FROM THE EDITOR
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This Newsletter issue reports the latest progress in the fields of Electroactive Polymers (EAP) and Biomimetics.

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ABOUT THE EXPERTS
Hani Naguib
Hani Naguib, Professor at University of Toronto, Canada, has been elected as a Fellow of the International Society for Optics and Photonics SPIE. The Fellowship of SPIE is awarded for outstanding leaders in the scientific community who have made significant scientific and technical contributions in optics, photonics, imaging, and related fields. Naguib was recognized for his major contributions in smart materials based sensors and actuators in particular for artificial muscles and electronic skins applications. Naguib is the founding director of the Toronto Institute for Advanced Manufacturing (TIAM) and the Smart Polymers and Composites Lab (SAPL) at the University of Toronto. His research group is exploring advanced manufacturing technologies for developing nanostructured active polymers and composites and to apply these materials in a range of industrial and health care technologies such as smart sensors and actuators, batteries and supercapacitors, artificial muscles, smart textiles. The main goal of his research program is to develop
sustainable and transformational materials and manufacturing for the energy management and health care sectors.

Naguib is the recipient of numerous honors and awards such as the Canada Research Chair, the Premier’s Early Research Award of Ontario, the Canada Foundation of Innovation, and the faculty Early Teaching Award. He is a Professional Engineer in Canada, a Chartered Engineer in U.K., a Fellow of the Institute of Materials Minerals and Mining IOM3 in UK, Fellow of the American Society of Mechanical Engineers ASME, Fellow of the Society of Plastics Engineers SPE, and Fellow of the Canadian Society of Mechanical Engineers CSME. He has been serving on the technical divisions’ board of directors for the SPE, ASME and CSME and has been organizing and chairing various conferences, symposia and seminars in national and international conferences. Naguib is the Associate Editor of the IOP Journal of Smart Materials, Journal of Cellular Plastics and Cellular Polymers.

Caleb Christianson
Caleb Christianson received the First Place SPIE Best Student Paper Award for his work on “Fluid Electrodes for Submersible Robotics Based on Dielectric Elastomer Actuators” at SPIE Smart Structures/ NDE 2017. Caleb is in his third year in the Nano-Engineering PhD program at UC San Diego. His Ph.D. research is on the development of dielectric elastomers as actuators and sensors for bioinspired robotics. He is coauthor of seven journal articles on a variety of topics including uncooled infrared detectors, a defect detection tool for superconductors, and micro- and nanorobotics for defense and biomedical applications. He has interned at NASA Jet Propulsion Laboratory, Science Applications International Corporation (SAIC), and two startups. Caleb holds a B.S. degree in Engineering Physics from the University of Kansas and an M.S. degree in Nano-Engineering from UC San Diego. He is supported by a National Science Foundation Graduate Research Fellowship.

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 a standard for EAP materials is posted on the internet and can be read at http://dx.doi.org/10.1088/0964-1726/24/10/105025

EuroEAP Society: new Executive Committee
Federico Carpi, University of Florence, Italy

During the annual meeting of the EuroEAP Society (European Society for Electromechanically Active Polymer Transducers & Artificial Muscles’ (www.euroeap.eu), which took place in Cartagena, Spain, on 6 June 2017, the following Executive Committee members have been elected for the new mandate 2017-2021:

The EuroEAP Society President: Anne Skov, Technical University of Denmark (Denmark)

Vice-Presidents:
- Ingrid Graz, University of Linz (Austria)
- Edwin Jager, Linköping University (Sweden)
- Gabor Kovacs, EMPA (Switzerland)
As the past President, I express to Anne and her collaborators my best wishes for their work. For those who are still not familiar with it, the EuroEAP Society is a non-profit 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. The Society operates at international level and it welcomes members from any country worldwide. If you are interested in learning more about the Society and the benefits of being a member, please visit the website www.euroeap.eu.

**EuroEAP Society Challenge**

**Challenge committee**

The first “EuroEAP Society Challenge” was held during the conference. The challenge consisted of an open competition where teams of talented researchers could showcase a project of their choice and compete with colleagues in academia and industry. As the final aim was to captivate and inspire the imagination of experts and the public alike with the possibilities that EAP technologies empower, the Challenge had no predefined goals; participants had the opportunity to showcase their pet projects, which they considered interesting, but not necessarily of profound scientific importance.

Four companies (CTSystems, LEAP Technology, Parker and StretchSense) sponsored the Challenge by offering materials and devices that the participants could request and use for their projects. The six teams participating had to build and test an EAP based new material, device or system, produce a short presentation video and present a demo at the conference. Each project was evaluated by two juries. The first jury consisted of a panel of experts allocating half of the possible scores. The second half of the scores was provided by the EuroEAP 2017 attendees, who also evaluated the exhibited demos.

