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EAP-in-Action Demonstration Session

Moderator: **Yoseph Bar-Cohen,** Jet Propulsion Laboratory

This 2015 EAP-in-Action Session highlighted some of the latest capabilities and applications of Electroactive Polymers (EAP) materials where the attendees are shown demonstrations of these materials in action (Figure 1). Also, the attendees interact directly with technology developers and given “hands-on” experience with this emerging technology. The first Human/EAP-Robot Armwrestling Contest was held during this session.

Figure 1: A view of the presenters and the participants of the 2015 EAP-in-Action Session.

This 2015 Session included 11 demonstrations which was a record for the EAPAD Conference and the demonstrations were as follow (listed by the country of the leading presenters). The session included teams of professors and their students as well as small companies who presented their innovations and potential new products that are driven by EAP.

Canada
M. S. Sarwar, E. Glitz, S. Kianzad, A. Rafiee, M. Pandit, J. D. Lewis, A. R. Berlingeri, M. Farajollahi, S. E. Takalloo, Y. Dobashi, S. Mirabbasi, E. Cretu and John D.W. Madden, Univ. of British Columbia (Figure 2). The presentation title was **“Conducting polymer and nylon-based sensors and actuators”**

Figure 2: From left to right, Mirza Sarwar, John D. W. Madden, and Soheil Kianzad demonstrating conducting polymer and nylon-based sensors and actuators

Description: The demonstration featured ionic EAP sensor membranes, miniature trilayer actuators, and large force nylon linear actuators. The nylon thermal actuators, which are helical in form, can be woven into fabrics (Figure 3).

Figure 3: Nylon thermal actuators

China

Two group from China presented demonstrations this year:

1. J. Leng, J. Li and L. Liu, Harbin Institute of Technology (Figure 4). The presentation title was "**Soft Crawling Robot Based on Dielectric Elastomer"**

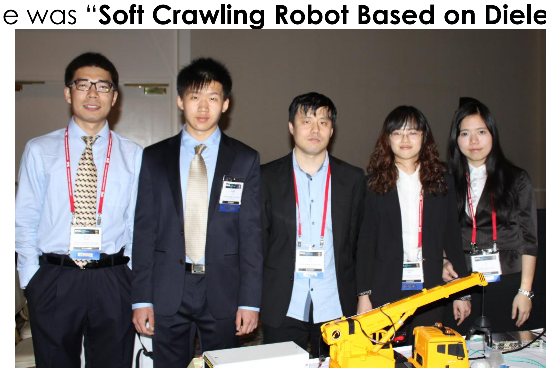

Figure 4: From left to right, Hetao Chu, Jinrong Li, Liwu Liu, Honogiu Wei, and Che Yi demonstrating applications of dielectric elastomers.

Description: A simple crawling robot based on dielectric elastomers was demonstrated (Figure 5). This robot is quadrupedal and each foot is a dielectric elastomer based spring-roll actuator having the appropriate deformation and response time. The power supply and control were tethered through wires. The speed of robot crawling can be changed by changing the amplitude and frequency of the control signal.

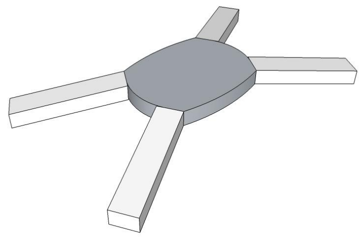

Figure 5: Soft crawling robot

2. T. Li, Chi Li, Y. Xie, and X. Yang, Institute of Applied Mechanics, Zhejiang Univ., (Figure 6). **"Softrobot Using Dielectric Elastomers"**

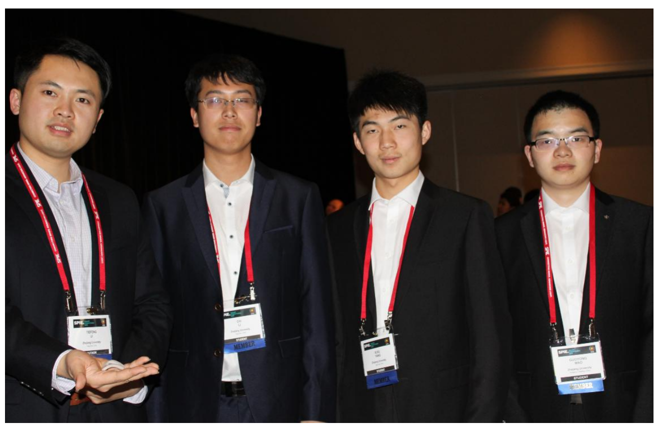

Figure 6: From left to right, Tiefeng Li, Chi Li, Xuxu Yang, and Guoyong Mao presenting their softrobot using dielectric elastomers

Description: Inspired by the natural invertebrates like worms and starfish, a novel soft robot was developed using a flexible elastomer as the body and driven by dielectric elastomer as the actuation muscle (Figure 7). This configuration makes the robot run fast and is resilient to extreme mechanical conditions.

