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 Electroactive Polymers (EAP) and Biomimetics.

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ABOUT THE EXPERS

In Memoriam: Siegfried Bauer

Professor Siegfried Bauer, Soft Matter Physics chair and head of department at Johannes Kepler University in Linz, Austria, passed away on 28 December 2018. He was 57. At the same month, he had been newly appointed a 2019 Fellow Member of SPIE. He was a co-organizer of the SPIE Electroactive Polymers and Devices (EAPAD) conference in 2012, and, over several years, a member of the SPIE Advisory Board of the EAPAD Conference Series.

Since 2016, Bauer was also a Fellow of the IEEE, recognized for his understanding and application of electro-active polymer dielectrics. Other honors included the Dr. Wolfgang Houska Recognition Award and the Rudolf Trauner Award, both for exemplary co-operation between academia and industry; a Pioneer of Smart Production Award from the Austrian Society for Environment and Technology; and the Karl-Scheel Award of the Physical Society of Berlin. He served as a reviewer

for a multitude of international journals and science organizations including the *Nature Publishing group, Soft Matter, Small, Journal of Materials Chemistry, Advanced Functional Materials*, American Institute of Physics journals, the Alexander von Humboldt Foundation, the National Science Foundation, and the US Department of Energy.

A pioneer in the field of ultra-flexible, stretchable electronic devices such as transistors, diodes, and solar cells, Bauer received his PhD in applied physics (summa cum laude) in 1990, from the Institute of Applied Physics, University of Karlsruhe. Most recently, he had participated in initiating the International Winterschool on Bioelectronics with several colleagues: the 2019 session runs from March 16 to March 23, in Kirchberg in Tirol, with a particular focus on the field of biocompatible devices and the biointegration of electronics into medical research and applications.

"Professor Siegfried Bauer served the scientific community with great energy as a referee, editor, supervisor, and mentor, as well as a great educator," notes his scientific collaborator and academic colleague SPIE Fellow and Professor of Physical Chemistry Niyazi Serdar Sariciftci. "He was one of the strong scientific pillars of our physics department at Johannes Kepler University, and will be greatly missed."

Bauer loved tinkering with antique radios - so-called "steam radios." He was an avid fan of cartoonist Carl Barks and comic-book writer and illustrator Don Rosa, both of Donald Duck fame, as well as of television's scientifically prescient, empathetic, and groundbreaking *Star Trek* series.

GENERAL NEWS

This issue is the 41th of the WW-EAP Newsletter. Over the last 21 years, this Newsletter has been published twice a year as an eDocument on the WW-EAP Webhub http://eap.jpl.nasa.gov This Webhub is a link of the JPL's NDEAA Lab Website http://ndeaa.jpl.nasa.gov of the Electroactive Technologies Group.

Standard for EAP

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

UPCOMING CONFERENCES

2020 SPIE EAPAD Conference

The SPIE's 22nd EAPAD conference is going to be held from April 26 thru 30, 2020, in Anaheim, California. This conference, which is part of the Smart Structures and Materials Symposium, is going to be chaired by Yoseph Bar-Cohen, JPL, and Co-chaired by Iain A. Anderson, The Univ. of Auckland, New Zealand; and Herb Shea, École polytechnique fédérale de Lausanne, Switzerland. The Conference Program Committee consists of representatives from 32 countries. The call for papers is posted at http://www.spie.org/eap and the submissions due date is October 16, 2019. In the 2020 EAPAD Conf., a Special Session is going to be "Advances in EAP Manufacturing".

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.

There are going to be two Keynote Speakers and they are:

1. Pinhas Ben-Tzvi, VT Robotics and Mechatronics Lab, Virginia Tech, Blacksburg, VA, will present "Novel Field Robots and Robotic Exoskeletons: Design, Integration and Applications".
2. Yoseph Bar-Cohen, Jet Propulsion Lab (JPL)/California Institute of Technology (Caltech) will present the paper "Highlights from Chairing the EAPAD Conference for 22 Years". As Yosi informed SPIE already, he is not going to continue chairing the EAPAD annual conference that he established and this is his farewell presentation.

On the record of the EAPAD conferences archive, the following is the list of the Co-chairs since the start 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
2018	Iain A. Anderson, The Univ. of Auckland	New Zealand
	Iain A. Anderson, The Univ. of Auckland	New Zealand
2019	Nancy L. Johnson, General Motors Co.	USA

SENSORDEVICES 2019

The 10th International Conference on Sensor Device Technologies & Applications (SENSORDEVICES 2019) has a call for abstracts that is due on July 7, 2019. The abstracts submission can be done thru http://www.iaria.org/conferences2019/SubmitSENSORDEVICES19.html. The Conf. will be held from October 27 to 31, 2019 at Nice, France. Its proceedings will be submitted for indexing in Web of Science (WoS) (ISI Thompson Reuters). Authors of selected papers will be invited to submit extended article versions to one of the IARIA Journals: http://www.iariajournals.org

The topics suggested by the conference can be discussed in term of concepts, state of the art, research, standards, implementations, running experiments, applications, and industrial case studies. Authors are invited to submit complete unpublished papers, which are not under review in any other conference or journal in the following, but not limited to, topic areas.

MDA 2020 - 3rd Int. Conf. on Mat. Design & App.

The 3rd International Conference on Materials Design and Applications 2020 will take place in Porto, Portugal, 25-26 June 2020. The conference venue is the campus of the Faculty of Engineering of the University of Porto (FEUP), which offers excellent facilities for high quality scientific interactions. FEUP is located in the town of Porto in the Northern region of Portugal. Porto is a beautiful and lively city, steeped in history and rich in great experiences. With its magnificent location by the Atlantic coast, Porto is the city of the world famous Port Wine and the River Douro. This conference is held every two years in Porto and chaired by Prof Lucas F. M. da Silva.

