EuroEAP 2018

8th international conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles

Lyon, France
5-6 June 2018

Technical programme

Book of abstracts

List of participants

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Local organization

Conference Chairperson

EuroEAP 2018 is chaired by:
Ass. Prof. Claire Jean-Mistral
INSA de Lyon - LaMCoS
Bat. Sophie Germain
27 bis avenue Jean Capelle
69100 Villeurbanne

Local organizing institution

EuroEAP 2018 is organized by
Contact and Structural Mechanics Laboratory (LaMCoS)
National Institute of Applied Science (INSA Lyon)
Campus Lyon Tech La Doua
69100, Villeurbanne, France

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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 referred 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 EuroEAP Society as a non-profit Association, whose main purpose is to contribute to and promote the scientific and technological advancement and the diffusion of Transducers and Artificial Muscles based on EAPs. In an effort to disseminate current advances in this emerging field of science and technology, gathering experts from all over the world, the Society 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 Chairperson for the valuable local organization of this new edition. I am sure that you will enjoy this event and will leave it with plans to attend the future annual editions, which will be moving across Europe.

Anne Skov
EuroEAP Society President

Conference committees

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The EuroEAP conference is steered by the conference committee of the EuroEAP Society:

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Vice-President
Edwin Jager, Linköping University (Sweden)

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Peter Sommer-Larsen, Danish Technological Institute (Denmark)

Tuesday, 5 June 2018

General programme of the day

Opening	8:45- 9:00	Welcome & introductory remarks **Claire Jean-Mistral** INSA-Lyon, France
Plenary Talk	Session 1.1 part I *Chair: Claire Jean-Mistral, INSA-Lyon, France*	
	9:00- 9:30	**Iain Anderson** University of Auckland, New Zealand
Invited Lectures	Session 1.1 part II *Chair: Iain Anderson, University of Auckland, New Zealand*	
	9:30- 9:50	**Hidenori Okuzaki** University of Yamanashi, Japan
	9:50- 10:10	**Jian Zhu**, National University of Singapore, Singapore
Break	10:10- 10:30	Coffee break (sponsorised by Wacker)
Interactive Talks	Session 1.2 *Chair: Jian Zhu, Nat. U. of Singapore, Singapore*	
	10:30- 11:30	**Oral presentations** 15 presentations of research activities (3 minutes each + 1 minute to change speaker)
	11:30- 12:30	**Posters & exhibitions** 15 posters

Lunch	12:30-14:00	Lunch
Invited Lectures	Session 1.3 *Chair: Helmut F. Schlaak, Tech. U. Darmstadt, Germany*	
	14:00-14:20	**Steffen Hau** Saarland University, Germany
	14:20-14:40	**Francesco Greco** TU Graz, Austria
	14:40-15:00	**Shuo Li** Cornell University, USA
Interactive Talks **EuroEAP Society Challenge**	Session 1.4 *Chair: Edwin Jager, Linköping University, Sweden*	
	15:00-16:00	**Oral presentations** 15 presentations of research activities (3 minutes each + 1 minute to change speaker)
	16:00-16:30	**Challenge pitch oral presentations** 7 presentations (3 minutes each + 1 minute to change speaker)
	16:30-18:00	**Posters & Challenge exhibitions** 15 posters + challenge exhibit (coffee served during the session)
Social event	18:00-20:00	Wine & Cheese testing (Nunc Est Bibendum, an oenological event agency)
Social dinner	20:00	Social dinner at the conference hotel (Barbecue)

Session 1.1

(abstracts are listed in the order of presentation)

1.1.1 Turning a lemon of a sensing model into lemonade

Iain A. Anderson (1) (2)

(1) Biomimetics Lab, Auckland Bioengineering Institute, Auckland, New Zealand;
(2) StretchSense Ltd., 114 Rockfield Rd. Penrose, Auckland, New Zealand;

Presentation given by Prof. Iain Anderson

Dielectric elastomer (DE) sensors are being used for measurement of large strains on everything from soft engineering actuators to human limbs. These sensors are soft capacitors consisting of layers of silicone dielectric sandwiched between carbon-filled silicone electrodes. Changes to sensor capacitance are linear with uniaxial stretch: we sense capacitance by interrogating a periodic electrical signal applied to the sensor and calculating its electrical parameters including instantaneous capacitance and the electrical resistance of its electrodes. In the past we have treated the sensor as a single variable capacitor with capacitance and two electrical resistances, one for the high resistance of the electrodes and one for the leakage of charge across the dielectric. Lumping electrical parameters together has earned this model the title: "Lumped Parameter Model". We have discovered that this model can be a bit of a lemon, giving poor results for capacitance if the sensing frequency is too high. But lemons can be turned into lemonade.

Our lemon to lemonade opportunity presented in 2014 when we began an ESNAM COST Action collaboration with a colleague from EMPA (Silvain Michel) who was measuring unrealistically low values for capacitance on large artificial muscle actuator stacks. DE actuators, like DE sensors are soft capacitors. We discovered that the high surface and interconnect electrode resistance of these large multi-stack actuators resulted in a transmission line phenomenon, with frequency dependent filtering along the actuator stack. We reasoned that an individual DE sensor with high resistance electrodes would also suffer signal attenuation at high frequencies. Our Lumped Parameter model would no longer be appropriate. Together with EMPA we developed a protocol for identifying maximum frequency that would allow us to avoid this transmission line phenomenon. This work lead to a technique for measuring touch or stretch at a specific location anywhere along a DE sensor, achieved by using multiple discrete sensing frequencies. It then became possible for us to demonstrate how this could be used for music: turning our sensor into a rubbery keyboard; and to measure touch in two dimensions through double layering of the sensor. Recently we have returned to the opportunity of measuring the capacitances of multiple sensors using a multi-frequency signal down a single channel. This could substantially reduce electronics for garments with many wearable sensors. For these daisy-chained sensors we have used hard and fixed resistances between them to establish the transmission line. This year at the SPIE EAPAD in Denver we demonstrated how the instantaneous resistances of stretchy resistance sensors with fixed hard capacitors between them could each be calculated individually too[5]. Now we are investigating how to bring it all together in a system of variable resistances and capacitances along a set of sensors daisy chained together. Our lemon of a model will have produced lemonade!

1.1.2 Flexible acceleration sensors with highly conductive polymer electrodes

Hidenori Okuzaki (1),

(1) University Of Yamanashi, Kofu, Japan

Presentation given by Prof. Hidenori Okuzaki

In this study, fabrication and characterization of flexible acceleration sensors driven by piezoionic effect have been demonstrated. The ionic liquid-polyurethane (IL-PU) gels were prepared by casting the N,N-dimethylacetoamide (DMAC) solution of 1-ethyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide ([EMI][TFSI]) and thermoplastic polyurethane. Then, poly(3,4-ethylenedioxythiophene) doped with poly(4-

styrenesulfonate) (PEDOT:PSS) as flexible electrodes were spray-deposited on both sides of the IL-PU gel. Upon bending the gel, positive electric charges are rapidly generated, whereas the equivalent negative charges are formed when the bending stops. On the other hand, the opposite phenomenon was observed when the bent gel recovers to the original straight shape, indicative of an acceleration sensor. The mechanism can be explained in terms of the "piezoionic effect" based on the difference of ionic mobilities between the EMI+ and TFSI-. On the basis of this phenomenon, we have succeeded in fabricating a wearable sensor glove, in which the flexible acceleration sensors located on the three fingers are operating individually. Since the acceleration sensor can provide information not only the acceleration but also force, velocity, and displacement, the wet-processbable, stretchable, and wearable flexible sensors based on the piezoionic effect will be available for motion sensors in a wide field of application.

1.1.3 Soft robots based on dielectric elastomer actuators

Jian ZHU (1),

(1) National University Of Singapore

Presentation given by Dr. Jian ZHU

Robots have been proposed to relieve human beings from dangerous environments or tedious manufacturing processes, or mimic human beings or animals in appearance, behaviour, and/or cognition. Most of traditional robots use hard materials. Inspired by natural creatures, researchers recently become more and more interested in soft robots, which are made of soft materials, say polymers. To exploit animal-like locomotion and behaviour, it is essential to develop muscle-like actuators with properties close to biological systems. Dielectric elastomer actuators (DEAs), one class of soft active materials, are capable of functioning as artificial muscles. A DEA can deform in response to voltage, and can exhibit unique attributes, including large voltage-induced deformation, fast response, low weight, quiet operation, etc. In this talk I will discuss several soft robots based on DEAs, which have recently been developed by my group, such as a jellyfish robot, a flog robot, an inchworm robot, artificial muscles for jaw movement and 3D motion of eyeballs, etc.

Session 1.2

(abstracts are listed in the order of presentation)

1.2.1 Hydrogel based braided artificial muscle

Bidita Binte Salahuddin (1), Holly Warren (1), Geoffrey M. Spinks (1),

(1) University Of Wollongong, ARC Centre Of Excellence For Electromaterials Science And Intelligent Polymer Research Institute, North Wollongong, Australia

Presentation given by Ms. Bidita Binte Salahuddin

Braided (McKibben) artificial muscles are one of the most attractive biomimetic actuators since they exhibit similar static and dynamic performance to skeletal muscles. Recently, a growing attention has been found in replacing the pump or compressor usually used to develop pressure to actuate the braided muscles. One possibility is to use an expandable material, such as hydrogels or paraffin wax. This work investigates the development of hydrogel based braided artificial muscle that can produce work by controlled hydrogel swelling in the presence of water. Hydrogel bead filled braided mesh with an outside diameter of 6 mm and a length of 47 mm was prepared. No bladder was needed for these systems since the bead size was larger than the braided mesh. A spring test method was introduced to measure force generation and strain developed by the braided mesh when the thermo-responsive gel was cooled from 60°C to 5°C. Reducing the temperature caused hydrogel swelling and braided mesh length contraction due to the internal pressure generated. Blocked forces and actuation strokes of 5-6 N and 7-13% were observed. A long response was the limiting factor of these actuators due to the slow diffusion properties of the hydrogel. Therefore, a new concept of hydrogel coated braided mesh has been developed to reduce the response time of the actuator. The effects of gel swelling ratio and braided mesh dimensions on the actuator stroke, blocked force and response time have been investigated.

1.2.2 Molecularly imprinted polymer/Fe3O4 nanoparticles modified platinum electrode for selective detection of dapsone

Houda Essousi (2), Houcine Barhoumi (2),

(1) Faculty Of Sciences, Laboratory Of Interfaces And Materials (LIMA), University Of Monastir, Tunisia
(2) Faculty Of Sciences, Laboratory Of Interfaces And Materials , University Of Monastir, Tunisia

Presentation given by Dr. Houda Essousi

A novel electrochemical sensor, based on molecularly imprinted polyaniline film matrix prepared on a Fe3O4 nanoparticles modified platinum electrode (Pt). the developed sensor was used for convenient and selective detection of dapsone (DDS), which plays the role of the template. The molecularly imprinted polymer (MIP) containing the cavities compatible with dapsone molecules was synthesized using aniline (PAN) as functional monomers. The resulting MIP sensor was characterized by Fourier Transform Infrared Spectroscopy (FTIR), UV-Vis, Scanning Electron Microscopy (SEM) and electrochemical methods. The sensing conditions and the performance of the constructed sensor was investigated and optimized by cyclic voltammetry (CV) and impedance spectroscopy (EIS). Under the optimum conditions, the current response had a linear relationship with the concentration of dapsone in the range from 6.0x10-7 to 2.0x10-4 M and with detection limits of 1,77x10-7M. In addition, the sensor showed high selectivity towards DDS in comparison to other interferents. Considering these advantages, the Pt/Fe3O4NPs/PAN-MIP electrochemical sensor showed high selectivity for DDS detection and recognition, excellent stability and it was successfully utilized for the determination of dapsone in real samples analysis with good recoveries.

1.2.3 Dielectric elastomers put to work

Dorina Maria Opris (1), Frank Nüesch (1), Yauhen Sheima (1), Simon Dünki (1), Philip Caspari (1), Song Ko (1), Elena Perju (1),

(1) Empa

Presentation given by Dr. Dorina Maria Opris

This presentation gives an overview of novel dielectric elastomers with high dielectric permittivity which allow construction of dielectric elastomer actuators operated at unprecedentedly low voltages and of piezoelectric elastomers that generate an electric signal when mechanically stressed. High permittivity elastomers were achieved by modifying polysiloxanes with polar groups. Piezoelectric elastomers were prepared by poling specially designed silicone composites under an electric field.

