WorldWide ElectroActive Polymers

EAP

(Artificial Muscles) Newsletter

Vol. 16, No. 2 (32nd issue) **WW-EAP Newsletter** **December 2014**
http://eap.jpl.nasa.gov

FROM THE EDITOR

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

This issue reports the latest progress in the fields of Electroactive Polymers (EAP) and biomimetics.

LIST OF CONTENTS

FROM THE EDITOR 1
GENERAL NEWS 1
ABOUT OUR EXPERTS 1
Novasentis Received CTIA Award 1
Obituary to Ephrahim Garcia 2
POSITIONS AND OPENINGS 2
2 Postdoc openings at UCLA 2
Several PhD student openings at ITN 3
UPCOMING CONFERENCES 3
2015 SPIE EAPAD Conference 3
BAMN 2015 8
RECENT CONFERENCES 8
EAP Workshop 2014 8
ADVANCES IN EAP 9
CSIR, Central Mech. Eng. Res. Inst. (CMERI), India . 9
Center for Mater. Elect. Tech. (C-MET), India 9
Duke University, Durham, NC 11
Fraunhofer Inst, Germany & Inst of Sound and Vibration, Southampton, UK 12
Independent Researcher, Aerospace Eng.-Prop./MEMS . 13
ITN the "Microactuators" (MICACT) project 14
Queen Mary University of London, London, UK 14
VDI-Society Technologies of Life Sciences 15
Yamagata University, Japan 16
NEW PUBLICATIONS 17
Biological Materials Science 17
FUTURE CONFERENCES 17
EAP ARCHIVES 17
Biomimetics books series 18
Books about robotics 19

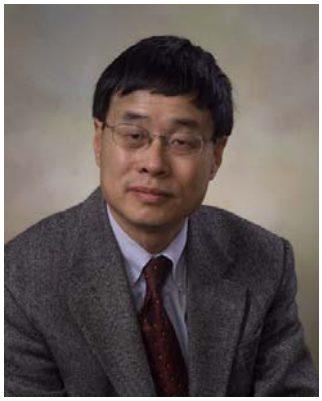
GENERAL NEWS

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

ABOUT OUR EXPERTS

Novasentis Received CTIA Award

Novasentis, Inc. was named a recipient of a Cellular Telecommunications and Internet Association (CTIA) emerging technology (E-Tech) award during the Super Mobility Week (Sept. 9-11, 2014) at the Sands Expo and Convention Center in Las Vegas. Novasentis took third place in the M2M, IoT, Sensors, RFID and NFC category for its Clic™ 1010 Actuator. These are the first Electro-Mechanical Polymer (EMP) products and they are using the world's thinnest polymer



films. Made of a radically new polymer materials, these digitalskin™ can be used for devices that are capable of providing meaningful tactile and acoustic effects synchronized with touch actions. The result is a wider range of feedback or vibrations for hundreds of different activities and messages.

Novasentis was founded in 2006 as StrategicPolymer Sciences, Inc. by Ralph Russo, entrepreneur and former Apple Corporation executive, and Qiming Zhang, distinguished professor of electrical engineering of Penn State University. The company has expanded to include four locations in California, Pennsylvania, Japan and Korea.

Obituary to Ephrahim Garcia

The Smart Structures research community has lost one of its leading scientists - Ephrahim Garcia passed away on September 10, 2014. Ephrahim has been a Professor in the Dept. of Mechanical and Aerospace Engineering at Cornell University. He specialized in electro-mechanical engineering based on smart materials. During the 90s, he was an assistant professor at Vanderbilt University and owned and operated the technology company now known as Dynamic Structures and Materials. According to a University press release, Ephrahim was named by President Bill Clinton in 1993, a National Science Foundation Presidential Faculty Fellow. From 1998 to 2002, he served as a program manager at DARPA. He is attributed for kicking off and managing the Compact Hybrid Actuator Program (CHAP) and also for creating MAS (Morphing Aircraft Structures) and the smart wing program. In 2008, he served as the Editor-in-Chief of the Smart Materials and Structures (SMS) Journal. He is survived by his wife Maria, his son Isaac and daughter Sarah.

POSITIONS AND OPENINGS

2 Postdoc openings at UCLA

The Soft Materials Research Laboratory directed by Qibing Pei in the Dept. of Materials Science and Engineering at University of California, Los Angeles is an interdisciplinary research group developing synthetic polymers and nanocomposites for advanced electronics, electromechanical, and photonic devices. Current research activities include but not limited to dielectric elastomers for muscle-like actuation, bistable electroactive polymers for large-strain rigid-to-rigid actuation, and stretchable electronics. The Dept. has opening for two postdoctoral fellows who will develop functional nanocomposites, dielectric elastomer materials and actuators. One position mainly focuses on materials development, and the other on coating, multilayer stacking, and DEA actuator design and fabrication, with extensive overlap between the two.

Required qualifications include:

1. PhD in polymer science, materials engineering, mechanical engineering, chemical engineering, or related fields
2. Strong hands-on experience in several of these fields: materials development, synthesis of nanocomposites (e.g. graphene nano-composites), nanomaterial processing, polymer thin film coating, compliant electrode materials, 3D printing, multilayer stacking processing, DEA actuator design and fabrication, high voltage converting circuit design and fabrication, characterization of thermal conductivity, modeling of heat transfer processes.
3. Strong communication skill and interpersonal skill

The appointment is initially for 1 year, and may be extended for up to 3 years.

Contact information

Interested candidates may contact Professor Qibing Pei at qpei@seas.ucla.edu for further information.

Equal Employment Opportunity
UCLA is committed to a policy of equal employment opportunity and to the principles of affirmative action in accordance with state and federal laws.

Several PhD student openings at ITN

Innovative Training Network (ITN) will start its "Microactuators" (MICACT) program in January 1st 2015 and it has openings for several PhD students. The program is funded by the H2020-MSCA-ITN-2014 Marie Skłodowska-Curie Actions. The main objective of the project will be the improvement of the career perspectives (in academia and in industry) of young researchers by training them at the forefront of research in the field of smart soft systems made of EAP microactuators for advanced miniaturized devices. This field that involves the use of smart materials is growing extremely fast. The overall objective of this scientific program is research and development of EAP materials and their integration into industrial applications. Special attention will be devoted to the development of microactuators. Materials whose stiffness and shape can be controlled, and that are capable of sensing their shape allow new classes of compliant complex systems. Through the MICACT program, ITN hopes to ensure that European researchers keep their leading role in this blossoming field, and to help them transition to industrial positions.

Contact information
Applications can be submitted to Alvo Aabloo alvo.aabloo@ut.ee or alvo.aabloo@gmail.com

Equal Employment Opportunity
ITN welcomes applications from all individuals, regardless of racial or ethnic origin, age, disability, or sexual identity. ITN is committed to treating all applicants fairly and avoiding discrimination.

UPCOMING CONFERENCES

2015 SPIE EAPAD Conference

The 17th SPIE's EAPAD conference is going to be held March 9-12, 2015, in San Diego, California. This Conference is going to be chaired by Yoseph Bar-Cohen, JPL, and Co-chaired by Gal deBotton, Ben-Gurion Univ. of the Negev, Israel. The Conference Program Committee consists of representatives from 27 countries and they are make from most continents.

