EuroEAP 2012

Second International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles

Potsdam, Germany
29-30 May 2012

Technical programme

Book of abstracts

List of participants

ESNAM
European Scientific Network for Artificial Muscles

cost
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

Contents

Conference venue

Kongresshotel Potsdam am Templiner See
Congress Hotel on Lake Templin

Am Luftschiffhafen 1,
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UP TRANSFER
Gesellschaft für Wissens- und Technologietransfer mbH
an der Universität Potsdam

Presentation of the EuroEAP conference series

Electromechanically Active Polymers (EAPs) represent a fast growing and promising scientific field of research and development. EAPs are studied for devices and systems implemented with 'smart materials' inherently capable of changing dimensions and/or shape in response to suitable electrical stimuli, so as to transduce electrical energy into mechanical work. They can also operate in reverse mode, transducing mechanical energy into the electrical form. Therefore, they can be used as actuators, mechano-electrical sensors, as well as energy harvesters to generate electricity. For such tasks, EAPs show unique properties, such as sizable electrically-driven active strains or stresses, high mechanical flexibility, low density, structural simplicity, ease of processing and scalability, no acoustic noise and, in most cases, low costs. Owing to their functional and structural properties, electromechanical transducers based on these materials are usually refereed to as EAP 'artificial muscles'.

The two EAP classes (ionic and electronic) are studied for applications in several fields, including haptics, optics, acoustics, microfluidics, automation, orthotics, artificial organs, and energy harvesting.

The rapid expansion of the EAP technologies has stimulated in Europe the creation of the 'European Scientific Network for Artificial Muscles - ESNAM', established as a COST Action (MP1003) since 8 December 2010. The network gathers the most active European research institutes, industrial developers and end users in the EAP field (www.esnam.eu).

In an effort to disseminate current advances in this emerging field of science and technology, gathering experts from all over the world, the network organises and supports the annual EuroEAP conference, which is meant to be primarily driven by scientific quality and industrial impact.

I wish to express my gratitude to the conference chairman and local organizer, for the valuable organization that I am sure will allow you to enjoy this event and leave it with plans to attend the future annual editions moving across Europe.

Federico Carpi
Chair of ESNAM

Conference committees

Organizing committee

The EuroEAP conference is steered by the conference committee of the '*European Scientific Network for Artificial Muscles*' (www.esnam.eu):

President:
Federico Carpi, University of Pisa (Italy)

Vice-President:
Edwin Jager, Linköping University (Sweden)

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Frédéric Vidal, University of Cergy-Pontoise (France)

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Peter Sommer-Larsen, Technical University of Denmark (Denmark)
Frédéric Vidal, University of Cergy-Pontoise (France)

Tuesday, 29 May 2012

General programme of the day

8:45 – 9:10	Welcome and introductory remarks

<u>Session 1.1</u> (Chairs: Reimund Gerhard, Kinji Asaka)

9:10 – 9:40	Plenary talk: Ray Baughman (University of Texas at Dallas, USA)
9:40 – 10:00	Invited talk: Iain Anderson (University of Auckland, New Zealand)
10:00 – 10:20	*Coffee break*
10:20 – 10:40	Invited talk: Kinji Asaka (AIST, Japan)
10:40 – 11:10	Invited talk: Manuel Aschwanden (Optotune, Switzerland)

<u>Session 1.2</u> (Chairs: Ray Baughman, Iain Anderson, Edwin Jager)

11:10 – 12:10	EAPills: 15 short oral presentations (3 minutes each + 1 minute to change speaker)
12:10 – 13:40	*Lunch*
13:40 – 15:10	EAPosters, EAPrototypes, EAProducts (Exhibitions &15 Posters)

<u>Session 1.3</u> (Chairs: Manuel Aschwanden, Marc Matysek, Mika Paajanen)

15:10 – 16:10	EAPills: 15 short oral presentations (3 minutes each + 1 minute to change speaker)
16:10 – 16:30	*Coffee break*
16:30 – 17:30	EAPosters, EAPrototypes, EAProducts (Exhibitions &15 Posters)

<u>Social event</u>

18:00 – 21:00	*Ship tour with social dinner*

Session 1.1

(abstracts are listed in order of presentation)

1.2.1 The diverse and growing family of carbon nanotube and related artificial muscles

Ray Baughman (1);

(1) Alan G. MacDiarmid NanoTech Institute, University Of Texas At Dallas

Presentation given by Dr. Ray Baughman

Collaborative work with colleagues at the University of Texas at Dallas, the University of Wollongong, the University of British Columbia, and Hanyang University has expanded the family of carbon nanotube artificial muscles from our original double-layer driven tensile muscles to pneumatic muscles, fuel driven muscles, giant stroke aerogel muscles, and even muscles that provide torsional actuation. These muscles, as well as carbon nanotubes muscles demonstrated by others, are here described. Extreme performance is demonstrated, like for our aerogel muscles that generate giant strokes and stroke rates of 220% and 37000 %/s, respectively, from near 0 K to over 1900 K; electrochemical muscles that generate a hundred times the tensile stress of natural muscle; and torsional muscles that rotate at up to 600 revolutions per minute and provide a hundred times higher rotation per unit length than previous torsional muscles. The properties of these electrically powered muscles, and related fuel powered muscles, are described and theoretically explained.

1.2.2 Emergent behavior from assemblies of artificial muscles

Iain Anderson (1) (2); Todd Gisby (1); Thomas McKay (1); Benjamin O'Brien (1);

(1) Biomimetics Laboratory, Auckland Bioengineering Institute
(2) Department Of Engineering Science, University Of Auckland

Presentation given by Prof. Iain Anderson

An emergent behavior can arise when a number of simple entities work together collectively within a more complex system. An example of an emergent behavior is the pumping of blood by the heart, due to the orderly contraction of the individual heart wall myocytes, each triggered by the wave of depolarization from the pacemaker. Simple robotic devices that can sense and actuate can also display emergent behavior. Dielectric Elastomer (DE) artificial muscle devices are ideal in this role. Piezoresistive DE switches can also be used with them for controlling charge. We describe three case studies of DE systems that have displayed emergent behavior: membrane DE rotary motors capable of multi-degree-of-freedom movement or that can self-commutate charge; a mechanosensitive DE actuator array for a conveyor and an artificial muscle ring oscillator. The oscillator began as a project to demonstrate how dielectric elastomer switches can be used in conjunction with DE muscles to roll a ball around a track. This has led to the development of an all-polymer DE ring oscillator with no mechanical parts. DE actuators and DE switches can also be assembled into all rubber NAND gates. Together with the oscillator we have the building blocks of a soft computer, demonstrating that distributed intelligence is feasible in a soft machine. Using arrays of simple DE devices, it now becomes possible to emulate living systems and explore new horizons for mechanical engineering.

1.2.3 Ionic-polymer-based electroactive polymer actuators

Kinji Asaka (1);

(1) Health Research Institute, National Institute Of Advanced Industiral Science And Technology (AIST), Ikeda, Japan

Presentation given by Dr. Kinji Asaka

In this presentation, two types of ionic-polymer-based electroactive polymer actuators, ionic polymer-metal composite (IPMC) and bucky-gel actuators are reivewed. The IPMCs that are composed of ionic gel polymer plated with metal electrodes, are one of the most promising electroactive polymer materials for artificial muscle-like actuators. The IPMCs are novel low-voltage driven actuator, which can be activated in water or in wet conditions. We have also developed a novel dry actuator that can be fabraicated simply by layer-by-layer casting, using 'bucky gel', a gelatinous ionic liquid containing single-walled carbon nanotubes. Our actuator (the bucky-gel actuator) has a bimorph configuration with a polymer-supported internal ionic liquid electrolyte layer sandwiched by bucky gel electrode layers which allow quick and long-lived operation in air at low applied voltages. Both types of actuators can be applied to various applications, such as bio-mimetic robots, bio-medical devices, tactile displays, micro-pumps, etc. In a very near future, commercial products based on ionic-polymer-based electroactive polymer actuators will appear.

1.2.4 *Topic*: Dielectric elastomer actuators for tunable optics

Manuel Aschwanden (1)

(1) Optotune, Switzerland

Abstract not available.

Session 1.2
(abstracts are listed in order of presentation)

1.2.1 Dielectric elastomer nanocomposites with enhanced electromechanical response

Kaiying Wang (1); Xuyuan Chen (1);

(1) Vestfold University College, Department Of Micro And Nano Systems Technology, Horten, Norway

Presentation given by Prof. Kaiying Wang

A series of dielectric elastomer nanocomposites with enhanced electromechanical response have been synthesized by loading TiO2 nanoparticles into polydimethylsilane (PDMS) polymer. The maximum loading capacity of TiO2 nanoparticles in the PDMS is about 37.5 wt% without obvious agglomeration. Scanning Electrone Microscopy (SEM) and nanoparticle analysis show that the average diameter of the nanoparticles/clusters is around 90 nm which is uniformly distributed in the PDMS matrix. Among the elastomer nanocomposites, the 15 wt% TiO2 loaded PDMS shows relatively low elastic modules (77 kPa), fast response (27 ?s) and high dielectric constants (6.4). The enhanced dielectric constant and relatively low elastic modulus are critical parameters for developing low driving voltage and high speed light modulators.

1.2.2 Patterning of polypyrrole trilayer actuators working in air for microrobotics

Edwin Jager (1) (2); Babita Gaihre (2); Gursel Alici (2); Geoff Spinks2 (2);

(1) Linkoeping University, Linkoeping, Sweden
(2) University Of Wollongong, Wollongong, Australia

Presentation given by Dr. Edwin Jager

Within the areas of cell biology, biomedicine and minimal invasive surgery, there is a need for soft and flexible manipulators for handling biological objects,

such as single cells and tissues. Polypyrrole (PPy) trilayer actuators are an attracting option since they use low power, are soft and can be operated without the need of an external electrolyte. The PPy trilayer actuator is made of three layers laminated together: two outer two layers of PPy and a middle, insulating layer of polyvinylidene difluoride (PVDF) to separate the two electrodes and contain the electrolyte. To date, only simple, individual actuators as have been fabricated and characterized. For the applications mentioned previously there is a need to be able to also fabricate complex structures, comprising individual addressable microactuators, for instance, in the form of multi-degree of freedom legs and microrobotic grippers. We have developed different microfabrication and patterning methods for both thick, membrane PVDF- and thin film PVDF-based trilayer actuators, which require different processing steps, thus extendeding our processing capabilities. We will present these new processing methods and initial articulated microactuator devices, i.e. actuators comprising individually controllable actuators/segments.

1.2.3 High performance DEA materials by chemical grafting of silicone networks on molecular level

Bjoern Kussmaul (1); Sebastian Risse (2); Michael Wegener (1); Guggi Kofod (2); Hartmut Krueger (1);

(1) Fraunhofer Institute For Applied Polymer Research, Department Polymers And Electronics, Potsdam, Germany
(2) University Of Potsdam, Faculty Of Science, Potsdam, Germany

Presentation given by Dr. Hartmut Krueger

Dielectric elastomer actuators (DEAs) enable a wide range of interesting applications such as arm wrestling robot, miniaturized pumps, optical adjustment actuators, electro-mechanical logic gate for distributed multi-element smart systems, etc., since they are soft, light-weight and have direct voltage control. However, one of the main obstacles to their wide-spread implementation is their high operating voltage, which tends to be several thousand volts. In principle, the operating voltage can be lowered by reducing the thickness of the elastomer film, increasing the permittivity or lowering the mechanical stiffness. Permittivity generally can be increased by inorganic filler particles with high dielectric constant or by modifying the chemical structure of the elastomer. A simple chemical method was established to enhance the actuation properties of silicones, by grafting functionalized organic dipole molecules to the cross-linker molecules at the same time as the network is formed. This one-step film formation approach prevents agglomeration and give elastomer films that are homogeneous even at molecular level. Furthermore it can be applied to any silicone which forms the network via hydrosilylation and works with a variety of different dipole molecules.The obtained films are superior due to their increased permittivity and simultaneously decreased stiffness.The actuation performance is improved by more than 400 percent compared to the non-modified silicone.

