WorldWide ElectroActive Polymers EAP (Artificial Muscles) Newsletter

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http://eap.jpl.nasa.gov

FROM THE EDITOR

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This Newsletter issue reports the latest progress in the fields of EAP and Biomimetics.

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ABOUT OUR EXPERTS

Award Recipient - Iain Anderson

Iain Anderson from Auckland University's Biomimetics Lab (www.biomimeticslab.com) and StretchSense Ltd. (www.stretchsense.com) received the Pickering medal of the New Zealand's Royal Society for his work on developing and commercializing dielectric elastomer technology. The details of this Royal Society award is available at:

http://www.royalsociety.org.nz/2016/11/23/pickering-medal-new-technology-that-mimics-nature/

Federico Carpi joined the University of Florence, Italy

After four rewarding years spent at Queen Mary University of London, since September 2016 Federico Carpi has joined the

Department of Industrial Engineering of the University of Florence, Italy, as an Associate Professor in Biomedical Engineering. At his new affiliation Federico is continuing his research activities on EAP transducers. So far, Federico has been acting as the President of the EuroEAP Society - a mandate that Federico will gladly conclude in June 2017, thus having more time to focus on co-operative research. Colleagues wishing to have a trip to the wonderful Florence and give a seminar are warmly invited to contact Federico at his new email address federico.carpi@unifi.it

GENERAL NEWS

The WW-EAP Webhub http://eap.jpl.nasa.gov is periodically being updated with information regarding the EAP activity worldwide. This Webhub is a link of the JPL's NDEAA Webhub of the Advanced Technologies Group having the address: http://ndeaa.jpl.nasa.gov

Standard for EAP

A paper about the recently published standard for EAP materials has been posted on the internet and can be read at
http://dx.doi.org/10.1088/0964-1726/24/10/105025

MICACT Course

MICACT (www.micact.eu) is a Marie Skłodowska-Curie Actions (MSCA) Innovative Training Networks (ITN) H2020-MSCA-ITN-2014 funded by the European Union's Horizon 2020 research and innovation program under the grant agreement No 641822. The main objective of the project will be the improvement of the career perspectives (in academia and in industry) of young researchers (15 PhD students) by training them at the forefront of research in the field of smart soft systems made of EAP micro-actuators for advanced miniaturized devices. The overall objective for the scientific program is research and development of EAP materials and their integration for industrial applications. Special attention will be devoted to the development of micro-actuators.

On January 17-19, the third MICACT Training School (TS3) will be held at Linköping University, Sweden. The theme of TS3 is Microfabrication. There will be lectures on Basics of Microfabrication, Microfabricating Conducting Polymer EAPs and Dielectric Elastomer EAPs, Soft Robotics, non-EAP Micro-actuators, PDMS based Microfluidics and non-traditional MEMS technologies. The lectures will be given by leading scientists in the fields of EAPs, microfabrication/ MEMS and soft robotics.

There are still some openings for PhD-students to participate. Participation in the lectures is free of charge. For more information or registration please contact the local organizer, Edwin Jager (edwin.jager@liu.se), or the MICACT coordinator Alvo Aabloo (alvo.aabloo@ut.et).

BIOMIMETICS/EAP PROFESSIONAL SOCIETIES

VDI-Society Technologies of Life Sciences

The VDI-Society (the Association of German Engineers) Technologies of Life Sciences presented the International Bionic Award of the Schauenburg Foundation,

Ljuba Woppowa woppowa@vdi.de

Young scientists have been awarded 10,000 EUR for the development of liquid transport based on the model of a horned lizard (**Figure 1**). The International Bionic Award of the Schauenburg Foundation this year goes to an interdisciplinary team of four individuals from Aachen and Linz. The award has been given to Philipp Comanns, RWTH Aachen, Kai Winands and Mario Pothen, Fraunhofer Institute for Production Technology IPT Aachen, and Gerda Buchberger, Johannes Kepler University Linz for their outstanding research work. They have developed structures for energy-neutral directional transport of fluids on surfaces. Their role model is the Texas horned lizard (**Figure 2**). The award ceremony took place on 21 October 2016 in the context of the Bionic Congress "Patents from Nature" in Bremen.

With microscopically small channels, the Texas horned lizard collects water from its surroundings. It's skin structure enables the lizard to transport the collected water directionally to its mouth. The interdisciplinary team of biologists, engineers, computer scientists and physicists has derived functional principles from this and transferred them to plastic and metal surfaces. The innovation can be used in industry in many areas, whether in nappies or as lubrication in car engines.

Figure 1: VDI presents the 2016 International Bionic Award of the Schauenburg Foundation: young scientists from Aachen and Linz were awarded 10,000 EUR for the development of liquid transport based on the model of a horned lizard (Picture: Labisch / BIC)

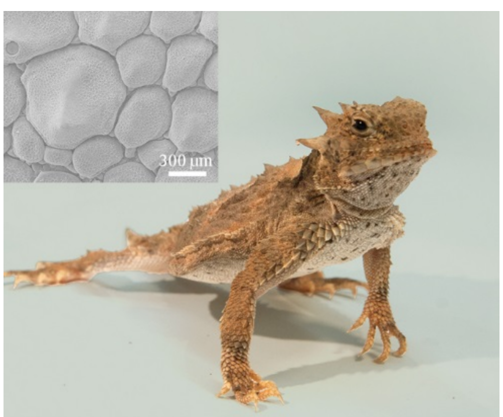

Figure 2: Texas horned lizard as role model for innovative surfaces.

"The phenomenon is based on the special geometry of the capillary channels. Through our interdisciplinary cooperation among the team members, we were able to abstract this channel geometry and optimize the structure to the extent that industrial production is possible and that we can even transport liquids directionally against gravity" the freshly graduated doctor of biology and team speaker Philipp Comanns explains. With this idea, the young scientists convinced the international jury of experts.

Antonia B. Kesel from the Bremen University of Applied Sciences and Chair of the Jury and the VDI Bionics Department stresses: "Our international Jury was especially fascinated by the potential to apply a wide range of fluid films highly effectively and not less efficiently in varying areas of application. This promises a great market potential in many sectors, we can't wait!"

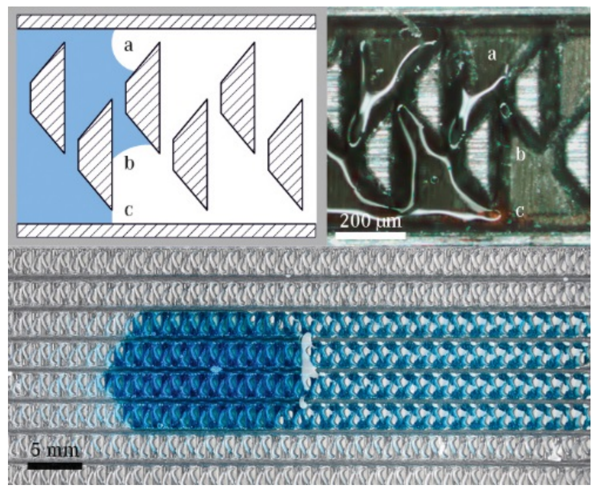

Figure 3: Inspired by the Texas horned lizard's skin, innovative capillary surface structures enable (uni)directional liquid transport for applications ranging from lubrication to lab-on-a-chip.

The International Bionic Award of the Schauenburg Foundation in the Stifterverband für die deutsche Wissenschaft (Donors' association for the promotion of humanities and sciences in Germany) is awarded by the VDI Society Technologies of Life Sciences (VDI-TLS). Bionics often acts as a source of ideas and an innovation driver with sustainable benefits for technology, business and society. "Interdisciplinary work and constructive lateral thinking are fundamental prerequisites in bionics and also the basis of success for companies", says Marc-Georg Schauenburg, son of the founder of the Bionic Awards.

In recognition of their work, Maryna Kavalenka, Felix Vüllers and Claudia Zeiger from the Karlsruhe Institute of Technology also received a certificate for their project "Bioinspired Multifunctional Nanofur for Environmental Applications".

The Bionic Award has been endowed by the Schauenburg Foundation since 2008. It was established in 1986 by Hans-Georg Schauenburg, the founder of the Schauenburg Group, which has been active in Mülheim an der Ruhr for over fifty years, and is held in trust by the Stifterverband für die Deutsche Wissenschaft. With the award, the Schauenburg Foundation and the VDI pursue the goal of promoting application focused research and development work as well as the innovation of young scientists in the area of bionics.

The International EuroEAP Society

Federico Carpi, University of Florence, Italy
Edwin Jager, Linköping University, Sweden
Gabor Kovacs, Empa, Switzerland

The 'EuroEAP – European Society for Electromechanically Active Polymer Transducers & Artificial Muscles' (www.euroeap.eu) is a non-profit International Association, whose main purpose is to contribute to and promote the scientific and technological advancement and the diffusion of Transducers and Artificial Muscles based on Electromechanically Active Polymers (EAP).