The Conference includes 112 papers and they will focus on issues that help transitioning EAP to practical use thru better understanding of the principles responsible for the electro-mechanical behavior, analytical modeling, improved materials and their processing methods, characterization of the properties and performance as well as various applications.

At the EAPAD 2015, the Keynote Speaker is going to be Brett Kennedy, Group Supervisor, Robotic Vehicles & Manipulators, Jet Propulsion Lab (JPL), Pasadena, CA. Brett will review and cover the progress in robotics for planetary applications. Brett Kennedy is currently the Supervisor of the Robotic Vehicles and Manipulators Group at JPL. His areas of expertise include space robotics, bio-inspired robotics, novel mobility systems, robotic manipulators, and underactuated grippers. He graduated from University of California, Berkeley in 1996 with his B.S. in mechanical engineering with an emphasis in controls and robotics. As an undergraduate, he was involved in research covering the design of composite material parts, the design of human amplification mechanisms, and the finite-element modeling of bones. In 1997, he received his M.S. in mechanical engineering from Stanford University concentrating on mechatronics and robotics. At JPL he has divided his time between research and space flight robotics. On the research front, he conceived and led the

development of the bio-inspired Lemur series of robots as well as acting as the lead mechanical engineer a number of other robotic systems. He has also acted as the lead robotic engineer on several DARPA studies of subjects such as orbital telescopes and humanoid robotic mobility. On the flight side, his major role has been as the Cognizant Engineer of the Robotic Arm for the Mars Science Laboratory (MSL), for which he was responsible for the design, fabrication, and testing. Previously, he had also been responsible for two elements of the Mars Exploration Rover (MER) chassis. Currently, he is leading the development of the RoboSimian robot for DARPA's Robotic Challenge.

As in past years, an EAPAD course (http://spie.org/SS12/special-events/Special-Event) will be given on Sunday, March 8, 2015, and the EAP-in-Action Session will be held on Monday, March 9, 2015.

The invited papers include

Su J., and H. Asanuma, "Applications of piezoelectric polymers in electrical power generation using ocean waves", Paper 9430-58

Zhang Q., "Multifunctional electroactive polymers and nanocomposites: fascinating properties and novel applications", Paper 9430-2

Vertechy R., M. Fontana, and S. Superiore, "Dielectric elastomers for wave energy harvesting: current status and future expectations", Paper 9430-4

Farajollahi M., .V. Woehling, C. Plesse, F. Vidal, V. X. D. Yang, F. Sassani, and J. D. W. Madden, "Cylindrical conducting polymer-based trilayer actuator for catheter application", Paper 9430-106

van Kessel R. C. L., A. Wattez,); P. Bauer, and S. Rosset, "Analyses and comparison of an energy harvesting system for dielectric electro active polymer generators using a passive harvesting concept: the voltage-clamped multi-phase system", Paper 9430-5

Quinsaat J. E. Q., S. Dunki, Y. S. Ko, M. Alexandru, C. Racles, F. A. Nüesch, and D. M. Opris, "Dielectric materials, chemistry, and design", Paper 9430-9

Chen W., "Nanoscale engineering of functional materials for high performance electrochemical actuator", Paper 9430-29

Li T., Y. Xie, C. Li, G.g Mao, and S. Qu, "Dielectric elastomer soft machines: mechanics and bionics", Paper 9430-66

The EAP-in-Action Session will include 11 demonstrations which a record for the EAPAD Conference. The demonstrations will be as follows:

Canada – M. S. Sarwar, E. Glitz, S. Kianzad, A. Rafiee, M. Pandit, J. D. Lewis, A. R. Berlingeri, M. Farajollahi, S. E. Takalloo, Y. Dobashi, S. Mirabbasi, E. Cretu and **J D.W. Madden,** University of British Columbia, Vancouver, **"Conducting polymer and nylon-based sensors and actuators"**

Description - The demonstration will feature ionic EAP sensor membranes, miniature trilayer actuators, and large force nylon linear actuators. The nylon thermal actuators, which are helical in form, can be woven into fabrics.

Figure 1: Nylon thermal actuators

China

1. J. Leng, J. Li and L. Liu, Harbin Institute of Technology "**Soft Crawling Robot Based On Dielectric Elastomer"**
   Description - A simple crawling robot based on dielectric elastomer will be demonstrated. This robot is quadrupedal and each feet is a dielectric elastomer based spring-roll actuator having the appropriate deformation and response time. The power supply and control are tethered through wires. The speed of robot crawling can be changed by changing the amplitude and frequency of control signal.

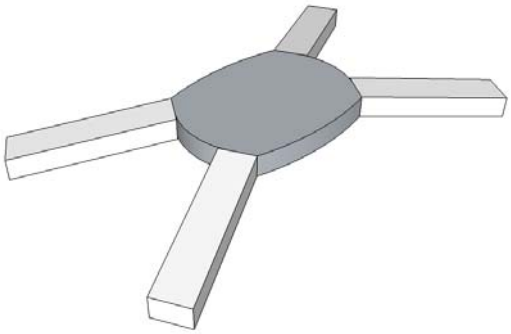


Figure 2: Soft crawling robot

2. T. Li, Chi Li, Y. Xie, and X. Yang, Zhejiang University, Institute of Applied Mechanics, Hangzhou, **"Softrobot Using Dielectric Elastomers"**

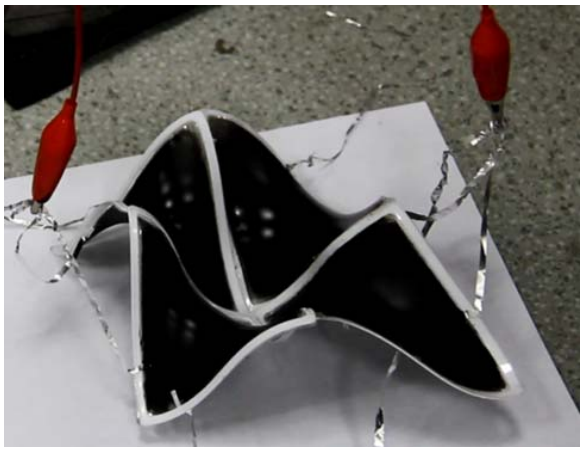


Figure 3: Softrobot

   Description - Inspired by the natural invertebrates like worms and starfish, a novel soft robot is being developed using a flexible elastomer as the body and driven by dielectric elastomer as the actuationmuscle. This configuration makes the robot run fast and resilient to extreme mechanical condition.

Denmark

R. Sarban[1] and A. L. Skov[2] **"Minimum energy structures from dielectric elastomers"**
[1]LEAP Technology, Science and Technology Park,
[2]Department of Chemical and Biochemical Engineering, DTU,
Description - An optimized minimum energy structure will be demonstrated using dielectric elastomers with optimized performance. The figure shows an example of a minimum energy structure.