1.2.4 Dielectric Elastomer Generators: Capacity, Design and Performance

Soo Jin Adrian Koh (1) (2);

(1) National University Of Singapore
(2) Institute Of High Performance Computing

Presentation given by Dr. Adrian Koh

A pre-stretched and pre-charged DE boosts voltage across its electrodes in the open-circuit condition, functioning as a generator. Previous estimates suggests that DE generators are capable of converting energy at a specific energy density of 400 mJ/g, which is comparable to a mid-scale electromagnetic generator. Our theoretical estimates suggest that, by selecting materials of suitable mechanical and dielectric properties, a much higher figure of up to 1000 mJ/g may be realized. Varying material properties of shear stiffness, dielectric constant and dielectric strength, we found that a stiff, field-tolerant elastomer, resembling that of natural rubber, is capable of converting energy in excess of 500 mJ/g, operating at a strain amplitude of 100%. Further gains in energy of conversion may be possible by customizing the properties of elastomers. Motivated by experiments, we develop a dissipative model and analyzed two processes: viscoelasticity and current leakage. We evaluate the performance of a DE generator based on three parameters: Specific energy of conversion, specific power and efficiency of conversion. We found that a DE generator may produce negative efficiency (wasting energy instead of generating) when operating at large strain amplitudes and low frequencies. On the other hand, efficiency of conversion may be optimized at moderate strain amplitudes. At frequencies of operation in excess of 1Hz, the efficiency of conversion may exceed 90%. Our analysis may aid in the evaluati

1.2.5 Orthophosphoric acid treatment enhances thermal stability of tubular-channel LDPE piezoelectrets

Dmitry Rychkov (1); Ruy Alberto Pisani Altafim (2); Werner Wirges (1); Ruy Alberto CorrÃªa Altafim (2); Reimund Gerhard (1);

(1) Applied Condensed-Matter Physics, Institute Of Physics And Astronomy, Faculty Of Science, University Of Potsdam, Potsdam, Germany.
(2) Department Of Electrical Engineering, Engineering School Of SÃ£o Carlos, University Of SÃ£o Paulo, SÃ£o Carlos - SP, Brazil

Presentation given by Dr. Ruy Alberto Pisani Altafim

It is well known that chemical treatments can modify the surfaces of polymer films and may help control their electrical properties, such as the thermal stability of charge retention. However, since most piezoelectrets are usually prepared as polymer-foam films with closed cells, it is not possible to apply such treatments to the internal surfaces of the voids where the essential charges are stored. Recently, a template-based thermal-lamination technique was introduced as an alternative method for fabricating piezoelectret systems with two or more polymer-electret films. One advantage of this method is that all geometrical parameters of the voids can be well controlled via the template(s). When the template is removed after lamination, a voided structure with open tubular channels is than generated. Here, thermal lamination was employed to prepare tubular-channel piezoelectrets from low-density polyethylene (LDPE) films. The tubular channels were internally treated with liquid orthophosphoric acid. As a result, the electric charges trapped on the inner surfaces of the channels after bipolar charging in high electric fields by means of dielectric-barrier discharges (DBDs) became thermally much more stable.

1.2.6 Photo-actuating properties of nanocomposites of elastomeric matrices and carbon nanotubes

Maria Omastova (1); Klaudia Czanikova (1); Dusan Chorvat, Jr. (2); Igor Krupa (1);

(1) Polymer Institute, SAS,Bratislava, Slovak Republic
(2) International Laser Center, Bratislava, Slovak Republic

Presentation given by Dr. Maria Omastova

Nanocomposites on the base of elastomeric matrix and carbon nanotubes display a reversible shape change property in response to light. These materials could be used for the construction of touch screen allowing to blind and partially sighted people to read text, equations, graphs, etc. This contribution will provide results of actuation of composites containing well dispersed carbon nanotubes (CNT) in ethylene vinyl acetate copolymer. Two polymeric matrices, ethylene vinyl acetate copolymer (EVA) containing 50 wt.% or 28 wt.% of vinyl acetate were used for preparing nanocomposite with two different types of CNT, multiwall CNT and singlewall CNT. The surface of CNT was modified by non-covalent method with the special synthesized surfactants based on pyrene molecules, cholesteryl 1-pyrencaroxylate (Py-Chol) for achieving good dispergation of nanofillers. The nanocomposites were prepared by casting from solution. Prepared nanocomposite was put between special punch and die molds to obtain Braille element shape. The presentation will demonstrate various techniques as SEM and nanoindentation, proving actuation of prepared elastomeric nanocomposites. The achieved results will be summarized with the aim to show variability of testing method applied for proving concept of actuation of elastomeric composites with well dispersed carbon nanotubes.

1.2.7 X-ray photoelectron-spectroscopy and conductivity studies of polypyrrole ageing

Jana Tabaciarova (1); Matej Micusik (1); Pavol Fedorko (2); Maria Omastova (1);

(1) Polymer Institute, Slovak Academy Of Sciences, Bratislava, Slovakia
(2) Department Of Chemical Physics, Faculty Of Chemical And Food Technology, Bratislava, Slovakia

Presentation given by Ms. Jana Tabaciarova

Polypyrrole (PPy) is one of the most studied conductive polymers due to its high electrical conductivity, good chemical and thermal stability and ease of preparation. These characteristics make it widely used in applications as sensors, flexible points in electronic devices, electromagnetic shielding, artificial muscles etc. From the application point of view it is important to know its long term stability and lifetime of usability associated with degradation of electroactivity. The assembly of polypyrrole determines the molecular structure and influences the properties. In this work polypyrrole was synthesised by chemical oxidative polymerization of pyrrole using four different oxidants, namely, FeCl3, FeCl3.6H2O, Fe2(SO4)3, and (NH4)2S2O8. Additionally, in the case of FeCl3 dodecylbenzene sulfonic acid as surfactant and co-dopant was used. The incorporation of anion or co-dopant species was considered by ratio anion/N+. The surface compositions of PPy aging (up to 15 months) were followed by X-ray photoelectron spectroscopy. Subsequently, the decrease of conductivity, as a marker of chemical stability, was related to the increase of oxygen species on the surface and change of chemical states of anion. Furthermore the disruption of the pi-conjugated system was followed by D-parameter of 1 differential of Auger C KLL peak.

1.2.8 Electromechanical performance of PVDF/CNT composites for strain sensor applications

Armando Ferreira (1); JosÃ© Gerardo Rocha (2); Alejandro AnsÃ³n-Casaos (3); Maria Teresa MartÃnez (3); Filipe Vaz (1); Senentxu Lanceros-MendÃ©z (1);

(1) Center/Department Of Physics, University Of Minho, Campus De Gualtar, 4710-057 Braga, Portugal.
(2) Algoritmi Research Center, University Of Minho, Campus De AzurÃ©m, 4800-058 GuimarÃ£es, Portugal.
(3) Instituto De CarboquÃmica ICB-CSIC, Miguel Luesma CastÃ¡n 4, 50018 Zaragoza, Spain.

Presentation given by Mr. Armando Ferreira

This work reports on the piezoresistive behaviour of polymer-based nanocomposites, composed of poly(vinylidene fluoride) - PVDF and carbon nanotubes (CNTs). PVDF is being widely investigated among the polymeric materials due to its remarkable pyro- and piezoelectric properties, especially when the material is in its electroactive beta-phase. These properties are in the origin of several types of applications, especially in the fields of sensing and actuating devices. When PVDF is in its alfa-phase, it is also an interesting material for several types of applications due, in particular, to its superior dielectric constant, chemical inertness, thermal stability and mechanical properties, when compared to other polymer materials. Taking all this into account, PVDF and its co-polymers are being widely investigated and commonly include in the research of smart sensors in each of its different phases . In the frame of this work, a set of PVDF samples were prepared by hot pressing with CNT sample concentrations up to loadings of 10 wt.%. The correlation between the electrical resistivity and mechanical solicitations is presented for the different composites and for varied mechanical solicitations. The values of the gauge factor, reaching up to 6.2, and the linearity of the response over a wide strain range, shows the viability of these materials to be used as piezoresistive sensors. The stability of the signal, the time response and the temperature behaviour were also evaluated. The observed electric

1.2.9 Electro-mechanical properties of thermoplastic elastomer SBS/CNT composites for large strain sensors

Pedro Costa (1) (2); JÃºlio Viana (2); Senentxu Mendez (1);

(1) Centro/Dept. Physics Of Minho University , Braga, Portugal
(2) Institute For Polymers And Composites IPC/I3N, University Of Minho, GuimarÃ£es, Portugal

Presentation given by Mr. Pedro Costa

Elastomers and thermoplastics are known for their capability to exhibit high deformation capability and high electrical and thermal resistance. These properties can be significantly modified by the addition of conductive fillers such as carbon allotropes. Within this family, carbon nanotubes (CNT) are known to produce composites with superior electrical and mechanical properties compared to other carbon allotropes such as carbon black (CB) or carbon nanofibers (CNF). The CNT unique electrical and mechanical properties allow that even at low concentrations (typically less than 5 wt%), they can strongly affect the composites electrical and mechanical properties. Thermoplastic elastomer tri-block copolymer styrene-butadiene-styrene (SBS) is widely studied and used in industry due to its high elongation at break, abrasion resistance and high durability. SBS can be used without vulcanization, which is an advantage as it does not degrade the mechanical and electrical properties obtained in composites from this copolymer. SBS copolymers can be composed by different ratios of styrene and butadiene. The application range of SBS, once suitably reinforced with CNT, can be extended to a variety of products: sensors and actuators for large deformations, biomaterials for medical devices, among others. Previous studies on SBS - carbon nanotube composites indicate that the final properties of the composite can change for different ratios of styrene and butadiene. SBS-CNT composites have been studied for

1.2.10 Study on mechanical and dielectric behavior of VHB 4910 for sensors and actuators applications

Raj Kumar Sahu (1); Bipul Pramanik (1); Karali Patra (1); Shovan Bhaumik (2); Arvind Kumar Pandey (3); Dipak Kumar Setua (3);

(1) Indian Institute Of Technology Patna, Department Of Mechanical Engineering,Patna, India
(2) Indian Institute Of Technology Patna, Department Of Electrical Engineering, Patna, India
(3) Defence Materials And Stores R & D Establishment (DMSRDE), Kanpur, India

Presentation given by Dr. Karali Patra

This paper describes the experimental investigations to characterize mechanical and dielectric behavior of VHB 4910 at large deformations. Attempts are made for accurate and precise experimental determination of mechanical behaviors such as nonlinear stress-strain, strain rate dependent hysteresis, cyclic softening and stress relaxation of this material. This paper also reports experimental study on frequency and stretch dependent dielectric constant of VHB 4910 film. Copper tapes are implanted on two opposite sides of a stretched elastomer film and dielectric constant of this material is estimated from measured capacitance using LCR meter. Variations of dielectric constant with different stretch ratio and with different applied voltage frequency are studied. Results show that the dielectric constant decreases with increasing frequency and stretch ratio. In this work we also explore the possible application of dielectric elastomer as sensor. Due to application of force, the thickness of the elastomer changes resulting change in capacitance. The change of capacitance is sensed with the help of electronics oscillator circuit which produces square wave whose frequency depends on the capacitance of the sample. The frequency to voltage converter circuit is used to obtain output DC voltage. So the thickness versus voltage curve is obtained which may be used to measure the capacitance hence the input force, elongation, pressure, etc. All these presented experimental results may be helpful for designers.

1.2.11 Layer by Layer Assembly Polyaniline based Actuators

Daisy Accardo (1) (2); Paolo Ariano (1); Sergio Bocchini (1); Paolo Fino (1) (2); Mariangela Lombardi (1) (2); Laura Montanaro (1) (2);

(1) Center For Space Human Robotics@PoliTo, Istituto Italiano Di Tecnologia, C.so Trento 21 10129 Turin, Italy
(2) Department Of Applied Science And Technology, Politecnico Di Torino, C.so Duca Degli Abruzzi 24, 10129 Turin, Italy

Presentation given by Ms. Daisy Accardo

Conducting Polymers, such as polyaniline (PANi), are used for production of actuators because of their ability to change in size or shape when undergo cyclic reduction/oxidation. Two of the main drawbacks in their use are high response times and short lifetimes. In order to overcome these problems, in this work layer-by-layer deposition (LbL), a technique that allows fabrication of thin film by depositing alternate layers of oppositely charged materials, was used. Actuators using different membranes and layer-by-layer technique with polyaniline and doping polyanions were produced. These actuators were compared with the ones obtained by direct deposition of polyaniline and polyanions by solvent casting.