The Society operates at international level and it welcomes members from any country worldwide. If you are interested in learning more about the Society, please visit the website www.euroeap.eu and subscribe to become a Member of this unique Association in the EAP field and take advantage of the benefits of being a Member:

- Being part of the largest international scientific and industrial Association in the EAP field;
- Facilitated networking with experts and professionals in the EAP field, and easier access to the most recent developments;
- Reduction on the registration fees for the annual EuroEAP Conference;
- Discount on the purchase of the EuroEAP Conference proceedings;
- Possibility to apply to annual calls for short term scientific missions' grants offered by the Society to foster or strengthen collaborations with any institution in any country of any continent;
- Possibility to participate to the annual Society Challenge;
- Possibility to disseminate your work via the broad EuroEAP emailing list;
- Possibility to participate to working groups on topics of scientific, technological and industrial relevance in the EAP field;
- Being a member of the General Assembly of the EuroEAP Society, with voting rights and eligibility to its Organs and Committees.

The next Annual Meeting of the Society will be held at the same place hosting the next EuroEAP conference: www.euroeap.eu/conference. The Meeting will take place in the afternoon of the day before.

UPCOMING CONFERENCES

2017 SPIE EAPAD Conference

The 19th SPIE's EAPAD conference is going to be held from March 26 thru 29, 2017. The conference, which is part of the Smart Structures Symp., is going to be at Portland, Oregon. Specifically, at the Portland Marriott Downtown Waterfront [http://www.marriott.com/hotels/hotel-photos/pdxor-portland-marriott-downtown-waterfront/]. This hotel is located on the Willamette River in downtown Portland with lots of options for restaurants and tourist activities. This Conference is being chaired by Yosi Bar-Cohen, JPL, and Co-chaired by Jonathan Rossiter, University of Bristol, England. The Conference Program Committee consists of representatives from 32 countries.

The Conference includes 120 papers and they will focus on issues that help transitioning EAP to practical use thru better understanding the principles responsible for the electro-mechanical behavior, analytical modeling, improved materials and their processing methods, characterization of the properties and performance as well as various applications.

At the Smart Structures Symposium that the EAPAD 2017 is part of, the first Plenary Speaker is David Hanson (**Figure 4**) and the title of his paper is "EAP Artificial Muscle Actuators for Bio-Inspired Intelligent Social Robotics**".** The presentation will focus on bio-inspired intelligent robots as they are coming of age in both research and industry, propelling market growth for robots and A.I. However, conventional motors limit bio-inspired robotics. EAP actuators and sensors could improve the simplicity, compliance, physical scaling, and offer bio-inspired advantages in robotic locomotion, grasping and manipulation, and social expressions. For EAP actuators to realize their transformative potential, further innovations are needed: the actuators must be robust, fast, powerful, manufacturable, and affordable. This presentation surveys progress, opportunities, and challenges in the author's latest work in social robots and EAP actuators, and proposes a roadmap for EAP actuators in bio-inspired intelligent robotics.

Figure 4: David Hanson is going to present a Plenary paper about humanlike robots and the need for EAP actuators.

At the EAPAD 2017, the Keynote Speaker is going to be Siegfried G. Bauer, Johannes Kepler Univ. Linz (Austria) **(Figure 5**) and the subject of his presentation is "Electroactive polymers for healthcare and biomedical applications".

Bauer was born in Karlsruhe, Germany, in 1961. He received the master's and Ph.D. degrees in physics from Technical University in Karlsruhe, in 1986 and 1990, respectively, and the Habilitation degree from the University of Potsdam, in 1996. In 1992, he joined the Heinrich Hertz Institute for Communication Engineering, Berlin, Germany. In 1997, he became a Professor of Experimental Physics with Johannes Kepler University Linz, Austria. Since 2002, he has been the Head of the Soft Matter Physics Department. His interests are in the areas of electroactive polymers, flexible and stretchable electronics, energy harvesting, and soft machines. He is a member of the Austrian Physical Society and the Association of German Electrical Engineers. He received the European Research Council Advanced Investigators Grant in 2011.

Figure 5: Siegfried G. Bauer, Johannes Kepler Univ. Linz (Austria) is the Keynote Speaker of the 2017 EAPAD Conf.

For the record of the EAPAD conferences archive, the following is the list of the Co-chairs since the first one that was held in 1999 at Newport Beach, CA.

Year	Co-chair	Country
1999	Mohsen Shahinpoor, U. of New Mexico	USA
2000	Steve Wax, DARPA	USA
2001	Danilo De Rossi, Univ. degli Studi di Pisa	Italy
2002	Yoshihito Osada, Hokkaido University	Japan
2003	Geoff Spinks, University of Wollongong	Australia
2004	Peter Sommer-Larsen, Risoe National Lab.	Denmark
2005	John D. Madden, U. of British Columbia	Canada
2006	Jae-Do Nam, Sung Kyun Kwan University	S. Korea
2007	Gabor Kovacs, EMPA	Switzerland
2008	Emillio P. Calius, Industrial Res. Limited	New Zealand
2009	Thomas Wallmersperger, Univ. Stuttgart	Germany
2010	Jinsong Leng, Harbin Institute of Tech.	China
2011	Federico Carpi, Univ. of Pisa	Italy

2012	Keiichi Kaneto, Kyushu Inst. of Tech.	Japan
2013	Siegfried Bauer, Johannes Kepler U.	Austria
2014	Barbar J. Akle, Lebanese American Univ.	Lebanon
2015	Gal deBotton, Ben-Gurion U. of the Negev	Israel
2016	Frédéric Vidal, U. de Cergy-Pontoise	France
2017	Jonathan Rossiter, University of Bristol	England

The invited papers in this Conference are:

Gabor M. Kovacs, EMPA (Switzerland), "From research to production", Session 1.

John D. W. Madden, Yuta Dobashi, Mirza S. Sarwar, Eden C. Preston, Justin K. M. Wyss, The Univ. of British Columbia (Canada); Vincent Woehling, Tran-Minh-Giao Nguyen, Cédric Plesse, Frédéric Vidal, Univ. de Cergy-Pontoise (France); Sina Naficy, Geoffrey M. Spinks, Univ. of Wollongong (Australia), "Proximity and touch sensing using deformable ionic conductors", Session 2.

Stoyan Smoukov, Univ. of Cambridge (United Kingdom), "Bottom-up approaches to multi-functional materials and artificial morphogenesis", Session 3.

Kam K. Leang, James D. Carrico, The Univ. of Utah (United States), "Fused filament 3D printing of ionic polymer-metal composites for soft robotics", Session 5.

William S. Oates, Paul Miles, Wei Gao, Jonathan Clark, Somayeh Mashayekhi, Mohammad Y. Hussaini, Florida State Univ. (United States), "Rate dependent constitutive behavior of dielectric elastomers and applications in legged robotics", Session 8A.

Christoph Keplinger, Univ. of Colorado Boulder (United States), "Reliable, robust, electrically powered soft actuators that self-heal from mechanical and electrical damage", Session 9A.

Seon Jeong Kim, Shi Hyeong Kim, Hanyang Univ. (Korea, Republic of); Ray H. Baughman, The Univ. of Texas at Dallas (United States), "Artificial muscles for electrical energy harvesting", Session 9B.

Gih-Keong Lau, Yao-Wei Chin, Kim-Rui Heng, Anansa S. Ahmed, Milan Shrestha, Nanyang Technological Univ. (Singapore), "From elastomeric flight muscles to tunable window", Session 10B.

Ramona Mateiu, Liyun Yu, Anne L. Skov, Technical Univ. of Denmark (Denmark), "Electrical breakdown phenomena of dielectric elastomers", Session 11B

Adrian Koh, Vy Khanh Vo Tran, Anup Teejo Mathew, National Univ. of Singapore (Singapore), "Stackable configurations of artificial muscle modules that is continuously-tunable by voltage", Session 12B

Also, the EAP-in-Action Session will be held on Sunday, March 26, 2017. It includes a 14 demonstrations and this is a record for the 19 years of the EAPAD Conf. The teams that are making the demonstration represent participants from 8 countries including China, Germany, Japan, New Zealand, Singapore, Switzerland, UK, and USA. The demonstrations are as follows:

<u>China</u>

1. Jing Dai, Bangyuan Liu, Feiyu Chen, Sukai Wang, Zhiqiang Fu, and Tiefeng Li, Soft Matter Research Center of Zhejiang University, China, "Soft robot group with multiple materials and configurations"

   Soft robotics and smart structures will be demonstrated that are made of multiple soft active materials, and can be fabricated by 3D printing method (**Figure 6**). Driven by dielectric elastomer, the robot shows excellent performances in large actuation and fast response.