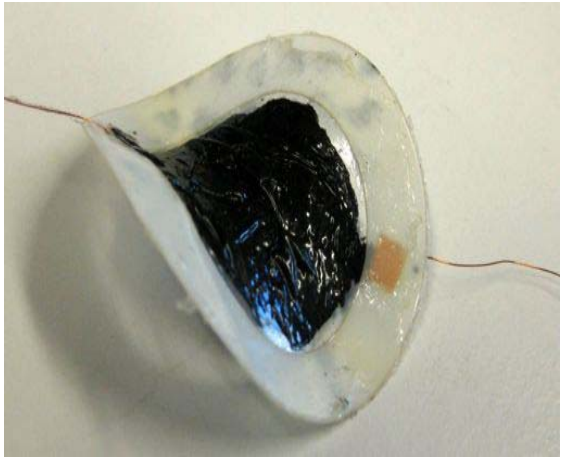


Figure 4: Minimum Energy Structure

Germany

H. Mößinger[1], H. Haus[1], M. B. Saif [2], K. Hofmann[2], Helmut F. Schlaak[1]
[1]Institute of Electromechanical Design, Technische Universität Darmstadt,
[2] Integrated Electronic Systems Lab, Technische Universität Darmstadt,
"**Reduced size electronics for controlling DEA**"
Description - As DEA move closer to the market providing suitable driving and sensing electronics becomes a crucial task. In the ongoing effort to develop small and efficient electronics, Technische Universität Darmstadt presents the first version of their custom designed application-specific integrated circuit (ASIC) for driving up to four DE-

actuators at voltages as high as 700 Volts. A total chip size of 20 mm² was developed that contains four signal generation units capable of generating switching signals in the kHz range, configurable by a serial digital interface.

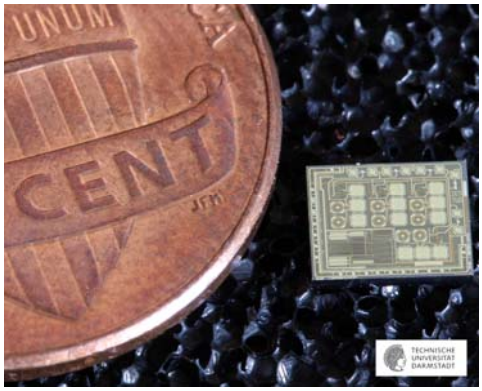


Figure 5: Four channel ASIC for driving DEA compared to the size a US penny.

Japan

M. H. Kabir, J. Gong, M. Makino, and H. Furukawa, Yamagata University, Yamagata, "**Thermo responsive shape recovery soft actuator"**

Figure 6: Thermally active gel used to drive a humanlike figure.

Description - A free forming deformed shape of polymeric gel can recover its original shape and size. The gel shows temperature dependent the functionality. The shape memory effect can be observed both in hot water and hot air. The material is suitable for soft actuator which might be applicable in biomedical science. Using this gel to drive a humanlike figure will be demonstrated along with the shape memory function.

New Zealand

I. Anderson, D. Xu, A. Veale, Biomimetics Lab - www.abi.auckland.ac.nz/biomimetics; and Stretchsense Ltd.- www.stretchsense.com

Applications of dielectric elastomers

Description - The Biomimetics Lab and its spinout StretchSense Ltd. will demonstrate advances leading to exciting wearable and portable energy harvesters as well as soft sensor technologies. The demos will include

Figure 7: Motion capture controller (left) and soft sensor (right)

(1) *An intuitive motion capture controller to play DOOM* – This is one of the first computer games featuring 3D graphics and first-person perspective. This novel game controller will be made from soft wearable sensor technology allowing a design that is more intuitive and simple to use.

(2) *Artificial Muscle Power* - An energy harvester using dielectric elastomer generators will be present in the new version of the Artificial Muscle Power (AMP) device.
(3) *Measuring human body motion* can provide valuable feedback for sports, medical, video and game applications. The latest soft sensor for this purpose will be presented.

Switzerland

S. Rosset, S. Araromi, A. Poulin, L. Maffli, J. Shintake, D. Floreano and H. Shea, EPFL, "**High speed silicone DEAs**"

Description - Precise patterning of robust and wear-resistant electrodes on silicone membranes allows for the fabrication of high-speed dielectric elastomer actuators with a long lifetime. At EPFL-LMTS, a broad range of fabrication processes were developed for the fabrication of high quality silicone membranes and the patterning of compliant electrodes presenting strong adhesion to the dielectric membrane. Several devices are going to be shown to illustrate the related activities. These include tunable lens with a settling time below 200 µm, a soft and compliant 1-g gripper capable of holding an egg, and capacitive sensing devices with miniaturized sub-mm electrodes.

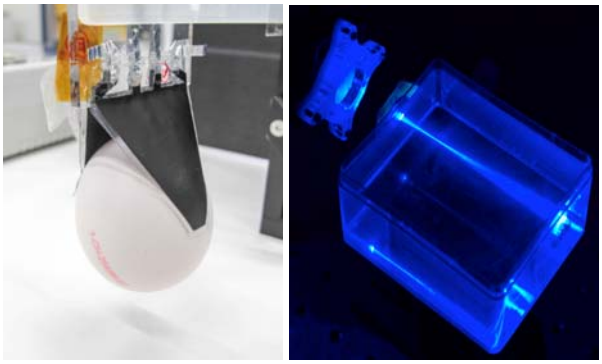


Figure 8: gripper and tunable lens

USA

1. Z. Ren, D. McCoul, W. Hu, and Q. Pei, Dept. of Materials Science and Engineering, University of California, Los Angeles, California, "**New EAP Materials and Actuators"**

   Description - Bistable electroactive polymers (BSEP) combine electrically induced large-strain actuation with a shape memory effect to present a unique opportunity for refreshable, repeated actuation. A new BSEP material will be presented that achieves prolonged cycle lifetimes. This refreshable rigid-to-rigid actuation simultaneously provides large-strain actuation and large load support. Other innovative forms of actuators will also be presented. One such device is a biomimetic pump fabricated from tubular dielectric elastomer actuators.

Figure 9: Actuation of dot actuator on the hotplate at elevated temperature

2. Lenore Rasmussen and Eric Sandberg, Ras Labs, www.raslabs.com, "**Synthetic Muscle™ – Shape-morphing EAP Based Materials and Actuators**

   Description - EAP will be demonstrated contracting and expanding. A thin shape-morphing film of the material in the expansion mode produces raised surface zones in desired shapes. Actuation can be performed using suitable elastomeric coatings, and in 2015 selected synthetic muscle samples are going to be tested for radiation resistance on the International Space Station.

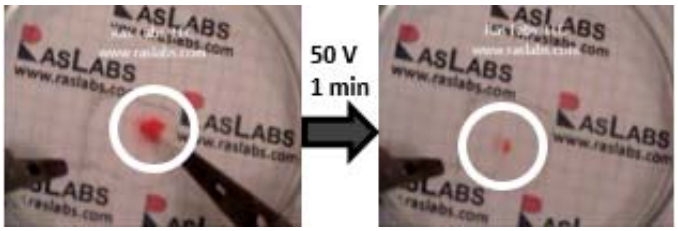


Figure 10: Contracting EAP (dyed red so easy to see)

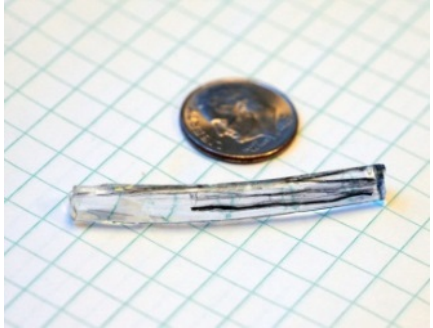


Figure 11: Carbon fiber infused EAP

BAMN 2015

Figure 12: Vancouver, Canada, is the location where the Congress BAMN 2015 will be held.

