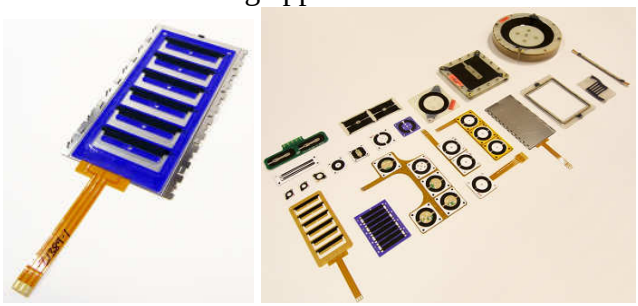

**Figure 15:** Reflex Haptic Actuators

Qibing Pei, UCLA: Refreshable tactile display devices – A bistable electroactive polymer actuators and a refreshable Braille display will be demonstrated. The device can display Braille text and tactile images and its content is refreshable.

**Figure 16:** Refreshable tactile display devices

Lenore Rasmussen, Ras Labs, LLC: Control algorithm - Voltage Step Functions Applied to a contractile EAP controls the level of contraction and modulate the movement

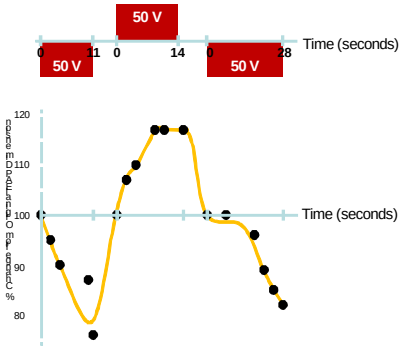


**Figure 17:** Control algorithm

Information about the EAPAD 2011 Conference can be found at http://www.spie.org/eap

## Electromaterials Symposium 2011

The Electromaterials Symposium 2011 is going to be held in Wollongong (Australia) Feb. 9-11, 2011. The themes of the Symposium are Nanostructured Electromaterials and Electro-materials for Energy, and various aspects of Electromaterials. The Chair of the Symposium is Gordon Wallace and the Co-Chairs are Justin Gooding and Jung-Ki Park. Further information about this biennial forum can be obtained by contacting Gordon Wallace, who is the Executive Director, ARC Centre of Excellence for Electromaterials Science & Intelligent Polymer Research Institute, AIIM Facility, Innovation Campus, University of Wollongong, Wollongong NSW Australia gwallace@uow.edu.au ACES website: http://electromaterials.edu.au, and IPRI website: http://ipri.uow.edu.au

## SMN2011 conference

3rd International Conference on Smart Materials and Nanotechnology in Engineering (SMN 2011), is going to be held from November 10 to 14, 2011, at Shenzhen (near Hong Kong), China. The conference is Chaired by Jinsong Leng, 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, Jian Lu, City University of Hong Kong, Hong Kong China.

This Conference will cover: Sensors and Actuators, Bio-inspired Materials Multifunctional Materials, Nanocomposites, and Structures, Adaptive Materials and Structures, Structural Health Monitoring, Mechanics, Modeling and Applications. After normal peer-review process, selected full-length papers will be published in the special issues of SCI cited journals.

Important Dates:

- Deadline of abstract submission: 1st May, 2011
- Date of abstract acceptance: 1st August, 2011
- Deadline of pre-registration: 1st October, 2011
- Deadline of final paper: 15th November, 2011

For more information please contact: Zhichun Zhang (Conference Secretary), smn2011@smart-nano.org. Web: http://smartnano.org/smn2011.

All abstracts should be submitted by email to smn2011@smart-nano.org.

# ADVANCES IN EAP

## Harvard University, Cambridge, MA

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Dielectric elastomers are capable of giant voltage-induced deformation. The phenomenon has inspired intense development of dielectric elastomers as transducers for diverse applications. A review has just been completed on the theory of dielectric elastomers, developed within continuum mechanics and thermodynamics, and motivated by molecular pictures and empirical observations. The theory couples large deformation and electric potential, and describes nonlinear and non-equilibrium behavior, such as electromechanical instability and viscoelasticity. The theory enables the finite element method to simulate transducers of realistic configurations, predicts the efficiency of electromechanical energy conversion, and suggests alternative routes to achieve giant voltage-induced deformation. It is hoped that the theory will aid in the creation of materials and devices.

