EuroEAP 2022

10th international conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles

Chianciano Terme, Tuscany, Italy
7-9 June 2022

Technical programme

Book of abstracts

List of participants

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Conference venue

Grand Hotel Excelsior
Via Sant'Agnese, 6
Chianciano Terme, Siena, Italy

Conference Chairperson

EuroEAP 2022 is chaired by
Federico Carpi
Associate Professor in Biomedical Engineering
University of Florence
Department of Industrial Engineering

Local organization

EuroEAP 2022 is organized by
University of Florence, Department of Industrial Engineering

Contact information

For any information about EuroEAP 2022 please contact
Federico Carpi
University of Florence
Department of Industrial Engineering
Via di S. Marta, 3 - 50139 Florence, Italy
E-mail: federico.carpi@unifi.it
Cell phone: +39 3393849879

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. Carpi and his team for the organization of this 2022 edition. I am sure that you will enjoy this event, meet new colleagues, start new collaborations, and will leave with plans to attend the next edition.

Herbert Shea
EuroEAP Society President

Conference committees

Organizing committee

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

Edwin Jager, Linköping University (Sweden) - President
Federico Carpi, University of Florence (Italy)
Ingrid Graz, Johannes Kepler University (Austria)
Cedric Plesse, University of Cergy-Pontoise (France)
Samuel Rosset, Auckland Bioengineering Institute (New Zealand)
Frédéric Vidal, University of Cergy-Pontoise (France)

Local organising committee

Federico Carpi, University of Florence –Conf. Chair
Gabriele Frediani, University of Florence (Italy)
Luigi Calabrese, Smolsys Ltd (Switzerland)
Giacomo Moretti, Saarland University (Germany)

Scientific committee

The EuroEAP conference is scientifically overseen by the scientific committee of the EuroEAP Society:

Toribio Otero, University of Cartagena (Spain) - President
Reimund Gerhard, University of Potsdam (Germany) - Vice-President
Alvo Aabloo, University of Tartu (Estonia)
Federico Carpi, University of Florence (Italy)
Ingrid Graz, University of Linz (Austria)
Edwin Jager, Linköping University (Sweden)
Dorina Opris, EMPA, (Switzerland)
Helmut Schlaak, Darmstadt University of Technology (Germany)
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, 6 June 2022

Arrival	17:00-19:30	**Registration**
	19:30	**Get together** (*)

(*) Although no dinner will be organised by the conference, the option exists for the conference participants to get together by having a dinner at the conference hotel or at nearby restaurants.
Those who are willing to share a dinner are welcome to meet at the conference lobby at 19:30.

Tuesday, 7 June 2022

Morning session in Chianciano Terme		
Arrival	8:00-8:30	**Registration**
Conference opening	8:30-8:45	**Debora Berti** Pro-Rector for Research of the University of Florence, Italy **Federico Carpi** Conference Chairman
EAPlenary	Session 1.1 part I *Chair: Federico Carpi, University of Florence, Italy*	
	8:45-9:15	**David Clarke** Harvard University, USA
Invited lecture	Session 1.1 part II *Chair: David Clarke, Harvard University, USA*	
	9:15-9:35	**Edwin Jager** Linköping University, Sweden

Interactive Talks & EuroEAP Society Challenge	Session 1.2 *Chair:* Edwin Jager*: Linköping University, Sweden*	
	9:35-10:00	**Oral presentations** 8 presentations of research activities (3 minutes each)
	10:00-10:15	**EuroEAP Society Challenge video projection** 5 Challenge videos (3 minutes each)
	10:15-11:00	**Poster session, exhibitions** and Coffee break
	Session 1.3 *Chair: Ingrid Graz, Johannes Kepler University, Austria*	
	11:00-11:40	**Oral presentations** 13 presentations of research activities (3 minutes each)
	11:40-12:30	**Poster session and exhibitions**
Lunch	12:30	Lunch at Grand Hotel Excelsior
Bus transfer	13:45	Departure to Montepulciano

Afternoon Session in Montepulciano		
Session opening	14:45-15:00	**Welcome from Montepulciano's town hall administration**
Invited lectures	Session 1.4 *Chair: Herbert Shea, Ecole Polytechnique Fédérale de Lausanne, Switzerland*	
	15:00-15:20	**Reimund Gerhard** University of Potsdam, Germany
	15:20-15:40	**Longfei Chang** Hefei University of Technology, China
	15:40-16:00	**Samuel Rosset** University of Auckland, New Zealand
EuroEAP Society meeting	16:00-17:00	**Annual meeting of the EuroEAP Society** (open to everyone)
Social event	17:00-18:30	Visit of Montepulciano
Social dinner	18:30	Departure to dinner place
	19:30	Dinner at Chiostro Cennini, Sarteano

Wednesday, 8 June 2022

Morning session in Chianciano Terme		
Inspirational talk	Session 2.1 part I *Chair: Edwin Jager, Linköping University, Sweden*	
	8:30-9:00	**Dario Floreano** EPFL, Switzerland
Invited lecture	Session 2.1 part II *Chair: Dario Floreano, EPFL, Switzerland*	
	9:00-9:20	**Jörg Weissmüller** Hamburg University of Technology, Germany
Interactive talks	Session 2.2 *Chair: Anne Skov, Technical University of Denmark, Denmark*	
	9:20-10:00	**Oral presentations** 13 presentations of research activities (3 minutes each)
	10:00-10:50	**Poster session, exhibitions** and Coffee break
	Session 2.3 *Chair: Frédéric Vidal, University of Cergy-Pontoise, France*	
	10:50-11:30	**Oral presentations** 13 presentations of research activities (3 minutes each)
	11:30-12:30	**Poster session and exhibitions**
Lunch	12:30	Lunch at Grand Hotel Excelsior
Bus transfer	14:00	Departure to San Quirico d'Orcia

Afternoon Session in San Quirico d'Orcia		
Session opening	15:00-15:15	**Welcome from San Quirico d'Orcia's town hall administration**
Invited lectures	Session 2.4 *Chair: Reimund Gerhard, University of Potsdam, Germany*	
	15:15-15:35	**Stefan Seelecke** Saarland University, Germany
	15:35-	**Zhongyang Cheng**

	15:55	Auburn University, USA
	15:55-16:15	**Gabor Kovacs** CT Systems, Switzerland
Social event	16:30-18:30	Visit of San Quirico d'Orcia and its surroundings
Social dinner	18:30	Departure to dinner place
	19:30	Dinner at Fattoria Pulcino, Montepulciano

Thursday, 9 June 2022

<table>
<tr><th colspan="3">Morning session in Chianciano Terme</th></tr>
<tr><td rowspan="2">Inspirational talk</td><td colspan="2">Session 3.1 part I
Chair: Federico Carpi, University of Florence, Italy</td></tr>
<tr><td>8:30-9:00</td><td>Danilo De Rossi
University of Pisa, Italy</td></tr>
<tr><td rowspan="4">Invited lectures</td><td colspan="2">Session 3.1 part II
Chair: Samuel Rosset, University of Auckland, New Zealand</td></tr>
<tr><td>9:00-9:20</td><td>Christopher Walker
Auckland University, New Zealand</td></tr>
<tr><td>9:20-9:40</td><td>Majid Taghavi
Imperial College, United Kingdom</td></tr>
<tr><td>9:40-10:00</td><td>Vito Cacucciolo
Politecnico di Bari, Italy</td></tr>
<tr><td rowspan="6">Interactive talks</td><td colspan="2">Session 3.2
Chair: Luigi Calabrese, Smolsys Ltd, Switzerland</td></tr>
<tr><td>10:00-10:40</td><td>Oral presentations
12 presentations of research activities
(3 minutes each)</td></tr>
<tr><td>10:40-11:30</td><td>Poster session, exhibitions and Coffee break</td></tr>
<tr><td colspan="2">Session 3.3
Chair: Giacomo Moretti, Saarland University, Germany</td></tr>
<tr><td>11:30-12:10</td><td>Oral presentations
12 presentations of research activities
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<tr><td>12:10-13:00</td><td>Poster session and exhibitions</td></tr>
<tr><td rowspan="3">Best Poster & Society Challenge Awards</td><td>13:00-13:05</td><td>Final collection of votes</td></tr>
<tr><td>13:05-13:15</td><td>Counting of votes</td></tr>
<tr><td>13:15-13:20</td><td>Winner of the EuroEAP Conference Best Poster Award (sponsored by Springer)
Winner of the EuroEAP Society Challenge Award (sponsored by PowerOn)</td></tr>
<tr><td>Closing</td><td>13:20-</td><td>Conference closure, handover to the next year's</td></tr>
</table>

ceremony	13:30	Chairperson and presentation of the next year's conference place
Lunch	13:30	Lunch at Grand Hotel Excelsior

Tuesday, 7 June 2022

Session 1.1

(abstracts are listed in the order of presentation)

1.1.1 New frontiers in the development of DEAs based artificial muscles: beyond the simple capacitor

David Clarke (1),

(1) School Of Engineering And Applied Sciences, Harvard University

Presentation given by Prof. David Clarke

Realizing the potential of artificial muscles based on dielectric elastomer actuators (DEAs)will require the development of concepts, improved materials, and manufacturing methods beyond those available when the idea was suggested ten years ago. In this talk will describe some of these developments we have taken towards this and the larger goal of enabling DEA technology. One key concept is to go beyond the simple compliant capacitor actuator configuration to manipulate the local electric field and stiffness by creating an internal architecture structure of dielectric and conductors. This not only produces shape anisotropy but also enables voltage-controlled shape morphing and electrically controlled shape reconfigurability. Another key development has been to exploit the capabilities of 4D printing to create multiple-strand, addressable fiber bundles. These exhibit intrinsic fault tolerance as well as reconfigurable motions. With increased complexity, however, comes increased needs for multiplexed voltage control and non-contact addressability. Crucial to the implementation of these concepts remains both improved reliability and increased dielectric breakdown fields; areas of importance for all electrostatic-based devices.

1.1.2 Electroactive Textiles

Edwin Jager (1),

(1) Linköping University

Presentation given by Prof. Edwin Jager

Conducting polymers like polypyrrole can be electrochemically oxidised and reduced. These redox reactions are accompanied by a flow of counter ions and solvents from the electrolyte into or out of the polymer matrix to maintain charge balance and osmotic pressure resulting in a volume change of the conjugated polymer. This volume change can be exploited to fabricate electrochemically driven actuators in various formats from bending bilayer microactuators to macroscopic textile actuators. Yarn and textile actuators are fabricated by coating commercially yarns and fabrics with the conjugated polymers. First a thin layer of PEDOT (poly(3,4-ethylenedioxythiophene)) is applied to make the yarns or fabrics electrically conductive. Next, the yarns/fabrics are coated with the electromechanically active polypyrrole using electro-synthesis. Finally, the yarn/textile actuators are actuated by applying the appropriate redox potentials. To achieve in-air actuation, the yarns/fabrics are coated with ionogels, that function as the ion source/sink to drive the electrochemical reactions. Two ionogel coated yarns are assembled forming the anode/cathode pair of the electrochemical circuit. Using advanced textile processing such yarn actuators are integrated into fabrics using weaving or knitting. The latest results of our textile actuators operating in liquid electrolytes and in open air will be presented.

Session 1.2
(abstracts are listed in the order of presentation)

1.2.1 Silicones for bioinspired damping structures

Rene Preuer (1) (2), Ingrid M. Graz (1) (2),

(1) Johannes Kepler University, Christian Doppler Laboratory For Soft Structures For Vibration Isolation And Impact Protection (ADAPT), Linz, Austria
(2) Johannes Kepler University, School Of Education, STEM Education, Linz, Austria;;

Presentation given by Dr. Ingrid M. Graz

Living systems use soft multilayered protective structures like skin or fruit peel that can not only sustain high dynamic, but also quasi-static mechanical loads while being built-up by a small range of basic materials. On the other hand, man-made dampers, built to suppress vibrations and protect against impacts, use hard materials and soft materials, such as metals and elastomers, respectively. The latter are inherently dissipative due to their viscoelastic nature. Their stress-strain relation with its built-in phase-lag, makes them the materials of choice for simple and cheap damping systems employed in everyday life. We take inspiration in biological inspired dampers and show simple approaches to damping structures with adjustable stiffness based on silicone elastomers and discuss material choices and characterization methods.

1.2.2 Self-healable dielectric elastomer actuators operated at low electric fields

Johannes von Szczepanski (1) (2), Patrick M. Danner (1) (2), Dorina M. Opris (1),

(1) Swiss Federal Laboratories For Materials Science And Technology, Duebendorf, Switzerland

(2) ETH Zurich, Department Of Materials, Zurich, Switzerland

Presentation given by Mr. Johannes Von Szczepanski

Dielectric elastomer actuators (DEAs) are a class of electromechanical transducers characterized by outstanding shape flexibility and elasticity, which have great potential to find applications in soft robotic devices or artificial muscles. Increasing the dielectric permittivity of the dielectric elastomer allows for reducing the driving voltage needed for actuation. We report a nitrile group-modified polar polysiloxane elastomer with a permittivity of up to 18.1 at 100 kHz. The material is obtained by in situ polymerization and cross-linking by anionic ring-opening polymerization of a cyanopropyl-functional cyclotetrasiloxane (D4CN), octamethylcyclotetrasiloxane (D4), and a specially designed co-monomer (tris-D4) that acts as cross-linker. The silanol end groups remain active in the product and the equilibrium between network and low molar mass fragments can be shift-ed by temperature. The material reversibly softens upon heating and undergoes self-healing. The mechanical properties can be tuned easily by varying the concentration of cross-linker and polar monomer D4CN. DEAs manufactured from melt-pressed thin elastomer showed a lateral strain of up to 3.8% at a low electric field of 5.2 V/micrometer. The actuator membranes can be recycled by dissolving in THF and the recycled material reached a strain of 2.5% at 4.5 V/micrometer. Manually stacked actuators reached an actuation strain of up to 5.4% at only 3.2 V/micrometer.

1.2.3 Solvent-free synthesis and processing of dielectric elastomer transducers

Patrick Marcel Danner (1) (2), Dorina Maria Opris (1),

(1) Empa, Laboratory For Functional Polymers, Duebendorf, Switzerland
(2) ETH Zurich, Department Of Materials, Zurich, Switzerland

Presentation given by Mr. Patrick Marcel Danner

Dielectric elastomer transducers (DET) manufacturing requires conductive as well as dielectric inks, which are co-printed by various techniques. Each processing technique requires suitable viscosity of the two inks, often achieved by diluting them with a solvent. Especially, DET made from composites require a significant amount of solvent. Here, we introduce the synthesis of a conductive, soft, stretchable, and flexible electrode material using anionic polymerization of cyclosiloxane monomers in the presence of graphene nano platelets. The synthesis approach allows tuning the viscosity of the uncured material to suit various processing techniques such as screen printing, spray coating, direct ink writing, or fused filament fabrication. Additionally, it can be transferred to the dielectric composite, making this a versatile approach. Since the composites are synthesized solvent-free, stack DET can be easily manufactured and problems like delamination and swelling on the underneath layers are prevented. The entire process from synthesis to device manufacturing requires no solvent, the developed DET are not only efficiently manufactured but are also enviromentaly friendly.