The first three classified projects were:

1st Steffen Hau (Saarland University) who received 2,000.00 Euros as cash prize. (video available at: [https://youtu.be/6sAtlsdXoog](https://youtu.be/6sAtlsdXoog)) See Figure 1.

2nd Michele Ghilardi & Hugh Boys (Queen Mary University of London) (video available at: [https://youtu.be/I-gPnLurqAU](https://youtu.be/I-gPnLurqAU))

3rd Gabriele Frediani (Queen Mary University of London) (video available at: [https://youtu.be/TRdZvCBnju0](https://youtu.be/TRdZvCBnju0))

The videos produced by the remaining participants are available at the EuroEAP Society challenge Youtube channel ([https://www.youtube.com/channel/UCFt1cHQin-LIFtTJgscjOvQ](https://www.youtube.com/channel/UCFt1cHQin-LIFtTJgscjOvQ)).

**Figure 1:** The winner of the “EuroEAP Society challenge 2017”, Steffen Hau (left), the EuroEAP Dissemination & Outreach Committee representative, Luigi Calabrese (center), the EuroEAP Society President, Anne Skov (right).

Given the good outcomes in terms of participation and scientific quality of the presented demos, the Challenge will be held again the next 2018. Detailed information will be made available at www.euroeap.eu.

**JOB OPPORTUNITIES**

**XCat, Inc., Houston, Texas**

**Position Summary:** Focus on the design, fabrication and characterization of ionic Electroactive Polymer actuators. Conduct research towards the improvement of electrode materials, polymer membranes and electrolytes. Interact with a large technically diverse team of engineers to integrate and optimize the EAP actuators for a microsurgical robotic application.
Position Key Accountabilities
1. A basic knowledge of electrochemistry and electrochemical techniques (e.g. cyclic voltammetry, electrochemical impedance spectroscopy).
2. Experience in battery (or capacitor) and materials development for electrochemical energy conversion/storage technologies (in particular with carbon materials and composites)
3. Individual must be highly motivated with excellent verbal and written communication skills.
4. Must be able to adapt to a fast-paced, dynamic work environment, and work independently and as a part of a team.
5. Assists research Engineer, Sr. Research Engineer, Engineering Scientist, or faculty members with specific phases of research projects.
6. Performs related duties as required.

Certifications/Skills:
Master’s degree in materials science, chemistry, chemical engineering or related field.
A basic knowledge of electrochemistry and electrochemical techniques (e.g. cyclic voltammetry, electrochemical impedance spectroscopy). Experience in battery (or capacitor) and materials development for electrochemical energy conversion/storage technologies.

Minimum Education: Master’s degree in materials science, chemistry, chemical engineering or related field.

Contact: biomechanicalengineer@gmail.com
XCath, Inc., Houston, Texas

Equal Employment Opportunity: XCath, Inc. is an Equal Opportunity/Affirmative Action employer. Women, minorities, veterans and disabled persons are encouraged to apply.

UPCOMING CONFERENCES
2018 SPIE EAPAD Conference
The 2018 SPIE’s EAPAD conference is going to be held at Denver, Colorado, from March 4 thru 8, 2018. This conference, which is part of the Smart Structures Symp., is going to be the 20th annual one and is going to be chaired by Yoseph Bar-Cohen, JPL, and Co-chaired by Iain A. Anderson, The Univ. of Auckland (New Zealand). The Conference Program Committee consists of representatives from 32 countries. The call for papers is posted at: http://www.spie.org/eap

The papers 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.

In the 2018 EAPAD Conf., a Special Session is going to be “Celebrating the EAP Advances in The Last 20 Years” and will have presentation by pioneers of the field. The speakers are going to give an overview of the progress in each of the key EAP materials.

The Keynote speaker is going to be Brian Trease (Figure 2), Mechanical, Industrial, & Manufacturing Engineering, The University of Toledo. His paper title is “Origami-inspired Engineering, from Minimally Invasive Surgery to Exoplanet Exploration”.

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.

<table>
<thead>
<tr>
<th>Year</th>
<th>Co-chair</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>Mohsen Shahinpoor, U. of New Mexico</td>
<td>USA</td>
</tr>
<tr>
<td>2000</td>
<td>Steve Wax, DARPA</td>
<td>USA</td>
</tr>
</tbody>
</table>

Figure 2: Brian Trease, the Keynote Speaker at the 2018 EAPAD.
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  
2018 Iain A. Anderson, The Univ. of Auckland  New Zealand  

**EuroEAP 2018 – the 8th international Conf. on EAPs**

The rapid expansion of the EAP technologies has stimulated in Europe the creation of the annual, international EuroEAP conference series, organised by the EuroEAP Society. The conference is a highly multidisciplinary event with international breath. It is always held in Europe, in charming and easy-to-reach locations, and gathers participants and experts from all over the world.

