EuroEAP 2019

9th international conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles

Dresden, Germany
4-6 June 2019

Technical programme

Book of abstracts

List of participants

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In Memoriam Siegfried Bauer

Professor Siegfried Bauer, Soft-Matter-Physics Chair and Department Head at the Johannes Kepler University (JKU) in Linz, Austria, Fellow of the IEEE and the SPIE, passed away on 30 December 2018. He was 57.

Over the past two decades, his highly creative approach yielded impressive results and remarkable successes in research and teaching mostly in Linz. He was a pioneer in the area of ultra-flexible, stretchable electronic devices such as transistors, diodes, and solar cells. Furthermore, he significantly advanced the new fields of polymer ferroelectrets and elastomer electro-electrets and made seminal contributions to the development of imperceptible and biocompatible electronics including sensors, actuators and displays.

Siegried Bauer completed his PhD degree in applied physics (summa cum laude) at the University of Karlsruhe in 1990 and his habilitation on "Poled polymers for applications in sensorics and photonics" at the University of Potsdam in 1996. For his work in Berlin and Potsdam, he received the prestigious Karl-Scheel Award of the German Physical Society. After his appointment as Lecturer at the University of Potsdam, he received offers from a number of universities and accepted a position as Associate Professor at the Johannes-Kepler University in 1997. In 2002, Siegfried Bauer was appointed Full University Professor of Experimental Physics and established the department of Soft Matter Physics at JKU.

His family, his friends and colleagues all over the world, his university, his former and present students, and others who knew him tremendously miss Siegfried Bauer, but will always remember him with deep gratitude sas a very special person full of humor and empathy and as an inspiring and supporting companion, good friend and inspiring mentor. His personality, his philosophy and his work will remain alive in and through all who met him directly or indirectly.

Conference venue

Hilton Hotel Dresden****
An der Frauenkirche 5
01067 Dresden
Germany

Conference Chairperson

EuroEAP 2019 is chaired by
Prof. Dr.-Ing. Andreas Richter
Chair of Microsystems
IHM, TU Dresden

Local organization

EuroEAP 2019 is organized by
Technische Universität Dresden
Faculty of Electrical and Computer Engineering
Institute of Semiconductors and Microsystems
Chair of Microsystems
Nöthnitzer Straße 64
01069 Dresden, Germany
https://tu-dresden.de/ing/elektrotechnik/ihm/ms

TECHNISCHE UNIVERSITÄT DRESDEN

IHM

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Presentation of the EuroEAP conference series

Electromechanically Active Polymers (EAPs) are a young and rapidly growing research area. Applications are being explored in many fields, while fundamental research in novel materials and device architectures promises new capabilities.

EAPs are ‘smart materials’, capable of changing dimensions or shape in response to electrical stimuli, thus transducing electrical energy into mechanical energy, and vice-versa. They can be used as actuators, sensors, and as energy harvesters

EAPs have unique and appealing attributes, including large electrically-driven actuation strain, high mechanical flexibility, structural simplicity, ease of processing and scalability, and high energy and force density, and low-coast materials. Owing to their functional and structural properties, electromechanical transducers based on these materials are usually referred to as EAP ‘artificial muscles’.

The two main EAP classes, ionic and electronic, enable applications in a braod range of fields, including haptics, optics, acoustics, microfluidics, automation, orthotics, artificial organs, energy harvesting and soft robotics.

The rapid expansion of the EAP research in Europe led to the creation of the EuroEAP Society as a non-profit Association. The Society’s main purpose is to promote the scientific and technological advancement of Transducers and Artificial Muscles based on EAPs. In an effort to disseminate the latest advances and to bring together experts from around the world, the Society organises and supports the annual EuroEAP conference, driven by both scientific quality and industrial impact.

I wish to express my sincere gratitude to the conference Chairperson Prof. Richter and his team for the organization of this 2019 edition. I am sure that you will enjoy this event, meet new colleagues, start new collaborations, and will leave with plans to attend the 2020 edition that will be held in Florence.

Herbert Shea
EuroEAP Society President

Conference committees

Organizing committee

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

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Federico Carpi, University of Florence (Italy)
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Herbert Shea, Ecole Polytechnique Fédérale de Lausanne (Switzerland)
Anne Skov, Technical University of Denmark (Denmark)
Peter Sommer-Larsen, Danish Technological Institute (Denmark)

Programme Overview

Monday, 3 June 2019

Arrival	17:00-18:00	**Registration** (Badge, Conference programme, Conference bag)
	18:00	Dinner at Hilton Hotel

Tuesday, 4 June 2019

Arrival	8:00-8:45	**Registration** (Badge, Conference programme, Conference bag)
Opening	8:45-9:00	Welcome & introductory remarks **Andreas Richter** TUD, Dresden
	9:00-9:10	**Commemoration Siegfried Bauer** Reimund Gerhard, Univ. Potsdam, Germany
EAPlenary	Session 1.1 part I *Chair: Andreas Richter, TU Dresden, Germany*	
	9:10-9:40	**Herbert Shea** EPFL Lausanne, Switzerland
Invited Lectures	Session 1.1 part II *Chair: Herbert Shea, EPFL Zurich, Switzerland*	
	9:40-10:00	**Dorina Opris** Empa, Switzland
	10:00-10:20	**Alvo Aabloo** University of Tartu, Estonia
Break	10:20-10:40	Coffee break
Interactive Talks	Session 1.2 *Chair: Alvo Aabloo, University of Tartu, Estonia*	
	10:40-11:40	**Oral presentations** 15 presentations of research activities

		(3 minutes each + 1 minute to change speaker)
	11:40-13:00	**Posters & exhibitions** 15 posters Coffee served during the session
Lunch break	13:00-14:15	Buffet lunch at Hilton Hotel
Interactive Talks **EuroEAP Society Challenge**	Session 1.3 *Chair: Dorina Opris, Empa, Switzland*	
	14:15-15:15	**Oral presentations** 15 presentations of research activities (3 minutes each + 1 minute to change speaker)
	15:15-15:35	**Challenge pitch oral presentations** 4 presentations (3 minutes each + 1 minute to change speaker)
	15:35-17:15	**Posters & Challenge exhibitions** 15 posters + challenge exhibition Coffee served during the session
EuroEAP Society meeting	17:15 - 18:15	**Annual meeting of the EuroEAP Society** – open to everyone
Social dinner	18:30	Transport by "DVB" tram to social dinner Meeting in front of Hilton Hotel
	19:30	Social dinner at Brewery "Waldschlösschen"
		Return transport by your own first to city center (Tram 11, in direction to Zschertnitz) Free ticket in your badge

Wednesday, 5 June 2019

EAPlenary	Session 2.1 part I *Chair: Andreas Richter, TU Dresden, Germany*	
	8:30- 9:00	**Oliver Schmidt** IWF Dresden, Germany
Invited Lectures	Session 2.1 part II *Chair: Oliver Schmidt, IWF Dresden*	
	9:00- 9:20	**Christoph Keplinger** CU Boulder, USA
	9:20- 9:40	**Aron Price** Western University, Canada
Break	9:40- 10:00	Coffee break
Interactive Talks	Session 2.2 *Chair: Christoph Keplinger, CU Boulder, USA*	
	10:00- 11:00	**Oral presentations** 15 presentations of research activities (3 minutes each + 1 minute to change the speaker)
	11:00- 12:30	**Posters & exhibitions** 15 posters Coffee served during the session
Lunch break	12:30 - 13:45	Lunch at Hilton Hotel
Invited Lectures	Session 2.3 *Chair: Markus Henke, TU Dresden, Germany*	
	13:45- 14:05	**Metin Giousouf** FESTO, Germany
	14:05- 14:25	**Frank Fitzek** TU Dresden, Germany
Social event	15:00- 18:00	City tour and city castle Meeting in front of Hilton Hotel
Gala dinner	18:00	Gala dinner at the "Pulverturm Dresden" (Historic restauant)

Thursday, 6 June 2019

EAPlenary	Session 3.1 part I *Chair: Andreas Richter, TU Dresden, Germany*	
	8:30- 9:00	**Metin Sitti** MPI, Germany
Invited lectures	Session 3.1 part II *Chair: Metin Sitti, MPI, Germany*	
	9:00- 9:20	**Xiaobin Ji** EPFL Lausanne, Switzerland
	9:20- 9:40	**Luigi Calabrese** UNITN-Trento, Italy
	9:40- 10:00	**Daniel Bruch** Universität des Saarlandes, Germany
Break	10:00- 10:20	Coffee break
Interactive Talks	Session 3.2 *Chair: Edwin Jager, Linköping University (Sweden)*	
	10:20- 11:20	**Oral presentations** 16 presentations of research activities (3 minutes each + 1 minute to change speaker)
	11:20- 12:30	**Posters & exhibitions** 16 posters Coffee served during the session
EuroEAP society challenge awards	12:30- 12:50	Annoucement of the first three classified teams of the Society Challenge award and presentation of the descriptive videos
Best poster awards	12:50- 13:10	Announcement of the winner of the best poster award
Closing ceremony	13:10- 13:20	Conference closure, handover to the next year's chairperson and presentation of the next year's conference place
Lunch Break	13:20	Lunch at Hilton Hotel

Tuesday, 4 June 2019

Session 1.1

(abstracts are listed in the order of presentation)

1.1.1 Fast DEAs for smart soft machines

Herbert Shea (1),

(1) Soft Transducers Lab, Ecole Polytechnique Federale De Lausanne (EPFL), CH-2000 Neuchatel, Switzerland

Presentation given by Dr. Herbert Shea

Dielectric Elastomer Actuators (DEAs) offer tantalizing possibilities for a broad range of applications thanks to their high energy density, compliance, and large actuations strain. Using examples from our work in soft robotics, wearable haptics, and in developing tools for cell biologists, I will illustrate how we have addressed several important limitations of DEAs, including obtaining high gripping forces (16 N for a 1 g device), high speed operation (> kHz), efficient control of arrays using integrated kV thin film transistors, and high robustness. Our devices are based on silicone elastomers with precisely printed carbon-based compliant electrodes. I will introduce a stretchable all soft-matter pump that allows making soft robots using fluidic actuators, but completely does away with the need for pumps or compressors. Our ongoing work is aimed at embedding intelligence in these soft machines.

1.1.2 Thin functional dielectric elastomers: synthesis and applications

Dorina Maria Opris (1), Yauhen Sheima (1), Philip Caspari (1), Elena Perju (1), Simon Dünki (1), Yee Song Ko (1), Jose E. Quinsaat (1), Mihaela Dascalu (1), Frank Nüesch (1),

(1) Swiss Federal Laboratories For Materials Science And Technology Empa, Laboratory For Functional Polymers, Dübendorf, Switzerland

Presentation given by Dr. Dorina Maria Opris

Soft materials that respond to either an electric stimulus by generating a mechanical stress or to a mechanical stress by generating an electric signal are of great technological importance and may find applications in actuators, sensors, generators, soft robotics, and implants. However, even after years of research it is still challenging to achieve such responsive materials, which are also easily accessible, environmentally friendly, up scalable, and easily processable. Thus, this presentation gives an overview of novel elastomers developed at Empa and the challenges faced during their synthesis and their incorporation in devices.

1.1.3 Physics based modelling of electromechanical transduction in ionic polymer actuators

Sunjai Nakshatharan (1), David Pugal (2), Andres Punning (1), Alvo Aabloo (1),

(1) IMS Lab, Institute Of Technology, University Of Tartu, Estonia
(2) OSIsoft, Dublin, California, USA

Presentation given by Prof. Alvo Aabloo

Ionic electroactive polymers (IEAPs) otherwise called as artificial muscles, refer to a group of polymeric materials that have the ability to convert electrical energy into mechanical energy. The aim of the research has been to develop a physics-based electrochemical model of IEAP actuators addressing some of the key aspects specific to the type of electrode materials. The fundamental working principle of IEAP actuators is based on the migration of ions and re-arranging ion pairs under the applied electric field and the subsequent swelling of the polymer membrane and electrodes. n carbon-based electrode materials, the electric double layer charging and discharging process play the role in driving the ion transport process. In conducting polymers, the driving kinetics is due to both: electric double layer charging-discharging and redox reactions. Considering modelling of the electroactive polymer actuators there are different methodologies based on different aspects of the working principle. They include: . Bending beam method related to the mechanical study of solid state beam bending; . Equivalent circuit model where the electrical equivalent circuit is developed giving a similar electrical response of the actuator; .

Electrochemical model based on faradic conditions that use a linear relationship between applied current and angular movement; Finite element modelling method (FEM).