1.2.4 LAMDA printing: a low-cost fabrication platform for soft, electroactive structures

Djen T. Kühnel (1) (2), Jonathan M. Rossiter (2) (3), Charl F. J. Faul (4),

(1) EPSRC Centre For Doctoral Training In Robotics And Autonomous Systems (FARSCOPE), University Of Bristol And University Of The West Of England, Bristol, UK
(2) Bristol Robotics Laboratory, Bristol, UK
(3) Department Of Engineering Mathematics, University Of Bristol, Bristol, UK
(4) School Of Chemistry University Of Bristol, Bristol, UK

Presentation given by Mr. Djen Kühnel

Soft electroactive structures like dielectric elastomers (DEs) show great potential for many applications such as soft robotics or wearable devices. Unfortunately, manufacturing of DEs is often time- and labour intensive or limited to relatively simple 2D structures. 3D printing is a promising fabrication technique that could overcome these limitations. However, not many soft and functional materials are available for 3D printing and sophisticated, expensive hardware is usually required to print functional structures. As an alternative, we propose Laser-Assisted Multi-material Direct-write Assembly (LAMDA), a novel 3D printing technique that combines simple direct ink writing with UV-curable elastomers and laser scribing in one integrated process. Laser scribing is used to alter the structure and chemical composition of the deposited materials, changing their electrical and mechanical properties. Using only low-cost (~?1000) hardware, our LAMDA process is capable of producing soft structures with complex geometries and high detail. It also enables incorporation of thin conductive layers for electrodes and layer separations for inflatable cavities without the need for multi-material deposition. This technique might pave the way for easier, more repeatable prototyping of DE devices and could enable completely new shapes, geometries and functionality of soft electroactive structures that would otherwise not be accessible by conventional manufacturing methods.

1.2.5 Design of artificial muscles based on dielectric elastomers for soft exosuits to support grasping motion

Florian Klug (1), Susana Solano-Arana (1), Florentine Förster-Zügel (1), Helmut F. Schlaak (1),

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

Presentation given by Mr. Florian Klug

The aims of development for wearable robots so far have been increased forces with high precision of motions. Therefore, these robots such as exoskeletons have mostly been built with rigid structures substituting the human joints to implement classical and precise control strategies known from the industrial automation. Since the complexity and weight of these systems is rising rapidly with increasing degrees of freedom, the next generation of wearable robots use compliant interfaces to interact with the human body. By using natural biomechanics instead of rigid structures, these so called exosuits are lightweight, don't constrain the wearers joints and enhance its safety. Nevertheless, most exosuits are based on traditional actuator principles, which requires a transition from soft structures to stiff actuators. To exploit the full potential of soft exosuits there is the need for innovative and compliant actuator principles. Thus, this work presents the design of cylindrical artificial muscles based on dielectric elastomers (DE) with high force and displacement. Presented results were taken from a numerical transducer model in ANSYS. Later, the actuators will be integrated in a grasping glove to assist those with reduced muscle activity due to physical or neurological disorders. By taking advantage of the sensory abilities of DE, an additional motion monitoring can be performed. These information can be used to control the glove and also to monitor rehabilitation processes.

1.2.6 Senskin deformable silicone-elastomer sensors for structural health monitoring: assessment of strain sensitivity and correction for thermal expansion

Fan He (1), Jingwen Wang (1), Dmitry Rychkov (1), Manuel Schulze (1), Werner Wirges (1), Reimund Gerhard (1),

(1) Institute Of Physics And Astronomy, Faculty Of Science, University Of Potsdam,Potsdam, Germany

Presentation given by Dr. Fan He

Structural health monitoring (SHM) is an engineering process including detection and characterization of the structure, and risk assessment. Within the framework of SENSKIN EU project (grant No. 635844), we have developed a soft capacitive sensor using silicone dielectric elastomer. This sensor has a thin layer of stretchable silicone dielectric film and soft silicone electrodes as the active layer, which transduces strain signal into the easy-monitored capacitance change. The sensor output is measured as a ration of the sensor's capacitance to the known value of the reference capacitor. The capacitive output of the sensor showed a linear response upon stretching in the strain range of 4.5 % to 5.5 %: with a pre-strain of 5.0 %. The sensor output increased by 0.01 when the strain was increased by 1.0 %. The temperature dependence of these sensors was measured in a climate chamber. The sensor was exposed to a temperature change from -35 oC to 55 oC (the supposed working temperature range) with a ramping of 0.2 oC/min and, as a result, it showed a linear temperature-dependence behavior with a slope of -0.001 sensor output per oC. Therefore, with the help of the embedded platinum 1000 temperature sensor, the thermal expansion effect on the capacitive output can be excluded from the actual strain-induced capacitance change. These results provide sufficient reference to the application of the silicon-elastomer sensor for the SHM systems.

1.2.7 Trapeziform ionic polymer pressure sensor unit for artificial skin

Zicai Zhu (1), Ximing He (1), Qiao Hu (1),

Presentation given by Prof. Zicai Zhu

Conventionally, ionic polymer sensor refers to ionic polymer-metal composite

(IPMC) or ionic polymer transducer (IPT) sensor etc., which works in the form of cantilever. Here we introduce a new ionic polymer pressure sensor based on a typical ionic polymer, Nafion. Inspired by sensing mechanism of IPMC strip, whose electrical response is induced by elastic stress gradient across thickness, we developed a trapeziform ionic polymer sensor. Under an applied pressure, elastic stress gradient will be generated across the upper and bottom surfaces, and cause cations migrate toward the lower pressure side, i.e. the bottom surface with large area. Then cations redistribution generates electrical response. In our experiments, the response mainly relates to the area ratio between the upper and the bottom. It increases with the ratio nonlinearly, but rarely changes with the thickness. The sensitivity and dynamic range can be regulated by structure design. Due to similar sensing mechanism to cell membrane potential of our tactile sensation, this ionic pressure sensor unit has great potential to imitate natural skin, i.e. to be used for artificial skin.

1.2.8 Electrical breakdown enhancement of electrostrictive polymers via synthesis and processing control

Francesco Pedroli (1), Alessio Marrani (2), Olivier Sanseau (4), Cédric Froidefond (3), Pierre-Jean Cottinet (1), Jean-Fabien Capsal (1),

(1) Univ Lyon, INSA-Lyon LGEF, Villeurbanne, France
(2) Solvay Specialty Polymers, Bollate, Italy
(3) Solvay, Paris, France
(4) P2D, CNRS/Rhodia-Solvay, Saint Fons, France

Presentation given by Mr. Francesco Pedroli

The interesting and highly promising features of electro-active polymers in the field of sensors and actuators, such as P(VDF-TrFE-CTFE), are severely limited by their low dielectric strength driven by ionic conductivity. The quadratic dependence of Applied-Electric Field on Field-Induced Strain highlights the importance of improving electrical breakdown of electro-active polymers: increasing the electrical breakdown of 32%, by controlling processing parameters from polymer synthesis to film fabrication, we will enhance the ideal Maximum Field-Induced Strain of about 73%. Effect of polymer crystallinity, molecular weight, solvent purity and crystallization temperature are investigated. The paper proposes an efficient method to characterize and evaluate ferro-relaxor P(VDF-TrFE-CTFE) terpolymers, allowing the identification of the most promising materials in terms of actuation among different molecular mass terpolymers. The method is based on thermal and electrical characterization aimed to the identification of physical material parameters, such as average trap distance, crystallinity degree and ferroelectric hysteresis, governing ionic conductivity and leading to material degradation.

1.2.9 Towards an untethered 800 mg robot driven by three dielectric elastomer actuators operating below 300 V

Xiaobin JI (1), Alae El Haitami (2), Sophie Cantin (2), Herbert Shea (1),

(1) Soft Transducers Laboratory (LMTS), Ecole Polytechnique Federale De Lausanne (EPFL), Neuchatel, Switzerland
(2) Laboratoire De Physicochimie Des Polymeres Et Des Interfaces (LPPI), Institut Des Materiaux, Universite De Cergy-Pontoise, France

Presentation given by Mr. Xiaobin Ji

Intrinsically compliant actuators are a key element in soft robots. Dielectric elastomer actuators (DEAs) are promising soft actuators due to their large achievable strain, high power density, and sub-ms response. DEAs however generally require several kilovolts to operate. The high voltage power supply makes integration and miniaturization very challenging, especially in view of an untethered system. One path to decrease the DEA operating voltage to below a few hundred volts is to decrease the thicknesses of both the dielectric membrane and electrodes. In this work, we report DEAs consisting of 4 µm-thick silicone membranes with ultrathin Single-Walled Carbon Nanotubes (SWCNT) electrodes fabricated using Langmuir-Schaefer technology. We stacked 3 DEAs to increase the output force. The stack achieves 6% linear strain at 300 V. We use these low-voltage DEAs to drive a legged insect robot. In a first step, insect robot prototypes working at 1 kV were developed to validate the design. For a 1 kV drive signal at 500 Hz, the robot moves at a speed of 25 mm/s. By driving the DEAs on or off resonance, the direction of the robot can be controlled, allowing the robot to be steered. Future work will focus on using the stacked 300 V DEAs to drive the insect robots. At 300 V, the integration of the low weight control electronics on the robot body become possible, which opens the door to autonomous untethered soft robots driven by low voltage operating DEAs.

1.2.10 Nano-carbon based bilayer actuators for bioinspired applications

Ying Hu (1), Wei Chen (2),

(1) Hefei University Of Technology, Hefei, China
(2) Suzhou Institute Of Nano-tech And Nano-bionics, Chinese Academy Of Sciences, Suzhou, China

Presentation given by Prof. Ying Hu

Actuators converting external stimuli into mechanical energy have attracted considerable interests in the recent years. For the fulfillment of these widely potential applications ranging from biomimetic devices, soft robotics, artificial muscles, to motors, significant efforts have been focused on the design of actuators with fast response, large deformation, and controllable motion output. Nano-carbon such as graphene and carbon nanotubes (CNTs) have superior mechanical, electrical and thermal properties, which make them promising host materials or building blocks of new composites for high-performance actuator constructions. Herein, Nano-carbon based actuators with bilayer structure are designed and fabricated, showing large, fast and reversible bending deformation in response to electrical or light stimuli. These remarkable actuation performances are attributed to the asymmetric thermal expansion between the two layers of the bilayers, excellent electrothermal as well as photothermal properties of graphene and CNTs, and the introduced thermal stress. Based on these actuators, a serious of bioinspired devices have been constructed, including smart "roller blinds" to automatically open and block the strong light incident, mechanical grippers for grabbing objects, jumping and crawling robots, and so on. These results reveal the bilayer actuator may have potential utilization in the development of smart biomimetic devices and robots.

1.2.11 Highly conductive microfibers for muscular filaments

Ayana Tomioka (1), Kazuki Kudo (1), Hidenori Okuzaki (1),

(1) Graduate Faculty Of Interdisciplinary Research/University Of Yamanashi, Kofu, Japan

Presentation given by Ms. Ayana Tomioka

Smart textiles, fibers and fabrics having electronic functions, are one of the key devices for wearable electronics. Conducting polymers are flexible, lightweight, and low cost suitable for the smart textiles. Previously, we succeeded in fabricating PEDOT:PSS microfibers by a wet-spinning and subsequent treatment with ethylene glycol (EG). However, the PEDOT:PSS microfibers had poor electrical conductivity and secondary dopant such as EG and DMSO is necessary to improve the electrical conductivity by a few orders of magnitude, namely, "solvent effect". In this study, highly conductive microfibers were fabricated by wet-spinning of a novel conducting polymer and electromechanical properties were investigated for the application to muscular filaments. The PEDOT derivative self-doped with an alkylsulfonic acid side chain bound to the ethylenedioxy ring (S-PEDOT) was synthesized by oxidative polymerization. The wet-spinning into acetonitrile yielded uniform microfibers, where the diameter increased with increasing the S-PEDOT concentration. It was found that the electrical conductivity was strongly dependent on the S-PEDOT concentration and attained as high as 1450 S/cm at 1.5 wt% without secondary dopant. The value was 1.5 times higher than that of the cast film, which can be explained in terms of the orientation of the S-PEDOT chains along the fiber axis. Furthermore, application of the S-PEDOT microfibers to muscular filaments for soft actuators was also demonstrated.

1.2.12 A low cost alternative to High Voltage Amplifier for driving Dielectric Electroactive Polymers

Alessandro Iannarelli (1), Mohamad Ghaffarian Niasar (1), Rob Ross (1),

(1) TU Delft

Presentation given by Mr. Alessandro Iannarelli

Dielectric electroactive polymer actuators/generators (DEA/DEG) are operated by mean of time-varying high voltages, typically square waves. The modulation of high voltage is commonly done through HV amplifier. Besides their excellent performances, these amplifiers are generally bulky, heavy and expensive. Here, it is presented an affordable alternative to HV amplifier for DEA/DEG use. The modulation of the voltage is done by a double-cascade of regular N-mosfets which operate as push/pull switches. The cascade configuration allows higher blocking-voltage than the single mosfet. Each board can handle up to 5 kV square waveform output, with a current of 20 mA and at a maximum frequency of 100 Hz, with a rise time from 0 to 5kV in 2.5 us, resulting in a slew rate of 2kV/uS. The board is modular: it is possible to stack more boards to achieve even higher blocking-voltages. The board design has a compact footprint of 100x100mm2 and its cost is restrained to less than 100 EUR.