1.2.4 Photo-crosslink bottlebrush polymers for voltage-driven artificial muscles

Yeerlan Adeli (1) (2), Francis Owusu (1) (2), Frank A. Nüesch (1) (2), Dorina M. Opris (1),

(1) Empa, Laboratory For Functional Polymers, Dübendorf, Switzerland
(2) EPFL, Institute Of Chemical Sciences And Engineering, Lausanne, Switzerland

Presentation given by Mr. Yeerlan Adeli

Applications of dielectric elastomer actuators (DEA) in implantable soft robots need soft elastomers that allow the manufacturing of reliable, durable, adaptable, and low voltage responsive actuators. However, currently, DEAs do not meet the safety standard due to the high driving voltage. Reducing the thickness and elastic modulus allows for lowering the driving voltage. However, soft materials are prone to electromechanical instability (EMI), which causes electric breakdown. The elastomers made by cross-linking bottlebrush polymers are one of the most promising approaches to achieving DEAs that suppress EMI. Dielectric materials prepared by chemically cross-linking bottlebrush polymers using free-radical UV-induced polymerization have been reported, but molds were required to prevent oxygen inhibition leading to rather thick films. Therefore, the respective actuators are operable at voltages above 4000 V. Herein, designed monomers that can be efficiently polymerized by ring-opening metathesis polymerization and subsequently cross-linked via a UV-induced thiol-ene click reaction were used. The developed strategy allowed us to produce defect-free thin films cross-linked within 5 min. The dielectric films gave up to 12% lateral actuation at 1000 V and survived more than 10'000 cycles at frequencies up to 10 Hz.

1.2.5 Coiled CNT and polycationic and polyanionic solid state ionogels for large stroke electrochemical artificial muscles

Bin Ni (1), Frederic Ribeiro (1), Cedric Vancaeyzeele (1), Giao T.M. Nguyen (1), Edwin Jager (2), Frederic Vidal (1), Cedric Plesse (1),

(1) CY Cergy Paris Université, LPPI - Chemistry Department, Cergy-Pontoise, France
(2) Division Of Sensor And Actuator Systems Department Of Physics, Chemistry, And Biology (IFM) Linköping University Linköping SE-581 83, Sweden

Presentation given by Dr. Cedric Plesse

Soft artificial muscles presenting a large contractile stroke in the open-air are potentially crucial for many applications, such as prosthetics, soft robotics or electroactive textiles and wearables. Coiled carbon nanotube (CNT) yarns are among the most promising candidates as electrochemical muscles operating under low voltage. While their air-operation has been previously achieved by their coating with hydrogels or organogels acting as ionic source/sink, their performances are either limited by an undesired bipolar behavior, rising from the competitive movement of both cations and anions, or by the inevitable drying of their volatile electrolytes. An open-air stable and unipolar stroke artificial muscle is presented here by the synthesis of two air-stable ionogels, their coating at the surface of coiled CNT yarns and their assembly, insuring ionic and mechanical junction. These polycationic and polyanionic materials are based on polymeric ionic liquids, a sub-class of polyelectrolytes, which can selectively enable only one type of ionic motion at each electrode of the device and turn its bipolar behavior into unipolar stroke. The resulting actuators showed air-stable contractile stroke, reaching 9.7% with a potential switch from 6V to -3 V and can be promising candidates for the development of electroactive textile muscles or wearable haptic devices.

1.2.6 Reproducing the cell damage after traumatic brain injury in vitro

Yihan Wu (1) (2), Thomas Park (2), Vickie Shim (1), Samuel Rosset (1),

(1) University Of Auckland, Auckland Bioengineering Institute, Auckland, New Zealand
(2) University Of Auckland, Centre For Brain Research, Auckland, New Zealand

Presentation given by Mr. Yihan Wu

Traumatic brain injury (TBI) is damage that negatively impacts the brain. TBI currently has no solution, thus understanding of its pathology is required. The aim of this study is to develop a cell injury device (CID) based on dielectric elastomer actuators (DEA) to characterize pathophysiological changes, especially the gene regulation patterns post-injury on human brain cells. We used DEAs to recreate TBI in an invitro model. This is suitable for TBI studies due to its ability to apply large strains at high rates. But this has not been used with human brain cells before. Hence, we first characterized DEA material features under various conditions to optimize for our study. Then DEAs were used to measure the mechanobiological changes in human brain pericytes after stretching via gene expression level changes. Pericytes were cultured in our CIDs and strained up to 40% prior to gene expression analysis. Our model produced significant gene fold changes at 4 and 48h. Results show that human brain cells can be cultured on DEAs and can be submitted to strains large enough to make a significant response. Our model is the first to use patient-derived brain pericytes, which are cells involved in injury response. The results demonstrate that our CID is suitable for simulating TBI as an in vitro model. This can contribute to long-term goals of producing realistic strain profiles of human TBI in vitro to measure cellular responses post-injuries.

1.2.7 Out-of-plane dielectric elastomer actuators manufactured with stacked single units for variable actuator configurations

Johannes Ehrlich (1), Peter Löschke (1), Angelika Nisalke (1), Holger Böse (1),

(1) Fraunhofer Insitut Für Silicatforschung

Presentation given by Mr. Johannes Ehrlich

Out-of-plane dielectric elastomer actuators (DEA) are known as spring-prestretched actuators to generate a controllable linear movement by the DEA film. To increase the force and/or the displacement of single film actuators, multilayer DEA films are used, but they exhibit the disadvantage of complete destruction, when only one layer gets damaged by electric breakdown. To get rid with this problem, flat and stackable single actuator units were used to create variable configurations of multi layered out-of-plane actuators with increased actuator force and displacement. The single actuators were manufactured with Wacker Elastosil 2030 silicone films with a thickness of 50 µm. The film is radially prestreched up to 10 % and carbon based electrodes are applied via spray coating. After electrode curing, a flat 2 mm thick 3D-printed PET ring is glued with a UV-curing epoxy adhesive to the pretreated silicone film. The manufactured single actuators were stacked in three, four and finally five unit multilayer configurations and prestretched with different springs. The actuator displacement and the blocking force were measured. Damaged actuators in the multilayer stack could be easily replaced with new actuators during the experiments. Moreover, a simple calculation model was established and the results of the measured displacement showed an excellent accordance to the calculation. A possible application is the integration in soft gripping tools for the handling of delicate objects

1.2.8 Piezo-electret elastomer with intriguing piezoelectric response

Francis Owusu (1) (2), Frank Nüesch (1) (2), Dorina Opris (1),

(1) Swiss Federal Laboratories For Materials Science And Technology Empa, Laboratory For Functional Polymers, Dübendorf, Switzerland.
(2) Ecole Polytechnique Federale De Lausanne, EPFL, Institute Of Chemical Sciences And Engineering, Lausanne, Switzerland

Presentation given by Mr. Francis Owusu

Materials that exhibit a thermal switchable dielectric permittivity and a large dielectric relaxation strength and required for tactile sensing and energy harvesting applications. When properly designed, such materials generate an electric signal when mechanically stressed. They are prepared using a composite approach in which polarized polymer nanoparticles with a large relaxation strength are embedded in an elastic matrix. We employed the power and versatility of ring-opening metathesis polymerization (ROMP) to tailor-make polymers with impressive dielectric relaxation strength. The polymers are processed into nanoparticles and used as fillers in a polydimethylsiloxane (PDMS) matrix. The resulting composites are processed into thin films and chemically cross-linked. A stable piezoelectric response (d_{31} = 37 pC/N) could be achieved by corona poling composite films in a strong electric field above T_g of the polymer nanoparticles.

EuroEAP Society Challenge Projects

(listed in the order of presentation)

	Project title	Last name	First name	Institution
1	MODES 3000	Bakardjiev	Petko	TU-Dresden
2	Super-sensitive interdigitated sensor for human-machine interaction	Hesam Mahmoudin ezhad	Masoumeh	University of Auckland
3	Dielectric elastomer rollercoaster	Nalbach	Sophie	Saarland University
4	Inkjet-printed stretchable zipping actuators for on-skin haptics	Grasso	Giulio	EPFL
5	Designing a demonstrator for elderly that shows the potential of a textile muscle	van Schaik	Melissa	University of Twente

The EuroEAP Society Challenge is generously sponsored by

PowerON Smart Elastic

https://www.poweron.one

Session 1.3

(abstracts are listed in the order of presentation)

1.3.1 Ionic Electromechanically active 4D porous polymer scaffold for cell culture monitoring

Franziska Hahn (1) (2), Ana Ferrandez Montero (1) (2), Remy Agniel (2), Johanne Leroy-Dudal (2), Cedric Vancaeyzeele (1), Cedric Plesse (1),

(1) Laboratoire De Physicochimie Des Polymères Et Des Interfaces (LPPI), I-Mat, CY Cergy Paris Université, 95000, Neuville Sur Oise Cedex, France.
(2) Equipe De Recherche Sur Les Relations Matrice Extracellulaire-Cellules (ERRMECe), I-Mat, CY Cergy Paris Université, 95000, Neuville Sur Oise Cedex, France

Presentation given by Dr. Cedric Vancaeyzeele

The development of cell culture platforms mimicking in vivo cell micro-environment is one of the key challenges in the fields of tissue engineering or drug screening. In this work, 3D porous materials based on polymerized high internal phase emulsion (polyHIPE) have been prepared, leading to materials with highly interconnected and open porosity. To explore the mechanical stimulation of cell or biological tissues, it has been homogeneously functionalized without any pore obstruction with an electroactive polymer, the poly(3,4-ethylenedioxthiophene) (PEDOT). Stimuli-responsive polymers give the exciting opportunity to implement a 4th dimension to these materials, providing the desired dynamic properties such as changes in their shape, morphology, pore size or stiffness under time-dependent external stimulation. The resulting polyHIPE-PEDOT scaffolds are compliant with cell culture requirements, keeping their electroactive properties after sterilization in autoclave, immersion in ions and proteins rich culture media and in presence of cells. The scaffolds present a suitable porosity for fast colonization and spreading of fibroblast cells into the pores. Under electrical stimulation, polyHIPE-PEDOT scaffolds present 10% volume variation in cell culture medium and allow stimulation of cells without inducing cytotoxicity. It allows the electromechanical stimulation of cells and the in-situ monitoring of their behaviors according to the dynamic of the microenvironment

1.3.2 Fabrication of photocurable PDMS fiber for dielectric elastomer linear actuator

Zhaoqing Kang (1) (2), Liyun Yu (1), Yi Nie (2), Anne Ladegaard Skov (1),

(1) The 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, Beijing Key Laboratory Of Ionic Liquids Clean Process, State Key Laboratory Of Multiphase Complex Systems, Institute Of Process Engineering, Chinese Academy Of Sciences, Beijing, China

Presentation given by Dr. Liyun Yu

Dielectric elastomers (DEs) exhibit high actuation speed, strain and work density, showing great potential for actuator applications. Varying configurations for DE actuators (DEAs) have been studied, e.g. planar, tube, roll, extender, diaphragm and bender. Tube DEA consists of a cylindrical DE tube with two compliant electrodes on internal and external surfaces. By applying voltage between electrodes, tube wall is squeezed causing axial elongation for linear actuation. Fiber DEAs include bundles of tube DEAs producing strong actuation force. If a fraction of fibers fail, actuator will in most cases continue to operate. Actuation voltage

1.3.3 Ionic liquid used as crosslinker of PDMS yielding an elastomer allowing for unprecedented strains at low electrical fields

Zhaoqing Kang (1) (2), Liyun Yu (1), Yi Nie (2), Anne Ladegaard Skov (1),

(1) The Danish Polymer Centre, Department Of Chemical And Biochemical Engineering/Technical University Of Denmark, Copenhagen, Denmark
(2) CAS Key Laboratory Of Green Process And Engineering, Beijing Key Laboratory Of Ionic Liquids Clean Process, State Key Laboratory Of Multiphase Complex Systems, Institute Of Process Engineering/Chinese Academy Of Sciences, Beijing, China

Presentation given by Mr. Zhaoqing Kang

Dielectric elastomers (DEs), commonly referred to as "artificial muscles", can present very large spatial deformation in response to an externally applied electrical field, giving them a great potential within the area of soft actuators. The DEs' driving voltages, which are usually high (typically 0.5 to 10 kV), have been shown to be significantly reduced via modification with high permittivity fillers. Nevertheless, for polydimethylsiloxane (PDMS) based elastomers most high permittivity moieties inhibit the sensitive platinum catalyst used for the addition curing scheme. Different from the traditional ways to prepare PDMS elastomers by addition curing reaction, a novel strategy is reported via the crosslinking reaction between multifunctional imidazole-grafted PDMS with difunctional bis(1-ethylene-imidazole-3-ium) bromide ionic liquid in this study. The prepared elastomer presents a relatively low Young's modulus (Y) of ~0.36 MPa and excellent mechanical stability with unchanged Y and strain at break after a year. Significant improvement in relative permittivity (11 at 0.1 Hz), which is ~4 times as high as that of commercial silicone elastomers (~2.8), is proven as well. Due to the excellent combination of properties, the dielectric actuator developed exhibits an area strain of 9 % at 18 V/micrometer. The novel strategy to prepare PDMS elastomers provides a new paradigm for achieving high-performance dielectric elastomer actuators in a simple manner.

1.3.4 Compliant ultrathin metallic electrodes for dielectric elastomer actuators enable the integration of optical diffraction patterns by laser patterning

Jonas Hubertus (1), Sipontina Croce (2), Julian Neu (3), Gianluca Rizzello (2), Stefan Seelecke (3), Günter Schultes (1),

(1) University Of Applied Sciences, Sensors And Thin Film Group, Saarbrücken, Germany
(2) Saarland University, Department Of Systems Engineering, Adaptive Polymer Systems, Saarbrücken, Germany
(3) Saarland University, Department Of Systems Engineering, Intelligent Material Systems Lab, Saarbrücken, Germany

Presentation given by Mr. Jonas Hubertus

The miniaturization of dielectric elastomers (DE) is a challenging task. This contribution reports on the design and fabrication of compliant metal thin film electrodes for DEs and demonstrates the potential for miniaturization by integrating optical diffraction gratings. A pre-stretched silicone film with a thickness of 50 µm (Wacker Elastosil 2030) is entirely coated on both sides with a 10 nm nickel thin film electrode by means of a magnetron sputtering process. After the coating the pre-stress is released resulting in a wrinkled electrode. This provides a mechanical buffer when the DE is stretched again. The desired electrode design is realized by a structuring process with an ultrashort pulse laser. The active areas as well as the conducting paths are created by either removing the electrodes on both sides with a high laser intensity or by using a low laser intensity to ablate only the electrode facing the laser. Micro structures are realized, allowing the integration of optical structures such as diffraction gratings into the DE. The observable diffraction pattern changes when the DE is actuated. DEs manufactured in this way offer good electromechanical properties. Among others, a low initial resistance in the range of 100 ?, a large stretchability up to 140 % and a force drop with an applied voltage. The latter is essential and proves the basic principle of DE actuators.

1.3.5 Measuring flow direction in a fish-like robot

Iain A. Anderson (1), Markus Haller (1), Orbaugh Derek (1), Sam Rosset (1), Chris Walker (1),

(1) Biomimetics Lab, Auckland Bioengineering Institute, Level 6, 70 Symonds St., Auckland, New Zealand

Presentation given by Prof. Iain Anderson

Fish can alter their swimming to point into the flow (rheotaxis), hold station behind bluff bodies (flow refuging) and harvest energy from environmental vortices, including the eddies behind their fellows in a school. This is made possible through sensory feedback that in addition to visual and inertial/balance sensing includes hydrodynamic sensing. The latter is largely made possible by the flow-sensitive neuromasts on the skin surface and in the channels of the lateral line. We seek to mimic fish hydrodynamic sensing for a fish-like unmanned underwater vehicle (UUV). A first step is to enable sensing for pointing into the flow: cyber-rheotaxis. For this we are using an elasto-tensegrity, fish-like robot whose overall shape is based on the Pacific Wahoo. We have fitted piezoresistive elastomer sensors, one each side to the head of the 'Robowahoo'. To demonstrate and test the sensors, the robot was placed in a flow-controlled water-flume tank and the head of the robot was slowly rotated in yaw. The resulting signal indicated whether the head was pointing straight or at an angle to the flow. This ability to sense flow direction will be directly linked to the actuator of the tail in closed-loop control. This represents a first step towards providing a fish-like robot with soft electroactive polymer hydrodynamic sensing capability. This brings us closer to the goal of accurate and efficient fish-like swimming.