Session 1.2

(abstracts are listed in the order of presentation)

1.2.1 The effect of humidity on the lifetime of silicone-based dielectric elastomer actuators under dc actuation

Fabio Beco Albuquerque (1), Herbert Shea (1),

(1) Ecole Polytechnique Fédérale De Lausanne (EPFL), Soft Transducers Laboratory (LMTS), CH-2000 Neuchâtel, Switzerland

Presentation given by Mr. Fabio Beco Albuquerque

The lifetime of silicone-based dielectric elastomer actuators (DEA) can be affected by several environmental factors such as temperature and humidity, as well as by operational factors such as the intensity of the applied electric field, strain achieved upon actuation, and the prestretch applied to the elastomer. In this work, we present the impact of humidity on the lifetime of silicone-based DEAs under DC voltage. The DEAs are composed of a 12 ?m thick prestretched Elastosil 2030 silicone membrane (20 ?m initial thickness) sandwiched between 4 ?m thick circular electrodes of diameter 5 mm made from a carbon powder - PDMS composite. DC voltages from 800 to 1100 V were applied to the devices, which were operated in several controlled temperature and humidity environments. 5 DEAs are tested for each set of experimental conditions (V, T, %RH). We find that humidity is a key factor for accelerating the failure of these DEAs under DC actuation. At 80% relative humidity, all DEAs failed in less than 24 hours at 80°C at 800 V, 900 V and 1000 V applied DC voltages. At 10% relative humidity, under the same conditions, all DEAs survived over 48 hours. We will report detailed lifetime results as a function of humidity, temperature and DC voltage.

1.2.2 High Performance of Cellulose Nanofibers/poly(3,4-ethylenedioxythiophene):poly(4-styrenesulfonate)/ruthenium oxide/ionic liquid Actuators

Naohiro TERASAWA (1),

(1) National Institute Of Advanced Industrial Science And Technology (AIST)

Presentation given by Dr. Naohiro TERASAWA

This study proposes novel actuators based on cellulose nanofiber/poly(3,4-ethylenedioxythiophene):poly(4-styrenesulfonate)/hydrous ruthenium oxide/ionic liquid (CNF/PEDOT:PSS/RuO2/IL) electrodes and aims to investigate the effect of hydrous ruthenium oxide on the electrochemical and electromechanical properties of the proposed actuators. The proposed system contains an electrochemical capacitor electrode, which acts as both a faradaic capacitor (FC) and small electrostatic double-layer capacitor (EDLC). This hybrid capacitor is based on the FC (RuO2) mechanism, and a base polymer (PEDOT:PSS) and a CNF skeleton is used instead of carbon nanotubes (CNTs). Therefore, this device functions differently from traditional CNT/poly(vinylidene fluoride-co-hexafluoropropylene) (PVdF(HFP))/IL actuators, which are only used as EDLC units, and CNF/PEDOT:PSS/IL (without RuO2) actuators, where PEDOT:PSS plays the role of both FC and base polymer. Devices built using the proposed actuators exhibit higher strain and maximum generated stress values than those exhibited by devices based on CNF/PEDOT:PSS/IL, i.e. without RuO2. Surprisingly, the synergistic effect obtained from the combination of the RuO2 and PEDOT:PSS is considerably greater than the enhancement achieved using PEDOT:PSS.The developed films are novel, robust, and flexible, and they exhibit potential for use as actuator materials in wearable energy-conversion devices.

1.2.3 A new type of Electroactive polymer stretch sensor for measuring human body movement

Nitin Kumar Singh (1),

(1) Squats Fitness Private Limited India

Presentation given by Mr. Nitin Kumar Singh

In the recent past, the Electroactive polymers (EAPs) sensors have attracted considerable attention because of their potential in healthcare & soft robotics fields. EAPs sensors can be used to measure strain, pressure, force, similar to the human skin & compliant properties enable the EAPs sensors to safely monitor soft movements or interactions with humans. We have developed EAP stretch sensor for measuring human body movement. We have fabricated Silicone based EAP film (370% stretchable) & sandwiched this film between highly stretchable Silver coated fabric electrodes. The whole system works as a variable capacitor and capacitance changes when the EAP film is stretched. With the help of basic calibration technique integrated with microelectronics, this variable capacitance forms the basis of a new type of sensor technology. Our EAP stretch sensor can measure human body movement precisely and further data can be transmitted to a Bluetooth enabled device, paired with the mobile application. We can also collect the data and uploads it to the cloud in order to be analysed by artificial intelligence. This type of EAP stretch sensor can be used for remote monitoring of different types of body postures and can provide feedback to users in real time. Our EAP stretch sensor can be customized for applications in sports training, healthcare. This type of sensor is also perfect for wearable devices & can be used on textiles including shoes and clothing. advantages that make the material useful in a dielectric actuator. First, the glycerol droplets efficiently enhance the dielectric constant which can reach very high values in the composite. Second, the liquid filler also acts as a softener that effectively decreases the elastic modulus of the composite. In combination with very low cost and easy preparation, the two property enhancements lead to a very attractive dielectric elastomer material. The main focus of this study lies on the electrical properties of the new composite - conductivity, dielectric loss and relative permittivity. PDMS, containing various amounts of glycerol, has been tested at increasing voltages in order to precisely characterize the influence of an electric field on the relevant material properties. Experimental permittivity data are compared to various theoretical models that predict relative-permittivity changes as a function of filler loading, and the applicability of the models is discussed. Furthermore, the influence of the diameter of the inclusions on the resulting dielectric constant of the glycerol-PDMS composites has been investigated.

1.2.4 3D printed sensitive pad based on ferroelectrets

Ruy Alberto Pisani Altafim (1) (2), Yuri Andrey Olivato Assagra (1) (2), João Paulo Pereira do Carmo (1), Ruy Alberto Corrêa Altafim (1), Mardson Freitas de Amorim (2),

(1) University Of São Paulo, Department Of Electrical And Computer Engineering, São Carlos, Brazil
(2) Federal University Of Paraíba, Computer Systems Department, João Pessoa, Brazil

Presentation given by Dr. Ruy Alberto Pisani Altafim

Functional materials have gained a lot of interest in the past decades and are being designed for innumerable applications, e.g., sensors and actuators. One particular type of functional material, known as ferroelectret, is based on electrically charged polymer films with cavities. Since their introduction in the late 1980's, these materials have been extensively researched by the electret community and other physicists and engineers. From these studies, new ferroelectret transducers were developed based on different polymers and processing with a wide range of properties. In this context, this paper presents a new ferroelectret made of polypropylene (PP) produced with well-defined cavities using the 3D printing technology. The samples were prepared printing two perpendicular layers of PP. This layout provided the inner gaps necessary for creating a ferroelectret. A sample of 50 mm x 100 mm, was prepared to create a fully functional flexible 3D-printed keypad. The keypad was designed with four sensing areas, used as individual keys. Each key was programed to perform a unique task i.e. produce a specific sound.

1.2.5 Sputtered metallic compliant electrodes for dielectric elastomer sensor and actor applications

Jonas Hubertus (1), Günter Schultes (1),

(1) University Of Applied Science Of Saarland, Department Of Sensors And Thin Film Technology, Saarbrücken, Germany

Presentation given by Mr. Jonas Hubertus

Preliminary results of the development of new metallic compliant electrodes for dielectric elastomer (DE) sensor and actor applications are presented. Sputtering, a vacuum based thin film technology, is used to deposit thin metallic films on biaxial and uniaxial pre-stretched silicone films. The electrical and mechanical properties of the so manufactured DE-membranes are explored. DE-

electrodes consist predominantly of carbon black (CB) manufactured by screen printing. The relatively thick CB-electrodes of some micrometers reveals a high initial resistance in the range of 10 kiloohm per square. In contrast, the metallic electrodes provide a low initial resistance of around 500 ohm per square, although their thickness is typically 20 nanometer only. Regarding the electro-mechanical properties, we demonstrate, that the resistance versus strain doesn't change significantly until the level of pre-stretch is reached, even after 10 million cycles of mechanical loading. Above the level of pre-stretch, the resistance increases, dependent on the pre-stretch conditions and on the layer thickness of the electrode. The capacitance is linearly dependent on the applied strain.

1.2.6 Field concentration in hydrogel-elastomer devices

Justina Vaicekauskaite (1) (2), Canhui Yang (2), Anne Ladegaard Skov (1), Zhigang Suo (2),

(1) Technical University Of Denmark, Danish Polymer Center, Department Of Chemical And Biochemical Engineering, Kgs. Lyngby, Denmark
(2) Harvard University, John A. Paulson School Of Engineering And Applied Sciences, Kavli Institute For Bionano Science And Technology, Cambridge, MA, USA

Presentation given by Ms. Justina Vaicekauskaite

Dielectric elastomer actuators (DEAs) are promising for many applications owning to their remarkable merits such as large deformation, fast response, high efficiency, low cost, and light weight. Recently, hydrogels have been used to activate DEAs. In these devices, hydrogels serve as the stretchable transparent electrodes and elastomers serve as the stretchable transparent dielectrics. However, the emerging of such hydrogel-elastomer devices has posed many challenges due to the distinct nature of hydrogel and elastomer. Intensive researches are taking place to learn more about hydrogel-elastomer systems. In this work, we study field concentration and its influences on hydrogel-elastomer devices. We fabricate a DEA by using polyacrylamide hydrogels containing lithium chloride as the electrodes and polydimethylsiloxane elastomer as the dielectrics. We find that most devices fail on the side of electrode, where field concentration is the strongest. We observe salting out phenomenon and local temperature increase, as well as plasma during the experiments. We hypothesize that electric field concentrates at the edges of hydrogels, causing the surrounding air to break down. Which produces plasma that heats up hydrogels thus leading to the salting out. We note that the breakdown of air helps dissipate energy into the air and protects the DEAs.

Electro active chemical marangoni locomotor

Shigeki Tsuchitani (1), Takumi Ikebe (2), Hirofumi Miki (1),

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

Presentation given by Prof. Shigeki Tsuchitani

Chemical Marangoni locomotors (CMLs) propel on fluid by an imbalance of surface tension of the surrounding fluid, which is caused by an anisotropic distribution of surfactant molecules on the fluid. CMLs are suitable for propelling micro objects for their simple structure due to direct conversion from chemical to kinetic energy. A large problem of CMLs is the difficulty of controlling the propulsion force. For this problem, we considered that the application of an external electric field (EF) to ionic surfactants on the fluid is expected to induce a rearrangement of their molecules by the electrostatic interaction and change the surface tension distribution. Therefore, we evaluated the effects of the application of the EF to the surfactant around the locomotor on the propulsion force. As propellant surfactants, we used ionic liquids (ILs) of imidazolium type. The application of the EF (~670 kV/m) decreased the propulsion force by more than 10%. The effect of the EF was larger in the locomotors using the ILs having hydrophobic anion and cation with longer alkyl chain. Evaluation about the effects of the EF on the surface tension of the IL layer on aqueous surface revealed that the change in the propulsion force by the EF application is attributed to the decrease in the surface tension difference between water and the IL layer behind the locomotor. This is the result of the decrease in the surface concentration of the surface active molecules due to the effect of the EF.

1.2.7 Electrical properties of polymer-free carbon nanotube fibers based on various carbon nanotube dispersed solutions by wet spinning

Ken Mukai (1), Shuuhei Ikenaga (1), Yoshiyuki Shibata (1), Masahiro Yamamura (1), Naoko Tajima (2), Takahiro Morimoto (2), Toshiya Okazaki (2), Takushi Sugino (1) (2), Kinji Asaka (1) (2),

(1) National Institute Of Advanced Industrial Science And Technology (AIST), Inorganic Functional Material Research Institute, Ikeda, Japan
(2) National Institute Of Advanced Industrial Science And Technology (AIST), CNT-Application Research Center,Tsukuba, Japan

Presentation given by Dr. Ken Mukai

Fibers composed of carbon nanotubes (CNTs) have the potential to form high-strength, lightweight and high electrical conducting materials and are expected for application of electrical cable, capacitor, sensor and actuator in the soft robotics field. Wet spinning, CNT dispersed solution injecting into a coagulating solution, is well known method for fabricating continuous CNT fiber. Recently, we successfully fabricated new high-performance CNT fibers with high electrical conductivity and strength by a wet spinning method, without the addition of a polymeric coagulating solution or strong acid solvent. Here we report electrical properties of polymer-free CNT fibers based on various CNT-dispersed solutions.

1.2.8 Changes in optical transmission of a soft membrane using a dielectric elastomer actuator

Leihao Chen (1) (2), Michele Ghilardi (1) (2), Federico Carpi (3), James Busfield (1) (2),

(1) Queen Mary University Of London, School Of Engineering And Materials Science, London, UK
(2) Queen Mary University Of London, Materials Research Institute, London, UK
(3) University Of Florence, Department Of Industrial Engineering, Florence, Italy

Presentation given by Mr. Leihao Chen

Dielectric elastomer actuators (DEAs) are a promising technology for developing new electrically tuneable devices. Here, we present research into DEA-based devices that are used to reversibly control the transmittance of light. Several operating modes have been developed to create a tuneable optical transmission between transparency and opacity. The first mode uses a thin layer of poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) as a transparent electrode applied on a pre-stretched 3M VHB acrylic membrane, which is subsequently partially relaxed to create surface wrinkles causing light scattering. A voltage-induced surface expansion is then used to flatten the wrinkles, allowing for an increase of light transmittance at 550 nm from 45% to 84%. The second mode uses an annular DEA encircling an unconnected PEDOT:PSS thin film. Upon electrical activation, the surrounding DEA compresses the PEDOT:PSS films to form wrinkles, thereby reducing the transmittance from 86% to 33%. A third mode integrates both approaches into a single DE membrane. This was made with wrinkled PEDOT:PSS electrodes with an intermediate transmittance at 50%. A subsequent electrically induced deformation by either expansion or compression could not only increase the transmittance to 83% but also further decrease it to 25% within a single device. Such DEA-based devices are potentially useful for tuneable transmission windows and controllable light diffusers.