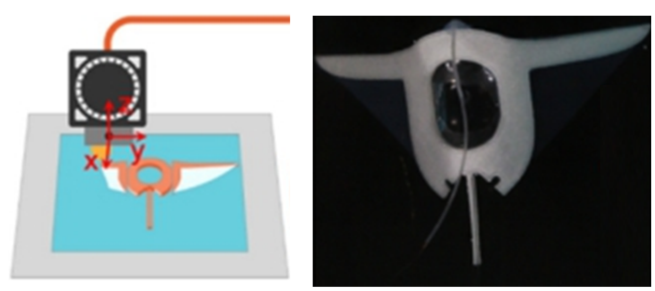

Figure 6: The 3D printing process and operation of soft robot.

   Using a common compact power and control electronics, various configurations of soft robot can be designed as actuated modules. Smart structures made of temperature active tough hydrogel will also demonstrate as actuators of bio-medical applications. The operation principles may guide the further design of soft robots for various applications.

2. Liwu Liu, Jinrong Li, Fengfeng Li, Xiongfei Lv, Xin Lan, Yanju Liu, and Jinsong Leng, Harbin Institute of Technology, China, "Applications of smart deformable polymers"

   This demonstration will show smart polymers in action taking advantage of their being light weight, fast response, and large deformation. These advantages make them attractive for applications in smart bionics, aerospace, biomedicine and other fields. The demonstration will include the applications of EAP, shape memory polymer (SMP) and pneumatic artificial muscle (PAM), such as soft robot, soft continuum manipulator, smart release device, adaptive eyewear frame and other deformable structures (**Figure 7** and **Figure 8**).

Figure 7: Soft robot

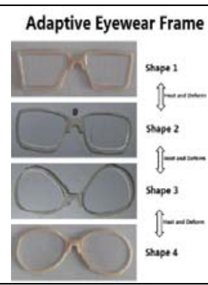

Figure 8: Adaptive eyewear frame.

Germany

Steffen Hau, Mathias Hoffmann, and Stefan Seelecke, Saarland University – Intelligent Material Systems Lab (iMSL), Germany, "DEA Driven Vibratory Feeder"

Vibratory feeders are widely used in part handling technology for transport, aligning and/or feeding parts to a certain process. Currently they are driven by electro-magnetic actuators and unbalance motors, which do not allow arbitrary vibration profiles or changes of amplitude / frequency during operation. Dielectric elastomer actuator (DEA) show potential to overcome these drawbacks. A fully functional DEA driven vibratory feeder transporting small goods will be demonstrated, showing DEAs potential in this new field of application. Picture is showing a CAD model of the feeder consisting of transport channel (grey) with four actuator modules underneath.

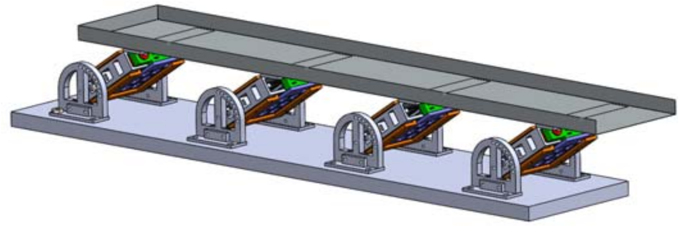

Figure 9: CAD model of the feeder consisting of transport channel (grey) with four actuator modules underneath.

Japan

Minoru Hashimoto, Yi Li, Aya Suzuki, Hanako Niwa, and Rina Yokotsuka, Shinshu University, Hashimoto-Tsukahara Laboratory, Nagano, Japan http://www.shinshu-u.ac.jp/faculty/textiles/chair/ht-lab/
"Multilayered PVC Gel Artificial Muscle".

Multilayered contraction type PVC gel actuator was developed using stainless mesh electrodes having many positive characteristics. This include being soft and lightweight, with stable actuation in air and with high output. It is activated by applying voltage of 400V, and the displacement of 60-layer artificial muscles is ~3.0mm, with contraction strain of ~10%, and the maximum output force is ~50kPa. The response rate is 9Hz, and the current is about 0.45mA.

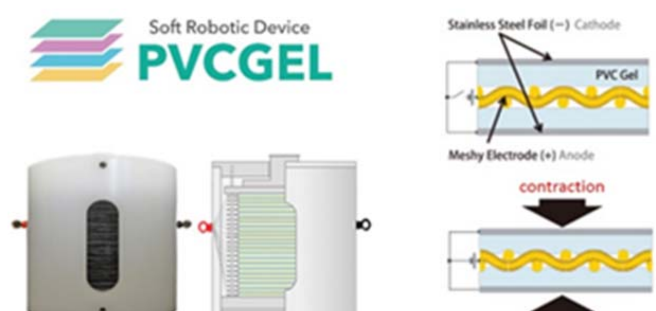

Figure 10: Multilayered PVC Gel Artificial Muscle

New Zealand

1. Markus Henke, Patrin Illenberger, Katie Wilson, Andreas Tairych, Chris Walker, and Iain Anderson, Biomimetics Lab, Auckland Bioengineering Institute, New Zealand, "Multilocation sensing on one input/output and EAP zoo". The presentation will consist of:
   a. The multisensor shirt that can measure stretch at several locations from one input/output.
   b. The Electroactive polymer zoo: we present the latest self-regulating crawling caterpillars and wing-flapping dragonflies (**Figure 11**) fabricated from printed polymer and electrode. No need for electronics!

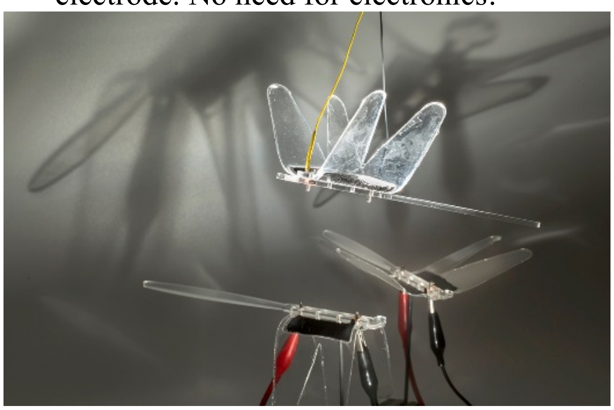

Figure 11: Jule the EAP dragonfly and friends

2. Antoni Harbuz and Iain Anderson, StretchSense, Ltd., New Zealand, "New EAP products"

   This demo will present what's new from StretchSense in wearable electroactive polymer sensing and energy harvesting (**Figure 12**).

Figure 12: StretchSense energy harvesting kit

Singapore

1. Godaba Hareesh, Jiawei Cao, and Jian Zhu, Dept. of Mechanical Engineering, National University of Singapore, Singapore, "Soft untethered robots"

   Soft untethered robot will be demonstrated that mainly consists of a deformable robotic body and two paper-based feet (**Figure 13**). Based on the optimal mechanical design, the robot is capable of achieving autonomous movements. In addition, an origami-based soft robot will be demonstrated (**Figure 14**).

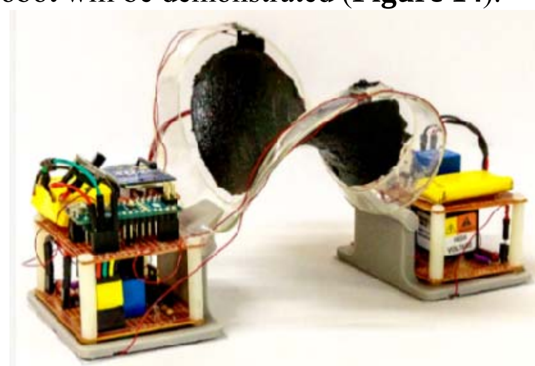

Figure 13: Soft untethered robot

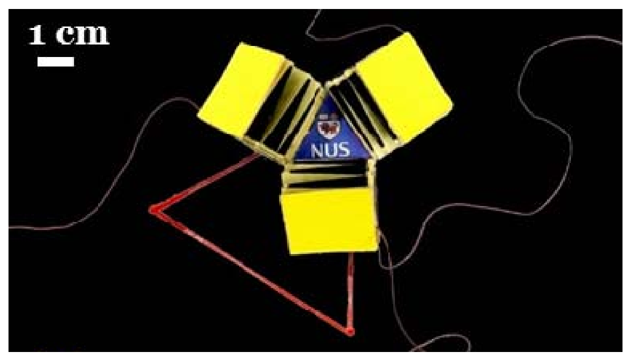

Figure 14: Origami-based soft robot

2. Anansa S. Ahmed and Lau Gih Keong, School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, "Dielectric elastomer grippers using tensioned arch flexures".

   The followings are going to be demonstrated
   a. Versatile DEA grippers with enhanced tip angle deflection and blocked force due to tension arch flexure structure.

b. Grippers capable of grasping and lifting a variety of objects including highly deformable materials without damage.

