

WorldWide ElectroActive Polymers



EAP

(Artificial Muscles) Newsletter

December 2003

WW-EAP Newsletter

Vol. 5, No. 2

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

10th issue

FROM THE EDITOR

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

It is hard to believe but this is the 10th issue of the WW-EAP Newsletter. There are many reasons to celebrate as the field of EAP is continuing to emerge as a viable technology for unique actuators that are biologically inspired. The field infrastructure is strengthening and many advances are continuing to be reported. The significant milestones that were announced in the last issue of this Newsletter, which include the first commercial product and the closeness that we are to the first Armwrestling contest, have received enormous attention from readers and the media. It is pleasing to note that the journal Scientific American had this topic as its cover page article for the month of October. As a feedback from the readers - the author received numerous e-mail inquiries about the potential of the field particularly for medical applications. One important question that has been asked in many e-mail messages: "where can I get these materials?" This issue of unavailability of commercial EAP materials is dampening the rate of progress in the field of EAP. To help users, the author has established a website to provide "recipes" describing how to make the various EAPs. The address of this website is: <http://ndea.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-recipe.htm>. To help further, the author compiled inputs from companies that make EAP materials, and prototype devices or provide EAP related processes and services. The input was

documented in a handy table that it is attached as an Appendix at the end of this issue and in a new WW-EAP website: <http://ndea.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-material-n-products.htm>.

While this list may not cover every company in the world it includes most of the companies that the Editor was aware of their existence.

As the armwrestling competition is becoming a closer reality, preparations are continuing. SPIE agreed to be the hosting and organizing society that will hold the competition in one of its future EAPAD conferences. Tentatively, it is scheduled for March 2005 but the actual date will be contingent on availability of a sizeable prize for the winner or having the agreement of the contestants to participate in the competition without a monetary award.

ABOUT THE EXPERTS

Paul Calvert

Dr Paul Calvert has recently joined the Dept. of Textile Sciences at the University of Massachusetts, Dartmouth as Chairman. The department is changing to encompass all soft materials, to reflect the movement in the local textile industry into advanced and specialty materials. Since 1988, Prof. Calvert has been a



Professor of Materials Science and Engineering at the University of Arizona. He graduated from Cambridge University and MIT, and afterward he taught Polymer Science in the Chemistry Department of the University of Sussex before joining UA. He has published over 200 papers and one book (in collaboration with a rheumatologist on joint diseases). Currently, his research focus is on inkjet printing and solid freeform fabrication as applied to the production of novel materials. Other recent research projects include bio-compatible bone prostheses, biomimetic mineralization, nanocomposite fibers and inkjet printing for OLEDs. He is a member of ICI's Scientific Advisory Board and consults regularly Sandia National Labs. He is editor (with D. de Rossi, M. Petty and T. Tateishi) of Materials Science and Engineering: C Biomimetic and Supramolecular Systems and is on the editorial boards of Journal of Materials Research, Chemistry of Materials, Advanced Materials and Bio-medical materials and engineering.

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T. Selim Eskiizmirliler

T. Selim Eskiizmirliler has been recently appointed as an Assistant Professor of Computational Neurosciences at the University of Denis Diderot (Paris 7) and joined INSERM U483 (National Institute of Health and Medical Research) as a Senior Research Scientist. Prior to this appointment, Eskiizmirliler was Assist. Prof. of Electrical and Electronics Engineering at Department of Technology of Orebro University in Sweden, and he was working as the lab leader of Biologically Inspired Systems Laboratory (BISL) at the Center for Applied Autonomous Sensor Systems (AASS) of



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the same Institution where he was involved mainly with the artificial head and artificial hand projects. His research interests include computational neurosciences, biologically inspired control systems, artificial muscles, sensory-motor information fusion, and digital signal & image processing.

At his new affiliation, together with Marc Maier, Selim is establishing a new of Biologically Inspired Systems Research Laboratory, where he will continue his investigation and development of robotic systems actuated by artificial muscles, including research on biological sensory-motor information fusion and dexterous manipulation in close collaboration with the research group at the BISL-AASS of Orebro University.