1.2.9 High permittivity dielectric elastomers with ionic liquid (IL) loading

Xue Liu (1) (2), Yi Nie (2), Liyun Yu (1), Suojiang Zhang (2), Anne Ladegaard Skov (1),

(1) Danish Polymer Centre, Department Of Chemical And Biochemical Engineering, Technical University Of Denmark, Kgs. Lyngby, Denmark
(2) CAS Key Laboratory Of Green Process And Engineering, Institute Of Process Engineering, Chinese Academy Of Sciences, Beijing, China;

Presentation given by Ms. Xue Liu

Dielectric elastomers (DEs) represent a promising transducer technology, due to their excellent ability to undergo large and reversible deformations under an applied electric field. The most obvious challenge that current elastomers face is the high driving voltages necessary to activate the elastomers. An effective way to overcome this shortcoming is to increase the permittivity of DEs. Ionic liquids (ILs) have high permittivity and conductivity. It is therefore meaningful to blend ILs in elastomers to increase their dielectric permittivity while focusing on maintaining the non-conductive nature of silicone elastomers. In this work, high permittivity dielectric elastomers were prepared through the synthesis of silicone elastomers loaded with ILs. The influence of the structure and amount of ILs on the material properties was discussed, and other important properties for the material's application as DEs, such as resulting gel fractions and mechanical properties, were investigated. It was found that 1-butyl-3-methylimidazolium hexafluoroantimonate (BmimSbF6) is the most suitable IL for the given system, and the dielectric permittivity of the elastomers increased with the increasing amount content of BmimSbF6. A simple figure of merit (Fom) for actuators was used and the resulting Fom of elastomer with 90 phr IL loading is 10.40, compared to that of the pristine elastomer indicating a great potential.

1.2.10 Dielectric elastomer generator at small rivers

Johannes Ehrlich (1), Bernhard Brunner (1), Thomas Gerlach (1), Johannes Ziegler (1), Kerstin Heinrich (1),

(1) Fraunhofer ISC, Center Smart Materials, Würzburg, Germany

Presentation given by Mr. Johannes Ehrlich

In the project DEGREEN the feasibility of new kind of modular energy converters based on dielectric elastomers for slow flowing waters without any impact on landscapes, flow situations, restrictions of flora and fauna was demonstrated. During the project mechanical systems to stretch the dielectric elastomer film significantly in a water environment were evaluated. To adapt the needs of the environment, special silicon polymer and electrode formulations where evaluated to guarantee a suitable strain for a maximum energy efficiency of the generator. The developed polymer and electrode formulations where tested to their mechanical and electrical durability with millions of load cycles under mechanical strain of 100% and high voltage of 4 kV before they were used in a large lab scale generator. To use the electrical energy, a constant voltage electronic was developed and laboratory tested. All disciplines where brought together in a laboratory scale generator with up to 80 multilayered dielectric films which were produced semi industrial on a roll to roll machine. The generator was tested under laboratory conditions with a 4 kV constant voltage electronic and maximum stretch up to 100% of each dielectric film. A maximum energy stroke of about 15 Joule where reached under laboratory conditions. The generator was also tested under free field conditions with a mechanical system using a venture tube at a small river to produce a vacuum to stretch the dielectric film.

1.2.11 Design and fabrication of multilayer dielectric elastomer tubular transducers

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

(1) Technische Universität Darmstadt, Laboratory Microtechnology And Electromechanical Systems, Darmtadt, Germany

Presentation given by Mr. Florian Klug

Nowadays, dielectric elastomer transducers (DET) commonly consists of multilayer systems. By laminating several micrometer thin dielectric layers between compliant electrodes, the driving voltage can be reduced while maintaining appreciable deformations. Established manufacturing methods for multilayered DET are based on thin-film fabrication technologies, applying layer by layer. Therefore typical transducer geometries are mostly plate-shaped with low aspect ratios (height to width or length to diameter). Some applications, e.g. artificial muscles, require high aspect ratios for meaningful use. Thus, a new manufacturing approach based on dip coating is presented in this work. Tubular DET with up to ten layers and 100 mm length, i.e. aspect ratios higher than 16:1, are fabricated. By additional circumferential stiffening, the deformation in longitudinal direction can be maximized and thus increased by more than 40%. Design guidelines are simulated with Ansys multiphysics FEM tool.

1.2.12 Contribution to the measurement of the electromechanical coupling of polyurethane films

Yan Zhang (1), Véronique Perrin (1), Laurence Seveyrat (1), Laurent Lebrun (1),

(1) Univ Lyon, INSA-Lyon, LGEF, EA682, F-69621, Villeurbanne, France

Presentation given by Ms. Yan Zhang

Electroactive polymers (EAPs) like polyurethane have emerged as promising candidates for actuators owing to their lightweight, ease of elaboration and large electric field induced strains. Great efforts have focused on the following restrictive points, for example, limited strain at low field, nonlinear and hysteretic behavior, easily breakdown field and large response time. The key to success is first of all to have available a correct characterization method. It is essential for accurate knowledge of the EAPs properties and for a good understanding of the electromechanical mechanisms. For the polyurethane EAPs, it is observed in the literature firstly some dispersion between the electromechanical coefficient values and afterward a discrepancy between the different underlying mechanisms responsible for the strain. Some authors claim that the strain mainly comes only from the Maxwell effect whereas others show an electrostriction origin. Two methods for the measurement of M31 coefficient were carried out. The first uses the flexural displacement of the EAPs bonded on a cantilever beam measured by a laser vibrometer. The second method consists of measuring the difference between strain-stress curves with and without electric field. The experimental electric field induced displacement was compared to the electromechanical deflection, which is due to electrostatic forces and was obtained with Comsol simulations.

1.2.13 Smart yarns as the building blocks of textile actuators

Shayan Mehraeen (1), Milad Asadi (2), Jose G. Martinez (1), Nils-Krister Persson (2), Edwin W.H. Jager (1),

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(2) Swedish School Of Textiles, Smart Textiles, Polymeric E-textiles, University Of Borås, Borås, Sweden

Presentation given by Dr. Shayan Mehraeen

The field of smart textile actuators has been progressing rapidly during the last years. Smart textiles are a class of textile products which exploit the determinant feature of responding to a stimulus, input, which can be chemical, mechanical, optical, magnetic or electrical. The building block for fabrication of such products is smart yarn. However, most smart textiles are focused on receiving an input stimulus (sensors) and only a few are dedicated to providing an output response (actuators). Yarn actuators show strain or apply force upon application of electrical stimulation in isotonic or isometric conditions, respectively. A small actuation in the yarn scale can be amplified by knitting or weaving the smart yarns into a fabric. In this work, we have investigated the effect of inherent properties of different commercial yarns on the linear actuation of the smart yarns in aqueous media. Since actuation significantly depends on the structure and mechanical properties of the yarns, elastic modules, and tenacity of the yarns were characterized. Investigating the actuation behavior, yarns were coated with PEDOT:PSS to make them conductive. Then polypyrrole which provides the electromechanical actuation was electropolymerized on the yarn surface under controlled conditions. Finally, linear actuation of the prepared smart yarns was investigated under aqueous electrolyte in both isotonic and isometric conditions.

1.2.14 High voltage switch for compact bidirectional dc-dc converter driving dielectric electroactive polymer actuators

Lucas Pniak (1) (2), Morgan Almanza (1), Raphael Mottet (1), Yoan Civet (1), Yves Perriard (1),

(1) EPFL, LAI, Neuchatel, Switzerland
(2) ENS Paris-Saclay, SATIE, Cachan, France

Presentation given by Mr. Lucas Pniak

Driving DEAs requires time-varying high voltage power supplies, up to 18kV for 200um polymer layers. HV amplifiers are commonly used but bulky and expensive. Designing embedded actuators requires compact and efficient power supplies. Furthermore, only a little part of the electrical energy delivered to the DEA is converted to mechanical energy. The major part is stored in the capacitance of the actuator and needs to be recollected to maximise the system's efficiency. Low cost integrated bidirectional DC-DC converters (ex. Flyback) have been proven reliable to drive DEAs at voltages up to 2,5kV. To design a reversible converter with an output voltage up to 18kV, a high voltage switch is needed. Yet, the maximum breakdown voltage for a MOSFET with current ratings inferior to 200mA is 4,5kV. Our simulation and experimental work demonstrate a reliable driving circuit for triggering two series connected MOSFETs. A wide voltage switching range is achieved (0 to 8kV) with a 200mA current rating. Using the Transformer Gate Driver topology, galvanic insulation and synchronisation of each gate driver is ensured. To gain an equal distribution of the bus voltage over the MOSFETs, mastering the parasitic capacitances is mandatory. A design method has been developed to compensate these parasites and ensure the reliability of the device. The architecture of the high voltage switch is N-scalable and a switching range from 0 to 18kV could be achieved when stacking five MOSFETs in series.

Session 1.3

(abstracts are listed in the order of presentation)

1.3.1 Fracture mechanics & fatigue life prediction of silicone based electroactive polymers: based on crack growth approach

Nitin Kumar Singh (1), Karali Patra (2),

(1) SQUATS Fitness Private Limited India
(2) Indian Institute Of Technology Patna

Presentation given by Mr. Nitin Kumar Singh

Electroactive polymers are smart material, are using in many areas such as sensors, soft robotics, energy harvesting etc. In most areas, Electroactive polymers are subjected to cyclic loading-unloading conditions consequently a small initial defect (like fatigue crack, flaws, notches, impurities, etc.) may grow to a critical size to induce catastrophic failure. For utilizing the Electroactive polymers for long life span, it is quite necessary to study the fracture mechanism of Dielectric elastomers under various deformation modes. Experiments were performed to determine the effects of geometry on the fracture toughness, crack propagation, and energy release rate under edge crack, trouser and pure shear deformation modes. It was found that fracture toughness is totally independent of the geometry of specimen and type of deformation, as it is the material property and will remain constant for all shapes and size of specimens under any type of deformation. The trouser and pure shear test specimens were used for finding the relationship between crack growth rate and energy release rate and further such relationship was fitted according to power-law. By using power-law, fatigue life of the Electroactive polymers can be predicted easily.

1.3.2 Electrically Tuned Dielectric Elastomer Windows: Engineering Surface Deformations

Kezi Cheng (1), Volodymyr Korolovych (1), David Clarke (1),

(1) Harvard University, School Of Engineering And Applied Science, Cambridge MA, USA

Presentation given by Ms. Kezi Cheng

Electrically tuning of morphology and dimensions of surface instabilities on dielectric elastomer surface is crucial for development of novel scalable and multifunctional optoelectronic devices to manage light transmission. However, large-scale engineering of electrode uniformity and control of elastomer surface deformation are still challenges. In this work, we study the correlation between electric field induced surface instabilities and macroscopic transmittance changes, by tuning photo-curable silicone elastomer properties. Furthermore, we fabricated high-uniform, stretchable and transparent carbon nanotube electrodes by spray-deposition of CNTs from surfactant-free, lower vapor pressure dispersion on elastomer surface. The electrode uniformity is controlled by 2D distribution of in-line transmittance across 9 cm2 area. The prototype of our electrically tuned window based on combination of designed elastomer and optimized surfactant free CNT's electrodes paves the way for developing multifunctional large-scale optoelectronic devices.

1.3.3 Fully ink-jet printed peristaltic pump

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

In microfluidics the pumping and sensing is often done externally. In order to miniaturise microfluidics and make it portable it is important to find sensing and actuation technologies which can be integrated. Technologies which are well suited for this are electrostatic actuators such as DEA and HASEL actuators. These can be integrated to produce pumps and valves and can also function as sensors. However, for this to work the fluidic chip must be soft so that the actuators can deform the channels and manipulate the fluids. In this work ink-jet printing is used to fabricate a soft fluidic system. HASEL actuators are embedded to pump an aqueous liquid around a circular channel and a pair of resistive strain sensors are patterned to measure the pressure inside the channel. The fluidic system was fabricated by printing a 7 layer structure consisting of Sylgard 184 silicone elastomer, carbon black electrodes, and sacrificial ethyl cellulose channels. The structure is 120 microns thick after printing, and the channels are rapidly opened by peeling and dissolving the sacrificial material. The multi-layer approach permits overlapping channels & connections making it possible to integrate many transducers, the transparency of the aqueous channel enables optical imaging, and the soft nature of the device allows for mechanical stimulation. The methods developed in this work enable highly integrated soft robotic systems with complex fluidics, actuation and sensing.

1.3.4 Taming the beast: an open-loop model to control soft actuators

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(2) Soft Transducers Lab, Ecole Polytechnique Federale De Lausanne, Switzerland

Presentation given by Dr. Samuel Rosset

Viscoelastic losses make the precise control of dielectric elastomer actuators (DEAs) difficult. Here, we present a simple open loop model that makes it possible to calculate the required voltage profile that must be applied to a DEA to obtain a target strain profile. The method relies on two simple characterisations of the actuator: the steady state actuation strain versus voltage, and the time-dependent response to a voltage step. If the targeted strain profile is a strain step, the model leads to a simple analytical solution to calculate the voltage profile that needs to be applied. For arbitrary strain profiles, the voltage profile can be numerically calculated. We have validated the model expanding circle actuators, made with VHB and Silicone. For step strain profiles, we demonstrate an efficient reduction of the viscoelastic drift, with the final strain value being reached much quicker and held constant. Compared to a simple voltage step input, the method leads to an increase in response speed of a factor of 150 for VHB actuators. We also calculate the voltage input required to produce arbitrary strain profiles, such as triangle or sine waves, and show that the proposed method allows to produce an output strain that closely matches the target. This method is very useful when a closed-loop approach is difficult to implement, for example when the use of an external sensor to measure the strain is impractical.