1.2.13 Drop-on-demand printed dielectric elastomer actuator

Samuel Schlatter (1), Samuel Rosset (2), Herbert Shea (1),

(1) École Polytechnique Fédérale De Lausanne (EPFL), Soft Transducers Laboratory (LMTS), Neuchâtel, Switzerland
(2) The University Of Auckland, Auckland Bioengineering Institute, Biomimetics Lab, Auckland, New Zealand

Presentation given by Mr. Samuel Schlatter

We present a fully drop-on-demand (DoD) printed dielectric elastomer actuator (DEA) to illustrate the benefits of digital fabrication. Silicone DEAs are typically fabricated by first casting or spin coating an elastomer membrane, followed by patterning the electrodes on the surface of the membrane. This approach produces high quality membranes; however the continuous membrane heavily limits design freedom as the electrical connections between the layers have to be made externally. With DoD printing the membrane can be patterned and the electrical connections can be integrated to create multi-layer devices consisting of many interconnected transducers. In addition, DoD printed DEA reap the benefits of digital fabrication such as: high resolution patterning, good reproducibility, rapid prototyping, and the possibility to print thin and fragile layers given that DoD is a non-contact printing method. To demonstrate some of these advantages we have printed a DEA, layer by layer, which can be used for characterisation. The DEA consists of 6 layers of UV curable silicone, and carbon black based electrodes. The dielectric membranes are approximately 3 micrometres thick, producing a DEA which can be actuated at low voltages (

1.2.14 Binary silicone elastomeric systems with stepwise crosslinking as a tool for tuning electromechanical behaviour

Adrian Bele (1), Lyiun Yu (2), Maria Cazacu (1), Carmen Racles (1), Anne Skov (2),
(1) "Petru Poni" Institute Of Macromolecular Chemistry, Department Of

Inorganic Polymers
(2) Technical University Of Denmark, Department Of Chemical And Biochemical Engineering, Danish Polymer Centre

Presentation given by Mr. Adrian Bele

Interpenetrating polymer networks (IPNs) represent an interesting methodology for tuning the properties of silicone elastomers due to the possible synergism that may arise between the two networks. A new approach is presented, which consists of mixing two silicone-based networks with different crosslinking pathways, the first network being cured by condensation route and the second network by UV curing. The networks were mixed in different ratios and the resulted samples yield good mechanical properties (moderate elongations, 100 - 250 %, and reduced Young's modulus, 0.03 MPa), thermal properties (one glass transition temperature, ~-123 degrees Celsius), good dielectric strength (40 - 60 kV/mm) and actuation/energy harvesting properties (estimated from figures of merit).

1.2.15 Assembling and comparative evaluation of stacked actuators based on different active elements

Codrin Tugui (1), Maria Cazacu (1),

(1) Inorganic Polymers Department, Petru Poni Institute Of Macromolecular Chemistry, Iasi, Romania

Presentation given by Dr. Codrin Tugui

In the last decade, dielectric elastomer actuators (DEAs) have been extensively studied mainly due to their wide range of applications. Four types of multilayer stacked circular membrane actuators were successfully obtained using different dielectric layers (silicone and acrylic) and electrodes (carbon black powder and in house prepared rubber electrode). Both dielectric and electrode membranes were investigated in terms of morphology, as well as the mechanical and electrical properties. Actuation measurements were performed on both single layer and multilayer stacked actuator. Moreover, to test the actuators effectiveness for high power applications, the maximum output force of each DEA was measured. The results were critically analyzed to identify the optimal actuator configuration.

Session 1.3

(abstracts are listed in the order of presentation)

1.3.1 High performance dielectric elastomer membrane actuator design

Steffen Hau (1), Stefan Seelecke (1),

(1) Saarland University, Department Of Systems Engineering / Department Of Material Science And Engineering, Saarbruecken, Germany

Presentation given by Mr. Steffen Hau

Dielectric elastomer actuators (DEAs) feature high energy efficiency, light weight, design flexibility and the use of low cost materials and processes. This holds particularly true for membrane actuators, which, in addition to the dielectric elastomer comprise of a separate biasing system. The particular design of the biasing system may dramatically improve the DEA performance, but at the same time, it adds complexity to such a design process. Therefore, in this work, a systematic design approach to adopt DEA systems to specific applications is developed. It allows to calculate all relevant design parameters and incorporates experimentally validated scaling laws to account for actuator geometry effects. Finally, the capability of the design process is illustrated by two examples. In the first one, the force output of circular membrane DEAs, which is typically in the hundreds of millinewton range, is increased by more than two orders of magnitude. For the first time record-high forces of 100 Newton are generated, while an innovative overall system design maintains compactness. The second system is designed for high reversible actuation strains in the range of >50%. The use of silicone as elastomer additionally results in high speed actuation. DEA systems with such outstanding performance prove that they are capable to compete with existing technologies such as solenoids, while adding additional functionality and, in the future, smartness through "self-sensing" properties.

1.3.2 Conducting polymer thin films: soft actuators/sensors in biorobotics and ultraconformable skin contact interfaces for bioelectronics

Francesco Greco (1) (2) (3),

(1) Graz University Of Technology, Institute Of Solid State Physics, Graz, Austria
(2) Waseda University, School Of Advanced Science And Engineering, Tokyo, Japan
(3) Istituto Italiano Di Tecnologia, Center For Micro-BioRobotics, Pontedera, Italy

Presentation given by Dr. Francesco Greco

Conjugated polymers, with their unique combination of tunable functional properties, offer several possibilities for the development of novel smart and active materials with applications in micro and biorobotics, as well as in biomedicine. In particular, poly(3,4-ethylenedioxythiophene) : polystyrene sulfonate (PEDOT:PSS), due to its availability as a waterborne dispersion, is amenable to several deposition and fabrication processes onto various substrates. Thanks to these features, by combining PEDOT:PSS thin films with other passive or active polymer layers it is possible to investigate new paradigms for soft actuation/sensing as well as to develop new biointerfaces. In this presentation I review some recent researches of my groups on: I) Smart (electro)active materials for actuators/sensors; II) conducting polymer nanosheets/ultraconformable skin-contact electrodes and organic bioelectronics. First, I report about bilayer actuators at different scales/thicknesses in which PEDOT:PSS was used in combination with other polymers and with several different fabrication and patterning techniques. Then, conducting polymer free-standing nanosheets prepared by spin-coating or R2R techniques and inkjet-printed temporary tattoo electrodes are introduced.

1.3.3 Additive Manufacturing of Soft Robots

Shuo Li (1), Robert Shepherd (1)

(1) Cornell University, USA

Presentation given by Shuo Li

This talk will present multidisciplinary work from material composites and robotics. We have created new types of actuators, sensors, displays, and additive manufacturing techniques for soft robots and haptic interfaces. For example, we now use stretchable optical waveguides as sensors for high accuracy, repeatability, and material compatibility with soft actuators. For displaying information, we have created stretchable, elastomeric light emitting displays as well as texture morphing skins for soft robots. We have created a new type of soft actuator based on molding of foams, new chemical routes for stereolithography printing of silicone and hydrogel elastomer based soft robots, and implemented deep learning in stretchable membranes for interpreting touch. All of these technologies depend on the iterative and complex feedback between material and mechanical design. I will describe this process, what is the present state of the art, and future opportunities for science in the space of additive manufacturing of elastomeric robots.

Session 1.4
(abstracts are listed in the order of presentation)

1.4.1 Insight into the dielectric breakdown of elastomers

Justina Vaicekauskaite (1) (2) (4), Piotr Mazurek (1) (2) (4), Liyun Yu (1) (2) (4), Anne Ladegaard Skov (1) (2) (4),

(1) Technical University Of Denmark
(2) Danish Polymer Centre
(3) Copenhagen
(4) Denmark

Presentation given by Ms. Justina Vaicekauskaite

Nowadays, dielectric elastomers are used in many different fields, such as:dielectric or transport layers, modern devices or flexible electronics. To test dielectric elastomer stability in electric field, dielectric breakdown measurements are used. These measurements have been used over many years and still gaining on importance, however, fundamentals behind the electrical breakdown of thin and elastic films are still not fully understood. There are only few theoretical models that assess the physical processes occurring during a breakdown phenomenon, for example: the hole-induced breakdown model, the electron-trapping breakdown model, the resonant-tunneling-induced breakdown model and the filamentary model. In all these theories, electrons movements from electrode to polymer film samples are considered. Other theory is the, so-called, electro-mechanical model, which implies that polymer films are not always smooth, and when an electric field is applied, the force gets bigger at the thinnest spot of the film, which causes the deformation of a film. Subsequently, when electric strength is reached at the thinnest spot - breakdown occurs. This is also referred to electro-mechanical instability (EMI) and has been extensively studied by modelling. In this work, microscopic processes taking place during the dielectric breakdown were captured using high-speed camera, to verify if the

time-scale and behavior of the electrical breakdown can elucidate the underlying behavior.

1.4.2 Stretchable and highly conductive composites for 3d printing

Kazumasa Marumo (1), Kudo Kazuki (1), Hidenori Okuzaki (1),

(1) University Of Yamanashi, Graduate Faculty Of Interdisciplinary Research

Presentation given by Mr. Kazumasa Marumo

Flexible and stretchable composites of conducting polymers with thermoplastic polymers are of great advantages for 3D printable sensors and actuators. However, PEDOT:PSS, commercially available conducting polymer as a water dispersion, is hard to dissolve in organic solvents to composite with various thermoplastic polymers. Recently, we have synthesized highly conductive PEDOT derivative self-doped with an alkylsulfonic acid side chain bound to the ethylenedioxy ring (S-PEDOT) which is soluble in various organic solvents. In this study, composites of the S-PEDOT with a TPU were fabricated and electrical and mechanical properties were investigated. It was found that electrical conductivity of the S-PEDOT:TPU composites linearly increased in proportion to the volume fraction of the S-PEDOT and the value was 26 siemens per centimeter at the volume fraction of S-PEDOT is 7.9 volume percent. According to the percolation theory, the percolation threshold and critical exponent of the S-PEDOT:TPU composites were 1.0 volume percent and 1.11, respectively. On the other hand, mechanical properties of the composites were performed by a tensile test, where Young's modulus, tensile strength, and elongation at break at the volume fraction of S-PEDOT is 7.9 volume percent were 0.3 gigapascal, 41 megapascals, and 330 percent, respectively. Furthermore, conductive filaments were fabricated by extruding the S-PEDOT:TPU composite for the application to the 3D printing.

1.4.3 Tailorable polymer gel electrolytes with reactive surfaces from thiol acrylate Michael reaction for ionic actuator

Yong Zhong (1), Giao TM Nguyen (2), Cédric Plesse (2), Frédéric Vidal (2), Edwin W.H. Jager (2),

(1) Sensor And Actuator Systems (SAS), Department Of Physics, Chemistry And Biology (IFM), Linkoping University, Linkoping, Sweden
(2) Laboratoire De Physicochimie Des Polymères Et Des Interfaces, Institut Des Matériaux, Université De Cergy-Pontoise, Cergy-Pontoise Cedex, France

Presentation given by Mr. Yong Zhong

A new family of solid gel electrolytes for electrochemical devices such as actuators was synthesized from a mixture of poly(ethylene glycol) diacrylate, multifunctional thiol cross-linker, and triethylamine in the presence of ionic liquid using thiol acrylate Michael addition chemistry. Polymerization kinetic studies show that the ionic liquid not only acts as an ion source for the gel electrolyte but also as a co-catalyst for polymer network formation. The high functional group conversion and 1: 1 stoichiometric nature of the thiol acrylate Michael addition together with the use of multifunctional thiols allow us to easily prepare solid polymer electrolyte with tailorable reactive surface and excellent mechanical properties. By taking advantage of the off-stoichiometry approach, solid gel electrolyte films with reactive surfaces have been prepared. Complex 3-dimensional structures were constructed by bonding flexible gel electrolyte films with the reactive surfaces together using the gel electrolyte precursor solution as an ionic conducting adhesive. A special tube actuator with PEDOT-PSS patterned on inner and outer tube wall was further prepared to illustrate the potential of these solid polymer electrolytes with reactive surfaces. All in all, this thiol acrylate Michael chemistry provides a platform to prepare various forms (films, micropatterns, 3-dimensional structures, and adhesive) of solid polymer electrolytes.

1.4.4 Natural sodium bentonite - a filler with unexpected effects on silicones

Mihail Iacob (1), Vasile Tiron (2), Codrin Tugui (1), Mihaela Dascalu (1), Maria Cazacu (1),

(1) Petru Poni Institute Of Macromolecular Chemistry, Iasi, Romania
(2) Alexandru Ioan Cuza University Of Iasi

Presentation given by Dr. Mihail Iacob

Natural sodium bentonite powder was used as filler for silicone in which it was

incorporated up to 100 wt%. The resulted nanocomposites were processed as films, which were stabilized by room temperature crosslinking. The morphology of resulted composite films was analyzed by scanning electron microscopy on cryo-fractured cross-section, while thermal properties were evaluated by thermogravimetric analysis and differential scanning calorimetry. Mechanical and dielectric measurements reveal that bentonite incorporated in increasing amounts act both as reinforcing filler and dielectric permittivity enhancer for silicone. Unexpectedly, it has been found that the presence of bentonite induces a remarkable piezoelectric response, much higher than polyvinylidene fluoride, which is one of the most used flexible materials in piezo-electric studies and applications.