The focus is on fundamental research and application areas in the field of the design and application of engineering materials, predominantly within the context of mechanical engineering applications such as automobile, railway, marine, aerospace, biomedical, pressure vessel technology, turbine technology, etc. This includes a wide range of materials engineering and technology, including metals, e.g., lightweight metallic materials, polymers, composites, and ceramics. Advanced applications would include manufacturing in the new or newer materials, testing methods, multi-scale experimental and computational aspects (e.g. micro- and nano-scale techniques).

Deadline for Submission of Abstracts: 6 March 2020; Notification of Acceptance to Authors: 31 March 2020; early bird registration: 17 April 2020. Abstracts should be sent electronically to Lucas F M da Silva at lucas@fe.up.pt. Indicate in the email if you want oral or poster presentation.

RECENT CONFERENCES

EuroEAP 2019 – 9th International Conf. on EAPs

Andreas Richter, Technische Universität Dresden, Germany, andreas.richter7@tu-dresden.de

Edwin Jager, Linköping University, Sweden, edwin.jager@liu.se

The annual international EuroEAP conference was held in Dresden, Germany from 4 to 6 June 2019 and was chaired by Prof. Andreas Richter, Technische Universität Dresden. Detailed information is 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 mixed with participant presentations that comprise a short orals 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. Confirmed plenary and main speakers included:

- Oliver Schmidt, Leibniz Institute for Solid State and Materials Research Dresden, Germany
- Metin Sitti, Max Planck Institute for Intelligent Systems, Germany
- Herbert Shea, École Polytechnique Fédérale de Lausanne, Switzerland
- Frank Fitzek, Centre for Tactile Internet with Human-in-the-Loop, Germany
- Christoph Keplinger, University of Colorado Boulder, USA
- Dorina Opris, Swiss Federal Laboratories for Materials Science and Technology, Switzerland
- Aaron Price, Western University, Canada
- Alvo Aablo, University of Tartu, Estonia

2019 SPIE EAPAD Conference

The SPIE's Electroactive Polymers Actuators and Devices (EAPAD) Conference continues to be the leading international forum for presenting the latest progress, challenges and potential future directions for the EAP field. The conference this year was Chaired by Yoseph Bar-Cohen, JPL/Caltech (United States), and Co-Chaired by Iain A. Anderson, The Univ. of Auckland (New Zealand) and Nancy L. Johnson, General Motors Co. (United States). This Conference has been the 21st since its start in 1999. Presented papers reported the significant progress made in topics that included: theoretical modeling and analysis of EAP mechanisms; improved EAP materials, processes, fabrication (including additive manufacturing such as 3D printing) and characterization techniques; emerging EAP actuators (including ionic, shape memory polymers, and dielectric EAP); applications of EAP materials including power generation and energy harvesting, robotics, haptic, tactile, and various sensors. The 2019 EAP-in-Action Session consisted of 12 demonstrations by teams from China, Germany, New Zealand, Switzerland, Sweden, and USA (see Appendix for the details).

On a sad note, the conference was opened with a brief acknowledgement for the late Prof. Siegfried Bauer by Martin Kaltenbrunner, Johannes Kepler Univ. Linz (Austria).

The Conference included 101 oral and poster 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. We are seeing significant improvements and breakthroughs in modelling, materials and applications for EAP. EAP with improved response were described including dielectric elastomer, hydraulically amplified self-healing electrostatic, IPMC, conducting polymers, gel EAP, carbon nanotubes, and other types. Specifically, there seems to be a continuing trend towards using dielectric elastomers as practical EAP actuators for commercial applications.

At this EAPAD Conf., there were two Keynote speakers including Ray H. Baughman, The Univ. of Texas at Dallas (**Figure 1**) and Douglas A. Litteken, NASA Johnson Space Ctr. (**Figure 2**).

Ray's presentation, in honor of his 75th birthday was titled: "Sixty years of fun in science and technology". In August 2001, Ray became the

Robert A. Welch Professor of Chemistry and Director of the NanoTech Institute at the University of Texas in Dallas, after 31 years in industry. Ray is a member of the National Academy of Engineering, the Academy of Medicine, Engineering and Science of Texas, the Academia Europaea, and the European Academy of Sciences and Arts; a foreign member of the European Academy of Sciences; a Fellow of the Royal Society of Chemistry, the National Academy of Inventors, and the American Physical Society; an Academician of The Russian Academy of Natural Sciences; and an honorary professor of 7 universities in China.

Figure 1: The Keynote Speaker Ray Baughman, NanoTech Institute, the University of Texas in Dallas

Figure 2: The Keynote Speaker Douglas Litteken, NASA's Johnson Space Center (JSC) in Houston, TX

Douglas A. Litteken was the 2nd Keynote speaker and the title of his presentation was "Inflatable technology: using flexible materials to make large structures". Doug is a structural engineer at NASA's Johnson Space Center (JSC) in Houston, Texas. He is the Lightweight Structures Domain Lead at JSC and a Subject Matter Expert in the agency for softgoods structures. He is also the sub-system manager for the Orion crew cabin primary structure. His interests include inflatable habitats, parachutes, composite structures, flexible electronics, and structural health monitoring. His experience includes the design, analysis and testing of softgoods structures including lunar surface habitats, airlocks, and deep space transit vehicles. He received both his Bachelor's and Master's degrees in Mechanical Engineering from the University of Illinois at Urbana-Champaign.