1.3.6 Tubular dielectric elastomer actuators

Markus Koenigsdorff (1), Sascha Pfeil (1), Johannes Mersch (1), Gerald Gerlach (1),

(1) Technische Universitaet Dresden, Institute Of Solid-State Electronics, Dresden, Germany

Presentation given by Mr. Markus Koenigsdorff

State-of-the-art applications of DEAs in soft robots mostly rely on stretchable carbon-based electrodes, like carbon black or carbon nanotube particles dispersed in silicone or grease. In this work a different electrode is employed - a highly anisotropic electrode based on unidirectional carbon fibre non-crimp fabric. This material not only serves as an electrical conductor, but additionally allows to manipulate the mechanical properties of the actuator and thus enables new actuator designs. A potential use for this is demonstrated in the three presented tubular actuator concepts - an axial elongating, a radial expanding, and a torsional twisting tube. The actuator showing axial deformation is manufactured by rolling the electrode fabric into a tube with the fibres running in the tangential direction. This leads to the blocking of the radial deformation. When instead the fibres are running in axial direction, the opposite effect is achieved. With activation, the actuator cannot expand axially and, therefore, expands in the radial direction. For the twisting actuator, a sheet with a fibre angle of 45° is rolled up, hence, allowing axial and radial expansion when activated, which also leads to a twisting deformation. The presented concepts show high potential for soft biomimetic systems as they allow the frameless application of DEAs. Furthermore, the actuators deformations can be enhanced by pre-stretching the dielectric in fibre direction.

1.3.7 Biohybrid variable-stiffness soft actuators that self-create bone

Danfeng Cao (1), Jose G. Martinez (1), Emilio Satoshi Hara (2), Edwin W. H.

Jager (1),

(1) Linköping University, Department Of Physics, Chemistry And Biology, Sweden
(2) Okayama University, Department Of Biomaterials Graduate School Of Medicine, Dentistry And Pharmaceutical Sciences, Japan

Presentation given by Dr. Danfeng Cao

We herein describe the fabrication, optimisation and characterisation of a biohybrid variable stiffness actuator that creates its own bone. by combining the electroresponsive properties of polypyrrole (ppy) with the compliant response of alginate gels functionalised with cell-derived plasma membrane nanofragments (pmnfs) it was possible to obtain bio-induced variable stiffness actuators. when the pmnfs were incubated into mem, i.e. exposure to ca, this caused the formation of calcium-phosphate minerals (i.e. amorphous calcium phosphate and hydroxyapatite) in the alginate gel, resulting in a more rigid layer and thus reducing and finally impeding the movement of the actuator, locking it in a fixed position within only 2 days. these actuators could morph in various, pre-programmed shapes and change their properties from soft to rigid. adding different patterns to the actuator allowed locking the device in a predetermined shape without energy consumption, facilitating its application as soft-to-hard robotics as a biohybrid variant of so-called 4d manufacturing. the devices could wrap around and integrate into bone by the induced mineralisation in and on the gel layer. this illustrates its use as a potential tool to repair bone or in bone tissue engineering.

1.3.8 EAP based actuators to be woven

Jose G. Martinez (1), Carin Backe (2), Nils-Krister Persson (2), Edwin W. H. Jager (1),

(1) Linköping University, Department Of Physics, Chemistry And Biology (IFM), Linköping, Sweden
(2) University Of Borås, The Swedish School Of Textiles, Borås, Sweden

Presentation given by Dr. Jose G. Martinez

The development of actuating wearable textiles is of great interest in fields as haptics or assistive devices. Electroactive conducting polymer-based actuators are being merged with yarns and fabrics to provide them with mechanical actuation. One way to speed up the development of such mechanically active wearable textiles is the development of conducting polymer-based actuators that can be incorporated into textile processing. This imposes extra requirements to the actuators such as the required size, improved mechanical and electrochemical stability, actuation in air or the use of low/non-hazardous materials. Tape yarn actuators composed of conducting polymer/ionically conducting layer/conducting polymer are being developed and optimized to that aim. The latest developments on integrating such EAP tape yarns in woven fabrics will be presented.

1.3.9 Light-coded biopolyester actuators with complex shape-shifting

Yaxin Qiu (1) (2), Jing Song (2), Defeng Wu (2),

(1) Department Of Physics, Chemistry And Biology (IFM), Linköping University, Linköping, 58183, Sweden
(2) School Of Chemistry & Chemical Engineering, Yangzhou University, Yangzhou, Jiangsu, 225002, China

Presentation given by Dr. Yaxin Qiu

For shape-morphing polymers, it is vital for shape shifting pathways to design material heterogeneity. This material heterogeneity is capable to induce a homogenous force so that a section of the material presents an unusual shape-shifting pathway. However, it is not convenient for the chemically cross-linked networks to reprogram the heterogeneity after these networks are cross-linked or encoded. Herein, the photoactive coumarin derivative provides a new photo-reversible way to introduce or reprogram the heterogeneity of polymer networks. Coumarin end-capped dangling chains were used to build photo-reversible polyester networks, meanwhile endowing the networks with reprogrammable heterogeneity and capability of room-temperature storage of entropic energy. Using poly(?-caprolactone)/poly(L-malic acid) as covalent skeleton, photo-reversible group end-capped dangling chains as regulator of network topology, and crystallizable chain segments as actuation-controlling units, a polyester elastomer was developed. The alterations of network topology with 365 nm/254 nm UV light and the strain-induced crystallization behavior of as-obtained polyester elastomers were researched, which can quantitatively control the spatiotemporal release of entropic energy to tailor asynchronous deformations. This work proposes a new method to simplify shape morphing manipulation and to diversify shape-shifting pathways of shape memory polymers.

1.3.10 Pressure sensitive dielectric elastomer sensors for monitoring breathing and SoC of clamped Li-ion cells

Johannes Ehrlich (1), Johannes Ziegler (1), Philip Daubinger (1), Detlev Uhl (1),

(1) Fraunhofer Insitut Für Silicatforschung

Presentation given by Mr. Johannes Ehrlich

Dielectric elastomer sensor (DES) films based on silicone rubber are widely known to be used as strain sensors for high deformations up to 100 % and more. By using special rubber based structures to be attached on both sides of the DES film, a thin and soft compression load sensor with high sensitivity for monitoring breathing of Li-ion cells during cell cycling was developed. To detect irregular expansion over the cell surface, the intermediate sensor layer comprises four sensor points to measure deformation changes arranged in a 2 x 2 matrix. A full area electrode layer, applied on top of the rubber structures, covering the sensor points ensures good electrical shielding against outer interferences. The change of capacity of each sensor point as a function of the applied pressure up to 170 kPa and the resulting displacement was characterized. The sensor array is mechanically clamped inside a test bench comprising a 10 Ah Li-ion cell, equipped with an additional load cell for force measurement. The cell is cycled from 100 % SoC to 0 % SoC, back to 80 %. During charging Li-ions are allocated in the electrode material, the cell volume expands and the pressure within this clamped setup increases. The change of compression load and the resulting inhomogeneous breathing of the cell can be monitored by the sensor array. The sensor signals correlate to the different states of SoC. This opens up great potential in the field of ageing monitoring of Li-ion cells.

1.3.11 Self-healable and reprocessable soft actuators based on vitrimer chemistry

Khoa Bui (1) (2), Giao T.M Nguyen (1), Cédric Vancaeyzeele (1), Frédéric Vidal (1), Chaoying Wan (2), Cédric Plesse (1),

(1) CY Cergy- Paris Université, LPPI, Cergy, France
(2) University Of Warwick, IINM, WMG, Coventry, UK.

Presentation given by Mr. Khoa Bui

We develop here a self-healable soft actuator consisting of biobased dielectric elastomer laminated with ionic gel electrodes. The implementation of a common vitrimer chemistry to the dielectric elastomer layer and the ionic gel electrodes enables covalently bonded interfaces and self-healing function, so that potentially recover the mechanical and electrical properties of the components in the event of mechanical damage and electrical breakdown. Specifically, an epoxidised natural rubber is crosslinked with polyacids to form covalent adaptable networks. The thermally-triggered reversible ?-hydroxy ester bonds allow the network to rearrange and enable self-healing. The nature of dynamic crosslinks also allows improving tensile strength, elongation and dielectric permittivity while maintaining low elastic modulus and dielectric loss. Thus, the vitrimer dielectric elastomer exhibit improved actuation performance at low voltages. Ionogel electrodes are prepared from crosslinked poly(ethylene glycol) vitrimer and ionic liquids. The latter prevents the gel from drying due to their exceptionally high boiling point, ensuring structural stability and high ionic conductivity. The common vitrimer chemistry with the elastomer has been chosen and has allowed a reversible network topology exchange leading to efficient welding between elastomer and electrodes. The initial results show that the dielectric elastomer and vitrimer ionogel are promising as materials for sustainable DEA.

1.3.12 Bioinspired compliant mechanism valve with low voltage dielectric elastomers

George Stiubianu (1), Adrian Bele (1), Alexandra Bargan (1), Mihaela Dascalu (1), Alina Soroceanu (1), Ana-Maria Macsim (1), Maria Cazacu (1),

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

Presentation given by Dr. George Stiubianu

Climate change is a significant challenge for the future of humanity. Scalable installations for Direct Carbon Capture of atmospheric carbon dioxide are one technological option for lowering the atmospheric content of greenhouse gases. For this purpose, we designed tunable shutter valves involving dielectric elastomers actuators to control the flow of air in such an installation for direct carbon capture. We designed the valves as compliant mechanism structures by drawing inspiration from the shape of pectoral fins of sea rays (Batoidea). For this, we used soft elastomer thin film dielectrics based on siloxane block copolymers, with Young modulus < 0.1 in the range 10^-1 - 10^6 Hz. The technology can be commercially scaled since the polymers used are easy to synthesize and have affordable price costs on industrial scale production. The laboratory tests showed the valves work without significant degradation of actuation performance for 10^7 cycles. The actuation of the dielectric elastomer takes place at voltages lower than 500V. Actuating the valves in desired positions it is possible to regulate an air flow of up to 10 m^3/hr, with each actuation requiring a one-time input of ~10 W/m^2 of valve surface as the valve moves in the positions of equilibrium of the compliant multistable mechanism.

1.3.13 Printing of stretchable electrodes for multilayer dielectric elastomer transducers

Ozan Çabuk (1), Tim Krüger (1), Jürgen Maas (1),

(1) Technical University Of Berlin, Mechatronic Systems Laboratory/Institute Of Machine Design And Systems Technology, Berlin, Germany

Presentation given by Ozan Çabuk

Electrodes for dielectric elastomer (DE) transducers are not only for electrical conductivity essential but also for keeping the transducer soft and providing the robustness of the multilayer structure. There are two main aspects to consider in this issue: electrode material and application method. This contribution presents an overall evaluation of both aspects based on experiments and measurements. On the one hand, contactless printing technologies are highlighted due to their precision and finest parameter adjustability. On the other hand, Carbon Black (CB) based silicone electrodes are emphasized as suitable for multilayer DE transducers because of the softness and good adhesion despite the moderate conductivity. Furthermore, the fluidic properties of CB-based electrodes, which are critical for printability, are adopted. Thus, the printing quality is improved. The results are discussed in terms of the production and actuation performance of the multilayer DE transducer.

Session 1.4

(abstracts are listed in the order of presentation)

1.4.1 Electrets: polymer-based electromechanically active transducer materials and beyond

Reimund Gerhard (1) (2),

(1) University Of Potsdam, Faculty Of Science, Potsdam, Germany
(2) Technical University Of Berlin, High-Voltage Engineering, Berlin, Germany

Presentation given by Prof. Reimund Gerhard

Electrets are dielectric materials with quasi-permanent space charges and/or dipole polarization. They come as electro-electrets, space-charge electrets, ferro-/piezo-electrets, molecular-dipole electrets, piezo-/pyro-/ferroelectric crystals or ceramics, and piezo-/pyro-electric composites. They are not always polymeric and soft and often not only electromechanically active (piezoelectric/electrostrictive), but can also be inorganic, hard, heterogeneous, ferroelectric, pyroelectric/electrocaloric, providing a quasi-permanent electric field, etc. An overview of various types of electrets and of intuitive ways to understand their relevant properties from their nano-, micro- or macro-level structures will lead to recent examples of new materials and systems with useful applications. Relaxor-ferroelectric fluoropolymers may - for instance - exhibit large electromechanical effects for electrostrictive transducers, slim (low-loss) ferroelectric hysteresis curves for efficient memory and storage devices, and large electrocaloric responses for micro-refrigerators. Electrically charged or conductive open-porous polymer-fiber structures and textile materials may offer large performance gains in new micro-energy-harvesting and soft and flexible sensor or actuator devices. The multi-faceted nature of electrets is not only a challenge when undesired effects must be suppressed or compensated, but also an opportunity for significantly enhanced and even unexpected synergies and applications.

1.4.2 Ionic electro-active polymer: fabrication, modeling and application

Longfei Chang (1) (2), Dongping Wang (1), Ying Hu (1), Alvo Aabloo (2),

(1) Anhui Province Key Lab Of Aerospace Structural Parts Forming Technology And Equipment, Hefei University Of Technology, Hefei 230009, P. R. China
(2) Intelligent Materials And Systems Laboratory, Institute Of Technology, University Of Tartu, Estonia

Presentation given by Prof. Longfei Chang

(Abstract for the oral presentation)Ionic electro-active polymer (IEAP) has been extensively explored as both actuators and sensors. Due to its unique advantages including low driven voltage, high flexibility, large deformation and feasibility in subaqueous environment, IEAP has been probed in various applications such as soft robotics, biomedical equipment and wearable devices. In this presentation, Ionic Polymer Metal Composite (IPMC), as one of the most promising and representative candidates of IEAP, will be introduced comprehensively from different aspects to present a general picture for this field, primarily with the authors' research achievements in recent years. The optimization of fabrication processes and the investigation of novel structures including single-layered-electrode structure, high-performance sensing structure, as well as simplified interface structures will be displayed to show the improvement strategies of the functional properties. In addition, the multi-physical modeling incorporating the main characteristics of the interface morphology, based on simplified profile and fractal structures with Weirstrass-Mandelbrot (W-M) function will be provided to explain the crucial influences of the interface on the electro-mechanical properties of IPMC. Besides, some application examples of IPMC in soft robotics and wearable sensors are demonstrated as well.