1.4.5 Development and characterization of conductive silicone rubber for electro active polymer generators

Johannes Ziegler (1), Detlev Uhl (1), Kerstin Heinrich (1),

(1) Fraunhofer Institute For Silicate Research ISC, Center Smart Materials, Wuerzburg, Germany

Presentation given by Mr. Johannes Ziegler

This work investigates the development and characterization of conductive silicone rubber for the use in electro active polymer generators. The electrical resistance inside the thin elastomeric electrode has to stay almost constant during operating time. Two different silicone binders with various crosslinking densities have been developed to investigate the disparate behavior during dynamic cycle stress. Carbon black is incorporated to ensure good electrical resistance. Crosslinking density is derived by measuring Shore A hardness and the dissipation factor inside a dynamic mechanical test. Material D1-2 with a Shore A hardness of 27 and a dissipation factor of 0.320 and Material D2 with Shore A hardness of 42 and a dissipation factor of 0.032 have been examined. For testing, a 3 layered sample is prepared, the developed conductive silicone layer in the middle, covered by commercial silicone material. The high mechanical stress is simulated with an eccentric engine to create a linear motion with sinusoidal excitation at a frequency of 5 Hz. The samples are clamped with a preload of 10 % and become stretched to a maximum of 110 % elongation. Silicone material D1-2 shows an increase of resistance of nearly 476 % over one million cycles, while silicone material D2 shows only an average increase of 75

%. Thus, the damage inside the conductive layer depends on the crosslinking density of this layer and results in different resistance behavior after testing one million cycles.

1.4.6 Dielectric elastomer actuators operated below 300 V

Yauhen Sheima (1), Simon J. Dünki (1), Frank Nüesch (1), Dorina M. Opris (1),

(1) Empa, Functional Polymers, Dubendorf, Switzerland

Presentation given by Mr. Yauhen Sheima

Dielectric elastomer actuators (DEA) are promising devices with applications ranging from valves, pumps, braille displays, loud speakers, optical and energy harvesting devices, to artificial muscles. Acrylic and silicone elastomers are the most widely studied materials for DEA applications. They however require high driving voltage (above 1 kV) for actuation due to their rather low dielectric permittivi-ty. Polar silicones hold promise as dielectrics for DEA. By incorporating polar groups into polysiloxanes, we were able to prepare elastomers with dielectric permittivity above 18. Polar nitrile groups were grafted to polymethylvinylsiloxane by a thiol-ene reaction and the formed polymer was processed in thin films and cross-linked. This resulted in an elastomer which exhibits high permittivity values (above 20 at 10 kHz) and excellent elastic properties (tan delta<0.05 at frequencies below 1 Hz). Actuators constructed with 20 µm thick films gave a lateral actuation strain of 2-3% at 250 V. Additionally, cyclic tests show that the actuation is stable over 100.000 cycles. Furthermore, the actuators can withstand a very high electric field of 80 V/µm, where ultra large actuation was observed.

1.4.7 A novel self-sensing strategy for dielectric elastomer actuators allowing simultaneous estimation of displacement and force

Federica Fugaro (1), Gianluca Rizzello (2), David Naso (1), Stefan Seelecke (2),

(1) Department Of Electrical And Information Engineering, Polytechnic University Of Bari, Bari, Italy
(2) Department Of Systems Engineering, Department Of Materials Science And

Engineering, Saarland University, Saarbrücken, Germany

Presentation given by Dr. Gianluca Rizzello

In this work, we presents a novel self-sensing strategy for dielectric elastomer (DE) membrane actuators. The proposed self-sensing scheme permits the simultaneous reconstruction of membrane displacement and force during actuation, based on voltage and current measurements only. The new method allows, in principle, to implement interaction control strategies without the need for additional electro-mechanical transducers, thus it appears as highly suitable for soft-robotics applications. First, an online identification algorithm based on recursive least squares is implemented, and used to reconstruct DE capacitance and electrodes resistance from voltage and current measurements. Subsequently, mathematical models are developed to relate the available information (capacitance, resistance, voltage, and current) to membrane displacement and force, and used to design real-time estimators. Several modeling approaches are developed and compared, ranging from physics-based ones to black box models (i.e., fitting polynomials, Hammerstein-Wiener models, and neural networks), in order to evaluate which strategy leads to the most accurate estimation. After discussing the complete self-sensing algorithm, several experiments are performed on a cone DE membrane in order to assess the effectiveness of the proposed method.

1.4.8 Carbon polymer composite based motion system

Sunjai Nakshatharan S (1), Andres Punning (1), Urmas Johanson (1), Alvo Aabloo (1),

(1) Intelligent Materials And Systems Laboratory, Institute Of Technology, University Of Tartu, Estonia

Presentation given by Mr. Sunjai Nakshatharan Shanmugam

The ionic electroactive polymer (IEAP) actuators based on carbon-polymer composite (CPC) are the type of smart material capable of generating large deformations on the application of a small potential across the electrodes. Unlike traditional ionic polymer metal composites (IPMC), these CPC actuators with ionic liquid as an electrolyte are capable of operating in an open-air environment for a longer period of time. These aspiring characteristics put forward these

actuators to be a promising candidate for replacing traditional actuators in micro-actuation applications. In this work, we propose to design, fabrication and modeling of a novel multi-degree of freedom motion platform based on CPC actuators. The platform is fabricated as a single structure with appropriate masking followed by slicing to required size and shape. The proposed system is highly dexterous and is capable of generating three different motion namely tip, tilt and piston motion. The experiment results have demonstrated high levels of manipulability from the CPC actuators that are outstanding in the class of soft ionic actuators while keeping the fabrication method simple, scalable and cost-effective.

1.4.9 Fatigue life of dielectric elastomer

Claire Jean-Mistral (1), Simon Chesné (1), Georges Jacquet-Richardet (1), Alain Sylvestre (2),

(1) Univ Lyon, INSA-Lyon, CNRS UMR5259, LaMCoS, F-69621, France
(2) Univ. Grenoble Alpes, CNRS, Grenoble INP, G2Elab, Grenoble, France

Presentation given by Dr. Claire Jean-Mistral

For energy scavenging applications, estimating fatigue life of dielectric elastomer is as crucial as computing the amount of scavenged energy. Thus, we present here a prediction of fatigue life of silicone dielectric elastomer (Elastosil 2030) based on crack growth approach. The power-law between the crack growth rate and the tearing energy was estimated through experiments on pure shear specimens. Thanks to this power-law, estimation of the fatigue life for pure shear specimens and edge crack specimens subjected to an initial intrinsic defect are conducted. Sample geometry (pure shear or edge) and mechanical quantities (tearing energy, elastic energy) significantly impact the estimation of fatigue life. Indeed, the power-law is the core of the crack growth approach and must be carefully defined for each dielectric material. Finally, estimations of fatigue life combined with scavenged energy density, calculated thanks to our thermodynamic modelling, are computed in a context of energy scavenging applications in order to compare and help choosing the best promising DE material.

1.4.10 Low voltage dielectric membrane actuators integrated into fast switching electronic circuit boards

Tobias Pointner (1), Sven-Oliver Seidel (2), Michael Wegener (2),

(1) Festo AG & Co. KG, Advanced Basic Technology, Esslingen Am Neckar, Germany
(2) Fraunhofer IAP, Sensors And Actuators, Potsdam-Golm, Germany

Presentation given by Mr. Tobias Pointner

In high-tech companies operating worldwide innovation is the key driver for long-term market success. Hence innovative engineering technologies not only provide technological challenges but also investment risks for decision makers in product development. Thus, the typical high operating voltage of dielectric elastomer actuators (EAP) as well as necessary high voltage power supplies constitute physical and psychological restrictions. Therefore, based on the view of product integration we aimed to limit the applicable voltage below 600 V. Regarding this requirement our development addressed two aims: (i) the implementation of EAPs in a membrane-actuator concept in order to use the actuators at lower voltages and (ii) development of low-cost power supplies in order to provide the required voltages. Compression fittings clamping the EAP-film enabling a simple electric contact between the actuator and the circuit board. The prefabricated actuator module was integrated in a fast switching, low-cost electronic circuit board which generates up to 550 V in a slew rate of a few micro seconds. A plunger connected to the EAP-film moves out of plane when the actuator is activated. With the use of magnets, interacting with the plunger, the system can be enhanced to meet industrial requirements in force and stroke. The resulting "embedded" system offers a platform for further applications in different industrial segments for instance in automation with valves, grippers or micro pumps.

1.4.11 Catalytic micromotor based on MnO2 : facile fabrication and toward chemotactic application

Eswaran Murugasen (1), Jalal Ghilane (1), Hyacinthe Randriamahazaka (1),

(1) ITODYS,University Paris Diderot, Sorbonne Paris Cite,Paris, France

Presentation given by Mr. Eswaran Murugasen

The chemically powered, autonomous micro- and nano-motors are vital components in wireless miniature functional devices. The self-propulsion is mainly attributed to the conversion of chemical energy of fuel into mechanical force in the form of motion and this motion is due to either chemical gradient or bubble formation at the solid-liquid interface. However, the main obstacle for the propulsion of micro objects in liquid are the domination of viscous forces and Brownian motion, so the careful fabrication and propulsion methods are crucial. Herein, we are reporting a wireless, self-propelling flexible electrode based micromotor that is fabricated by polymer assisted electroless metal deposition (PAMD) process of nickel on Nafion membrane. The MnO2 is electrodeposited within a porous polyaniline matrix which is previously electropolymerized onto the nickel flexible electrode. Here PANI acts as both stabilizing agent for MnO2 nanoparticles and redox buffer during the reaction between MnO2 and H2O2. MnO2 can decompose spontaneously H2O2 to oxygen and water in phosphate buffer with different pHs ranging from 5.5 to 13 and showing mobility based on bubble propulsion mechanism. The detailed fabrication procedure and mechanism behind the self-propulsion and the speed of the MnO2 micromotor increases with concentration of fuel and the influence of shape of micromotor on its speed will be presented. Finally, the potential application towards chemotaxis will be discussed.

1.4.12 Operation glove with different dielectric elastomer sensors

Holger Boese (1), Simon Stier (1), Maximilian Thuy (1),

(1) Fraunhofer Institute For Silicate Research ISC, Center Smart Materials (CeSMa), Wuerzburg, Germany

Presentation given by Dr. Holger Boese

Dielectric elastomer sensors are generally used to detect the deformation of an elastomer with a capacitive measuring principle. Beside the known stretch sensors, sensitive pressure sensors based on dielectric elastomers have been developed as well. Moreover, another type of dielectric elastomer sensor arises from two elastomer electrodes which approach each other working as a proximity sensor. In this contribution, a novel glove equipped with all of these three types of dielectric elastomer sensors is introduced. The sensors attached to the fingers of the glove serve as operating tools for the control of various technical functions such as the brightness of a light source or the loudness of a speaker. They consist of silicone elastomer dielectric layers and electrode layers prepared with silicone elastomer containing carbon black particles. Stretch sensors detect the bending of fingers, where the bending angle is the steering quantity of the technical function. A pressure sensor on the thumb compressed by another finger may be used for corresponding control tasks. Finally, proximity sensors distributed on different fingers detect the approach of the fingers and can be used as switches. The operation glove exploits the versatile skills of the human hand to execute finger motions in numerous degrees of freedom and to carry out quite complex operation tasks. By this way, it can serve as a wearable human-machine interface.

1.4.13 Electrical breakdown test setup for dielectric elastomers: design and first test results

Bettina Fasolt (1), Felix Welsch (2), Stefan Seelecke (2),

(1) Intelligent Materials Systems Lab, Center For Mechatronics And Automation Technologies (ZeMA) GGmbH, Saarbruecken, Germany
(2) Intelligent Materials Systems Lab, Department Of Systems Engineering, Department Of Materials Science And Engineering, Saarland University, Saarbruecken, Germany

Presentation given by Ms. Bettina Fasolt

Dielectric Elastomers (DEs) represent an attractive technology in the field of electromechanical transducers, and allow the realization of low cost actuators and sensors. DEs consist of a thin elastomer membrane with flexible electrodes printed on external surfaces, resulting in a stretchable capacitor. The actuator performance strongly depends on the material properties of the membrane, especially permittivity and breakdown field strength. In order to characterize and quantify the transduction properties of the materials, a reproducible testing method is required. This work presents a novel test stand which allows to investigate the electrical breakdown in dielectric elastomer films under different environmental conditions. Exchangeable electrode tips allow the investigation of different electric field distributions induced by the electrode geometry. Mechanical contact with the film surface is ensured for films of various thickness, allowing to test different membranes in a repeatable way, as well as to study the influence of the contact pressure on the electrical breakdown field strength. In order to characterize the film under different environmental conditions, the test stand is located in a climate chamber with controlled temperature and humidity. After presenting the experimental setup, the influence of several parameters on electrical breakdown is investigated. Tested parameters include electrode geometry, film thickness, contact pressure, temperature, and humidity.