The invited papers in the 2018 EAPAC Conference were:

1. Design of reliable silicone elastomers for dielectric elastomers and stretchable electronics (Paper 10966-9) - Piotr Mazurek, Liyun Yu, **Anne Ladegaard Skov**, Technical Univ. of Denmark (Denmark)
2. Manufacturing dielectric elastomer stack actuators: challenges and applications for industrialization (Paper 10966-29) - **Helmut F. Schlaak**, Technische Univ. Darmstadt (Germany)
3. From soft microrobotics to macroscopic wearables (Paper 10966-32) - **Edwin W. H. Jager**, Linköping Univ. (Sweden)
4. Soft electronic and robotic systems from biocompatible and degradable materials (Paper 10966-39) - **Martin Kaltenbrunner**, Johannes Kepler Univ. Linz (Austria)
5. Soft robotics for prosthetic devices: how dependent it is on smart materials? (Paper 10966-53)- **Gursel Alici**, Univ. of Wollongong (Australia)
6. Dielectric elastomer spring-roll bending actuators: applications in soft robotics and design (Paper 10966-56) - Yanju Liu, Liwu Liu, Jinsong Leng, Harbin Institute of Technology (China)

7. Soft hybrid generators for harvesting human kinetic energy (Paper 10966-72) - **Claire Jean-Mistral**, Institut National des Sciences Appliquées de Lyon (France); Alain Sylvestre, Lab. de Génie Électrique de Grenoble (France)

In closing, we would like to extend a special thanks to all the conference attendees, paper presenters, session chairs, 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 to make this conference a great success. Moreover, the Conference Chairs would like to thank Emily Power, SPIE, for providing some of the photos that were used in this Preface.

The EAP-in-Action Session of the EAPAD Conference/SPIE Smart Structures/NDE Symposia is highlighting some of the latest capabilities and applications of Electroactive Polymer (EAP) materials where the attendees are given demonstrations of these materials in action. In addition, the attendees are given opportunity to interact directly with the presenters as well as given "hands-on" experience with the presented technology. The first Human/EAP-Robot Armwrestling Contest was held in 2005 during this session. The 2019 EAP-in-Action Session was chaired by Yoseph Bar-Cohen, Jet Propulsion Lab.

Best EAP-in-Action Demonstration Award

As of 2017, as part of the EAP-in-Action Session a selection is made of the "Best EAP-in-Action Demonstration". This selection is intended to encourage excellence in developing EAP materials and accelerate the transition of EAPs to practical and commercial technologies. A judging committee, consisting of leading EAP experts, selects the award winner(s) among the presenters of the demonstrations at the EAP-in-Action Session. The judges assess the presenters' performance as well as the quality and content of the demos. The top ranked three are recognized and are being awarded with a certificate during the Symposium.

Evaluation criteria: The demo presenters are ranked based on the following criteria:

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

Scores: 4 excellent; 3 Good; 2 Fair; 1 Reasonable; 0 no show

The 2019 judges were (Figure 3):

1. Nancy L. Johnson, General Motors Co. (United States)
2. John D Madden, The Univ. of British Columbia (Canada)
3. Qibing Pei, University of California, Los Angeles, (UCLA), (USA)
4. Geoffrey M. Spinks, Univ. of Wollongong (Australia)
5. Ray H. Baughman, The Univ. of Texas at Dallas (United States)

Figure 3: The judges of the EAP-in-Action best demonstrations and the audience

The 2019 EAP-in-Action Session included 11 demonstrations with presenters from China, Germany, New Zealand, Switzerland, Sweden, and USA. The presenters consisted of professors and their students as well as engineers from industry. In addition to the formal demonstration participants, presenters from the University of Colorado presented their HASEL artificial muscle actuator and a prototype that they are currently considering for commercialization (**Figure 4**).

The top three best demonstration award recipients were:

- **First Place (Figure 5):** "Electro-ribbon actuators and electro-origami robots". The

recipients were Tim Helps, Majid Taghavi, Richard Suphapol Diteesawat, and Jonathan M. Rossiter, Univ. of Bristol (United Kingdom) (USA).

- **Second Place (Figure 6): "A fast 200 mg DEA robot"**. The recipient was, Herbert R. Shea, Ecole Polytechnique Fédérale de Lausanne (Switzerland)
- **Third Place (Figure 7):** "Synthetic muscle in prosthetics", Lenore Rasmussen, Ras Labs., Inc. (United States)

Figure 4: Members of the University of Colorado team (Christoph Keplinger and Shane Mitchell pictured) provided an impromptu demonstration of the latest developments for HASEL artificial muscles.

Figure 5: Recipients of the 1st place Best EAP-in-Action Demo - The team from the University of Bristol (Jonathan Rossiter, Yosi Bar Cohen, Tim Helps and Richard Diteesawat).

Figure 6: Yosi Bar Cohen congratulates Herb Shea, one of the recipients of the 2nd place Best EAP-in-Action Demo.

Figure 7: Yosi Bar Cohen with Lenore Rasmussen: recipient of the 3rd place EAP-in-Action Demo.

The 2019 EAP-in-Action demonstrations included innovative devices and potential new products that are driven by EAP and they were as follows:

1. **Novel dielectric elastomer membrane actuator concept for pneumatic valves** - **Steffen Hau**, Saarland Univ. (Germany)

Despite being relatively easy to manufacture and providing large strokes, dielectric elastomer (DE) membrane actuators suffer from low force outputs (for single layer systems). This demo presents a novel design concept that permits to retune the stroke-force trade-off of DE actuators, by allowing increasing force output of the actuator at the expense of a reduced stroke. This is of particular interest for valve applications, which typically need high closing forces and low strokes in the submillimeter regime. By means of the novel design concept, the valve closing force of single DE membranes can be increased by a factor of 3 to 4. The concepts still keeps the general advantages of DEAs, e.g., light weight, and energy efficiency. The use of strip-in-plane DE actuators additionally allows staying within the typical dimension of commercial valves.