1.4.3 Capacitive sensing that is out of the "geometry change" box

Samuel Rosset (1), Masoumeh Hesam Mahmoudinezhad (1), Iain Anderson (1),

(1) Biomimetics Laboratory, Auckland Bioengineering Institute, University Of Auckland, Auckland, New Zealand

Presentation given by Dr. Samuel Rosset

When it comes to capacitive dielectric elastomer sensing we rely on dielectric geometry change to detect deformation. This concept works beautifully for tensile strain sensors. However, making high sensitivity compression sensors is more challenging due to the incompressibility of elastomers: as the back of the sensor is fixed and cannot move, deformation is severely limited no matter how soft the dielectric material is. Clever approaches have been proposed to circumvent the issue, usually based on a structuration of the dielectric. These solutions solve the incompressibility issue but lead to an increased fabrication complexity. They stem from the paradigm that soft capacitive sensing must rely on a force-induced alteration of the sensor geometry to create a change of capacitance. But what if there was another way? We present a soft compression sensor that relies on a change of permittivity when deformed. A fringing field is created by a pair of interdigitated electrodes (IDEs) that extends into a composite whose dielectric constant can change by 250% when compressed. The IDEs can be fabricated on a standard PCB. As they are located at the sensor's base, there is no need for compliant electrodes. The sensing layer takes the form of a monolithic block that is moulded on the electrodes, thus resulting in a low-cost sensor that is extremely easy to manufacture. This sensor is ideal for sensing skins for robotic grippers, allowing the manipulation of soft and delicate objects.

Wednesday, 8 June 2022

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

2.1.1 Bio-inspired Aerial Robotics

Dario Floreano (1),

(1) EPFL, Institute Of Mechanical Engineering, 1015 Lausanne

Presentation given by Prof. Dario Floreano

Drones have taken the world by storm. In few years, they have become one of the fastest growing sectors in robotics and are even available on the shelves of your neighborhood supermarket. And yet, today's drones cannot compete with insects and birds in terms of mechanical resilience, agility and endurance, adaptability, and multi-functionality. In this talk I will describe work addressing these challenges that take inspiration from insect-inspired perception, exoskeletal structures, foldable and morphing bodies, multi-modal locomotion, grasping and perching, and cooperative manipulation. Do you want to fly?

2.1.2 Hybrid nanomaterials from electroactive polymers and metal

Jörg Weissmüller (1) (2),

(1) Hamburg University Of Technology
(2) Helmholtz-Zentrum Hereon

Presentation given by Prof. Jörg Weissmüller

The strong coupling between chemistry or electrochemistry and mechanics at

interfaces may be exploited for designing materials with enhanced or novel functional behavior. One example is provided by nanoporous-metal based hybrid materials that behave similar to piezoelectric ceramics: bodies of nanoporous gold impregnated with electrolyte emit exceptionally robust electric sig-nals when sub-jected to external load. The metal-based material may thus be considered as piezoelectric, in a literal interpretation of the term. Besides combining metals with water to act like ceramics, one may also add electroactive polymers to complement the range of materials classes in such hybrid materials schemes. Conformal coatings of polypyrrole (PPY) along the pore surfaces in nanoporous metals exemplify that approach. Here, the metal serves as load-bearing and electronically conductive backbone, PPY as functional active component for actuation and the aqueous electrolyte provides a pathway for fast ionic conduction. Understanding the performance of such materials as actuators or sensors requires a quantification of the electo-chemo-mechanical coupling strength in thin PPY films . Cantilever bending schemes provide a particularly robust access to such data. The talk will discuss the interrelation between the coupling strength at polypyrrole-functionalized planar model surfaces and the behavior of hybrid nanomaterials with a more complex microstructural geometry.

Session 2.2

(abstracts are listed in the order of presentation)

2.2.1 A platform for the mechanical and optical stimulation of cells

Samuel Rosset (1), David Bishop (3), Herbert Shea (2), Matthias Imboden (2),

(1) Biomimetics Laboratory, Auckland Bioengineering Institute, University Of Auckland, Auckland, New Zealand
(2) Soft Transducers Laboratory, Ecole Polytechnique Fédérale De Lausanne, Neuchâtel, Switzerland
(3) Department Of Mechanical Engineering, Boston University, Boston, USA

Presentation given by Dr. Samuel Rosset

We present the combination of a DEA-based cell stretcher and targeted optical stimulation. A varifocal micro-opto-electromechanical mirror couples the light from an optical fibre and directs it to a precise location on the cell-stretcher membrane. A set of 4 thermal micro-actuators tilt the mirror along two axes and can position the light spot in a 6 mm x 6 mm zone. The curvature of the mirror can also be electro-thermally modulated, thus making it possible to control the spot size on the membrane between 0.5 mm and 2 mm in diameter. The control of the spot position and size can be synchronised with the actuation of the cell-stretcher, thus making it possible to illuminate a targeted group of cells during the mechanical stimulation. The platform enables unprecedented experimental assays combining mechanical and localised optical stimulation with applications in optogenetics, light-activated drugs, fluorescent microscopy or laser stimulation.

2.2.2 High-performance ionic polymer metal composite actuators with macroscopic serrated interface

Longfei Chang (1) (2), Manting Rao (1), Alvo Aabloo (2),

(1) Anhui Province Key Lab Of Aerospace Structural Parts Forming Technology

And Equipment, Hefei University Of Technology, Hefei 230009, P. R. China
(2) Intelligent Materials And Systems Laboratory, Institute Of Technology, University Of Tartu, Nooruse 1, 50411 Tartu, Estonia

Presentation given by Prof. Longfei Chang

(This is an abstract for a poster)As a representative ionic electro-active polymer (IEAP), Ionic Polymer-Metal Composite (IPMC) has been widely characterized with typical sandwich-like layered structure as well as bidirectional electro-mechanical transformation ability. During recent few years, the importance of the interface between the electrode and substrate polymer received growing attention for the research on both the multi-physical modeling of ion-based mass transport and practical performance manipulation of ionic electro-active actuators. In this presentation, the influences of the interface in IPMC actuators will be investigated comprehensively based on a macroscopic serrated interface morphology, by distinguishing the effects respectively from the bending direction as well as the variation of interfacial area, excisional volume and moment of inertia. The offsetting interactions from those different parameters were analyzed in detail, of which an interesting result showed that, contrary to current understanding, due to the trade-off influences from the increasing excisional volume and decreasing bending inertia moment, the enlarged interface area didn't necessarily lead to better deformation. In addition, with a correspondingly established fabrication process, it was verified experimentally that IPMC with a super simple macroscopic serrated interface can present a high-performance electro-active performance, providing a minimalist design strategy of IEAP structures.

2.2.3 Experimental validation and modelling of a high voltage driving circuit for dielectric elastomer actuators

Carmen Perri (1), Gianluca Rizzello (2), Stefan Seelecke (2), David Naso (1),

(1) Polytechnic Of Bari, Department Of Electrical And Information Engineering, Bari BA, Italy
(2) Zentrum Für Mechatronik Und Automatisierungstechnik Gemeinnützige, Intelligente Materialsysteme Laboratory, Saarbruecken, Germany

Presentation given by Ms. Carmen Perri

Dielectric elastomer actuators (DEAs) need to be driven by high voltage (1 to 3.5 kV). The resulted electric field generates the so-called Maxwell stress that causes the expansion in area and the reduction in thickness of the DE. In order to support the DEA technology, a small, low power consumption source is necessary. In our poster, we present a control-oriented model of a novel high voltage electronic able to drive DEAs. The circuit in study is a DC-DC converter, which consists of a resonant circuit and a Greinacher circuit (10x5 cm). The first part operates at low voltage and converts the DC input voltage (3-5V) in AC voltage (±10V); the second part operates at high voltage, and doubles and rectifies the AC voltage in DC high voltage (1.5 - 3kV). Resonant and Greinacher circuit are coupled through a three coils transformer, which provides a galvanic isolation. Then a passive discharging path is added in parallel to the Greinacher circuit. The developed mathematical model accounts for many parasitic elements of the high voltage circuit in study, among which transformer stray and ohmic losses. The model can predict the high voltage given to the DEA and the current through the membrane at different capacitance values of the DEAs and at different input voltage values. After describing the circuit, an experimental validation is carried out and results are shown on this poster. The developed model will help to control high voltage electronics, used to drive DEAs.

2.2.4 Large force actuators with synergistic output of dielectric elastomer actuators and shape memory alloys

George Stiubianu (1), Adrian Bele (1), Codrin Tugui (1), Maria Cazacu (1), Firuta Borza (2), Marian Grigoras (2), Leandru-Gheorghe Bujoreanu (3),

(1) Department Of Inorganic Polymers, Petru Poni Institute Of Macromolecular Chemistry, Iasi, Romania
(2) National Institute Of R&D For Technical Physics, Iasi, Romania
(3) Technical University Of Iasi, Faculty Of Materials Science & Engineering

Presentation given by Dr. George Stiubianu

Shape memory alloys are used for the construction of devices without moving parts, with controllable shape and high force actuation. Here we show the use of dielectric elastomers as force enhancing actuator for devices with shape memory alloys. The energy stored in the dielectric elastomer in the strain phase is applied to return the shape memory alloy blade actuator to its initial position without supplementary input of energy in the system. Both the shape memory alloy and the dielectric elastomer film are embedded in a hard polymer frame shaped as compliant clip. The dielectric is a soft siloxane elastomer with low Young modulus (< 0.1 for 10^0 - 10^6 Hz. Each cycle of actuation takes up to 10 seconds and 10000 cycles have been tested on the same device at laboratory scale without performance degradation. The electrode for the dielectric elastomer is an ionic conductor whose conductivity is preserved for strain applied to the ionic conductor up to 200% linear strain. The tested devices have potential for devices with no moving mechanical for low frequency actuation.

2.2.5 Improvement of a soft electrostatic generator: polarization with a triboelectric function

Simon-emmanuel Haim (1) (2), Christophe Pollet (1), Axel Sanchez (1), Claire Jean-mistral (2), Alain Sylvestre (1),

(1) Univ. Grenoble Alpes, CNRS, Grenoble INP, G2Elab, Genoble, France
(2) Univ Lyon, INSA-Lyon, CNRS, LaMCoS, Villeubanne, France

Presentation given by Mr. Simon-emmanuel Haim

Soft electrostatic generators (SEG), typically made of electroactive polymers like silicone, represent an efficient way to power up devices widely used in the IoT, including smart clothes, biomechanical energy harvesters or sensors. The principle of these generators is to exploit in an external circuit the electricity produced by a variation of capacity induced by a mechanical deformation of the SEG. The electrical charges available for this circuit have been in most cases previously brought through a high voltage supply (HVS). To get rid of the HVS and make the SEG autonomous in energy, we present an original solution based on a TENG (Triboelectric nano generator) approach used in a sliding mode. In order to develop and optimize the electrical response performance of the TENG to be coupled with our silicone-SEG, a test bench equipped with Trek electrostatic probes, a Keithley electrometer and a decade box has been designed. Thanks to this over-equipped bench, we have monitored the transfer of electrical charges between the two materials that form the TENG (copper, PET, PTFE.) over thousands of cycles in sliding mode. Modeling with a finite element model is underway to account for the observed mechanisms. Finally, a first attempt to charge our SEG with the TENG has shown good charge transfer using passive conditioning circuits made of diode rectifiers.

2.2.6 A multi mode, multi frequency dielectric elastomer actuator

Sebastian Gratz-Kelly (1), Gianluca Rizzello (1), Marco Fontana (2), Stefan Seelecke (2), Giacomo Moretti (1).

Presentation given by Mr. Sebastian Gratz-Kelly

This contribution presents a concept of multi-function dielectric elastomer actuator (DEA) that can concurrently accomplish low-frequency linear actuation, sound generation, and deformation sensing through a single active element driven by a single electrical input. Multi-functionality is achieved by taking advantage of the dynamic response of a conically-deformed membrane, holding a heavy suspended mass free to move in the axial direction. The frequency response of the system shows an isolated low-frequency pumping mode (corresponding to a linear motion of the moving mass) and a series of structural modes of the membrane (whose eigenfrequencies fall within the acoustic range), whose passband presents little or no overlap with that of the pumping mode. Providing the DEA with a multi-chromatic voltage input allows separately exciting the pumping mode and the structural modes, thus generating two independent outputs: low-frequency linear actuation and sound generation. We built a centimeter-scale silicone-based cone-shaped DEA demonstrator, and we demonstrated that it is able to generate independent acoustic and actuation patterns (e.g., it can concurrently work as a speaker and a metronome that beats the tempo of a tune through its motion). Measuring the voltage and currents on the DEA further allows detecting external stimuli, making the DEA able to work as an audio-tactile interface, which produces a combined vibro-acoustic stimulus in response to a user's touch.

2.2.7 Influence of various solvents on PDMS dielectric film during DET manufacturing

Tobias Willian (1), Svenja Pohl (2), Bettina Fasolt (3), Sophie Nalbach (1) (3), Stefan Seelecke (1) (3), Gianluca Rizzello (1),

(1) Intelligent Materials Systems Lab, Department Of Systems Engineering, Department Of Materials Science And Engineering, Saarland University, Saarbruecken, Germany
(2) Inorganic Solid-State Chemistry, Saarland University, Saarbruecken, Germany

(3) Intelligent Materials Systems Lab, Center For Mechatronics And Automation Technology, ZeMA GGmbH, Saarbruecken, Germany

Presentation given by Mr. Tobias Willian

Dielectric elastomer transducers (DETs) offer numerous benefits comparing to common technologies for sensor and actuator applications, such as, e.g., a high energy efficiency, large deformations, and lightweight. DETs are composed of a dielectric film, which is sandwiched by two conductive and stretchable electrodes. These components are the basis of the DET performance. While several works investigated the observation and characterization of the finalized DET, details of the manufacturing process are often neglected, especially concerning the influence of the solvent used during the electrodes manufacturing. For many processes, a considerable amount of solvent is needed to optimize the properties of the resulting material. This contribution presents the comparison of a wide variety of solvents comprised of various chemical groups, each one interacting with the dielectric film in a different way. The influence of several solvents on the pure silicone film is investigated using infrared-spectroscopy as well as light-microscopy. Additionally, the influence is studied when polydimethylsiloxane (PDMS)-based carbon black electrodes are screen-printed on the film. The characterization of the screen-printability, the electrical resistance, and the breakdown field show that different interactions between solvents and silicone film enable the improvement of the electrodes.

2.2.8 Electrical characterization of dielectric elastomer transistors

Luca Ciarella (1), Andreas Richter (1), E.-F. Markus Henke (1) (2),

(1) Institute Of Semiconductors And Microsystems, TU Dresden, 01062 Dresden, Germany
(2) PowerON Ltd., Auckland, New Zealand

Presentation given by Mr. Luca Ciarella

Dielectric elastomer transistors (DETs) are composed of a dielectric elastomer actuator (DEA) and a dielectric elastomer switch (DES) that represents a piezoresistive element that significantly changes its resistivity upon mechanical deformation. Combining the two structures, it is possible to realize a device that works similarly to a conventional transistor. DETs show a change in resistance with an applied voltage, thus they can be used to realize electrical circuits. DETs have different electrical properties compared to transistors, and they are meant to be used inside DE structures because of their intrinsic compatibility with them. In this contribution, an electrical characterization of DETs is presented. It is defined which electrical properties are desired for DETs, and how they can be improved. The influence of parameters, such as the membrane thickness and the driving voltage, on the switching speed is investigated. The switching speed is a key parameter for electrical circuits and it should be as fast as possible. New materials need to be investigated to have better-performing DETs. Following the criteria presented in this work, it will be easier to design and optimize future devices.

