WorldWide ElectroActive Polymers

EAP

(Artificial Muscles) Newsletter

Vol. 11, No.2 **WW-EAP Newsletter** **December 2009**

http://eap.jpl.nasa.gov

FROM THE EDITOR

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

The need for niche applications of EAP is still one of the ongoing constraints of this field. One of the possible areas that may offer potential niche is the development in haptic interfaces using EAP actuators. This includes development of Active Braille Display prototypes that are intended to allow for blind persons to read a refreshable full page display. The topic of haptic interfaces and Braille displays is going to be the subject of a Special Session at the upcoming EAPAD Conference of SPIE. It coincides with the 200 years bicentennial birthday of Braille. The EAPAD Conference is going to be held in San Diego in March, 2010 and will include also several demonstrations at the EAP-in-Action Session. At this Session, representatives from the National Braille Press are going to demonstrate commercial active Braille displays in order to give the attendees prospective of the state-of-the-art capability.

GENERAL NEWS

The WW-EAP Webhub is continually being updated with information regarding the EAP activity Worldwide. This webhub can be accessed at http://eap.jpl.nasa.gov and it is a link of the JPL's NDEAA Technologies Webhub of the Advanced Technologies Group having the address: http://ndeaa.jpl.nasa.gov

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ABOUT THE EXPERT

Jinsong Leng selected as SPIE Fellow

Jinsong Leng, who is the co-Chair of the upcoming Electroactive Polymers Actuators and Devices (EAPAD) Conference, was selected by SPIE to become a Fellow. He will formally receive the title in March 2010 during the Smart Structures Conference in San Diego. This selection was made in recognition of his contributions to science and technology as well as to the technical community and to SPIE. Jinsong is a Cheung Kong Scholars Professor at the Harbin Institute of Technology, Centre for Composite Materials and Structures, Harbin, PR China. He is also the Editor-in-Chief of the International Journal of Smart and Nano Materials that was recently established and will have its first issue published in March 2010.

Figure 1: Jinsong Leng presenting a demo at the EAP-in-Action Session of the EAPAD 2008

RECENT CONFERENCES

2009 ASME Conference on Smart Materials

The ASME 2009 Conference on Smart Materials, Adaptive Structures and Intelligent Systems was held on September 21-23, 2009 at Oxnard, California. This conference consisted of 6 Symposia including: Multifunctional Materials; Active Materials, Mechanics and Behavior; Enabling Technologies and Integrated System Design; Structural Health Monitoring/NDE; Modeling, Simulation and Control; and Bio-inspired Smart Materials and Structures. The purpose of this conference was to assemble world experts across engineering and scientific disciplines (mechanical, aerospace, electrical, materials, and civil engineering, biology, physics chemistry, etc) to discuss the latest breakthroughs in smart materials, cutting edge in adaptive structure applications and recent advances in both new device technologies and basic engineering research exploration. This conference included several EAP related papers. For further details about this conference see: http://www.asmeconferences.org/SMASIS09/index.cfm

UPCOMING CONFERENCES

2010 SPIE EAPAD Conference

The 12th SPIE's EAPAD conference is going to be held on March 7 - 11, 2010, in San Diego, California. This Conference will be chaired by Yoseph Bar-Cohen, JPL, and Co-chaired by Jinsong Leng, Harbin Institute of Technology, China. It is interesting to note that the Conference Program Committee has grown in its international nature and includes now representatives from 22 countries as follows: Australia, Canada, China, Czech Republic, Denmark, England, Estonia, Germany, India, Iran, Israel, Italy, Japan, Lebanon, New Zealand, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, and USA.

As in past years, EAPAD will include presentations from leading world experts from the academia, industry, and government agencies in the USA and overseas. This upcoming conference includes 120 papers and it is a record number substantially larger than any prior year where the number of papers was in the 90s. There are going to be 95 oral presentations and 25 posters. Seven of the papers are Invited ones.

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.

In the EAPAD 2010, we are going to have a Special Session entitled "**EAP-based Tactile and Haptic Interfaces/ Displays".** Haptic and tactile interfaces/displays are increasingly becoming part of the tools that are used to interact with and/or thru computers. The general applications include tele-operators and simulators, computer interfaces and video games (e.g., joysticks and Wii), robotics, tactile displays, surgical force-feedback devices, and many others. EAP materials have enormous potential for enabling effective and exciting tactile/haptic mechanisms and Braille Displays are already being developed.

The Keynote Speaker is going to be Bharat Bhushan, The Ohio State University (**Figure 2**) and his presentation is titled “Biomimetics: lessons from nature”.

Figure 2: The EAPAD's Keynote Speaker, Bharat Bhushan, Ohio State University.

Bharat is an Ohio Eminent Scholar and The Howard D. Winbigler Professor in the College of Engineering, and the Director of the Nanoprobe Laboratory for Bio- & Nanotechnology and Biomimetics (NLB^2) at the Ohio State University, Columbus, Ohio. He holds two M.S., a Ph.D. in mechanical engineering/mechanics, an MBA, and three semi-honorary and honorary doctorates. His research interests include fundamental studies with a focus on scanning probe techniques in the interdisciplinary areas of bio/nanotribology, bio/nanomechanics and bio/nanomaterials characterization, and applications to bio/nanotechnology and biomimetics. He has authored 6 scientific books, more than 90 handbook chapters, more than 700 scientific papers (h factor – 42+), and more than 60 scientific reports, edited more than 45 books, and holds 17 U.S. and foreign patents. He is co-editor of Springer NanoScience and Technology Series and Microsystem Technologies. He has organized various international conferences and workshops. He is the recipient of numerous prestigious awards and international fellowships including the Alexander von Humboldt Research Prize for Senior Scientists, Max Planck Foundation Research Award for Outstanding Foreign Scientists, and the Fulbright Senior Scholar Award. He is a member of various professional societies, including the International Academy of Engineering (Russia). He has previously worked for various research labs including IBM Almaden Research Center, San Jose, CA. He has held visiting professor appointments at University of California at Berkeley, University of Cambridge, UK, Technical University Vienna, Austria, University of Paris, Orsay, ETH Zurich and EPFL Lausanne.

The 2010 EAPAD will include the following 7 invited papers:

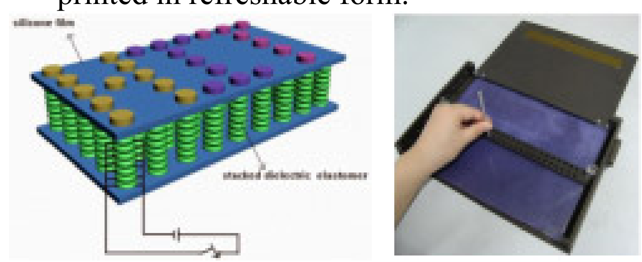
- “Carbon nanotube yarn as a microscale rotational actuator” - Javad Foroughi, Univ. of Wollongong (Australia); Tissaphern Mirfakhrai, The Univ. of British Columbia (Canada); Ray H. Baughman, Shaoli Fang, Mikhail E. Kozlov, The Univ. of Texas at Dallas (United States); John D. W. Madden, The Univ. of British Columbia (Canada); Geoffrey M. Spinks, Gordon G. Wallace, Univ. of Wollongong (Australia)
- “Bistable electroactive polymers (BSEP)” - Qibing Pei, Univ. of California, Los Angeles
- “Materials science on the nano-scale for improvements in actuation properties of dielectric elastomer actuators” - Guggi Kofod, Hristiyan Stoyanov, Matthias Kollosche, Sebastian Risse, Huelya Ragusch, Denis N. McCarthy, Univ. Potsdam (Germany)
- “IPMC: recent progress in modeling, manufacturing, and new applications” - Kwang J. Kim, Univ. of Nevada, Reno (United States)
- “Conducting polymers as simultaneous sensor-actuators” - Toribio Fernandez-Otero, Gemma Vazquez, Laura Valero, Univ. Politécnica de Cartagena (Spain)
- “Dielectric electro active polymers: development of an industry” - Michael J. Tryson, Danfoss PolyPower A/S (United States); Hans-Erik Kiil, Danfoss PolyPower A/S (Denmark)
- “Large planar dielectric elastomer actuators for fish-like propulsion of an airship” - Christa Jordi, Silvain A. Michel, EMPA (Switzerland); Alexander Bormann, Christian Gebhardt,

Aeroix (Germany); Gabor M. Kovacs, EMPA (Switzerland)