1.3.5 Integration of pedot:pss-based transducers in soft microchips

Lauréline Seurre (1), Kätlin Rohtlaid (2), Chia-Ju Peng (3), Cédric Plesse (2), Giao Nguyen (2), Barthélémy Cagneau (3), Frédéric Vidal (2), Caroline Soyer (1), Sébastien Grondel (1), Luc Chassagne (3), Eric Cattan (1),

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(2) LPPI, EA2528, Institut Des Matériaux, Université De Cergy-Pontoise, Cergy Cedex, France
(3) Université De Versailles, UVSQ/LISV, Vélizy, France

Presentation given by Ms. Lauréline SEURRE

Due to their rigidity and for some of them high manufacturing temperatures, classic micro-transducers are unsuitable to integrate soft microsystems or soft micro-robotic, thus leaving the door open to the development of actuators or sensors based on electronically conducting polymer (ECP). Trilayers structured from ion reservoir membrane sandwiched between two ECP (poly(3,4-ethylenedioxythiophene):poly(styrene sulfonate)) as electrodes are promising transducers due to their excellent mechanical properties, low operation voltage, and open air function. The aim of this work is to develop some reliable processes in order to shape the trilayer transducer and to integrate it in a soft microchip or to fabricate function for soft micro-robots. Technologies of micro-fabrication are suitable for collective fabrication and are a required criterion for MEMS integration. Resulting micro-transducers with different shape integrated in a soft structure with bottom and top gold remote contact electrodes will be shown. These integrated polymeric actuators show good performances in terms of strain and blocking force at their scale. Micro-beams sensing ability are demonstrated and appear linear with the strain and the force applied. Moreover, the microcombs are able of actuation and sensing individually to each other.

1.3.6 Drastic breakdown field reduction in multilayer DEA

Morgan Almanza (1), Jonathan Chavanne (1), Yoan Civet (1), Yves Perriard (1),

(1) Integrated Actuators Laboratory (LAI), Ecole Polytechnique Fédérale De Lausanne (EPFL), Switzerland

Presentation given by Mr. Morgan Almanza

The electrical properties such as the electrical breakdown and the permittivity but also the softness of the elastomer are key factors for the performance of DEA. In order to have the best use of elastomer films, single-layer actuators have been deeply studied, regarding the breakdown and its dependence on the stretch and on the thickness. Multilayer DEAs boost the volume of active material, without any voltage or surface increase. Such multilayer structure is mandatory to achieve high power actuator. Nevertheless, our experiments show a significant reduction of the breakdown field when multilayer configuration are used. Whatever the film thickness staked in the multilayer DEA (200 or 100 micrometers) the breakdown voltage is half the one obtained for single layer. Various factors could explain this discrepancy. A careful analysis of breakdown location in several configurations suggest electrical field concentration at edges of the electrode, as possible cause for this unusual low breakdown field. Even if the numerical simulations suffer from a lack of data on conduction phenomena in the elastomer, it shows the key role of the air in the reduction of the field concentration in single layer structure. Different breakdown mechanisms, such as the electromechanical instability or the electrothermal, have already been pointed out. This work brings up that the field concentration at edges is a tremendous limiting factor of multilayer DEA.

1.3.7 Hydraulically amplified dielectric actuators for haptic cutaneous feedback

Edouard Leroy (1), Herbert Shea (1),

(1) Ecole Polytechnique Fédérale De Lausanne (EPFL), Soft Transducers Laboratory (LMTS), Neuchatel, Switzerland

Presentation given by Dr. Edouard Leroy

Virtual reality (VR) and augmented reality (AR) headsets such as Oculus Rift or HTC Vive provide immersive visual and audio feedback. They cannot provide however the sense of touch, i.e., give haptic feedback on the hands and fingers for a realistic sensation of touching and manipulating objects for gaming, teleoperation or training purposes. To address this, we report a soft actuator designed for cutaneous haptic feedback. Based on a hydraulically amplified dielectric actuator mechanism, similar to HASEL devices, it uses the electrostatically-drive displacement of a dielectric oil between two flexible layers to deform a stretchable cavity. We report promising results with forces up to 100 mN and 500 µm displacement for an actuator diameter of 6 mm and a thickness of 1.5 mm at 2.5 kV. The properties of the actuator are easily tuned by changing the actuator geometry and its initial filing pressure. Our manufacturing process uses a stack of flexible layers that is easily scalable to dense arrays of actuators. These actuators will be integrated in a glove for VR applications or into textile for a full body haptic suit.

1.3.8 Incorporating polyrotaxane materials in dielectric elastomer actuators

Jakob-Anhtu Tran (1), Jeppe Madsen (1), Anne Ladegaard Skov (1),

(1) Technical University Of Denmark, Danish Polymer Center, Kgs. Lyngby, Denmark

Presentation given by Mr. Jakob-Anhtu Tran

Polyrotaxane materials composed of threaded molecular rings can be assembled into a novel type of elastomeric material that has moving cross-linking points instead of the stationary cross-links seen in conventional networks. These sliding cross-links impart unique mechanical properties due to a molecular scale phenomenon caused by the sliding entropy that is commonly called the pulley effect. When a force is applied to the material, the sliding cross-links dissipate stress throughout the material in a similar manner to a pulley. This allows for the design of softer elastomers with higher strains at break. Additionally, the sliding elastomers have been seen to exhibit low hysteresis during cyclic loading which has been attributed to the air-spring like behavior of the threaded cyclic rings. These mechanical properties are desirable for dielectric elastomer actuators (DEAs) where softer materials enable higher degrees of actuation and where low hysteresis is necessary for their energy efficient operation. It is thus of interest to incorporate polyrotaxane cross-linkers to existing polysiloxane based DEA platforms. Here, we propose a synthetic pathway to create polyrotaxane cross-linkers based on polyethylene glycol and ?-cyclodextrin that contain vinyl groups allowing them to be incorporated into polysiloxane networks through hydrosilylation. This type of curing chemistry is commonly used in silicone elastomers due to its high efficiency and selectivity.

1.3.9 All-Solid ionic conducting materials based on polymeric ionic liquids for electrochemical devices

FENGDI LI (1), Frederic Braz Ribeiro (1), Giao T. M. Nguyen (1), Cedric Vancaeyzeele (1), Alexander S. Shaplov (2), Frederic Vidal (1), Cedric Plesse (1),

(1) Laboratory Of Physico-Chemistry Of Polymers And Interfaces, University Of Cergy-Pontoise, Cergy-Pontoise Cedex, France
(2) Department Materials Research And Technology, Luxembourg Institute Of Science And Technology (LIST), Hautcharage, Luxembourg

Presentation given by Ms. FENGDI LI

Ionic electro-active polymers (EAPs) are promising materials for actuation and sensing due to their unique benefits such as flexibility, low driving voltage, and large displacement. Currently, ionogels, ionic conducting gels combining the properties of crosslinked polymer networks with ionic liquids (ILs), are used as the ion source in conducting polymer actuators allowing their air-operational durability. However, the presence of embedded IL represents a risk of liquid leakage. In this work, we present the first results towards the development of easily processable ionic conducting materials based on polymeric ionic liquid (PIL). PIL is a polyelectrolyte with ionic liquid-like species covalently bonded to the polymer backbone. Their ions are highly dissociated and mobile without any additional solvent, resolving de facto any potential leakage and toxicity issues of liquid type electrolytes. PIL-based materials offer a unique possibility to develop truly all-solid-state electrochemical devices. They can be processed through classical coating methods compatible with textile production. Hence, they appear as promising materials for the development of actuators integrated in active and haptic clothes.

1.3.10 Two-photon polymerization of free-form 3D micromechanics for microrobotic applications

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(2) Vilnius University, Laser Research Center, Vilnius, Lithuania

Presentation given by Mr. Linas Jonusauskas
Two-photon polymerization (TPP) based on femtosecond lasers is a powerful tool for true free-form 3D nanofabrication. One of the recent trends in the field is making freely movable intertwined structures. Due to the peculiarities of the TPP technique these can be printed with micro features and in cm scale without any supports in a single-step process in time frame from minutes to few hours (depending on the size and complexity). This allows easy manufacturing of components for micromechanics and, possibly, microrobotics. In this contribution several areas where TPP 3D printing and Electromechanically Active Polymers (EAP) can be combined are discussed. These include possibility to print on special EAP substrates or prepare EAPs on 3D printed objects. Capability to print variable size micromechanical 3D elements is shown. Their movement in air and liquids is demonstrated. Outlook on possibility of direct laser 3D nanostructuring of EAPs is considered.

1.3.11 Towards an ultra-high voltage gain, compact, and energy recovering flyback dc/dc converter

Raphael Mottet (1), Morgan Almanza (1), Alexis Boegli (1), Yves Perriard (1),

(1) Laboratory Of Integrated Actuators, EPFL, Lausanne, Switzerland

Presentation given by Mr. Raphael Mottet

As part of the Center for Artificial Muscles' project to create a heart-assisting device using DEAs, a compact power supply capable to generate the high voltage levels required is being designed. The final goal of the electronics will be to amplify a low input voltage of around 12V to a maximum output voltage of around 10kV. Additionally, the system will allow not only the charge of DEAs but also the discharge of such actuators in order to recuperate as much energy as possible. The system proposed is based on the bi-directional Flyback DC/DC Converter. This structure has the added benefit of having a variable output voltage and thus may be used for other applications needing lower output voltage. With the initial designs, a maximum output voltage of 4.2kV was reached across a capacitive load in fewer than 10ms with a maximum output pulse power of 8W and an efficiency of about 75% in a volume of a few cubic centimeters. At the conference, the behavior of the Flyback when plugged to a 200µm thick planar DEA will also be presented and at a hopefully higher output voltage.

1.3.12 Piezoelectric polymer sensors embedded into laminated composites

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Presentation given by Dr. Michael Wegener

Electroactive Polymers (EAP) such as copolymers of Poly(vinylidene fluoride) with Trifluoroethylene (P(VDF-TrFE)) are well established as piezoelectric sensors and actuators. As sensors, they detect mechanical impacts or excitations by providing an electrical signal. As actuators, the applied electric field changes the transducer geometry e.g. in thickness or lengths/width. The underlying vibration amplitudes are relatively small, however, the thickness resonances occur at high-frequencies typically in der MHz frequency range which allows applications as ultrasonic transducers. Here we demonstrate the integration and usage of free-standing transducer films into laminates of fiber reinforced composites as they were used for lightweight constructions e.g. in windmills, aircraft, composite pressure vessels or automotive. We evaluate the integration process taking into account various parameters such as pressure, temperature and time for processing the fiber composites with integrated piezoelectric transducers. In detail, we study the process to functionalize the embedded transducer by an appropriate electric poling process. Finally, the properties of different fiber composite laminates with embedded piezoelectric sensors were analyzed to evaluate and describe impacts scenarios.

1.3.13 Multi-level high-voltage power supply for dea application

Lucas Depreux (1) (2), Lucas Pniak (1) (2), Morgan Almanza (1), Yoan Civet (1), Yves Perriard (1),

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(2) Ecole Normale Supérieure Paris-Saclay, Electrical Engineering Dpt, Cachan, France
Presentation given by Mr. Lucas Depreux

In order to reap the benefits of Dielectric Elastomer Actuator (DEA) high energy density, the electronics powering the actuator should be as small as possible. Knowing that only a small fraction of the energy delivered to DEAs is effectively converted into mechanical energy, the power supply has to be highly efficient and bidirectional in order to recover the unused energy, which requires more volume. Furthermore, DEA applications call for high voltage (up to 18kV for a 200um film), but as the voltage increases, so does the volume. In addition, there are no MOS transistors rated above 4.5kV, which limits our options. Since these goals are contradictory, we need to demonstrate the feasibility of DEA integration and find its limits. Therefore we present a prototype of Multi-Level Converter designed for DEA, which is a bidirectional structure that has proven to be especially effective in the power electronics field. A Multi-Level Converter overcomes the voltage limitation by equally distributing the desired voltage among levels; because the voltage of each level is sufficiently low, smaller available parts can now be used. Our prototype includes 20 levels of 1kV each. A numerical study of this topology has demonstrated that the efficiency is above 90%. Upcoming experimental works will discuss the advantages and the drawbacks of such Multi-Level Converters. Finally, the volume of the DEA will be compared with the volume of electronics.