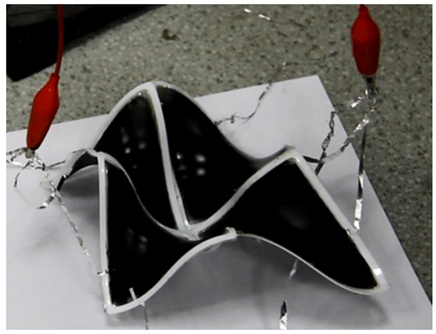

Figure 7: Softrobot

Germany

H. Mößinger[1], H. Haus[1], M. B. Saif [2], K. Hofmann[2], Helmut F. Schlaak[1] (Figure 8).
[1]Institute of Electromechanical Design, Technische Universität Darmstadt,
[2] Integrated Electronic Systems Lab, Technische Universität Darmstadt

"**Reduced size electronics for controlling DEA**"

Figure 8: From left to right, Helmut F. Schlaak, Henry Haus, and Holger Mößinger demonstrating reduced size electronics for controlling DEA.

Description: As DEA moves closer to the market, providing suitable driving and sensing electronics becomes a crucial task. In the ongoing effort to develop small and efficient electronics, Technische Universität Darmstadt presented the first version of their custom designed application-specific integrated circuit (ASIC) for driving up to four DE-actuators at voltages as high as 700 Volts. A total chip size of 20 mm^2 was developed that contains four signal generation units capable of generating switching signals in the kHz range, configurable by a serial digital interface (Figure 9).

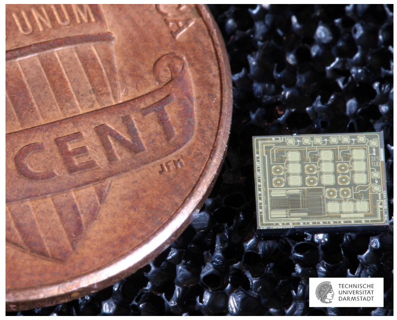

Figure 9: Four channel ASIC for driving DEA compared to the size a US penny.

Japan

M. H. Kabir, J. Gong, M. Makino, and H. Furukawa, Yamagata University, Yamagata (Figure 10). "**Thermo responsive shape recovery soft actuator"**

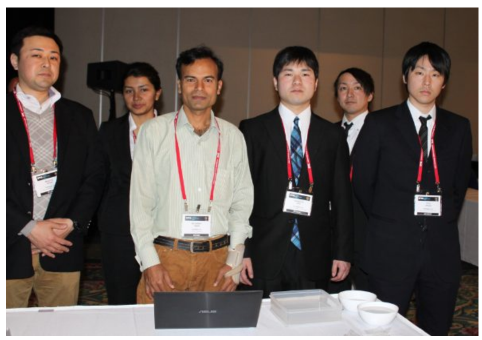

Figure 10: From left to right, Masato Makino, Kumkum Ahmed, M. Hasnat Kabir, Masonori Arai, Naoya Yamada, and Koji Okada demonstrating a thermo responsive shape recovery soft actuator.

Description: A free forming deformed shape of polymeric gel can recover its original shape and size. The gel shows temperature dependent functionality. The shape memory effect can be observed both in hot water and hot air. The material is suitable for soft actuators which might be applicable in biomedical science. Using this gel to drive a humanlike figure was demonstrated along with the shape memory function (Figure 11).

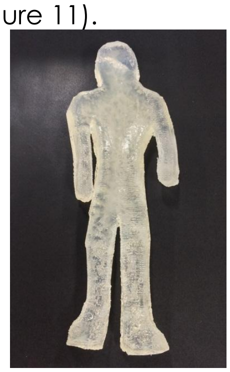

Figure 11: Thermally active gel used to drive a humanlike figure.