1.4.14 Simulation of thermal breakdown in a multi-layered stack of dielectric elastomers

Line Riis Madsen (1), Ole Hassager (1), Anne Ladegaard Skov (1),

(1) DPC, Department Of Chemical And Biochemical Engineering, Technical University Of Denmark

Presentation given by Ms. Line Riis Madsen

Several aging mechanism are prone to occur during operation of dielectric elastomers. Some breakdown mechanisms are somewhat instantaneous, such as electrical, electro-mechanical and thermal breakdowns, while others are slow in order of hours, such as electrical and water trees. One of the most significant aging mechanisms is thermal breakdown, which increases its frequency significantly when stacking multiple layers of dielectric elastomers. Thermal breakdown occurs due to build-up of heat within the stacked dielectric elastomer. Heat is generated mainly through Joule heating, and if the heat generated exceeds the heat loss at the surface of the stack, the temperature will increase exponentially and a thermal breakdown is likely to occur. Thermal breakdown may happen either locally or macroscopically. The focus of our work is to obtain a better understanding of thermal breakdown in a multi-layered stack of dielectric elastomers. This we obtain by performing numerical simulations in COMSOL Multiphysics® where joule heating and deformation, due to an externally applied voltage, is combined. From the simulation results the importance of thermal breakdown has been examined, and furthermore it has been studied how various parameters affects the point of thermal breakdown. The material of interest is PDMS which is modelled using experimentally determined material parameters and using the Yeoh model as the hyperelastic material model.

1.4.15 Soft dielectric elastomer robots

Ernst-Friedrich Markus Henke (1) (2) (3), Sascha Pfeil (1) (2), Gerald Gerlach (1), Andreas Richter (2),

(1) TU Dresden, Solid State Electronics Lab, Dresden, Germany
(2) TU Dresden, Institute Of Semiconductors And Microsystems, Dresden, Germany
(3) The University Of Auckland, Auckland Bioengineering Institute, Biomimetics Lab, Auckland, New Zealand

Presentation given by Dr. Ernst-Friedrich Markus Henke

Multifunctional Dielectric Elastomer (DE) devices are well established as actuators, sensors and energy harvesters. Since the invention of the DE Switch (DES), a piezoresistive electrode that can directly switch charge on and off, it became possible to expand the wide functionality of dielectric elastomer structures even more. It is possible to couple arrays of actuator/switch units so that they switch charge between themselves on and off. One can then build DE devices that operate as self-controlled oscillators. With an oscillator one can produce a periodic signal that controls a soft DE robot. Now one has a DE device with its own DE nervous system. We have demonstrated a variety of components for autonomous soft robots without conventional electronics. The combination of digital logic structures for basic signal processing, data storage in dielectric elastomer flip-flops and digital and analogue clocks with adjustable frequencies, made of dielectric elastomer oscillators (DEOs), puts us in the position to design self-controlled and electronics-free robotic structures. The last remaining stiff structures in DE robotic structures were stiff PMMA frames to maintain necessary pre-strains to enable sufficient actuation of dielectric elastomer actuators (DEAs). Here we present a design and production technology for a first robotic structure consisting only of soft silicones and carbon black. We present different promising designs for entirely soft DE-driven robots.

EuroEAP Society Challenge Projects

(listed in the order of presentation)

N.	Project title	Last Name	First Name	Institution
1.	SMARTLE-SMARt throtTLE system for motorcycle applications	Guarino	Roberto	University of Trento, Italy
2.	Acoustic energy harvesting through membrane resonators	Isotta	Eleonora	University of Trento, Italy
3.	DE technology Demonstrator	Linnebach	Philipp	University of Saarland, Germany
4.	Visuo-Haptic Display enabled by soft actuators (ViHDESA)	Yu	Chan Jun	University of Nanyang, Singapore
5.	Compliant electroactive micromanipulators for scanning electron microscopes	Aablo	Alvo	University of Tartu, Estonia
6.	Haptic Feedback Demonstrator for Touchscreens	Loew	Philipp	Unversity of Saarland, Germany
7.	Dielectric Elastomer Loudspeaker	Bruch	Daniel	University of Saarland, Germany

Wednesday, 6 June 2018

General programme of the day

Plenary Talk	Session 2.1 part I *Chair: Claire Jean-Mistral, INSA-Lyon, France*	
	9:00-9:30	**Xuanhe Zhao** Massachusetts Institute of Technology, USA
Invited Lectures	Session 2.1 part II *Chair: Xuanhe Zhao, MIT, USA*	
	9:30-9:50	**Kathlin Rohtlaid** University Cergy-Pontoise, France
	9:50-10:10	**Helmut F. Schlaak** Technische Universität Darmstadt
Break	10:10-10:30	Coffee break
Interactive Talks	Session 2.2 *Chair:Francesco Greco, TU Graz, Austria*	
	10:30-11:30	**Oral presentations** 15 presentations of research activities (3 minutes each + 1 minute to change speaker)
	11:30-12:30	**Posters & exhibitions** 15 posters
Lunch	12:30-14:00	Lunch
Invited Lectures	Session 2.3 *Chair: Steffen Hau, Saarland University, Germany*	
	14:00-14:20	**José Martinez** Linköping University, Sweden
	14:20-14:40	**Michele Ghilardi** Queen Mary University of London, UK
	Session 2.4	

Interactive Talks	*Chair: Hidenori Okuzaki, U. of Yamanashi, Japan*	
	14:40-15:40	**Oral presentations** 17 presentations of research activities (3 minutes each + 1 minute to change speaker)
	15:40-16:40	**Posters & exhibitions** 17 posters (coffee served during the cession)
EuroEAP Society Challenge awards	16:40-17:00	Annoucement of the first three classified teams of the Society Challenge 2018 award and presentation of the descriptive videos
Best poster awards	17:00-17:20	Announcement of the winner of the best poster award (Sponsorised by Solvay)
Closing ceremony	17:20-17:30	Conference closure, handover to the next year's chairperson and presentation of the next year's conference place
EuroEAP Society Annual meeting	17:30-18:30	Annual meeting of the EuroEAp Society – open to everyone
Social dinner	19:30	Departure to the Social dinner Dining cruise – Lyon City Boat

Session 2.1
(abstracts are listed in the order of presentation)

2.1.1 Ferromagnetic 3D Printing of Untethered Fast-Transforming Soft Robots

Xuanhe Zhao (1),

(1) MIT

Presentation given by Dr. Xuanhe Zhao

In this talk, we will highlight MIT SAMs Lab's recent development of soft robots based on magneto-active polymers that can potentially perform various tasks inside human body. The soft robots are constructed by 3D printing of a new biocompatible magneto-active polymer into various structures. Our approach is based on direct ink writing of an elastomer composite containing ferromagnetic microparticles, a method named as ferromagnetic 3D printing. By applying a magnetic field on the dispensing nozzle while printing, we make the particles reoriented along the applied field to impart patterned magnetic polarity to printed filaments. This method allows us to theoretically and experimentally program ferromagnetic domains in complex 3D-printed soft robots, enabling a set of unprecedented functions including crawling, jumping, grasping and releasing objects, and transforming among various 3D shapes controlled by applied magnetic fields. The actuation speed and power density of our ferromagnetic 3D-printed soft robots with programmed ferromagnetic domains are orders of magnitude greater than existing 3D-printed active materials and structures. We will demonstrate a set of clinically relevant applications uniquely enabled by the ferromagnetic 3D-printed soft robots.

2.1.2 LbL based pedot:pss microactuators and microsensors

Kätlin Rohtlaid (1), Cédric Plesse (1), Giao T. M. Nguyen (1), Caroline Soyer (2), Eric Cattan (2), Frédéric Vidal (1),

Presentation given by Ms. Kätlin Rohtlaid

Conducting polymers (CPs) are functional materials that respond to external electrical stimulus and are able to generate reversible contraction and expansion which leads to changing the shape or the size of these materials. They are soft, lightweight, easily processed and manufactured which has made them attractive for actuator and sensor applications. The integration of electrical contacts to microfabricate self-standing microsystems has been a stumbling block in this field. The two distinct steps in realization of a microdevice are the optimization of the materials and finally the fabrication of a device. Microfabrication could enable a broad range of applications, but large strains and forces of these materials are essential to involve them in microelectromechanical systems (MEMS) or soft robotics. This work grounds on microfabrication of devices based on conducting interpenetrating polymer network (C-IPN) architecture and on their electromechanical characterization as microactuators and microsensors. The optimization of materials has been carried out with poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) based actuators, which were fabricated with Layer-by-Layer (LbL) process and micropatterned via laser ablation technique. The second part of the work describes the fabrication of self-standing PEDOT:PSS microdevices with two integrated electrical contacts.

2.1.3 Dielectric elastomer stack transducers towards industrialization - Technology and applications

Helmut F. Schlaak (1), Florian Klug (1), Florentine Förster-Zügel (1), Susana Solano-Arana (1), Holger Moessinger (1), Henry Haus (1),

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Presentation given by Prof. Helmut F. Schlaak

Dielectric elastomer stack transducers (DEST) consist of a multilayer stack of soft elastomer films covered with patterned compliant electrodes. The stack transducer layers act mechanically in series. Different material classes have been examined. Best results have been achieved with silicone for the dielectric due to low relaxation and low transition temperature and carbon powder for the electrodes. The stack transducer fabrication can be performed using additively cured fluid two-component silicone or prefabricated thin films covered by protective foils. The first stack actuators were fabricated by our spin-coating process where the electrodes are sprayed through shadow masks. Meanwhile for fluid film deposition slot and blade coating have been developed. The stacking of prefabricated films however is much more difficult; film lamination and film folding are automated but restricted in size. To pattern carbon powder electrodes on silicone films spraying, stamping, drop on demand and screen printing are in use. For industrialization sophisticated test and process control of many parameters has been developed as in-line breakdown field strength, thermal overheat at electrical feeding zones and lifetime investigation. A lot of promising applications with industrial impact have been demonstrated over the last decade for universal actuators for pneumatic valves, switches, active vibration damping and cancellation, haptic displays and user interfaces, pumps and valves.

Session 2.2

(abstracts are listed in the order of presentation)

2.2.1 Multilayered modified terpolymer actuator for next generation mirror

Kritsadi Thetpraphi (1), Pierre-Jean Cottinet (1), Minh Quyen Le (1), Gil Moretto (2), Jeff Khun (3), Jean-Fabien Capsal (1),

Presentation given by Ms. Kritsadi Thetpraphi

The novel semi-crystalline electroactive polymer (EAP) called fluorinated terpolymer P(VDF-TrFE-CFE) reaches large strain response to an electric field at low-frequency active actuators, and shows the highest level of conversion from electrical to mechanical energy. Thanks to its high dielectric permittivity (?r ~ 50) and high mechanical modulus. However, a large electrical field is required (E > 100 V/µm) to reach sufficient strain levels (> 2.0 %). In this work, the terpolymer P(VDF-TrFE-CFE) was doped with Diisononyl phthalate (DINP). This modified terpolymer shows a 5-fold increase of the strain (S33) under low applied electric field. In order to approach actuation performance at the same applying electric field, multilayered modified terpolymer, deposed layer by layer as a series of capacitors, depicted an increase of strain total from 0.5 % to 2.0 % with the sample 1 to 6 layers respectively under E = 10 V/µm. According to the project of "Hybrid dynamic structures for optical quality surfaces shape control", an extremely smooth surface and deformable mirror including smart remote sensing system are now still required for replacing the classical polished rigid glass. To achieve active surface shape control, force actuator-sensor fabricated from an optimized EAP will be integrated into the hybrid system. In addition, the modification we propose here is cheap, industrially used and greater than any conventional electroactive polymer.