The EuroEAP conference has a unique format, which is conceived to facilitate interaction among participants and includes:
- ‘EAPlenaries’: plenary talks;
- ‘EAPodiums’: invited lectures;
- ‘EAPromises’: invited lectures given by young emerging researchers;
- ‘EAPills’: very short oral presentations given by all the non-invited contributors;
- ‘EAPosters’: poster presentations (associated with the ‘EAPills’) given by all the non-invited contributors;
- ‘EAPrototypes’: exhibitions of prototypes (optional and free-of-charge for all attendees);
- ‘EAProducts’: exhibitions of products (optional and free-of-charge for all attendees).

The entire event is condensed in two dense days, made of consecutive single-track sessions, consisting of oral and poster sessions.

During the oral sessions, all the contributors (invited and not) present the significance of their work, in front of all the participants.

For non-invited participants, the oral presentation is very short (EAPill) and it is aimed at anticipating in no more than 2 minutes key aspects of the work, which then has to presented more extensively with a poster (EAPoster), during a subsequent dedicated poster session.

EAPills and EAPosters have to be prepared according to special templates: see the section ‘Templates’.

The invited oral presentations are given by world-leading scientists, young emerging researchers, as well as representatives of industry.

The oral sessions are intertwined by long poster sessions that facilitate discussions among participants in a friendly atmosphere.

Prototypes and products can be shown during the whole event (EAPrototypes and EAProducts) by any attendee, at no cost.

Discussions and networking continue also during the organised lunch on each day and the social dinner on the first day, whose costs are entirely included within the registration fees that are maintained competitively low by the non-for-profit approach taken in organising this unique event.

The next edition, EuroEAP 2018, will take place in Lyon, France, on 5-6 June 2018 and will be chaired by Prof. Claire Jean-Mistral (INSA Lyon, France). Detailed information will be made available at www.euroeap.eu/conference.

**TechSurge Workshop**

Kocak, Donna dkocak@harris.com

The Marine Technology Society (MTS) is hosting a TechSurge Workshop on “Marine Propulsion and Design Inspired from Nature”, in Norfolk, VA, on July 19 – 21. This workshop will provide an opportunity to discuss multi-disciplinary work in bio-inspired marine vehicles, sensors and propulsion. Panels and breakout will provide collaboration among industry, government and
academic participants. The agenda and registration information link of this workshop can be found at: https://www.mtsociety.org/Conferences/marinedesign2017.aspx

This event will also include launching a new MTS Professional Committee on Bio-Inspired Marine Systems. This Committee will provide the marine community a unique forum for maintaining an awareness of new insights into the dynamic capabilities of underwater creatures in bio-propulsion, bio-sensing, and dynamic systems evolved for extreme environments. The forum will foster unique collaboration among zoologists, marine biologists, materials scientists, hydrodynamicists, naval architects and engineers, to enable incorporation of biologically inspired technology into high performance underwater system designs.

Finally, a special issue of the MTS Journal will capture information presented at this event as well as other submissions on the topic. There is still an opportunity to submit a commentary to this issue by contacting one of the event organizers.

RECENT CONFERENCES

2017 SPIE EAPAD Conference
The 19th SPIE’s Electroactive Polymers Actuators and Devices (EAPAD) conference was held at Portland, Oregon from March 25 thru 29, 2017. This Conf., which is part of the Smart Structures Symp. (SSM), is the leading international forum for presenting the latest progress and information exchange among the attendees regarding the advances, capabilities, challenges and potential future directions. The conference was Chaired by Yoseph Bar-Cohen, JPL/Caltech, and Co-Chaired by Jonathan M. Rossiter, Univ. of Bristol (United Kingdom). The Conference included 122 presentations and it was well attended by internationally leading experts in the field including members of academia, industry, and government agencies from the USA and overseas.

This year, the SSM Symposium included two planetary speakers that made EAP related presentations. David Hanson (Figure 3), Hanson Robotics, presented “Electroactive polymers for healthcare and biomedical applications”. His presentation included a demonstration of his humanlike robot, Sophia, conversing with him and making facial expressions. Hanson pointed out that bioinspired intelligent robots are coming of age in both research and industry, and they are propelling market growth for robots and AI. However, conventional motors limit the capability of bioinspired robotics. EAP actuators and sensors could improve the simplicity, compliance, physical scaling, and offer bioinspired 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. In his presentation, Hanson reviewed the progress, opportunities, and challenges in his latest work with social robots and EAP actuators, and he proposed a roadmap for EAP actuators in bio-inspired intelligent robotics.