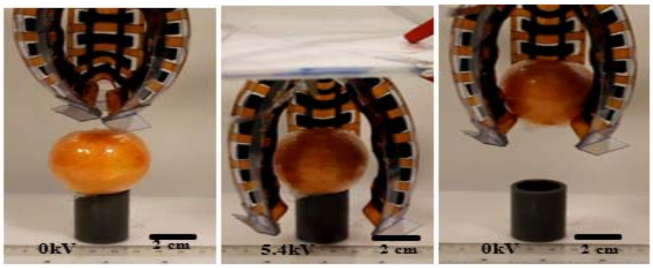

Figure 15: Soft untethered robots

1. Milan Shrestha[1, 2], Rosmin Elsa Mohan[1], Anansa Ahmed[1], Anand Asundi[1], Gih-Keong Lau[1, *] [1]School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore; [2]Singapore Center for 3D Printing (SC3DP), Nanyang Technological University, Singapore, "Electrically tuning transparency by wrinkling of ZnO/Ag thin film"

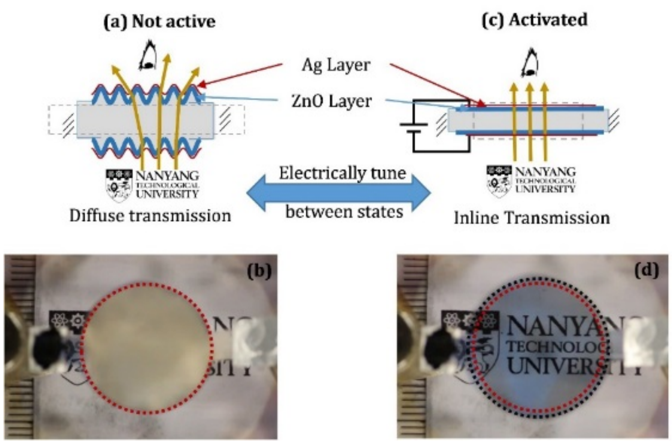

Figure 16: Electrically tuning transparency by wrinkling of ZnO/Ag thin film

This demonstration unit consists of transparency tunable device. It works based on wrinkling and unfolding a ZnO/Ag-coated elastomer substrate using a dielectric elastomer actuator (DEA). Initially, the membrane is at wrinkled state and the device is opaque. An object placed underneath the membrane will not be visible. When the DEA device is electrically activated, the wrinkles are flattened turning the device to a transparent membrane and the object placed behind the device becomes clearly visible. Reversible tuning between the two states can be obtained electrically for a large number of cycles.

Singapore and UK

Koh Soo Jin Adrian, Stoyan Smoukov, Ang Marcelo H. Jr., Vy Khanh Vo Tran, Anup Teejo Mathew, Lionel Chong, and Lester Leong, National University of Singapore (NUS) and Cambridge University, UK, "A stackable and configurable antagonistic actuator system for a wrestling arm"

Two stackable loudspeaker-type dielectric elastomer actuator (DEA) modules which have continuous-tuneable movement by voltage will be demonstrated. When voltage is continuously switched between two DEA modules, the linear motion will be transferred to the controllable rotation of the arm with the extra mechanical design.

During operation, a voltage is applied across the elastomer on the right, causing it to expand and "relax". The elastomer on the left contracts due to tension in itself, pulling on the disc and rotating the arm anti-clockwise. No voltage is applied across the left elastomer. The force exerted by the left elastomer is determined by the pre-stretching done mechanically.

A discharge circuit also be included to remove the charge stored in DE membrane immediately once turning off voltage to get faster actuation, hence increases the power for the arm.

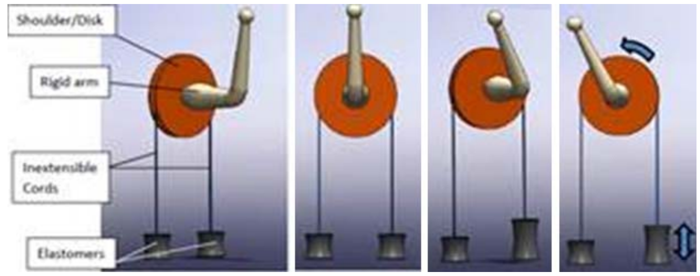

Figure 17: A stackable and configurable antagonistic actuator system for a wrestling arm

Switzerland

1. Samuel Rosset and Samuel Schlatter, EFPL, Switzerland, "PetaPicoVoltron: an open-source portable high-voltage supply"

   A portable high voltage power supply (HVPS) will be demonstrated that is specifically designed to drive DEAs. Its output DC voltages is up to 5kV with a resolution of 0.1% of full scale, and can generate square signals from 1mHz to 1kHz with a slew rate faster than 15V/µs. It has a user friendly GUI enabling easy interaction with the HVPS, and using LabView library makes it simple to integrate the power supply with other instruments. The circuit layout and the software have been released as an open-source project, for anyone to use and improve.

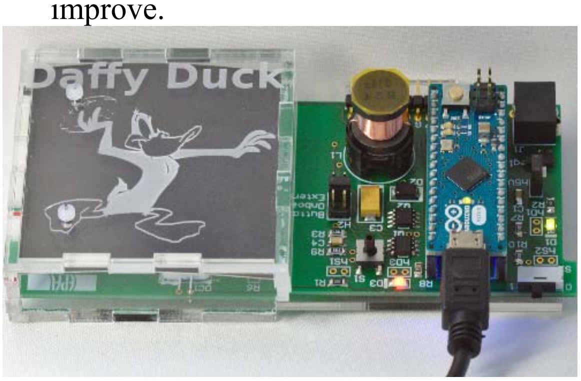

Figure 18: PetaPicoVoltron: an open-source portable high-voltage supply.

2. Bekin Osmani, Tino Topper and Burt Miller, Biomaterials Science Center, University of Basel, c/o University Hospital, Switzerland, "Apparatus for measuring the actuation forces of DEAs via cantilever bending".

   A compact, simple-to-operate apparatus for measuring the generated forces of planar dielectric elastomer actuators (DEA) will be demonstrated. DEA structures are fabricated on top of a cantilever substrate material with well-known mechanical properties such as PEN, PEEK, or Kapton film. When a DC-voltage is applied to the planar electrodes on either side of the elastomer layer, the resulting deformation of the incompressible elastomer bends the cantilever. The bending curvature is measured by the deflection of a laser beam reflected from the cantilever onto a position sensitive detector. This cantilever system can be used to evaluate the maximal strains of single- as well as multilayer DEAs.

   Light from a laser (1) reflects off from a DEA-based cantilever (2). When a DC-voltage is applied, the cantilever bends (bottom schematic). A position sensitive detector (3) measures the resulting deflection of the laser beam.

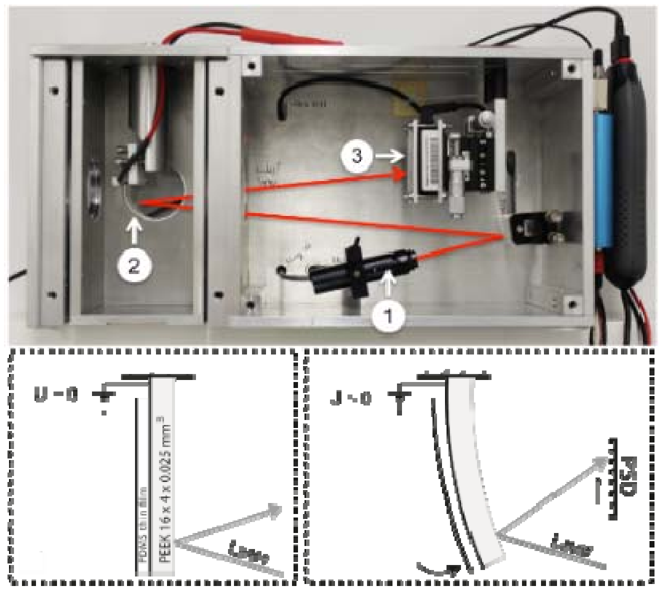

Figure 19: Apparatus for measuring the actuation forces of DEAs via cantilever bending

USA

1. Qi Shen, Sarah Trabia, Tyler Stalbaum, Taeseon Hwang, Robert Hunt, Zakai Olsen, and Kwang Kim, Univ. of Nevada, Las Vegas (USA), "Development of an origami soft robot using "Multiple shape memory ionic polymer-metal composite"

   The multiple-shape-memory ionic polymer-metal composite (MSM-IPMC) actuator is used to demonstrate complex 3D deformation. The MSM-IPMC has two characteristics, which are the electro-mechanical actuation effect and the thermal-mechanical shape memory effect. The bending, twisting, and oscillating motions of the actuator could be controlled simultaneously or separately by means of thermal-mechanical and electro-mechanical transactions. Using the MSM-IPMC, a soft biomimetic robot was developed that has origami structure. The multiple shape memory effect enables the robot to change its shape and in return enables the robot to move forward in water. This work may bring inspiration for designing new soft robotic systems with the MSM-IPMC actuators.