2.2.2 Non-linear dynamic modeling of ultrathin conducting polymer actuators

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(3) LPPI, Institut Des Matériaux, Université De Cergy-Pontoise, Cergy Cedex, France

Presentation given by Mr. Ngoc Tan Nguyen

Trilayer ionic EAP actuators exhibit nonlinear electrical and mechanical properties as a function of their oxidation state making it more challenging to accurately predict their mechanical behavior. In this study, an analytical multi-physics model of the conducting polymer actuators is proposed to predict their non-linear dynamic mechanical behavior. To demonstrate the accuracy of the model, a trilayer actuator composed of a solid polymer electrolyte sandwiched between two poly(3,4-ethylenedioxythiophene) (PEDOT) electrodes was fabricated and characterized. This system consists of an electrical subsystem, an electro-mechanical coupling matrix, and a mechanical subsystem described by using a rigid finite element method. The electrical conductivity and the volumetric capacitance, an empirical strain-to-charge ratio, and Young's modulus of the actuator as a function of the PEDOT electrode charge state were also implemented into the model, using measured values. The proposed model was represented using a Bond Graph formalism. The concordance between the simulations and the measurements confirmed the accuracy of the model in predicting the non-linear dynamic electrical and mechanical response of the actuators. In addition, the information extracted from the model also provided an insight into the critical parameters of the actuators and how they affect the actuator efficiency, as well as the energy distribution including dissipated, stored, and transferred energy.

2.2.3 Screen the best ionic liquids for keratin dissolution by using COSMO-RS

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Process Engineering, Chinese Academy Of Sciences, Beijing, China;

Presentation given by Ms. Xue Liu

Wool keratin is a kind of degradable natural biopolymer and extensively used in the textile and biomedical fields. But keratin is hard to reuse because it is difficult to dissolve in conventional solvents. An increasing interest has been manifested in the use of ionic liquids (ILs) as solvents for dissolution of wool keratin due to their tuneable and excellent properties. However, it is nevertheless a challenge to identify the best ILs for keratin dissolution. Experimental measurement of all these systems is not practically feasible; hence a rapid and a priori screening method to predict the keratin solubility capacity for ILs is needed. Based on our previous work, we designed three models for describing wool keratin, and 462 ILs formed from 21 cations and 22anions were selected for evaluation of their ability to dissolve wool keratin by COSMO-RS. From the prediction results of logarithmic activity coefficients (ln?) of the three keratin models, it can be concluded that keratin dissolution capacity is mostly determined by the anion while the cation only has a moderate effect on the dissolution process. Ac?, Dec?, HCOO?, Cl?, BEN?, DMP?, DEP?, DBP?, TOS? and Br?with various cations studied in this work exhibited particularly good properties for keratin dissolution. The excess enthalpy calculations indicated that the main forces in the keratin dissolution in ILs are H-bonds, while the contribution of misfit forces and van der Waals forces are secondary.

2.2.4 PDMS/PEDOT:PSS electrothermal polymer actuators

Yukino Fujiwara (1), Masaki Sato (1), Takahiro Kondo (1), Naoya Katsuyama (1), Hidenori Okuzaki (1),

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Presentation given by Ms. Yukino Fujiwara

Soft and stretchable elastomers exhibiting rubber elasticity show contraction upon heating, which can be explained in terms of the "entropy elasticity". On the other hand, conducting polymers having high electrical conductivity can be applied to low cost, lightweight, and flexible organic electronics. In this study, novel electrothermal polymer (ETP) actuators composed of polydimethylsiloxane (PDMS) elastomer and highly conductive poly(3,4-ethylenedioxythiophene) doped with poly(4-styrenesulfonic acid) (PEDOT:PSS) were fabricated and electromechanical properties of the ETP actuators have been investigated. The PDMS/PEDOT:PSS films were fabricated by casting the water dispersion of the PEDOT:PSS (1 wt%) containing polyglycerin as secondary dopant and plasticizer on one side of the PDMS film (100 micrometers thick) under stretching by 80%. When the tensile stress is removed, the PEDOT:PSS film (10 micrometers thick) wrinkles without disconnection compliant to the large deformation of the PDMS film. Upon application of the electric field to the ETP actuator from both ends of the PDMS/PEDOT:PSS film (20 mm long, 5 mm wide), the electric current and surface temperature of the ETP actuator increased with increasing the applied voltage due to the Joule heating of the PEDOT:PSS electrode. Concomitantly, the ETP actuator under loading condition showed contraction due to the entropy elasticity of the PDMS film, where contractile strain under 0.6 MPa reached as high as 12.5% at 7 V.

2.2.5 An attempt to improve the performance of silicone dielectric elastomers through the filling strategy

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Presentation given by Dr. Mihaela Dascalu

Octakis(phenyl)-T8-silsesquioxane, phenyl-T8, was prepared ex-situ, well characterized and used as a potential voltage stabilizer silicone filler. Taking into account the crystalline nature of phenyl-T8, incorporation and good dispersion in the amorphous matrix is the main challenge of this study. Different percentages of phenyl-T8 were incorporated in increasing amounts in the silicone matrix by two strategies: a) mixing the matrix and filler in solution; b) dispersing the filler in the polymeric matrix by using a suitable surfactant working in organic medium. Films were cast from solution and stabilized by condensation crosslinking at the same time as solvent removal. The matured films were characterized in terms of morphology, thermal, mechanical, dielectric and actuation tests. The results were compared with those previously obtained on samples where phenyl-silsesquioxane structures were generated in-situ, directly in the polymer matrix.

2.2.6 Strategy in the choice of silicone composites to optimize the performance of dielectric elastomer generator

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Presentation given by Prof. Alain Sylvestre

Silicone elastomers work on a broad range of temperature, develop low chemical reactivity and low electrical conductivity leading to low mechanical and dielectric losses. For these reasons, silicone elastomers pick up the attention of the scientific community for the development of Dielectric Elastomer Generators (DEGs). The drawback of silicone elastomers is its low dielectric constant. Several methods were explored in order to enhance this dielectric constant, including the addition of high dielectric constant insulating particles, the mixing of conductive particles or the modification of the elastomer polarization via grafting of high polarizable side chain. From these approaches, the dielectric constant was increased but other parameters of the composite elastomers such as dielectric strength or elastic modulus can be degraded. The performances of silicone elastomers with improved dielectric constant have been well studied in the literature. However, there is no work to evaluate the real benefit of this approach for the improvement of the performances for DEGs. In this study, we attempt to model the variations of mechanical and electric parameters of three types of composites as a function of the dielectric constant enhancement. Based on our original laws, scavenged energy and efficiency of DEGs are computed according to thermodynamic models. A guide for the best strategy for the choice of the DEG material is then proposed for a desired specific energy to scavenge.

2.2.7 Actuation and blocking force of stacked nanocarbon polymer actuators

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Presentation given by Dr. Ken Mukai

We developed nanocarbon polymer (NCP) actuators based on carbon-nanotube (CNT) electrodes, which are a type of ionic EAP actuators. Our NCP actuators are operable in air at low applied voltage, and they achieve stability for more than 100,000 cycles. However, there are trade-off relations between the thickness of the actuator film (electrode and electrolyte) and bending displacement, speed, and force. In this presentation, we have developed stacked nanocarbon polymer actuators that are composed of several nanocarbon polymer actuator units and nonwoven fabrics as insulation layers. The nonwoven fabric prepared through electrospinning methods has extremely-low-density structures, which do not significantly prevent the motions of each nanocarbon actuator layer. With the excellent nonwoven fabric in hand, we can develop the stacked nanocarbon polymer actuator that shows both large bending motion and blocking force.

2.2.8 Finite element model of an ultrasoft pdms-based optical micromirror

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Presentation given by Mr. Philipp J. Mehner

Dielectric elastomers have a wide variety of applications in e.g. soft-robotics, microfluidics, force and pressure sensing. In this work, an ultrasoft dielectric elastomer setup is used for a micro-mirror application for low-cost laser development. The employed PDMS has an extremely low elastic modulus, which keeps the driving voltage under 100 V. However, the experimental investigations have shown that different shape configurations have been established for different electrode widths. But some of the shape deformations are not desirable for the targeted microcavity application. For a better understanding of the shape-change of the electrodes, a finite element model was developed to visualize and describe the measured behavior. We propose a finite element method implemented in ANSYS which utilizes coupled elements for accurate and time efficient simulation runs. In addition, a concept for the implementation of a depth-dependent, elastic stiffness is presented which recreated the shape configuration measured in the experiments. This approach helps to formulate novel design parameters to improve the development of dielectric elastomer actuators.

2.2.9 Dielectric elastomer based prototype of a mechanically resonating inchworm-like robot with unidirectional claws

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Presentation given by Mr. Luigi Calabrese

We present a proof-of-concept where a robot, actuated via a Dielectric Elastomer Actuator (DEA), simultaneously exploits both vibration and inchworm locomotion to move. The robot consists of an assembly of three components: a plastic beam able to store elastic energy upon deformation, a planar DEA and four clawed pads featuring asymmetric rigid steel bristles. In order to accumulate elastic energy, the thin plastic beam is highly bent upon assembly so that when coupled to the DEA, it composes a self-standing structure. From this configuration, owing to the capability of the DEA to

elongate upon application of a driving voltage V, we show that it is possible to increase the length of the structure when the voltage V is applied and to return to the original length when the voltage V is removed. In this way, by opportunely modulating the voltage, it is possible to exploit the asymmetric orientation of the bristles to trigger the unidirectional stick-slip locomotion of the robot. The fundamental frequency of the robot was estimated by using the Rayleigh method and locomotion tests were carried out at that frequency. We observed that when the actuation frequency of the DEA was close to the fundamental frequency of the structure, the measured locomotion speed exceeded by 25% the theoretical speed (calculated as the free stroke of the actuator times the actuation frequency), revealing the presence of a forward sliding triggered by the dynamic effects due to the resonance.

2.2.10 Ionic EAP actuators in minimally invasive healthcare products

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(2) Philips Research, Eindhoven, The Netherlands

Presentation given by Prof. Alvo Aabloo

At various times during the medical process, invasive procedures can be applied to the patient either for diagnostic or therapeutic reasons1. There is a global trend towards diagnostic and interventional medical devices become less invasive and the number of invasive procedures that are being replaced by non-invasive ones is increasing steadily over time. This results in a need for smaller devices with increased manoeuvrability in many types of minimally invasive devices such as for instance needles, endoscopes, endovascular devices and minimally invasive surgical tools. Ionic electroactive polymer (iEAP) actuators are a promising class of materials for soft robotics and biomedical applications. An iEAP bends in response to electrical stimuli and can be controlled remotely via the electrical input. Furthermore, iEAP actuators are soft and easily miniaturized, which makes them promising materials for actively navigating inside the body, especially inside complex and delicate blood vessel networks where vessels have a diameter of less than 1 mm. Here we show miniaturized compliant carbon-based iEAP actuators that could be applied in minimally invasive devices for active navigation. We anticipate this to be a good starting point for more sophisticated application of iEAPs that could in the future alter the course of minimally invasive diagnostics and treatment.

2.2.11 Auxetic structures for harvesting human kinetic energy

Marine FERRERE (1), Claire Jean-Mistral (1),

(1) Univ Lyon, INSA-Lyon, CNRS UMR5259, LaMCoS, F-69621, France

Presentation given by Ms. Marine FERRERE

Harvesting human kinetic energy to produce electricity is an attractive alternative to batteries for applications in wearable electronic devices and smart textile. Dielectric elastomers generators (DEGs) may represent a promising technology as they are lightweight, compliant, low-cost, and can develop high energy densities (up to 0,834J*g-1). Maximizing the energy scavenged with these DEGs requires maximizing the variation of capacity. Auxetic structures, namely structures developing a negative Poisson coefficient, can be the solution to design smart frames for DEGs. These structures allow converting a uniaxial deformation (as the one present on human body) into a biaxial one with a low embedded weight and size, and a control of the stress distribution, insuring the role of a performant mechanical extraction mechanism. Two different patterns of auxetic structures are modelled using FEM software, and compared to meet our specifications in terms of force and displacement. These soft frames are printed thanks to a 3D printer using Ninjaflex filaments. Finally, dielectric elastomer generator using this smart frame within a total area of 10cm per 2.5cm, and as thin as possible, is designed and output performances are compared to classic DEG.

2.2.12 Towards sustainable electroactive polymers

Kadi-Anne Küppar (1) (2), Kaija Põhako-Esko (1), Alvo Aabloo (1), Jonathan Rossiter (2),

(1) Intelligent Materials And Systems Laboratory, Institute Of Technology, University Of Tartu, Tartu, Estonia
(2) Bristol Robotics Laboratory, University Of Bristol, Bristol, United Kingdom

Presentation given by Ms. Kadi-Anne Küppar

Electroactive polymers have gained a great interest in science and since their integration in technology at an industrial scale is rising, it is important to take responsibility towards the impact of new technology on the environment. Developing electroactive polymers that are biocompatible and degradable will produce less emissions and exposes fewer risks towards the environment. In this work we take the first steps towards biocompatibility and degradability by conducting a series of experiments with such materials to produce an ionic polymer-metal composite. They consist of a polyelectrolyte between two flexible metallic electrodes. We use gelatine gels as the polyelectrolyte as its production is simple and inexpensive. Sodium chloride and ionic liquids are used as electrolytes. To preserve gelatine, we use glycerol and 1-ethyl-3-methylimidazolium acetate as a plasticiser. Mixing different percentages together enables to produce gels with variable stretch and durability. We conduct gelatine absorption test to understand the effect of plasticiser on the gel structure. The electrode materials are soft conductive fabrics and have low electrical resistance. We characterise the electrodes by looking at their weave patterns, fibre thicknesses and resistance change during stretch. We investigate methods of attaching the electrodes to the gel. Our goal is to make a composite where electrodes adhere well, and where these electrodes have the lowest conductivity for better actuation.