The 8th World Congress on Biomimetics, Artificial Muscle and Nano-Bio will be held in Vancouver, Canada this year between August 23rd and 26th. The congress follows on from highly successful meetings including Jeju, Korea (www.BAMN2013.org) and Cergy, France (2011). Once again there will be broad coverage of topics (as in the title). It will take place on the campus of the University of British Columbia, surrounded by ocean and forest, 20 minutes from Vancouver International Airport and downtown. Further information can be found at www.BAMN2015.org , and by contacting chair John Madden, jmadden@ece.ubc.ca .

RECENT CONFERENCES

EAP Workshop 2014

Federico Carpi, Queen Mary University of London, UK

An international EAP Workshop was held at Queen Mary University of London, UK, from November 25 to 26, 2014. The program consisted 42 talks and 13 demos presented by delegates from 15 countries. Figure 13: Group photo of the 2014 EAP Workshop participants **Figure 13** shows a group photo of the delegates.

Figure 13: Group photo of the 2014 EAP Workshop participants.

The workshop was organized as the final event that closed the European COST Action grant 'ESNAM - European Scientific Network for Artificial Muscles' (www.esnam.eu). ESNAM has taken place over the last four years which has been gathering the European community in the EAP field, and included by today 70 active institutions. With presentations and demos, the workshop showed the most exciting scientific and technological achievements obtained within ESNAM.

The ESNAM legacy will now be taken by the new-born EuroEAP Society (www.euroeap.eu), which will also manage the annual EuroEAP international conference (www.euroeap.eu/conference).

ADVANCES IN EAP

CSIR, Central Mech. Eng. Res. Inst. (CMERI), India

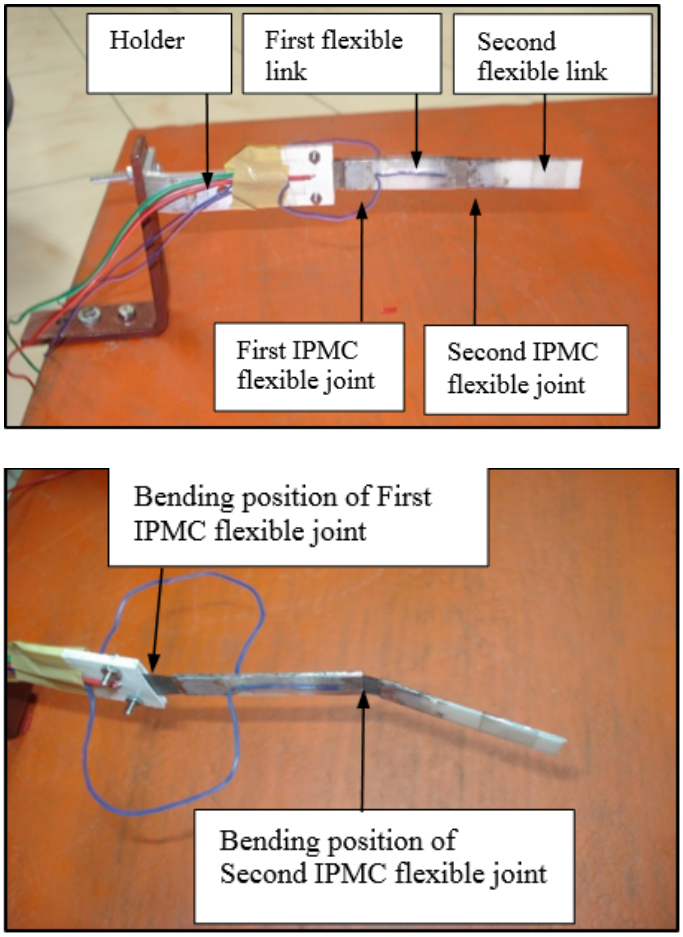
Two Link Based Flexible Manipulator Using IPMC for Soft Micromanipulation

R. K. Jain and S. Majumder, rkjain@cmeri.res.in

In order to develop soft robots, the ionic polymer metal composite (IPMC) provides a good solution compared to the conventional actuation technology of robotics. When using conventional technology, mechanical devices need heavy rigid links, gears and bearing mechanism, conventional motors for rotating joints etc. These major disadvantages lead to producing complex, rigid and noisy systems and they are not feasible for developing the soft robots. In contrast, IPMC materials offer a complementary alternatives to mechanical devices. They are light weight, soft and flexible, noiseless, easy to miniaturize, and permit distributed actuation and sensing. Therefore, CSIR have started designing and developing a novel flexible micro manipulator using IPMC (**Figure 14**).

The developed flexible micro manipulator consists of two flexible links which are made by plastic material and flexible joints driven by IPMC. The size of each flexible link is 40 mm×10mm×0.2mm and flexible IPMC joint is also 40 mm×10mm×0.2mm. One end of flexible manipulator is fixed with holder and other end is free which have movements in desired work space. By providing the small voltage (0-3 V), each IPMC flexible joint is rotated and this provides the bending. Through bending of each IPMC flexible joints, the manipulator attempts locomotion behavior in desired work space. By putting the end-effector or IPMC micro gripper, this can be used for soft micromanipulation.

The developed novel flexible micro manipulator using IPMC demonstrated the capability of the active flexible joint for micromanipulation (**Figure 14**). It showed the positional accuracy, less reaction time and reachable workspace within a short period in soft micromanipulation without using any conventional technology.



Left - Before actuation of IPMC flexible joints
Right - After actuation of IPMC flexible joints

Figure 14: Two links based flexible manipulator using IPMCs

Correspondence Address: R. K. Jain, Senior Scientist, Design of Mechanical System, Group/Micro Robotics Laboratory, CSIR-Central Mechanical Engineering Research Institute (CMERI), Durgapur-713 209, West Bengal, India.
Phone No: +91-343-6452137 (O)

Center for Mater. Elect. Tech. (C-MET), India

Successful Journey of Conducting Polyaniline from Non Soluble and Non Processable Powder to Processable, Aqueous, Ink-jet Printable Ink for Flexible Electronics Applications

Milind V. Kulkarni, milind@cmet.gov.in or milindcmet@yahoo.com

Among the organic conducting polymers, polyaniline (Pani) is regarded as one of the most technologically promising electrically conductive polymers due to its ease of synthesis, low cost, versatile processability and relatively stable electrical conductivity. However, a major problem related to its successful utilization lies in its poor mechanical properties and processability due to its insoluble nature in common organic solvents. In the past few years, much progress has been made to improve both these aspects. Among these areas of progress the approach of the chemical synthesis method and use of functional dopant is more attractive as it eliminates the use of volatile dopant. The functional dopants are introduced in the polymer matrix either by a secondary doping method or by blending the polymer with doping species. The preparation method of polyaniline involves two main techniques (chemical and electrochemical polymerization) using suitable protonation media. We have successfully developed an in situ chemical polymerization process, which yields a processable polyaniline directly without the need for a post-doping process. The reaction is unique, since it is a single step process for the direct synthesis of conducting emeraldine salt phase of the polyaniline and eliminates the post-processing steps which involve: (i) neutralization of the emeraldine salt to form emeraldine base and (ii) reprotonating the base with a second protonic acid.