1.2.12 Investigations on a new type of folded dielectric elastomer actuator with structural integrity

Michele Ghilardi (1); Gabor Kovacs (2); Silvain Michel (2); Federico Carpi (1) (3);

(1) University Of Pisa, Interdepartmental Research Centre `E. Piaggio`, School Of Engineering, Pisa, Italy
(2) EMPA, Materials Science & Technology, Duebendorf, Switzerland
(3) Technology & Life Institute, Pisa, Italy

Presentation given by Mr. Michele Ghilardi

This work presents an investigation on a new kind of folded dielectric elastomer actuator based on an improved design with respect to the state of the art. The concept relies on folding a single stripe, with electrodes that are on both sides but cover each film surface according to a specific periodical pattern. In particular, the electrode layout is conceived to have surface regions coated and un-coated with the electrode material, so as to avoid any overlap of two coated regions with the same polarity when the stripe is folded. Therefore, the structural integrity against tractions of the device when it is electrically charged is expected to be preserved, as opposed to the possibilities of the state of the art. This concept was investigated using the Danfoss PolyPower silicone film, on which carbon based compliant electrodes were manufactured by spraying. The folding process was facilitated by an air ionizer to reduce the electrostatic effects which tended to wrap the stripes during handling. Despite this, the folding process turned out to be very challenging in terms of manufacturing complexity, especially with purely manual procedures. To date, only scarce and non-repeatable results have been obtained, showing that developing further this concept requires completely new approaches to cope with the manufacturing challenges.

1.2.13 Harvesting microgenerators based on longitudinal and transversal elastomeric effects

Mircea Ignat (1); Gabriela Hristea (1); Daniel Lipcinski (1); Maria Cazacu (2); Carmen Racles (2);

(1) National Institute For Research And Development In Electrical Engineering,Micro And
(2) "Petru Poni" Institute Of Macromolecular Chemistry, Iasi, Romania

Presentation given by Dr. Ignat Mircea

The paper presents some harvesting experimental models with specific structure of the longitudinal (mechanical traction effects) and transversal (mechanical compression effects) to an elastomeric membrane. In paper are presented the specific characteristic (voltage versus frequency) of the electromechanical harvesting microgenerators ;with longitudinal and transversal effects where are evidented the resonance frequence and the optimum functional fields. The voltage fiel of this microgenerators : 0- 400mV with a micropower field by 0-0,2mW. We describe the geometry , the structure of this harvesting microgenerators and the specific elements. A high molecular mass polydiorganosiloxane copolymer, polydimethylmethylvinyl-? alfa, omega -diol (Mn=350000), heat curable in presence of a peroxide (2,4-dichlorobenzoyl peroxide) was used as matrix for the incorporation of the silica and titania powders in weight percent of 28 and 50, respectively related to the polymer and this elastomeric material was used for realisation the compression and tractional microgenerators. The authors present , also the specific experiments, tests and interpret this experiments and the influence of the carbon rigid and flexible electrodes which represent the mein reper of this microgenerators.

1.2.14 Modelling of electromechanical behaviour of EAP materials

Anna Ask (1); Sara Thylander (1); Ralf Denzer (2); Andreas Menzel (1) (2); Matti Ristinmaa (1);

(1) Lund University, Div. Of Solid Mechanics, Lund, Sweden
(2) TU Dortmund, Inst. Of Mechanics, Dortmund, Germany

Presentation given by Ms. Sara Thylander

The need for reliable modelling and related robust simulation techniques continue to increase as the industrial applications of electroactive polymers continue to grow. From a continuum mechanics point of view, modelling of coupled electro-elastostatics is relatively straight-forward. Numerical solution schemes based on the finite element method, where the scalar electric potential is added to the displacement field as an unknown at element integrations points, have proven successful . Our work, related to electromechanical modelling of EAP, is mainly focused on a subgroup of the electroactive polymers, the electrostrictive polymers. The work includes; (i) a phenomenolocical model with electrostriction including rubber-like, incompressible behaviour along with time-dependent, viscoelastic response to model the electro-viscoelastic behaviour of Polyurethane, (ii) an electromechanically coupled micro-sphere framework that enables the use of physics-based and micromechanical constitutive models, like the worm-like chain model, to be used and expended to the three-dimensional continuum setting directly, and (iii) an inverse-motion based form finding method for electroactive polymers that for a given load and desired deformed shape find the corresponding initial form of the body.

1.2.15 Bioinspired tunable lens made of dielectric elastomer artificial muscles

Federico Carpi (1) (2); Gabriele Frediani (1); Danilo De Rossi (1) (2);

(1) University Of Pisa, Interdepartmental Research Centre "E. Piaggio", Pisa, Italy
(2) Technology & Life Institute, Pisa, Italy

Presentation given by Dr. Federico Carpi

Lens systems with tunable focus are needed in several fields of application, such as consumer electronics, medical diagnostics and optical communications. To address this need, lenses made of smart materials able to respond to mechanical, magnetic, optical, thermal, chemical, electrical or electrochemical stimuli are intensively studied. Here, we report on an electrically tunable lens made of dielectric elastomer artificial muscles. The optical device is inspired to the architecture of the crystalline lens and ciliary muscle of the human eye. It consists of a fluid-filled elastomeric lens integrated with an annular elastomeric actuator working as an artificial muscle. Upon electrical activation, the artificial muscle deforms the lens, so that a relative variation of focal length comparable to that of the human lens can be achieved. The device combines optical performance with compact size, low weight, fast and silent operation, shock tolerance, no overheating, low power consumption, and possibility of implementation with inexpensive off-the-shelf elastomers. Results show that combing bioinspired design with the unique properties of dielectric elastomers as artificial muscle transducers has the potential to open new perspectives on tunable optics.

Session 1.3

(abstracts are listed in order of presentation)

1.3.1 Synthesis of dielectric and conductive materials for dielectric elastomer actuators

Dorina M. Opris (1);

(1) Empa, Functional Polymers Laboratory

Presentation given by Dr. Dorina Maria Opris

This presentation describes the use of silver nanoparticles (AgNPs) coated with a silica shell as high dielectric constant filler and of graphene composite in polydimethylsiloxane (PDMS) as conductive material. AgNPs were prepared and their electronic properties used to increase the dielectric constant of PDMS by blending. Prior to the dispersion into the polymeric matrix, the AgNPs require an initial silica coating via hydrolysis of tetraethoxysilane to prevent possible percolation leading to electric shortcuts. The dielectric constant of such particles as function of shell thickness will be presented. A conductive printable and stretchable composite based on graphene in PDMS was developed. It has a sheet resistance of 0.1 kOhm/sq and a low modulus of elasticity. Additionally, it is able to self-heal the actuator after a breakdown and thus increases significantly its lifetime and reliability. The actuator can suffer many breakdowns and is able to undergo self-healing repeatedly without loss of performance.

1.3.2 Smart fillers - intelligent plasticizers for superior silicone based DEA materials

Bjoern Kussmaul (1); Sebastian Risse (2); Guggi Kofod (2); Hartmut Krueger (1);

(1) Fraunhofer Institute For Applied Polymer Research, Potsdam, Germany
(2) University Of Potsdam, Faculty Of Science, Potsdam, Germany

Presentation given by Mr. Bjoern Kussmaul

The interest in dielectric elastomer actuators (DEAs) is growing since many applications for those materials were discovered, e.g. haptic devices, optical adjustment actuators, miniaturized pumps or energy harvesting devices. One of their main disadvantages is the high operation voltage, which lies in the range of several kilovolts. Attemps have been made to improve the actuators' performance by reducing the thickness, increasing the permittivity or soften the elastomer. To decrease the stiffness of the materials, plasticizers such as silicone oils are widely used, which widen the network and therefore decrease the network density. A disadvantage of those fillers is that the permittivity of the silicones remains unchanged. The authors present the concept of smart fillers, which consist of unreactive cross-linker molecules that bear silicone compatible groups as well as high polar groups, which lead to an increased permittivity. These materials act as plasticizers leading to reduced stiffnesses of the materials, comparable to normal silicone oils. The syngergetic effect of softening and permittivity increase leads to more than five times better actuation performances for materials with high filler contents.

1.3.3 Concentration and temperature dependencies of asymmetric bilayers conducting polymer actuator based

Masaki Fuchiwaki (1); Toribio Otero (2);

(1) Kyushu Institute Of Technology
(2) Universidad Politecnica De Cartagena

Presentation given by Dr. Masaki Fuchiwaki

A soft actuator based on a conducting polymer has the form of a thin film and so is small and light. In addition, soft actuator can be driven with high responsiveness, durability, and flexibility, which are useful characteristics in an actuator. In particular, polypyrrole-based conducting polymer soft actuators are constructed from high-quality film. Electrodeposition is a simple method by which to obtain high-quality soft actuator films based on polypyrrole, and the electrochemical activity of soft actuator films provides a wide pH region ranging from 3 to 10. The authors have proposed an asymmetric bilayers conducting polymer actuator with anion-driven and cation-driven layers based on polypyrrole. Moreover, the newly developed micro pump driven by the asymmetric bilayers conducting polymer soft actuator has been developed. A wider range of flow rates and greater maximum delivery heads were obtained and the energy consumption rate of the micro pump was dramatically lower than the energy consumption rates of the conventional micro pumps. The objective of the present study is to clarify the characteristics of the asymmetric bilayers conducting polymer actuator based on polypyrrole. Especially, we clarify the concentration dependence and the temperature dependence of the simple bending actuation of the asymmetric bilayers conducting polymer actuator which consisted of an anion-driven layer actuator, PPy.TFSI, and a cation-driven layer actuator, PPy.DBS.

1.3.4 Uptake of metal ions from aqueous solutions by conducting polymeres with electrical control

Ari Ivaska (1);

(1) Abo Akademi University

Presentation given by Dr. Ari Ivaska

Conducting polymers are semiconducting material that can be doped with cations or anions depending on the polymer material. Doping can be done either chemically or electrochemically. In doping process positive or negative charges will be created in the polymer backbone. In electrochemical doping the doping process can be controlled by adjusting the potential of the polymer to a desired level. The conducting polymer polypyrrole, PPy, was used as the active component of a cation exchange membrane for transferring a range of metal ions between two solutions by electrical modulation of the polymer between its conducting and non-conducting states. The cation exchange membranes consisted of platinum sputter-coated polyvinylidene difluoride (PVDF) which had been coated with polypyrrole doped with sulfonated calix[6]arene (PPy(C6S)). It was shown that applying a constant potential in the range -0.4 V to +0.6 V did not result in any metal ion flux across the PVDF/Pt-PPy(C6S) membrane. However, a gradual but steady increase in metal ion concentration was detected in the receiving cell when -0.8 V was applied to the membrane. The permeability of the metals across the membrane increased as the PPy(C6S) film thickness decreased and was found to decrease in the following order: Ca2+>K+>Mn2+>>Co2+, when the receiving cell contained deionised water. The PVDF/Pt-PPy(C6S) composite membrane showed significant permeability towards metal ions such as Ca2+, K+ and Mn2+, with the flux for Ca2+ higher than that s

1.3.5 Plasma treatment of polymer materials for adhesion improvement and electret charge stabilization

Mikhail Yablokov (1); Andrey Rychkov (2); Dmitry Rychkov (3);

(1) Institute Of Synthetic Polymer Materials, Russian Academy Of Sciences, Moscow, Russia
(2) Department Of Technical Science, Herzen State Pedagogical University Of Russia, St-Petersburg, Russia
(3) Applied Condensed-Matter Physics, Department Of Physics And Astronomy, Faculty Of Science, University Of Potsdam, Germany

Presentation given by Dr. Mikhail Yablokov

Dielectric elastomer actuators require reliable compliant electrodes. It is also necessary to enhance dielectric properties of elastomer material. This work presents the study of modification of polymer surfaces under the action of direct current glow discharge. It is shown that polymer materials exhibit significant adhesion improvement and increase of electret charge stability according to the parameters and the conditions of plasma treatment. Adhesion properties of polymer films as well as adhesion of aluminum layer deposited onto polymer films in vacuum were measured with the use of standard adhesive tape. Electret charge stabilization in polymer films after plasma treatment was established on the basis of thermally stimulated surface potential decay measurements. It was shown that plasma treatment in direct current glow discharge leads to formation of oxygen-containing polar groups on the polymer surface. These groups lead to adhesion enhancement and simultaneously to formation of deep surface traps for positive charge. Low-temperature relaxation process, responsible for the instability of electret charge in original films is suppressed after plasma treatment. Results showed that plasma treatment may represent a new promising route to obtain EAP materials with improved properties. It is especially important for the design of compliant electrodes for dielectric elastomer actuators.