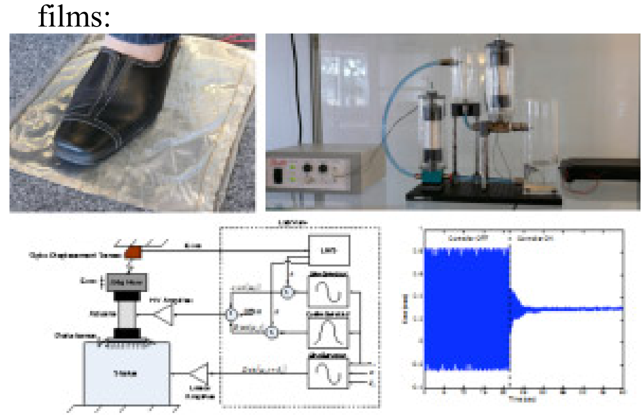
As in past years, a course will be given on Sunday, March 7, and it will provide an overview of the field of EAP covering the state of the art, challenges and potential. The two groups of EAP materials will be described, namely those that involve ionic mechanisms (Ionic EAP), and field activated materials (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, at the University of California, Los Angeles (UCLA) and the topic of ionic EAP materials will be covered by John Madden who is an Assistant Professor of Electrical & Computer Engineering at the University of British Columbia, Vancouver, Canada. The basic mechanisms responsible for the electroactive behavior of EAP materials will be covered and compared with natural muscles. Analytical models, fabrication processes and methods of characterizing these materials will be described. Moreover, the currently considered applications will be reviewed including actuators, robotics, animatronics, medical, and biologically inspired mechanisms, so-called biomimetics. The course begins with an overview of the field, current capabilities, potential and challenges. The course follows with a description of the currently available EAP materials and principles of operating them as actuators and artificial muscles. The course ends with a review of the future prospect of EAP as actuators in systems, mechanisms and smart structures for space, industrial and medical applications. Further information can be found at http://spie.org/x12234.xml

On Monday, March 8, 2008, we are going to hold the EAP-in-Action Session http://spie.org//app/program/index.cfm?fuseaction=secategorydetail&catid=306&event_id=894245&export_id=x12536&ID=x37799&redir=x37799.xml This Session 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 demonstrations of state-of-the-art unique EAP capabilities. This Session offers a forum for interaction between developers and potential users as well as a "hands-on" experience with this emerging technology. It was during this session that the first Human/EAP-Robot Armwrestling Contest was held in 2005. We are going to have 8 research and industry presenters from 5 countries (USA, China, Denmark, Italy, and New Zealand) demonstrating their latest EAP actuators and devices including:

- **Jinsong Leng, Zhen Zhang, Liwu Liu, Xin Lan,** Harbin Institute of Technology (China) *Demonstrating*:
  1) Tactile display using stacked dielectric elastomer: 8×8 matrix tactile display cells actuated by stacked dielectric elastomer with mechanical load-transmitting and voltage control systems.
  2) Braille printer using refreshable shape-memory polymer (SMP) paper: Using thermosetting SMP paper Braille text is printed in refreshable form.



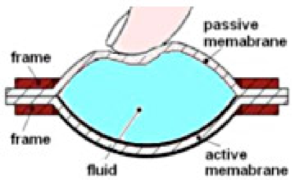
- **HansErik Kiil and Mike Tryson,** Danfoss PolyPower A/S (Denmark) *Demonstrating*: Demos actuated by PolyPower dielectric EAP films:



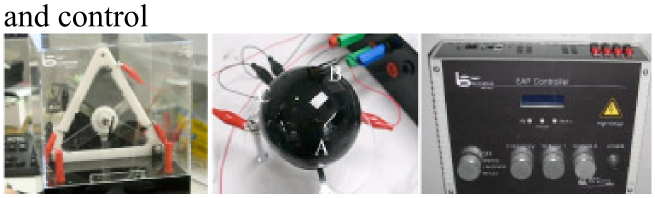
1) High Strain PolyPower Films (>100%)
2) fluid control system using EAP actuators
3) vibration isolation

4) force sensor array.

- **Federico Carpi,** Univ. of Pisa, Research Centre "E. Piaggio" (Italy) *Demonstrating*: Hydro-statically coupled dielectric elastomer actuators: A fluid is used to hydrostatically transfer forces to a load without direct contact with active elements offering improved safety and higher versatility.

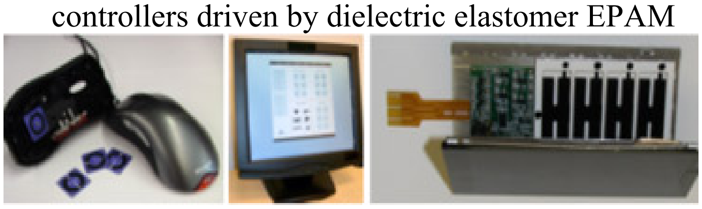


- **Iain Anderson Emilio Calius, Todd Gisby, Thomas McKay and Ben O'Brien** , The Auckland Bioengineering Institute's Biomimetics Lab. (New Zealand) *Demonstrating*: Dielectric elastomer actuator (DEA): demonstrations of actuation, sensing, and control



1) Capacitive, high specific torque rotary motor
2) Biomimetic multi-segment DEA spherical rotor
3) 4-channel EAP controller
4) Other self-sensing and DEA-based demonstrations focusing on bio-inspired DEA

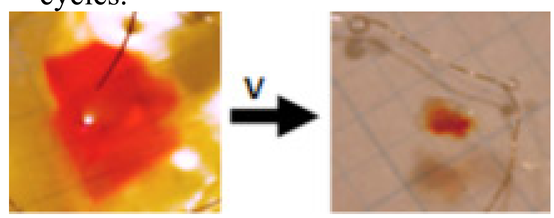
- **Marcus Rosenthal, James Biggs and Al Zarrabi**, Artificial Muscle, Inc. (AMI) (United States) *Demonstrating*: *R*eflex haptic feedback technology: Platforms for consumer electronics including touch screen devices and gaming controllers driven by dielectric elastomer EPAM



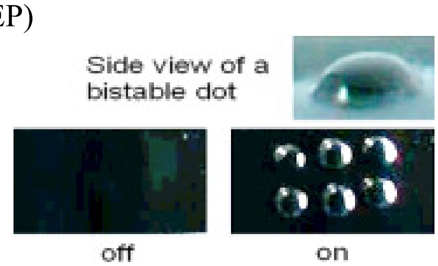
- **Deane Blazie and Noel Runyan**, National Braille Press (United States) *Demonstrating*: Commercial active Braille displays

- **Lenore Rasmussen**, Ras Labs. LLC (United States) *Demonstrating*: Contractile EAPs

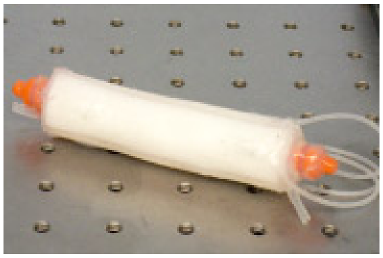
(1) Contractile EAPs with low electric input
(2) EAPs capable of contraction-expansion cycles.



- **Qibing Pei, Zhibin Yu, Paul Brochu, Xiaofan Niu, Wei Yuan, and Huafeng Li,** Univ. of California, Los Angeles (United States) *Demonstrating*: Bi-stable electroactive polymers (BSEP)



- **Erik Steltz and Annan Mozeika**, iRobot G&I Research (United States) *Demonstrating*: Jamming as an Enabling Technology for Soft Robotics



1) Jamming Skin Enabled Locomotion prototype - A completely soft, approximately six inch robot capable of both dramatic self-induced shape change and a rolling gait.
2) Jamming Modulated Unimorph - A new actuator concept in which a central actuator (in this case a pneumatic McKibben actuator) is modulated by jamming chambers to make a controlled, multi-DOF unimorph actuator.

Further information is available at http://spie.org//app/program/index.cfm?fuseaction=conferencedetail&export_id=x12536&ID=x12233&redir=x12233.xml&conference_id=896956&event_id=894245

ACTUATOR 2010

The 12th International ACTUATOR Conference is going to be held on June 14-16, 2010, in Bremen, Germany. Generally, this Conference attracts over 500 participants from more than 30 countries. It covers new actuators including EAP. The participants include executives and researchers from industrial companies as well as institutes, colleges and universities who are interested in the transfer of R&D results into innovative actuator applications and drive technologies. The ACTUATOR Conference is a forum for promoting actuators based on smart materials and micro technologies as well as their applications in all areas of engineering for more than twenty years. Over the years, a large range of ideas and results have been reported and many of them where advanced from concept to mass production. Among the success stories, there are quite a number of established applications of new actuators for use in fuel injection, adaptive shock absorbers, nanopositioning, precision engineering like cameras lenses and other applications of miniaturized drives. Further information about ACTUATOR 2010 is available at http://www.actuator.de

JOURNALS

IEEE/ASME Transactions on Mechatronics

Special Issue on EAP Mechatronics

A focused section is currently being prepared for the IEEE/ASME Transactions on Mechatronics and the guest editors are:
F. Carpi (f.carpi@ing.unipi.it)
R. Kornbluh (roy.kornbluh@sri.com)
P. Sommer-Larsen (pesl@risoe.dtu.dk)
D. De Rossi (d.derossi@ing.unipi.it)
G. Alici (gursel@uow.edu.au)