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GENERAL NEWS

The WW-EAP Webhub is continually being updated with information regarding the EAP activity

Worldwide. This webhub is a web-address link of the JPL's NDEAA Technologies Website: <http://ndeaa.jpl.nasa.gov>

The first armwrestling match is getting closer

In response to the statement that researchers from SRI International made that they believe they have the capability to meet the Armwrestling challenge preparation are underway for the 1st Armwrestling Match of EAP Robotic Arm against Human (AMERAH).

SPIE agreed to be the hosting and organizing society and to hold the competition in one of its future EAPAD conferences. Tentatively, it is scheduled for March 2005 but the actual date will be contingent upon availability of a prize for the winner or having the agreement of the contestants to participate in the competition without seeking monetary award. The selection of the committee members have already begun and information about the competition is updated on the especially dedicated WW-EAP website:

<http://ndeaa.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-armwrestling.htm>

2004 SPIE EAPAD Conference

The EAPAD Conferences started in 1999 and it is continuing to be the leading international forum for the field of EAP. The conference is held in San Diego, California, over four days from March 15 to 18, 2004. The presentations will cover a broad range of topics from analytical modeling to application. The program of the EAPAD 2004 Conference is available as a link thru:

<http://spie.org/Conferences/Programs/04/ss/conferences/>. The papers are going to focus on issues that can 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 properties/performance characterization as well as various applications.

The upcoming conference will be opened with another interesting and exciting Keynote presentation. The speaker will be Hugh Herr (Figure 1) from the MIT-Harvard Division of Health Sciences and Technology and his presentation is entitled "New horizons for orthotic and prosthetic technology: merging body and machine." In this presentation he will

cover the topic of artificial limbs and prosthetics to which EAP can contribute enormously.



FIGURE 1: The Keynote Speaker, Hugh Herr, MIT As in the previous EAPAD conferences, another

EAP-in-Action Session is planned for Mon., March 15, 2004, where some of the latest practical implementations of EAP will be demonstrated. This Session is a forum of interaction between the technology developers and potential users and it offers a "hands-on" experience with this emerging technology. During this session, the attendees are given opportunity to see demonstrations of EAP actuators and devices.

On Wed. March 17, 2004, an Open Panel Discussion Session will be held to debut the status of the field of EAP. The conference Chair, Cochair, and the invited speakers will serve as the discussion panelists. Each of the panelists will be given an opportunity to make a short statement and the attendees will be invited to express their thoughts and to debut the topics that will be presented. This session is intended to stimulate ideas and thought and help define the future direction of the development of EAP. The three key topics for the open discussion include:

- Areas of EAP weakness and shortcoming of the EAP technology infrastructure.
- What is the gap between the needed and available EAP and how to bridge it.
- Future science and engineering directions.

Course on EAP during the EAPAD 2004

An introductory course about EAP is planned to be held on Sunday, March 14, 2004 as part of the EAPAD 2004 Conference. The course is entitled "Electroactive Polymer Actuators and Devices," and lead the instructor is the Editor, Y. Bar-Cohen, who will present an overview, and cover applications that

are currently developed and ones that are being considered. The subject of Ionic EAP will be covered by J. Madden from the University of British Columbia, Vancouver, Canada. Further, the topic of Electronic EAP will be covered by J. Su from NASA Langley Research Center, USA. This course is intended for Engineers, scientists and managers who need to understand the basic concepts of EAP, or are interested in learning, applying or engineering mechanisms or devices using EAP materials. Also, it is intended for those who are considering research and development in EAP materials and their present and/or future applications. Details about this SPIE course are available thru:

http://spie.org/app/education/index.cfm?fuseaction=offeringdetail&offering_id=553259

2nd Conference on Artificial Muscles - Biomimetic System Engineering

The 2nd conference on Artificial Muscles - Biomimetic System Engineering will be held on May 20-21, 2004 at AIST, Kansai, Ikeda Osaka, Japan. This conference is sponsored by Special Division for Human Life Technology, National Institute of Advanced Industrial Science and Technology (AIST), as well as several companies and technical societies from Japan who are involved with biomimetics, biophysics and robotics. Papers are being sought on the following three topics:

1. The biomolecular systems as models for artificial systems,
2. The functional polymers as artificial soft materials,
3. The integrated bio-mimetic system including the artificial muscles.