2.2.9 Chemically designed silicones for 3D printing elastomers

Codrin Tugui (1), George Stiubianu (1), Maria Cazacu (1), Manole-Stelian Serbulea (2), Alin Stefan (3),

(1) Department Of Inorganic Polymers, Petru Poni Institute Of Macromolecular Chemistry, Aleea Grigore Ghica Voda 41A, 700487 Iasi, Romania
(2) Technical University Of Civil Engineering Bucharest, Soil Mechanics And Foundation Engineering Department, Bd. Lacul Tei 122, Sector 2, 022396 Bucharest, Romania
(3) S.C. UNDA TECH S.R.L., Str. Moinesti Nr. 40, 061231, Bucharest, Romania

Presentation given by Dr. Codrin Tugui

Silicone elastomers can traditionally be produced by casting or injection, well-developed processes for large-scale production. However, for small series of custom products with complex geometries, these processes are often inappropriate. This has motivated the development of 3D printing technologies, which allows the construction of three-dimensional objects following a digital model. Our printing process is based on UV-activated thiol-ene addition of ?,?-bis(trimethylsiloxy)poly(dimethylsiloxane-co-thiopropylmethylsiloxane) to ?,?-bis(trimethylsiloxy)poly(dimethylsiloxane-co-vinylmethylsiloxane). The silicone formulation allows a fast-printing process and deposition of smooth and uniform layers with high resolution. Moreover, the variation of molecular weight and crosslinking density enables tunability of mechanical strength, elasticity and stretchability. The electromechanical tests show a substantial change in actuation strain and dielectric strength through variation of the two structural parameters. Alongside the customized-formulated silicones, the new built 3D-printing machine with adaptive mechanical and software parameters allow its users to create highly complex-shaped objects and may serve as a springboard for new directions in DET technologies and beyond.

2.2.10 Double coiled yarn actuator working in air for haptic garments

Shayan Mehraeen (1), Daniel Melling (1) (2), Cedric Plesse (2), Cedric Vandercayle (2), Nils-Krister Persson (3), Edwin W.H. Jager (1),

(1) Sensor And Actuator Systems, Department Of Physics, Chemistry And Biology (IFM), Linkoping University, SE-581 83 Linkoping, Sweden
(2) Laboratoire De Physico-chimie Des Polymeres Et Des Interfaces (LPPI), EA2528, CY Cergy Paris Universite, 95000 Cergy, France
(3) Swedish School Of Textiles, Smart Textiles, Polymeric E-textiles, University Of Boras, SE-501 90 Boras, Sweden

Presentation given by Dr. Shayan Mehraeen

Smart textile yarns have already shown their potential for fabrication of textile actuators. However, their actuation strain and force have been limited so far. Accordingly, twisting, and coiling techniques have attracted much attention to enhance the strain and force of yarn actuators. In this regard, coiled yarns that actuate under a liquid electrolyte have been studied well, but coiled yarn actuators that work in air are not explored as much. In this work, a double coiled yarn structure that works in air is designed, prepared, and investigated. Commercial textile yarns were coated with poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS) solution. Thereafter, yarns were coiled using a motorized stage. Two coiled yarns, as cathode and anode, are then placed near each other and covered with an ionogel precursor mixture containing an ionic liquid as ion reservoir. The gel is cured and set using UV emission. The actuation properties of the prepared double coiled yarn actuator were investigated in air. A square wave potential of ±2 V was applied, and strain response of the actuator yarns was measured. The results showed that prepared double coiled yarn can potentially be a promising candidate as soft actuators in wearables and garments, e.g. for haptic applications.

2.2.11 Capacitive strain sensor based on dielectric elastomeric material for elastic element of jaw coupling

Artem Prokopchuk (1), Arthur Ewert (2), Johannes Menning (3), Berthold Schlecht (2), Thomas Wallmerspreger (3), Markus Henke (1) (4) (5),

(1) Technical University Dresden, Institute Of Semiconductors And Microsystems, Dresden, Germany
(2) Technical University Dresden, Institute Of Machine Elements And Machine Design, Dresden, Germany
(3) Technical University Dresden, Institute Of Solid Mechanics, Dresden, Germany
(4) PowerON Group, Auckland, New Zealand
(5) The University Of Auckland, Auckland Bioengineering Institute, Biomimetics Lab, Auckland, New Zealand

Presentation given by Mr. Artem Prokopchuk

In mechanical engineering, couplings are important connecting elements, they are one of the central elements that are used in almost every transmission. Their main function is to transfer power between two shafts, through a mechanical connection. To connect two coupling halves, an elastic element or a spider coupling is used. Spider couplings are rubber-elastic couplings of medium elasticity, which are used to compensate for shaft misalignment and starting shocks. On the one hand, the elastic coupling is an ideal interface for torque measurement and, on the other hand, the elastomer elements offer the possibility of using mechano-sensitive sensors to record the process-relevant data "in situ" and with a high degree of reliability. The sensor-integrated coupling could therefore also be used temporarily for tuning and acceptance of drive systems. In this contribution we present the concept and design of a compliant sensor for integrated measurement, data processing and transmission, which minimizes the amount of equipment required. Due to the high electrical resistance of the sensor elements, they are energy efficient, which means that such a sensor integrated into the machine element will be widely used both in drive technology and can be adapted to other tasks.

2.2.12 Inkjet printable polydimethylsiloxane/carbon black composites for soft robotic device

Jianan Yi (1), Luca Ciarella (1), Frank Babick (2), Dmitry Borin (3), Moritz Scharff (4), Katherine Wilson (4) (5), Iain Anderson (4) (5) (6), Andreas Richter (1), Markus Henke (1) (4) (5),

(1) Dresden University Of Technology, Institute Of Semiconductors And Microsystems, Dresden, Germany
(2) Dresden University Of Technology, Institute Of Process Engineering And Environmental Technology, Dresden, Germany
(3) Dresden University Of Technology, Institute Of Mechatronic Engineering, Dresden, Germany
(4) PowerON Group, Auckland, New Zealand
(5) The University Of Auckland, Auckland Bioengineering Institute, Auckland, New Zealand
(6) StretchSense Ltd., Auckland, New Zealand

Presentation given by Mr. Jianan Yi

Soft robots have the capability of mimicking or assisting in the complex motion of animals. Inkjet printing can advance the manufacturing of soft robotic device as it is able to achieve high resolution, miniaturization, and fast processing. However, there is still a lack of compatible inkjet materials suitable for soft robotics. In this work, a novel inkjet printable ink, composing of polydimethylsiloxane/carbon black (PDMS/CB) composites and an organic solvent, is presented. The formulation, stability, rheology, surface tension, and jettability of the ink were investigated in order to meet the printing requirements (viscosity range: 4-8 mPa-s; surface tension range: 28-32 mN/m) of Dimatix 2831 inkjet printer. The optimized ink drop formation was obtained by determining proper jetting voltage, frequency, and pulse length. Dielectric elastomer dot actuators were successfully printed using this ink and the actuation performance was evaluated with the help of camera tracking. This novel ink can be potentially applicated in soft robotic device as well as other flexible/stretchable electronics.

2.2.13 Combining electroadhesion and gecko-inspired fibrillar adhesion in soft robotic grippers

Lihaoya Tan (1) (3), Jonathan Rossiter (2) (3), Andrew Conn (1) (3),

(1) University Of Bristol, Department Of Mechanical Engineering, Bristol, UK
(2) University Of Bristol, Department Of Engineering Mathematics, Bristol,UK
(3) Bristol Robotics Laboratory, Bristol, UK

Presentation given by Lihaoya Tan

Soft robotic grippers have rapidly emerged over the last decade thanks to their passive conformability to the complex shapes of objects, which can reduce control complexity. The performance of these grippers can be improved using flexible adhesive skins to increase adhesive forces, which is particularly important when grasping thin objects and flexible substrates. In this work, we investigate how actively controlled electroadhesion and passive gecko inspired fibrillar adhesion can be combined as the skin of a novel pneumatically-driven soft robotic gripper. The passive gecko-inspired outer skin enables adhesion with no power consumption, but its permeability and relative permittivity affect the electroadhesive forces generated by electrodes embedded within the elastomer gripper. A numerical finite-element model is used to investigate how electrostatically controlled adhesion is affected by a commercially available gecko-inspired skin. The results show that the normal electroadhesive force is reduced by 20%, 27% and 67% when gripping PVC, glass and copper substrates respectively with the addition of gecko-inspired skin. Despite the compromise in the performance between the two approaches to adhesion, the results show that electrically controllable and passive adhesion can be combined to improve the handling of thin and flexible substrates.

Session 2.3

(abstracts are listed in the order of presentation)

2.3.1 Multi-mode dielectric elastomer loudspeaker

Petko Bakardjiev (1) (2), Markus Franke (2), Uwe Marschner (2), Andreas Richter (2), Ercan Altinsoy (1),

(1) TU-Dresden Chair Of Acoustics And Haptics
(2) TU-Dresden Chair Of Microsystems

Presentation given by Mr. Petko Bakardjiev

In previous works we presented a DEA-loudspeaker configuration that is based on multilayer, core-free dielectric elastomer roll-actuators (DERA) that expansion drive loudspeaker membranes. Extensive modelling with electromechanical networks incorporating the mechanical and acoustic loads allowed a significant improvement of the loudspeaker's performance with reduced size and capacitive load. In a new configuration we are able to also utilize the circumferential expansion (radial modes) as direct source of sound radiation, exposing the actuator directly to the sound field. We designed, realized and tested several configurations of loudspeakers with actuators of different configurations and PDMS materials. The new design leads to a complementary behaviour of the different structural modes in the frequency range, improving the overall sound radiation, efficiency, reliability and extending the frequency response. Due to the additional radial radiation at high frequencies a much wider radiation pattern can be achieved compared to conventional broadband membrane loudspeakers. The presented loudspeaker design shows very promising characteristics that some in areas (efficiency, radiation pattern, weight, cost and material use) even outperforms conventional electrodynamic speakers.

2.3.2 Polypyrrole-based soft actuators driven by glucose

Amaia B. Ortega-Santos (1), Yaxin Qiu (1), Jose G. Martinez (1), Edwin W. H. Jager (1),

(1) Linkoping University

Presentation given by Ms. Amaia Ortega

Conducting polymer-based actuators are of great interest for their biocompatibility, possibility to be miniaturized and low power consumption. These features make soft actuators attractive for implantable or wearable bioelectronics applications. However, these artificial muscles have been driven by external power sources that are not compatible with biological environments. There is a need for a novel energy source that could power untethered implantable medical devices by using physiological processes. We present the latest results in the development of polypyrrole-enzyme-functionalized soft actuators powered by glucose. The actuator consists of Au/PVDF/Au tri-layer conductive substrate on which the polypyrrole is electrodeposited in both sides. The polypyrrole layers act as the electromechanically active part expanding and contracting upon a redox reaction. TTF-TCNQ and ABTS electron transfer mediators are casted on the surface of the polypyrrole. The glucose oxidase and laccase enzymes are immobilized in the modified-conducting polymer layer, integrating the biofuel cell into the actuator. The bio-catalysis of enzymes in presence of glucose and oxygen provides the actuator with the electrons needed for the redox reaction, converting the biochemical energy into mechanical energy, i.e., bending movement. The glucose-powered soft actuator may contribute to the development of more complex implantable or wearable biomedical devices such as cardio-stimulators or insulin pumps.

2.3.3 Design of high-performance dielectric elastomer actuator system with configurable linear transmission mechanism

Daniel Bruch (1), Tobias Willian (1), Hendrik Schäfer (2), Paul Motzki (1) (2), Stefan Seelecke (1) (2),

(1) Saarland University - Intelligent Material Systems Lab (iMSL)
(2) ZeMA GGmbH - Intelligent Material Systems Lab (iMSL)

Presentation given by Mr. Daniel Bruch

The outstanding properties of Dielectric Elastomer Actuators (DEAs) cause a high level of scientific interest and increasing attention is being paid on developing them towards marketreadiness. Compared to conventional actuators, DEAs are based on inexpensive and widely available polymeric materials, which is advantageous for a potential market launch. However, DEA systems with specific layout and dimensions, especially those with high convertible energy output, show a fixed force-stroke characteristic. Thus, specific dimensioning and design must be realized for different loads, leading to a large variety of products. This results in small production volumes and high costs, limiting the above-mentioned competitive advantage. This poster proposes an approach to counteract this effect by coupling high performance DEA systems with configurable transmission mechanisms, which enable to manipulate the forcestroke-characteristics and simultaneously maintain the system performance. For this, 3 highperformance DEA systems are designed, based on identical strip-shaped DEAs combined with a negative biasing spring. Two of these systems are coupled to linear transmission mechanisms, one providing transmission ratio 3:1 and one 1:3, respectively. Those enable to adapt the forcestroke characteristics of the system to varying load profiles. In this work the system design is explained in detail and the functional principle is validated by an experimental evaluation.

2.3.4 Artificial sphincter for urinary incontinence based on dielectric elastomer actuators

Quentin De Menech (1), Yoan Civet (1), Yves Perriard (1),

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

Presentation given by Mr. Quentin De Menech

Dielectric Elastomer Actuators (DEAs) are a family of soft actuators that react to an electrical stimulus. As this technology allows reaching large strain and due to its natural softness, it is an appropriate solution to replace muscles and is often referred as an artificial muscle. This technology has promising application in the field of urology, where urinary incontinence is a huge problem affecting millions of people worldwide. One of the main causes is a loss of control over the urinary sphincter muscle. Existing solutions as Artificial Urinary Sphincters (AUS) has already been developed, tested and implemented within patients. However, until today they are not convenient, too expensive and difficult to implement within the body. Thanks to its muscle like behavior, ease of activation and low production cost, DEA's could be a potential solution to replace AUS. In this work, the medical context and motivations will be presented. A theoretical model of the urethra mechanical behavior and simulation results will be compared. The different constraint to take into consideration as well as the scientific approach leading to a first design of an AUS will be exposed. Finally, the upcoming perspectives and challenges to develop a complete AUS will be discussed.

2.3.5 Evaluation of the breakdown electric field for multilayered tubular dielectric elastomer actuators

Thomas Martinez (1), Armando Walter (1), Yoan Civet (1), Yves Perriard (1),

(1) Ecole Polytechnique Federale De Lausanne, Integrated Actuators Laboratory, Neuchatel, Switzerland

Presentation given by Dr. Thomas Martinez

The design of efficient dielectric elastomer actuators is highly dependent on the evaluation of the breakdown strength of the used dielectric. Although several studies have tackled the evolution of the dielectric strength as a function of the prestretch, temperature or humidity level, they focus on simple planar samples equibiaxially prestretched. Currently, we are designing a cardiac assist device based on a multi-layered tubular DEA. In this complex configuration and subject to really high strains, the prediction of the dielectric strength of the material and the influence of the humidity and deformation of the actuator on this value can be challenging. In this work, we propose a solution to evaluate the true electric field in the structure based on the measurement of the current flowing inside the DEA. The evolution of the current during the discharge is linked to the deformation of the DEA and thus to changes in the capacitance value. For this experiment, instead of continuously increasing the applied voltage, we apply voltage steps to the actuator with increasing maximum values. This allows to have a more sensible measurement of the current and thus a more accurate estimation of the capacitance of the DEA. Finally, by using an analytical model of the tubular DEA, we can linked the capacitance value to the thickness of the deformed elastomer and estimate the true electric field in the structure.

2.3.6 Development and characterization of a dielectric elastomer based smart massage system

Sophie Nalbach (1) (2), Lukas Roth (1), Bettina Fasolt (1), Daniel Bruch (2), Christian Müller (1), Gianluca Rizzello (2), Paul Motzki (1) (2), Stefan Seelecke (1) (2),

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

Presentation given by Ms. Sophie Nalbach

The advantages of dielectric elastomers (DE) in terms of controllability and soft system design, as well as the combination of actuator and sensor functionalities, open up several possibilities for novel applications. As an example, DEs can be used to develop smart devices capable of delivering massages to users through vibrations. The massage system can be adapted to variable loads, e.g., different persons including their sitting positions, as well as to personal preferences, by adjusting the pressure as well as through variable control options. In this work, we present a massage device based on DEs, for which a flexible design is presented with considerations of parameter variations. An experimental setup is built to characterize the required components, as well as the final actuator-sensor system. The measured characteristic curves of the system components represent the basis for a detailed system design, which is first performed theoretically and then implemented in an experimental setup. The actuator-sensor system is finally characterized, and the design validated via quasi-static measurements. Application-oriented processes are simulated by dynamic measurements, thus demonstrating the potential of the system. After the validation of the actuator design, a prototype is assembled to showcase the possibilities of our vibration system concept, that is able to recognize a load force while it simultaneously can give feedback with a number of signal shapes.