1.3.14 Hybrid energy harvesting through electroactive and piezoelectric materials for a nearshore sea wave surge converter

Gregorio Boccalero (1), Claire Jean-Mistral (1), Simon Chesne (1), Nicolas Riviere (2), Emmanuel Mignot (2),

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(2) LMFA, INSA-Lyon, Lyon, France

Presentation given by Dr. Gregorio Boccalero

The incessant movement of the sea waves represents among the other renewable resources a precious solution for the production of electrical energy. Various approaches have been explored in the last decades, both as regards the techniques of capture of mechanical energy, and as regards transduction solutions. Dielectric elastomer generators (DEG) used as direct power-take-offs in submerged sea consist in a cheap, high energy density, chemically resistant conversion solution, thus requiring low maintenance costs. Since these materials need to realize energetic cycles to convert mechanical energy into electrical one, an external polarization source is required. The centimeter-sized prototype presented in this contribution consists of a clamped elastomeric membrane coupled with two stretchable electrodes, mounted on a rigid vertical plate anchored to the sea floor though two piezoelectric elements. Under sea waves, the plate oscillates impacting the piezoelectric elements thus generating electric charges, used to polarize the DEG, leading to the design of hybrid structures. The horizontal component of wave celerity is exploited to deform the DEG, which is not typical for shallow water conditions in nearshore applications. Experimental measurements on the deformation of the DEG, performed in a water flume through standing waves, are enriched with a complete analytical modelling, which aims to describe both the mechanical and the electrostatic response of the DEG.

1.3.15 Supply circuit for dielectric elastomer actuators in dynamic applications

Petko Bakardjiev (1) (2), Ercan Altinsoy (1), Andreas Richter (2),
(1) TU-Dresden IAS AHA
(2) TU-Dresden IHM MST

Presentation given by Mr. Petko Bakardjiev

The development and characterisation of DEA in dynamic applications are often restricted by the limitations of the power amplification. The amplification should be able to provide a sufficiently high bias voltage and sufficiently high current to achieve the desired amplitude and bandwidth with a linear behaviour. Commercial devices are costly, yet often show insufficient AC signal amplification capabilities. Usually, the available current output reduces significantly with increasing voltage range, limiting the overall applicability. Alternative solutions, e.g. inducing the AC signal through a transformer onto a DC high voltage circuit, show also constrains in the achievable performance and are not easily adaptable to a wider range of DEA. We developed a circuitry for laboratory use which allows the coupling of separate dedicated sources to provide the bias voltage and the AC-signal using an isolating capacitance. The circuitry can safely operate up to a maximum voltage of 10 kV, has a very linear frequency response with a lower cut-off frequency of less than 1 mHz and can operate with fairly large DEA (> 100 nF). Safety measures are included to ensure a discharge of the system within less than 1 s. With the realized circuitry, a greater performance at significantly lower costs compared to commercially available devices is achievable. This enables further development and better characterisation of DEA in dynamic applications.

EuroEAP Society Challenge Projects
(listed in the order of presentation)

	Project title	Last Name	First Name	Institution
1	DEA driven pneumatic pump	Linnebach	Philipp	Saarland University, Germany
2	Virtual-reality training environment for gesture-based diver-robot communication (Project ADRIATIC)	Walker	Christopher	The Biomimetics Laboratory, The University of Auckland, New Zealand
3	MIDA – a versatile inflatable actuator for space exploration	Ashby	Joseph	The Biomimetics Laboratory, The University of Auckland, New Zealand
4	Robotic sense of touch enabled by dielectric elastomer sensors and machine leaning	Stier	Simon	Fraunhofer Institut für Silicatforschung ISC Würzburg. Germany

Wednesday, 5 June 2019

Session 2.1

(abstracts are listed in the order of presentation)

2.1.1 Shapeable nanomembrane materials, devices and microsystem architectures

Oliver Schmidt (1),

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Presentation given by Prof. Oliver Schmidt

Multifunctional nanomembranes with outstanding properties are self-assembled into fully integrative microtubular devices and microsystem architectures (MDMAs). MDMAs are attractive for a broad range of applications and scientific research fields ranging from new concepts for electronic, photonic and energy storage devices to targeted drug delivery and reproduction technologies. MDMAs are used to construct ultra-compact microbatteries and supercapacitors as well as novel highly efficient cylindrical electronic circuitry, nanophotonic cavities, 3D magnetic sensors and optofluidic components towards the implementation of advanced microtubular lab-on-chip systems. Off-chip applications include biomimetic microelectronics for regenerative cuff implants and the development of biomedical microrobots for paradigm shifting reproduction technologies. Cellular cyborg machinery is put forth for novel schemes in targeted drug delivery and cancer treatment.

2.1.2 HASEL artificial muscles

Christoph Keplinger (1) (2),

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(2) University Of Colorado Boulder, Materials Science And Engineering Program, Boulder, USA.

Presentation given by Prof. Christoph Keplinger

Hydraulically Amplified Self-healing ELectrostatic (HASEL) transducers are a new class of self-sensing, high-performance muscle-mimetic actuators, which are electrically driven and harness a mechanism that couples electrostatic and hydraulic forces to achieve a wide variety of actuation modes. Current designs of HASEL are capable of exceeding actuation stress of 0.3 MPa, linear strain of 100%, specific power of 600W/kg, full-cycle electromechanical efficiency of 30% and bandwidth of over 100Hz; all these metrics match or exceed the capabilities of biological muscle. Additionally, HASEL actuators can repeatedly and autonomously self-heal after electric breakdown, thereby enabling robust performance. Further, this talk introduces a facile fabrication technique that uses an inexpensive CNC heat sealing device to rapidly prototype HASELs. New designs of HASEL incorporate mechanisms to greatly reduce operating voltages, enabling the use of lightweight and portable electronics packages to drive untethered soft robotic devices powered by HASELs. Modeling results predict the impact of material parameters and scaling laws of these actuators, laying out a roadmap towards future HASEL actuators with drastically improved performance. These results highlight opportunities to further develop HASEL artificial muscles for wide use in next-generation robots that replicate the vast capabilities of biological systems.

2.1.3 From Smart Materials, 4D Printing, and the Future of Additive Manufacturing

Aaron Price (1),

(1) Organic Mechatronics And Smart Materials Laboratory, Western University, London, Canada

Presentation given by Prof. Aaron Price

3D Printing has emerged as a ubiquitous technology in today's manufacturing landscape resulting in explicit identification of this field as a strategic research area. In this talk, the frontier of contemporary AM research is explored with a focus on recent advancements leading to specially developed printable and multifunctional electroactive polymers and the corresponding innovative 3D printing processes specially developed to enable their utilization. To this end, several research initiatives conducted at the Organic Mechatronics and Smart Materials Laboratory will be showcased that demonstrate recent AM innovations that aim to develop shape-shifting 3D components realized through integrated smart material transducers via a process known as 4D Printing. Components employing electroactive polymers fabricated through these methods may be employed as actuators, and associated methods have be employed to fabricate sensors and energy harvesters that are particularly attractive for integration within an extensive variety of potential engineering applications. The talk concludes with an introduction to Canada's recently established Advanced Manufacturing Innovation Supercluster, Next Generation Manufacturing Canada (NGen), whose aim is to develop new AM technologies and drive the industrialization of additive manufacturing in concert with both Canadian and International partners from academia and industry.

Session 2.2
(abstracts are listed in the order of presentation)

2.2.1 .Bidirectional model for ultrathin pedot-based trilayer transducers

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Presentation given by Prof. Sébastien Grondel

PEDOT-based trilayer ionic polymer exhibits bidirectional electromechanical coupling. For such a material system, application of 2 V produces a strain of 1-2 % and millimeter displacements, while a few millivolts are produced when such a millimeter level displacement is applied. To simulate such a behaviour, this study presents a bidirectional sensing and actuation model for the ultrathin PEDOT-based trilayer transducers. The model consists of three elements: an electrochemical part described by a simple RC circuit, a mechanical part represented using dynamic Euler - Bernoulli beam theory, and an empirical strain-to-charge ratio coupling charge to strain in actuation and applied stress to voltage in sensing. A self-consistent Bond Graph language is used to give a clear physical and power interpretation of the mechanisms. To confirm the prediction ability of the resulting model, a 17 micrometers thick trilayer transducer is fabricated using a stacking layer method, and a complete dimensional, electrical, electro-chemical and mechanical characterization is performed. Good agreement is obtained between the temporal and frequency simulations and experiments in both sensing and actuation, showing that the modeling approach advances the understanding of the operation principles of the studied transducer devices.

2.2.2 Inflatable dielectric elastomer space robots

Joseph Ashby (1), E.-F. Markus Henke (1) (2), Samuel Rosset (1), Iain A. Anderson (1),

(1) University Of Auckland, Auckland Bioengineering Institute, Auckland, New Zealand
(2) Technische Universitaet Dresden, Institut Fuer Festkoerperelektronik, Dresden, Germany

Presentation given by Mr. Joseph Ashby

Dielectric elastomer actuators (DEAs) offer a way to reduce the mass of a spacecraft, by replacing heavy traditional electronic mechanisms with soft, lightweight polymer alternatives. In this project we propose combining DEAs with inflatable/expandable structures to form low mass, low density robots with high packing efficiency. Current inflatable space structures (such as the Bigelow Expandable Activity Module (BEAM), which recently completed its 2-year mission) promise large operational space at greatly reduced launch mass and volume. DEA robots would likewise be capable of being stowed in volumes a fraction of their final size for launch and then inflated once on orbit. DEAs have the additional benefit of doubling as strain sensors, giving them built-in proprioceptive capabilities. This is a significant improvement over traditional actuators, which require additional monitoring systems to verify correct operation. This poster outlines the work to date on exploring the different motions achievable using simple inflated structures powered by integrated DEAs and the challenges which must be overcome in order for DEAs to become viable alternatives to current space technology.

2.2.3 Dive into the future: EAP sensors to enhance diver safety and robotics interaction underwater

Christopher Walker (1), Samuel Rosset (1), Iain Anderson (1),

(1) The Biomimetics Laboratory, University Of Auckland

Presentation given by Mr. Christopher Walker

The human race has been captivated with diving since 4500 BC when

Mesopotamian divers decorated artefacts with pearls. However, after 6500 years and several technological developments, we are still plagued with diver fatalities. The Divers Alert Network reported 169 North American deaths in 2016 and 3,593 hyperbaric chamber cases. Research indicates fatigue, buoyancy control, and panic behaviour to be contributing factors of the fatality count. Improvements in diver monitoring and assistive underwater autonomous vehicles (UAV) could help mitigate these risks. Here we introduce the Advancing Diver-Robot Interaction Capabilities (ADRIATIC) project which evaluates the feasibility of a gesture-based communication protocol for diver-robot interaction and implements monitoring of the diver's physiological state. Previously, we have developed dielectric elastomer strain sensors for underwater use. In this project, we integrated these sensors and an IMU into a prototype glove to recognise hand gestures. The gestures are transmitted acoustically as commands to an UAV to perform a variety of established functions. A virtual-reality training environment is in development where the glove can reconstruct hand movements inside the virtual scene and interact with a simulated UAV. This allows divers to familiarise themselves with the system prior to use. In the next phase, sensors are integrated into the dive suit to correlate respiration and motion data with the diver's physiological state.

2.2.4 Use of conducting yarns to develop textile actuators

Jose G. Martinez (1), Klaus Richter (2), Nils-Krister Persson (3), Edwin W H Jager (1),

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(2) ITP GmbH Gesellschaft Für Intelligente Produkte (ITP), Weimar, Germany
(3) University Of Borås, Smart Textiles, Borås, Sweden

Presentation given by Dr. Jose G. Martinez

The feasibility of textile actuators and their advantages to develop soft actuators with synergetic actuation have been proven. They are composed of a passive fabric coated with an electroactive polymer that provides the mechanical motion. Until now, a two-step coating process was followed to make the textile actuators: a first coating that provided conductivity to the passive fabrics and, once conducting, a second coating by electropolymerization was used to get a highly electroactive (moving as much as possible) material. To simplify the fabrication process, we here used different commercially available conducting yarns (polyamide+carbon, silicon+carbon, polyamide+silver coated, cellulose+carbon, polyester+2 × INOX 50 ?m, polyester+2 × Cu/Sn and polyester+gold coated) to develop such textile actuators. Thus, it was possible to coat them through direct electrochemical synthesis, avoiding the first step, which should provide with an easier and more cost-effective fabrication process. The conductivity and the electrochemical properties of the yarns were sufficient to allow the electropolymerization of the conducting polymer polypyrrole on the yarns. The electropolymerization was carried out and both the linear and angular the actuation of the yarns was investigated. These yarns may be incorporated into textile actuators for assistive prosthetic devices.

2.2.5 An energy-efficient artificial muscle from carbon nanotube/ polypyrrole coated polymer yarn

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(3) School Of Mechanical, Materials And Mechatronic Engineering, University Of Wollongong, Wollongong, NSW, 2522, Australia

Presentation given by Dr. Shazed Aziz

Electrochemically driven twisted/coiled carbon nanotube (CNT) yarn actuators are of great interest in the field of wearable artificial muscle technologies as they induce high-strength. However, due to the need for high activation power, these CNT yarns have limited their feasibility in lightweight and inexpensive smart textiles. An alternative approach is to use conductive polymer coated textile yarns. Here, we demonstrate the hybrid textile yarns that adapt both the mechanical strength of CNT and high conductivity of polypyrrole to provide both strength and actuation properties in terms of applied power. CNT-coated PET textile yarns were mechanically twisted and coiled and subjected to the electrochemical coating of polypyrrole to obtain the hierarchical structures. Once twisted, the polypyrrole coated yarns produce fully reversible 25 degrees/mm rotation in a three-electrode electrochemical system providing +0.4

V and -1.0 V (vs Ag/AgCl) of the potential window. The polypyrrole coated coiled yarns generate fully reversible 0.22% contraction strain when operated within the same potential window. The volume alteration of polypyrrole due to the electrochemical charge injection and the helical twisted/coiled structure combined to contribute to the actuation properties. These actuators exhibit high tensile properties with excellent abrasion resistance under extreme shear condition that could match to the requirements for making wearable textile exoskeletons.