In our previous publications, we have reported the synthesis, characterization and successful utilization of polyaniline and some of its substituted derivatives for sensing applications [1-3]. Here, we extend this work, by investigating the processable, aqueous, sulphonic acids doped ink-jet printable polyaniline based ink and successive printing of interdigitated (IDT) pattern on flexible, untreated polymeric substrates and its use as a thin, inkjet printed, flexible, humidity sensor. For chemical sensing applications, the more 'open' morphology of inkjet printer films (i.e. a series of connected droplets) may allow rapid diffusion of the water vapor molecules into and out of the film, leading to fast response and recovery times. The advantage of using inkjet print technology for this type of humidity sensor is the high speed and low cost of fabrication as well as the possibility of printing onto flexible substrates.

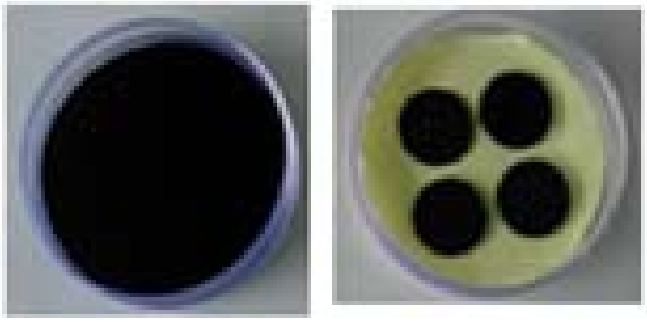


Figure 15: Free flowing powder of polyaniline emeraldine salt and pressed pellets using hydraulic press.

We also have fabricated and demonstrated the polymer based flexible, thin, light weight and ultra low cost battery. The conducting polyaniline was used as a cathode material and aluminum foil as an anode with aqueous saline water soaked paper as an electrolyte for the fabrication of battery. The size of the developed battery is '2.5 cm X 2.5 cm' and weight is just 400-500 mg. The Open circuit voltage (OCV) of the battery was measured and found to be 1.16-1.18 V. The detail electrochemical characterization is in progress in our laboratory.

This conducting polyaniline based aqueous ink will also have potential applications in low cost RFID tags, flexible polymer photovoltaic cells and in printed flexible electronics devices. Recently, we have also developed Silver and Gold nanoparticles, Carbon nanotubes (CNTs) and Graphene based ink for flexible electronics devices.

Figure 16: Polyaniline based ink and inkjet-printed IDT pattern on flexible untreated polymer substrate.

Figure 17: Polyaniline based thin, flexible, light weight batteries

References:

1) Kulkarni M. V., and A. K. Viswanath, "Comparative studies of chemically synthesized polyaniline and poly (o-toluidine) doped with p-toluene sulphonic acid", ***European polymer Journal***, *40 (2004) 379.*
2) Kulkarni M. V., and A. K. Viswanath, "Spectroscopic, thermal and electrical properties of sulphonic acids doped poly (o-anisidine) and their application as humidity sensor", ***Sensors Actuators B Chemical*** *107, 2, (2005) 791*
3) Kulkarni M. V., S. K. Apte, S.D. Naik, J. D. Ambekar, and B. B. Kale, "Processing and formulation of ink-jet printable Conducting Polyaniline based ink for low cost, flexible humidity sensor using untreated polymeric substrate", ***Smart Materials and Structures*** *21, (2012) 03502.*

Duke University, Durham, NC

Synthetic Cephalopod Skin

NC Gossweiler[2], Stephen L. Craig[2], Xuanhe Zhao[1,3,4] zhaox@mit.edu; stephen.craig@duke.edu

[1] *Department of Mechanical Engineering and Materials Science, Duke University, Durham, NC 27708, USA.*

[2] *Department of Chemistry, Duke University, Durham, NC 27708, USA.*

[3] *Soft Active Materials Laboratory, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139, USA;*

[4] *Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139, USA.*

Cephalopods can display dazzling patterns of colors by selectively contracting muscles to reversibly activate chromatophores – pigment-containing cells under their skins. Inspired by this novel coloring strategy found in nature, we design an electro-mechano-chemically responsive elastomer system that can exhibit a wide variety of fluorescent patterns under the control of electric fields.

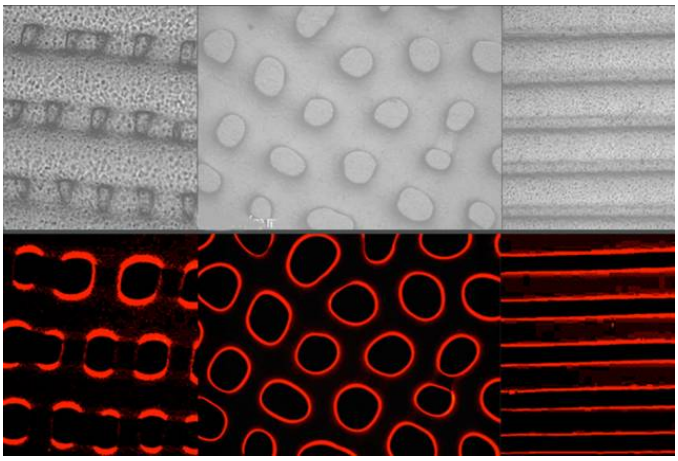


Figure 18: Images show textures (top) and fluorescent light (bottom) produced by the new synthetic elastomer material that can mimic some of the camouflage abilities of octopuses and other cephalopods.

We covalently couple a stretchable elastomer with mechanochromic molecules, which emit strong fluorescent signals if sufficiently deformed. We then use electric fields to induce various patterns of large deformation on the elastomer surface, which displays versatile fluorescent patterns including lines, circles and letters on demand. Theoretical models are further constructed to predict the electrically-induced fluorescent patterns and to guide the design of this class of elastomers and devices. The material and method open promising avenues for creating flexible devices in soft/wet

environments that combine deformation, colorimetric and fluorescent response with topological and chemical changes in response to a single remote signal.

Reference

1. Qiming Wang, Gregory R. Gossweiler, Stephen L. Craig, Xuanhe Zhao, Cephalopod-inspired Design of Electro-mechano-chemically Responsive Elastomers for On-demand Fluorescent Patterning, Nature Communications, 5, 4899 (2014)
2. Squid skin inspires colorful display, Nature, 513, 463 (2014)

Fraunhofer Inst, Germany & Inst of Sound and Vibration, Southampton, UK

DE loudspeaker

William Kaal, Fraunhofer Institute for Structural Durability and System Reliability LBF, Darmstadt, Germany, william.kaal@lbf.fraunhofer.de
Emiliano Rustighi, Institute of Sound and Vibration, Southampton, UK, er@isvr.soton.ac.uk

The Fraunhofer Institute LBF in Darmstadt (Germany) and the Institute of Sound and Vibration (ISVR) in Southampton (UK) are collaborating in a research project on dielectric elastomer (DE) loudspeakers. The loudspeakers are based on the design approach for DE transducers with rigid metallic electrodes comprising a microscopic hole pattern, allowing the elastomer to locally deform in these cavities when a high voltage signal is applied (**Figure 19**). The good conductivity of the metal electrodes compared to flexible electrodes normally used for DE components permit a high frequency operation of the transducers, emitting acoustic waves within and even above the audible frequency range. In addition, since the DE membrane is reacting against a rigid support, such loudspeakers behave differently from conventional flat loudspeaker, they resemble more an array of pistonic loudspeakers and they do not need a loudspeaker enclosure. The flat loudspeaker shown in **Figure 20** consists of 16 active layers of natural rubber as dielectric elastomer and has a thickness of less than 2.2 mm without the housing structure. It has been thoroughly analyzed in the anechoic chamber and by contactless laser measurements and has proven the high potential of the innovative design approach showing an almost flat response in the audible range. It was first presented at the ESNAM closing event held in London in November 2014.