2. DEA-based pneumatic pump - Philipp Linnebach, Saarland Univ. (Germany)

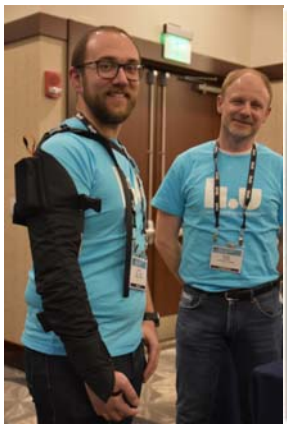
This demonstrator shows the use of circular out-of-plane dielectric elastomer actuators (COP-DEA) in a pneumatic pump application. The presented concept allows building very small and lightweight pumps. It is related to the paper with the title "Design of a dielectric elastomer actuator driven pneumatic pump".

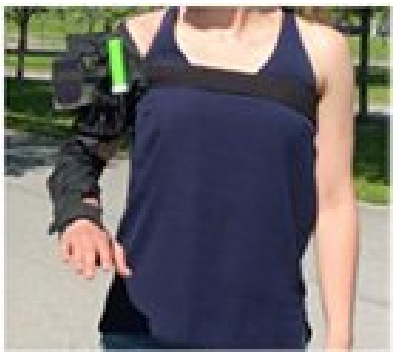
3. A fast 200 mg DEA robot - X. Ji, B. Aksoy, H. Shea, EPFL (Switzerland)

This team presented a DEAnsec, which is an ultra-light (0.2 g) soft robot driven by stacked dielectric elastomer actuators (DEAs) operating at 450V. The DEAnsect has a flexible silicone body and three legs, each driven independently by a DEA stack. The DEAnsect moves at four body lengths per second and can be accurately steered thanks to the independent control of each DEA. It is robust, can climb slopes of 15°, and survives being flattened with a fly swatter.

4. **Textile exoskeletons - Edwin W. H. Jager, Jose G. Martinez**, Linkoping Univ. (Sweden), **Nils-Krister Persson**, Univ. of Boras (Sweden)

Various diseases or aging can cause a reduction in the muscle function of a person. Robotic exoskeletons have been developed to augment or replace the movement of various limbs and thus for instance assist walking or aid rehabilitation. Current exoskeletons are rigid, heavy, stiff and non-compliant. This team is developing textile-based exoskeletons that can be worn like items of clothing being light-weight, soft, compliant and comfortable. In this EAP-in-Action, demonstrators of the prototype textile exoskeleton-arm-sleeves developed by Linköping University and University of Borås was shown. The exoskeleton arm-sleeve prototypes use small electrical motors or McKibben actuators and enable lifting the arm, including a weight, of the wearer without using the user's own muscles.



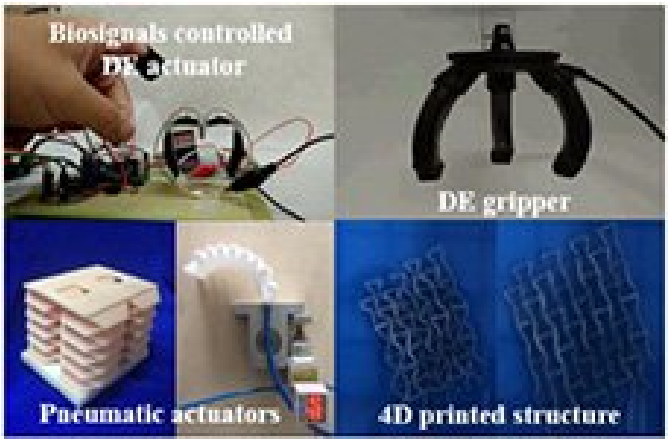


5. **Smart soft polymers and structures - Liwu Liu, Qinghua Guan, Jinrong Li, Yanju Liu, Jinsong Leng**, Harbin Institute of Technology (China)

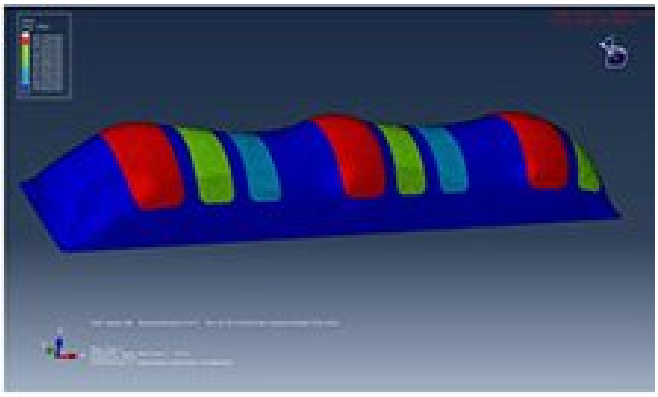
These demonstrations were focus on the applications of smart soft polymers, including dielectric elastomer (DE), shape memory polymer (SMP) and other smart soft structures. The presentations included:

a. Biosignals controlled DE actuators - Biosignals are acquired, processed and then amplified to drive DE actuators.

b. Smart morphing structures based on DE and SMP: Structures may include deployable gripping devices or lock-release structures, etc.
c. Flexible pneumatic actuators. Multi-degree-of-freedom motions could be realized by combining multiple flexible pneumatic actuators together.
d. SMP based 4D printing technique. The 3D printable filaments with shape memory effect and some representative printed structures, which can change shape along with time, will be demonstrated.