2.3.7 A bi-stable soft robotic bendable module driven by rolled DEAs: modeling, control, and self-sensing

Johannes Prechtl (1), Matthias Baltes (2), Julian Kunze (2), Paolo Roberto Massenio (3), Stefan Seelecke (1) (2), Gianluca Rizzello (1),

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

Presentation given by Mr. Johannes Prechtl

In this work, we present on modeling, control, and self-sensing of a planar soft robotic module actuated by tightly rolled dielectric elastomer actuators (RDEAs). The structure consists of a flexible backbone capable of continuously bending along all planar directions, and a rigid plate connected to its top. The actuation is provided by an antagonistic pair of RDEAs. When actuated via high voltage, they expand axially and, in turn, cause the structure to bend along the opposite direction. A physics-based model is developed, which accounts for the effects of gravity, inertia, the load-dependent elasticity of the flexible backbone, and aims to accurately describe the electromechanical behaviour of the RDEAs, covering the actuation as well as the sensing modes. Studying the behaviour of the formulated model, we can predict how both monostable and bistable configurations depend on design parameters such as mounting distances, actuator size, and beam stiffness, with the bistable configuration exhibiting a significantly improved actuation performance. Furthermore, the efficient formulation enables us to develop system-level self-sensing schemes, which allow to estimate the configuration of the robot in real-time via electric measurements only. Finally, we show how the challenges of designing a motion controller for the considered highly nonlinear system can be systematically accounted for via closed-loop optimal control, based on an Adaptive Dynamic Programming approach.

2.3.8 Impedance of monolithic capacitive carbon electrodes

Oleksandr Syzoniuk (1), Saoni Banerji (1), Alvo Aabloo (1), Indrek Must (1),

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

Presentation given by Mr. Oleksandr Syzoniuk

Activated carbon cloth (ACC) is a promising electrode material that combines high specific area and monolithic structure on a large (meter) scale, making it appealing as electron-to-ion transducers in various electroactive systems. Furthermore, monolithic nature of ACC offers the possibility to transfer electrons within a single electrode of even a meter scale without carbon-to-carbon contacts (not achievable even with 1D carbons such as CNTs). This contrasts with composite electrodes that may experience repulsion of like charges upon charging, in turn rendering a charged composite electrode less conductive due to an increased distance for electron tunnelling. Moreover, as formation of an electrical double-layer at the electrode surface increases the local charge density, the impedance is expected to decrease. In composite electrodes, this increase may not be observable, but an electrode with monolithic structure may reveal impedance decrease. The monolithic nature of carbon thus results in unique electrical characteristics: upon injecting more charge to an electroactive laminate with ACC electrodes, the system may become increasingly conductive. This work investigates the in-situ impedance of an ACC electrode whilst charging simultaneously or intermittently. Favorable impedance behavior makes ACC an attractive electrode material for wearable technologies and medical devices.

2.3.9 A bi-stable soft robotic bendable module driven by rolled deas: design, fabrication, and characterization

Julian Kunze (1), Matthias Baltes (1), Johannes Prechtl (2), Gianluca Rizzello (2), Stefan Seelecke (1) (2),

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

Saarbruecken, Germany

Presentation given by Mr. Julian Kunze

In this work, we present a novel concept of a planar soft robotic module actuated by tightly rolled dielectric elastomer actuators (RDEAs). The structure consists of a flexible backbone capable of continuously bending along all planar directions, and a rigid plate connected to its top. The actuation is provided by an antagonistic pair of RDEAs. When actuated via high voltage, they expand axially and, in turn, cause the structure to bend in the opposite direction. The RDEAs consist of 50 µm silicone film with screen-printed electrodes based on carbon black. Two silicone films with electrodes are stacked together and then tightly rolled in a spiral-like structure without an inner hollow core. Readily available off-the-shelf wire end ferrules are used to implement both electrical and mechanical contacts. Experiments show that the choice of the flexible beam geometry, as well as the RDEAs mounting points, strongly influence the bending angle. Mono-stable configuration results in a maximum bending angle of ± 11°. Furthermore, it is found that some combinations of parameters lead to a bi-stable behavior, caused by the beam buckling instability. In this case, bi-stability can be exploited to obtain large bending angles of up to ± 25. Finally, a prototype of a 2D-soft robotic tentacle arm, comprised of a serial connection of multiple modules, is presented.

2.3.10 New dielectric elastomer strain sensors for the measurement of small elongations over long distances

Holger Boese (1), Thomas Gerlach (1), Tatjana Shinkar (1), Detlev Uhl (1), Johannes Ehrlich (1),

(1) Fraunhofer Institute For Silicate Research, Center Smart Materials And Adaptive Systems, Wuerzburg, Germany

Presentation given by Dr. Holger Boese

With conventional dielectric elastomer (DE) strain sensors, large elongations over long distances can be accurately measured by monitoring the capacitance. To enhance the measuring sensitivity also at small elongations, a modified sensor design was established. The advanced DE strain sensor consists of two parts, a relatively short stretchable active zone with the same elastomer layer

composition as in conventional strain sensors and a long non-stretchable passive zone without electrode layers. When the advanced DE strain sensor is elongated, the stretch is concentrated only in the short active zone, which causes a much higher strain in the active zone and a corresponding larger relative increase of the capacitance than in a conventional strain sensor. To demonstrate the advantage of the advanced DE strain sensor principle, such sensors were manufactured, characterized with a self-constructed stretching device and compared with conventional DE strain sensors as a reference. At small elongations of about 1 % of the total sensor length, the advanced DE strain sensor exhibits a relative increase of the capacitance, which is higher than the corresponding increase of the reference sensor by an order of magnitude. Finite element (FE) simulations confirm this result. The strongly enhanced measuring sensitivity of the advanced DE strain sensor can be used for the structural health monitoring (SHM) of civil structures such as bridges, large buildings and industrial facilities.

2.3.11 Fibre reinforced dielectric elastomer actuators for an in-plane contraction displacement.

Stefania Konstantinidi (1) (2), Thomas Martinez (1) (2), Yoan Civet (1) (2), Yves Perriard (1) (2),

(1) Ecole Polytechnique Fédérale De Lausanne
(2) Integrated Actuators Laboratory

Presentation given by Ms. Stefania Konstantinidi

Dielectric Elastomer Actuators (DEAs) are a recent type of smart materials that show impressive performances as soft actuators. The deformation of DEAs can be configured to adapt for different applications, for example by forming them into a tubular shape to generate a radial expansion. However, implementing DEAs that mimic natural muscles has been proven difficult, as DEAs provide in-plane expansion when actuated, while natural muscles contract upon stimulation. Embedding fibres within the DEA allows to alter the DEA mechanical characteristics to obtain an anisotropic movement, such as a movement of contractile nature. The thickness, spacing as well as the geometry of the fibres affect the performance of the DEA. The highest reported contractile strain is of 6.3%, however this strain was reported under no boundary load. The possibility to use fibre reinforced DEAs to obtain a movement of contractile nature is explored with an applied load. To that end, finite element simulations were first run to determine the optimal angle between the fibres, which was found to be at 45 degrees. Measurements were then performed; due to the load applied, a contraction of only 0.4% is observed. The DEA displacement is significantly reduced with the fibre reinforced configuration. However, it can also be observed that the DEA presents less parasitic movements. Guiding the DEA displacement could thus improve the performance of the actuator, giving place to a more precise control.

2.3.12 Fluid mixer with multiple degrees of freedom enabled by dielectric elastomer actuators

Giacomo Sasso (1), James Busfield (1), Federico Carpi (2),

(1) Queen Mary University Of London, School Of Engineering And Materials Science, London, United Kingdom
(2) University Of Florence, Department Of Industrial Engineering, Florence, Italy

Presentation given by Mr. Giacomo Sasso

This presentation describes a fluid mixer made of a double-cone dielectric elastomer actuator. The device consists of two conically shaped elastomeric membranes forming a 3D hyperbole. Each membrane is spray-coated on either side with carbon black-silicone stretchable electrodes, forming four independent radial actuation segments. The two conical membranes support a central end effector. Via image processing-based motion tracking, we show how, by modulating the activation of the actuation segments, the end effector can finely be positioned with multiple degrees of freedom. The direction and the amplitude/speed of motion of a central dot are tuned via a custom-made, Arduino-driven, multichannel, high-voltage control unit. Different trajectories forming geometrical shapes (such as figure of eight, star, square, cross and circle) are shown, demonstrating the possibility of mixing fluids in a chamber on the end effector plane, according to different mixing patterns.

2.3.13 Thin film based sheet-to-sheet manufacturing process for multilayer dielectric elastomer transducers

Tim Krüger (1), Ozan Çabuk (1), Jürgen Maas (1),

(1) Technical University Of Berlin, Mechatronic Systems Laboratory/Institute Of Machine Design And Systems Technology, Berlin, Germany

Presentation given by Mr. Tim Krüger

Manufacturing dielectric elastomer transducers (DETs) using prefabricated elastomer material has the advantage, that homogeneous and reproducible properties of the dielectric elastomer films are ensured. Nevertheless, the handling and the tension-free lamination of very thin elastomer films, avoiding any air inclusions, is a challenge. The work presents an alternative manufacturing process for dielectric elastomer laminates which can be processed to DE multilayer transducers. The lamination of prefabricated film sheets combined with a contactless electrode application facilitates manufacturing laminates with low residual stress, a high number of layers and individualizable electrode patterns. The conceptual process design, including different process steps such as sheet creation, stacking and applying structured electrodes, is depicted. Furthermore, the laboratory scale process realization is introduced and manufactured specimens are presented.

Session 2.4

(abstracts are listed in the order of presentation)

2.4.1 Dielectric elastomer applications - a multi-disciplinary systems engineering approach

Stefan Seelecke (1),

(1) Intelligent Material Systems Lab (iMSL), Dept. Sys. Eng./Dept. Mat. Sci. & Eng., Saarland University, Saarbrücken, Germany

Presentation given by Prof. Stefan Seelecke

The talk introduces Systems Engineering as key enabling technology for the development of Dielectric Elastomer (DE) solutions. It gives an overview of the contributions from multiple engineering disciplines that are required for the development of actuator (DEA) and sensor (DES) applications. It starts with manufacturing and experimental characterization of DEA or DES components and emphasizes the importance of modeling and simulation for successful system design. The next step focuses on the development of integrated electronics solutions for high-voltage actuation and/or sensing, followed by systems manufacturing (rapid protoyping) and subsequent system integration. Modern electronics also consist of a micro-controller architecture to implement smart sensor data interpretation and control schemes for actuation as well as communication with the environment. All of the above steps are necessary for the successful development of novel DE-based solutions, and it is the natural role of Systems Engineering to integrate these contributions from material science, mechanical, electrical and controls engineering. The approach is illustrated with examples from two German Science Foundation Priority Programs (SPP 2100 Soft Material Robotic Systems and SPP 2206 Cooperative Multi-stable Multi-Stage Micro-Actuator Systems) as well as several application-oriented examples from, e.g., pneumatics, haptics and acoustics.

2.4.2 Fundamental issues related to the development of high-performance EAP

Zhongyang Cheng (1),

(1) Auburn University

Presentation given by Prof. Zhongyang Cheng

EAP can be classified into electronic and ionic EAP. The former includes electrostrictive and Maxwell stress effect. Their response is fast, but require a high electric field. The latter is based on the motion of ions in the EAP. They require a low driving voltage, but response is slow. For the development of high performance of electronic EAPs, the issues related to electrostrictive effect are discussed and a classic physics model is introduced by introducing the "partially ordered region (POR)" to explain the electromechanical reposne of dielectric elastomer. For ionic EAP, due to its slow response, it is critical to determine the time dependence of its strain response. Therefore, different models/formulas were introduced. These models are reviewed and compared with experimental results obtained in a typical EAP - PEO doped with lithium perchlorate. A new formula to describe the time dependence of the strain response for the EAP under a constant electric field is introduced to better fit the experimental results. The so-called back relaxation was experimentally observed in ionic EAP and explained based on the interaction between the ions and water molecules. To deepen the understanding of this phenomenon, PVDF based ionic EAPs were fabricated by using different ions and characterized. It is concluded that the mechanism for the back relaxation is more complicated than our current understanding.

2.4.3 Electro-active polymer transducers - from start-up to industry

Gabor Kovacs (1),

(1) CTsystems AG

Presentation given by Dr. Gabor Kovacs

Normally applied research should end up in specific commercial product offering additional benefit for user and the society in general. This principle was always the basic of the mission of Empa and the follow-up CTsystems as spin-off company. The long way from research to commercial product is characterized of many ups (highlights) and downs (failures) combined with trade-off decisions between scientific opportunities and industrial constraints. This contribution presents the narrow path between scientific "nice to have" and the rough reality of commercial boundary conditions such as price, safety requirements, usability in harsh conditions, lifetime specs and mass production feasibility and requirements. In this context some challenging technological and device-design aspects will be demonstrated with paramount impact on the production method with very high output volume.

Thursday, 9 June 2022

Session 3.1

(abstracts are listed in the order of presentation)

3.1.1 Enhanced animacy and improved fine tuning of expressions in humanoid robots through soft sensory-motor components

Danilo De Rossi (1)

(1) University of Pisa

Presentation given by Prof. Danilo De Rossi

A socially intelligent robot must be capable to extract meaningful information in real time from the social environment and react accordingly with coherent human-like behavior.
In the last decades, neuroscience research highlighted the link between the evolution of such complex behavior and the evolution of a certain level of consciousness, which cannot leave out of a body that feels emotions as discriminants and prompters.
In order to develop cognitive systems for social robotics with greater human-likeliness, we used an "understanding by building" approach to model and implement a well-known theory of mind in the form of an artificial intelligence, and we tested it on a sophisticated robotic platform.
The aim of obtaining an agent with human-like intelligence and behavior cannot be separated from the objective of providing the agent with a body and with the instruments of perception and actuation that are inspired by those of a human being. As a consequence, the body of a robot should be considered not only for

its aesthetic appearance but as the specific interface that allows the robot to internalize the information, on which to build any abstraction, reasoning, and feeling of what happens, as much as displaying its internal states.
EAP-based sensors and actuators in their distributed form appear to be ideally suited to enhance performances and perceived features. A few examples in this context will be given.

3.1.2 Advancing scuba diver capabilities and safety using dielectric elastomer sensors

Christopher Walker (1), Dula Nad (2), Derek Orbaugh (1), Igor Kvasic (2), Samuel Rosset (1), Nikola Miskovic (2), Iain Anderson (1),

(1) University Of Auckland, Auckland Bioengineering Institute, Biomimetics Laboratory, Auckland, New Zealand
(2) University Of Zagreb, Department Of Electrical Engineering And Computing, Zagreb, Croatia

Presentation given by Mr. Christopher Walker

Despite technological advancements and improvements in diving practice, such as the introduction of the buddy system, diving remains a dangerous activity. The Diver Alert Network reported 228 fatalities in 2017 and that 57% of decedents are separated from their buddy prior to death. Improved buddy communication, situational awareness and physiological monitoring could help mitigate risks in both recreational and commercial diving. As part of a collaboration between the University of Zagreb and the University of Auckland, we are developing technical solutions using dielectric elastomer sensors to support divers in these areas. A dive glove integrated with stretch sensors on each finger has been developed, which detects intentionally performed gestures using a trained machine learning algorithm. These gestures are interpreted locally on dedicated electronics and mapped to messages telemetered through the water using an integrated acoustic modem. Further a wetsuit integrated with 17 dielectric elastomer sensors along with other non-invasive technologies is in development to monitor diver posture and physiological parameters, such as respiration, in real-time. This talk begins with a brief overview of the characterisation and development required for dielectric elastomer sensors to operate effectively underwater, followed by evaluation of the performance of these sensors in scuba diving applications.