New Zealand
This year two organizations from New Zealand participated in the EAP-in-Action Session:

1. Iain Anderson, Daniel Xu, Alan Veale, Biomimetics Lab. (Figure 12) www.abi.auckland.ac.nz/biomimetics; and Stretchsense Ltd. - www.stretchsense.com

Figure 12: From left to right, Alan Veale, Daniel Xu, Todd Gisby, and Iain Anderson, demonstrating applications of dielectric elastomers

Applications of dielectric elastomers
Description: The Biomimetics Lab. and its spinout StretchSense Ltd. demonstrated their advances that lead to exciting wearable and portable energy harvesters as well as soft sensor technologies.

The demos included:

Figure 13: Motion capture controller (left) and soft sensor (right)

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

(2) *Artificial Muscle Power* - An energy harvester using dielectric elastomer generators was present in the new version of the Artificial Muscle Power (AMP) device (Figure 13 left).

(3) *Measuring human body motion* can provide valuable feedback for sports, medical, video and game applications. The latest soft sensor for this purpose was presented (Figure 13 right).

2. Stacy Hunt, biomym.com (Figure 14), **"Self-healing dielectric elastomer actuators".**

Figure 14: Stacy Hunt presenting a self-healing dielectric elastomer actuator.

Description: Self-healing dielectric elastomer actuators was demonstrated. After suffering mechanical trauma the material was self-repaired and continued working.

Switzerland

S. Rosset, S. Araromi, A. Poulin, L. Maffli, J. Shintake, D. Floreano and H. Shea, Ecole Polytechnique Fédérale de Lausanne (Figure 15 and Figure 16) - "**High speed silicone DEAs**".

Figure 15: From left to right, S. Rosset, Sluwaseum Araromi, Alexander Poulin, and Jun Shintake, demonstrating high speed silicone DEAs.

Figure 16: From left to right Sluwaseum Araromi, Alexander Poulin, Herbert Shea, and S. Rosset during the demonstration.

Description: Precise patterning of robust and wear-resistant electrodes on silicone membranes allows for the fabrication of high-speed dielectric elastomer actuators with a long lifetime. At EPFL-LMTS, a broad range of fabrication processes were developed for the fabrication of high quality silicone membranes and the patterning of compliant electrodes presenting strong adhesion to the dielectric membrane. Several devices were shown to illustrate the related activities. These include tunable lens with a settling time below 200 µm, a soft and compliant 1-g gripper capable of holding an egg, and capacitive sensing devices with miniaturized sub-mm electrodes (Figure 17).

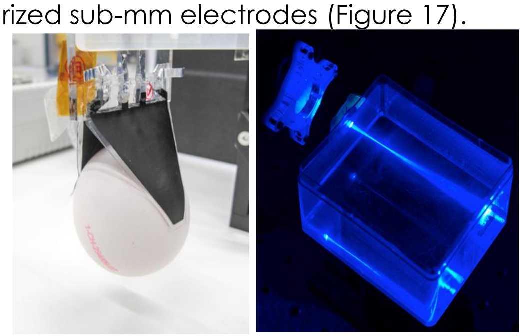

Figure 17: Gripper and tunable lens

United States

1. Z. Ren, D. McCoul, W. Hu, and Q. Pei, Dept. of Materials Science and Engineering, University of California, Los Angeles, California (Figure 18) - "**New EAP Materials and Actuators".**

Figure 18: From left to right, Zhi Ren, Qibing Pei, Maggie Hu, and David McCoul demonstrating bistable electroactive polymers.

Description: Bistable electroactive polymers (BSEP) combine electrically induced large-strain actuation with a shape memory effect to present a unique opportunity for refreshable, repeated actuation. A new BSEP material was presented that achieves prolonged cycle lifetimes. This refreshable rigid-to-rigid actuation simultaneously provides large-strain actuation and large load support. Other innovative forms of actuators will also be presented (Figure 19). One such device is a biomimetic pump fabricated from tubular dielectric elastomer actuators.

Figure 19: Actuation of dot actuator on the hotplate at elevated temperature

2. Lenore Rasmussen and Eric Sandberg, Ras Labs, www.raslabs.com (Figure 20). "**Synthetic Muscle™: Shape-morphing EAP Based Materials and Actuators**

Figure 20: Lenore Rasmussen showing her Synthetic Muscle™

Description: EAP samples were demonstrated contracting and expanding (Figure 21 and Figure 22). A thin shape-morphing film of the material in the expansion mode produces raised surface zones in desired shapes. Actuation can be performed using suitable elastomeric coatings, and in 2015 selected synthetic muscle samples are going to be tested for radiation resistance on the International Space Station.