This special issue is sought in recognition that after years of basic research, today the field of EAP field is starting to transition from academia into commercialization, with companies starting to invest in this technology. The objective of this Focused Section is to disseminate current advances enabled by EAP. Papers are solicited on all aspects of EAP Mechatronics, including materials, devices, modeling, control, conceptual design and characterization, reliability, fabrication, technological and research challenges and applications and the due date is **April 1, 2010.** Manuscripts should be submitted through the online submission service available at: http://mc.manuscriptcentral.com/tmech-ieee. The cover letter should report the following statement: "*This paper is submitted for possible publication in the special issue on Electroactive Polymer Mechatronics*". All manuscripts will be subjected to the peer review process. If there are any questions relating to this Focused Section they can be emailed to one of the Guest Editors. Further information about this call for papers is available at: http://www.ieee-asme-mechatronics.org

International Journal of Smart and Nano Materials

Recently, the International Journal of Smart and Nano Materials was established to provide a forum of publication in the areas of smart materials and nano technology. The Editor-in-Chief is Jinsong Leng, who is a Cheung Kong Scholars Professor at the Harbin Institute of Technology, Harbin, PR China. The first issue is scheduled to be published in March 2010 and will include the following 9 papers:

Multifunctional shape-memory polymer nanocomposite	Jinsong Leng, Centre for Composite Materials and Structures, Harbin Institute of Technology (China)
Green Nanocomposites	Alan K T Lau, Department of Mechanical Engineering, The Hong Kong Polytechnic University (Hong Kong)
Mechanical Behavior of Advanced Composite Laminates Embedded with Carbon Nanotubes	Gang Zhou, Department of Materials, Loughborough University (UK)
Nanocomposites with Auxetic Nanotubes	F Scarpa, University of Bristol (UK)
Fault Tolerant Silicone Dielectric Elastomers	Qibing Pei, University of California, Los Angeles (USA)
Nano-diamond drug delivery technique and feedback system control (FSC) for combinatorial medicine and to discuss the future direction	Chih-Ming Ho, Henry Samueli School of Engineering and Applied Science(USA)
Nanoindentation in Elastoplastic Materials	Majid T. Manzari, George Washington University(USA)
Viscoelastic Behavior of Nanotube Filled Polycarbonate: Effect of Aspect Ratio and Interface Chemistry	Linda Schadler, Materials Science and Engineering Rensselaer Polytechnic Institute(USA)
biologically inspired materials	Sookie S. Bang, South Dakota School of Mines and Technology(USA)

For further information about this journal see http://www.tandf.co.uk/journals/authors/tsnmauth.asp and papers can be submitted to the Editorial Office at ijsnm@hit.edu.cn

Journal of Bionic Engineering

The international Journal of Bionic Engineering (JBE) provides a platform for scientists and engineers to publish their research work in bionics/ biomimetics/ bioinspiration. Its Editorial Board consists of about 50 experts from 14 countries. JBE is sponsored by Jilin University, China, and is currently published quarterly. The electronic version of JBE is distributed at www.ScienceDirect by Elsevier. The scope of JBE includes, but is not limited to, the following areas:

- Study of the locomotion, dynamics and behaviors of animals; application of the knowledge in design and dynamic analysis of robotics, submarine and aircrafts, etc.
- Chemical compositions, mechanical properties, structures and functions of biological and nature materials; development of bio-inspired synthetic materials and devices, such as IPMC and PZT ceramics for artificial muscles and actuators.
- Morphologies of animal and plant surfaces/skins and application in development of novel materials with functional surfaces, such as anti-wear, anti-adhesion, anti-friction and self-cleaning surfaces.
- Self-healing, self-assembling and self-organization of biological systems and application in biomedical engineering, such as developments of artificial limbs and joints.
- Bio-inspired algorithms, such neural-network, genetics and insect colony, and application in information technology, artificial intelligence, control and optimization of engineering systems.

In the last couple of years, JBE has progressed significantly and it is now covered by the Science Citation Index Expanded (SCI-E) and the Engineering Index (EI). Manuscripts are submitted to JBE from all over the world, and over 50% published papers are submitted from outside China. JBE papers have been cited in world top journals, such as Science, Progress in Materials Science, Advances in Cancer Research, Langmuir and Soft Matter etc.

Further information about JBE is available at: http://jbe.jlu.edu.cn/ and papers can be submitted by e-mail to: fsxb@jlu.edu.cn.

ADVANCES IN EAP

China - Harbin Institute of Tech. (HIT)

Electromechanical stability of Mooney-Rivlin-type dielectric elastomer

Jinsong Leng lengjs@hit.edu.cn
http://smart.hit.edu.cn

The stability is analyzed by applying a new kind of free energy model, which couples Ogden elastic strain energy and electric field energy density with nonlinear permittivity. Then, nominal electric field and nominal electric displacement of dielectric elastomer have been induced. Based on this point, the electromechanical stability of Mooney-Rivlin-type dielectric elastomer has been analyzed by simplifying the Ogden elastic strain energy. According to the simulation results, with a larger dimensionless constant k of the dielectric material, the critical nominal electric field gets higher, the corresponding dielectric elastomer or structure is more stable and the electromechanical stability of dielectric elastomer is proved to be remarkably enhanced by the pre-stretching process. These results agree well with the experimental data and can be used as guidance in the design and fabrication of dielectric elastomer actuators.

In recent years, the dielectric elastomer's electromechanical stability analysis is more and more thorough and concrete.[1-5] Based on Kofod's data for VHB 4910, the following relation holds approximately[6],

$$\varepsilon(\lambda_1,\lambda_2,\lambda_3)=\begin{cases}(-0.016S^{\sim}+4.716)\varepsilon_0=(C_1S^{\sim}+C_2)\varepsilon_0, S^{\sim}\le 16\\ 4.48\varepsilon_0, S^{\sim}>16\end{cases}$$

(1)

where ε_0 is permittivity of free space, and $C_1=-0.016, C_2=4.716$ for VHB4910. Note here $S^{\sim}$ is area increase ratio and has a critical value of 16, $S^{\sim}=(1+\lambda_1)(1+\lambda_2)$. By considering the incompressibility of dielectric elastomer, i.e. $\lambda_1\lambda_2\lambda_3=1$, we can get $\lambda_3=1/\lambda_1\lambda_2$.

The Ogden model has been proposed by Ogden in 1972. According to this model, the elastic strain energy function can be written as

$$W_0(\lambda_1,\lambda_2)=\sum_{p=1}^{N}\frac{\mu_p}{\alpha_p}(\lambda_1^{\alpha_p}+\lambda_2^{\alpha_p}+\lambda_1^{-\alpha_p}\lambda_2^{-\alpha_p}-3) \quad (2)$$

where μ_p is material constant determined by experiments, and α_p is a constant (positive or negative real number).

We postulate that $\mu_1=k_2\mu_2=k_3\mu_3=...k_N\mu_N$, k_2, k_3,.... k_N are material constants, the nominal electric field and the nominal electrical displacement can be evaluated.

$$\begin{cases}\begin{cases}\frac{D^{\sim}}{\sqrt{\varepsilon_0\mu_2}}=\sqrt{\frac{2k_2}{N}(\lambda^{\alpha_1-1}-\lambda^{-2\alpha_1-1})+\frac{2(\lambda^{\alpha_2-1}-\lambda^{-2\alpha_2-1})}{N}+\frac{2k_2}{Nk_3}(\lambda^{\alpha_3-1}-\lambda^{-2\alpha_3-1})+...+\frac{2k_2}{Nk_N}(\lambda^{\alpha_N-1}-\lambda^{-2\alpha_N-1})-\frac{2s}{N\mu_2}}\\ \frac{E^{\sim}}{\sqrt{\varepsilon_0\mu_2}}=\sqrt{\frac{2k_2}{P}(\lambda^{\alpha_1-1}-\lambda^{-2\alpha_1-1})+\frac{2(\lambda^{\alpha_2-1}-\lambda^{-2\alpha_2-1})}{P}+\frac{2k_2}{Pk_3}(\lambda^{\alpha_3-1}-\lambda^{-2\alpha_3-1})+...+\frac{2k_2}{Pk_N}(\lambda^{\alpha_N-1}-\lambda^{-2\alpha_N-1})-\frac{2s}{P\mu_2}}\end{cases} & \lambda_1\lambda_2\le\chi\\ \begin{cases}\frac{D^{\sim}}{\sqrt{\varepsilon_0\mu_2}}=\sqrt{k_2c(\lambda^{\alpha_1+4}-\lambda^{-2\alpha_1+4})+c(\lambda^{\alpha_2+4}-\lambda^{-2\alpha_2+4})+\frac{ck_2}{k_3}(\lambda^{\alpha_3+4}-\lambda^{-2\alpha_3+4})+...+\frac{ck_2}{k_N}(\lambda^{\alpha_N+4}-\lambda^{-2\alpha_N+4})-\frac{sc}{\mu_2}\lambda^5}\\ \frac{E^{\sim}}{\sqrt{\varepsilon_0\mu_2}}=\sqrt{\frac{k_2}{c}(\lambda^{\alpha_1-4}-\lambda^{-2\alpha_1-4})+\frac{(\lambda^{\alpha_2-4}-\lambda^{-2\alpha_2-4})}{c}+\frac{k_2}{ck_3}(\lambda^{\alpha_3-4}-\lambda^{-2\alpha_3-4})+...+\frac{k_2}{ck_N}(\lambda^{\alpha_N-4}-\lambda^{-2\alpha_N-4})-\frac{s}{c\mu_2}\lambda^{-3}}\end{cases} & \lambda_1\lambda_2>\chi\end{cases}$$

(3)

where

$$N=\frac{[2C_1(1+\lambda)^2+2C_2+C_1(\lambda^2+\lambda)]}{[C_1(1+\lambda)^2+C_2]^2},$$

$$P=[2C_1(1+\lambda)^2+2C_2+C_1(\lambda^2+\lambda)]\lambda^3, c=4.48.$$

Equation (3) illustrates the electromechanical stability analysis method by applying Ogden elastic strain energy when dielectric elastomer undergoes large deformation under the condition of two kinds of stretching ratios. Evidently they are functions taking the stretch ratio λ as the variable parameter. It means that the relationship between the nominal electric field and the nominal electrical displacement can be derived by changing the value of s/μ_2.