3.1.3 Dielectrophoretic liquid zipping actuators: recent progress and future opportunities

Majid Taghavi (1),

(1) Imperial College London, Department Of Bioengineering, London, UK

Presentation given by Dr. Majid Taghavi

Dielectrophoretic Liquid Zipping (DLZ) has been introduced as a new class of electric actuators, which exploits an interplay of electrostatic force and dielectrophoresis in zipping structures and generates giant electrostatic force amplification when a small bead of dielectric liquid is introduced. DLZ offers a broad design capacity made of any combination of conductive and non-conductive materials to deliver lightweight systems with a range of embodied features. The bow-shaped electro-ribbon structure, for example, has shown ultra-high contraction (over 98%), approaching a paper-thin material when fully zipped. I will discuss recent advances in this technology and show how it offers new solutions for electroactive origami, collapsible structures, low-power-consumption self-locking mechanism, and self-sensing capabilities. I will also review the new directions in this research which extends the application of the DLZ actuation concept in pneumatic pumps and micro aerial vehicles: Air-filled pouch (EPP) drives pneumatic actuators through lightweight, flexible, and thin electric sources. Direct deforming of a compliant structure mimics the bumblebee flapping mechanism and extended performance of the DLZ actuators for high-speed flapping enables a direct-drive artificial muscle system for flapping-wing robots.

3.1.4 Soft grippers with electroactive contact

Vito Cacucciolo (1) (2),

(1) Politecnico Di Bari, Bari, Italy
(2) Omnigrasp Srl, Bari, Italy

Presentation given by Dr. Vito Cacucciolo

Soft grippers address an important problem: how to grasp objects that are delicate, have a wide variety of shapes or undergo large deformations when handled. Examples are fruit and vegetables, fluid-filled pouches, fabric. Soft fingers made of pneumatic elastomers or kirigami structures conform to the object and enable a delicate grasp. However, forces can be limited and need to be well balanced to avoid slippage. Electroactive contact such as electroadhesion adds one extra layer of control to the physics of grasping. Soft grippers with electroadhesion show superhuman abilities, lifting hundreds of times their own weight and grasping difficult objects with simple control. This talk presents our work in advancing electroadhesion soft grippers to industry-grade by increasing lifetime, easing fabrication, and improving integration. I will present some of the fundamental limitations of electroadhesion and how we are addressing them by means of models developed in the last decades for contact mechanics of soft materials. One example is how understanding peeling makes it possible to design grippers with 1000x higher forces and 100x faster release. I will discuss how these models shed new light on electroactive polymers beyond grippers, especially when contacts are important, such as in zipping actuators. The talk will end by describing some practical applications of soft grippers with electroactive contacts and our efforts to launch them on the market with Omnigrasp Srl.

Session 3.2

3.2.1 Counter-electrode-free dual actuation of polypyrrole-based yarns

Amaia B. Ortega-Santos (1), Jose G. Martinez (1), Edwin W. H. Jager (1),

(1) Linkoping University

Presentation given by Ms. Amaia Ortega

The combination of conducting polymers and textiles is presented as a low-cost and industrial scalable option for wearable electroactive applications, e.g., textile exoskeletons. The actuation of these fabrics is based on the movement of yarns coated with conducting polymers: CP-yarns. The movement is driven by ionic exchange between the polymer and the ions source. While the CP-yarn is oxidizing or reducing, the opposite redox reaction happens in an external counter electrode, which is not electromechanically active. The simultaneous use of CP-yarns coated with anion- and cation-driven conducting polymers is one possible solution to build textile actuators with active counter electrode. The anion-driven CP-yarn is doped with small anions and swells (shrinks) upon oxidation (reduction). The cation-driven CP-yarn is doped with big anions and swells (shrinks) upon reduction (oxidation). Thus, the same movement is created during opposite redox reactions. Here we present CP-yarns with dual actuation, in which both yarns contribute cooperatively to the movement. Our dual actuators use two types of yarns with two polymer layers. The anion-driven CP-yarn is first coated with PEDOT:Tos. Then, polypyrrole is electropolymerized in LiClO4, pyrrole aqueous solution. The cation-driven CP-yarn is coated with PEDOT:PSS, and polypyrrole is electropolymerized in NaDBS, pyrrole aqueous solution. Both yarns are actuated in the same counter-electrode-free electrolyte and showed 1% of strain.

3.2.2 A cooperative flexible array of dielectric elastomer actuator/sensor elements: modeling and simulation

Sipontina Croce (1), Julian Neu (1), Giacomo Moretti (1), Jonas Hubertus (2), Stefan Seelecke (1) (3), Guenter Schultes (2), Gianluca Rizzello (1),

(1) Department Of Systems Engineering, Saarland University, Saarbruecken, Germany
(2) Department Of Sensors And Thin Films, University Of Applied Sciences Of Saarland, Saarbruecken, Germany
(3) Center For Mechatronics And Automation Technologies (ZeMA) GGmbH, Saarbruecken, Germany

Presentation given by Ms. Sipontina Croce

Dielectric elastomers (DE) transducers are highly suitable for the design of soft mechatronic devices, e.g., wearables and soft robots. If many independently-controllable DEs are closely arranged in an array-like configuration, sharing a common elastomer membrane, new types of cooperative and soft actuator/sensor systems can be developed. The common elastic substrate, however, introduces strong electro-mechanical coupling effects among nearby DEs, which highly influence the overall system actuation and sensing behavior. To effectively design soft cooperative systems based on DEs, those effects need to be systematically understood and modeled first. As a first step towards the development of soft and cooperative DE systems, in this poster we present a finite element simulation approach for a 1-by-3 soft array of DE transducers biased by buckling polymeric domes. The model describes the spatially coupled electro-mechanical interactions among the different DEs in the array. It is shown how the model accurately reproduces the experimentally observed changes in force (actuation) and capacitance (sensing) of the array elements, when their neighbors are subjected to different electro-mechanical loads. The validated model is also used to perform simulation studies, aimed at understanding how the array performance change when modifying relevant design parameters. The obtained results will provide fundamental guidelines for the future design of cooperative systems based on DEs.

3.2.3 Nanocomposite polymer filaments for integrated strain sensor applications

Jeanette Ortega (1), Thomas Gries (1),

(1) Institut Fuer Textiltechnik Of The RWTH Aachen University

Presentation given by Ms. Jeanette Ortega

Filament based sensors are critical for the monitoring of textile structures such as fiber reinforced composites and geotexiles. Although many measurement principles are available, such as fiber Bragg gratings and piezoelectric filaments, polymer filaments based on nanocomposite materials offer relative ease of production and data interpretation. Such filaments have been researched, but often on small laboratory scaled machines. In this work, bicomponent monofilaments are extruded using a pilot spinning line up to speeds of 100 m/min. Various thermoplastic materials and nanoparticles are investigated and the resulting sensor response is quantified in tension tests. It has been shown that a consistent resistance-strain response can be generated, despite the relatively high resistances. Additionally, with these filaments, strains up to 50% can be measured, which has previously not been possible with standard strain gauges. Such filaments can be integrated into textile structures to monitor deformations over time and enable structural health monitoring. These specific applications range from light weight hydrogen tanks for e-mobility to geotextile monitoring for the online inspection of dams and dykes. Through further modification of the versatile melt spinning process, the strain-resistance properties can be tailored. Lastly, such filaments can be further modified and implemented in order to detect and measure temperature, pressure and moisture.

3.2.4 A soft-rigid hybrid pneumatic anthropomorphic gripper with piezoresistive tactile sensor array

Rafal Andrejczuk (1), Moritz Scharff (2), Junhao Ni (2), Andreas Richter (1), Markus Henke (1) (2),

(1) TU Dresden, Institute Of Semiconductors And Microsystems, Dresden, Germany
(2) PowerON Group, Auckland, New Zealand

Presentation given by Mr. Rafal Andrejczuk

Soft anthropomorphic robotic grippers are interesting because of their inherent property of compliance, which gives them the ability to adapt to the shape of grasped objects and the overload protection needed for safe human robot interaction or gripping delicate objects with any sophisticated control. Due to the anthropomorphic design the gripper profits from the result of the biological evolution of the human hand in order to make a multifunctional robot end effector. Fully soft grippers are on the other hand not very efficient, because they yield under high loads. A trending solution is a hybrid gripper, a combination of soft and rigid elements. This work describes a prototype of an anthropomorphic, underactuated five-finger gripper with direct pneumatic drive from soft bending actuators and an integrated piezoresistive tactile sensor array. It is a hybrid construction with soft robotic structures and rigid skeletal elements, which reinforce the body, focus the direction of actuator's movement and makes the finger joints follow the forward kinematics. The hand is equipped with a piezoresistive tactile DE sensor array that directly triggers the hand's actuation, in a sense of reflexes. The hand can execute precision grips with two and three fingers, lateral grip and strong grip types. The joint's softness allows the finger to adapt to the shape of the objects.

3.2.5 Moisture responsive silk fibroin actuators

Manikandan Ganesan (1) (2), Ravi Kumar (2), Dillip K Satapathy (1),

(1) Soft Materials Laboratory, Department Of Physics, Indian Institute Of Technology Madras, Chennai, India
(2) Laboratory For High Performance Ceramics, Department Of Metallurgical And Materials Engineering, Indian Institute Of Technology Madras, Chennai, India

Presentation given by Mr. Manikandan Ganesan

Complex three-dimensional movements upon various triggers with time scales ranging from fractions of a second to a few minutes exist in nature. Inspired by nature, soft actuators comprised of biopolymeric materials are attaining more focus in recent times. These actuators found their applications in biomedical devices, unconventional energy harvesting systems, and soft robotics. Silk fibroin obtained from Bombyx Mori silkworms comprises a sequence of hydrophilic and hydrophobic amino acids with hierarchical structures. Our work demonstrates the rapid moisture responsive behaviour of single-layer silk fibroin films fabricated through the facile solution casting method. Interestingly, these films respond upon absorption of a few tens of micrograms of water yet generate forces that can lift hundreds of micrograms of a load. Further, the actuation retention behaviour, repeatability (around 1000 cycles), mechanism, and some proof of concepts will be presented in detail.

3.2.6 Electro-pneumatic pumps for soft robotics

Richard Suphapol Diteesawat (1) (2), Nahian Rahman (1) (2), Sam Hoh (1) (2), Jonathan Rossiter (1) (2),

(1) University Of Bristol, Department Of Engineering Mathematics, Bristol, United Kingdom
(2) Bristol Robotics Laboratory, Bristol, United Kingdom

Presentation given by Dr. Richard Suphapol Diteesawat

The Electro-pneumatic Pump (EPP) is an inexpensive, lightweight, flexible electrostatic pump, using a dielectric-liquid zipping mechanism to control air volume and pressure and generate high air flow rate. A tiny volume of dielectric liquid is added to the actuator to considerably amplify induced electrostatic force between opposite electrodes, cause shape deformation and air transferring. In the original study, the 5.3 gram, 1.1 millimetre thick EPP could drive a soft pneumatic actuator to achieve maximum contraction change of 32.40% and actuation velocity of 54.43% per second. Three EPP-driven embodiments, for example, an antagonistic mechanism, an arm-flexing robotic device, and a continuous-pumping system, were demonstrated, showing their versatility and wide applicability for wearable assistive devices and lightweight, mobile, multi-functional robots, and potential to overcome limitations of existing pneumatic power sources. Recently developed EPPs attained higher actuation performance, delivering larger maximum pressure generation of 12.24 kilopascals and maximum flow rate of 238 millilitres per minute, corresponding to 481% and 48% improvements, respectively. They consumed power lower than 0.5 watts, of which power density is ten times less a commercial pump. The EPP is controllable and has high durability; it was able to actuate over 10,000 cycles. An addition of liquid dielectric at only 18% of the maximum available volume was found to reach maximum EPP performance.

3.2.7 Intelligent dielectric elastomers and their application as sensors in shoe technologies

Andreas Meyer (1), Martin Wagner (2), Dorota Werner (2), Tobias Willian (1), Paul Motzki (1), Stefan Seelecke (1),

(1) IMSL - ZeMA GGmbH, Intelligent Material Systems Lab, Saarbruecken, Germany
(2) Pruef- Und Forschungsinstitut Pirmasens E.V., Pirmasens, Germany

Presentation given by Mr. Andreas Meyer

The combination of flexibility and the resulting high integrability as well as their sensing capability enable dielectric elastomer sensors to be integrated into a variety of applications. A suitable field of application are smart fabrics that are being developed to support athletes or monitor medical conditions to make life easier for patients. Until today sensor inlays for shoes based on resistive and capacitive sensors enable a partial monitoring of the loads and load distributions on our feet while the interaction with the shoe shaft remains unknown. The novel sensor integration into the shaft in addition to a new sole concept combined with a wireless real-time measurement are beeing developed. The results create the basis for the support of diabetic patients suffering under the diabetic foot syndrome with damaged pain feelings, to support athletes analyzing walking patterns as well as bringing safety shoes to a digital age. This contribution displays the results of two sensor concepts for the sole and the shaft as well as the electronics development. The first smart shoe concentrates on the integration of six shaft sensors distributed over the shoe and their measurement in real-time. The shoe is designed and manufactured in collaboration with the "Prüf- und Forschungsinstitut Pirmasens ", including the sensors during the manufacturing process. The evaluation of the sensor values allows the analysis of different load scenarios.

3.2.8 Dielectrophoretic liquid-amplified zipping actuators for transmission-free micro-air vehicles

Tim Helps (1) (2), Christian Romero (1) (2) (3) (4), Majid Taghavi (1) (2), Andrew Conn (2) (5), Jonathan Rossiter (1) (2),

(1) University Of Bristol, Department Of Engineering Mathematics, Bristol, UK
(2) University Of Bristol, Bristol Robotics Laboratory, Bristol, UK
(3) University Of Bristol, Bristol Centre For Functional Nanomaterials, School Of Physics, Bristol, UK
(4) University Of Bristol, School Of Chemistry, Bristol, UK
(5) University Of Bristol, Department Of Mechanical Engineering, Bristol, UK

Presentation given by Mr. Christian Paul Romero Negrete

Flapping micro air vehicles are a class of aerial vehicles that mimicking the biological insects can achieve flapping motions, manoeuvrability, and hovering ability. Whereas land vehicles depend on roads and paths to perform different activities, micro air vehicles can reach several locations to execute activities of exploration, monitoring, indoor aerial imaging, research, and rescue. However, current flapping micro air vehicles require transmission systems between their actuators and wings. Here, we present a high-performance electrostatic flapping actuation system, the liquid-amplified zipping actuator, which induces wing movement by direct application of liquid-amplified electrostatic forces at the wing root, eliminating the requirement of any transmission system and their associated downsides. The liquid-amplified zipping actuator allows for accurate control of flapping frequency and amplitude, exhibits no variation in performance over more than 1 million actuation cycles, and delivers peak and average specific powers of 200 and 124 watts per kilogram, respectively, exceeding mammalian and insect flight muscle and on par with modern flapping micro air vehicles actuation systems. The inclusion of passively pitching wings in a dragonfly-sized liquid-amplified zipping actuator flapping system allowed the rectification of net directional thrust up to 5.73 millinewtons.