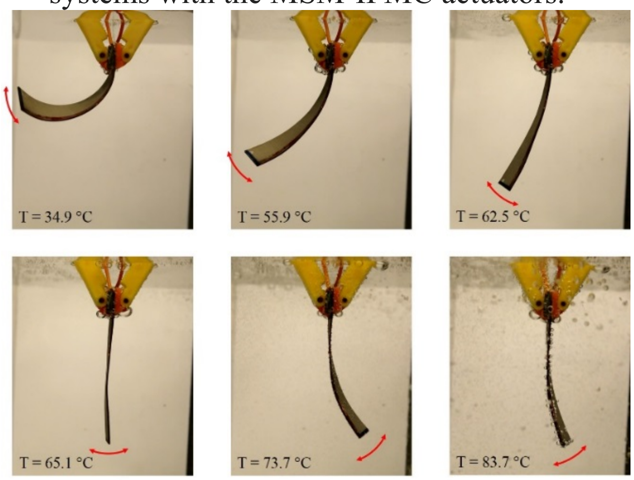

Figure 20: Multiple-shape-memory ionic polymer-metal composite (MSM-IPMC) actuator

2. Lenore Rasmussen, Ras Labs LLC, "Synthetic Muscle™ – Shape-morphing and Sensing EAP Based Materials and Actuators"

   The operation or the latest Synthetic Muscle™ based actuators will be demonstrated. These are actuators that contract and expand, attenuate impact, and sense pressure. Actuation will be performed underwater, on land with suitable elastomeric coatings, and impact (mechanical pressure) resistance demonstrated. Also, prosthetic liner prototype with self-adjusting EAP based pads and sensing robotic gripper will also be demonstrated.

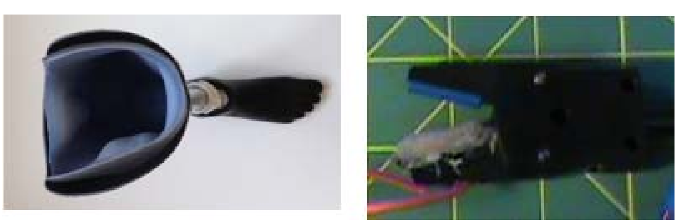

Figure 21: Prototype of prosthetic liner with self-adjusting EAP based pads

EuroEAP 2017 – the 7th intern. Conference on EAPs

Toribio Otero, University of Cartagena, Spain
Federico Carpi, University of Florence, Italy

The annual EuroEAP 2017 conference is going to be held in Cartagena, Spain, on 6-7 June 2017 and will be chaired by Toribio Otero (University of Cartagena). Detailed information will be made available at www.euroeap.eu/conference.

The EuroEAP conferences are attended by experts from a diversity of countries worldwide and is designed to maximize interactions among participants, with invited lectures in the morning followed by participant presentations that comprise a short oral and an extended poster session. The invited oral presentations are given by world-leading scientists, young emerging researchers, as well as representatives of industry. The oral sessions, which allow all contributors to present their works, are intertwined by long poster sessions that facilitate discussions in a friendly atmosphere.

In addition, there is ample time for spontaneous meetings during breakfasts, coffee and lunch breaks, as well as the evening social events, as all the participants stay in the same hotel during the conference. The cost for all the organized lunches and dinners are entirely included within the registration fees, which are also maintained competitively low by the non-for-profit approach taken in organizing this unique event.

EuroEAP 2019: Call for candidates

From the EuroEAP Conference Committee

European groups active in the EAP field are warmly invited to nominate candidates for the organization of the EuroEAP 2019 – the 9th International Conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles. The event is expected to be held during the first half of June 2019, in a nice location well connected to an international airport. The previous locations at which the EuroEAP Conferences were held are listed at http://www.euroeap.eu/conference. Candidate Chairpersons are kindly requested to contact by email the President and Vice-President of the EuroEAP Conference Committee, Federico Carpi <federico.carpi@unifi.it>, and Edwin Jager <edwin.jager@liu.se>.

RECENT CONFERENCES

1st NASA Biomimicry Summit & Education Forum

The 1st Annual NASA Biomimicry Summit and Education Forum has been held in Cleveland, Ohio from August 2 through August 4, 2016. The objective for holding this Summit has been to provide a groundbreaking forum, bringing together aerospace, biology, paleontology, art and design. The bio-inspired topics included:

- Materials Processing and Structures for Extreme Environments
- Physical and Life Sciences: Persistence of Life in Hostile Environments
- Guidance, Navigation & Communications
- Next Generation Aeronautics and In-space Propulsion
- Sustainable Energy Conversion and Power.

On August 4, a networking session and workshop was held to identify collaboration and funding opportunities for participants in support of NASA goals. This session resulted in working groups and white papers that are intended to feed into future NASA biomimicry summits. E-resources regarding this forum can be found at:

- The summit website (updated periodically): http://www.tinyurl.com/Biomimicry2016
- NASA's biomimicry website: https://www.grc.nasa.gov/vibe

EuroEAP 2016 – 6th international Conference on EAP

Anne Ladegaard Skov, Technical University of Denmark, Denmark; and Federico Carpi, University of Florence, Italy

EuroEAP 2016, the 6th international conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles, has been held in Helsingør, Denmark, on 14-15 June 2016.

The conference was chaired by Anne Ladegaard Skov (Technical University of Denmark) and was organized by the EuroEAP Society (www.euroeap.eu). The event was attended by more than 100 participants and **Figure 22** shows a group picture of some of the attendees. The technical program, the Conference proceedings and pictures from the Conference are available at www.euroeap.eu/conference.

Figure 22: EuroEAP 2016 group picture.

During the event, Reimund Gerhard (University of Potsdam, Germany) was given an award by the EuroEAP Society "for his fundamental scientific contributions in the field of Transducers based on Dielectric Polymers". Toribio Otero (University of Cartagena, Spain) was awarded "for his fundamental scientific contributions in the field of Transducers and Artificial Muscles based on Conjugated Polymers". Also, Ingrid Graz (Johannes Kepler University, Linz, Austria) received the EAPromising European Researcher Award "for evidences of a promising career in the field of EAP electronic transducers" (**Figure 23**).

Figure 23: The recipients of the 2016 EuroEAP Society awards are shown holding the certificate.

These include Reimund Gerhard (left), Ingrid Graz (middle) and Toribio Otero (right).

ADVANCES IN EAP

Aerospace Engineering-Propulsion/ MEMS

High Much Number Range (HMR) TurboDEA

Babak Aryana, Independent, Researcher/ Inventor Babak.Aryana@Gmail.com

Following introduction of DEA compressor in [1], and TurboDEA in [2], the current work on a special type of TurboDEA that can operate in a wide range of flight Much numbers (High Much Number Range HMR). It is going to be shown that its particular capability to cover working envelope of turboramjets, when it is not a combination of two types of engines. Using unique specification of dielectric elastomer actuators (DEAs), DEA compressor can potentially work in airflow with higher Much numbers, because unlike conventional compressors, it is not so sensitive to input airflow speed, particularly with special configuration that is considered for it in HMR TurboDEA.

In this new engine, the same compound of [1] is used for DEA actuators, but more elongation is used than previous one (25%) (**Figure 24** and **Figure 25)**, while number of actuators in each cell (**Figure 26)** are also more than previous design. Estimating the required voltage for such an elongation, ANSYS Multiphasic package is used (**Figure 26**). It is important that DEAs endure for fast and response for long time, when actuator mechanism can tolerate force applied by pressurized vessel through the tubes.

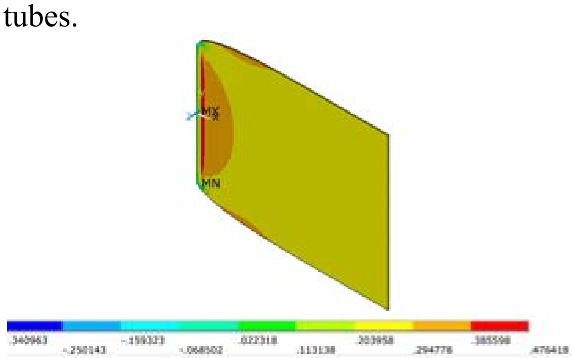

Figure 24: Total mechanical strain of a dielectric elastomer sheet under electric field

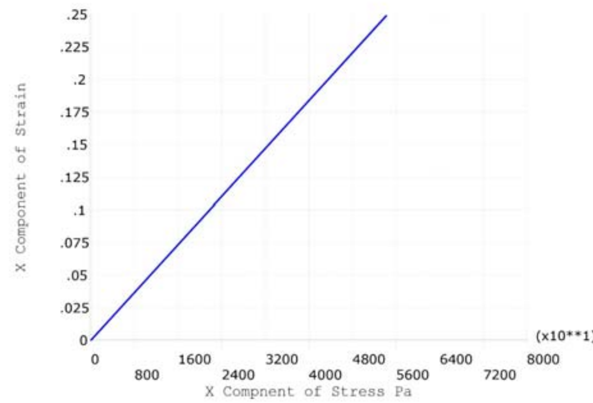

Figure 25: Stress-Strain curve of a DEA sheet under electric field.