2.2.13 Polyoxometalate doped polypyrrole linear actuators

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(2) Ton Duc Thang University, Faculty Of Applied Sciences, Ho Chi Minh City, Vietnam

Presentation given by Ms. Zane Zondaka

Conducting polymer-based actuators show good displacement and actuation. The most commonly used polymer in the field of actuation is polypyrrole (PPy). Addition of dopants may improve the performance of polypyrrole-based actuators. Doping polypyrrole with polyoxometalates has shown improved linear actuation properties of polypyrrole freestanding film in aqueous electrolyte. Here we present our research on polypyrrole films doped with a different concentration of phosphotungstic acid. Polypyrrole freestanding films were synthesized electrochemically with the addition of 0.005M, 0.01M, and 0.05M phosphotungstic acid. Polyoxometalates' electrocatalytic nature has an influence on electropolymerization, as it lowers potential leading to better films. We performed the electrochemomechanical deformation experiments to evaluate the influence of phosphotungstate anion concentration on the linear actuation properties: stress and strain

2.2.14 Enhancing the electro-mechanical properties of polydimethylsiloxane elastomers through blending with poly(dimethylsiloxane-co-methylphenylsiloxane) copolymers

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Presentation given by Ms. Liyun Yu

Dielectric elastomers (DEs) hold great promise as materials for advanced electromechanical applications such as actuators, generators and sensors. Choosing the right polymer for the blending approach is of utmost importance to improve the properties of DEs. In this work, improved electromechanical properties of silicone-based dielectric elastomers are achieved by means of adding so-called "voltage-stabilisers" prepared from phenyl-functional copolymers prepared using oxyanionic ring-opening polymerisation of octamethylcyclotetrasiloxane (D4) and either tetramethyltetraphenylcyclotetrasiloxane (T4) or octaphenylcyclotetrasiloxane (O4). The concentration of the voltage stabiliser was varied both by changing the molar ratio between methyl and phenyl groups in the copolymer and also by varying the amount of copolymer mixed into a polydimethylsiloxane (PDMS)-based elastomer. The phenyl-functional copolymers were generally found to disperse homogeneously in the PDMS matrix and this resulted in networks with improved mechanical and electrical properties. The developed elastomers were inherently extensible with enhanced tensile and tear strengths, due to phenyl-rich microphases acting as reinforcing domains. Furthermore, addition of phenyl-functional copolymers resulted in elastomers with increased relative permittivity and electrical breakdown strength compared to control elastomers while retaining a low dielectric loss. This demonstrates their efficiency as voltage stabilisers.

2.2.15 Soft wearable non-vibratory tactile displays based on dielectric elastomer actuation

Hugh Boys (1) (2), Gabriele Frediani (1) (3), Michele Ghilardi (1), Stefan Poslad (2), James C. Busfield (1), Federico Carpi (3),

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(2) Queen Mary University Of London, School Of Electrical Engineering And Computer Science, London, UK
(3) University Of Florence, Department Of Industrial Engineering, Florence, Italy

Presentation given by Mr. Hugh Boys

This work presents recent progress on the development of a new type of wearable finger-tip tactile display aimed at providing electrically tuneable tactile stimuli for interactions with soft bodies. This is achieved by using hydrostatically-coupled dielectric elastomer actuation, capable of generating large and quasi-static displacements at moderate forces. This is intentionally different from the high-frequency small vibrations at high forces that are used in several state-of-the-art tactile displays. We describe the ongoing development of devices having a volume of 20x12x23 mm and weigh of only 6 g on finger, which can render electrically tuneable displacements of up to 3.5 mm and forces of up to 1 N.

Session 2.3
(abstracts are listed in the order of presentation)

2.3.1 Artificial muscles: reducing the gap with natural muscles

Jose G. Martinez (1),

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Presentation given by Dr. Jose G. Martinez

Humans, animals and plants are a source of inspiration for developing robots. Materials, devices and biomimetic systems and robots are being developed with similar properties to biological systems (e.g. appearance, movements, behavior). However, the components of most of them (even those called artificial muscles) are based on dry devices exploiting various physical phenomena. Actual robots need a motor to produce movement and different sensors to control that same movement. Humans and animals only have muscles. Here I will outlook artificial muscles imitating natural muscles, based on chemical reactions as natural muscles do. For the first time, artificial proprioceptive devices are being developed that move at a set rate or up to a set position while sensing mechanical (mass displaced), physical (temperature, applied current) and chemical variables (electrolyte concentration). All this valuable information is included in the only two connecting wires needed to close the electrical circuit. Despite these interesting properties, there is still room for improvement. As an example, it has been recently proposed to use textile structures to get alignment and synergetic effects between the different fibers mimicking the structure of fibrils in natural muscles.

2.3.2 Dielectric elastomer-based devices for optics, haptics and tissue engineering

Michele Ghilardi (1) (2), Hugh Boys (3), Leihao Chen (1) (2), Joana Costa (4) (5), James JC Busfield (1) (2), Federico Carpi (2) (6)

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Presentation given by Mr. Michele Ghilardi

Dielectric Elastomer Actuators (DEAs) are one of the most promising new soft actuation technologies. This talk will describe recent multidisciplinary efforts from our group to design and demonstrate new devices and systems based on this exciting new technology. The talk will tackle problems from different fields: from haptic display devices for tactile feedback in virtual reality environments, to electrically deformable bioreactors for tissue engineering, to the development of brand new tuneable optical components. We are looking to exploit the unique characteristics of DEAs to develop key innovations in soft mechatronics.

Session 2.4
(abstracts are listed in the order of presentation)

2.4.1 Encapsulation of ionic capacitive laminates: towards operation in fluids

Pille Rinne (1), Tarmo Tamm (1), Friedrich Kaasik (1), Urmas Johanson (1), Alvo Aabloo (1), Ron Hovenkamp (2), Marcel Mulder (2), Daan van den Ende (2),

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(2) Philips Research, Eindhoven, The Netherlands

Presentation given by Prof. Alvo Aabloo

Ionic electroactive polymer actuators (iEAP) move (e.g. bend) in response to electrical stimuli, which makes them promising materials for soft robotics and biomedical applications. The ability to operate safely in different environments (e.g. water or buffer) would make iEAPs available for an even larger number of applications. Leaching out of the electrolyte that drives the actuation, the electrolysis of water, and contamination are the three main concerns that make actuation in fluids challenging. One possible solution to enable precision operation in a variety of fluids would be encapsulation. However, this process needs to be compatible with the actuator manufacturing process and the resulting protective layer may not restrict the actuation performance. Encapsulation of carbon-based iEAPs has not been systematically investigated. Here we show encapsulation of carbon-based iEAP actuators in polydimethylsiloxane (PDMS) and its effect on actuation in liquids. We found that dip-coating iEAPs with PDMS dissolved in hexane or isooctane resulted in functional actuators that are covered with a thin protective film. Our result demonstrates the suitability of this encapsulation method and material for carbon-based iEAP actuators. We anticipate this result to be a starting point for testing carbon-based iEAPs for applications in different environments that have until now been considered not suitable, e.g. as active components interacting with biological fluids or tissue.

2.4.2 4D printing based electroactive polymer for smart of guide wire

Nellie Della Schiava (1) (2) (3), Minh-Quyen LE (1), Patrick Lermusiaux (1) (2) (3), Antoine Millon (2) (3), Jean-Fabien Capsal (1), Pierre-Jean Cottinet (1),

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Presentation given by Dr. Nellie Della Dchiava

Image-guided endovascular interventions have gained in popularity in clinical practice as they are greater efficiency and offer lower mortality rates compared to traditional open surgery. Most interventions today involve the use of flexible guide wires introduced into appropriate vessels under real-time X-ray imaging. However, the difficulty of steering and controlling the guide wire considerably increases the risks of complications. To deal with such problematics, several solutions based on organic polymers with large electromechanical response have been investigated on recent works. This research demonstrates the possibility of using electroactive polymers transducer for flexible cardiovascular tools, with steerable and haptic feedback properties. It has been demonstrated in study that the typical bending angles achievable by the developed guide wire varied from 20° to 90°, which is largely sufficient for most endovascular interventions. The proposed material and fabrication process is considered to be an excellent candidate for endovascular navigation thanks to its high flexibility and low current consumption. Furthermore, the developed electrostrictive polymer can be configured in both sensor and actuator configurations, making a possibility of force measure and control. Such characteristics are extremely interesting for performing a multifunctional medical tool integrated with haptic-feedback information.

2.4.3 Polysiloxanes modified with Disperse Red 1 forming stimuli responsive free-standing thin film

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Presentation given by Dr. Mihaela Dascalu

N-ethyl-N-(2-hydroxyethyl)-4-(4-nitrophenylazo)aniline (Dispersed Red 1, DR1), a molecule with high dipole moment was attached to polysiloxanes in two steps. First, thiol-ene addition of mercaptopropionic acid on vinyl-siloxanes was achieved, followed by direct condensation reactions with DR1 and dicyclohexylcarbodiimide as activator. The spectral characterization showed a complex structure of the final copolymers, which contain un-reacted carboxyl groups, DR1 and urea (DCU) molecules attached by H-bonding. The amount of DR1 in the modified polysiloxanes was 1.5 and 3 mol% (i.e. 5.7 and 10.1 wt%). Free-standing transparent thin films were obtained after cross-linking, with increased dielectric permittivity, high breakdown field and relatively poor mechanical properties. Lateral actuation strain of 8.7 % at 40 kV/mm was obtained for a film with 5.7 wt% DR1. The materials were also characterized by DSC, dynamic vapor sorption (DVS) and piezoelectric force microscopy (PFM), which allowed measurement of d33 piezoelectric coefficient.

2.4.4 New composite elastomers for soft wave energy converters

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Presentation given by Prof. Alain Sylvestre

Offshore wave energy converters (WECs) based on dielectric elastomer generators (DEGs) constitute a reliable solution to convert ambient mechanical energy into electricity. In order to improve the efficiency of WECs, one solution consists in the increase of the poor dielectric constant of the elastomer. In such a way, one can mix micro/nano particles inside the polymer matrix in order to obtain high dielectric constant. Unfortunately, the major drawbacks are linked to the fact that this higher dielectric constant is accompanied by a drastic increase in the dielectric losses and a collapse of the dielectric strength. One reason of that is the neighboring of particles inside the polymer matrix which promotes conducting paths and reinforcing fields at the interfaces. The main goal of our study was to develop original polymer composite dielectrics for WECs. For that, carbon nanotubes (CNT) coated with a polymer (parylene) were mixed with a silicone matrix (Dow Corning Sylgard 184). The evidence is unequivocal: uncoated-CNT polymer composites present a dielectric strength of 40 kV/mm against 85 kV/mm with coated (1% in weight)-CNT. In same time, the dielectric constant was 6.5 and 8 for the uncoated-CNT and coated-CNT respectively.

2.4.5 Study of the underlying mechanism of conducting polymer based strain sensors

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Presentation given by Dr. Cedric Plesse

Electronic Conducting Polymers (ECPs) have been widely studied in a tri-layer configuration as soft actuator. However these electroactive materials have been reported to behave as mechanical strain sensors able to convert mechanical stimulation into electrical signal. This sensing behavior is attributed to the so-called piezoionic effect and is observed and reported in most of ionic IEAPs. In this work, the sensor mechanism of trilayer ECP actuators is studied and discussed as a function of different physical and chemical parameters. For that, we studied the particular but representative case of ECP pseudo-trilayers combining (i) poly(ethylene oxide) (PEO) - Nitrile rubber (NBR) interpenetrating polymer network (IPN) and EMITFSI electrolyte as ionic conducting membrane, and (ii) poly(3,4-ethylenedioxythiophene) (PEDOT) electrodes interpenetrated within both faces of the membrane. These pseudo-trilayers, referred in the following as conducting IPNs, have been demonstrated to be robust IEAPs as well as downsizable using microsystem technics and to behave as mechanical strain sensors. Interestingly, the synthesis versatility of these materials is ideal to get a deeper understanding of the sensing behavior since it allows an easy tuning of parameters such as geometry, especially thickness, electrode nature as well as electrolyte nature.