2.2.6 Harvesting fast electrochemical actuation from PEDOT:PSS coated textile yarns

Shazed Aziz (1), Edwin W H Jager (1),

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Presentation given by Dr. Shazed Aziz

Commercially made inexpensive yarns are of great interest for use as the artificial muscles in smart fabric-based textiles. Electrochemically induced conductive polymer coated yarns have already shown their potentiality to be used as the building blocks of the smart fabrics. Unfortunately, the feasibility of using these yarns is still hindered due to their slow ion exchange properties and low contraction strain. Here, we demonstrate a method to morph PEDOT:PSS coated textile yarns in highly twisted and coiled structures to aid the rapid and substantial actuation, providing more than 1% linear actuation in 1 second in a three-electrode electrochemical system providing a potential of 0.6 V. A potential window of +0.6 V and -1.2 V triggers the fully reversible actuation providing more than 1.5% linear strain. A simple hydrostatic mechanism explains the occurrence of yarn's lengthwise actuation during the fundamental volume alteration of conductive polymer layer caused by electrochemical charge injection. However, the helical opening/closing of the twisted/coiled yarns dominates mostly to the rapid and large linear actuation. These PEDOT:PSS coated textile yarn actuators are of great interest for smart textile exoskeletons.

2.2.7 A Soft robotic structures with artificial muscles and skeletal enforcement

Markus Franke (1), Markus Henke (1), Andreas Richter (1),

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Presentation given by Mr. Markus Franke

Robotic research is demanding for lightweight and stable motive systems able to respond with high frequency and force. Since generations, natural existing motion types inspired researchers to realize approaches fulfilling these essential needs. In our study, we realized a soft and finger-sized robotic structure with two antagonistic working artificial muscles based on dielectric elastomer actuators (DEAs) that are fixed on a flexible body with skeletal enforcement. The body is consisting of a molded silicone support structure possessing embedded transverse 3D-printed PLA struts. These comparably stiff bone-like elements enable an anisotropic stiffness only allowing bending in one plane and further stabilize the robotic structure. The DEAs are manufactured by airbrush spray coating of a carbon-silicone ink through a shadow mask to process stretchable and accurate electrodes on both sides of a pre-stretched silicone membrane. Afterwards, the two actuators are bonded on the top and bottom of the support structure. The robotic system is able to show large and defined bimorph bending curvature and can operate a static and in dynamic motion. Our investigation show a high influence of membrane pre-stretch on the bending amplitude and cut-off frequency of the robotic structure. These results are confimed by FEM simulations and analytical modelling. The simple-processable and cost-efficient design of our new approach opens a wide range of robotic application.

2.2.8 Hydraulically-coupled dielectric fluid transducer for tactile display devices

Ion-Dan Sîrbu (1), Gioacomo Moretti (2), Sandra Dirè (1), Luca Fambri (1), Rocco Vertechy (3), Devid Maniglio (1), Marco Fontana (1),

(1) University Of Trento
(2) Scuola Superiore Sant"Anna

(3) University Of Bologna
Presentation given by Dr. Marco Fontana

Recent studies on Electroactive Polymer Transducers have led to the development of new actuator concepts, such as the Liquid-based Electroactive Polymers (LEAPs). These are shells made of flexible dielectric-electrode composites, inside which a volume of insulating liquid is sealed. Their working principle is electrostatic and it is very similar to Dielectric Elastomer Transducers (DETs) but due to their liquid component they have a lower mechanical stiffness than and, in turn, can produce larger actuation strokes. In this contribution, we propose a novel LEAP actuator that can be potentially employed as a tactile display. The device is built using soft, widely-available materials and easy to scale-up methods. The working principle is based on the displacement of incompressible liquid caused by the contraction of an polymeric pouch that is exposed to electric field. The fluid motion induces an out-of-plane deformation of a membrane that functions as the tactile interface, thus creating an activated tactile dot. A single-dot prototype has been built and tested by measuring the blocking force at different strokes with a cyclical actuation in the frequency range of 0 - 3Hz. The results show a promising maximum output force in the range of 10-15 mN and a maximum stroke of approximately 1 mm. Large improvements for this performance can be achieved by using different combination of liquid and solid dielectric materials.

2.2.9 Hardware-in-the-loop testing and validation of dielectric elastomer generators for wave energy conversion

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(1) Scuola Superiore Sant"Anna
(2) University Of Bologna
(3) University Of Trento

Presentation given by Dr. Marco Fontana

In the last few years, dielectric elastomer generators (DEGs) emerged as a disruptive new solution for ocean wave energy converters (WECs), which allow the potential replacement of bulky electromagnetic drives with cheap polymeric units. A promising concepts of DEG-based WEC is the oscillating water column (OWC) with circular DEG diaphragm. This device consists in a hollow collector housing a water column (put into oscillations by the waves) and an air chamber closed by a set of cyclically inflating DEG diaphragms. In the past, we developed DEG-OWC prototypes up to a scale of 1:30 ant tested them in wave tanks, demonstrating power outputs of up to a few Watts (equivalent to hundreds of kilowatts at full-scale). In this work, we discuss the deployment and validation of a dry-run test bench for DEGs, which allows hardware-in-the-loop testing of control strategies and performance assessment in laboratory environment. The setup emulates the operation of an OWC and includes: a hardware DEG diaphragm equipped with control electronics and a volumetric pump (driving the DEG deformation), and a software model of the OWC hydrodynamics. The volumetric pump is driven by the OWC model, which in turn receives the measured DEG pressure as an input. The setup has been validated against results obtained in wave tank tests, showing its ability to faithfully reproduce the dynamics of a DEG-OWC prototype operating in a wave tank while drastically reducing the experimental burden.

2.2.10 Thermal expansion explained: continuum mechanical background and application for active materials

Adrian Ehrenhofer (1), Thomas Wallmersperger (1),

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Presentation given by Mr. Adrian Ehrenhofer

The simulation of the active behavior of electroactive polymers has to be simple and accessible in order to allow the design of complex adaptive structures. Therefore, the actuation response of a material to an activation stimulus must be represented in a form that makes it possible to perform simulations inside a professional software environment like e.g. Ansys or Abaqus. However, many models that describe the actual effects require a profound background knowledge about electrochemistry and material sciences. The analogy between active behavior and thermal expansion is widely used in literature. In many cases the mathematical and mechanical backgrounds especially for nonlinear kinematics and nonlinear elasticity are not well formulated. In our current work, we provide the continuum mechanical formulation of thermal expansion based on the (i) balance equations, (ii) linear and nonlinear kinematics and (iii) different constitutive laws. A material- and stimulus-dependent parameter depicting the actuation response is derived. The formulation allows the easy implementation in commercial Finite Element tools. In the current research, we demonstrate the approach at the example of hydrogels. Using the described model can reduce the number of experiments required for the design of an adaptive structure and therefore allows more resource efficiency in engineering science for these materials.

2.2.11 Chemofluidic oscillator

Andreas Voigt (1), Georgi Paschew (1), Jörg Schreiter (2), Joseph Paez Chavez (3), Uwe Marschner (1), Stefan Siegmund (4), Frank Jülicher (5), Frank Ellinger (6), Andreas Richter (1),

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Presentation given by Dr. Andreas Voigt

Microfluidic valves based on stimuli-responsive hydrogels facilitate inherent chemical sensing and fluidic actuation without the need for external wiring and control. These smart valves ("chemofluidic transistors") can be used to build microfluidic circuits akin to basic circuits known from electronics. Here we present an autonomous chemofluidic oscillator circuit. The oscillator is based on the principle of negative feedback (realized by a mixing junction and a chemofluidic transistor) applied with a delay (realized by a microfluidic delay channel placed between the junction and the transistor). The oscillator is driven by constant fluidic sources and effects oscillations of chemical concentration and flow rates. One potential application of chemofluidic oscillators could be the coupling to biochemical reaction networks or biological cell systems, with the goal of autonomous on-chip control schemes. The circuit also shows the functionality of chemofluidic transistors in the context of a small system and thus paves the way towards the construction of larger systems with the vision of microfluidic large-scale integration.

2.2.12 Dielectrophoretic liquid zipping electro-ribbon actuators

Tim Helps (1), Majid Taghavi (1), Jonathan Rossiter (1),

(1) University Of Bristol, Engineering Mathematics, Bristol, UK

Presentation given by Dr. Tim Helps

Electrostatic forces in zipping devices have the potential to be extremely large, but are limited by the breakdown strength of air, which cannot sustain strong electric fields. One solution is submerging the device in liquid dielectric, however this considerably increases the system's overall mass. Here we show that only a tiny droplet of liquid dielectric is required to greatly amplify electrostatic force. Serendipitously, the droplet of liquid dielectric is kept in place by dielectrophoretic forces. This phenomenon, whereby dielectrophoretic forces retain a bead of liquid dielectric as it amplifies electrostatic zipping, is called dielectrophoretic liquid zipping. Its simplest embodiment, electro-ribbon actuators, can lift 1000 times their own weight, contract by 99.8% of their length, and deliver specific energy and specific power equivalent to muscle. We demonstrate their versatility in high-stroke and high-force morphologies, multiactuator lattices, 3D-printed and paper actuators, self-twisting spirals, and tensile elements inspired by spider silk.

2.2.13 Thermoplastic electroactive PVC gel for 3D printing artificial muscle

Majid Taghavi (1), Tim Helps (1), Jonathan Rossiter (1),

(1) University Of Bristol, Engineering Mathematics, Bristol, UK

Presentation given by Dr. Majid Taghavi

Despite the substantial benefits of using 3D printers in manufacturing, there are only a few examples of 3D-printable artificial muscles, such as 3D-printed fluidic actuators, fluidically actuated soft robots and dielectric elastomer structures. Here we introduce the concept of thermoplastic electroactive gels, new smart materials that can be fabricated simply and rapidly by heating, enabling hot-pressing, melt-recycling, extrusion and 3D-printing. We based our studies on polyvinyl chloride (PVC) gel which is a promising, soft-smart material. When PVC gel is placed between two electrodes, it exhibits unusual "anodophilic" (anode-loving) behaviour, creeping towards the anode and increasing its anode-contacting surface area. We present and characterise PVC-DIDA (polyvinyl chloride and diisodecyl adipate) gel with microstructures on the surface to achieve contractile actuation. We demonstrated an entirely soft multi-layer PVC-DIDA gel actuator with thin conductive rubber electrodes. Finally, the extrudability of PVC-DIDA gel is confirmed, and an artificial muscle made from extruded electroactive gel is presented. The electroactivity and extrudability of these thermoplastic gels highlights them as excellent candidate materials for 3D-printing artificial muscle structures.

2.2.14 Dielectric electrical breakdown under long-term voltage application for silicone thin films

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(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 represent an attractive technology for the realization of low cost actuators and sensors. The transduction performance of such systems strongly depends on the material properties of the membrane, especially permittivity and breakdown field strength. To properly characterize these quantities, a reproducible testing method is required. This work presents the results of an ongoing study aimed at investigating the electrical breakdown in dielectric elastomer thin films subject to different environmental conditions. In practice, early breakdown is known to increase at higher temperatures and humidity. In previously conducted breakdown tests, however, no influence of humidity and only slightly higher breakdown voltage with higher temperatures were observed. Such tests were conducted by increasing a voltage until breakdown occurs. In technical applications, however, voltage is applied either periodically or long-lasting. To better reflect those operating conditions, in this work we present first test results on silicone thin film, in which a constant voltage is applied over a period of 6 hours. The magnitude of the voltage is determined from the previous study, using 90% and 100% of the median breakdown voltage for each test sequence. To allow the characterization under different external conditions, the test stand is located in a climate chamber. First results indicate an influence of temperature, showing decreasing withstand times with higher temperatures.

2.2.15 A dielectric elastomer actuator concept for increased force output

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(2) Zentrum Für Mechatronik Und Automatisierungstechnik (ZeMA) GGmbH, Saarbrücken, Germany

Presentation given by Dr. Steffen Hau

The structure of dielectric elastomer actuators (DEAs) is based on a thin elastomer layer, which is sandwiched in-between compliant electrodes. This capacitor like structure enables to build light-weight and energy efficient actuators with high design flexibility. An applied high voltage leads to a thickness compression and to a simultaneous area expansion of the elastomer, which can be exploited for actuation. Despite being relatively easy to manufacture and providing large strokes, membrane DEAs suffer from low force outputs (for single layer systems). This poster presents a novel design concept in which the DEA-element is suspended between two different spring elements. One spring element is a linear compression spring, while the other one is a negative-rate bias spring (NBS). With this concept some of the stroke is sacrificed to increase the force output of the overall system. This is of particular interest for valve applications, which typically need high closing forces and low strokes in the submillimeter regime. By means of the novel design concept, the force output of a single membrane DEA can be increased by a factor of 3 to 4. An additional unique property of the floating design is that a higher stiffness of the elastomer material increases the force output, too. This can help to improve the reliability of DEA systems.