One possible application of flat DE loudspeakers is active noise control. To show the potential of this approach a thin DE loudspeaker (**Figure 21**) was successfully integrated into a double-glazed window and the sound transmission significantly reduced by using a special control algorithm.

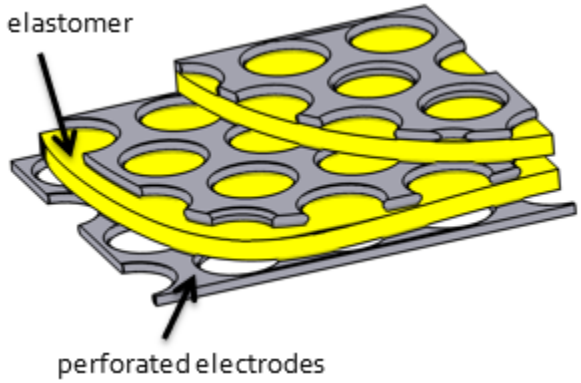


Figure 19: Working principle of dielectric elastomers with perforated electrodes

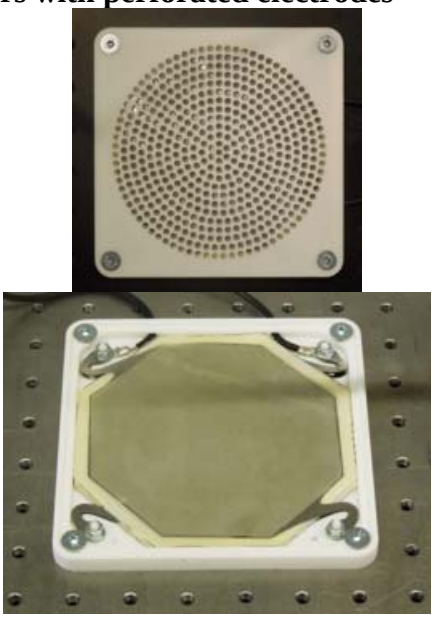


Figure 20: DE loudspeaker (with and without lid)

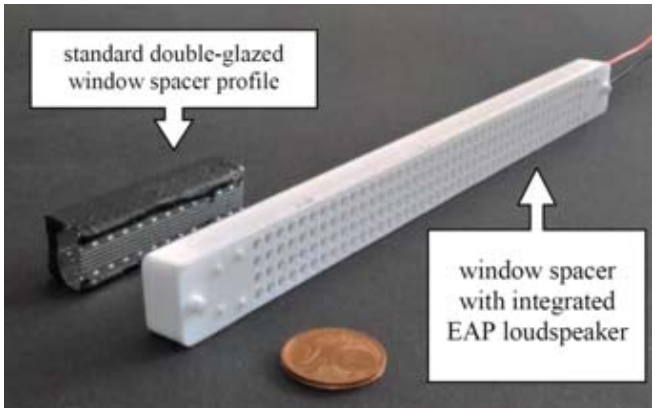


Figure 21: DE loudspeaker for active noise control in double-glazed window

Independent Researcher, Aerospace Eng.-Prop./MEMS

Redesigning Novel Compressor

Babak Aryana, Babak.Aryana@Gmail.com

The redesign process of the previously reported novel DEA compressor [Aryana, 2010] has been continued seeking a proper type of EAP for the compressor and its most important section, the cell. Since no reliable documented empirical data was found as far as the response time of DEA, it was decided to create a new design based on a complete computer simulation.

In first step, a proper material needed to be selected, and then consider the reliability based on the capability to endure higher cycles of work. Accordingly, Soft Silicon improved by Single Wall Carbone Nanotubes was used as reported in [Brochu, 2012]. The type with vinyl:hydride ratios 50:50 was considered since it has the biggest value of Young's module among the others. Using mechanical characteristic of these materials, the process was simulated for an actuator with 2 mm length, 1 mm width and 50 micro meter thickness. To model switch on-off process two steps of loadings were considered, one when the actuator is just under constraints and the other when it is under 400 V electric load. Total time for the process is 0.01 second. **Figure 22** shows the results of the simulation.

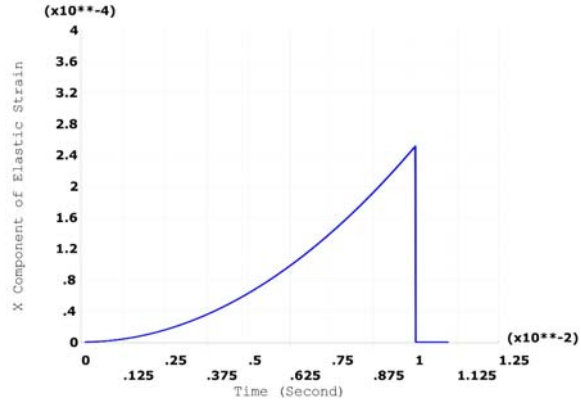


Figure 22: Response time for the model in 0.01 second under 8 MV/m electric field.

According to the results in 0.01 second, which is intended response time in design, an elongation of about 25% elongation was determined. With regard to the design where the elastomer activation is switched off – the cell must sustain a pressure of about 1 MPa. Therefore, another simulation was made to evaluate the capability of the Soft Silicone. Here, the elastomer is subjected to two steps loading: switch on and switch off. After and elongation is generated by the electric field activation, the generated stress was determined under the switched off condition (the negative section in **Figure 23**).

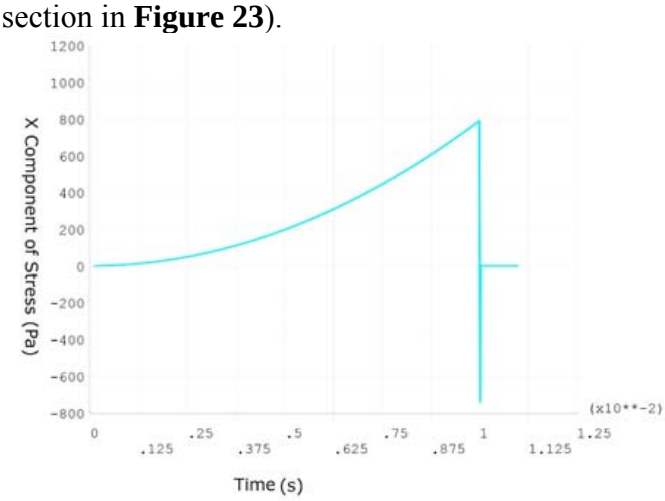


Figure 23: Variation of the X component of stress during switching on and off the electric field.