The 2nd Planetary presenter has been Chiara Daraio, California Institute of Technology (United States). She presented a planetary paper entitled “Plant nanobionic materials for thermally active, soft, artificial skins”. In her paper, she described bionic materials as a class of materials that aims to preserve, enhance, and exploit properties of living systems for engineering purposes. In most cases, however, creating synthetic materials that reproduce or surpass the performance of natural materials has been elusive. In her lab, she fabricated synthetic materials that combine carbon nanoparticles in a matrix of plant cells, to create new temperature
sensors with record-breaking responsivity. She had extracted the active molecule, pectin, responsible for the temperature sensitivity in plants, to create ultra-sensitive, flexible membranes that can map temperature changes from a distance. These materials augment properties of synthetic skins for robotics and prosthesis, and can find applications in consumer electronics or NDE.

During the SSM Symposium, a notable award recipient in the Smart Structures Symposium has been Hani E. Naguib, Univ. of Toronto, Canada (Figure 4). He received the 2017 SPIE Fellow Award for his contributions to multifunctional materials development and characterization including EAP materials. Photos from the conference were posted at the SPIE website http://spie.org/about-spie/press-room/spie-smart-structures/nondestructive-evaluation-2017-news-and-photos.

A notable accomplishment of the students who participated and made a presentation at the EAPAD Conference, has been the winner of the #1 best student paper. The winner has been Caleb Christianson, UCSD, and the title of his paper was “Fluid electrodes for submersible robotics based on dielectric elastomer actuators” [10163-57] (Figure 5).

In the EAPAD Conf., the Keynote speaker has been Siegfried G. Bauer (Figure 6), Johannes Kepler Univ., Linz, Austria, and the title of his paper has been “Electroactive polymers for healthcare and biomedical applications”. In his paper, he noted that electroactivity has been noticed in biological substances, including proteins, polynucleotides and enzymes. In addition, piezo- and pyroelectricity were found in wool, hair, wood, bone and tendon. He stated that there is still a strong debate about the physiological importance of electroactive effects in biological materials, but it is interesting that electroactive phenomena are widespread in natural materials. According to Bauer, already with the currently available science and technology, we are at the verge of witnessing the demonstration of truly complex bionic systems and the future of EAP materials is bright.

Overall, the presented papers at the EAPAD Conf. reported the significant progress that was made in each of the topics of the EAP field infrastructure. The topics included: theoretical modeling and analysis of EAP mechanisms; improved EAP materials, processes, fabrication (including 3D printing) and characterization techniques; emerging EAP actuators (including ionic, conducting, shape memory polymers, CNT and dielectric EAP); applications of EAP materials including power generation and energy harvesting, robotics, haptic, tactile, and other sensors. Of significant interest, Gabor M. Kovacs, EMPA, Switzerland (Figure 6) presented a paper entitled “From research to production” in which he...
described his company efforts to create a commercial EAP actuator at mass production scale and the related issues.

The efforts described in the presented papers are showing significant improvements in understanding the electromechanical principles towards better methods of dealing with the challenges to the materials applications. Researchers are continuing to develop analytical tools and theoretical models to describe the electro-chemical and -mechanical processes, non-linear behavior as well as methodologies of design and control of the activated materials. EAP with improved response were described including dielectric elastomer, IPMC, conducting polymers, gel EAP, carbon nanotubes, and other types. Specifically, there seems to be a significant trend towards using dielectric elastomers as practical EAP actuators.

The invited papers in the 2017 EAPAD Conference were:

1. Gabor M. Kovacs, EMPA (Switzerland), “From research to production” Paper 10163-2
2. 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”, Paper 10163-3
3. Stoyan Smoukov, Univ. of Cambridge (United Kingdom), “Bottom-up approaches to multifunctional materials and artificial morphogenesis”, Paper 10163-8
6. Christoph Keplinger, Univ. of Colorado Boulder (United States), “Reliable, robust, electrically powered soft actuators that self-heal from mechanical and electrical damage”, Paper 10163-55
7. 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”, Paper 10163-60
8. Gih-Keong Lau, Yao-Wei Chin, Nanyang Technological Univ. (Singapore); Thanh-Giang Lau, Nanyang Technological Univ (Singapore), “Development of elastomeric flight muscles for flapping wing micro air”, Paper 10163-69
9. Mohammad Vatankhah-Varnosfaderani, William F. M. Daniel, Alexandr P. Zhushima, Qiaoxi Li, Benjamin J. Morgan, The Univ. of North Carolina at Chapel Hill (United States); Krzysztof Matyjaszewski, Carnegie Mellon Univ. (United States); Daniel P. Armstrong, North Carolina State Univ. (United States); Andrey V. Dobrynin, The Univ. of Akron (United States); Sergei S. Sheyko, The Univ. of North Carolina at Chapel Hill (United States); Richard J. Spontak, North Carolina State Univ. (United States) , “Bottlebrush elastomers: a promising molecular engineering route to tunable, prestrain-free dielectric elastomers”, Paper 10163-72.
11. Vy Khanh Vo Tran, Anup Teejo Mathew, Adrian Koh, National Univ. of Singapore (Singapore), “Stackable configurations of artificial muscle modules that is continuously-tunable by voltage”, Paper 10163-88