The invited speakers in this conference are: Y. Bar-Cohen (JPL/Caltech/NASA, USA); T. F. Otero (Cartagena, Spain); N. Hogan (MIT, USA); R. H. Baughman (Univ. of Texas at Dallas, USA); Y. Osada (Hokkaido Univ., Japan); K. Kaneto (Kyusyu Institute of Tech., Japan); T. Hirai (Shinshu Univ., Japan); Y. Maeda (RIKEN, Japan); T. Yoshikawa (Kyoto Univ., Japan); and S. Hosoe (RIKEN, Nagoya Univ., Japan)

200-words size abstracts are due on Jan., 10, 2004 and the Proceedings manuscript (2-4 A4 Pages) is due on Feb., 28, 2004. Abstracts should be written in English and submitted to Dr. Kinji Asaka via e-mail address asaka-kinji@aist.go.jp.

2nd World Biomimetics Congress

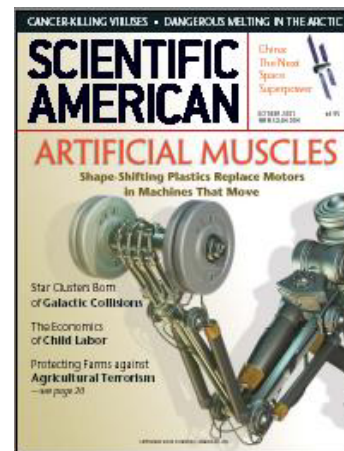
The 2nd Biomimetics world congress will be held in July 25-28, 2004 at the historic Colonial Williamsburg's Hospitality House. The submittal of abstracts and papers to this Biomimetics, Artificial Muscles & Nano-Bio 2004 World Congress can be done via the following web address www.world-congress.net. The third world congress will be held at INSA, Lyon, France in August of 2005. A new non-profit society of "Biomimetics" has also been registered and is now accepting members. For information or to become a member you can contact Mohsen Shahinpoor (shah@unm.edu).

MEDIA COVERAGE

The media is increasingly recognizing that the significance of the field of EAP, its being inspiring to the public as well as its enormous potential to bringing great benefits to humans and to turning science fiction ideas to engineering reality. This interest in the subject of EAP or more specifically the artificial muscle aspect, i.e., actuators with a large displacement and strong force, is drawing significant interest. Further, the Armwrestling challenge has added an exciting aspect to the progress in this field. In the last three months, the topic of EAP and related technology was on the cover page of three popular technical journals that include Popular Science, Scientific American and the Industrial Physicist. Reaching such a visibility cannot be left unnoticed and the Editor decided to add this Section to the 10th issue of the Newsletter and briefly cover these articles.

EAP - Cover page article of Scientific American

The topic of EAP has been the cover page subject of the October issue of Scientific American. The article was authored by Steve Ashley and it is entitled "Artificial Muscles," (pp. 52-59). The author was inspired by the major milestones for



the field of EAP as mentioned in the section “From the Editor” in the previous issue of this Newsletter. While describing the activity in various labs worldwide, major part of the discussion reviewed the activity at SRI International and their dielectric EAP type actuator and the various applications that are being pursued towards potential commercial products.

Industrial Physicist –ERF the fluid EAP for Haptics

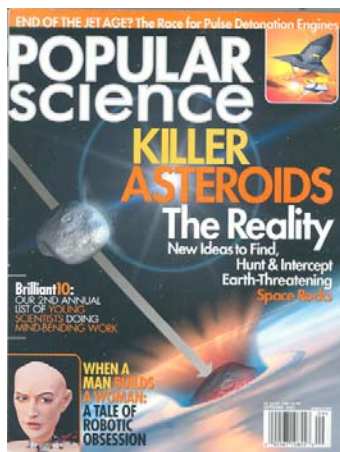
The December-03/January-04 issue of the journal The Industrial Physicist has the cover page article on the topic of haptic interfaces using Electro-rheological Fluids (a fluid type EAP). The article is covering the recent development in this field towards



introduction of products in the marketplace. Some of the technology that is described includes virtual surgery and robotic telepresence. The page 14 thru 17 article is entitled “Smart fluids move into the marketplace,” and the article was authored by J. Ouellette.