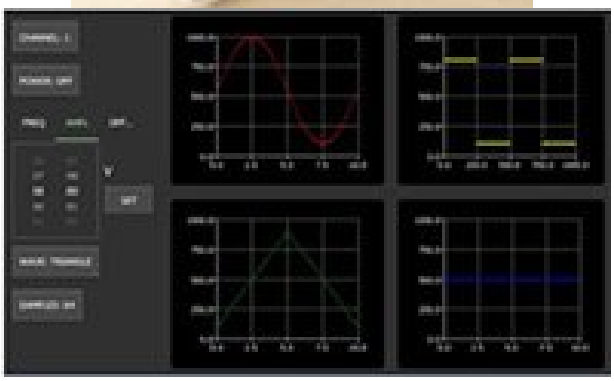


6. **Inflatable dielectric elastomer conveyor - Joseph Ashby, E. -F. Markus Henke, Sam Rosset, Iain Anderson**, Biomimetics Lab. (New Zealand)



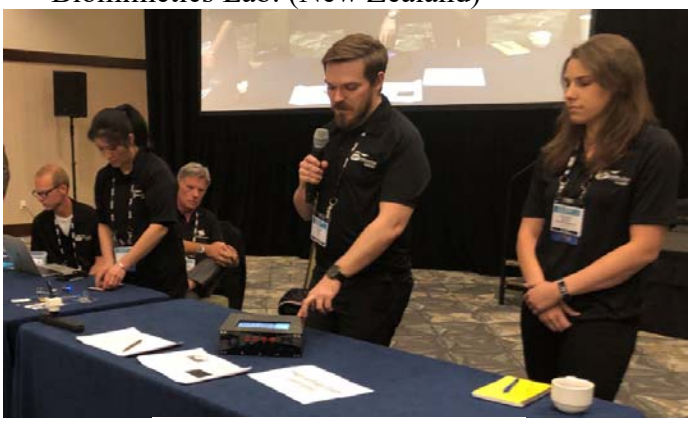
This team presented an inflatable robot, created from a sheet of silicone and airbrushed electrodes, which uses out of phase segmented actuation to produce linear conveyance of a light load along its length. In addition, they presented the results of their finite element simulation of their model. This demonstration has potential application for inflatable dielectric robotics.

7. **High voltage EAP controller - E.-F. Markus Henke,**, Biomimetics Lab. (New Zealand) and TU Dresden (Germany), **Patrin Illenberger, Katie Wilson, Sam Rosset, Iain Anderson**, Biomimetics Lab. (New Zealand)



This demo is a new EAP high voltage controller that is at α stage. This new controller is intended to help university labs and other research institutions to power their EAP actuators easily without the need of developing complicated driving electronics. It comes with four channels, a touch-screen user-interface, and is battery powered. The controller provides DC, rectangle, sinusoidal and triangle signals, with an amplitude having up to 5kV @ 1mA per channel. The Channels can be programmed independently.

8. **Geometric limit switches (gDES) for robotics and automation industry - E.-F. Markus Henke,**, Biomimetics Lab. (New Zealand) and TU Dresden (Germany), **Patrin Illenberger, Katie Wilson, Sam Rosset, Iain Anderson**, Biomimetics Lab. (New Zealand)



Geometric dielectric elastomer switches (gDES) have been demonstrated as a switch of both high and low voltages. They only consist of soft materials such as silicones and carbon-doped conductive silicones. Arrays of these switches can be integrated in soft robotic grippers and extend the features of those grippers by touch and shear force detection. Furthermore, gDES can act as limit switches and can be introduced in automation technology. One of the key advantages is that the switches themselves are entirely shielded and not affected by environmental influences.

9. **From StretchSense Ltd.: the latest in EAP gloves - Marco Tabor, Iain Anderson**, StretchSense Ltd. (New Zealand) (In the picture: Sam Rosset, Iain Anderson, Yuting Zhu)

StretchSense have demonstrated their putting EAP sensors into garments using fabric-backed sensors and combining information from different sensor types. To illustrate the technology, they presented an EAP glove that can capture and send in real-time hand-posture (rotation) and finger bending to a device with an application to visualize the data e.g. game.

10. **Synthetic Muscle in prosthetics - Lenore Rasmussen, Damaris Smith**, Ras Labs, Inc. (United States)

Ras Labs Synthetic Muscle™, which is an EAP based actuator that contracts, and with reversed electric input polarity, expand. Ras Labs has begun testing their EAP system on amputees to maintain continual perfect prosthetic socket fit and is going to present their prototype. These EAPs serve dual use as sensors, which can be tied in to automatic adjustment and touch biofeedback, and can determine the number of impacts (or steps) and severity of impact/pressure for protective gear and comfortable shoe wear and insoles

11. **Versatile dielectric loudspeakers - Florian Klug and Helmut F. Schlaak,** Technische Univ. Darmstadt (Germany)

Electronic EAPs, such as the dielectric elastomer transducer, offer higher frequencies up to several kilohertz. This team presented an EAP loudspeaker. Due to their nonlinear behavior and high driving voltages, they suffer from poor audio quality and high costs. In this demonstration, the team presented a configuration for low cost, flexible or low distortion loudspeakers. Sound pressure levels higher than 100 dB with <10 kHz bandwidth and distortion <2 % depending on the configuration, they can be adaptable to various shapes and produced with large surfaces.