Now consider a special loading case, it is assumed that the DE film is uniformly pre-stretched, $s_1=s_2=s$, and $S^{\sim}\le 16$. We postulate that $n=km$, where k is constant and factorization of the resulting equation gives

$$(\lambda_1-\lambda_2)\{(1+\lambda_1^3\lambda_2^3)+k(\lambda_1^2+\lambda_1\lambda_2+\lambda_2^2-\lambda_1^4\lambda_2^4)+\frac{D^{\sim 2}}{2m\varepsilon_0}[\frac{2(C_1S^{\sim}+C_2)\lambda_1\lambda_2+C_1\lambda_1^3\lambda_2^3}{(C_1S^{\sim}+C_2)^2}]\}=0$$

(4)

The solution of the equation above is that $\lambda_1=\lambda_2=\lambda$, it means that the stretch ratios in the plane two major directions are the same when exerting equal-axis pre-stress over the dielectric elastomer. The equation of nominal stress can be rewritten in another form

$$\frac{D^{\sim}}{\sqrt{m\varepsilon_0}}=\sqrt{\frac{2(\lambda^6-1)}{N}+\frac{2k(\lambda^8-\lambda^2)}{N}-\frac{2s\lambda^5}{Nm}}$$

(5)

where $N=\frac{[2C_1(1+\lambda)^2+2C_2+C_1(\lambda^2+\lambda)]}{[C_1(1+\lambda)^2+C_2]^2}$. Hence the nominal electric field is

$$\frac{E^{\sim}}{\sqrt{m/\varepsilon_0}}=\sqrt{\frac{2(\lambda-\lambda^{-5})+2k(\lambda^3-\lambda^{-3})}{[2C_1(1+\lambda)^2+2C_2+C_1(\lambda^2+\lambda)]\lambda^3}-\frac{2s}{m[2C_1(1+\lambda)^2+2C_2+C_1(\lambda^2+\lambda)]\lambda^3}}$$

(6)

When k is assigned with different values, for the variables in the stretch ratio λ, we can analyze the electromechanical stability of different dielectric elastomers undergoing large deformation process. **Figure 3**(a) (b) (c) (d) represent the relationship between $\frac{D^{\sim}}{\sqrt{m\varepsilon_0}}$ and $\frac{E^{\sim}}{\sqrt{m/\varepsilon_0}}$ when $k=1$ $k=1/2$ $k=1/4$ $k=1/8$. In each case, set $\frac{s}{m}$ different values so that (0, 0.5, 1, 1.5, 2, 2.5), $E^{\sim}$ will reach peak values. The left side of curves separated by these peaks makes Hessian matrix positive definite, conversely, the right side of curves makes Hessian matrix negative definite, however, peaks makes Hessian matrix det (H) = 0. With $\frac{s}{m}$ increasing, nominal electric field decreases for different constants of *k*. The shows that pre-stretch can be enforced to improve stability of dielectric elastomers.

As k increases, the critical electric field increases, indicating that larger value of *k* dielectric elastomer material leading to higher electrical and mechanical stability, the corresponding threshold can be achieved and the thickness of the tensile strain rate is also higher.

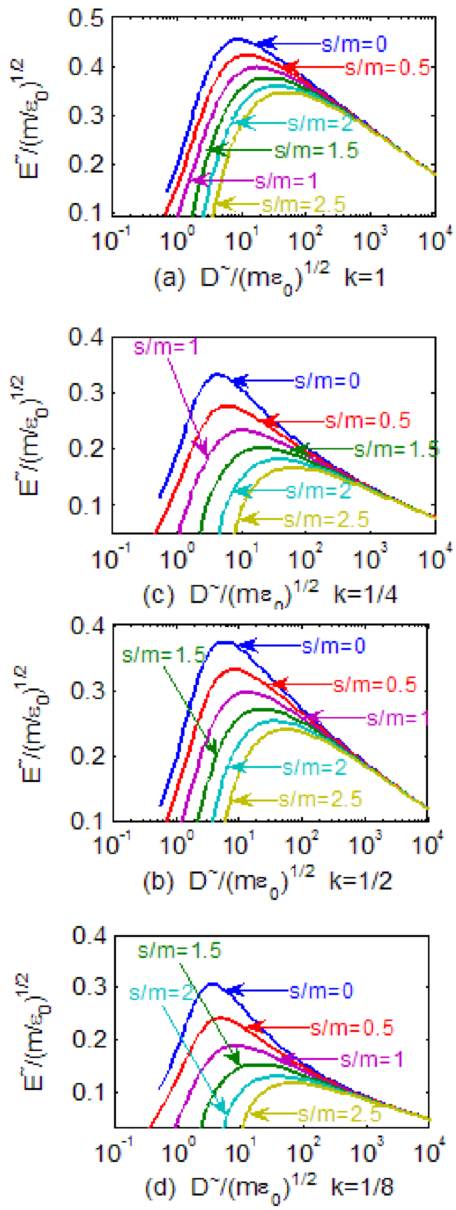


Figure 3: The nominal electric field vs the nominal electric displacement when $k=1$ $\lambda_1=\lambda_2=\lambda$, $S^{\sim}\le 16$

In **Figure 4** shows k (1, 1 / 2, 1 / 4, 1 / 8) for different values the diagram between stretching rate and nominal electric. With the $\frac{s}{m}$ increase can be seen, $\frac{E^{\sim}}{\sqrt{m/\varepsilon_0}}$ is smaller, that is, as the nominal stress increase, the nominal electric field decreases. This shows that dielectric elastomers to impose pretension can significantly improve its electromechanical stability. The electrostriction experiments on the pre-stretching dielectric elastomer by Kofod's group showed that when the two in-plane pre-stretch ratios increase from 0% to 500%, the breakdown electric field increases from 18MV/m to 218MV/m, mounting up 1100%.[6] This means that the electromechanical stability performance is evidently enhanced.

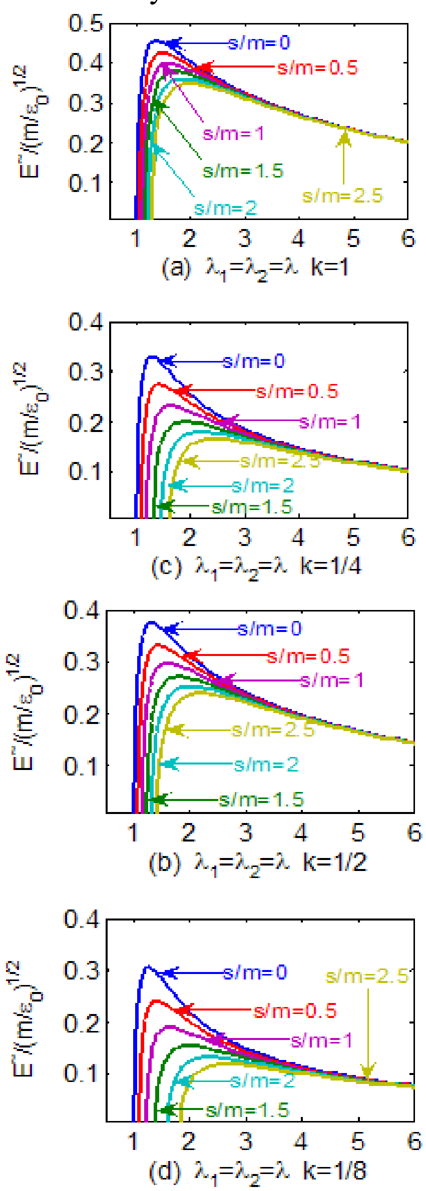


Figure 4: The nominal electric field vs the stretch ratio for $k=1$ $\lambda_1=\lambda_2=\lambda$, $S^{\sim}\leq 16$

For both two situations $S^{\sim}\leq 16$ and $S^{\sim}>16$, it is clear that if DE film is pre-stretched, its permittivity will decrease and the critical nominal electric field will increase (For example $k=1$, the critical nominal electric fields under the two kinds of stretch ratio are $0.4536\sqrt{m/\varepsilon_0}$ and $0.5424\sqrt{m/\varepsilon_0}$ respectively.) Hence, dielectric elastomer treated by pre-stretching shows better electromechanical stability.