The 2017 EAP-in-Action Session highlighted some of the latest capabilities and applications of Electroactive Polymer (EAP) materials where the attendees have been shown demonstrations of these materials in action. In addition, the attendees were given an opportunity to interact directly with the
presenters as well as have been given “hands-on” experience with the presented technology. The first Human/EAP-Robot Armwrestling Contest was held in 2005 during this session.

This year, the session has been opened by David Hanson’s robot, Sophia (Error! Reference source not found.), who welcomed the attendees of the session and gave general introductory words. Then, he presented the new toy robot, Prof. Einstein and demonstrated its capabilities (Figure 3). This participation of humanlike robot has given great excitement to the participants with the feeling of the “future is here”.

As part of the Session, Gabor Kovacs presented his company’s new contractile multilayered stack EAP actuator that they are developing towards mass production (Figure 7).

The Session included 13 demonstrations with presenters from China, Germany, Japan, New Zealand, Singapore, Switzerland, and USA. The presenters consisted of professors and their students as well as engineers from companies. The demonstrations were competed and the ranking evaluation criteria of the demonstration were:

1. Originality/creativity  
2. Use of EAP to drive the demo  
3. Performance of the demo  
4. Potential impact

The scores has been as follows: 4 excellent; 3 Good; 2 Fair; 1 Reasonable; 0 no show.

The 2017 judges have been:
• Siegfried Bauer, Johannes Kepler Univ. Linz (Austria)
• David Hanson, Hanson Robotics LLC (USA)
• Gabor Kovacs, EMPA (Switzerland)
• John D Madden, The Univ. of British Columbia (Canada)
• Qibing Pei, University of California, Los Angeles, (UCLA), (USA)
• Jonathan Rossiter, Univ. of Bristol (United Kingdom)

The top three winners were:
• **First Place:** Multilayered PVC gel artificial muscle - Minoru Hashimoto, Yi Li, Aya Suzuki, Hanako Niwa, Rina Yokotsuka, Shinshu Univ., Japan (Figure 8).
• **Second Place:** DEA-driven vibratory feeder - Steffen Hau, Mathias Hoffmann, Stefan Seelecke, Saarland Univ., Germany (Figure 9)
• **Third Place:** "Multilocation sensing on one input/output and the EAP zoo", Markus Henke, Patrin Illenberger, Andreas Tairych, Chris Walker, Katie Wilson, and Iain Anderson, Biomimetics Lab, Auckland Bioengineering Institute, Auckland, New Zealand (Figure 10).

Figure 7: Gabor Kovach presenting his company’s new contractile multilayered stack EAP actuator.

Figure 8: The winners of the #1 best demo awards for the 2017 EAP-in-Action Session. From Left to Right: Rina Yokotsuka, Yi Li and Minoru Hashimoto.
Figure 9: The winners of the #2 best demo awards for the 2017 EAP-in-Action Session. From Left to Right: Steffen Hau, Saarland Univ. (Germany) and Yoseph Bar-Cohen.

Figure 10: The winners of the #3 best demo awards for the 2017 EAP-in-Action Session. From Left to Right: Katie Wilson, Andreas Tairych, Iain Anderson, Chris Walker, Markus Henke, Patrin Illenberger, Biomimetics Lab, Auckland Bioengineering Institute, Auckland, New Zealand.

The demonstrations in 2017 included innovative devices and potential new products that are driven by EAP and they were as follows (listed by the country of the leading presenters):

China

1. Jing Dai, Bangyuan Liu, Feiyu Chen, Sukai Wang, Zhiqiang Fu, Tiefeng Li, Soft Matter Research Center of Zhejiang University, China, “Applications of smart polymers” (Figure 11) - This demonstration showed Soft robotics and smart structures that are made of multiple soft active materials, and can be fabricated by 3D printing method. Driven by dielectric elastomer, the robot shows excellent performances in large actuation and fast response. 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.

Figure 11: The team from Zhejiang University demonstrating their EAP actuated soft robotic mechanism.

2. Liwu Liu, Jinrong Li, Fengfeng Li, Xiongfei Lv, Jinsong Leng, Harbin Institute of Technology, China (Figure 12), “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 12: Hui Gao, Fanlong Chen (speaker), Liwu Liu (from left to right) (Harbin Institute of Technology), presenting the demo “Applications of smart deformable polymers”

Germany

Steffen Hau, Mathias Hoffmann, and Stefan Seelecke, Saarland Univ., Germany (Figure 13), “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. This demo has been recipient of the #2 Best EAP-in-Action Award.