1.3.6 Improvement of a formation method of patterned electrodes for IPMC by selective plasma treatment

Kunitomo Kikuchi (1); Tomohisa Taniguchi (2); Hirofumi Han (1); Shigeki Tsuchitani (1);

(1) Wakayama University, Faculty Of Systems Engineering, Wakayama, Japan
(2) Wakayama University, Graduate School Of Systems Engineering, Wakayama, Japan

Presentation given by Dr. Kunitomo Kikuchi

Ionic polymer-metal composite (IPMC) is one of the most attractive soft actuators because it exhibits large strain under low application voltages. It consists of a polyelectrolyte membrane and thin noble metal electrodes formed on the both surface of the membrane. In conventional IPMCs, commercialized membranes were mainly used. So, it is difficult to fabricated miniaturized IPMC freely, because it is generally cut into small pieces mechanically. By combining IPMC fabrication technologies with micro machining technologies, we can make miniaturized IPMCs together with MEMS devices. There are many technological subjects to fabricate it. Formation method of the electrodes is one of the most difficult problems. Conventionally, the most reliable method is a chemical plating method. In this report, we present a formation method of the patterned electrode of IPMC using selective plasma treatment of Nafion membrane, i.e., SF6 and O2 plasma irradiation onto Nafion membrane through a micro-stencil as a reusable mask. In this method, the electrode cannot be formed on the SF6 plasma-irradiated areas, and O2 plasma-irradiated areas were etched chemically. Therefore, during the plating, the electrode forming areas can be controlled by the plasma treatments. The proposed method has the potential to fabricate miniaturized IPMC actuators and MEMS devices when it is combined with micromachining techniques.

1.3.7 Conducting interpenetrating polymer network based microactuators

Ali Maziz (1) (2); Cedric Plesse (1); Alexandre Khaldi (1) (2); Caroline Soyer (2); Claude Chevrot (1); Dominique Teyssiè (1); Eric Cattan (2); Frederic Vidal (1);

Presentation given by Mr. Ali MAZIZ

The present work deals with the synthesis of a thin conducting Interpenetrating Polymer Network (C-IPN) actuators based on high molecular mass elastomer NBR (nitrile butadiene rubber) or PTHF (polytetrahydrofurane) for the mechanical resistance, poly(ethylene oxide) as solid polymer electrolyte, and poly(3,4-ethylenedioxythiophene) (PEDOT) as the electronically conductive polymer. The design of the C-IPNs greatly improves the actuator performances such as mechanical resistance, output force, and response speed. First, we report the decrease of IPN layer thickness by using two different methods: a spin coating one, where the thickness of the polymer films depends on the selected spinner speed, time and solution viscosity. The second method is based on IPN polymerization by hot pressing. Despite their thickness (1 to 7 micrometers), NBR (or PTHF)/PEO films are relatively robust and they can be manipulated many times without suffering from cracks. Secondly, PEDOT have been interpenetrated on both faces of the NBR (or PTHF)/PEO IPN by oxidative polymerization in order to get a tri-layer configuration. Very thin C-IPN films of 6 micrometers are obtained. Finally, ionic liquid incorporation and actuation measurements are performed. Displacements have been observed and measured until 70 Hz corresponding to the resonance frequency of the beam. The relevant field of this work is also to demonstrate that these materials can be integrated into micro structures. Patterning through standard photolithography

1.3.8 Large Volume Testbed for Ionic EAP-s

Andres Punning (1); Indrek Must (1); Veiko Vunder (1); Georgi Olentsenko (1); Lauri Mihkels (1); Alvo Aabloo (1);

(1) IMS Lab, Institute Of Technology, University Of Tartu, Estonia

Presentation given by Prof. Alvo Aabloo

In order to consider electromechanically active materials for real-life applications, especially for space technology, an extensive knowledge on how different environmental effects influence the reliability of electroactive polymer (EAP) actuators is required. We have designed, constructed, and implemented an intricate experimental setup for measuring electromechanical parameters of bending EAP actuators. This setup allows simultaneous experimentation of over 240 EAP actuators with the size of 5 Ã— 20 mm. The electrical and mechanical parameters used to characterize all the actuators include impedance, current, blocking-force, curvature, displacement, and frequency response. The central objective of these experiments is to obtain understanding about the reliability of different EAP actuators, such as several types of ionic polymer-metal composites (IPMC), carbon-polymer composites (CPC), and conducting polymer actuators. The performance and durability of the actuators is monitored after exposing each type of EAP to the environmental conditions stated above. The presentation gives an overview of current state of the on-going reliability experiments for EAP bending actuators.

1.3.9 Active catheter using a conductive polymer actuator driven in air

Shigeki Tsuchitani (1); Yuu Hanayama (2); Kunitomo Kikuchi (1); Hirofumi Han (1);

(1) Wakayama University, Faculty Of Systems Engineering, Wakayama, Japan
(2) Wakayama University, Graduate School Of Systems Engineering, Wakayama, Japan

Presentation given by Prof. Shigeki Tsuchitani

Active catheter is a catheter whose bending motion is controllable by actuators integrated with the catheter tube. It is highly desired in the medical field, since special skills are necessary to operate conventional catheters. We have developed an active catheter using a conductive polymer actuator driven in air. Polypyrrole (PPy) was used as an actuator. The active catheter consists of a silicone tube (outer diameter: 1.0mm, inner diameter: 0.5mm), four thin film electrodes of gold formed around the tube, four PPy films deposited on each gold electrode, and an electrolyte gel layer covering the PPy films. The PPy films extend along the axis of the tube with a gap of 0.15mm between the adjacent PPy films. PPy changes its volume by the insertion and the release of dopant ions in electrolyte solutions including them. When the PPy is anionic expansion type, by applying voltages between the two PPy films arranged on the opposite sides of the tube, the PPy film at higher potential expands and that at lower potential shrinks. As a result, the catheter bends toward the lower potential side. The active catheter were fabricated as follows: (1) formation of a thin film of gold on a silicone tube by an electroless plating, (2) deposition of a PPy film on the gold film by the electropolymerization in a solution including pyrrole and tetra-n-butylammonium bis(trifluoromethanesulfonyl)imide (TBA-TFSI), (3) division of the PPy/gold film into four parts along the axis of the tube by excimer laser processing, a

1.3.10 Electroactive composites based on polydimethylsiloxane and some new metal complexes

Maria Cazacu (1); Carmen Racles (1); Mirela Zaltariov (1); Ana-Maria-Corina Dumitriu (1); Mircea Ignat (2); George Stiubianu (1);

(1) "Petru Poni" Institute Of Macromolecular Chemistry, Iasi, Romania

(2) National Institute For Research And Development In Electrical Engineering ICPE-CA, Bucharest, Romania

Presentation given by Dr. Maria Cazacu

Metal complexed by siloxane ligands of Schiff bases and carboxyl acids type were used as ligands for different 2d metals. Either molecular or polymeric well-determined complex structures were obtained, which were incorporated into a polymeric matrix based on a polydimethylsiloxane of low molecular weight. After the complex incorporation, the matrix crosslinking was performed with tetraethyl orthosilicate, resulting in free standing films. The presence of the siloxane moiety in the ligand by its surface effect improves the compatibility between the metal complex and the silicone matrix that ensures good mechanical properties. Thus, modulus values between 0.05-0.20 MPa and elongations of 200-400% were obtained. Depending on the metal type and the complexation pattern, an increasing of the dielectric constant value until 4.5 as compared with 2.5 value for the matrix was obtained. This is reflected in the electromechanical properties that were investigated.

1.3.11 Robust method based on grafting strong dipoles for enhancement of silicone elastomers

Sebastian Risse (1); BjÃrn Kussmaul (2); Hartmut KrÃ¼ger (2); Guggi Kofod (1);

(1) University Of Potsdam, Institute Of Physics And Astronomy, Potsdam, Germany
(2) Fraunhofer Institute For Applied Polymer Research, Potsdam, Germany

Presentation given by Mr. Sebastian Risse

The current poster comprises the fabrication of elastic, homogeneous composite films for dielectric elastomer actuator (DEA) applications with off-the-shelf silicones. Strong push-pull dipoles were grafted to the polymer backbone in a Pt-catalyzed one step film formation process. The functionalization of the dipole allows a homogeneous distribution in the polymer network. The studied films were manufactured with Elastosil RT 625 and Sylgard 184 by Wacker and Dow Corning, respectively, and were chemically and physically characterized. DSC, 13C-NMR and FT-IR spectroscopy confirm the homogeneous distribution and the successful attachment of the dipoles to the silicone matrix. The permittivity

increases with the amount of dipole for all frequencies, while Young's modulus and electrical breakdown strength are reduced. Actuation strain measurements in the pure shear configuration confirm the increase in electromechanical sensitivity indicated by the detailed material characterization. The application of this robust approach to off-the-shelf silicones benefits from the technological development invested in such systems, regarding durability, weathering, network reinforcements, rheological properties, etc.

1.3.12 Effects of shape, size and electrode constraints on the performance of dielectric elastomer loudspeakers

Benny Lassen (1); Morten Willatzen (1);

(1) The University Of Southern Denmark, Sonderborg, Denmark

Presentation given by Dr. Benny Lassen

In this work the application of a dielectric elastomer sheet as a membrane in a loudspeaker setup is theoretically investigated. The first investigation of the loudspeaker performance was performed at SRI International more than 10 years ago. More recently Zhu et al. did a theoretical investigation of a circular membrane, showing good agreement between theory and experiments. We extend this investigation to take into account more complicated geometries and constraints due to electrodes chosen. First a short description of the two dimensional model is given with emphasis on the assumptions made. The model is defined based on a free-energy description and include hyper-elastic contributions. The membrane is subject to an applied back pressure, giving the membrane a certain pre-strain, around which the membrane is actuated by the application of an applied ac voltage. In order to be able to perform relatively fast calculations of the mechanical impedance of the structure, the nonlinear equations are linearized around the given pre-strained configuration. Based on the model, the impact of changing the geometry and size of the structure is investigated. Furthermore, it is shown that the performance of the loudspeaker is enhanced by increasing the applied pressure. Finally, two types of compliant electrodes are considered, these being, fully compliant electrodes and electrodes which are only compliant in one direction.

1.3.13 Functionalized carbon nanotubes loaded polyurethane dielectric elastomer for transduction

Fabia Galantini (1); Giuseppe Gallone (1) (2);

(1) University Of Pisa, Interdepartmental Research Centre "E. Piaggio", Pisa, Italy
(2) University Of Pisa, Dept. Of Chemistry, Industrial Chemistry And Material Science, Pisa, Italy

Presentation given by Dr. Fabia Galantini

Dielectric elastomers, thanks to their particular dielectric and mechanical properties, have recently been the focus of several works regarding electromechanical transduction. Silicones, polyurethanes and acrylic elastomers are, in fact, the main representatives of electronic polymers for transduction among the broad class of electro-active polymers. In order to be employed as matrices for actuation, however, they have to show high dielectric constant, low elastic modulus and, possibly, restrained dielectric and mechanical losses, so to maintain high dielectric strengths and allow large deformations. In this work, for the first time, a study on the effect of the loading of an elastomeric polyurethane with covalent functionalized carbon nanotubes, is presented. Composites, obtained by casting of a solution of matrix and filler in chloroform, have been dielectrically, mechanically and electromechanically characterized and the parameters obtained have been compared with those showed by the same compositions containing pristine carbon nanotubes as filler. Strains values, showed by some of the prepared systems, allow to affirm that an increase in the electromechanical performance is possible by using such a type of filler and open the way for future investigations.

1.3.14 Dielectric Elastomer Actuators for Microfluidics

Luc Maffli (1); Samuel Rosset (1); Herbert R. Shea (1);

(1) EPFL, Microsystems For Space Technologies Laboratory (LMTS), Neuchatel, Switzerland

Presentation given by Mr. Luc Maffli

One of the goals of microfluidics is to bring a whole laboratory processing chain on a few square centimeters, Lab-On-Chips (LOC). But current LOCs require many heavy and power-consuming off-chip controls like pneumatics, pumps and valves, which keep the small chip bound to the lab. Miniaturized Dielectric

Elastomer Actuators (DEA) are excellent candidates to make LOC truly portable, since they combine electrical actuation, large stroke volumes and high output forces. We report on the use of zipping actuation applied to DEAs for an array of 3 mm-size chambers, forming a peristaltic pump. Unlike the traditional actuation mechanism of DEAs that squeezes an elastomer between 2 compliant electrodes, zipping DEAs use electrostatic attraction between a compliant electrode and a rigid one (the sloped chamber walls). A zipping analytical model was developed to predict the actuator's behavior and help for the design (chamber dimensions, silicone type and thickness.). Three chambers connected by an embedded channel were wet-etched into a silicon wafer and subsequently covered by a gold-implanted silicone membrane. Static deflections up to 300 micrometers were measured on chambers with square openings from 1.8 to 2.6 mm on a side in very good agreement with the model, but breakdown occurs before predicted. The design parameters are varied to assess the model and determine the most relevant factors to achieve a fully zipped depth of 525 micrometers.