Popular Science – Biomimetic Robots

The September issue of the journal Popular Science (a photo on the cover page) covered the topic of biologically inspired robots with a focus on the human face. The page 60 thru 70 article is entitled “The man who mistook his girlfriend for a robot,” was authored by D. Ferber. The article reviews the topic of biomimetic robots



with mostly describing David Hanson’s work on androids and his efforts to incorporate EAP actuators. Hanson is formerly from Imagineering, Disney, and he currently working on his PhD at the University of Texas, Dallas. In his thesis he is combining art and engineering where EAP driven robots can play an important role. A view of Hanson and one of his android heads from the article is shown in Figure 2. It is interesting to mention that Hanson prepared an Android head that is available at the JPL’s NDEAA Lab as a test-bed for the worldwide EAP community to demonstrate developed artificial muscle as actuators. Hanson has been presenting his latest android heads in each of the last three “EAP-in-Action” Sessions of the SPIE EAPAD Conference and he is also planning to do so in the upcoming Conference in March.



FIGURE 2: David Hanson and one of his android heads shown in the Popular Science article.

EAP ADVANCEMENTS

JAPAN - Tokyo Institute of Tech., RIKEN and AIST

Development of linear muscle actuator with redoping capability and its application to a walking robot

M. Yamakita (Tokyo Institute of Technology), N. Kamamichi (Tokyo Institute of Technology), Z. W. Luo (RIKEN), K. Asaka (AIST)
yamakita@ctrl.titech.ac.jp

A linear muscle actuator composed of IPMC films as depicted shown in Fig. 3 is currently being developed. As shown in Fig. 4 (a) and (b), the bending characteristics and current of IPMC film are highly affected by doped counter ions. Therefore, it should be possibility to change the properties of the

actuator according to environment or purpose. In an effort to develop a walking mechanism, the property can be changed such that the actuator is suitable for slow walking with low energy consumption or fast walking with high energy consumption, or possibly even allow running. We investigated the possibility of such an adaptation by experimenting with doping of the actuator for walking control using numerical simulations. It is interesting to point out that for the IPMC films the doped ion can be exchanged as many times as required.

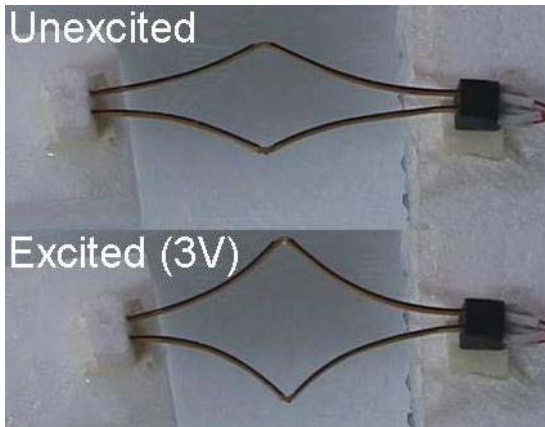
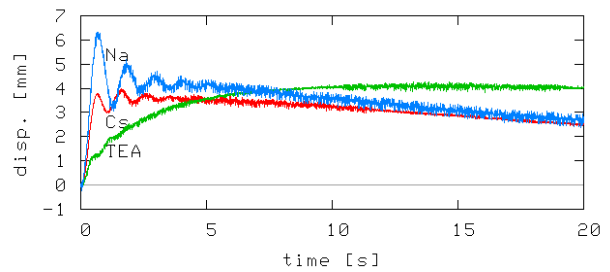


FIGURE 3: The structure of the actuator

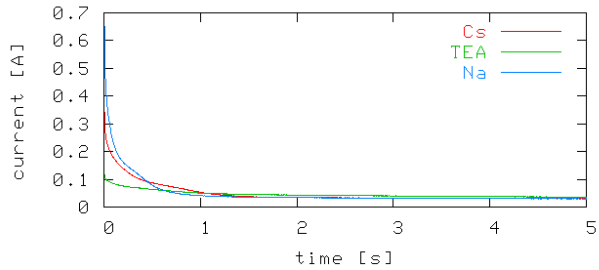
We compared at a same input voltage the walking speeds and walking efficiencies for actuators that are composed of IPMC films doped with Na^+ and Cs^+ . For this purpose, we considered a compass-like walking robot with the actuators as shown in Figure 5. We assumed that the input voltage is rectangular and its amplitude is 2.5 V, and that it is applied to the system in an open loop fashion. Further, in the simulation we assumed that the mass of the leg is 0.001 kg, whereas the other parameters as listed in Table 1.