References

Aryana B., "Implementing DEA to Create a Novel Type of Compressor", Materials Science and

Engineering C 30 (2010) 42–49, doi: http://dx.doi.org/10.1016/j.msec.2009.08.007

Brochu P. A., "Dielectric Elastomers for Actuation and Energy Harvesting", PhD thesis for in Materials Science and Engineering, Electronic Thesis and Dissertations UCLA, 2012

ITN the "Microactuators" (MICACT) project

MICACT network is going start Jan 1st 2015

Alvo Aabloo alvo.aabloo@ut.ee

The Innovative Training Network (ITN) "**Microactuators**" (MICACT) Program is going to start January 1st 2015. The program is going to be funded by the EU H2020-MSCA-ITN-2014 Marie Skłodowska-Curie Actions. The main objective of the project will be the improvement of the career perspectives (in academia and in industry) of young researchers by training them at the forefront of research in the field of smart soft systems made of EAP microactuators for advanced miniaturized devices.

Figure 24: The EU framework program

The overall objective for the scientific program is research and development of EAP materials and their integration for industrial applications. Special attention will be devoted to the development of microactuators. The field of smart materials is growing extremely fast. Materials whose stiffness and shape can be controlled, and that are capable of sensing their shape allow new classes of compliant complex systems. Through the MICACT program, we hope to ensure that European researchers keep their leading role in this blossoming field, and to help them transition to industrial positions.

Queen Mary University of London, London, UK

Wearable wireless tactile display

Gabriele Frediani, Daniele Mazzei, Danilo De Rossi, Federico Carpi f.carpi@qmul.ac.uk

The School of Engineering and Material Science, Queen Mary University of London, London, UK, has recently reported a wearable, wireless, compact and lightweight tactile display. This device is able to mechanically stimulate the fingertip of users, so as to simulate contact with soft bodies in virtual environments.

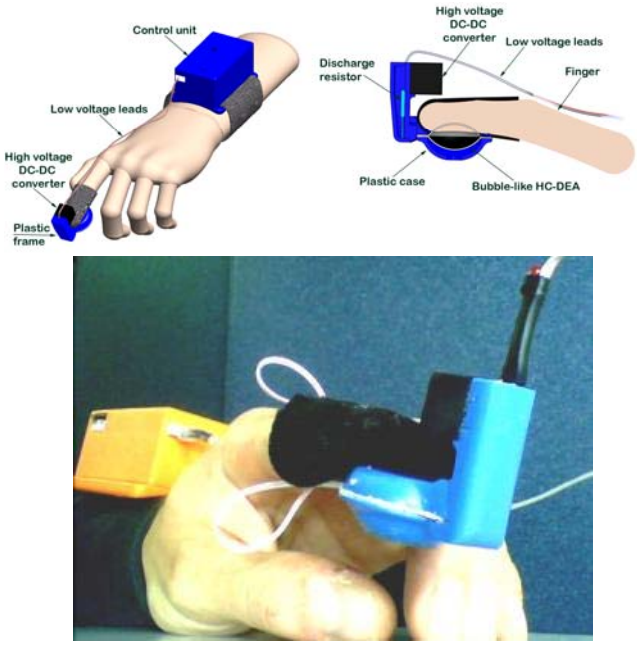


Figure 25: Finger-tip wearable tactile display: (left and center) schematic drawings; (right) picture of a prototype.

The device is based on a hydrostatically coupled dielectric elastomer actuator, which is arranged at the user's fingertip, integrated within a plastic case that also hosts a compact high-voltage circuitry. A custom-made wireless control unit is arranged on the forearm and connected to the display via low-voltage leads. Fig. 1 shows two drawings and a

picture of the system. Design and characterization (both electromechanical and psychophysical) are presented in [Frediani et al., 2014].

Reference

Frediani G., D. Mazzei, D. De Rossi, F. Carpi, "Wearable wireless tactile display for virtual interactions with soft bodies", Frontiers in Bioengineering and Biotechnology, Vol. 2, Article 31, pp. 1-7, 2014.

VDI-Society Technologies of Life Sciences

Development of omniphobic surface structures using springtails as a role model

Angelika Baumann baumann@vdi.de

VDI endowed the International Bionic Award of the Schauenburg-Foundation: Cuticle structure of springtails as a role model for liquid-repellant surfaces (**Figure 26**)

The International Bionic Award of the Schauenburg-Foundation has been endowed this year to a three member, interdisciplinary team from the Leibniz Institute for Polymer Research in Dresden/Germany: René Hensel, Ralf Helbig, and Julia Nickerl for their outstanding work on the development of robust, water- and oil-repellant polymer membranes using the cuticle structure of springtails as a role model. The award was presented by Marc Schauenburg, a representative of the Schauenburg-Foundation, on 24 October 2014 during the Bremen Biomimetic Congress "Inspired by Nature".

The International Bionic Award from the Schauenburg-Foundation was awarded by the VDI Society "Technologies of Life Sciences" (VDI-TLS). The winning team from Saxony characterized the morphology and chemistry of the cuticle of springtails in the context of their work. They were able to transfer the basic features of springtails in terms of their wetting behavior and mechanical stability to an artificial membrane with a bio-inspired surface structure. With the help of this biomimetic approach, the range of application of water-repellant surfaces was extended to include a variety of liquids and was combined with a long-lasting, mechanically stable structural model.

The young scientists impressed the international jury of experts with their idea. "The excellent work is a breakthrough advancement of the well-known Lotus effect", explains jury member Antonia B. Kesel from the University of Bremen. "The unique wetting properties of the cuticle of springtails allowed the development of innovative materials with new areas of application, for example in the area of occupational safety."

Figure 26: Cuticle structure of springtails as a role model for liquid-repellant surfaces (Figure: Leibniz Institute for Polymer Research Dresden e.V./Germany)

"Interdisciplinary collaboration and constructive, out-of-the-box thinking are basic prerequisites in biomimetics and are also the foundation for success of companies", says Marc-Georg Schauenburg, the son of the founder of the Bionic Award. "This year, an especially large number of convincing concepts were submitted." A team from the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA), Stuttgart/Germany, for example, was awarded second place. Kiyoharu Nakajima, Kai Tausch, Patrick Maurer, and Luis Paulo, developed SIREX, a reciprocating rasp for orthopedic surgery based on a model of the wood wasp that may revolutionize orthopedics and prosthetics in future. Furthermore, Adrian Klein and Hendrik Herzog

from the University of Bonn/Germany as well as Harmen Droogendijk from the University of Twente/The Netherlands shared the award for third place.

Figure 27: The evening ceremony (left to right): Juri Tschernjaew (laudatio), Karin Luckey (president Universität Bremen/Germany); Marc Schauenburg (representative Schauenburg-Stiftung); Antonia Kesel (chair of VDI Society Technologies of Life Sciences), Gijs Krijnen (supervisor 3rd place Bionic Award 2014), Julia Nickerl (winner Bionic Award 2014), Kai Tausch (2nd place Bionic Award 2014), Ralf Helbig (winner Bionic Award 2014), René Hensel (winner Bionic Award 2014), Adrian Klein (3rd place Bionic Award 2014), Hendrik Herzog (3rd place Bionic Award 2014) (Picture: VDI / Woppowa)

Biomimetics often generates ideas and acts as an engine for innovation with long-lasting benefits for technology, business, and society. The Bionic Award is endowed by the Schauenburg-Foundation since 2008. The foundation was established in 1986 by Hans-Georg Schauenburg, the founder of the Schauenburg Group, which has existed for over 50 years in Mülheim and der Ruhr in Germany and is managed as a trust fund by the Association of German Industry for the Promotion of Science and the Humanities. The goal pursued by the Schauenburg-Foundation and the VDI with the prize is to promote application-oriented research results and developments as well as innovations by young scientists in the field of biomimetics.