1.3.15 Concept of an add-on tactile display for smart phones as a helping device for blind users

Marco Ramacciotti (1); Gabriele Frediani (1); Marc Matysek (2); Barbara Leporini (4); Claudia Buzzi (4); Federico Carpi (1) (3); Danilo De Rossi (1),(3);

(1) University of Pisa, Interdepartmental Research Centre `E. Piaggio`, School of Engineering, Pisa, Italy
(2) Philips Research, Eindhoven, The Netherlands
(3) Technology & Life Institute, Pisa, Italy
(4) CNR (IIT - ISTI), Pisa, Italy

The aim of this work is to develop a system able to assist blind users during navigation over the touch-screen of smart phones. This kind of user interface is widely used in the field of communication devices and poses significant problems for the blinds, owing to the lack of tactile references. Our idea is to create a plastic frame (case) for a smart phone, integrating a number of ‘active’ dots that can be dynamically raised or lowered, so as to serve as variable tactile references controlled by the application currently run by the smart phone. Such a sort of ‘mapping’ via an external hardware to be used with and controlled by the phone provides new tactile functionality for the blinds, without any (industrially unrealistic) modification of the phone itself. So, the proposed system is a sort of hardware add-on for the smart phone. To reduce encumbrance and costs, we are developing such a system using dielectric elastomer actuators (DEAs). In particular, the tactile dots are being developed as inherently active elements, consisting of hydrostatically coupled DEAs. They are based on an incompressible fluid that mechanically couples a DE-based active membrane to a passive membrane interfaced to the user's finger. This presentation describes the current developmental stage with reference to selected navigation contexts: operative system home page, Gmail home page, email-writing, phone key pad.

Wednesday, 30 May 2012

General programme of the day

Session 2.1 (Chairs: Reimund Gerhard, Eiichi Fukada)

9:10 – 9:40	Plenary talk: Gerhard Sessler (Darmstadt University, Germany)
9:40 – 10:00	Invited talk: Eiichi Fukada (Kobayasi Institute of Phys. Res., Japan)
10:00 – 10:20	*Coffee break*
10:20 – 10:40	Invited talk: Yoshiro Tajitsu (Kansai University, Japan)
10:40 – 11:10	Invited talk: Jadranka Travas-Sejdic (Auckland Univ., New Zealand)

Session 2.2 (Chairs: Gerhard Sessler, Yoshiro Tajitsu, Frédéric Vidal)

11:10 – 12:10	EAPills: 15 short oral presentations (3 minutes each + 1 minute to change speaker)
12:10 – 13:40	*Lunch*
13:40 – 15:10	EAPosters, EAPrototypes, EAProducts (Exhibitions &15 Posters)

Session 2.3 (Chairs: Jadranka Travas-Sejdic, Ingrid Graz, Herbert Shea)

15:10 – 16:10	EAPills: 15 short oral presentations (3 minutes each + 1 minute to change speaker)
16:10 – 16:30	*Coffee break*
16:30 – 17:30	EAPosters, EAPrototypes, EAProducts (Exhibitions &15 Posters)

Social event

19:00	*Dinner*

Session 2.1
(abstracts are listed in order of presentation)

2.1.1 Piezoelectrets and their applications

Gerhard Sessler (1);

(1) Technische Universitat Darmstadt, Communications Engineering, Darmstadt, Germany

Presentation given by Prof. Gerhard Sessler

Since their first description in the late 1990's, piezoelectric materials based on permanently charged cellular polymers, also referred to as piezo- or ferroelectrets, have been studied in several laboratories around the world and have experienced a significant development. Of particular importance is the growing understanding of the physical properties of these materials, their improved performance, and the realization of a number of experimental and commercial applications. Examples of the better understanding pertain to models for the piezoelectric activity, to a description of the dielectric properties, and to the explanation of the frequency, pressure, and temperature dependences of the piezoelectric coefficient. The performance was improved by considerably increasing the piezoelectric d33-coefficient by methods such as pressure expansion and DC-biasing and by enhancing the thermal stability of the piezoelectric activity by use of materials more suitable than the original polypropylene and by employing layered structures. As far as applications are concerned, some electro-mechanical gadgets have already been commercialized while devices such as microphones, headphones, tweeters, ultrasonic transducers, and accelerometers are under study. These tools are of interest since they exhibit advantages compared to their conventional counterparts. In this paper, the development of cellular piezoelectrets and their applications are discussed and future perspectives are considered.

2.1.2 From shear piezoelectricity to ferroelectricity in polymers

Eiichi Fukada (1);

(1) Kobayasi Institute Of Physical Research, Tokyo, Japan

Presentation given by Dr. Eiichi Fukada

The early studies of shear piezoelectricity were initiated on wood cellulose and bone collagen. Later synthetic polypeptides and optically active polymers were found to show the larger shear piezoelectric constant, d14 = - (0.1 - 5) pC/N. The uniaxial orientation of crystallites and the polarity of chiral molecules are required for shear piezoelectricity. Pyroelecticity was also found in bone and tendon. It suggests that the polar axes of collagen crystallites orient in the same direction. Shear piezoelectricity is originated from the field induced internal rotation of dipoles such as CONH in molecules. Drawn films of poly-L-lactic acid exhibit the highest shear piezoelectric constant d14 = - 20 pC/N. Poled drawn films of polyvinylidene fluoride exhibit tensile piezoelectricity. The large piezoelectric constants d31 = 20 pC/N, d33 = - 30 pC/N developed broad applications in acoustics and ultrasound. The observation of dielectric hysteresis and Curie transition temperature established ferroelectricity in polymer. Electret films of porous polypropylene exhibit very high tensile piezoelectricity, d33 = (200 - 400) pC/N. It is called as ferroelectret because the sign reversal of trapped charges on the walls of pores takes place during discharge. Recently Li et al. discovered ferroelectric hysteresis in aorta walls by using Piezoresponse Force Microscopy. It suggests the possibility of electric control of dipoles CONH in collagen molecules.

2.1.3 Development of sensor device using piezoelectric chiral polymer high-transparency film and fiber

Yoshiro Tajitsu (1);

(1) Kansai University,Electrical Engineering Department, Osaka, Japan

Presentation given by Prof. Yoshiro Tajitsu

The research and development of a new piezoelectric polymer sensor using a chiral polymer film with high transparency have been energetically pursued. Recently, through joint research with Kansai University and Mitsui Chemicals Inc., Murata Manufacturing Co., Ltd., introduced new human-machine interface devices that apply the piezoelectric chiral polymer film, such as a "Leaf Grip Remote Controller", which can control a TV using bending and twisting motion, and a "Touch Pressure Pad", which is a touch panel with pressure detection. The chiral polymer film used for sensing is a modified film of poly-(l-lactic acid) (PLLA), which is a chiral polymer with shear piezoelectricity. The PLLA film has the following physical characteristics: (1) a high shear piezoelectric output constant, (2) high transparency (light beam transmittance of over 98%), and (3) freedom from the pyroelectric effect. We emphasize here that the PLLA film can separately detect both twisting and bending motion by using its shear piezoelectricity. Since the PLLA film is not subject to the pyroelectric effect, simply touching it with a human finger does not generate voltage. As a result, the PLLA film is capable of high-precision detection compared with conventional piezoelectric ceramics exhibiting the pyroelectric effect. This promising field of human-machine interface research using piezoelectric chiral polymers has just begun, and future studies are anticipated.

2.1.4 Fabrication and characterization of conducting polymers using scanning pipette techniques

Cosmin Laslau (1) (2); David E Williams (1) (2); Karthik Kannappan (1) (2); Jadranka Travas-Sejdic (1) (2);

(1) Polymer Electronics Research Centre, School Of Chemical Sciences, University Of Auckland
(2) MacDiarmid Institute For Advanced Materials And Nanotechnology, New Zealand

Presentation given by Prof. Jadranka Travas-Sejdic

The limited toolbox for conducting polymer (CP) microscale fabrication and characterization hampers the development of applications such as sensors and actuators. To address this issue, we developed a robust and integrated methodology capable of electrochemical fabrication and characterization of CPs in a highly localized manner, allowing for CP patterning and spatial mapping of voltammetric response. This is enabled by scanning probe microscopy (SPM) tipped with a single-barreled micropipette to electrochemically polymerize CP microspot arrays. Stationary electropolymerization produces individual microspots; lateral movement produces long microribbons; retraction produces extruded microstructures. Subsequently the same SPM setup is tipped with a double-barreled micropipette to carry out localized cyclic voltammetry. Similar experimental setup we demonstrated to be suitable for the measurements of the ion fluxes associated with CPs. This is for the benefit of applications such as artificial muscles which require a better understanding of the ion flux that underpins the actuation of CPs. These results are correlated with in-situ AFM measurements and supported with modeling studies of simultaneous ion flux and topography measurements. Overall, these developments represent key steps towards the localized fabrication and characterization of small-scale conducting polymer structures.

Session 2.2

(abstracts are listed in order of presentation)

2.2.1 Measuring contact resistance in electrical interconnections of dielectric elastomer stack

Holger Moessinger (1); Henry Haus (1); Helmut F. Schlaak (1);

(1) Technische Universitaet Darmstadt, Institute Of Electromechanical Design, Darmstadt, Germany

Presentation given by Mr. Holger Moessinger

Electrically interconnecting the single buried electrode layers is still one major issue in improving dielectric elastomer stack transducers (DEST). The interconnection needs to provide a good and mechanically stable electrical connection between the layers of graphite electrode of the DEST and an external metal wire. By now the interconnection is the main cause for failure of DEST. To improve the interconnections first it is necessary to be able to characterize their performance. In a second step one can compare different interconnection methods to find the best solution. So far performance of DEST and therefore performance of the electrical interconnections is tested in our life time test setup. From life time testing a correlation between contact resistance of the interconnection and overall DEST performance can be seen. Therefore it makes sense to measure the contact resistance of the interconnections directly to compare different interconnection techniques. However reliable measurement of contact resistance in DEST is not easily achieved. There are different sources for inaccuracies in the electrical parameters of the DEST, e.g. the resistance of the electrode may vary from layer to layer and even over the surface of a single layer. All these inaccuracies result in potentially large measurement errors. To minimize the inaccuracies we derived a test setup to determine as many electrical parameters of the electrodes and interconnection as possible. This data allows us to determine the contact res

2.2.2 Dielectric elastomer actuators from natural rubber

Giao T.M. Nguyen (1); Cedric Plesse (1); Frederic Vidal (1); Gabriele Frediani

(3); Federico Carpi (2) (3);

(1) University Of Cergy-Pontoise, Department Of Chemistry, Neuville Sur Oise, France
(2) University Of Pisa, Interdepartmental Research Centre 'E. Piaggio', Pisa, Italy
(3) Technology & Life Institute, Pisa, Italy

Presentation given by Dr. Frederic Vidal

Dielectric elastomer actuators (DEAs) have been invented by electrifying natural rubber (NR) at high voltages, hundreds years ago. A DEA consists of a thin elastomeric film, sandwiched between two compliant electrodes. The actuation is obtained by applying a high voltage (hundreds to thousands of V) to the system. Under electric field action, an electrostatic stress is applied onto the elastomeric film leading to an expansion of the material. To increase the electromechanical performance, the material must have a high dielectric permittivity. However, due to its low dielectric permittivity, natural rubber usage as DEA matrix cannot be exploited to obtain high performing actuator. Nowadays, elastomeric materials used in DEAs are essentially an acrylic film (3M VHB tape) or silicone polymers (e.g. PDMS) due to their commercial availability and their simple manipulation. To obtain for higher performance, it is necessary to tailor material properties by synthetic approaches. The University of Cergy Pontoise in collaboration with the University of Pisa has just started the investigation of DEAs based on synthetic polymer/NR Interpenetrating Polymer Network and natural rubber filled with charge (ionic salt : iron (III) p-tosylate or conducting polymer : PEDOT). Preliminary interesting results were obtained with crosslinked natural rubber filled with iron (III) -p-tosylate.