The nonlinear expression of permittivity as a function of the stretch ratio is also proposed. In our study, the electromechanical stability is analyzed by a free energy model consisting of Ogden elastic strain energy and electric field energy with non-linear permittivity. Based on the model, the relations between nominal electric displacement and nominal electric field are evaluated. Further, the simple form of Ogden elastic strain energy, with only two material constants, is applied to investigate the stable performance of Mooney-Rivlin-type dielectric elastomer and the critical breakdown electric fields of different dielectric elastomer are evaluated. The pre-stretch deformation can notably improve the performance of film's electromechanical stability. These results match experimental data well and can be applied as guidance in design and fabrication of dielectric elastomer actuators.

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Denmark - Danfoss PolyPower A/S

Students' Innovation Contest

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Since September, Danfoss PolyPower A/S was involved with their initiated students' innovation contest. The challenge that was sought is the *design and construction of the most innovative working prototype that uses PolyPower DEAP technology*. The background for the contest is to facilitate a competition that encourages the development of novel applications that employ their EAP product and promote development of EAP technology. For this purpose, teams of 2-6 students could sign up for the contest and ten teams were selected to compete against each other to win the prize of 10,000 Euros. The selected teams for the contests were:

Application Idea	**Represented University**
DEAP for HVAC systems to reduce energy consumption	Politecnico di Bari, Italy
Wave energy generator: Converting mechanical energy from waves to electrical energy	Norwegian University of Science and Technology
Scavenge energy from wind energy using the DEAP	Tongji University, Shanghai, China
Develop a refreshable cell for Braille displays	University of Pisa, Italy
Using PolyPower film as the basis for a non-invasive breathing monitor, primarily for sleeping infants with known or suspected sleep disordered breathing	University of Queensland, Australia
Using the technology for a very compact, light and elegant solution (sensors) for continuous blood pressure measuring and monitoring	Belgrade University, Serbia
A new pump-solution consisting only of a flexible hose.	University of Technology Hamburg-Harburg, Germany
Developing a universal standard modular component for mounting Micro-fluidics Lab On a Chip (LOC) system on patients.	Danish Technical University, Denmark
To use cables made of PolyPower sheets fastened between a floating pontoon and the bottom of the ocean, to harvest the energy of the waves.	Danish Technical University, Denmark
Develop active and interactive solutions for application in an architectural context.	University Stuttgart Germany

The winner will be selected by the evaluation committee that consists of: Constantinos Mavroidis (Ph.D., Professor; Director of the Biomedical Mechatronics Laboratory at Northeastern University in Boston); Tobias Melz (Dr.-Ing.; Head of Department Mechatronics / Adaptronics at Fraunhofer-Institute for Structural Durability and System Reliability LBF); David Smith (Dr.; Business Development Manager & Magnetics Technical Specialist at TTP, UK); Will Sutherland (Vice President of Operations at Artificial Muscle Inc.) and Mads Thimmer (Co-founder at Innovation Lab, Denmark).

The criteria for the selection of the winner include the degree of innovation; ability to demonstrate unique features of the PolyPower technology; potential for commercialization and reliability of the demonstrated device. The winners are supposed to be announced soon and further information about winning team and all the participating projects see: www.polypower.com.

India - Central Mechanical Engineering Research Institute (CSIR), Durgapur

Control of IPMC-Based Artificial Muscle Using EMG Signal for Hand Prosthesis

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There is an ongoing need for assistive devices such as prosthetic and orthotic devices which are actuated by muscle power. The force is generated by these devices through an electro-mechanical system like an electric motor. Such devices are heavy and are not compatible with muscular system.

Ionic polymer metal composite (IPMC) has potential as artificial muscles and is driven by low voltage in the range of 0-4 V. In this reported study, biomimetic actuating behavior was investigated. The electric voltage is detected by Electromyographic (EMG) signals through human muscles and is passed to IPMC. The actuated IPMC produces bending behavior that is controlled according to the human wrist action. The actuation of IPMC through human muscles is provided by interfacing it with an ADC/DAC card and DAQ Assistant Express VI in LabVIEW 8.5 software. An Electromyographic (EMG) signal generates voltage from the muscles and is fed to the input port of an ADC (Analog–to-Digital Converter) (see **Figure 5**).

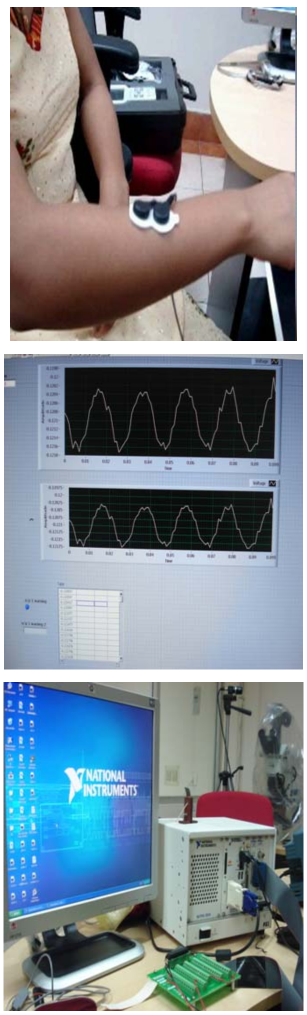

Figure 5: (a) EMG signal placed at body muscles (b) Input and output pulses (c) Interfacing PXI system.

The input parameter from muscles is acquired in the range of 12-30 mV through referenced single-ended (RSE) signal along with continuous sampling rate of pulses. The pulse is amplified with the help of a PXI system and the amplification factor is 400. The desired output voltage range (1-3V) is generated through a DAC port at the same frequency range. The output signal is connected to the IPMC strip. Due to amplified output voltage from the DAC, an IPMC strip bends in one direction as shown in **Figure 6**. By changing the polarity of the signal, the bending behavior can be changed towards the other side. The input and output behavior of the strips are shown in **Figure 7** and **Figure 8**.

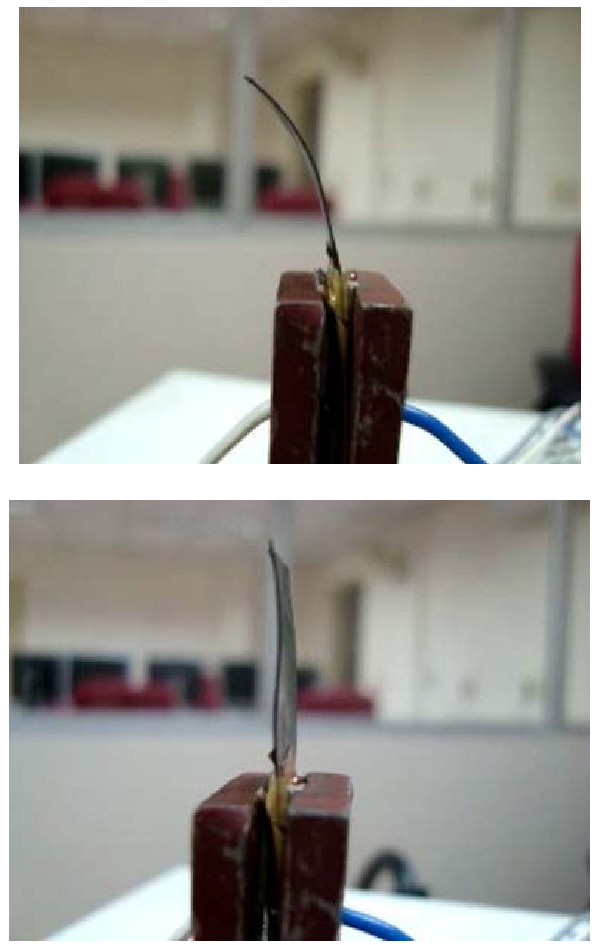

Figure 6: (a) Initial position of IPMC (b) Bending position through muscles

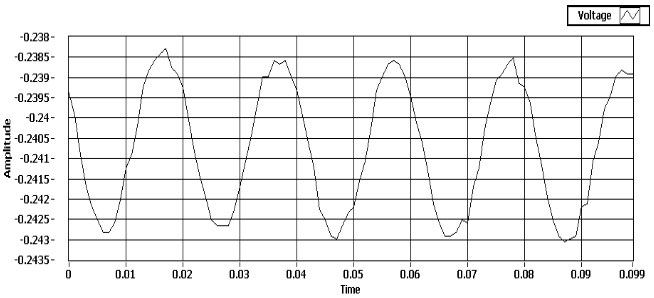

Figure 7: Input voltage vs time when the strip is straight in initial position

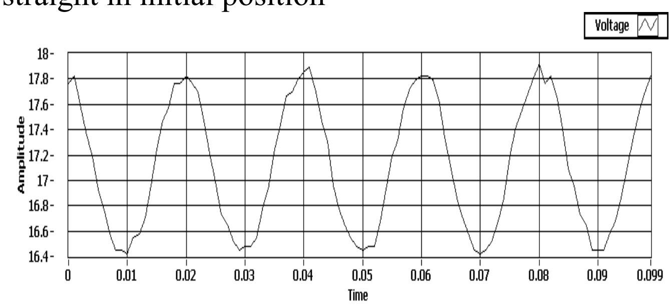

Figure 8: Output voltage vs time when the strip is actuated by muscles

An EMG signal is generated by an intended contraction of muscles in the forearm and provides the actuation to an IPMC. An IPMC acts as both capacitive and resistive element actuator that behaves like biological muscles. This feature can potentially be utilized in the application field of rehabilitation technology and industrial application.