In 2016, the International Bionic Award will be presented for the fifth time. The deadline for submitting applications is February 29, 2016. The conditions for participation and all other relevant information can be found on the homepage of the International Bionic Award at www.vdi.de/bionic2016. The International Bionic Award is endowed with 10.000 € by the Schauenburg-Foundation and will be awarded by VDI.

The VDI, the Association of German Engineers (registered association), represents engineers and technology. With 152,000 members, the VDI is the largest technical scientific association in Germany. As an independent non-profit organization, it is a central contact partner for technical, professional and political questions. Its strong network supports exchanges among the fields of industry, science, society, politics and engineering.

Yamagata University, Japan

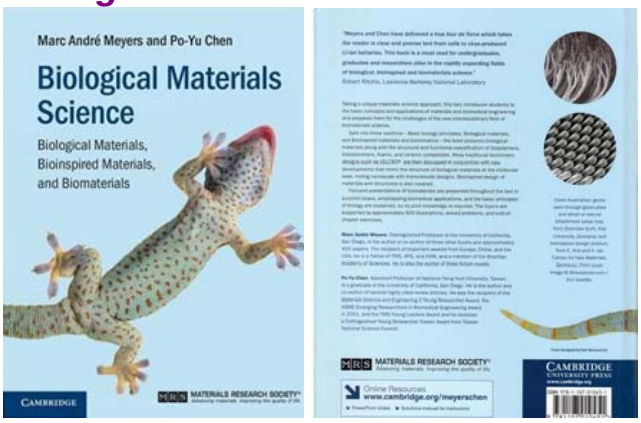
Thermo responsive shape recovery soft actuator

M. Hasnat Kabir, Jin Gong Masato Makino and Hidemitsu Furukawa, furukawa@yz.yamagata-u.ac.jp

A free forming deformed shape of polymeric gel can recover its original shape and size. The gel shows the functionality with temperature. The shape memory effect can be observed both in hot water and in hot air. The material is suitable for soft actuator, contact lens, gel optical fiber for photo coupling, etc. This gel may be applicable in biomedical science due to its biodegradability and biocompatibility properties. A mimicking of a human shape using this gel has been demonstrated along with its shape memory function at the EAP-in-Action Session of the 2014 EAPAD Conference (**Figure 6**).

NEW PUBLICATIONS

Biological Materials Science



The book entitled "Biological Materials Science," authored by Marc Andre and Meyers Po-Yu Chen has been recently published by Cambridge University Press. This 644 page book is intended to be a text that introduces the fertile field of Biology to Materials Science and Mechanical Engineering students. It is written for senior/graduate students and is based on courses that Marc Andre and Meyers Po-Yu Chen taught.

FUTURE CONFERENCES

Date	Conference/Symposium
March 8 - 12, 2015	The 17th EAPAD Conf., SPIE's Smart Structures & Materials and NDE Symposia, will be held in San Diego, CA., For information contact: Megan Artz megana@spie.org, Website: http://spie.org/x12233.xml
June 3 to 6, 2015	7th ECCOMAS Thematic Conference on Smart Structures and Materials will be held at the University of the Azores, Ponta Delgada, Azores, Portugal. Please visit http://www.dem.ist.utl.pt/smart2015/ for up-to-date information.
June 9-10, 2015	The EuroEAP 2015 will take place in Tallin, Estonia. It will be chaired by Alvo Aablo. Detailed information will be made available at http://www.euroeap.eu/conference
August 23 to 26, 2015	The 8th World Congress on Biomimetics, Artificial Muscle and Nano-Bio, will be held on the campus of the University of British Columbia, Vancouver, Canada. Further information can be found at www.BAMN2015.org and by contacting the chair John Madden, jmadden@ece.ubc.ca

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

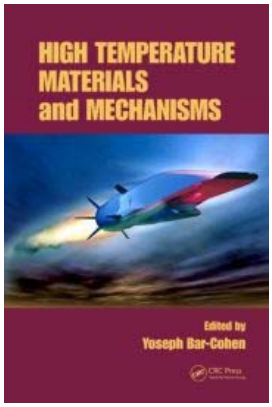
High Temperature Materials and Mechanisms

Yoseph Bar-Cohen (Editor)

http://www.crcpress.com/product/isbn/9781466566453

This book is addressing the growing interest in high-temperature technologies. This book covers technology related to energy, space, aerospace, electronics, metallurgy, and other areas. While some applications involve the use of materials at high temperatures, others require materials processed at high temperatures for use at room temperature.

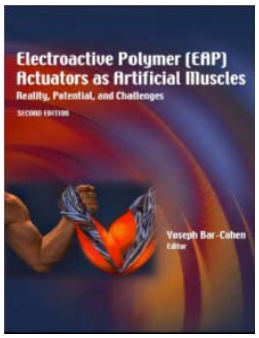
Reflecting the multidisciplinary nature of the subject of high-temperature materials and mechanisms, the chapters bring as broad a perspective to the field as possible and are authored by leading experts in the specific subject. The book addresses the various related science and engineering disciplines, including chemistry, material science, electrical and mechanical engineering, metallurgy, and physics.



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.

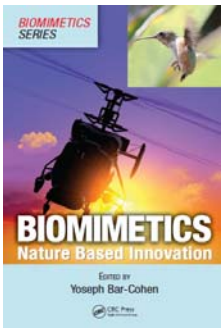


Biomimetics books series

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 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

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

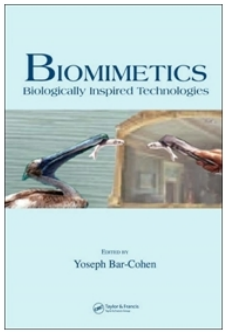
The book entitled "Architecture Follows Nature - Biomimetic Principles for Innovative Design" has been published by CRC Press as part of the book series on Biomimetics for which Y. Bar-Cohen is the editor. The homepage of this book series is:

http://www.crcpress.com/browse/series/?series_id=2719

Biomimetics - Biologically Inspired Technologies

Y. Bar-Cohen (Editor)

http://ndeaa.jpl.nasa.gov/nasa-nde/yosi/yosi-books.htm

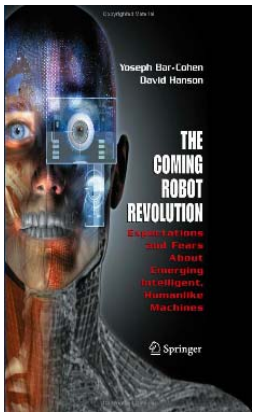


This book about Biomimetics review technologies that were inspired by nature and outlook for potential development in biomimetics in the future. This book is intended as a reference comprehensive document, tutorial resource, and set challenges and vision for the future direction of this field. Leading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

Books about robotics

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

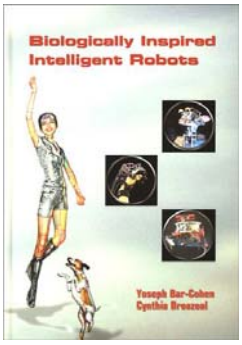
Yoseph, Bar-Cohen and David Hanson (with futuristic illustrations by Adi Marom), Springer, ISBN: 978-0-387-85348-2, (February 2009)



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.

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.

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

Copyright 2014. All rights reserved. Clearance: CL#14-5257, Dec. 11, 2014