2.2.3 Dynamic non-linear energy absorbers based on dielectric elastomers

Fotios Papaspyridis (1); Dimitrios Venetsanos (1); Ioannis Antoniadis (1);

(1) National Technical University Of Athens, School Of Mechanical Engineering, Laboratory Of Dynamics And Structures , Athens, Greece

Presentation given by Prof. Ioannis Antoniadis

The amount of energy that can be harvested using a Dielectric Elastomer (DE) harvester depends on the maximum deformation of the (DE) material. For a dynamic absorber, maximum deformation is achieved for frequencies near resonance. Therefore, it is of interest to examine the performance of a (DE) harvester considered as a dynamic absorber operating near its resonance frequency. Towards this direction, the present work investigates, from a theoretical perspective, the behavior of a single degree of freedom m-c-k harvesting system considered as a Non-Linear Dynamic Absorber (NLDA) operating in a wide bandwidth near resonance. It was assumed that the spring k of the (NLDA) was made of a (DE) material obeying a given non-linear material law, thus introducing a tunable non-linear stiffness to the system. It was also assumed that the energy dissipated on the damper c equals the harvested energy. The constraint that the spring at no time is in compression was also imposed. A parametric investigation was carried out, concerning various parameters of the system, resulting in plots of the normalized amplitude of the system response and the normalized energy dissipated on the damper versus the normalized excitation frequency. The main conclusion drawn from these plots is that, when compared to a dynamic linear absorber, a (DE) harvester having the characteristics of a (NLDA) is superior in terms of energy harvesting in a wide bandwidth near resonance.

2.2.4 Progress in Bucky Gel Actuators: Carbon Nanotubes/Polypyrrole Bucky Gel Hybrid

Maurizio Biso (1); Alberto Ansaldo (1); Davide Ricci (1);

(1) Istituto Italiano Di Tecnologia, Robotics, Brain And Cognitive Sciences Department, Genoa, Italy

Presentation given by Dr. Davide Ricci

Bucky gel actuators are attractive because they can operate at low voltage in air with promising frequency and strain performance which can be significantly improved by a combination of physical and chemical modifications. By introducing the in-situ combination of carbon nanotubes (CNTs) with polypyrrole (PPy), a well-known active polymer, it is possible take advantage of the peculiar properties of the two active materials in terms of maximum strain and conductivity. PPy was synthesized on the surface of the jellified CNTs by using AuCl3 as oxidant in an ionic liquid medium. The resulting devices benefit from the combination of the actuating characteristics of both CNTs and conducting polymer and, when compared with similar ones made using CNT based bucky gel, the maximum strain is increased of 400%. Looking at the strain obtained for a given charge an improvement up to twenty five times can be observed. The energy that is necessary to store in the device to obtain the same strain decreases greatly ranging from a little bit less than two orders of magnitude up to more than five orders of magnitude. These results demonstrate that a viable approach to the creation of higher performance materials for soft actuation may well reside in a carefully thought combination of materials following their individual areas of superiority.

2.2.5 Energy harvesting with dielectric elastomer generators

Richard Baumgartner (1); Rainer Kaltseis (1); Reinhard SchwÃdiauer (1); Soo Jin Adrian Koh (2) (3); Christoph Keplinger (1) (2); Choon Chiang Foo (2); Zhigang Suo (2);

(1) Johannes Kepler University, Soft Matter Physics, Linz, Austria
(2) School Of Engineering And Applied Sciences, Harvard University, Cambridge, USA
(3) Engineering Science Program And Department Of Civil And Environmental Engineering,
National University Of Singapore, Singapore

Presentation given by Prof. Siegfried Bauer

Dielectric elastomer generators are deformable capacitors, assembled by coating an elastomer membrane with compliant electrodes. They are capable of converting mechanical into electrical energy with attributes such as high energy density, low cost and light weight. Applications in small scale energy harvesting will enable the charging of mobile electronic devices from the excess energy available while walking, whereas large scale energy harvesting applications will provide clean energy from renewable sources such as wind or ocean waves. One of the most essential and urgent challenges for research on dielectric elastomer generators is to identify or design materials with ideally suited properties. Therefore we perform experiments with an experimental setup that allows for assessing the aptitude of different materials for energy harvesting. We depict the cyclic path of the generator state in electrical and mechanical work-conjugate planes to enable a visual assessment of material performance and calculate the specific electrical energy generated per cycle, the mechanical to electrical energy conversion efficiency and the specific average power of the generator. This procedure is used to compare the generator performance of the commonly used acrylic elastomer (3MT VHBT 4910) with cheap and sustainable natural rubber. Based on a theoretical and experimental analysis of the region of allowable generator states in mechanical and electrical work-conjugate planes, we operate a generator utilizing a com

2.2.6 A soft robotic actuator using dielectric minimum energy structures

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(2) Microsystems For Space Technologies Laboratory, EPFL, Neuchatel, Switzerland

Presentation given by Mr. Jun Shintake

Soft robotics is an exciting field of robotics that shows many advantages compared to traditional approaches using rigid materials, such as safe human-robot interaction, bio-inspired mechanisms for efficient locomotion, adaptive morphology and re-configuration of robot body. The objective of this study is to develop an artificial-muscle-based actuator for soft robotics using dielectric elastomer minimum energy structures (DEMES). DEMES are capable of large actuation stroke, and consist of a pre-stretched dielectric elastomer actuator (DEA) laminated onto a flexible frame, which makes it easy to obtain both simple and complex shapes. We report here on the fabrication and characterization of a prototype capable of one-dimensional bending actuation. The device has silicone based adhesive foil as frame material (~100 mu thickness with dimension 20 mm X 40 mm). For the DEA, several combinations of ion-implanted PDMS membranes and uniaxial pre-stretch ratio were used. The actuator was characterized by measuring the deformation and output force vs. applied voltage. The results showed that the prototype is able to exhibit bending actuation in the range of around 60 deg. Additionally the initial deformation depends on fabrication parameters such as thickness of the materials, pre-stretch ratio as well as dose of implanted ions. A DEMES-based demonstrator has been built in the form of a robot hand that has two flexible arms, able to manipulate an object by grasping motion.

2.2.7 Experimental investigation and numerical modelling of VHB 4910 polymer

Mokarram Hossain (1); Duc Khoi Vu (1); Paul Steinmann (1);

(1) Chair Of Applied Mechanics, University Of Erlangen-Nuremberg, Germany

Presentation given by Dr. Mokarram Hossain

In the last couple of decades, one important class of materials that exhibit electro-mechanical couplings is the so-called electronic electro-active polymers (EEAPs) which have potential applications, e.g. as dielectric elastomers (DE) in artificial muscles. EEAPs in actuators are utilized as a thin film that is sandwiched between two electrodes and then exposed to a potential difference which creates Maxwell forces between the electrodes. VHB 4910 is an important polymeric material widely used in EEAP actuators. The mechanical behaviour of such acrylic elastomer is typically viscoelastic that is characterized by few standard large strain experiments. The experimental data obtained in such mechanical tests are prerequisite for identifying constitutive model parameters as well as validation and simulation procedures for electromechanical coupling appearing in EEAP actuator simulation. A complete mechanical characterization of this important viscoelastic material by various standard experimental tests at different strain rates and at various extent of deformations is inadequate in the literature. In order to model the material for electro-mechanical coupled behaviour, a full-scale mechanical characterization is essential to obtain representative mechanical parameter sets that can be used in the case of electro-mechanical coupled modelling. In this contribution, the micromechanically-inspired chain models are applied to model the viscoelastic behaviours of VHB 4910.

2.2.8 Influence of solvents on the mechanical properties of dielectric elastomer actuators

Klaus Flittner (1); Michael Schlosser (1); Helmut F. Schlaak (1);

(1) Technische Universitat Darmstadt, Institute Of Electromechanical Design, Darmstadt, Germany

Presentation given by Mr. Klaus Flittner

To integrate dielectric elastomer actuators (DEA) into microsystems different processes are used during fabrication of the complete system compared to the fabrication of stand-alone DEA. These include processes like e.g. electroplating, chemical wet etching of metals and removal of photoresists using solvents. Therefore it is important to know how these processes and the corresponding materials influence the mechanical properties of the DEA. During the fabrication of a DEA based valve we noticed a shrinkage of the elastomer during a process to remove a sacrificial photoresist layer using acetone. Due to this effect and the DEA being partially bonded to the substrate results in a kind of buckling deformation. This inhibits the desired use case of the actuator. Therefore we investigated the influence of different solvents on the mechanical properties of the polydimethylsiloxane (PDMS) used as dielectric material. In table 1 the change in thickness, weight and Young's modulus after exposing the dielectric material for two hours to different solvents are shown. As it can be seen, using acetone or isopropanol the mechanical properties change drastically. The Young's modulus increases by 20%, the thickness decreases by 5% and the weight decreases by 4.6% and 14.2% respectively. In comparison dimethyl sulfoxide (DMSO) only increases the Young's modulus by 2% and decreases the thickness and weight by only 0.5% resulting in less deformation of the actuator.

2.2.9 Biologically inspired nano-engine

Vaclav Bouda (1);

(1) Czech Technical University In Prague, Department Of Electrotechnology, Prague, Czech Republic

Presentation given by Prof. Vaclav Bouda

A major revolution in life on earth took place in the Siluvian period, from 425 million to 405 million years ago. This time period marks the appearance of jawed fish. A new principle of skeletal muscle contraction was evolved and applied by predatory animals plundering or exploiting others. Today, a major revolution in the development of electromechanical transducers based on ionic electro-active polymers may have the same kind of effect, since it follows from a new interpretation of the function of mammalian skeletal striated muscle. The interpretation is based on the alternating functions of repulsion (electrostatic) and attraction (van der Waals) directed by the reversible counter-ion insertion and expulsion that occurs during action potential cycling. Nanotechnology enables engineers to apply the same kind of interactions at the nanoscale, and to construct new engines with a highly optimized function at a level comparable to that of mammalian skeletal striated muscles evolved in the course of hundreds of millions of years. The principle has been patented in the USA and in the Russian Federation. A patent is pending in the EU and in Japan.

2.2.10 Electrostatically controlled band-gaps in fiber-reinforced dielectric elastomers

Gal Shmuel (1);

(1) Ben-Gurion University, Department Of Mechanical Engineering, Beer-Sheva, Israel.

Presentation given by Dr. Gal Shmuel

The fascinating band-gaps phenomenon corresponds to ranges of frequencies at which waves cannot propagate in periodic structures. Traditionally investigated in elastic or piezoelectric media, the new family of soft smart materials termed dielectric elastomers (DEs) offers an unexplored potential for a study of its band structure. The motivation for using DEs as the composite constituents stems from their ability to sustain large strains and change their properties in response to an electric stimulation. Toward this end, static large deformations of ?ber-reinforced composites are determined when subjected to electromechanical loadings. Particular modes of small electroelastic waves propagating on top of the deformed con?gurations are determined next. The resultant band structures of exemplary composites are evaluated for representative values of the bias ?elds and phases properties. The analysis reveals how the stop-bands can be shifted and their width can be modi?ed by properly adjusting the electrostatic excitation and pre-stretched. These results usher DE composites to be used as mechanisms for the control and manipulation of electric and elastic waves.

2.2.11 Power electronics and current-mode control for feeding dielectric elastomer transducers

Lars Eitzen (1); Juergen Maas (1);

(1) Ostwestfalen-Lippe University Of Applied Sciences, Control Engineering And Mechatronic Systems, Lemgo, Germany

Presentation given by Mr. Lars Eitzen

The operation of Dielectric Elastomer Transducers typically requires high voltages in the kilovolt range and relatively low currents. Therefore, for feeding Dielectric Elastomer Transducers a high voltage power electronics is necessary. The operation of Dielectric Elastomer Transducers poses special requirements to the design and selection of a suitable high voltage power electronics. 1. The switched-mode converter topology must provide a bidirectional energy flow enabling generator as well as energy efficient actuator applications. In case of actuator applications electrical energy stored in the capacitance of the device can be fed back to the DC link circuit and therefore be reused, which reduces heat generation and increases actuator efficiency. 2. To realize both actuator and generator applications the output voltage of the converter must be controlled from nearly zero to a maximum output voltage in the kilovolt range. 3. Since high voltage semiconductors with blocking voltages of more than 1500V exhibit very poor electrical characteristics, it is essential to use standard semiconductors with lower blocking voltages in order to achieve acceptable efficiency levels. 4. Although Dielectric Elastomer Transducers typically require high operational voltages, their electrodes are sensitive to over-currents. Consequently, the electrode current must be limited to prevent electrode damage. 5. As a Dielectric Elastomer Transducer represents a mainly capacitive load the utilized con

2.2.12 Effect of anisotropy in the design of soft dielectric composites

Massimiliano Gei (1); Roberta Springhetti (1);

(1) University Of Trento

Presentation given by Prof. Massimiliano Gei

Dielectric elastomers are an important class of materials currently employed to design and realize electrically-driven, highly-deformable actuators and generators which find application in several fields of engineering. The use of composites may improve the performance of such systems as a thorough design may lead to a substantial increase of the dielectric constant of the material and then of the coupling between electrical input and mechanical response. However, the mechanics of electroelastic soft dielectric composites is still under development and a number of problems are still open in this field. In the talk, results related to the following issues will be presented and discussed: i) the effect of the microstructure on the overall behaviour of layered composite actuators; ii) the difference between charge-controlled and voltage-controlled type of actuation in anisotropic electroelastic material; iii) the role of instabilities in limiting large-strain performance in soft layered composites; iv) how to exploit instabilities to conceive unusual operation principles.