Acknowledgment

The authors are grateful to the Director, Central Mechanical Engineering Research Institute, Durgapur, West Bengal India for providing the permission to publish the articles. The project is financially supported by the Council of Scientific Industrial Research, New Delhi, India under XIth five year plan on "Modular Re-configurable Micro Manufacturing Systems (MRMMS) for Multi Material Desktop Manufacturing Capabilities (NWP-30)". Miss Debanjali Sadhu, Sreyashi Samanta, Koushani Banerjee and Subhasree Mukherjee students of Asansol Engineering College are carried out research work along with authors.

Italy - School of Engineering, University of Pisa

Dielectric elastomer actuators as haptic displays of organ motility and tissue compliance

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We have recently presented a novel approach to develop haptic displays of biological organ motility and tissue compliance, aimed at combining structural simplicity with realistic appearance and consistence. The dielectric elastomer (DE) actuation technology has been used to mimic mechanical passive properties and electromechanical active functions of biological tissues. In particular, prototype displays of cardiac contractility (Figure 2**Figure 9**), pulsatile blood pressure (**Figure 10**) and compliance of soft tissues (**Figure 11**) have been developed and tested.

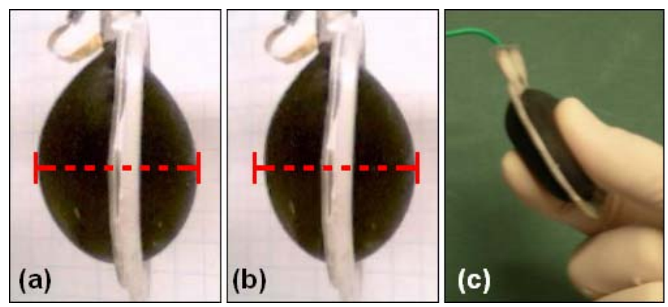

Figure 9: Silicone-made prototype display of cardiac chamber contractility: (a, b) contractility due to an electrical driving of the left-side membrane (the dashed segment can be used for comparison); (c) palpation of the prototype.

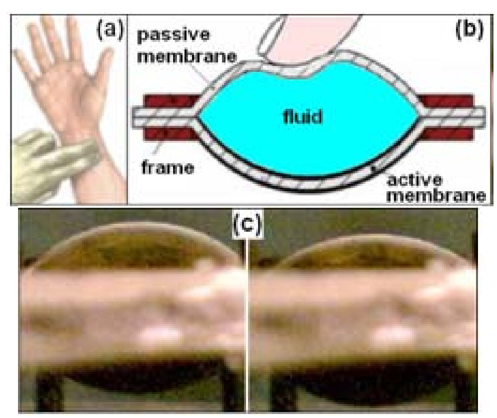

Figure 10: Haptic display of pulsatile blood pressure made of a DE actuator: (a) radial artery

pulse detection; (b) drawing of a sectional view of the device; (c) lateral view of an electrical activation of a silicone-made prototype.

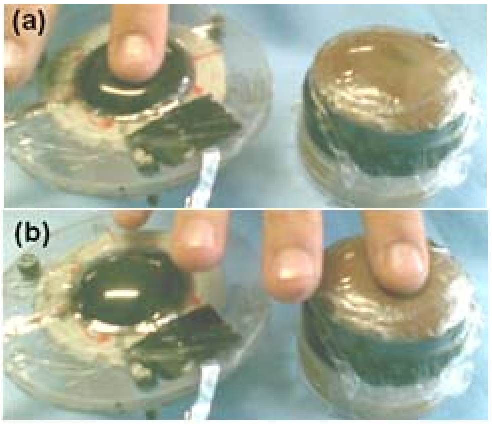

Figure 11: Experimental set-up of a psychophysical test used to compare the compliance of a DE-based haptic device with that of a sample of animal liver.

Interested readers are invited to refer to [1]. Results of proof-of-concept tests reported in [1] suggest that such kinds of displays might offer new opportunities for medical training in cardiology and surgical force feedback in minimally invasive procedures.

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Italy – University of Catania; and Netherland - University of Twente

Characterization of poly[ferrocenylsilane] hydrogels as sensor-actuators

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The goal of this research project is to synthesize and characterize organometallic polyion hydrogels of poly[ferrocenylsilane] (PFS) [1, 2] to produce sensor-actuators. These 'smart materials' are ionic electroactive polymers (EAPs) that expand or contract reversibly during chemical and electrochemical redox. The quick and repeatable response to electrical stimuli is attracting attention because of their potential use as human-like muscles.

Two types of hydrogels composed of redox-responsive poly(ferrocenylsilane) polyanions and polycations were synthesized using covalent crosslinking. The ionic networks showed a large water uptake and could be reversibly dried and rehydrated. Swelling ratios of ± 60 and ± 120 were observed for the polycationic and polyanionic networks, respectively [3]. So far, the activity was focused on the mechanical/electrochemical characterization and the viscoelastic modeling of the polyanionic hydrogel of PFS (**Figure 12**). For this purpose, a novel machine was designed and prototyped (**Figure 13**). The elastic modulus of this material was found between 1.5 - 3.2 kPa by relaxation tests. The best theoretical viscoelastic model experimentally valued was the Maxwell and Kelvin-Voight in series and it is described by the following 4 parameter equation with an error of ± 15.28 Pa (**Figure 14**):

$$\sigma(t) = \frac{\varepsilon_0}{p_1 - p_2}\left[(E_1 p_1 + c)e^{p_1(t-t_0)} - (E_1 p_2 + c)e^{p_2(t-t_0)}\right]$$

Figure 12: PFS polyanion hydrogel.

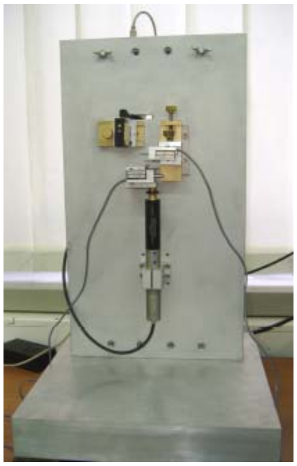

Figure 13: Testing machine.

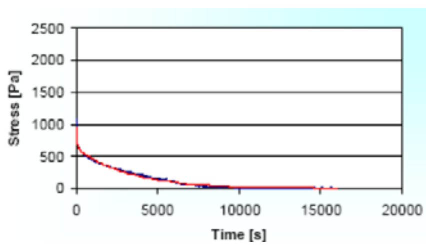

Figure 14: Comparison between relaxation curves, experimental (blue) and theoretical (red).

During cyclic voltammetry tests (**Figure 15**), the polyanionic hydrogel collapses upon oxidation and expands upon reduction. The generated thrust during expansion is proportional to the sample size and therefore to the integrated charge transfer. To create a unidirectional thrust, the hydrogel was put inside a cylinder (**Figure 16**). For samples of 100 mm^3 the force measured was 50 Pa.

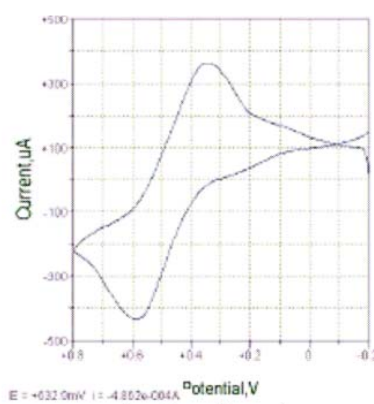

Figure 15: Example of cyclic voltammetry test.

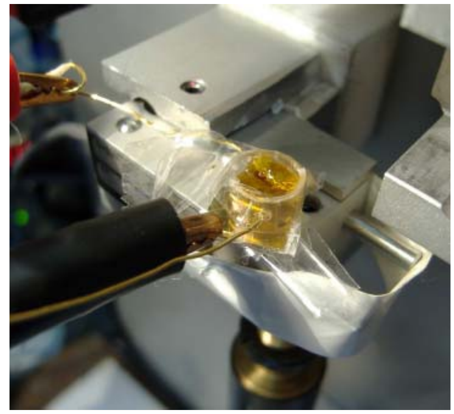

Figure 16: PFS polyanion hydrogel during a cyclic voltammetry test.