Section II of the review describes the thermo-dynamics of a transducer of two independent variations. Emphasis is placed on basic ideas: states of the transducer, cyclic operation of the transducer, region of allowable states, equations of state, stability of a state, and nonconvex free-energy function. These ideas are described in both analytical and geometrical terms. Section III develops the theory of homogeneous fields. After setting up a thermodynamic framework for electromechanical coupling, we consider several specific material models: a vacuum as an elastic dielectric of vanishing stiffness, incompressible materials, ideal dielectric elastomers, electrostrictive materials, and nonlinear dielectrics. Section IV applies nonequilibrium thermodynamics to dissipative processes, such as viscoelasticity,

dielectric relaxation, and electrical conduction. Section V discusses electromechanical instability, both as a mode of failure and as a means to achieve giant voltage-induced deformation. Section VI outlines the theory of inhomogeneous fields. The condition for thermodynamic equilibrium is formulated in terms of a variational statement, as well as in terms of partial differential equations. The model of ideal dielectric elastomers is described. Also described is a finite element method for analyzing elastic dielectric membranes of arbitrary shapes. We perturb a state of static equilibrium to analyze oscillation and bifurcation. We examine the conditions of equilibrium for coexistent phases. The review is available online: http://www.seas.harvard.edu/suo/papers/243.pdf

## University of the West of England, UK

**Advanced Sensor Materials**

Tony Killard, Dublin City University, Dublin, Ireland tony.killard@uwe.ac.uk or tony.killard@dcu.ie

Under the lead of Tony Killard, a team of researchers at the University of the West of England (UWE) in Bristol, UK, is investigating application of organic conducting polymers for the development of electrochemical sensors as well as electrocatalytic materials for sensing applications and other areas such as fuel cells. Tony was previously based at the National Centre for Sensor Research at Dublin City University where he established expertise in areas of electroanalytical chemistry, fabrication of conducting polymer nanomaterials and their application to sensor fabrication particularly through the medium of inkjet printing.

His team has developed an array of sensors for environmental, industrial and biomedical diagnostic measurement applications. They are currently commercializing several related technologies including probes for monitoring toxic gas leak detection, the development of enuresis alarms in adults and children, development of diagnostic breath sensors for liver and kidney dysfunction and the development of a range of inkjet printable biosensors for glucose, cholesterol, urea and creatinine. He is currently coordinating an FP7 project on integrated miniaturized smart systems and his effort is focused on the integration of printed sensors into the wider printed electronics industry.

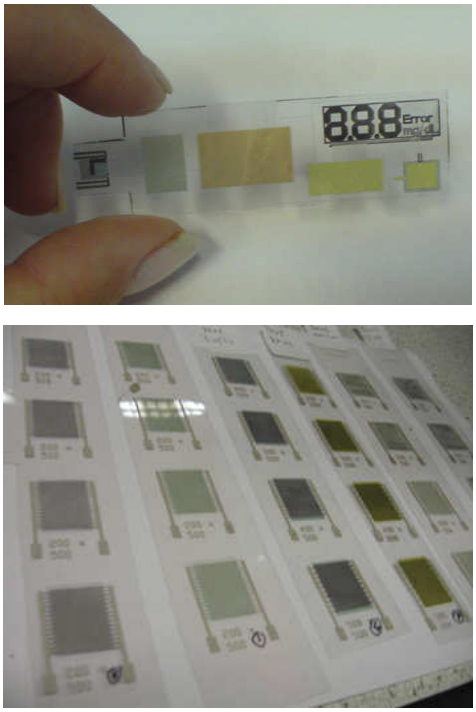

**Figure 18:** Printed sensors

## University of Nevada, Reno, NV

***hp*-FEM modeling of ionic polymer metal composites**

Kwang Kim*, David Pugal, and Pavel Solin
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*kwangkim@unr.edu;
http://wolfweb.unr.edu/homepage/kwangkim/laboratories/index.html

The University of Nevada, Reno has been developing the physical model of IPMC based on the ionic transport processes using a higher-order finite element method *hp*-FEM. The *hp*-FEM is a general version of FEM that employs elements of variable size (*h*) and polynomial degree (*p*). The automatic adaptivity both in *h* and *p* space makes the solution converge exponentially fast, while keeping the relative error within pre-set limits. In conjunction with the multi-mesh approach where the different meshes are used for different physical

fields such as charge concentration and voltage, the method is very promising for solving the Poisson-Nernst-Planck system of equation coupled to the continuum equations. Namely, the physical fields of Poisson equation and Nernst-Planck equations are very different in space and time – the gradients do not coincide and shift in time as demonstrated in **Figure 19**. This makes finding an optimal mesh for finite element calculation very difficult and that is where the multi-mesh and automatic adaptivity are very beneficial.

We have derived the weak formulation of Poisson-Nernst-Planck system of equations and implemented it in the open source *hp*-FEM solver Hermes (http://www.hpfem.org). The 2D solutions shown as 3D images (height and color denote magnitude) are shown in **Figure 20**. Automatic anisotropic *hp*-adaptivity was used to keep the relative error of the solution below 0.5%. Furthermore, adaptivity combined with the multi-mesh results in the small problem size throughout the solving process. We are currently working on coupling the cation concentration to the body force to calculate the actuation both in 2D and 3D.