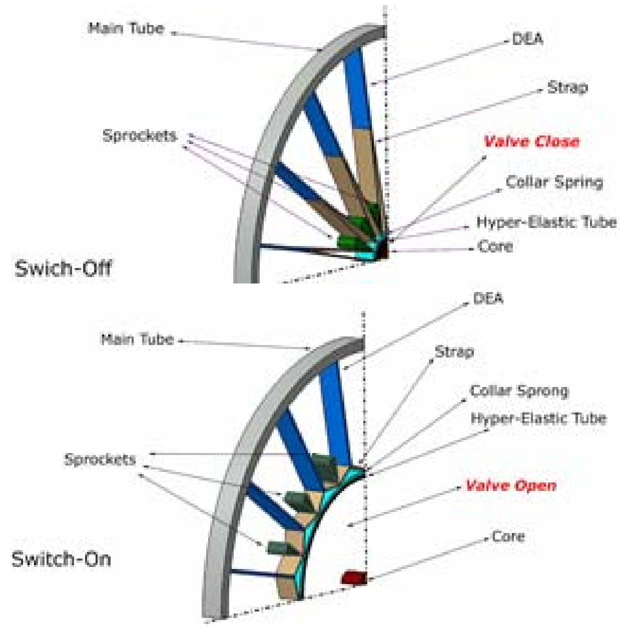

Figure 26: Cell actuator mechanism depicted schematically in 1/4th of a cell

Considering all these requirements the DEA compressor is designed when its output needs to be available in very short time period in high frequencies. The results of current design will be published in my next paper.

References

1. B. Aryana, "Implementing DEA to create a novel type of compressor," Materials Science and Engineering C, vol. 30, p. 42–49, 2010.
2. B. Aryana, "New version of DEA compressor for a novel hybrid gas turbine cycle: TurboDEA," Energy, vol. 111, pp. 676-690, 15 September 2016.

Ras Labs, LLC

***E*AP Based Synthetic Muscle™ Updates**

Lenore Rasmussen rasmussl@raslabs.com

The Synthetic Muscle Experiment that was lunched by Ras Labs has returned to Earth in May this year, and the results after a 1+ yearlong exposure on the International Space Station (ISS) were very good. All the 32 flown samples survived with similar material integrity and electroactivity profiles compared to the 32 ground control samples. This work was presented as an invited speaker at the ISS R&D conference in July, at Princeton University in August, and as part of the presentations when NASA administrator Charles Bolden visited Worcester Polytechnic Institute (WPI) in September, and will be presented at EAPAD 2017 in March. At WPI, Lenore Rasmussen created and now teaches the “Smart Materials, Actuation, and Biomimicry” graduate level course cross-referenced through the robotic engineering and biomedical engineering departments. Ras Labs was honored to receive two prestigious awards in 2016: the 2016 Innovation in Commercialization & Nongovernment Utilization Award at the American Astronautically International Space Station Research and Development Conference; and Ras Labs was a 2016 Finalist for Innovative Technology of the Year in Robotics through the Massachusetts Technology Leadership Council. Ras Labs also received additional Philadelphia Pediatric Medical Device Consortium funding administered through the Children’s Hospital of Philadelphia for sensing characterization of our EAPs.

Ras Labs EAP based Synthetic Muscle™ contracts and expands at low voltages, including use with off the shelf batteries. There are many uses for its smart EAP materials that can shape-morph at low voltage (0 to 50 V) with minimal noise and heat signatures, that can sense pressure over a wide range, and attenuate force. An adjustable dynamic prosthetic liner and an autonomous human-like hand comprising EAP based Synthetic Muscle™ are under development. Robots made of these smart EAP materials that can withstand a variety of extreme environments (2 to 408 K, high and low pressures, corrosion resistance, radiation resistance, including broad spectrum radiation on the ISS) could perform essential tasks where humans and other life forms cannot enter, in space and on Earth. At the 2017 SPIE’s EAPAD EAP-in-Action Session, the operation of the latest Synthetic Muscle™ based actuators will be demonstrated. Actuation will be performed underwater, on land with suitable elastomeric coatings, and mechanical pressure sensing demonstrated. Also, a prosthetic liner prototype with self-adjusting EAP based pads and sensing robotic gripper will be demonstrated.

In the news:

Ras Labs was highlighted in:

CASIS ISS Upward Magazine:
http://www.raslabs.com/wpcontent/uploads/2016/08/Upward-Issue-2-Ras-Labs.pdf

Philadelphia Pediatric Medical Device Consortium:
https://www.phillypediatricmeddevice.org/projects

Interview from the 2016 ISS R&D Conference:
https://www.youtube.com/watch?v=_406gfSToBs

Contact information:
Lenore Rasmussen, PhD, CEO, CTO, and Founder Ras Labs, LLC, Synthetic Muscle™ for Prosthetics & Robotics, Adjunct Faculty, WPI, Robotics Engineering, 85 Prescott Street, Worcester, MA 01609, Email: rasmussl@raslabs.com Web-site: www.raslabs.com

SNAPSHOTS

Figure 27: Prototype in collaboration with United Prosthetics, Inc.

Figure 28: Prototype of a robotic gripper with Ras Labs' EAP that senses pressure – what we know as touch.

Figure 29: PPPL Intern Logan Valenza, Lenore Rasmussen, MLSC Interns Charles Sinkler, and Catherine Poirier with stereo-microscope at US DOE's Princeton Plasma Physics Lab.

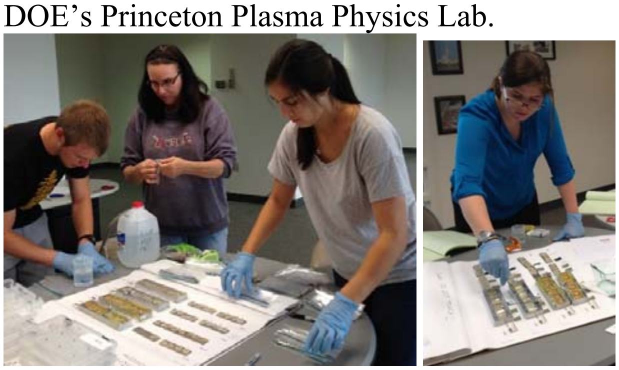

Figure 30: MLSC Intern Charlie Sinkler, Lenore Rasmussen, Simone Rodriguez, and MLSC Intern Catherine Poirier preparing samples returned from the ISS at Ras Labs.

Figure 31: Lenore Rasmussen (center right) discussing the Synthetic Muscle Experiment with NASA Administrator Charles Bolden (center left) at Worcester Polytechnic. Institute. Source: NASA

University of Nevada, Las Vegas (UNLV)

An IPMC Driven Soft-Robot: Replicating Travelling Waves of Flying-Fish Wings during Descent

Kwang J. Kim, Kwang.kim@unlv.edu

An array of IPMC actuators has been used to generate travelling wave motions similar to those observable in the wings during descent and landing in flight of a four-wing flying-fish. Four-wing flying-fish have been observed to exhibit a travelling wave motion in their wings during landing (see video for reference: https://youtu.be/9uFjmeWnFZ4?t=79), which has been suggested to have drag-control characteristics that possibly contribute to the smooth, controlled landing of flying-fish. In this way, biomimicry of travelling waves may be useful to marine and aerodynamic applications. A method of generating travelling wave-like motion in a soft-robotic system was developed using IPMCs. Inspired by the observed travelling wave in flying-fish wings during descent and landing, a structure was made to mimic wing dimensions of a four-wing flying-fish.

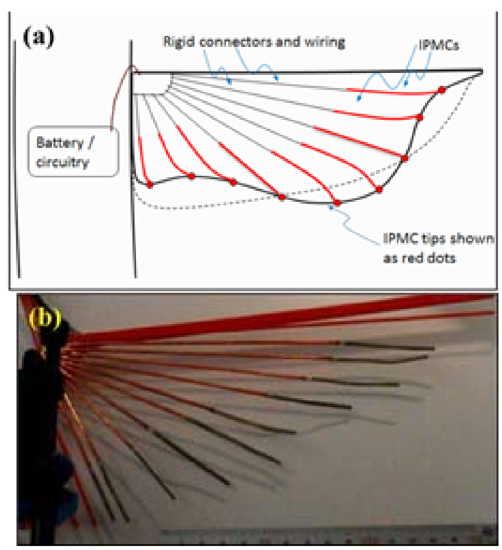

Figure 32: a) Schematic of conceptual design for biomimicry of the flying-fish using IPMCs; **b)** IPMCs attached to a 3D printed artificial wing structure. Contributors include Tyler Stalbaum, Taeseon Hwang, Sarah Trabia, Qi Shen, Robert Hunt, Zakai Olsen, and Kwang J. Kim of UNLV (www.kwangjinkim.org).