Figure 6 shows a plot of average walking speed as a function of the cycle time of walking which is approximately linear to the applied input frequency. The solid line shows the plot for the actuator with Na^+ and dotted line shows the data for the Cs^+ . From this figure it can be seen that there is a cross point of the lines indicating that the walking speed is altered before and after the point for the same frequency of the control input. This indicates that if an input with the same frequency is applied to the robot a faster walking can be realized by the actuator that is doped with Na^+ rather than with Cs^+ . It is interesting to note that this type of crossing point may not exist if the

parameters of the robot are not properly designed. Therefore, the design of the robot is important for the doping to be effective for adaptation of walking.



(a) Time response of the bending displacement



(b) Time response of the current

FIGURE 4: Response of various counter-ion

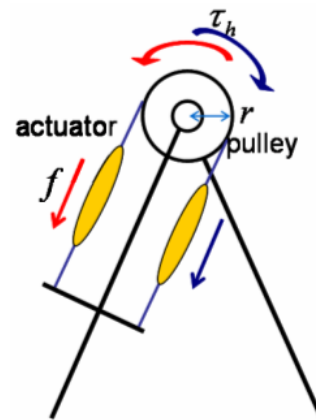


FIGURE 5: The structure of the compass-like walking robot

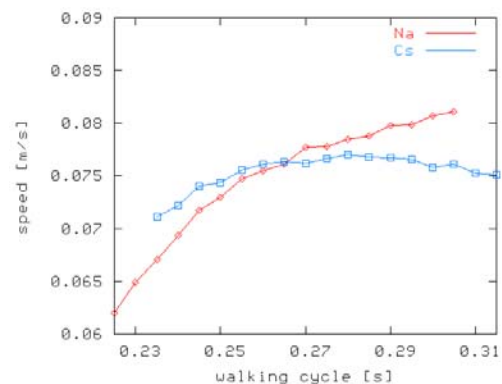


FIGURE 6: Walking speed vs. walking cycle

Figure 7 shows a plot of walking speed as a function of the averaged consumed power. Since the input current to the actuator is almost irrelevant to the walking pattern, the peak value of inject current and corresponding consumed power are large for the actuator that is doped with Na⁺.

To test the actuators we constructed a walking device as shown in Figure 8. Based on our observation described herein, it can be suggested that if the input voltage is the same, the actuator doped with Na⁺ realizes a high speed of walking and it consumes more energy. On the other hand, the actuator that is doped with Cs⁺ can generate slow walking pattern that consume lower energy. This result shows that it is feasible to change the properties of the EAP actuator according to environment or the application as desired.

TABLE 1: Parameters of the robot

Leg mass	0.001 or 0.005	[kg]
Hip mass	0.010	[kg]
Leg length	0.10	[m]
Radius of hip pulley	0.004	[m]

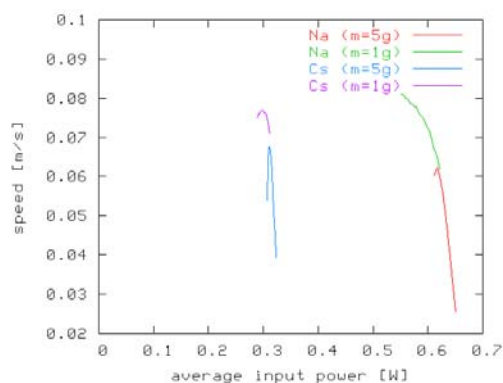


FIGURE 7: The walking speed vs the consumed power for the actuators with various dopings.



FIGURE 8: The experimental system a walking setup

USA – NanoSonic, Inc.

Self-Assembled Conducting Electrode Materials for EAP Actuators

Jennifer Lalli, jlalli@nanosonic.com or Richard Claus, roclaus@nanosonic.com

Recently, using a molecular-level self-assembly processing, a new method was developed for producing free-standing electrically-conducting elastomeric thin film materials. The resulting mechanically robust materials have electrical conductivity of approximately $10^6 \Omega^{-1}\text{m}^{-1}$, or one order or magnitude less than that of bulk metals, and elastic moduli less than 100 MNm^{-2} . The synthesis of these materials has been made possible through significant improvements in conventional nanoscale self-assembly processes that typically yield ultra-thin (100nm) films on substrates and require extensive (days to weeks) processing times. Using the new processing method, self-assembled materials as thick as 1-cm have been formed with micron to millimeter-thick films are typically fabricated in less than one day. Shown in Figure 9, a view of a sample material made by the new method as it is being tested for its high conductivity.