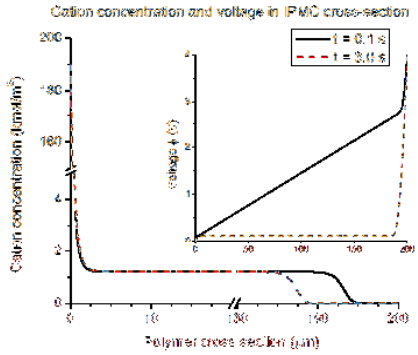
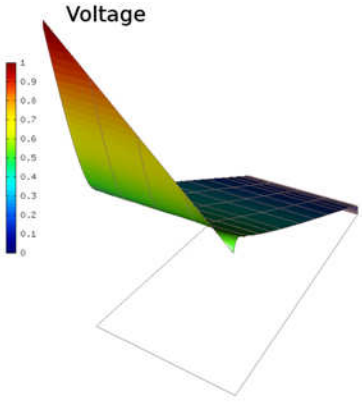



**Figure 19:** Cation concentration C and voltage φ in the cross section of IPMC at different times.



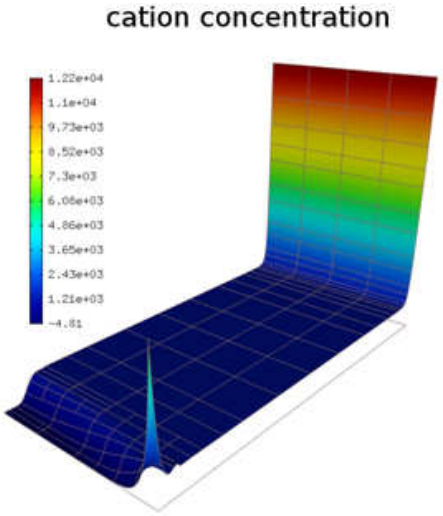
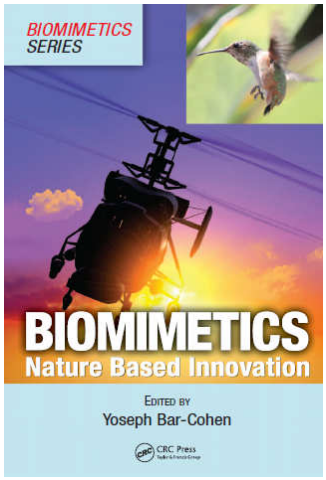




**Figure 20:** Cation concentration and voltage in IPMC cross-section, calculated with Hermes

# NEW BOOKS

## Biomimetics – Nature Inspired Innovation

**Yoseph Bar-Cohen (Editor)**




This Edited book that is about to be published by CRC Press in June 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 Behavioural 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

# UPCOMING EVENTS

| Date | Conference/Symposium |
|---|---|
| Feb. 9-11, 2011 | The Electromaterials Symposium 2011, Wollongong (Australia). For information contact: gwallace@uow.edu.au |
| March 6 -10, 2011 | 13th 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 |
| Nov. 11-13, 2011 | 3rd International Conference on Smart Materials and Nanotechnology in Engineering, Shenzhen (near Hong Kong), China. For information contact: Jinsong Leng, lengjinsong@yahoo.com Web: http://smart-nano.org/smn2011 Abstract should be submitted to smn2011@smart-nano.org |
| 2012 | 5th International Conference on Electroactive Polymers: Materials and Devices (ICEP-2012), India. For information contact: Prof. 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

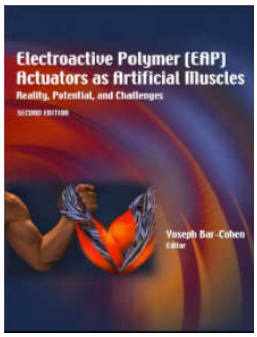
**EAP Companies**: http://ndeaa.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-material-n-products.htm

**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)*

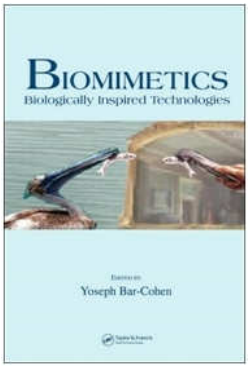



In March 2004, the 2nd edition of the "Electroactive Polymer (EAP) Actuators as Artificial Muscles - Reality, Potential and Challenges" was published. This book includes description of the available materials, analytical models, processing techniques, and characterization methods. This book is intent 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*

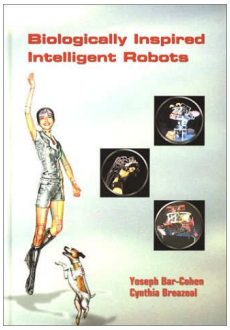



This book about Biomimetics review technologies that were inspired by nature and outlook for potential development in biomimetics in the future. This book is intended as a reference comprehensive document, tutorial resource, and set challenges and vision for the future direction of this field. Leading 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

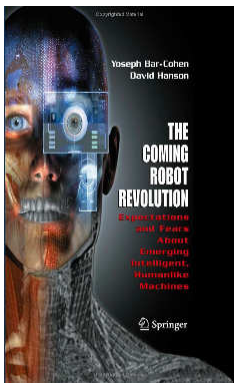
*Y. Bar-Cohen and C. Breazeal (Editors)*




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**

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