An array of IPMC actuators was attached to the structure. Preliminary tests show that generation of a travelling wave with IPMC actuators is possible with good displacement and operational frequency in comparison to the flying-fish; however, further testing needs to be done to determine the optimal actuator characteristics. This work provides an experimental platform for further investigation of the effects of travelling wave motion in the wings of flying-fish and offers a feasible method of recreating these effects for applications in marine technology. Using IPMC actuators, the design is fully operable in water and offers the unique advantage of controlled waveform generation in a wing or fin.

University of North Carolina

Bottlebrush elastomers: A new platform for freestanding electroactuation

Mohammad Vatankhah-Varnosfaderani,[1] William F. M. Daniel,[1] Alexandr P. Zhushma,[1] Qiaoxi Li,[1] Benjamin J. Morgan,[1] Krzysztof Matyjaszewski,[2] Daniel P. Armstrong,[3] Richard J. Spontak,[3,4] Andrey V. Dobrynin,[5] Sergei S. Sheiko[1](Sergei@email.unc.edu)

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[3]*Department of Chemical and Biomolecular Engineering, North Carolina State University, Raleigh, North Carolina 27695, USA*
[4]*Department of Materials Science and Engineering, North Carolina State University, Raleigh, North Carolina 27695, USA*
[5]*Department of Polymer Science, University of Akron, Akron, Ohio 44325, USA*

Dielectric elastomers (DEs) are the leading technology for artificial muscles due to a favorable combination of large stroke, fast response, and high energy density [1-3]. However, at large actuations, DEs are prone to spontaneous rupture from electromechanical instability. This shortcoming is currently circumvented by chemical or physical bracing [4] which increases bulk and rigidity of the total actuator assembly and leads to significant cutbacks in device efficiency and utility [5-6]. Now, we present a molecular design platform (**Figure 33**A) for the creation of freestanding actuators that allow for large stroke (>300%) at low applied fields (<10 V μm^{-1}) in unconstrained as cast shapes (**Figure 33**B). This approach is based on bottlebrush architecture, which features inherently strained polymer networks that eliminate electromechanical instability and the need for bracing. Through accurate control of side-chain length (n_{sc}) and crosslink density (n_x), we obtained effective actuation properties on par with commercial actuators with the advantage of lighter weight, lower voltage operation, and ease of fabrication, which open new opportunities in soft-matter robotics [7-8].

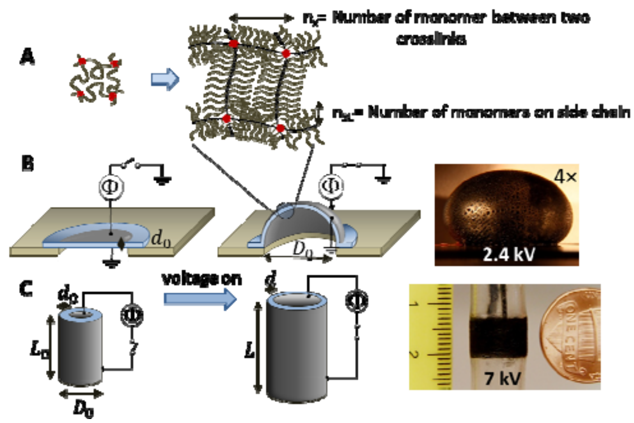


Figure 33: Freestanding DE actuators. A Schematic of bottle brush networks and definition of their structural parameters (n_X, n_{sc}), B, Deflection of a circular diaphragm ($d_0 = 0.44$ mm) and C, uniaxial extension and lateral dilation of a tube ($d_0 = 0.80$ mm and $D_0 = 11$ mm) are evident upon electroactuation with increasing voltage Φ. The maximum strain achieved in the diaphragm and tube actuators was $\varepsilon_a = (\lambda_a - 1)100\% = 300 \pm 50\%$ and $25 \pm 5\%$, respectively. Both samples employ the same PDMS bottlebrush elastomer ($n_{sc} = 14, n_x = 200$).

References

1. Pelrine, R., Kornbluh, R., Pei, Q. & Joseph, J., High-speed electrically actuated elastomers with strain greater than 100%. *Science* **287**, 836-839 (2000).

2. Carpi, F., Bauer, S. & De Rossi, D., Stretching Dielectric Elastomer Performance. *Science* **330**, 1759-1761 (2010).
3. Brochu, P. & Pei, Q., Advances in Dielectric Elastomers for Actuators and Artificial Muscles. *Macromol. Rapid Comm.* **31**, 10-36 (2009).
4. Romasanta, L. J., Lopez-Manchado, M. A. & Verdejo, R., Increasing the performance of dielectric elastomer actuators: A review from the materials perspective. *Prog. Polym. Sci.* **51**, 188-211 (2015).
5 Madden, J. D., Mobile robots: motor challenges and materials solutions. *Science* **318**, 1094-1097 (2007).
6. Ha, S. M., Yuan, W., Pei, Q., Pelrine, R. & Stanford, S., Interpenetrating Polymer Networks for High-Performance Electroelastomer Artificial Muscles. *Adv. Mater.* **18**, 887-891 (2006).
7. Cho, A., Stretching Horizons for Electrical Devices. *Science* **287**, 783 (2000).
8. Bar-Cohen Y. *Biomimetics: Biologically inspired technologies* (Taylor & Francis Group, Boca Raton, FL, 2005).

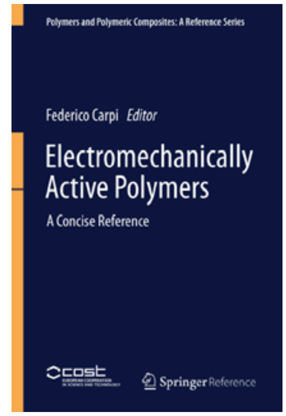
NEW PUBLICATIONS

New Book "Electromechanically Active Polymers "

F. Carpi, Editor, *Electromechanically Active Polymers: A Concise Reference*, Zurich: Springer, 2016.
http://link.springer.com/referencework/10.1007%2F978-3-319-31530-0

Prepared under the aegis of the 'European Scientific Network for Artificial Muscles', this book is the product of extensive collaborative efforts led by European researchers and involving respected experts from around the globe.

It provides a comprehensive and clearly structured introduction to the broad field of transducers and artificial muscles based on EAPs, the goal being to present basic concepts and established knowledge in an accessible form. Its tutorial style and structure make this book an easy-to-use reference guide for students, researchers and practitioners alike. Different sections cover all categories of EAP materials, with separate chapters addressing the fundamentals, materials, device configurations, models, and applications, as well as operative guidelines on how to get started in experimentation with electromechanically active polymers. The functional and structural properties of EAP transducers are described and explained, and their broad range of applications in optics, acoustics, haptics, fluidics, automotive systems, robotics, orthotics, medical tools, artificial organs and energy harvesting is illustrated.



Invited paper in Applied Physics Reviews

In an invited article in Applied Physics Reviews (doi: 10.1063/1.4963164), Rosset and Shea review recent progress in miniaturized Dielectric Elastomer Actuators, Sensors and Energy Harvesters. The review focuses primarily on devices where the large strain, compliance, and high level of integration offered by dielectric elastomer transducers provide significant advantages over competing actuation technologies at a size-scale from 0.1 mm to 100 mm. The most actively investigated application areas are presented including: tuneable optics, soft robotics, haptics, micro fluidics, biomedical devices, and stretchable sensors. The fabrication challenges related to miniaturization are discussed. Finally, the impact of miniaturization on strain, force, and driving voltage on the performance of mm-scale DEAs is addressed.

Reference

S. Rosset and H. R. Shea, "Small, fast, and tough: Shrinking down integrated elastomer transducers", Applied Physics Reviews, doi: 10.1063/ 1.4963164, 3, 031105 (2016).