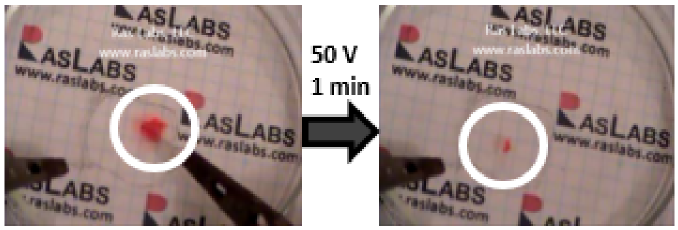

Figure 21: Contracting EAP (dyed red so easy to see)

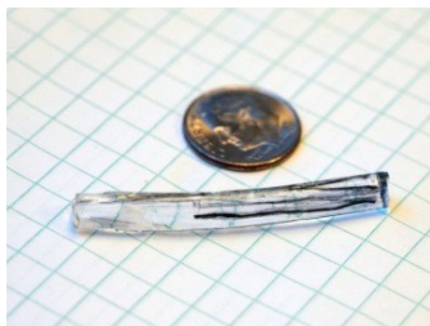
Figure 22: Carbon fiber infused EAP

3. Qi Shen, Tyler Stalbaum, Shelby E. Nelson, Sarah Trabia, Jameson Lee, Viljar Palmre, and Kwang J. Kim, Univ. of Nevada (Figure 23). **"Advanced IPMC actuators and sensors".**

Figure 23: From left to right, Viljar Palmre, Kwang J. Kim,Qi Shen, Jameson Lee, Sarah Trabia, Tyler Stalbaum, and, Shelby E. Nelson demonstrating advanced IPMC actuators and sensors.

Description: Conventional IPMC is produced in a strip form. In this EAP-in-Action, advanced IPMC actuators and sensors in a variety of different forms (cylinder, tube, square, fiber, etc.) were presented (Figure 24).

Figure 24: An IPMC actuators in the form of a tube being manipulated.

Introduction

This SPIE's Electroactive Polymers Actuators and Devices (EAPAD) Conference is the leading international forum for presenting the latest progress and holding discussions amongst the attendees regarding the capabilities, challenges, and potential future directions of the field. The conference this year was Chaired by Yoseph Bar-Cohen, JPL, and Co-Chaired by Gal deBotton, Ben-Gurion Univ. of the Negev (Israel) and it included 112 presentations.

The Conference was well attended by internationally leading experts in the field including members of academia, industry, and government agencies from the United States and overseas. This year the Keynote speaker was Brett Kennedy, JPL, and his paper title is "RoboSimian and the Advancement of Mobile Manipulation in Robotics". In his presentation he covered the progress in robotics for planetary applications, the development of the robot, RoboSimian, as well as details of the DARPA challenge where this robot reached the 5th place out of 16 participants.

Overall, the papers that were presented reported the significant progress that was made in each of the topics of the EAP infrastructure. The topics included Emerging Actuators; Power Generation and Energy Harvesting; EAP Materials and Actuators (including ionic, conducting and dielectric EAP), Nano-Tech and CNT EAP; New EAP Materials, Processes, and Fabrication Techniques; Analytical Modeling and Simulations of EAP Mechanisms; Applications of EAP Materials; New EAP Actuators and Applications of EAP Materials; Shape Memory Polymers and Other EAP Materials; Haptic, Tactile, and Other Sensors.

The papers addressed issues that can forge the transition to practical use, including improved materials, better understanding of the principles responsible for the electromechanical behavior, analytical modeling, processing, and characterization methods as well as considerations and demonstrations of various applications.

The efforts described in the presented papers are showing significant improvements in understanding of the electromechanical principles and 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, conductive polymers, gel EAP, carbon nanotubes, and other types. Specifically, there seems to be a significant trend towards using dielectric elastomers as practical EAP actuators.

This year, the conference included a half-day course about electroactive polymers. The instructors were Yoseph Bar-Cohen, Jet Propulsion Lab/Caltech., Pasadena, CA; John Madden, Univ. of British Columbia, Vancouver, Canada; and Qibing Pei, Univ. of California, Los Angeles. Also, an EAP-in-Action Session was held and it consisted of eleven demonstrations with presenters from Canada, China, Germany, Japan, New Zealand, Switzerland, and USA. The presentation of 11 demonstrations is a record for the EAPAD Conference.

In closing, I would like to extend a special thanks to all the conference attendees, session chairs, the EAP-in-Action demo presenters, and the members of the EAPAD program organization committee. In addition, special thanks are extended to the SPIE staff that helped making this conference a great success.

Yoseph Bar-Cohen