2.2.13 Hydrostatically coupled dielectric elastomers actuators with shapes other than circular

Gabriele Frediani (1); Marc Matysek (2); Federico Carpi (1) (3); Danilo De Rossi (1) (3);

(1) University Of Pisa, Interdepartmental Research Centre "E. Piaggio", Pisa, Italy
(2) Philips Research, Eindhoven, The Netherlands
(3) Technology & Life Institute, Pisa, Italy

Presentation given by Dr. Gabriele Frediani

In previous work we have proposed so-called hydrostatically coupled dielectric elastomer actuators (HC-DEAs) as a promising technology for haptic displays and tactile feedback devices. A bubble-like HC-DEA consists of two circular membranes, one of which is electroactive. The two membranes are mechanically coupled via a fluid. As a result of applying a voltage, the active membrane buckles outwards while the passive membrane follows inwards. This principle avoids any direct contact between the active membrane and the user's finger, allowing for safe transmission of actuation. To date, bubble-like HC-DEAs have been presented with circular shape only. However, different shapes might be useful, in order to cope with functional or aesthetic requirements of particular applications; also, different shapes might provide different kinds of stimuli. Here, we present new HC-DEAs with three geometrical shapes: square, eight-points star, and ellipse.

2.2.14 Dielectric Elastomer Actuators based on CaCu3Ti4O12/Polydimethylsiloxane composites

Laura J. Romasanta (1); Pilar Leret (2); Marianella HernÃ¡ndez (1); Miguel Angel de la Rubia (2); JosÃ© Francisco FernÃ¡ndez (2); Miguel Angel LÃ³pez-Manchado (1); Raquel Verdejo (1);

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(2) Instituto De CerÃ¡mica Y Vidrio, ICV-CSIC, Electroceramic Dep., Madrid, Spain

Presentation given by Ms. Laura J Romasanta

Soft dielectric elastomer actuators (DEAs) are a fast growing scientific field of research due to their active deformation potential. However, their drawback is the huge voltages required to stimulate the mechanical actuation. Ferroelectric ceramics have been used as high dielectric constant fillers to reduce the high driving voltages. Nevertheless, these materials are characterized by a permanent dipole moment which results in a strong mechanical resonance in devices during charging and discharging decreasing the reliability in DEA applications. CaCu3Ti4O12 (CCTO) possesses a cubic distorted perovskite-like structure, a giant dielectric constant frequency independent at room temperature and properties very different from those of ferroelectric materials, which makes it an ideal candidate to improve DEA performances. In the current work, the potential of CCTO micro-sized particles as high dielectric constant filler in a polydimethylsiloxane (PDMS) matrix has been examined. The dielectric, mechanical and electro-mechanical behaviour of samples with three CCTO loading fractions (10, 20 and 30 wt.%) were thoroughly characterized. The inclusion of CCTO particles enabled an increase of the relative permittivity as a function of the filler content without significantly modifying the tensile strength values at different strains levels, thus resulting in the actuation performance being improved by a factor of 2 compared to the raw elastomeric matrix.

2.2.15 Finger-tip tactile display based on hydrostatically coupled dielectric elastomer actuators for virtual reality systems

Federico Carpi (1) (2); Gabriele Frediani (1); Danilo De Rossi (1) (2);

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(2) Technology & Life Institute, Pisa, Italy

Presentation given by Dr. Federico Carpi

Diverse virtual reality systems require new wearable devices to provide users with vibro-tactile feedback. Here, we present a wearable tactile display, compact and comfortable for the user, based on a hydrostatically coupled dielectric elastomer actuator (HC-DEAs). The actuator uses an incompressible fluid that hydrostatically couples a DEA-based active membrane to a passive membrane interfaced to the user's finger. Electrical driving of the active membrane causes a deformation of the passive membrane. This principle allows for safe transmission of actuation from the active membrane to the finger, without any direct contact between them. Compared to alternative actuation technologies, HC-DEAs combine high comfort for the user (mechanical compliance, low specific weight, no acoustic noise, no heating and suitable electrical safety) with high versatility for design (ease of manufacturing according to different shapes, scalability, low power consumption and low cost). We are using this technology to develop a finger-tip display. The HC-DEA and a miniaturized high-voltage DC/DC converter that drives the actuator are integrated within a plastic case, arranged at the fingertip. The display is used to create the sensation of contact with virtual objects.

Session 2.3

(abstracts are listed in order of presentation)

2.3.1 Geometry dependent performance of bucky gel actuators: increasing operating frequency by miniaturization

Maurizio Biso (1); Alberto Ansaldo (1); Don Futaba (2); Kenji Hata (2); Davide Ricci (1);

(1) Istituto Italiano Di Tecnologia, Robotics, Brain And Cognitive Sciences Department, Genoa, Italy
(2) National Institute Of Advanced Industrial Science And Technology, Nanotube Research Center, Tsukuba, Japan

Presentation given by Dr. Alberto Ansaldo

Actuation speed is macroscopically related with the product of the resistance and the capacitance of the equivalent circuit (circuit time constant), and from the ion diffusion speed inside the active electrodes. To enhance the actuator performance it is necessary to increase the ion drift current in the electrolyte without significantly increase the voltage at the electrodes and shorten ion path necessary to charge the bucky gel electrodes. Fast device response can be achieved using very thin electromechanical electrode elements. By using an hot press set-up we successfully reduced the thickness of the actuators to one third of the original size. Such miniaturization significantly enhanced the response time of the actuators, in particular the maximum operating frequency of the actuator was shifted up of one order of magnitude and the strain at higher frequencies was increased too. The combination of such thickness reduction process with other parameters, such as using more efficient CNTs type (e.g. super-growth carbon nanotubes) or chemical cross linking, could lead to actuator with superior performance in terms of frequency response.

2.3.2 Charge injection into the silicone films from single-walled carbon nanotubes sprayed network electrodes

Dmitry Rychkov (1); Werner Wirges (1); Reimund Gerhard (1);

(1) Applied Condensed-Matter Physics, Department Of Physics And Astronomy, Faculty Of Science, University Of Potsdam, Germany

Presentation given by Dr. Dmitry Rychkov

Electrodes for dielectric elastomer actuators should be compliant i.e. electrodes must change their dimensions according to the movement of actuating elastomer film. At the same time electrodes must be conductive in the whole range of actuator movement while keeping mechanical properties of the whole system as close as possible to that of the original elastomeric material. Another desired property of the electrodes is the ability to withstand many actuation cycles without considerable deterioration of the above characteristics. This also includes stability in ambient environment (e.g. heat and humidity). The combination of these important properties can be found in single-walled carbon nanotubes (SWNT) electrodes deposited on the surface of the elastomer film via spraying. One problem, however, is usually overlooked when the use of such electrodes is being considered - namely the injection of charges into the elastomer film. It can lead to build up of charges inside the film, early aging, breakdown and other processes that compromise the working and efficiency of the actuator. In the present study we investigate charge injection from the SWNT electrodes by means of isothermal and thermally stimulated surface potential decay. It has been found that the silicone films with SWNT network electrodes discharge considerably faster than the same films with aluminum evaporated electrodes. This result has been obtained both in isothermal and thermally stimulated regimes.

2.3.3 Electrochemical dual sensing-actuators sense chemical conditions while working

Jose G. Martinez (1); Toribio F. Otero (1);

(1) Universidad Politecnica De Cartagena, Center For Electrochemistry And Intelligent Materials (CEMI), Cartagena, Spain

Presentation given by Dr. Jose G Martinez

A theoretical model is being developed for electrochemical artificial muscles based on basic principles of chemical and electrochemical kinetics. A good agreement was attained between simulated and experimental chronopotentiometric results when a bending actuator was driven through the same angle in different temperatures. Now the model has been improved to include the effect of chemical variables as the electrolyte concentration. The attained sensing-actuating equations describe the evolution of the potential or that of the consumed electrical energy (sensing signals) during the movement of the muscle as a semilogarithmic function of the electrolyte concentration. The equations also include the driving current (actuating signal). Good agreement between theoretical and experimental results is attained using either, polypyrrole self-supported films or bilayer actuators, in different electrolyte concentrations. Only two connecting wires contain actuating (current) and sensing (potential) signals that are detected, simultaneously and at any actuating sample time, by the computer.

2.3.4 Novel electroactive polymer composites that perform rotation in uniform DC and AC electric field

Miklos Zrinyi (1); Masami Nakano (2);

(1) Semmelweis University, Laboratory Of Nanochemistry, Department Of Biophysics And Radiation Biology, Budapest, Hungary
(2) Intelligent Fluid Control Laboratory, Institute Of Fluid Science,Tohoku University, Sendai, Japan

Presentation given by Prof. Miklos Zrinyi

Electric and magnetic field responsive polymeric materials are a specific subset of smart materials, which can adaptively change their physical properties in external electric- or magnetic fields, respectively. Electro- and magnetoactive polymers exhibit a change in size and shape when stimulated by electric- or magnetic field. Novel electroactive polymer composites have been developed that perform rotation in uniform DC and AC electric field around to an axis that perpendicular to the direction of applied field. The angular motion of insulating polymer composite disk immersed in slightly conducting oil was studied as a function of DC and AC electric field intensities as well as the frequency of AC field. It was found that above a critical value of electric field the disk begins to rotate. In DC field the disk rotates at a constant rate. With increasing field intensities the angular velocity of rotating disk increases. Three regimes have been identified as the strength of static DC field is accounted for. We have presented the first experimental observation of AC electric field induced rotational motion. The rotating polymer disk acts like micro sized motor with tuneable angular frequency. A microscopic motor of which operation is based on the principle of electrorotation is just one step away.

2.3.5 Dielectric elastomer actuators with fluorinated silicone rubber

Holger Boese (1); Detlev Uhl (1); Raman Rabindranath (1);

(1) Fraunhofer-Institut Fur Silicatforschung, Center Smart Materials, Warzburg, Germany

Presentation given by Dr. Holger Boese

The actuation strain of dielectric elastomer actuators (DEA) at fixed electric field strength is determined by the permittivity of the elastomer material and its Young's modulus. In a rough approximation, the actuation strain is proportional to the permittivity and inversely proportional to the Young's modulus. Silicone rubber can be prepared with very small Young's modulus, but the permittivity of 2.8 is also relatively low. Therefore, the silicone elastomer was modified by the introduction of fluorinated propyl groups in order to enhance its permittivity. Mechanical and electric properties of the modified silicone elastomer were investigated. Model actuators were prepared by coating the fluorinated silicone films with graphite electrodes. The actuation strain of the model DEA at variable field strength was studied. It was demonstrated, that the permittivity could be increased by ca. 70 % compared to the unmodified silicone. Simultaneously, the conductivity of the elastomer was not significantly enhanced and the Young's modulus was even diminished. The consequence of all these properties was that the actuation strain of the model DEA at fixed electric field strength was nearly doubled with respect to the unmodified silicone elastomer. Moreover, the increase of the permittivity also enhances the Maxwell pressure and the corresponding actuation stress. This strong gain in actuation performance gives the fluorinated elastomer material a high potential for future applications.

2.3.6 Voltage tunable polymer laser device

Matthias Kollosche (1); Sebastian DÃring (2); Rabe Torsten (3); Joachim Stumpe (2); Guggi Kofod (1);

(1) Institute For Physics And Astronomy, University Potsdam
(2) Fraunhofer Institute For Applied Polymer Research
(3) Institute Of Highfrequency Technology, Technical University Braunschweig

Presentation given by Mr. Matthias Kollosche

We report on a compact organic laser device that allows for voltage controlled continuously wavelength tuning. The device consists of an elastomeric distributed feedback (DFB) laser and an electro active elastomer actuator. Second order DFB lasing is realized by a grating line structured elastomer substrate covered with a thin layer of dye doped polymer. To enable wavelength tuning the elastomer laser is deformed by the electro active elastomer actuator which results in a decrease of grating period and thus of emission wavelength. The increase of actuation voltage to 3.25 kV decreased the emission wavelength from 604 nm to 557 nm.