Japan

1. Minoru Hashimoto, Yi Li, Aya Suzuki, Hanako Niwa, Rina Yokotsuka, Shinshu University, Hashimoto-Tsukahara Laboratory, Nagano, Japan (Figure 14), “Multilayered PVC Gel Artificial Muscle” - Multilayered contraction type PVC gel actuator was developed using stainless mesh electrodes having many positive characteristics.

Figure 14: The Multilayered PVC Gel Artificial Muscle being presented (from Left to Right) by Rina Yokotsuka, Minoru Hashimoto, and Yi Li.

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. This demo has been recipient of the #1 Best EAP-in-Action Award.

2. Tempuu Siva, Teruo Toyoda, and Fujio Mine, Haloworld Inc., Fukushima, Japan, “Biomimetic robot system for plumbing tests” (Figure 15) - A tubular inchworm robot mechanism that is driven by electroactive polymer and air pressure will be presented. This robot will be equipped with a camera to allow testing the plumbing of the decommissioned Fukushima Daiichi Nuclear
Power Plant. The robot is capable of traversing thru the many elbow sections along the more than several hundred meter plumbing. The use of the EAP actuation mechanism allows for smooth operation thru the curvatures along the plumbing path.

Figure 15: Tempuu Siva (on the right) and Teruo Toyoda (on the left), Haloworld Inc., presenting their Biomimetic robot system

New Zealand
1. Patrin Illenberger, Katie Wilson, Andreas Tairych, Chris Walker, Antoni Harbuz and Iain Anderson, Biomimetics Lab, Auckland Bioengineering Institute, Auckland, New Zealand (Figure 16), “Multilocation sensing on one input/output and EAP zoo”, The Biomimetics Lab presented:

1. The multisensor shirt that can measure stretch at several locations from one input/output.
2. The Electroactive polymer zoo: we present the latest self-regulating crawling caterpillars and wing-flapping dragonflies fabricated from printed polymer and electrode. No need for electronics!

This demo has been recipient of the #3 Best EAP-in-Action Award.

2. Mark Williamson (Figure 17), StretchSense Ltd., Auckland, New Zealand, “New EAP products” - What’s new in wearable electroactive polymer sensing and energy harvesting. This included soft sensors with soft electronics.

Figure 17: StretchSense Ltd., Auckland, New Zealand, presented their New EAP products.

Singapore
1. Jiawei Cao, Lei Qin and Jian Zhu, National University of Singapore, Singapore, “Soft untethered robots” (Figure 18) - The soft untethered robot mainly consists of a deformable robotic body and two paper-based feet. Based on the optimal mechanical design, the robot is capable of achieving autonomous movements.
2. Anansa S. Ahmed and Gih-Keong Lau (Figure 19), School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, “Dielectric elastomer grippers using tensioned arch flexures” - The followings are going to be demonstrated
   1. Versatile DEA grippers with enhanced tip angle deflection and blocked force due to tension arch flexure structure.
   2. Grippers capable of grasping and lifting a variety of objects including highly deformable materials without damage.

3. Milan Shrestha, Anansa Ahmed, Anand Asundi, Gih-Keong Lau, Nanyang Technological University, Singapore, “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.

Switzerland
Samuel Rosset and Samuel Schlatter, EFPL, Switzerland (Figure 20), “PetaPicoVoltron: an open-source portable high-voltage supply” - A portable high voltage power supply (HVPS) has been 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.
United States
1. Qi Shen, Sarah Trabia, Tyler Stalbaum, Taeseon Hwang, Robert Hunt, Zakai Olsen, and Kwang Kim, **Univ. of Nevada, Las Vegas (Figure 21)**, “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.

2. Lenore Rasmussen, Ras Labs, demonstrating her latest Synthetic Muscle™ Figure 22) – The operation of the latest Synthetic Muscle™ based actuators was demonstrated. These are EAP based actuators that contract and expand, attenuate impact, and sense pressure. In addition, prosthetic liner prototype with self-adjusting EAP based pads and sensing robotic gripper was shown.

![Figure 21: The team Univ. of Nevada, Las Vegas, under the lead of Kwang Kim (right) and their origami soft robot using multiple shape memory ionic polymer-metal composite (left).](image1)

![Figure 22: Lenore Rasmussen, Ras Labs, demonstrating her latest Synthetic Muscle™ based actuator, with sensing EAP pads retrofitted to a standard EMI® robotic gripper.](image2)

**EuroEAP 2017—the 7th international Conf. on EAPs**
EuroEAP 2017, the ‘Seventh international conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles’ (www.euroeap.eu/conference) took place in Cartagena, on 6-7 June 2017.