FIGURE 9: An example of the new self-assembled, low modulus, electrically conducting, nanostructured materials being tested.

The developed materials are ideal as elastomeric conductive electrodes for EAP actuators, due to their high conductivity, low modulus and excellent cyclic fatigue properties, even for strains greater than 100%. Through proper materials design and self-assembly processing conditions, the change in the electrical conductivity of the materials as a function of strain is low. Also, after deformation the materials relax to the original shape without buckling or wrinkling. More importantly, the conductive

nature of these materials is not degraded by the type of extended mechanical cycling typical of EAP actuator devices. These are important advantages over conventional deposited metal electrodes on EAP actuators which when strained even at low levels, deform, crack and spall.

**USA - University of Nevada, Reno
Benzenoid Helicene Based Molecular-to-Artificial Muscles**

Benjamin T. King (king@chem.unr.edu) and Kwang J. Kim (kwangkim@unr.edu)

A research activity at University of Nevada, Reno (UNR) was initiated towards synthesizing and characterizing a new artificial muscle system based on benzenoid helicenes (BHs). Both computational and synthetic work is performed and it was demonstrated that benzenoid helicene based materials are feasible for use to create linear actuators that are similar to mammalian muscles (Figure 10). A model systems was studied and the key reactions were demonstrated. It should be noted that these materials can be tailored to function as conductors and/or semiconductors such that it is feasible to electrically control these materials. The mechanical properties of these helicenes are currently being characterized and initial results are shown in Table 2.

TABLE 2: Actuation properties of helicene.

Modulus	Generative strain (linear strain)
160 MPa - 7 GPa	180-220%

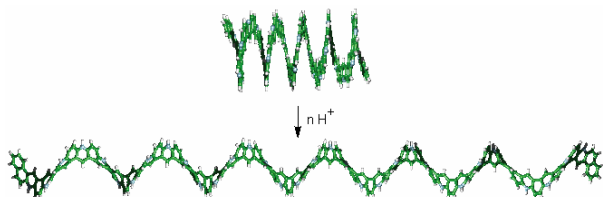


FIGURE 10: Molecular actuation of a helicene.

EMERGING EAP SUPPLIERS

New product from Environmental Robots Inc.

Environmental Robots Inc. (ERI) has announced a new EAP product called "Assortment of Polymeric Artificial Muscles". This product

contains five different types of ionic polymeric artificial muscles of different thickness as well as a fiber bundle of contractile polymeric artificial muscles that exhibits over 100% strain. Information about this product is available at the ERI web site www.environmental-robots.com.

Nanosonic, Inc.

Nanosonic, Inc. is a company that is developing processes to support the EAP technology. It was created in 1998 in cooperation with Virginia Tech and the Commonwealth of Virginia. Recently, as reported in this issue, its researchers have developed new molecular self-assembly processes that allows control of synthesized material structure at the nanometer level as well as the manufacturing of new materials with designed constitutive behaviors.

BOOK REVIEWS

Coming out soon – the 2nd Edition of the book on EAP

Y. Bar-Cohen (Editor)

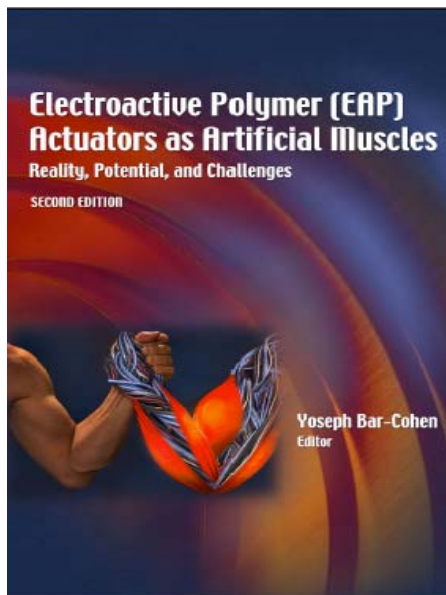


FIGURE 11: The cover page of the 2nd Edition of the book about EAP

In March 2004, SPIE Press is expecting to publish the 2nd Edition of the book entitled “Electroactive Polymer (EAP) Actuators as Artificial Muscles - Reality, Potential and Challenges”. This new edition was prepared in response to the high demand for the first edition and the fact that the available copies are starting to run out. In preparing this