ADVANCES IN EAP

Aerospace Engineering-Propulsion/MEMS

DEA Compressor to Create a Full Electric Distributed Propulsion

Babak Aryana, Independent Researcher/ Inventor *Babak.Aryana@gmail.com*

Currently, for many researchers in aircraft propulsion the trend is toward developing full-electric propulsion. Regarding challenges to create a full electric propulsion system, distributed propulsion is in focus, because such a propulsion system could heighten performance of aircraft reducing energy consumption, and the less energy to operate the lighter and more compact propulsion system [1]. However, heavy electric sources like batteries and fuel cells, in addition to limited capability of fans and propellers increase challenges to configure efficient and practical full electric propulsion system for aircrafts [2].

DEA compressor as a full electric system has considerable potential to develop a full electric distributed propulsion for aircraft. (Dielectric Elastomer Actuator) DEA compressor can dynamically be configured according to aerodynamic requirements of the aircraft. Moreover, DEA compressor can be used to design an engine working in higher pressure ratio and its

ability to adapt to environmental elements helps the system to be tuned for the best performance [3] [4].

I am working on a DEA compressor powered by a (Proton Exchange Membrane) PEM fuel cell whose vessel is integrated with a nozzle. Considering this fact that vessel inlet pressure can dynamically be regulated, the exit nozzle can be kept chock in most of the flight condition increasing thrust. The engine can simply be divided to several units and distributed in proper position in the aircraft (**Figure** 8). Nevertheless, actuators of DEA compressor need to be redesigned toward the less energy consumption, and all the influential factors to reduce fuel cell size and weight should be considered for creating a practical full electric propulsion (**Figure 9** and **Figure 10)**.

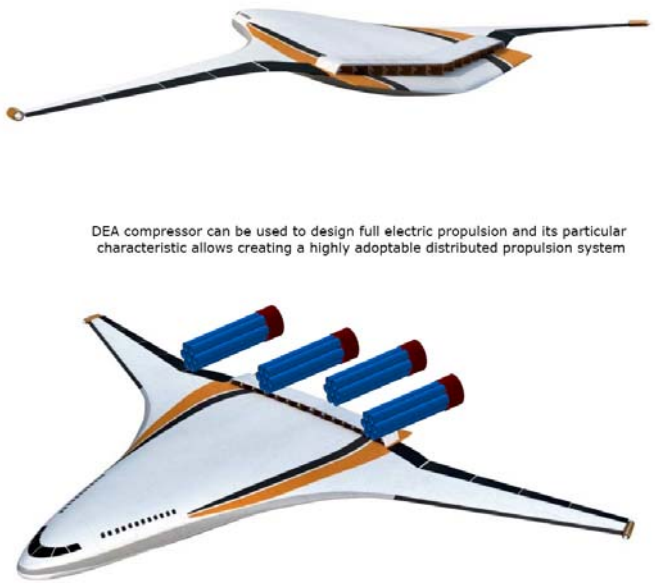


Figure 8: Full electric engines made based on DEA compressor can potentially be formed toward the best distributed configuration for creating optimum performance in different flight condition (The picture is for NASA N3-X, a conceptual design with turboelectric distributed propulsion that DEA compressors are placed on it to present the basics of the idea).

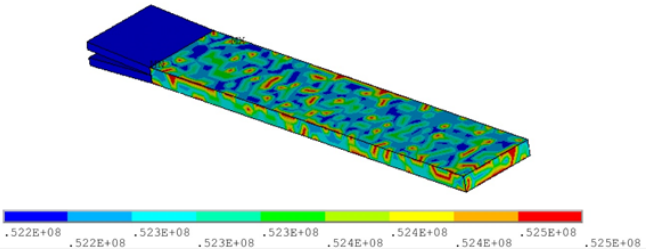


Figure 9: Distribution of electric field on a (Dielectric Elastomer) DE sheet, simulated by ANSYS [4]

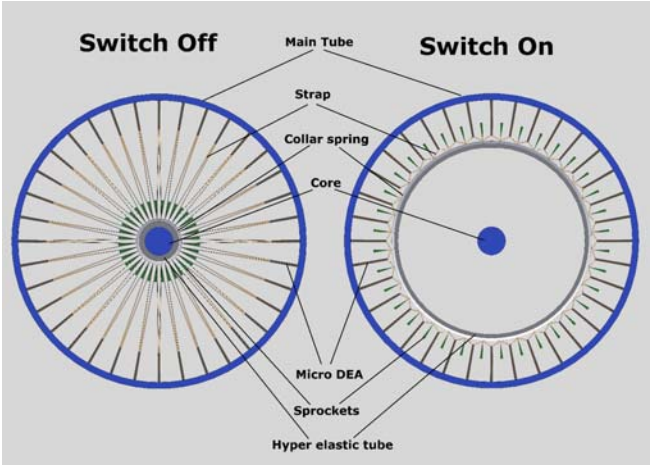


Figure 10: Although, each DEA sheet needs low electric power to operate, but each actuator is made of several DE sheet and each cell of DEA compressor tubes encompasses several actuators. Furthermore, each tube is created of many cells, and then a DEA compressor, depends on its capacity may need hundreds kilowatt of power [4]. This fact in addition to limited capability of electric sources makes designing actuators using lower power to operate an important factor for a full electric propulsion.

References

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generation on-board commercial airplanes," *Applied Energy,* vol. 101, pp. 776-796, 2013.

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[4] B. Aryana, "New version of DEA compressor for a novel hybrid gas turbine cycle: TurboDEA," *Energy,* vol. 111, pp. 676-690, 2016.