The conference was chaired by Prof. Toribio Otero (Technical University of Cartagena) and was organized by the ‘EuroEAP – European Society for Electromechanically Active Polymer Transducers & Artificial Muscles’ (www.euroeap.eu).

The event was attended by about 110 delegates from Europe, USA, Canada, Korea, Japan, China and Singapore with a large number of participants coming from industry. **Figure 23** shows a group picture of the participants.
The conference format focusses on interaction between the participants with invited lectures in the morning followed by participant presentations that comprise a short oral and an extended poster session. In addition, there is ample time for spontaneous meetings during breakfasts, coffee and lunch breaks, as well as the evening social event, as all the participants stay in the same hotel during the conference.

The speakers invited to this edition were:
- Aurélie Mossé, Ecole Nationale Supérieure des Arts Décoratifs, France
- John Madden, University of British Columbia, Canada
- Gih-Keong Lau, Nanyang Technological University, Singapore
- Takushi Sugino, National Institute of Advanced Industrial Science and Technology, Japan
- Rocco Vertechy, University of Bologna, Italy
- Leonid Ionov, University of Georgia, USA
- Espen Knoop, Disney Research, Switzerland
- Frédéric Vidal, University of Cergy-Pontoise, France
- Anne Ladegaard Skov, Technical University of Denmark, Denmark
- Martin Kaltenbrunner, University of Linz, Austria
- Zane Zondaka, University of Tartu, Estonia
- Piotr Mazurek, Technical University of Denmark, Denmark

The technical programme and conference proceedings are available at www.euroeap.eu/conference.

During the event, Prof. John Madden (University of British Columbia, Canada) was awarded by the EuroEAP Society, with an informal ceremony in a friendly atmosphere, ‘for his fundamental scientific contributions in the field of Transducers and Artificial Muscles based on Conjugated Polymers’. Likewise Prof. Danilo De Rossi was awarded by the EuroEAP Society ‘for his fundamental scientific contributions in the field of Transducers and Artificial Muscles based on several types of actuator materials.’

Pictures from the conference can be watched at www.euroeap.eu/conference.

ADVANCES IN EAP
Independent Researcher/Inventor
PDTurboDEA: Novel Pulse Detonation Engine Based On DEA Compressor
Babak Aryana, Aerospace Engineering-Propulsion/MEMS Babak.Aryana@Gmail.com
Particular configuration of DEA compressor [1] allows using a special intake, in which compressor does not confront airflow stream directly. In fact, compressor is placed at an annular hatch and it just swallows almost stationary air with static pressure that is about that of airflow. The main flow entering to the intake passes freely through a core duct. This configuration removes some problems of conventional compressor in higher flight Mach numbers (Figure 24).

Duty of the compressor vessel in PDTurboDEA also differs from TurboDEA and it is compression/detonation chamber. The pressurized air in the vessel is mixed with fuel and detonated when it reaches desirable pressure ratio. Like the TurboDEA introduced in [2] a part of the exit flow of the vessel is bypassed to the turbine providing other components with electric power and reminder is directed toward the exit nozzle (Figure 25). Output flow of turbine and direct flow from the chamber are mixed and produced thrust in the exit nozzle. Regarding this fact that pressure ratio of
detonated flow delivered from the chamber is high, the nozzle is always choked. As a result, implementing truncated plug aerospike nozzle is advantageous, because this type of nozzle can regulate exit flow to environmental changes and produce higher rate of thrust, when its primary nozzle is choked. Moreover, core free flow of the engine can be directed through the truncated plug for cooling purpose. Detail of PDTurboDEA will be published in next few months.

Figure 24: Cutaway view of PDTurboDEA engines schematically depicted by its sections and zones

Figure 25: TurboDEA and Turbojet engines schematically depicted by their sections and zones

References

University of Colorado Boulder and University of California Riverside
A Transparent, Self-Healing, Highly Stretchable Ionic Conductor
Yue Cao, Timothy G. Morrissey
timothy.morrissey@colorado.edu, Eric Acome, Sarah I. Allec, Bryan M. Wong, Christoph Keplinger
Christoph.Keplinger@colorado.edu, and Chao Wang

Hydrogels that contain salt solutions are ionic conductors that can be readily designed to have functional properties such as extreme stretchability and high transparency, enabling applications in a growing number of areas [1]. Challenging applications, such as transparent electrodes for dielectric elastomer actuators (DEAs), require ionic conductors that simultaneously feature all these properties. Polyacrylamide hydrogel containing NaCl as the electrolyte has been used for electrodes of DEAs [2] where the hydrogel may experience mechanical wear that degrades actuation performance. The implementation of autonomous self-healing capabilities in such electrodes as well as the dielectric [3] promises to significantly extend lifetime of these devices.