Session 2.3

(abstracts are listed in the order of presentation)

2.3.1 Applications and Challenges of Electroactive Polymer Actuators in Automation Technology

Metin Giousouf (1), Tobias Pointner (1),

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Presentation given by Dr. Metin Giousouf

The idea of the use of alternative actuators in industrial environments is an interesting field of research. Dielectric elastomer actuators (DEA) have specific benefits like lightweight, energy-efficiency, noiseless operation and proportional drive mode in comparison to e.g. solenoids. For some years we are dealing with DEAs, in which we have demonstrated pneumatic valves with DEAs used as drive means. With improved control electronics for the DEAs it is possible to build up particularly power-saving valves. This is demonstrated by a 2/2-way proportional media valve, remote controllable and powered by a solar cell. During low frequent or steady-state operations the actuator does not heat up the fluid within the valve, which could be critical for certain fluids. Therefore, such valves can be used in process industry or laboratory automation. In addition to valves, lightweight grippers can also be realized by using several DEA stacks to increase the gripping movement.

A big challenge with DEAs is their high operating voltage. Common solutions work with operating voltages up to 2.5 kV. The high voltage makes it necessary to use corresponding electronic components that make the drive circuits large-building and above all very expensive.

At this point, we are also pursuing a new approach, by which we study single-layer membrane actuators. The developed actuators can be driven at lower voltages provided by low-cost power supplies. In detail, a particular device was developed with specially designed compression fittings clamping the DEA-film, which enabling a simple electric contact between the actuator and the circuit board. The power supply generates up to 550 V with a slew rate of a few

microseconds, whereas the whole circuit has the geometrical dimension of a credit card. A plunger connected to the DEA-film moves out of plane when the actuator is activated. With the use of permanent magnets, interacting with the plunger, the system can be enhanced to meet industrial requirements in force and stroke. The system offers a platform for further applications in different industrial segments and applications for instance in automation with valves, grippers or micro pumps in process automation and life sciences.
In summary, it can be stated that a well-developed DEA technology in combination with a low-cost drive-electronics system is useful in many applications if other actuator types cannot offer a replacement due to geometry, form factors and other physical restrictions. However, beside cost aspects the requirements for reliability and lifetime must meet the requirements of industry standards.

2.3.2 Tactile Internet with Human-In-The-Loop

Frank H.P. Fitzek (1),

(1) Center for Tactile Internet, Technische Universität Dresden, Germany

Presentation given by Prof. Frank H.P. Fitzek

The talk will address the technology needed to build up the tactile Internet. Main focus is on low latency and ultra-reliable communication and how it can be realized in softwarized networks. Current technologies such as 5G are discussed to enable the tactile Internet. Furthermore, the talk will highlight inter disciplinary research on tactile Internet with focus on phycology and medicine building the required human to machine interfaces to have mutual learning between humans and machines.

Thursday, 6 June 2019

Session 3.1

(abstracts are listed in the order of presentation)

3.1.1 Shape-programmable Magnetic Soft Actuators for Small-scale Robotics

Metin Sitti (1),

(1) Max Planck Institute for Intelligent Systems, Stuttgart, Germany

Presentation given by Prof. Metin Sitti

Inspired by soft-bodied animals, soft functional active materials could enable physical intelligence for small-scale (from a few millimeters down to a few micrometers overall size) robots by providing them unique capabilities, such as shape changing and programming, physical adaptation, safe interaction with their environment, and multi-functional and drastically diverse dynamics. In this talk, our recent activities on design, manufacturing, and control of new bio-inspired shape-programmable active soft matter and untethered soft robots at the milli/microscale are reported. Untethered soft millirobots inspired by spermatozoids, caterpillars, and jellyfishes are proposed using elastomeric magnetic composite materials. Static and dynamic shapes of such magnetic active soft materials are programmed using a computational design methodology. These soft robots are demonstrated to be able to have seven or more locomotion modalities (undulatory swimming, jellyfish-like swimming, water meniscus climbing, jumping, ground walking, rolling, crawling inside constrained environments, etc.) in a single robot for the first time to be able to move on complex environments, such as inside the human body. Preliminary ultrasound-guided navigation of such soft robots is presented inside an ex vivo tissue towards their medical applications to deliver drugs and other cargo locally and heat the local tissues for hyperthermia and cauterization. Next, a more specialized soft-bodied jellyfish-inspired milliswimmer is shown to realize multiple functionalities by producing diverse controlled fluidic flows around its body using its magnetic composite elastomer lappets bent by remote magnetic fields. This jellyfish robot can conduct four different robotic tasks: selectively trap and transport objects of two different sizes, burrow into granular media consisting of fine beads to either camouflage or search a target object, enhance the local mixing of two different chemicals, and generate a desired concentrated chemical path.

3.1.2 Fast low-voltage dielectric elastomer actuators for soft robots and wearables

Xiaobin JI (1), Xinchang Liu (2), Vito Cacucciolo (1), Matthias Imboden (1), Yoan Civet (2), Alae El Haitami (3), Sophie Cantin (3), Yves Perriard (2), Herbert Shea (1),

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(2) Integrated Actuators Laboratory (LAI), Ecole Polytechnique Federale De Lausanne (EPFL), Neuchatel, Switzerland
(3) Laboratoire De Physicochimie Des Polymeres Et Des Interfaces (LPPI), Universite De Cergy-Pontoise, Cergy-Pontoise, France

Presentation given by Mr. Xiaobin Ji

We present ultra-thin compliant layered DEAs reaching full actuation strain at 450V, and operating up to 600 Hz. The DEAs are manufactured using 6 µm thick silicone membranes and CNT-based Langmuir-Schaefer electrodes. The low voltage enables control electronics weighing less than 1 gram. We demonstrate an untethered 1 g, 4 cm long soft robot, a DEA-insect, which can carry its own power supply, and is able to autonomously follow complex paths using on-board vision. The bare (i.e. without electronics) DEA-insect is robust: it can be crushed and then resume its activities; it is fast, with a maximum velocity of 20 mm/s. The DEA-insect is strong: it can carry up to 950 mg payload for a body weight of only 190 mg. Using the same DEA technology, we also report wearable haptics by mounting the low-voltage DEAs directly on a finger, enabling the user to feel notifications between 1 Hz and 500 Hz, while remaining free to use the finger for typing or eating. We anticipate our results will enable much broader use of stretchable DEAs for soft exoskeletons, autonomous soft robots, wearables and haptic interfaces.

3.1.3 From scissors to lasers: how to exploit dielectric elastomers for building (not only) actuators.

Luigi Calabrese (1), Enrico Gallus (1), Armando Favi (1), Gualtiero Fantoni (2), Danilo De Rossi (3) (4), Massimiliano Gei (5), Nicola Pugno (6) (7) (8),

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Presentation given by Mr. Luigi Calabrese

Technological innovation is a process that allows for the continuous development of new and more advanced tools. These tools often enable for pushing further the "possible limit", so that the development of new types of devices becomes possible. Dielectric Elastomer Actuators (DEA) are one of these technologies: basically made of a soft deformable membrane coated on both sides with compliant electrodes, they feature large voltage-induced strains, allowing for the development of new types of smart devices that find application in a variety of industries. In some cases, dielectric elastomer-based devices can be effectively manufactured with very simple tools. This is the case of the first application presented: a smart soft robot structure that exploits anisotropic friction to achieve stick-slip locomotion. In other cases, cutting edge technologies must be used to feature the DEA with particular capabilities. This is the case of the second application presented, where femtosecond laser pulses are used to drill micrometer scale holes on a dielectric elastomer membrane that find application for in-vitro cell cultures. An outlook on the potentials of the femtosecond laser technology on the micromachining of soft elastomer membranes and in general on the engineering of new materials is eventually given.

3.1.4 Modeling and optimized design of load specific dielectric elastomer actuator systems

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Presentation given by Mr. Daniel Bruch

Dielectric elastomer actuators (DEAs) feature high energy efficiency, design flexibility, light weight and the use of low-cost materials and processes. These characteristics make them well suited to be used as reasonable drive units in many applications with restricted energy consumption and construction space. In order to obtain a desired performance, the overall system needs to be designed precisely with regards to the characteristics of the (pre-) load and the operation mode. The common quasi-static design method of DEA systems does not yield an optimal design for dynamic applications, e.g., valves or switches. It leads to a system oversize with larger construction space, higher weight, energy-consumption and cost. In order to avoid this problem, the presented work introduces a systematic modeling and design approach based on energy considerations, which enables the design of load specific dielectric elastomer actuator systems by considering their required dynamic characteristics. This method allows a proper dimensioning of the DEA membranes and to predict the step response of the system. The capability of the method is illustrated by designing several large-stroke DEA systems, which consist of multiple strip in-plane DEAs, biased with buckled beam springs. The comparison between predicted step responses and experiments show good agreement. Additionally, a reduction of required DEA layers by a factor of 5 to 6 in comparison to the quasi-static design is validated.

Session 3.2

3.2.1 An actuator, a sensor and a battery working simultaneously into a multifunctional conducting polymer device to improve energetic efficiency

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Presentation given by Dr. Jose G. Martinez

Conducting polymers are very promising materials for the development of soft actuators (also called soft motors or 'artificial muscles', as they mimic processes and materials of natural muscles) for many different applications. They are multifunctional materials changing different properties such as volume, electrical potential or stored charge at the same time driven by the same reversible electrochemical reaction. Here we explore the simultaneous change on the three properties mentioned above to develop actuators that, while moving, are able to sense mechanical conditions (such as any lifted mass) and store charge. It is possible then to recover up to 83% of the consumed charge during de-bending and increase the energetic efficiency of the actuator by several orders of magnitude. Three tools (actuator-sensor-battery) work simultaneously in a trilayer driven by oxidation/reduction reactions of the constitutive polypyrrole films. Only two connecting wires contain, simultaneously, actuating, sensing and battery magnitudes.

3.2.2 Towards a matlab toolbox for microfluidic logic gate design combining finite element and network simulation methods

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Presentation given by Mr. Philipp J. Mehner

Microfluidic circuits are used in wide variety of Lab-on-Chip applications. Often, they consist of passive components like channels, reaction chambers and microfluidic mixers. Therefore, integrable and active components like peristaltic pumps and a hydrogel-based transistor have been proposed, which are scalable and can be fully integrated into the microfluidic system. With these components, active microfluidic logic circuits are designed as known for digital circuits. However, the complexity of microfluidic systems increases due to miniaturization and functional integration for which a comprehensive design environment is desired. We propose a microfluidic toolbox implemented in Matlab. The key component is a hydrogel-based microvalve model which has a transistor like behavior. This model is implemented as a network model in Matlab Simscape, which parameters are gained from a fluid structure interaction (FSI) model implemented in ANSYS. Further components like pumps and channels, including a concentration delay, are implemented respectively. With these three components, microfluidic logic circuits can be designed and even an automated layout synthesis for manufacturing is possible. The goal of this work is to demonstrate the advantages of a comprehensive computer aided design process which can predict the behavior of complex microfluidic systems.

3.2.3 New glove with operation elements based on dielectric elastomer sensors

Holger Boese (1), Stefan Muth (1), Simon Stier (1),

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Presentation given by Dr. Holger Boese

A new glove equipped with various types of dielectric elastomer sensors is described. The capacitive flexible sensors serve for technical operation functions controlled by defined finger actions. A first type of sensor detects the touch between different fingers. In contrast to other proximity sensors, the electrodes are distributed on different fingers. The approach of one finger to another one increases the capacitance between the electrodes. A second sensor type consists of three electrodes where two electrodes are located on one finger and the third electrode is located on another finger. Sliding the second finger on the first finger causes an increase or decrease, respectively, of two capacitances depending on the relative position of the third electrode with respect to the first two electrodes. A third sensor type is a pressure sensor located at the thumb of the glove. The applied pressure of the thumb on another finger can tune a technical function. The adjusted value can be frozen by simultaneously operating a touch sensor. All capacitive sensors are manufactured with silicone elastomer components, where the electrodes contain carbon black particles to become conductive. In addition, the glove is equipped with an electronic compartment with a microprocessor to measure and process the sensor capacitances. The data is wirelessly transmitted to a tablet computer where the status of the sensors can be graphically demonstrated.

3.2.4 Geometrical study and simulation analysis of a multi-dof double cone dielectric elastomer actuator for soft robotic systems

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Presentation given by Ms. Sophie Nalbach

Dielectric elastomers (DEs) consist of highly compliant electrostatic transducers which can be operated both as actuators and as sensors. Due to large achievable deformation and high flexibility, DEs appear as highly suitable for the design of soft robots capable of multi degree-of-freedom actuation. Despite several concepts of DE soft robots have been presented in recent literature, up to date there is still a lack of systematic studies aimed at optimizing the design of such systems. As a first step towards the performance optimization of complex DE soft robots, in this poster we investigate the effects of geometry scaling on the performance of a specific actuator system. The device under study consists of two cone DE membranes rigidly connected along the outer diameter, and pre-compressed out-of-plane against each other via a rigid spacer. The electrodes of each membrane are partitioned in four sections which can be activated independently, thus allowing to achieve different motion patterns. Different prototypes are assembled and tested, to study the influence of the inner diameter as well as the length of the rigid spacer on the achievable rotation angle of the spacer. The collected experimental results are then used to validate a simulation model. Finally, the developed model is used to perform a theoretical geometry optimization aimed at maximizing the rotation angle.