FUTURE CONFERENCES

Date	Conference/Symposium
Feb. 20-23, 2017	The 6th International Conf. on Electroactive Ceramics and

	Polymers (ICEP-2017) will be held at the Indian Institute of Technology Kharagpur, India. For information contact *Amreesh Chandra* *achandra@phy.iitkgp.ernet.in* or *amreesh.chandra@gmail.com*
March 25-29, 2017	The 19th EAPAD Conf., SPIE's Smart Structures & Materials and NDE Symposia will be held at Portland, Oregon. For information see http://spie.org/eap or contact: Megan Artz megana@spie.org
April 10 – 12, 2017	The Conference "Chemical Physics of Electroactive Materials": a *Faraday Discussions meeting* will be held in Cambridge, UK. For information contact: Alexei Kornyshev a.kornyshev@imperial.ac.uk
June 6-7, 2017	EuroEAP 2017 will be held in Cartagena, Spain, and chaired by Toribio Otero (University of Cartagena). Detailed information will be made available at www.euroeap.eu/conference
July 24 – 28, 2017	The 6th Living Machines International Conference on Biomimetic and Biohybrid Systems will be held at Stanford University. Information is available at http://csnetwork.eu/activities/living-machines-2017
June 2019	The EuroEAP 9th International Conference on Electro-mechanically Active Polymer (EAP) transducers & artificial muscles will be held during the first half of June 2019

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

Recipes: http://ndeaa.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-recipe.htm

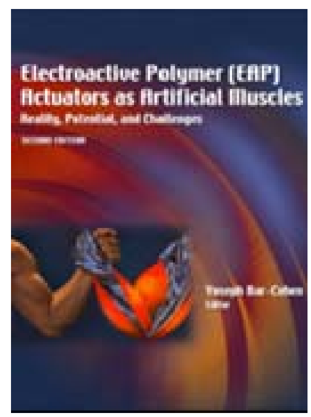
EAP Companies: http://ndeaa.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-material-n-products.htm

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

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

2nd Edition of the book on EAP

Y. Bar-Cohen (Editor)

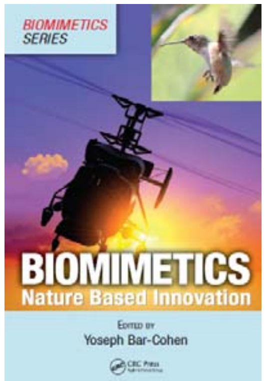


In March 2004, the 2nd edition of the "Electroactive Polymer (EAP) Actuators as Artificial Muscles - Reality, Potential and Challenges" was published. This book includes description of the available materials, analytical models, processing techniques, and characterization methods. This book is intent to provide a reference about the subject, tutorial resource, list the challenges and define a vision for the future direction of this field. Observing the progress that was reported in this field is quite heartwarming, where major milestones are continually being reported.

Biomimetics books series

The following 3 books are part of the CRC Biomimetics Book Series, for which Yosi Bar-Cohen is the Editor.

Biomimetics – Nature Inspired Innovation
Yoseph Bar-Cohen (Editor)

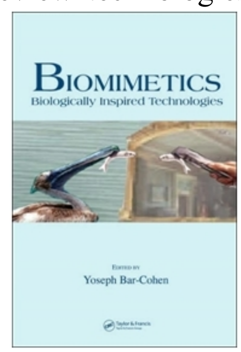


This book contains 20 chapters covering various aspects of the field of biomimetics including Nature as a source for inspiration of innovation; Artificial Senses & Organs; Bio-mimicry at the Cell-Materials Interface; Multiscale modeling of plant cell wall architecture and tissue mechanics for biomimetic applications; Biomimetic composites; EAP actuators as artificial muscles; Refreshable Braille Displays Actuated by EAP; Biological Optics; Biomimicry of the Ultimate Optical Device: Biologically Inspired Design: a tool for interdisciplinary education Enhancing Innovation Through Biologically-Inspired Design; Self-reproducing machines and manufacturing processes; Biomimetic products; Biomimetics for medical implants; Application of biomimetics in the design of medical devices; Affective Robotics: Human Motion and Behavioral Inspiration for Safe Cooperation between Humans and Humanoid Assistive Robots; Humanlike robots - capabilities, potentials and challenges; Biomimetic swimmer inspired by the manta ray; Biomimetics and flying technology; The Biomimetic Process in Artistic Creation; and Biomimetics - Reality, Challenges, and Outlook. Further information is available at:
http://www.crcpress.com/product/isbn/9781439834763

Architecture Follows Nature - Biomimetic Principles for Innovative Design
Authored by Ilaria Mazzoleni ***www.imstudio.us*** *info@imstudio.us in collaboration with Shauna Price* http://www.crcpress.com/product/isbn/9781466506077

The book entitled "Architecture Follows Nature - Biomimetic Principles for Innovative Design" has been published by CRC Press as part of the book series on Biomimetics for which Y. Bar-Cohen is the editor. The homepage of this book series is: http://www.crcpress.com/browse/series/?series_id=2719

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

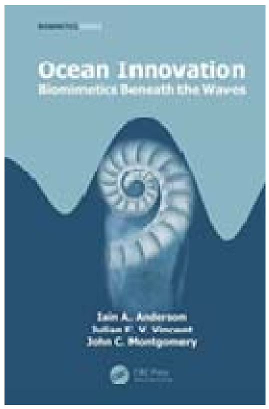


This book about Biomimetics review technologies that were inspired by nature and outlook for potential development in biomimetics in the future. This book is intended as a reference comprehensive document, tutorial resource, and set challenges and vision for the future direction of this field. Leading experts (co)authored the 20 chapters of this book and the outline can be seen on
http://ndeaa.jpl.nasa.gov/ndeaa-pub/Biomimetics/Biologically-Inspired-Technology.pdf

Ocean Innovation: Biomimetics Beneath the Waves
Authored by Iain A. Anderson i.anderson@auckland.ac.nz, Julian Vincent, and John Montgomery
https://www.crcpress.com/Ocean-Innovation-Biomimetics-Beneath-the-Waves/Anderson-Vincent-Montgomery/p/book/9781439837627

Generally, biomimetics is the idea of creating new technologies abstracted from what we find in biology. The book "Ocean Innovation: Biomimetics Beneath the Waves" seeks that technological inspiration from the rich biodiversity of marine organisms. Bringing both a biological and engineering perspective to the biomimetic potential of oceanic organisms, this richly illustrated book investigates questions such as:

- How can we mimic the sensory systems of sea creatures like sharks, sea turtles, and lobsters to improve our ability to navigate underwater?
- What can we do to afford humans the opportunity to go unnoticed by marine life?
- How can we diffuse oxygen from water to enable deep diving without the risk of decompression sickness?



Each chapter explores an area where we, as divers and technologists, can benefit from understanding how animals survive in the sea, presenting case studies that demonstrate how natural solutions can be applied to mankind's engineering challenges.

Books about robotics

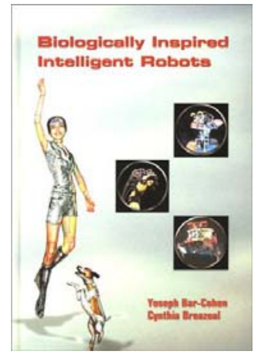
The Coming Robot Revolution - Expectations and Fears about Emerging Intelligent, Humanlike Machines

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

This book covers the emerging humanlike robots. Generally, in the last few years, there have been enormous advances in robot technology to which EAP can help greatly in making operate more lifelike. Increasingly, humanlike robots are developed for a wide variety of applications. These "smart" lifelike robots are designed to help with household chores, as office workers, to perform tasks in dangerous environments, and to assist in schools and hospitals. In other words, humanlike robots are coming and they may fundamentally change the way we live, even the way we view ourselves.

Biologically Inspired Intelligent Robots

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



The book that is entitled "Biologically-Inspired Intelligent Robots," covering the topic of biomimetic robots, was published by SPIE Press in May 2003. There is already extensive heritage of making robots and toys that look and operate similar to human, animals and insects. The emergence of artificial muscles is expected to make such a possibility a closer engineering reality. The topics that are involved with the development of such biomimetic robots are multidisciplinary and they are covered in this book. These topics include: materials, actuators, sensors, structures, control, functionality, intelligence and autonomy.

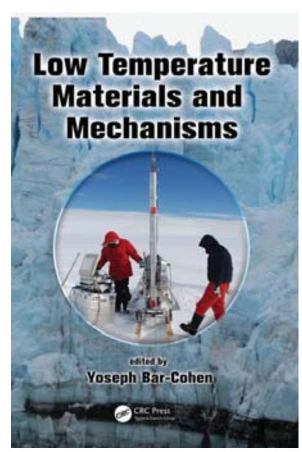
Other books

Low Temperature Materials and Mechanisms

Yoseph Bar-Cohen (Editor)

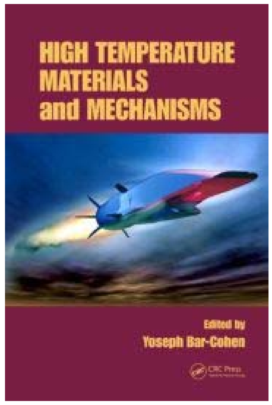
https://www.crcpress.com/Low-Temperature-Materials-and-Mechanisms/Bar-Cohen/p/book/9781498700382

Published on July 2016, this book addresses the growing interest in low temperature technologies. Since the subject of low temperature materials and mechanisms is multidisciplinary, the chapters reflect the broadest possible perspective of the field. Leading experts in the specific subject area address the various related science and engineering chemistry, material science, electrical engineering, mechanical engineering, metallurgy, and physics.



High Temperature Materials and Mechanisms

Yoseph Bar-Cohen (Editor)
http://www.crcpress.com/product/isbn/9781466566453



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

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

Happy New Year

WorldWide Electroactive Polymers (EAP) Newsletter

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