JOURNALS RELATED TO EAP & BIOMIMETICS

Bioinspiration & Biomimetics - Peer-reviewed journal publishing research that discovers and uses principles from natural systems to create physical models, engineering systems and technological designs.
http://iopscience.iop.org/journal/1748-3190

Biomimetics - Peer-reviewed open access journal regarding biomimicry and bionics published quarterly online.
https://www.mdpi.com/journal/biomimetics

Intelligent Material Systems and Structures - is an international - Peer-reviewed journal that publishes research results of experimental or theoretical work on any aspect of intelligent materials systems and/or structures research also called smart structure, smart materials, active materials, adaptive structures and adaptive materials.
https://journals.sagepub.com/home/jim

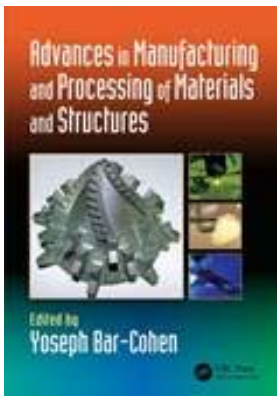
International Journal of Smart and Nano Materials – Peer-reviewed open access journal publishing cutting-edge research into smart and nano materials and their applications, including energy harvesting, sensing, self-healing, and self-assembly.
https://www.tandfonline.com/toc/tsnm20/current

Smart Materials and Structures – multi-disciplinary journal dedicated to technical advances in (and applications of) smart materials, systems and structures; including intelligent systems, sensing and actuation, adaptive structures, and active control.
http://iopscience.iop.org/journal/0964-1726

Soft Robotics - Peer-reviewed journal covering research on the emerging technologies and developments of soft and deformable robots, including coverage of flexible electronics, materials science, computer science, and biomechanics.
http://home.liebertpub.com/publications/soft-robotics/616

NEW BOOKS

Adv. in Mnfg. & Processing of Materials & Structures



The 10th book of this Newsletter Editor has been published by CRC Press. This edited and coauthored book is entitled "*Advances in manufacturing and processing of materials and structures"* and it contains 544 pages [https://www.amazon.com /Advances-Manufacturing-Processing-Materials-Structures/dp/1138035955]. The book covers the latest advances in manufacturing and processing including additive and subtractive processes and it is intended to provide a compiled resource that reviews details of the advances. 3D printing is a key development that has been incorporated into this book covering its use to produce complex parts including composites with odd shape fibers as well as tissue and body organs.

The 20 chapters are

1. "State-of-the-art of the manufacturing and processing methods in the digital era", Y. Bar-Cohen, JPL
2. "Computer-aided design (CAD)", Nikolaos Bilalis, Technical University of Crete, Greece; and Emmanuel Maravelakis, School of Applied Sciences, Technological Educational Institute of Crete
3. "Biologically inspired designs", Jacqueline Power University of Tasmania, Launceston TAS; and Rina Bernabei, University of New South Wales, Sydney, Australia
4. "Current capabilities and research trends in rapid and virtual prototyping", Sriram Praneeth Isanaka and Frank Liou, Missouri University of Science & Technology

5. "Biofabrication and Bio-Inspired Manufacturing Techniques for the Built Environment", Brook S. Kennedy, School of Architecture + Design, Virginia Tech, Blacksburg, VA; Christopher Maurer, Redhouse Studio, Cleveland, OH; and William Sullivan, FLEXcon Company, Inc., Spencer, MA
6. "Cyber Manufacturing" Mostafa Bedewy, Mai Abdelhakim, and Alex K. Jones, University of Pittsburgh, PA
7. "Manufacturing via 3D printing techniques and 4D with functionality", R. Peter Dillon, Bryan McEnerney, John Paul Borgonia, JPL
8. "Medical Applications for 3D Printing", David K. Mills, Karthik Tappa, Uday Jammalamadaka, Patrick A.S. Mills, Jonathan S. Alexander and Jeffery A. Weisman, Louisiana USA
9. "Additive, subtractive and hybrid manufacturing processes", Javaid Butt and Hassan Shirvani, Anglia Ruskin University, UK
10. "Integrated Manufacturing", Robert Richardson, Jordan Boyle, and Nicholas Fry, School of Mechanical Engineering, University of Leeds,
11. "Adhesion bonding techniques", M. Costaa, R. Carbasa, E. Marques, G. Viana, L. F. M. da Silva, Portugal
12. "Metal joining techniques using brazing", Y. Bar-Cohen, JPL; Dusan P. Sekulic and Rui Pan University of Kentucky, Lexington, KY; Sudarsanam Suresh Babu and Anming Hu, University of Tennessee, Knoxvile, TN; Xiaoqi Bao, Mircea Badescu, Hyeong Jae Lee, and Stewart Sherrit, JPL
13. "Diffusion Bonding", Rui Pan, Dusan P. Sekulic, College of Engineering, University of Kentucky, Lexington, KY
14. "Manufacturing technologies for electroactive composite actuators and sensors", Hyeong Jae Lee, JPL; and Shujun Zhang, ISEM, Australian Institute for Innovative Materials, University of Wollongong, NSW, 2500, Australia
15. "Guidelines for making Ionic Polymer-Metal Composite (IPMC) materials as artificial muscles by advanced manufacturing methods: State-of-the-Art," Kwang J. Kim, Tyler Stalbaum, Sarah Trabia, Taeseon Hwang, Zakai Olsen, Shelby Nelson, Qi Shen, Dong-Chan Lee, University of Nevada, Las Vegas; James Carrico, Kam K. Leang, University of Utah; Viljar Palmre, Jungsoo Nam, The University of Texas Health Science Center at Houston; Ilseok Park, UES Inc.; Rashi Tiwari, Dow Chemical: Doyeon Kim, Apple; Sungjun Kim, Samsung Electronics
16. "Multifunctional Materials and Structures", Paul E. Kladitis, University of Dayton Research Institute, Dayton, OH;
17. "In-Situ Resources Utilization (ISRU)", Gerald E Voecks, JPL
18. "Sustainable Manufacturing", Sara Behdad, University at Buffalo; Jacquelyn Nagel, JMU; and Mostafa Sabbaghi, University of Buffalo
19. "Nondestructive Evaluation (NDE) of materials and structures from production to retirement", Weibin Li and Tribikram Kundu (Bikram), University of Arizona College of Engineering, Tucson, AZ
20. "Past and the outlook at the manufacturing and processing technologies", Y. Bar-Cohen, JPL