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Japan - Kyushu Institute of Technology

Creeping and Enhancement of Electro-chemo-mechanical Deformation in Conducting Polymers under high tensile loads

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Linear soft actuators based on electro-chemo-mechanical deformation (ECMD) of conducting polymers are progressively being developed [1]. The ECMD is caused by injection and ejection of bulky ions as well as conformational change of polymer chains due to the delocalization of πelectron [2]. The ECMD showed large creeping under high tensile loads, due to the rheological variation during electrochemical cycle (EC) [2, 3]. The creeping is a serious problem for the use of actuator. However, by the release of tensile loads the creeping was recovered to some extent [4]. The result has been explained by that the creeping is partially due to anisotropic strain, and the recover results from elasticity or thermal relaxation of polymer chains [4]. It is also found that the stroke of ECMD in polypyrrole [4] after removal of high tensile loads increased somewhat compared with those before the application of high tensile loads. The increased stroke has been explained by an idea of superimpose of the ECMD and the recovery of anisotropic deformation (or creeping).

Figure 17 shows the incremental elongation of the ECMD for a polyaniline (PANi) film with the original length (L_0) of 10 mm. The film showed EC strokes of expansion and contraction (ΔL) being 0.4 ~ 0.6 mm (corresponding strain of 4 ~ 6%) and also creeping, being remarkable for lager tensile loads. By the release of tensile loads, the creeping was recovered more dramatically than the case of polypyrrole [4]. It should be noted that the ΔL after experience of 3MPa was substantially larger than that of initial stage, indicating the training effect. From cyclic voltammograms and ΔL curves vs. injected charges, it was found that the training effect was derived from the increased electrochemical activity, being different from the case of PPy.

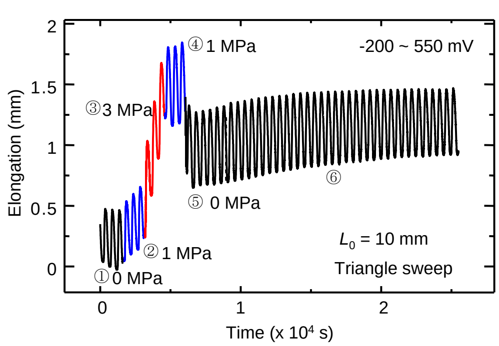

Figure 17: ECMD of PANi film operated by a scan rate of 2mV/s under tensile loads up to 3MPa. ①～⑥ indicate the sequence of measurement.

Acknowledgement

This work has been supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

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Poland - Wroclaw University of Technology

MEMS cantilever micro-dilatometer for EAP thickness strain monitoring

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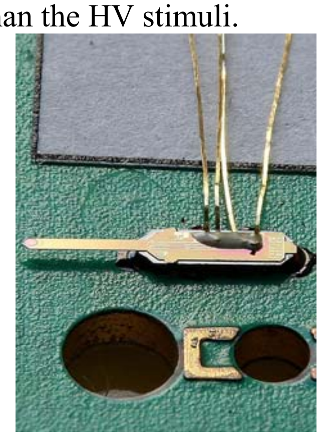
Despite the large (even exceeding 100%) relative mechanical strains that are produced by dielectric electrostatic actuators (DEA), the absolute thickness displacements are microscopic (of the order of μm) due to the thin thickness of DEA specimens. Such small deformations are difficult to monitor because of high elasticity of test samples and interferences produced by strong actuating electric field. Optical laser interferometers [1] or mechanical piezoelectric bimorph cantilever dilatometers [2] are thus commonly applied in measurements and monitoring of electro-mechanical performance of electro-statically-stricted dielectric EAP specimens.

A MEMS-based micromechanical dilatometer was developed for measuring sub-micrometric static as well as dynamic thickness variations of soft polymeric DEA samples. It consists of MEMS cantilever displacement microsensor designed originally as a "sense of touch" for micro-robotic arm manipulator [3], shown in **Figure 18a**. The sensor is fitted with a dielectric 15 mm long stylus attached perpendicularly at the end of the cantilever. The stylus put in contact with the electroded DEA specimen surface transfers its movement to the sensor flexible beam and piezoresistive CMOS Wheatstone bridge build into the beam footing. The

Wheatstone bridge differential output voltage is highly linear with the stylus displacement as it is shown in **Figure 18b**. The sensitivity of the constructed contact micro-dilatometer is on the order of 0.27 µm/mV and, therefore, sub-micrometric displacement measurements are possible.

Application of the developed microdilatometer in monitoring of thickness variations in DEA model made of 10 % pre-strained 225 µm thick 3M VHB acrylic PSA elastomer is illustrated **Figure 19**. DEA model was activated by high voltage step-increasing stimuli ranging from 1 to 4.5 kV (each step lasting 60 s). DEA thickness variations monitored by MEMS microdilatometer are shown in **Figure 19**a. Relative thickness change of the test specimen almost perfectly follows quadratic dependence on actuating voltage (**Figure 19**b) because actuation mechanism in case of VHB DEA actuator is Maxwell stress-related.

The MEMS microdilatometer allows also for dynamic measurements over wide frequency range (from DC up to approximately 5 kHz) because of its stylus and cantilever lightweight construction. Synchronous measurements performed using TREK 610e high voltage amplifier and SR810DSP lock-in amplifier allowed to measure dynamic thickness displacement amplitudes of the order of 20 nm. The additional benefit of synchronous-mode measurement is related to significant attenuation of interferences produced by high-voltage stimuli as the measured MEMS output signal has frequency twice higher than the HV stimuli.



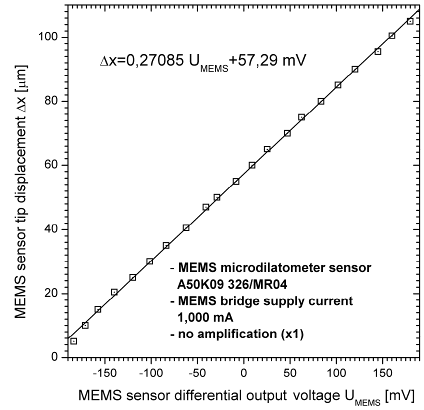


Figure 18: MEMS cantilever displacement microsensor:

a) general view (with no stylus attached);
b) stylus tip displacement-differential output voltage scaling curve (1 mA MEMS piezoresistive Wheatstone bridge supply current).

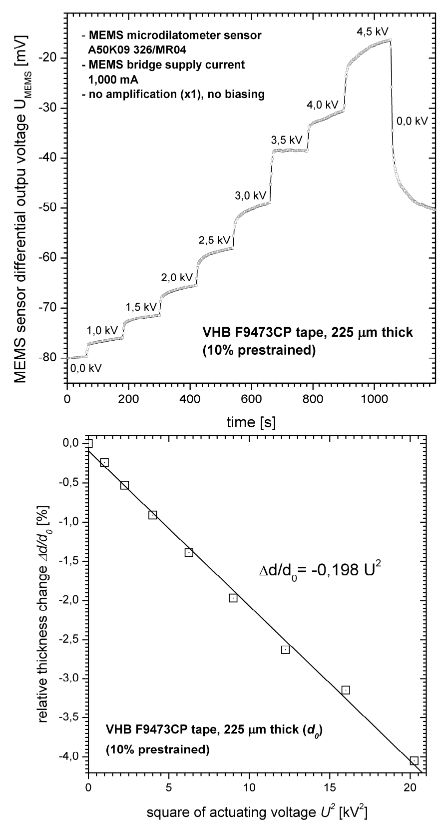


Figure 19: High-voltage field-induced thickness variations in 10% pre-stretched, 225 µm thick acrylic VHB elastomer specimen monitored by MEMS cantilever micro-dilatometer:

a) MEMS sensor response for step HV voltage actuation.

b) MEMS response converted to thickness displacement vs. square root of actuating voltage.

Acknowledgement
The research work presented concisely herein was financially supported within the framework of 2007-2009 science funding program as individual research project no. NN510 2117 33.

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MWCNT stretchable electrodes for EAP applications

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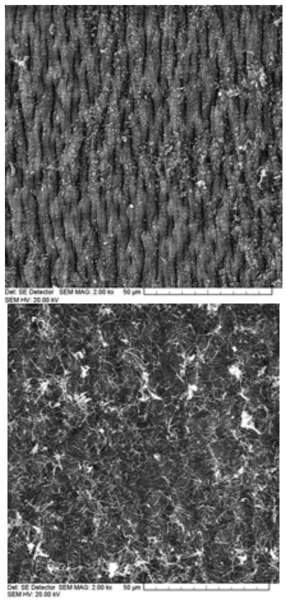
Electroactive polymers (EAP) require thin, highly conducting, compliant and mechanically durable electrodes for their effective operation. Current progress in electroding materials for EAP actuators involves application of various types of conducting grease, electro-conducting silicone rubber-carbon black composites, thin “wrinkled” metallic films, metal ion implantation or “metal rubber” electroconducting molecular films obtained in ESA process. Conducting carbon black powdered electrodes are also applied in case of acrylic pressure sensitive adhesive (PSA) elastomers (like 3M VHB) which are commonly used as electroactive base polymer in dielectric electrostatic DEA actuators. However, dust, grease or colloidal electrodes are subjected to quick wear and coalescence, leading to formation of isolated islands of conducting material on dielectric EAP surface.