second edition efforts were made to update the chapters in the topic areas that sustained major advances since the first issue was prepared before about three years. Twelve out of the total of twenty one chapters were revised at various degrees where some like Chapters 6 and 18 were significantly rewritten. As in the first edition, this new edition of the book is reviewing the state-of-the-art of the field of Electroactive Polymers (EAP), which are also known as artificial muscles for their functional similarity to natural muscles. The cover page of the book (see Figure 11) was also revised where the new icon of the armwrestling challenge is used. This new icon represents the desire to see that the robotic arm will not only be driven by polymer actuators but also be made of polymer materials.

The new edition of the book, which is identified as Volume PM136, also covers the field of EAP from all its key aspects, i.e., its full infrastructure. This includes covering the available materials, analytical models, processing techniques, and characterization methods. The intent in issuing the book is to provide a reference about the subject, technology users' guide, 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 heart warming, where major milestones are continually being reported. These advances are bringing the field significantly closer to the point of having EAP considered by engineers as actuators of choice.

Further information about this book will be available on: <http://ndea.jpl.nasa.gov/nasa-nde/yosi/yosi-books.htm>

14-16 June 2004	ACTUATOR 2004, Messe Bremen GMBH, Germany. H. Borgmann, actuator@messe-bremen.de Website: http://www.actuator.de
25-28 July 2004	2nd "Biomimetics and Artificial Muscles," Williamsburg, Virginia, M. Shahinpoor shah@unm.edu

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):

Books and Proceedings:

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

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

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

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

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

Biomimetics: <http://ndea.jpl.nasa.gov/nasa-nde/biomimetics/bm-hub.htm>

Armwrestling Challenge:

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

UPCOMING EVENTS

14-18 March, 2004	EAPAD, SPIE's joint Smart Materials and Structures and NDE Symposia, San Diego, CA., Pat Wight patw@spie.org Website: http://spie.org/Conferences/Calls/04/ss/conferences/index.cfm?fuseaction=SS03
20-21 May 2004	Second Conference on Artificial Muscles Biomimetic System Engineering, Asaka Kinji, AIST, asaka-kinji@aist.go.jp

Happy Holiday Season and Best Wishes for the New Year!



WorldWide Electroactive Polymers (EAP) Newsletter

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

All communications should be addressed to:








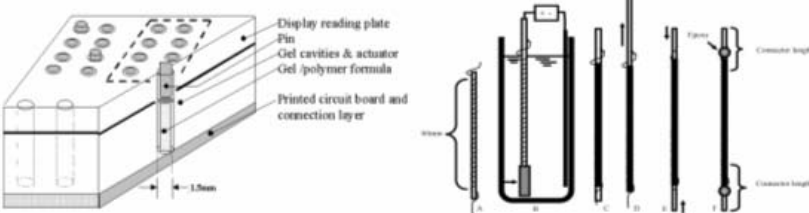

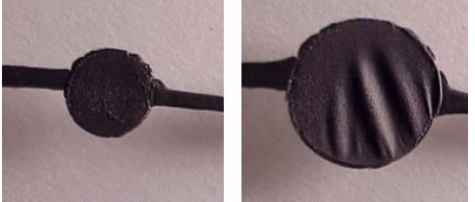
Dr. Y. Bar-Cohen, JPL, M.S. 82-105, 4800 Oak Grove Dr., Pasadena, CA 91109-8099