FUTURE CONFERENCES

Date	Conference/Symposium
June 25-27, 2019	Sensors Expo & Conference, San Jose, CA. www.sensorsexpp.com
June 2019	Nature, Art & Habitat Residency (NAHR): An ECO-Laboratory of Multidisciplinary Practice Taleggio valley, Bergamo - Northern Italy. Information is available at https://nahr.it/NAH_Residency-Grasses-Erbe
October 23-24, 2019	International Conference on Robotics and Automation Engineering being held at Rome, Italy. For information, you can contact Pranay Reddy, Robotics-2019, Operating Committee robotics@madridge.com
October 27 - 31, 2019	The Tenth International Conference on Sensor Device Technologies and Applications, SENSORDEVICES 2019 will be held in Nice, France. Information is available at http://www.iaria.org/conferences2019/SENSORDEVICES19.html
April 26 - 30, 2020	The 2020 SPIE's EAPAD Conf. is going to be held again in Anaheim, CA. This Conf. will be the 21th annual one and is going to be chaired by Y. Bar-Cohen, JPL, and Co-chaired by I. A. Anderson, The Univ. of Auckland, New Zealand, and Herb Shea, École polytechnique fédérale de Lausanne, Switzerland. The call for papers is posted at http://www.spie.org/eap and the abstracts are due on Oct. 16, 2109.
15-19 June, 2020	15th International Ceramics Congress (CIMTEC), will be held at Montecatini Terme, Italy, and it is its 50th anniversary. The meeting is managed by the Techna Group Techna Group, Secretariat Office Faenza, Corso Mazzini, Italy, e-mail: Info@technagroup.it & web: https://www.technagroup.it/
25-26 June 2020	3rd International Conference on Materials Design and Applications, Porto, Portugal. For information the contact person is Lucas F M da

	Silva at lucas@fe.up.pt The website is www.fe.up.pt/mda2020

EAP ARCHIVES

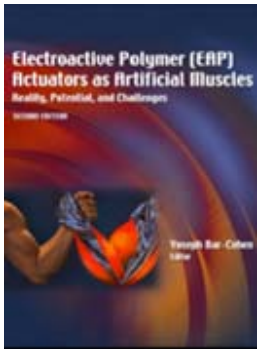
Information archives and links to various websites worldwide are available on the following (the web addresses below need to be used with no blanks):

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)

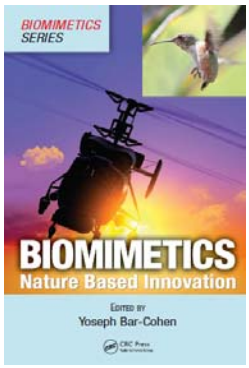
In March 2004, the 2nd edition of the "Electroactive Polymer (EAP) Actuators as Artificial Muscles - Reality, Potential and Challenges" was published.



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

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



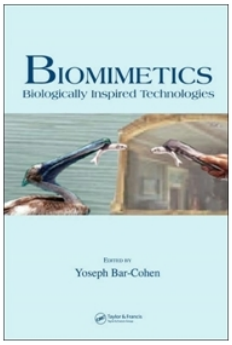
Architecture Follows Nature - Biomimetic Principles for Innovative Design
Authored by Ilaria Mazzoleni www.imstudio.us info@imstudio.us in collaboration with Shauna Price http://www.crcpress.com/product/isbn/9781466506077

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 humankind's engineering challenges.

Books about robotics

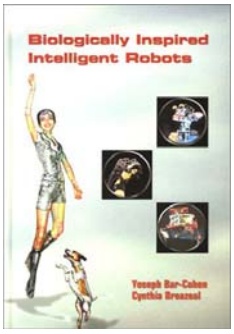
The Coming Robot Revolution - Expectations and Fears about Emerging Intelligent, Humanlike Machines

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)



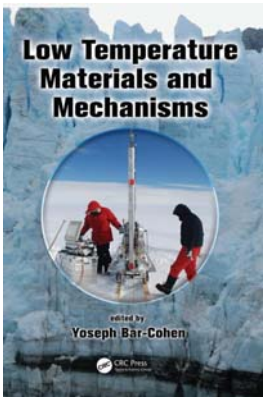
The book that is entitled "Biologically-Inspired Intelligent Robots," covering the topic of biomimetic robots, was published by SPIE Press in May 2003. There is already extensive heritage of making robots and toys that look and operate similar to human, animals and insects. The emergence of artificial 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 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.

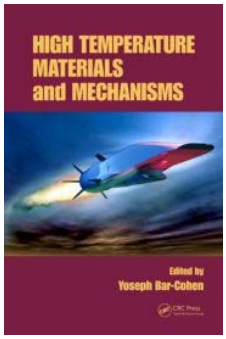
High Temperature Materials and Mechanisms

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.



WorldWide Electroactive Polymers (EAP) Newsletter

EDITOR: Yoseph Bar-Cohen, http://ndeaa.jpl.nasa.gov/nasa-nde/yosi/yosi.htm

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