2.4.6 Voltage-induced changes in optical transmission based on dielectric elastomer actuators

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Presentation given by Mr. Leihao Chen

Smart electrically tuneable optics is one of the most significant areas of interest for possible upcoming applications of dielectric elastomer actuators (DEAs). Here, we present our ongoing research on devices with variable optical transmission based on DEAs, consisting of transparent elastomer membranes sandwiched between nearly transparent electrodes. The electrode surfaces are made with crumpled patterns, by applying the electrodes to a prestretched membrane and partially reducing the prestrain. When the device is at electrical rest, the electrodes scatter light, thereby showing opacity. Then, voltage-induced surface expansions are used to flatten the corrugations, so as to increase the optical transmission. Therefore, light transmittance can be adjusted electrically. Such devices could be useful in electrically tuneable windows. In this work, planar DEAs made of flexible poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) electrodes spray coated on acrylic VHB films by 3M were used to electrically achieve a tunability of transmittance at 550 nm between 79% and 85%. Silver nanowires (AgNWs) were also mixed with PEDOT:PSS to increase light scattering, obtaining electrodes that showed an increase in tuning range from 68% to 76%, although at the expense of reduced transparency. In addition, we also explored devices with a stacked DEA configuration, obtaining lower transparency but broader tuning range between 58% and 69% for three VHB layers stacked together.

2.4.7 Lifetime performances of silicone-based dielectric elastomer transducers under cyclical electric-stress loading

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Presentation given by Dr. Lorenzo Agostini

Dielectric Elastomer Transducers (DETs) are deformable capacitors that can be used as sensors, actuators and generators. As compared to other transduction technologies, DETs presents attributes such as large energy and power densities, good resistance to shocks and corrosion; silent operation; low-cost. However, the general effectiveness of DETs for several practical application is strongly affected by their long-term performance. To date, very little knowledge and experimental results are available on the subject. In this context, this contribution reports on an extensive lifetime electric-stress test campaign conducted on a promising silicone film conceived and commercialized by Wacker Polymers specifically for DET applications. In order to test this material in close-to-operating conditions, frame-stretched specimens are manufactured using as dielectric layer the ELASTOSIL® Film 2030 by Wacker polymers of 0.150 mm in thickness and a mixture of carbon black and silicone for electrodes. Such specimens have been tested through a purposely designed experimental set-up and procedures. The acquired data are elaborated and presented, introducing statistical models that can be used to correlate lifetime and performance of DET specimens. Obtained results show promising response of this dielectric material to cyclical electrical-stress, with several samples subjected to electric field in the range of 70 - 80 MV/m that survived to millions of load cycles.

2.4.8 Energy harvesting with dielectric fluid transducers

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Presentation given by Dr. Giacomo Moretti

Dielectric fluid transducers (DFTs) are electrostatic devices which alternate solid compliant dielectric layers/electrodes with dielectric fluid layers, and they enable the conversion of electrical energy into mechanical work (and vice versa) through capacitance variations associated with a modification of their shape. Compared to other capacitive transducers, e.g., dielectric elastomer transducers, DFTs feature better tolerance to electrical break-down and larger ratio between converted energy and stored elastic energy. To date, practical DFT topologies have been proposed and demonstrated for both actuation and generation purposes, showing promising performance in terms of converted energy density and efficiency. This presentation provides an overview on operating principles, numerical modeling and experimental characterization of DFTs, with a particular emphasis on their employment as generators for energy harvesting applications.

2.4.9 Stretchable electrochromic polymer films for soft displays

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Presentation given by Ms. Claire Preston

Conducting polymers are well known for their actuation properties, but several of them also exhibit electrochromic properties, changing colour between their reduced and oxidized states. This offers the possibility of creating polymer-based electrochromic displays for integration into soft devices such as on-skin wearable electronics or robotic skin. Electrochromic displays have advantages over electroluminescent displays based on OLEDs or phosphors in that they offer lower power operation, higher stability and high contrast. Some of these polymers are flexible. Making them stretchable provides a challenge that researchers have approached by incorporating various elastomeric or ionic additives. We have investigated two approaches to stretchable films composed of electrochromic poly(3,4-ethylenedioxythiophene) (PEDOT) and additives comprising either an elastomer or ionic additive. We have demonstrated polyurethane-PEDOT composite films that exhibit high electrochromic contrast and stretchability up to 80%. Additionally, we have obtained high contrast and stretchability of approximately 15% in PEDOT:PSS films using ionic additives bis(trifluoromethane)sulfonimide lithium salt (LiTFSI) and 1-butyl-3-methylimidazolium octyl sulfate (BMIM OSU). In further studies, we have investigated how different additives affect the material conductivity, electrochromic and mechanical properties in application to stretchable displays.

2.4.10 Dynamic modeling approach for dielectric elastomer actuator systems

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Presentation given by Mr. Daniel Bruch

Dielectric Elastomers (DEs) represent an attractive technology for electromechanical transducers, which features high energy-efficiency, design flexibility and lightweight. Their possibility to be used as sensors, generators and actuators opens a wide range of applications. Membrane DE-Actuators (DEAs) are usually biased with mechanical elements, which need to be dimensioned precisely in order to obtain the desired performance. A quasi-static design approach based on force equilibriums is commonly used for the system design process. However, this approach neglects the system dynamics and may lead to oversized system designs, which are not suitable for some applications with limited installation space. Therefore, this poster presents an enhanced modeling approach for DEA-systems, which includes the dynamics by using energy considerations. Compared to the common quasi-static approach, it enables the design of slim and efficient DEA-systems. The modeling procedure is demonstrated by designing a strip-in-plane DEA-system, which is used to drive a load, which is represented by a force jump. For validation purposes, this system is characterized experimentally and the measurement results are compared to the dynamic model predictions. It is shown that the number of DEA layers can be significantly reduced, when considering the dynamics within the design process.

2.4.11 Characterization of pumping micromixers based on dielectric elastomer stack actuators

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Presentation given by Ms. Susana Solano Arana

In this work we consider a novel application of dielectric elastomer stack actuators (DESA): a pumping micromixer based on peristaltic movements, which acts as a mixer and a pump for microfluids. The proposed pumping micromixer is suitable for biomedical and pharmaceutical applications, due to the biocompatibility of its materials (PDMS and graphite). The pumping micromixer consists of two inlet chambers and a mixing chamber. The fabrication of the pumping micromixer with varying film thicknesses is done automatically in a continuous and scalable process. The pumping micromixer has been characterized between 1000 V and 1500 V at frequencies between 1 Hz and 10 Hz for rectangular and sinusoidal signals. The rectangular input signal proved to operate more effectively, with a maximal channel deformation of 180%. The mixing capability was successfully demonstrated using colorants.

2.4.12 Sensing properties of PPy/DBS films for artificial muscles

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Presentation given by Mr. Victor H Pascual

The idea of developing new technological devices that mimic the way in which living muscles work has always been in the mind of the scientists. Conducting polymers have proven to be materials whose way of working resembles that of the biological organs. Placed in an electrolytic solution and subjected to a reversible electrochemical reaction of oxidation-reduction there is a solvent molecules and ions exchange between the polymer and the electrolyte which

brings to mind the one occurring between the intracellular matrix and the cellular surroundings. Besides, as it happens with living muscles, these are real dual sensing/actuating systems, producing motion and detecting changes in the working conditions. One of these promising materials is the polymeric blend of polypyrrole/dodecylbenzene sulfonate (PPy/DBS). Having been some of its properties already studied. This work focuses on the study of two different sensing properties.

2.4.13 Innovative bioreactor based on dielectric elastomer actuation to dynamically stretch cells in vitro

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Presentation given by Dr. Joana Costa

Currently, most of the studies of cells in vitro are performed on traditional two-dimensional static cell cultures. However, their predictive efficacy for stretchable tissues, such as the lung, muscle or gastro-intestinal tissues, is limited by the lack of deformable substrates. Indeed, effective in vitro models of those tissues require mimicking the same mechanical cues to which cells are continuously exposed in their dynamic microenvironment in vivo. To address that requirement, we present here a modular bioreactor system based on an hydrostatically-coupled dielectric elastomer actuator (HC-DEA). The device was characterized in terms of electromechanical performance to determine its ability to achieve physiological strains and maintain long term stability in an incubator. Ultimately, the proposed bioreactor was tested with cultured fibroblasts exposed to cyclic stretching (stimulus of 4.5 kV at a frequency of 0.15 Hz) that provided a strain of around 5% to a cell substrate for 8 hours. The mechanical stimulation delivered by the HC-DEA was able to induce changes in the organization of the cells cytoskeleton showing a shift in cell behavior. The bioreactor is advantageously compact and easy to handle, and, unlike conventional pneumatic cell stretchers, it does not require additional external mechanical equipment.

2.4.14 Selective polymerization of polypyrrole by electron beam irradiation

Ben Holness (1), Andrew Cullen (1), Aaron D. Price (1),

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Presentation given by Mr. Ben Holness

The conjugated polymer polypyrrole (PPy) exhibits favourable actuation performance that is well suited for microelectromechanical systems (MEMS). However, PPy is traditionally synthesized via an electropolymerization process that limits its form to planar films or coatings. Recent work by the Organic Mechatronics and Smart Materials Laboratory has resulted in the development of a photosensitive PPy formulation that is compatible with light based additive manufacturing technologies which have enabled the production of 3D microscale PPy structures. This technique is particularly advantageous for conjugated polymer actuators since their actuation is dependent on the movement of ions. Therefore, smaller feature sizes create reduced ion diffusion distances, and the speed and power density of these actuators can be greatly increased. To further improve the performance of conjugated polymer devices this photosensitive PPy formulation has been adapted to enable polymerization under electron beam irradiation. The electrical conductivity and electromechanical activity of these devices have been compared to traditional fabrication techniques to demonstrate improved performance. This new polymerization method represents the development towards the fabrication of nanoscale actuators and a new frontier of potential MEMS and lab-on-a-chip applications.

2.4.15 Nanomaterials- and calix[n]arene-thin-film-coated surface acoustic wave sensor applications for volatile organic compounds detection

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Presentation given by Ms. Funda Kus

Many patients with diseases like asthma generate specific patterns of marker volatile organic compounds (VOCs) found in breath analysis that could potentially be helpful in the early diagnosis. Surface Acoustic Wave (SAW) devices are small size mass sensors that are capable of detecting mechanical changes in the surface and converting them into electric signals. The adsorption of VOCs to the SAW surface shifts the oscillation frequency of the transducer SAW device. Supramolecular chemistry has been of great interest for gas sensing applications since host-guest chemistry allows molecular selectivity, which provides better sensors for e-Nose applications. Calix[n]arenes, are considered important molecular receptors since the void with hydrophobic and hydrophilic regions create diffusion to trap gaseous vapours and the variety in their size make them specific to the analyte. Nanomaterials are also used as sensing materials due to their large surface to volume ratio that enables highly active interfaces. In our study, calix[n]arenes and nanomaterials are investigated as coating materials onto SAW surfaces. Thin film layer is acquired via electrospray deposition and is tested on VOCs like toluene, hexane, and acetone. Sensor responses of calix[4,6,8]arene derivatives and Ag/Au nanomaterials towards selected VOCs is discussed for various humidity and concentration levels. Sensitivity and selectivity is compared to previous studies on Quartz Crystal Microbalance (QCM) devices.

2.4.16 Fabrication of 3D Conjugated Polymer Structures via Vat Polymerization Additive Manufacturing

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Presentation given by Dr. Aaron Price

Conjugated polymers are a class of electromechanically active materials that can produce motion in response to an electric potential. This motion can be harnessed to perform mechanical work, and therefore these materials are particularly well suited for use as transducers in microelectromechanical systems. Conventional methods to fabricate conjugated polymer actuators typically yield planar polymer films that limit fabricated devices to primitive linear or bending actuation modes. To overcome this limitation, this investigation reports a conjugated polymer formulation and associated additive manufacturing method capable of realizing three-dimensional conductive polymer structures. A light-based additive manufacturing technique known as vat polymerization is employed due to its ability to fabricate complex microscale features. A specially-formulated photosensitive polypyrrole resin was optimized for the production of microscale 3D structures. The transduction properties of the photosensitive polymer formulation were characterized to assess the material's suitability for mechanical sensing and actuation applications.

2.4.17 Challenges and opportunities of dielectric elastomer based micro-generators to power autonomous systems

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Presentation given by Saber Hammami
The dielectric elastomer material allows the device to generate energy. The problem of the structure of generators was discussed in the literature. Energy can be directly used to power, for example, the connected objects. The latter is set to revolutionize everyday use and life: connected wristbands and watches, smart buildings, and the internet of things serving industry, of the logistics and of the services. Scavenging human kinetic energy to produce electricity is an attractive alternative for the power supply of these low-power-consumption devices. With regard a literature, the voltage across the storage capacitor is boosted from 0 to 250 V after 5s. Among the factors that limit the use of these generators to power these connected objects the high output voltage. In spite of the complex power circuit, dielectric elastomer based micro-generators are still a

promising candidate to scavenge energy from human motion, but not a reality this is the challenge faced by micro-generators. Indeed, these circuits are not yet integrated and can interfere with normal human walking. In this present work our solution the design of specific circuits in order to design a completely autonomous, and lightweight dielectric elastomer generator. The second part of our work summarizes the research progress in micro-generators, but also underlines the next challenges and opportunities of dielectric elastomer for soft micro-generators to power autonomous systems.

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