Phone: (818)-354-2610, Fax: (818)-393-3254 or E-mail: yosi@jpl.nasa.gov

APPENDIX

EAP material and product manufacturers

Company Name, Contact person, E-mail, Website	EAP materials/processes/products
<p>Artificial Muscle, Inc. (AMI)* 333 Ravenswood Ave., Menlo Park, CA 94025 <i>Artificial Muscle Inc</i></p>  <p>Alex N. Beavers, Jr., Ph.D. Chief Executive Officer; alex@artificialmuscle.com www.artificialmuscle.com *Founded by SRI International</p>	<ul style="list-style-type: none"> • Design and manufacture EAP based solid state actuators, sensors, and generator components for automotive, industrial machinery and automation, electronics, consumer goods, medical, and aerospace. • EAP devices including valve controllers, pumps, electric servo motor replacement, force and pressure sensors, acoustic speakers, and linear position actuators. 
<p>EAMEX Corporation 5-16-608 Uhocyou, Ikeda city, Osaka, Japan</p>  <p>Shingo Sewa or Kazuo Onishi; web@eamex.co.jp; http://www.eamex.co.jp/index_e.html</p>	<ul style="list-style-type: none"> • Conductive polymer EAP and IPMC actuators • EAP actuators for medical applications (nursing equipment, catheter, guide wires, and rehabilitation instrument); robotics; industry (manipulator and conveyance equipment); hobby and art, as well as customized EAP products  <p>EAP based hand</p>
<p>Environmental Robots Incorporated 909 Virginia, NE., Suite 205, Albuquerque, New Mexico 87108, USA</p>  <p>Mohsen Shahinpoor or Massoud Ahghar; shah@environmental-robots.com or mahghar@environmental-robots.com; www.environmental-robots.com</p>	<ul style="list-style-type: none"> • IPMC-based and ionic polymer actuators, transducers, and sensors • IPMC and conductive polymer EAP for biomedical engineering and medical applications • Kits of bending and contractile EAP, ionic polymeric fiber bundles, conductive polymers and chemically activated polymers  <p>IPMC</p>
<p>MCNC Research and Development Institute</p>  <p>Scott Goodwin, goodwin@mcnc.org, http://www.mcnc.org/rdi/</p>	<p>Dielectric EAP device development and prototyping of</p> <ul style="list-style-type: none"> • "Artificial Eyelid" polymer flexible film • Electrostatic MEMS actuator • Integrated force array and electrostatic polymer actuator  <p>Artificial Eyelid</p>

<p>Micromuscle AB Westmansgatan 29, 582 16 Linköping, Sweden,</p>  <p>Edwin Jager, CTO, edwin.jager@micromuscle.com; Gert Kindgren, CEO, gert.kindgren@micromuscle.com; www.micromuscle.com</p>	<ul style="list-style-type: none"> • EAP Products include materials and devices ranging from cellular levels for lab-on-a-chip to implantation in the human body. • Conductive polymers EAP actuators ranging in size from micrometers to several centimeters. • Components and devices for medical devices, vascular surgery, MEMS and biomedicine micro-systems. 
<p>Molecular Mechanisms LLC</p>  <p>Customer Support, sales@molecularmechanisms.com, www.molecularmechanisms.com</p>	<ul style="list-style-type: none"> • Development of EAP based mechanisms • Polypyrrole (PPy) tapes for Conductive Polymers (CP) EAP  <p>Bilayer CP EAP activated in air</p>
<p>NanoSonic, Inc. 1485 S. Main Street Blacksburg, VA 24060</p>  <p>Richard O. Claus, President; info@nanosonic.com; http://www.nanosonic.com</p>	<ul style="list-style-type: none"> • Low modulus sensors for strain, vibration and fluid flow • Free-standing conductive and reflective elastomeric membranes • Flexible electroding for EAP actuators using modified self-assembly (demonstrated for dielectric EAP)  <p>Stretchable electroding material</p>
<p>Quantum Technology Pty. Ltd. 5 South Street, Rydalmere, N.S.W. 2126, Australia</p>  <p>Tim Connell tconnell@quantech.com.au http://www.quantech.com.au/</p>	<ul style="list-style-type: none"> • Development of EAP actuators for Braille Cells as an aid to visually impaired and blind. 
<p>SRI International* 333 Ravenswood Avenue, Menlo Park, CA 94025</p>  <p>Philip von Guggenberg, Director of Business Development, pvong@sri.com, www.sri.com/artificialmuscle</p> <p>* In 2003, AMI was found to commercialize the EAP technology</p>	<ul style="list-style-type: none"> • Dielectric EAP actuators • Devices and mechanisms that are driven by dielectric EAP • R&D contracts to explore and extend the application of EAP technologies to scientific, industrial, and military environments from nano to mega scale devices.  <p>Dielectric EAP Voltage Off Voltage On</p>

Santa Fe Science and Technology

3216 Richard Lane, Santa Fe, NM 87505

Benjamin Mattes, President and C.E.O., mattes@sfst.net

- Conductive polymer EAP in the form of fibers and yarns
- Prototyping linear EAP Actuators called Panion