Figure 20 shows such effect in HVB PSA elastomer covered with a thin layer of conducting carbon black. After just 2000 cycles of 100% uni-axial stretching a substantial change in the elastomer surface microstructure becomes visible. Transverse ridges emerge, which are weakly covered with carbon black particles accumulating in the grooves. It leads to a substantial (even by several orders of magnitude) drop of the electroding layer conductance. On the other hand, it is suggested (e.g. by Mathew [1]) that high conductance of electrodes is essential in obtaining elevated thickness displacements of DEA actuating structures.

However, as the reported recent research suggests effortless fabrication of highly conductive, durable and elastic dust films deposited on PSA elastomers is still possible using multi-walled carbon nanotube (MWCNT) fine particles. Detrimental effect of quick wear and coalescence may be almost completely eliminated when carbon black is replaced by MWCNT powder mixture, characterized by high (>40) shape factor and high conductivity. A layer of nanotubes deposited (e.g. by simple surface brushing) on sticky PSA surface forms complex, and three-dimensional network of multi-point electrical contacts. Such structure hardly undergo any degradation or deformation even after many substantial and repetitive stretching cycles of the PSA substrate, as it is shown in **Figure 20b**. MWCNT dense mesh arrangement results not only in lower initial resistivity of the MWCNT electroding layer (of the order of 2,4 kΩ/square, measured along the layer) comparing to carbon black coating (10,6 kΩ/square measured for Printex carbon black) but also in maintaining its low value during repetitive stretching. Although MWCNT network is subjected to continuous configuration rearrangement and alteration of contact point density during PSA substrate straining and relaxation yet long nanotubes, when sliding over each other, preserve persistent mutual multipoint ohmic or tunneling electrical contact. They are also not subjected to aggregation and do not take part in ridges formation (see **Figure 20a**). MWCNT deposit also exhibit excellent adhesion to PSA-type elastomers and does not reduce its stretching. Initial tests performed for silicone rubber elastomeric DEA specimens electroded using MWCNT layer also produced appealing results although in this case silicone rubber-MWCNT conducting composite would be more beneficial.



a.

b.

Figure 20: SEM image of conducting thin film compliant electrodes deposited on acrylic pressure sensitive adhesive VHB elastomer (0,25 mm thick) after 2000 uni-axial stretch-relax cycles:
a) conducting carbon black (Printex XL, Degussa)
b) multi-walled carbon nanotubes (Merck).

ACKNOWLEDGEMENT

The research work presented briefly herein was financially supported within the framework of 2007-2009 science funding program as individual research project no. NN510 2117 33.

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Switzerland - EMPA, Dübendorf

Lighter-than-Air Vehicles

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The first EAP propelled airship was made at Empa in collaboration with aeroix GmbH and the Technical University of Berlin. This lighter-than-air vehicle is 8 meters long and consists of a slightly pressurized Helium filled biologically inspired body with the shape of a fish. This vehicle is propelled by Dielectric Elastomer (DE) actuators acting as muscles and deforming the body and wagging its tail in a fish-like manner.

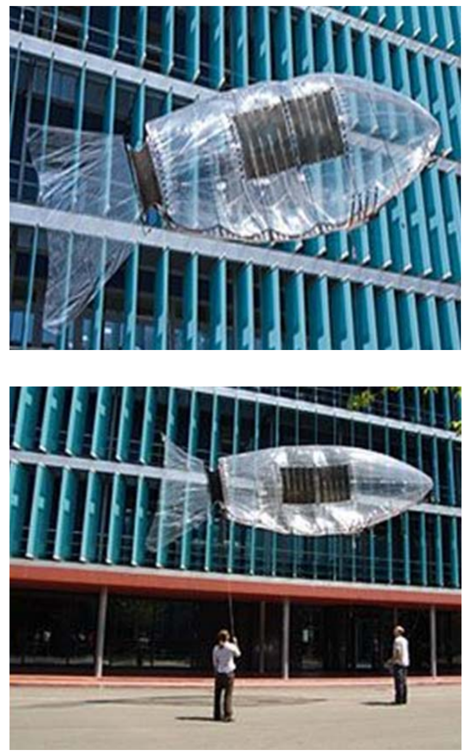


Figure 21: Model of the airship with EAP actuators in black

On this airship, the EAP actuators work in an agonist-antagonist configuration like biological muscles. When the actuators on one side of the airship are activated, their corresponding actuators on the other side are contracting. Thus, the body and tail are excited in an undulating movement, which are propelling the airship like a fish through the air. The EAP actuators can be driven by varying frequency, activation voltage and a phase shift between the body and the tail movement. In fluid-dynamical similarity to the rainbow trout, the appropriate motion pattern (deflections, frequency and phase shift) were defined and verified by wind tunnel tests. The expected travelling velocity was calculated. The “skeleton” and passive parts of the airship consist of an ultra-light carbon-sandwich structure and a model-airship hull material developed by aeroix GmbH in Berlin. The electrical supply and control system was developed at Empa and everything was optimized for minimum of weight. The flight of this fish-like airship can be controlled with a joy stick connected to a ground-based portable computer. The flight control data are processed by a LabView program and transmitted by WLAN to the receiver system in the gondola on the airship. This version of the fully EAP propelled airship had his maiden flight on 16th of July 2009 in Duebendorf Switzerland. For the first time, actuators of this size could be manufactured, characterized and employed and allowed demonstrating the functionality of the fish-like propulsion in air. For further information see www.empa.ch/airship

UPCOMING EVENTS

Date	Conference/Symposium
March 7 - 11, 2010	12th EAPAD Conf., SPIE's Smart Structures & Materials and NDE Symposia, San Diego, CA., For information contact: Rob Whitner, SPIE, mikes@SPIE.org Website: http://spie.org/smart-structures-nde.xml?WT.mc_id=RCALLACE
June 14-16, 2010	ACTUATOR 2010 will be held at Messe Bremen. For further information contact Federico Carpi at f.carpi@ing.unipi.it or Hans-Erik Kiil hekiil@danfoss.com and see www.actuator.de
28 - 30 June 2010	The 5th International Conference on Comparing Design in Nature with Science and Engineering, Pisa, Italy For further information contact Irene Moreno Millan imoreno@wessex.ac.uk Website: http://www.wessex.ac.uk/10-conferences/design-and-nature-2010.html
Nov. 11-13, 2011	3nd International Conf. on Smart materials and Nanotechnology in Engineering, Weihai, China For information contact: Jingsong Leng, lengjinsong@yahoo.com Web: http://smart-nano.org/smn2009

NEW BOOKS

Electroactive Polymer Gel Robots

- Modeling and Control of Artificial Muscles

Mihoko Otake (Author)

The book about EAP Gel Robots is expected to be published by Springer-Verlag in March 2010. This book is Vol. 59 of the Book Series: Springer Tracts in Advanced Robotics, ISBN: 978-3-540-23955-0. This monograph was written by Mihoko Otake and it combines ideas from chemistry and physics, material science and engineering for the revolutionary development of the so-called gel robots. EAP materials are introduced to build new types of muscular-like actuation for deformable robots. The book covers the field from modeling and design to the development, control and experimental testing. A number of methods are proposed for describing the shapes and motions of such systems. The results are demonstrated for beam-shaped gels curling around an object and starfish-shaped gel robots turning over. For more information visit the following webpage. http://www.springer.com/engineering/robotics/book/978-3-540-23955-0

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

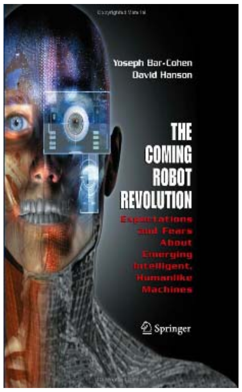
Armwrestling Challenge: http://ndeaa.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-armwrestling.htm

Books and Proceedings:

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

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

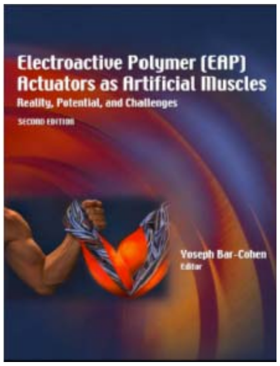
Yoseph, Bar-Cohen and David Hanson (with futuristic illustrations by Adi Marom)



Published in February 2009 by Springer, 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.

2nd Edition of the book on EAP

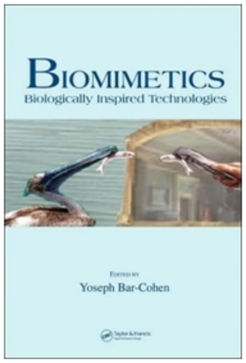
Y. Bar-Cohen (Editor)



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

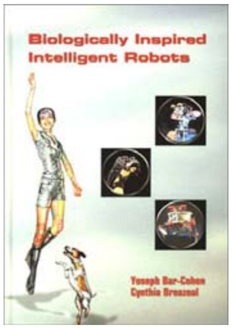
Y. Bar-Cohen (Editor)



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.

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.

WorldWide Electroactive Polymers (EAP) Newsletter

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