A recent collaboration between the Keplinger Research Group at the University of Colorado Boulder and the Wang Polymer Research Group at the University of California Riverside aimed to address the challenge of mechanical damage in electrodes of DEAs. A new material based on a polar, stretchable polymer combined with a mobile, high ionic-strength salt was developed [4]
This material combines four functional properties: high transparency (visible spectrum average transmittance of 92%), extreme stretchability (up to 5000%), ionic conductivity (10^-4 S cm^-1), and autonomous self-healing. The material can fully heal from severe mechanical damage (physical cuts) within 24 hours without relying on external stimuli. The self-healing capability of the material is attributed to ion–dipole interactions acting as dynamic bonds for self-healing. We show that a DEA using this material can sustain severe mechanical damage and autonomously self-heal without losing functionality.

Figure 26: A transparent, self-healing, highly stretchable ionic conductor is introduced that autonomously self-heals after experiencing severe mechanical damage. The design of this self-healing polymer uses ion–dipole interactions as the dynamic motif. We demonstrate the unique properties of this material when used to electrically activate transparent artificial muscles.

While we have already demonstrated that this material can be used to create more robust actuators, we expect a range of additional applications for this transparent, highly-stretchable, self-healing ionic conductor. Additionally, we anticipate that the approach of harnessing ion–dipole interactions will be a powerful tool in the creation of next-generation, self-healing materials.

This paper is now published: *Advanced Materials*, 2017 10.1002/adma.201605099

References:

NEW PUBLICATIONS

Bioinspired Actuators and sensors
Minoru Taya et al, 2016, Cambridge University Press

This book has been coauthored by experts who are renowned in the fields of engineering and biology. This book covers sensor and actuator technology with bioinspired design. It begins with detailed descriptions of actuation and sensing mechanisms in plants and animals, the authors move on to apply these principles to synthetic design, offering in-depth knowledge of the development of state-of-the-art smart materials and devices. All of this is supported with a range of real-world applications, from tactile sensory systems in insects linked with the development of robotic hands, to the structural colour systems in nature used to inspire camouflage technology. Further examples are given
of successful designs along with their integrated autonomous systems, such as flying and swimming unmanned systems, and autonomous zero-energy building design.

With a wide interdisciplinary appeal, this is an ideal resource for any student, practicing engineer, or researcher interested in the connection between natural systems and synthetic design. The book was coauthored by:

Minoru Taya is Professor of Mechanical Engineering at the University of Washington and Director of the Center for Intelligent Materials and Systems (CIMS).

Elizabeth Van Volkenburgh is Professor of Biology at the University of Washington. She is also President of the Society for Plant Signaling, Behavior, and a Fellow of the American Association for the Advancement of Science.

Makoto Mizunami is Professor in the Faculty of Science at Hokkaido University and vice-chairman of the Japanese Society for Comparative Physiology and Biochemistry.

Shûhei Nomura is Senior Curator of the Division of Terrestrial Invertebrates in the Department of Zoology at the National Museum of Nature and Science in Tokyo. He is also vice-president of the Coleopterological Society of Japan.

FUTURE CONFERENCES

<table>
<thead>
<tr>
<th>Date</th>
<th>Conference/Symposium</th>
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<tbody>
<tr>
<td>July 19–21, 2017</td>
<td>The Marine Technology Society (MTS) is hosting a TechSurge Workshop on “Marine Propulsion and Design Inspired from Nature”, in Norfolk, VA. For further information contact Donna Kocak <a href="mailto:dkocak@harris.com">dkocak@harris.com</a></td>
</tr>
<tr>
<td>March 4 - 8, 2018</td>
<td>The 2018 SPIE’s EAPAD conference is going to be held at Denver, Colorado, from March 4 thru 8, 2018. This conference will be the 20th annual one and is going to be chaired by Y. Bar-Cohen, JPL, and Co-chaired by I. A. Anderson, The Univ. of</td>
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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


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

**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](http://www.crcpress.com/product/isbn/9781439834763)

**Architecture Follows Nature - Biomimetic Principles for Innovative Design**  

**Biomimetics - Biologically Inspired Technologies**  
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](http://ndeaa.jpl.nasa.gov/ndeaa-pub/Biomimetics/Biologically-Inspired-Technology.pdf)
Ocean Innovation: Biomimetics Beneath the Waves
Author: Iain A. Anderson
i.anderson@auckland.ac.nz, Julian Vincent, and John Montgomery

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

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)
Published on July 1, 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.

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.

**High Temperature Materials and Mechanisms**

*Yoseph Bar-Cohen (Editor)*


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.