3.2.5 Multimodal and spatially resolved dielectric elastomer sensors and their application in robotics

Simon Stier (1),

(1) Fraunhofer-Institut Für Silicatforschung ISC, Würzburg, Germany

Presentation given by Mr. Simon Stier

Dielectric elastomer sensors are based on alternating and structured layers of conductive and insulating elastomers, which together act as multi-electrode capacitors. The reversible deformation of such a soft dielectric film system by external mechanical forces can therefore be measured by changing the capacitance of one or more electrodes. In this way, strain, pressure and force sensors as well as capacitive proximity sensors through superficial electrodes can be realized. In contrast to conventional sensors based on (semi)metallic structures, elastomer sensors are highly flexible and stretchable, they can be used for any surface geometry and, due to their uniform design, they can be combined with each other excellently. This makes it possible to create complex sensor systems that can measure several physical quantities simultaneously (multimodal) and at different positions (spatially resolved). This can be, for example, the spatially resolved combination of a proximity sensor and a pressure sensor, which acts as a sensor skin and allows both non-contact and tactile perception at the same time. In this presentation I will explain the operating principle of such systems and describe the challenges in manufacturing, electrical integration and measurement control. As a representation of the broad field of application, I will specifically address the implementation as a robot sensor skin that provides safety, input and handling functions for interaction with objects and humans.

3.2.6 Reliability evaluation of dielectric elastomer transducers through experimental analysis of different materials and damage evolution models

Lorenzo Agostini (3), Marco Fontana (2), Rocco Vertechy (1),

(1) University Of Bologna
(2) University Of Trento
(3) Scuola Superiore Sant"Anna

Presentation given by Prof. Rocco Vertechy

Dielectric Elastomer Transducers (DETs) are deformable capacitors made with polymeric materials and represent an emerging technology with great potential for low-cost high-performance mechatronic applications. DETs enable the static conversion of electrical energy into mechanical energy and vice-versa, making it possible to exploit them as soft actuators and generators. The success of DETs in real-world applications is strongly affected by their long-term performance. In the last years, the lifetime properties of DETs made of acrylic, silicone, natural and styrenic rubbers have been investigated by means of experimental tests and stochastic models. Very recently, a novel modelling approach for the evolution of electro-mechanical damage in DETs has been proposed which relies on a free-energy formulation. To better investigate the main phenomena involved in the damaging process, this poster presents a consistent approach for the reliability assessment of DETs which includes: 1) statement of a theoretical model for damage accumulation; 2) description of experimental set-up and procedures for specimen testing; 3) selection of suitable experimental testing conditions; 4) analysis of experimental data and their use for the identification of unknown model parameters.

3.2.7 How padding impacts the sensitivity of dielectric elastomer compression sensors

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Presentation given by Ms. Yuting Zhu

Robotic grippers designed to pick up delicate objects can have a soft padding to minimize damage. Compression sensors integrated with the padding can help to monitor the applied force on objects. There are many types of compression sensors on grippers. In this paper, we focus on Dielectric Elastomer (DE) compression sensors. Some research shows that the thickness of the padding impacts the sensitivity of DE compression sensors. We present an approach to instruct the design and fabrication of DE compression sensors with an optimum padding thickness, which enables grippers to identify and pick up a variety of objects without breakage and without compromising sensor sensitivity. This approach is based on the Finite Element Method (FEM) for calculating sensor deformation, along with a MatLab script for calculating capacitance change. The FEM model is set up with an axisymmetric indenter and assumes frictionless contact between the indenter and the sensor. This study has used a set of structured DE compression sensors with different padding thicknesses to obtain the value change of capacitance as a function of applied force, which was then validated with experimental tests on several fabricated DE compression sensors. The study developed and presented here will be helpful for applications in robotics and bio-instrumentation, in particular for the design of grippers capable of identifying and picking up different objects.

3.2.8 Dielectric elastomer generators based on silicone/nanospring-carbon-nanotubes composite

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Presentation given by Mr. Yauhen Sheima

Dielectric Elastomer Generators (DEGs) can generate electrical energy from mechanical motion. The operation principle of DEGs is rather simple. An elastic capacitor is mechanically stretched by an exter-nal mechanical force and charged at a certain voltage by an external power source. After charging, the capacitor is relaxed back by the elastic restoring forces, whereby the volt-age of the capacitor is in-creased. The disadvantage of such generators is the operation close to the di-electric breakdown of the dielectric. This problem is overcome by using an electret to polarize the dielectric. For the electret DEG, the dielectric breakdown is less critical, since the electric fields involved in these devices are far below the dielectric breakdown field. Additionally, the dielectric exposure time to maximum electric field is rather short, therefore the probability of dielectric failure in electret DEG is significantly lower as compared to regular DEG. In this work, materials with improved properties were synthetized for this application. Thus, an elastic material was developed, which has a dielectric permittivity of 4.6, a mechan-ical loss factor of 0.03 and a strain at break of 270%. The output voltage of the dielectric elastomer generator increased from 9.3 V for a regular PDMS to 14.5 V for the improved material at 66% strain. The safer and easier operation of electret DEGs allows their use on the humans and may be used one day for recharging portable electronic devices.

3.2.9 Inkjet printed strain-sensitive logic gates

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Presentation given by Ms. Katherine Wilson

Soft structures and robotics with integrated control present an opportunity for a new era of robots. To provide local signal processing, stretchable electronics are required. The dielectric elastomer switch (DES) is a piezoresistive electrode that turns charge on and off with stretch, and it can provide local control in smart soft devices. We have previously demonstrated that arrangements of dielectric elastomer actuators (DEA) and DES can form all the basic Boolean logic gates and memory elements. Due largely to manual fabrication, however, the complexity of logic is limited. Only simple logic functions with a couple of gates can be hand fabricated. We are investigating improving switch and logic performance by automatic inkjet material deposition. This allows for reproducible fabrication of smaller logic elements, allowing for lower voltages to be applied and more complex soft logic arrays. We present here printing and evaluation of custom ink formulae comprising carbon semi-conductive filler and silicone. Carbon is a popular electrode material. Although it has a relatively high resistance, it is compliant and produces electrodes that perform well with DEAs. We will discuss the assembly of logic arrays with our custom inks deposited on soft, stretchable materials.

3.2.10 Uv curable dielectric elastomer with high dielectric constant and compatible for 3d printing

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Presentation given by Mr. Ramadan Mohamed

Dielectric elastomers are soft materials able to convert electrical energy to mechanical energy. The fabrication process in complex geometry for such materials still one of the challenges. Also, the need for high voltage to actuate is considered a disadvantage. Recently, 3-dimensional printing solved many problems for complex geometries fabrication. Here, Direct Light Processing Printer, DLP, has been used to fabricate a new dielectric elastomer complex geometries with unique electromechanical properties. Acrylic based monomers have been used to formulate a new class of UV printable dielectric elastomer. The investigated novel dielectric elastomer has a 700% strain to failure, 0.2MPa Young's Modulus, 30KV/mm as a breakdown voltage. The value of the dielectric constant for the novel investigated acrylate dielectric elastomer is 38 at 1KH which considered being the highest because of the existence of polar groups in the main monomers used. The printable dielectric elastomer can actuate at low voltage up to 800V/mm which is considered as an achievement to overcome the high voltage actuation obstacles. The present work can help in designing the dielectric elastomers in complex geometry for different applications to actuate at low voltage.

3.2.11 3D Electrostimulable polymeric scaffolds for drug screening-applications

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Presentation given by Dr. Cedric Vancaeyzeele

In vivo, cells are surrounded by the extracellular matrix (ECM), a 3D-meshwork of macromolecules. A great variety of topographical and electrical clues emanates from ECM. The ECM modulates cell phenotype and response to drug agents and targeted therapies. To take into account this native 3D-environment, various synthetic scaffolds have been developed but they lack the combined regulatory inputs as porosity, elasticity, or electrical clues from the ECM. Besides, conducting polymers change volume and mechanical properties when electrochemically oxidized or reduced. They exchanges counter-ions with surrounding electrolyte, leading to electrochemically controllable volume changes. In this context, we present the first results on electroactive materials that are of critical interest to mimic the cell environment. Such materials is elaborated from highly interconnected porous poly(High Internal Phase Emulsion) structures. A conducting polymer is embedded into this matrix by oxidative chemical vapor phase polymerization of corresponding monomer. The polymer matrix contain electrolyte for conducting polymer actuation and is stable to autoclave sterilization. Primary culture cell results have shown that these materials are not cytotoxic. In future, we intend to functionalize these scaffolds with adhesive ECM glycoproteins for displaying controlled properties and signal dynamic of in vivo cell environments. Then, we will show that they are adapted for drug response screening.

3.2.12 A biomimetic fish fin robot based on textile reinforced silicone

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Presentation given by Mr. Sascha Pfeil

The presented biomimetic concept shows a fish fin-like robot that performs a waving motion in lateral direction. To enable the bending movement, dielectric elastomer actuators are positioned on both sides of the structure. To achieve a selectively directional bending stiffness, the body of the demonstrator is build of a fiber-elastomer compound, consisting of parallel oriented carbon fibers placed right in the neutral plane of the compound. Based on the adjusted mechanical behavior, the dielectric elastomer actuators generate the waving movement of the fish fin. The poster presentation is about the manufacturing process, the mechanical properties and the characterization of the demonstrator.

3.2.13 Monitoring flexions and torsions of the human trunk with dielectric elastomer stretch sensors

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Presentation given by Dr. Gabriele Frediani

Several biomedical and non-biomedical fields, such as rehabilitation, sports medicine and control of virtual reality systems, require measurements of the kinematics of human body movements. This is typically performed employing accelerometers, electrogoniometers, electromagnetic senscalors or cameras, which however are usually bulky, or can cause discomfort to the user, or are insufficiently accurate, or require expensive instrumentation. As an alternative to those state-of-the-art systems, stretchable piezocapacitive sensors based on dielectric elastomers (DE) represent a competitive technology, which might enable wearable, lightweight and cost-effective devices. DE sensors consist of stretchable capacitors whose mechanical deformation causes a change of capacitance, which can be measured and related to linear or angular motions, depending on the sensors' arrangement. Here, we present a wearable wireless system able to monitor the flexion and torsion of the lumbar region of the back. The system consists of two DE sensors arranged on shoulder straps, and a custom-made wireless electronics designed to measure the capacitance of the sensors and calibrate them when the user wears them for the first time. We describe preliminary results related to the characterisation of the sensors and the electronics.

3.2.14 A dielectric elastomer actuator driven pneumatic pump for soft robotics

Chongjing Cao (1) (2), Xing Gao (1) (2), Andrew Conn (1) (2),

(1) University Of Bristol
(2) Bristol Robotics Laboratory

Presentation given by Mr. Chongjing Cao

This work presents the design of a dielectric elastomer actuator (DEA) driven pneumatic pump and demonstrates its applications in soft robotics. The novel DEA configuration allows the resonant actuation under the existence of the damping of pressurized air and maximizes the pressure and flowrate output of this DEA driven pump. Several demonstrations specifically for soft robotics including inflating balloons, actuating a soft pneumatic gripper and suction cups are also presented in this work.

3.2.15 Change in actuation mechanism with film thickness for polypyrrole actuators

Daniel Melling (1),

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Presentation given by Dr. Daniel Melling

Ionic electro-active polymers (EAPs) are promising materials for production of fibre and textile linear actuators for active and haptic clothing. One approach to production is the electrodepositon of polypyrrole on a conducting fibre substrate. Synthesis conditions, geometric parameters and cycling conditions are known to impact the actuation of these films and require tuning to achieve optimum performance. Remarkably, we have observed that film thickness can be tuned to determine the type of actuation mechanism displayed. This behaviour is a consequence of changes in the structure of the polymer with film thickness. Changes in doping levels, effective conjugation coordinate, density, and porosity of the films with thickness, will be used to explain the observed behaviour. This behaviour has potential for exploitation for practical applications. It is vital that engineers are aware of these issues when designing EAP actuators with predictable and stable behaviour.

3.2.16 Optimisation of ionogels for conjugated polymer fibre and textile actuators

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Presentation given by Dr. Daniel Melling

Fibre and textile actuators employing ionic electro-active polymers require an ion source. This can be provided by a new family of photopolymerisable ionogels based on a mixture of multifunctional thiols, diacrylate and photobase generator for crosslinking via Michael addition reactions. These ionogels are one of the most recent classes of ionic conducting gels combining crosslinked polymer networks and ionic liquids. They permit operation in air/dry conditions. For optimal actuator performance the ionogels should be highly extensible and possess high ionic conductivity. We are currently optimising the polymer gel network and both the type and amount of ionic liquid incorporated as part of the EU project Weafing, which aims to produce fibre and textile linear actuators for active and haptic clothing.

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