2.3.7 Electrical Breakdown in Soft Elastomers: The Direct Influence of Stiffness in Un-prestretched Elastomers.

Matthias Kollosche (1); Guggi Kofod (1);

(1) Institute For Physics And Astronomy, University Potsdam

Presentation given by Mr. Matthias Kollosche

The relation between electrical breakdown and mechanical properties in soft polymeric materials is of particular interest for multiple applications, such as smart and flexible materials. In the literature, this relation is commonly investigated by variation of temperature, which indirectly causes a change in mechanical properties, but it also affects other factors that may influence the electrical breakdown, such as conductivity. Here, we present experiments that are performed at a constant temperature, on blends of chemically identical tri-block thermoplastic elastomers with different stiffnesses. Stress-strain measurements proved that continuous variation in mechanical properties could be obtained, here a range of 94-316 kPa was found. Breakdown measurements found that the breakdown field increases with Youngs modulus. The results were compared to several theories in literature.

2.3.8 Electrochemical actuation of ultra-thin freestanding PEDOT:PSS/SU8 bilayer microactuators

Silvia Taccola (1); Francesco Greco (1); Edwin Jager (2); Virgilio Mattoli (1);

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(2) Biosensors And Bioelectronics Group, Department Of Physics, Chemistry And Biology, University Of Linkoeping (Sweden)

Presentation given by Dr. Silvia Taccola

Conjugated polymers are of great interest for microactuators because, compared to large scale actuators, miniaturization improves their electrochemical properties by increasing speed, stress output etc. Recently, a novel fabrication process for obtaining robust large area free standing ultra-thin films made of the conjugated polymer poly (3, 4-ethylenedioxythiophene) doped with the polyanion poly(styrenesulfonate) (PEDOT:PSS) has been demonstrated. These nanofilms show a thickness ranging between few tenths to several hundredths of nm. This opens up the possibility of using such freestanding PEDOT:PSS nanofilms to realize new all polymer electrochemical microactuators using facile microfabrication methods. Here, we report the processing methods and a validation of the microactuators' working principle. Free standing PEDOT:PSS/SU8 bilayer microactuators in the form of micro-fingers have been fabricated and patterned using a combination of standard microfabrication procedures. Reversible actuation of the PEDOT:PSS microactuators caused by electrochemical oxidation/reduction cycles was demonstrated and resulted in bending of the micro-fingers. Small, soft actuators may be useful for a number of applications, including microrobotics, microsurgery, and cell handling.

2.3.9 Dielectric elastomer and ferroelectret films combined in a single device: How do they reinforce each other?

Sebastian Raabe (1); Xunlin Qiu (1); Werner Wirges (1); Reimund Gerhard (1);

(1) University Of Potsdam, Department Of Physics And Astronomy, Potsdam, Germany

Presentation given by Dr. Xunlin Qiu

Dielectric elastomers (DE) -also called "electro-electrets" - are soft polymer materials exhibiting extremely large deformations under electrostatic stress. When a pre-stretched elastomer is stuck to a flexible plastic frame, the frame changes its shape upon release of the DE film from the pre-stretch, and finally a complex structure that can be used as a bending actuator is formed. Here, such an actuator was equipped with an additional ferroelectret film. Ferroelectrets are internally charged polymer foams with large piezoelectricity. In broad-band dielectric spectroscopy, ferroelectrets show piezoelectric resonances that can be used to analyze their electromechanical properties. The anti-resonance frequencies (fp) of ferroelectrets are not only directly related to their geometric parameters, but are also sensitive to the boundary conditions during the respective experiment. In this contribution, the dielectric resonance spectra (DRS) of the ferroelectret film were measured in-situ during the actuation of the DEA. It is found that fp is a monotonic function of the bending angle of the actuator. Therefore, the actuation strain from a DEA can be used to modulate the fp of an attached ferroelectret, while fp can also be evaluated for in-situ diagnosis and for precise control of the actuation of the DEA via feedback. Clever combinations of DEAs and ferroelectrets should allow for a number of exciting device applications.

2.3.10 Hydrostatically coupled dielectric elastomer actuators with dipole grafted silicone films

Sebastian Risse (1); Gabriele Frediani (2); Federico Carpi (2) (3);

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(2) University Of Pisa, Interdepartmental Research Centre "E. Piaggio", School Of Engineering, Pisa, Italy
(3) Technology & Life Institute, Pisa, Italy

Presentation given by Mr. Sebastian Risse

A silicone elastomer grafted with strong organic dipoles was successfully combined with the hydrostatically coupled dielectric elastomer (HC-DE) actuation technology. Vinyl terminated polydimethylsiloxane (PDMS) was cured with a methylhydrosiloxane-dimethylsiloxane copolymer (HMS) and strong push-pull dipoles with allyl functionalization in a Pt-catalyzed one step film formation process. This approach yields soft, silicone based elastomers with enhanced electromechanical sensitivity. The completeness of the dipole grafting and the homogeneous distribution were investigated with 13C-NMR and differential scanning calorimetry (DSC), respectively. The applicability of this molecular modified material was investigated with HC-DE actuators. The devices were characterized with a laser distance meter, regarding their frequency behaviour and maximum displacement.

2.3.11 Electroactive hydrogels for minimal invasive cardiovascular procedures

Frank Stam (1);

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Presentation given by Mr. Frank Stam

The European Commission has funded a project called "Heart-e-Gel", under the FP7 Specific Programme "Cooperation", to develop biomedical microsystem solutions, based on electroactive hydrogels (EAH), for the treatment of cardiovascular conditions requiring occluding, filling or sealing of vessels or cavities. Minimal invasive procedures are targeted, such as "arterial occlusions", for which a catheter type delivery system is required. The ability of the EAH to swell or shrink in volume under electrical bias, allows it to be inserted in the body in a small dimensional format, and later on fulfil its required function by swelling up. So far the research has concentrated on developing EAH's which are compliant and biocompatible with blood, while also able to withstand the long-term effect of pulsating blood flow.

2.3.12 Electrorotation in uniform electric field of millimeter-sized silicone disks

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Presentation given by Dr. Gabriele Frediani

In 1896 G. Quincke observed that some solid particles can spontaneously rotate in certain media if a large uniform electric field is applied (Quincke rotation effect). The phenomenon exhibits a threshold value of the electric field and occurs only if certain conditions concerning to the conductivity and permittivity of the particles and of the liquid are satisfied. In experiments, the rotating materials are mainly oxides with poor fabrication possibilities. Shaping or micro-fabricating the solid particles is rather difficult due to rigidity and fragility. It is therefore an important challenge to find proper materials with good fabrication possibilities. In previous work, some of us showed Quincke rotation of micron-sized disk-shaped polymer composites. Here, we present the first experimental demonstration of two findings: 1) effective rotation in a uniform DC electric field can be achieved from samples made of a commercial silicone elastomer (rotating within an oil containing triglicerid of oleic-, palmitic-, and linoleic acids); 2) electro-rotation is effective also at the meso/macro-scale (millimeter size). These findings are of particular interest, as they open the possibility of exploiting the Quincke rotation effect with materials that are widely commercially available, very cheap, and very easy to work with.

2.3.13 Carbon nanotube based stretchable optically transparent electrodes for dielectric elastomer actuators

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Presentation given by Mr. Dominik Nemec

Dielectric elastomer actuators (DEAs) show promise for number of applications. Significant research and industrial interest lies in development of vibrotactile displays for consumer electronics. One of the most significant challenges in development is the lack of viable solutions to obtain stretchable optically transparent electrodes. Carbon nanotubes (CNTs) when used as electrodes provide both electrical conductivity and transparency. Furthermore, high aspect ratio of the CNTs is es-sential as it allows the electrodes to be designed to comply with the deformations of the elastomer. However, as elastomeric films possess different surface characteristics than the substrates typically used to deposit CNTs, experimental investigations had to be undertaken to evaluate the compatibility of those materials. The goal of this work was to determine preferred material combination for manufacturing of transparent electrodes on the 3M VHB film. Moreover, several coating methods with various process parameters were evaluated for preparation of electrodes and their influence on actuation properties. It has been shown that coatings based on CNTs can be used as transparent electrodes for stretchable actuator systems. Additionally, investigations on various coating methods showed differences in the quality of the prepared electrodes and the superior performance, in terms of actuation and optical quality, of samples prepared by airbrush technique over those prepared by inkjet was demonstrated.

2.3.14 Low pressure sensing using dielectric electro-active polymers: design, testing and analysis

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Dielectric Electro-Active Polymers (DEAP's) can achieve substantial deformation (>300% strain) while, compared to their ionic counterparts, sustaining large forces. When deformed, the electrical properties of the DEAP undergo measurable changes in resistance and capacitance. This makes DEAP an attractive sensing element especially for light weight, low cost applications. This work focuses on using DEAP film to perform pressure sensing for inline low pressure applications. Both capacitive and resistive sensing techniques are explored for a variety of designs and configurations. Resistive sensing is performed using the DEAP as a variable resistor in a Whetstone bridge circuit. Capacitive sensing is performed using the DEAP as a variable capacitor in a high pass filter circuit. Experimental tests are performed on the different sensing systems and the advantages and challenges of each method are discussed.

2.3.15 Collaboration on polymer research Germany - Brazil

Ruy Alberto Pisani Altafim (1); Osvaldo Novais de Oliveira Jr. (2); Heitor Cury Basso (1); Ruy Alberto Corrêa Altafim (1);

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With Bernhard Gross, a great German-born researcher who emigrated to Brazil in the early 1930s, began this wonderful saga. One of Prof. Gross´ pupils, Prof. Sergio Mascarenhas, invited him to join the São Carlos Physics Institute, USP, in 1970, where Prof. Gross established a long-lasting Brazil-Germany research

cooperation in polymer science. This included Prof. Sessler, Prof. Von Seggern from Darmstadt University, and Prof. Reimund Gerhard, who met Prof. Gross when he was a student supervised by Prof. Sessler. Like Prof. Gross, Prof. Reimund Gerhard was to choose Brazil as his second country. Many opportunities were then created over the years for research on several topics involving Prof. Gerhard´s Brazilian collaborators. During his sabbatical in 2005, Prof. Gerhard established a stronger collaboration with the Engineering School of São Carlos-USP, working with Prof. Ruy Altafim, Heitor Basso and Dr. Ruy Pisani Altafim. The main results from this latter collaboration included creation of thermo-formatted piezoelectrets with the financial support from the PROBRAL-CAPES-DAAD Program. Now a third generation of researchers include other nationalities, indicating that this collaboration is being expanded naturally as can be seen by reference and that prof. Reimund still seeks for new partnerships in Brazil and worldwide.

LATE SUBMISSIONS:

The following abstract has been submitted late and thus it appears in the programme's electronic version only.

2.3.16 EAP-transducers as adaptive components

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Electroactive polymer transducers have been widely used as actuators, sensors and generators. A transducer design developed at the Fraunhofer LBF with rigid, perforated electrodes has been shown to yield good results as actuator especially for dynamic applications in previous publications. Due to its special design its stiffness varies significantly with the applied voltage. Therefore it can be used as adaptive component in static and dynamic systems. This work presents measurement results obtained with a functional demonstrator and highlights the potential of EAP transducers for adaptive components.

2.3.17 Electrochemistry of doped polypyrrole phenazine derivative as redox stimulated actuator material

Priscilla Baker (1); Faiza Iftikhar (1); Abd-Almoneem Baleg (1); Emmanuel

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The use of polymers as actuator materials have been widely studied in recent years and find application in the design of microelectromechanical systems (MEMS) as actuator valves intended for drug delivery application. The actuation properties of functionalized polypyrrole directed phenazine derivative was studied by CV, SWV and UV/Vis spectroscopy as well as EIS studies. The redox properties and the release profiles with respect to redox dyes for the novel actuator polymer-Poly(Phenazine 2,3-diimino(pyrole-2-yl)) doped with PVSA- which incorporated short chains of PPY linked by a molecular hinged linking molecule 2,3-diamino phenazine was therefore, studied. The actuation thus developed was tested on model compounds like pyrocatechol violet and methyl orange by electrochemical impedance spectroscopy as well as UV/visible spectroscopy.

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