3.2.9 Ionogel for electroactive polymers

Giao T. M. Nguyen (1), Fengdi Li (1), Katlin Rohtlaid (1), Vincent Woehling (1), Cedric Vancaeyzeele (1), Cedric Plesse (1), Frederic Vidal (1),

(1) LPPI, CY Cergy Paris Université, Cergy-Pontoise, France

Presentation given by Dr. Giao T. M. Nguyen

Ionically conducting materials play an important role in electrochemical and electroactive applications such as batteries, ionic actuators, sensors. In these materials, the ionic conductivity is primordial, but mechanical properties is also an important criterion. Ionogels are solid polymer network loaded with ionic liquid. The resulting ionically conducting solid materials combine both the mechanical properties of crosslinked polymer networks and the ionic conductivity, non-volatility and non-flammability of ILs. They appear as a promising ionic source for electrochemical and electroactive polymers devices.

By adjusting the chemistry and the processing method, the properties of ionogel can be tuned for according to requirements of the application. In this presentation, the synthesis of ionogel with tuned mechanical properties and processing method will be presented for using as ionic source in ionic actuators, which can also be used as ionic compliant electrodes in dielectric elastomer actuators. These ionogels are based on interpenetrating polymer network or on single network obtained by thiol-ene addition. In the frame of these actuator applications, ionogels are usually subjected to repeated deformation, making them susceptible to damage. A simple and effective strategy to improve their durability and life span by imparting them with healing ability, through vitrimer chemistry will be also presented.

3.2.10 Influence of environmental conditions and manufacturing methods on the electrical breakdown of DE thin films

Bettina Fasolt (1), Fabio Beco Albuquerque (2), Jonas Hubertus (3), Stefan Seelecke (4), Herbert Shea (2), Günter Schultes (3),

(1) Intelligent Materials Systems Lab, Center For Mechatronics And Automation Technology, ZeMA GGmbH, Saarbrücken, Germany
(2) LMTS Soft Transducers Laboratory - EPFL Ecole Polytechnique Fédérale De Lausanne, Neuchâtel, Switzerland
(3) Sensors And Thin Film Group, University Of Applied Sciences, Saarbrücken, Germany
(4) Intelligent Materials Systems Lab, Department Of Systems Engineering, Department Of Materials Science And Engineering, Saarland University, Saarbrücken, Germany

Presentation given by Ms. Bettina Fasolt

Dielectric Elastomers (DEs) represent an attractive technology in the field of electromechanical transducers and enable the realization of energy efficient and compact actuator and sensor systems. Inherent self-sensing capability based on capacitance measurements allows controlled actuation without external sensors, and high voltage operation in the kilovolt range with microampere currents minimizes thermal losses. The limiting factor for high voltage application, however, is dielectric breakdown. To extent the application field of DEs from lab scale to a commercially up-scaling level, a thorough understanding of the effect of the parameters impacting this behavior is necessary. This presentation focusses on two of these parameters. The first one is the effect of environmental conditions on the breakdown strength of silicone thin films. The influence of temperature, humidity, and water content on the breakdown field was extensively studied under environmental conditions ranging from 1°C to 80°C and 10% to 90% rel.-humidity. The second one investigates the influence of the manufacturing method of the electrode application on the breakdown behavior. Five different application methods were investigated, each of them having their unique application scope: Screen-printing, inkjet-printing, pad-printing, gold sputtering, and nickel sputtering. Each method was tested under the environmental conditions mentioned above.

3.2.11 Tailoring applications-relevant properties in polyvinylidenefluoride-based terpolymers by means of thermal treatment

Thulasinath Raman Venkatesan (1) (2), David Smykalla (3), Bernd Ploss (3), Michael Wübbenhorst (2), Reimund Gerhard (1),

(1) University Of Potsdam, Institute Of Physics And Astronomy, Potsdam, Germany
(2) KU Leuven, Department Of Physics And Astronomy, Leuven, Belgium
(3) University Of Applied Sciences Jena, Department Of SciTec, Jena, Germany

Presentation given by Dr. Thulasinath Raman Venkatesan

P(VDF-TrFE-CFE) relaxor-ferroelectric (R-F) terpolymers are attractive materials for transducer and memory devices due to their large electrostriction and their thin hysteresis loops, respectively. The introduction of CFE groups into the ferroelectric P(VDF-TrFE) copolymer reduces the interaction between the VDF-TrFE segments, ultimately converting the polymer into a relaxor-ferroelectric (R-F) material. Further, by annealing the terpolymer at different temperatures, it is shown that the semi-crystalline morphology and in turn the R-F properties can be tailored. Without a heat treatment, only a lower fraction of CFE molecules are included within the crystallites, which results in a terpolymer showing predominantly ferroelectric behaviour including a high Curie-transition temperature (Tc) and a broad hysteresis loop compared to an annealed sample. Annealing favours inclusion of more CFE units within the crystalline structure and hence, a lower Tc and a thin R-F hysteresis loop is observed at RT. The higher the temperature of annealing, the stronger is the relaxor-ferroelectric character of the terpolymer. In addition, terpolymer films with different thermal histories show hysteresis loops which vary from that of a ferroelectric to that of an R-F polymer at different temperatures, including double hysteresis loops typically found in anti-ferroelectric materials. Thus, by choosing appropriate processing conditions, the terpolymer can be tailored for specific applications.

3.2.12 4D printing of artificial muscles through direct ink writing of light-responsive liquid crystalline elastomers

Bruno Grandinetti (1), Ruggero Rossi (1), Leonardo Caserio (1) (3), Daniele Martella (1) (2), Caterina Credi (1) (4), Federico Carpi (3), Cecilia Ferrantini (6), Leonardo Sacconi (1) (4) (7), Camilla Parmeggiani (1) (2) (5), Elisabetta Cerbai (1) (8),

(1) European Laboratory For Non-Linear Spectroscopy/University Of Florence, Sesto Fiorentino (FI), Italy
(2) Istituto Nazionale Di Ricerca Metrologica, Torino, Italy
(3) Department Of Industrial Engineering/University Of Florence, Florence, Italy
(4) National Institute Of Optics/National Research Council, Sesto Fiorentino (FI), Italy
(5) Department Of Chemistry/University Of Florence, Sesto Fiorentino (FI), Italy
(6) Department Of Experimental And Clinical Medicine/University Of Florence, Florence, Italy
(7) Institute For Experimental Cardiovascular Medicine/University Of Freiburg, Freiburg Im Breisgau, Germany
(8) Department Of Neurosciences, Psychology, Drugs And Child Health/University Of Florence, Florence Italy

Presentation given by Dr. Caterina Credi

Liquid Crystalline Elastomers (LCEs) are a class of smart materials that have gained rising attention in the biomedical field, due to their wide range of properties such as their biocompatibility and the possibility to change their shape upon stimulation. In particular, light-responsive LCEs enable high spatio-temporal accuracy during the actuation process, whose path is generally encoded in the microstructure of the polymer network. Indeed, LCE with planar homogeneous alignment contract along the direction of the material molecular director. Alignment is usually achieved through non-scalable methods exploiting surfactants or electric/magnetic fields. Here, we report ongoing work on an aligned network, obtained through the extrusion of high-viscosity LCE-based formulations synthesized exploiting thiol-acrylate reaction of a polyfunctional Liquid Crystalline monomer with a chain extender. Light responsive LCE are optimized to be processed by UV-assisted additive manufacturing, aiming at 4D printing of light-responsive contractile membranes. The targeted long-term goal of this investigation is the engineering of custom-sized implantable cardiac patches, possibly working as artificial-muscle-like contraction assistance devices for diseased cardiac chambers.

Session 3.3

3.3.1 Effect of oxygen plasma and primer treatments on the electro-adhesive performances of devices featuring inkjet-printed electrodes on PI substrate and silicone encapsulation

Lorenzo Agostini (1), Nicolò Berdozzi (1), Marco Fontana (2), Irene Fassi (3), Lorenzo Molinari Tosatti (3), Rocco Vertechy (1) (3),

Presentation given by Dr. Lorenzo Agostini

Electro-adhesion is a physical principle that provides a grasping force at the interface between a gripper mechanism and an object: a promising feature for many applications, such as industrial, agritech, and aerospace. In recent years, several designs and fabrication methodologies have been proposed to obtain electro-adhesive devices (EADs), that correspond to an electrostatic system mainly composed of two electrodes on a dielectric substrate covered by an insulation layer. Among the possible manufacturing procedures, inkjet printing demonstrated an excellent propensity for the realization of EADs, allowing, for instance, the deposition of interdigitated electrodes onto a polyimide (PI) substrate followed by their encapsulation with a silicone elastomer dielectric layer. As the performance of an EAD is significantly affected by the quality of the bonding between PI substrate and silicone encapsulation layer, this work further investigates this process by evaluating the effectiveness of an oxygen plasma treatment and a silicone primer application. In this contest, several EAD samples obtained with these two surface treatments and without any are experimentally tested, assessing their performance in terms of measured adhesive shear force up to 3kV and the breakdown voltage of the device. The reported results clearly show the difference between the proposed treatments, identifying which one is best to boost a reliable electro-adhesion effect.

3.3.2 Electro-lattice actuator: a compliant high-contractile active lattice structure

Richard Suphapol Diteesawat (1) (2), Sam Hoh (1) (2), Tim Helps (1) (2), Majid

Taghavi (1) (2), Jonathan Rossiter (1) (2),

(1) University Of Bristol, Department Of Engineering Mathematics, Bristol, United Kingdom
(2) Bristol Robotics Laboratory, Bristol, United Kingdom

Presentation given by Dr. Richard Suphapol Diteesawat

Electro-ribbon actuators are high-performance electrically-driven artificial muscles with high flexibility, low mass, low power consumption, high contraction, and high force-to-weight ratio. They use a tiny volume of dielectric liquid to considerably amplify electrostatic forces between two opposite electrodes, resulting in zipping motion between them and mechanical work. They show great promise for driving the deployment of compact folding structures. Applying this phenomenon, the Electro-lattice Actuator (ELA), a compliant, three-dimensional, free-standing lattice structure, was developed, which could fully contract to a flat sheet upon the application of a potential difference. The ELA was designed in the form of multiple interconnected buckled structures and fabricated using polyvinyl chloride sheets and insulated tape and copper electrodes. The ELA structure was pre-set into an open-cell configuration by annealing in an oven. Isometric testing at varying compressions showed that the tensile stress of the proposed lattice actuator reaches a maximum of 184 pascals (a 472 pascal change in tensile stress compared with its unactuated state). A cuboid shaped ELA (13.6 centimetre length × 10.0 centimetre width × 5.4 centimetre height) achieved a contraction of 92.6% and a contraction rate of 35.6% per second. This novel ELA opens up the use of electro-ribbon actuation to more complex and more effective 3D actuating and deploying structures.

3.3.3 Electro-ribbon muscles for biomimetic wing flapping

Jian Huai Chong (1) (2), Christian Romero (1) (2), Majid Taghavi (3), Jonathan Rossiter (1) (2),

(1) University Of Bristol, Department Of Engineering Mathematics, Bristol, UK
(2) University Of Bristol, Bristol Robotics Laboratory, Bristol, UK
(3) Imperial College London, Department Of Bioengineering, London, UK

Presentation given by Mr. Christian Paul Romero Negrete

Birds and bats flap their wings using muscles attached directly to the wing. Bumblebees and other insects, however, drive wing movement by two pairs of muscles in the thorax, the contraction of which squeezes the whole body and causes the wings to flap. Here, we present a bumblebee-inspired compliant actuation mechanism for future autonomous and aerial robotics. The mechanism is powered by a novel thin, lightweight, inexpensive, efficient and powerful solenoid electro-ribbon actuator that exploits the dielectrophoretic liquid zipping phenomenon. The actuator can be easily fabricated using a combination of flexible conducting and insulating materials. A solenoid electro-ribbon actuator, made of a circular steel strip and PVC dielectric, was characterised in terms of stroke, load and work. Its behaviour was studied with different stiffnesses and a flapping-wing architecture was demonstrated to quantify wing shaft movement at various frequencies.

3.3.4 Increasing the performance of electro-adhesive devices via inkjet printing

Federico Bertolucci (1), Lorenzo Agostini (1), Nicolò Berdozzi (1), Marco Fontana (2), Irene Fassi (3), Lorenzo Molinari Tosatti (3), Rocco Vertechy (1) (3),

waiting

Presentation given by Dr. Federico Bertolucci

Electro-adhesive devices (EADs) represent a top-notch technology for gripper applications in several industrial sectors, especially when dealing with fragile objects. Indeed, EADs can generate a relevant adhesion force when electrically activated without inducing any compression. In their most straightforward configuration, this phenomenon is obtained by applying a voltage difference between two interdigitated electrodes insulated between two dielectric layers, exerting an electrostatic attraction on the target object. Their performance is characterized by electro-mechanical features such as electro-adhesive stress (EAS) and the maximum voltage sustained by the device before an electrical breakdown of one of the dielectric layers occurs. In this context, this work presents an innovative strategy to increase the EAD performance by inkjet printing a dielectric ink over the electrodes to obtain a compliant interfacing gripping layer with several advantages concerning its mechanical and dielectric properties. For this purpose, multiple EAD samples are realized with this manufacturing process and experimentally characterized on a testbench able to measure the EAS on different grasped materials. As a final result, the proposed strategy demonstrates a paramount increment of the EAD performance, with measured EAS levels also three times greater with respect to the state-of-the-art.

3.3.5 A soft, fast and self-sensing electrohydraulic gripper

Zachary Yoder (1) (2), Daniela Macari (1) (3), Gavriel Kleinwaks (2), Ingemar Schmidt (1) (2), Eric Acome (2), Christoph Keplinger (1) (2),

(1) Max Planck Institute For Intelligent Systems, Robotic Materials Department, Stuttgart, Germany
(2) University Of Colorado Boulder, Paul M. Rady Department Of Mechanical Engineering, Boulder, USA
(3) Max Planck ETH Center For Learning Systems, Tübingen/Stuttgart, Germany & Zürich, Switzerland

Presentation given by Ms. Daniela Macari

Traditional rigid grippers excel at precise and repetitive tasks in controlled environments. However, they lack versatility and require sophisticated controls and sensor feedback systems to effectively detect and handle a variety of objects. Soft grippers take advantage of compliant and adaptable materials to simplify the complex task of grasping objects of different shapes, sizes and rigidities, thus enabling their operation in dynamic and unpredictable environments. Furthermore, soft robots increasingly make use of embedded intelligence by merging actuation and sensing in their material and structure. In this poster, a soft, fast and versatile gripper made of a continuum stack of self-sensing HASEL (hydraulically amplified self-healing electrostatic) actuators is presented. The gripper can grasp a wide variety of objects with only binary voltage control, and it can grasp delicate objects such as raspberries without inflicting damage. The gripper utilizes capacitive self-sensing to detect its own deformation state, to identify a successful grasp, and to estimate the size of the grasped object. An integrated, compact, and portable high voltage amplifier is also presented, which allows for the gripper to be used on any commercially available robotic arm with a 5 W power supply. This new type of soft gripper is fast, smart, energy-efficient and inexpensive to fabricate, and helps to further expand the application space of soft robotics.

3.3.6 An anthropomorphic robot finger driven by multilayer dielectric elastomer actuators

Junhao Ni (1) (2), Andreas Richter (1), Markus Henke (1) (2),

(1) Institute Of Semiconductors And Microsystems, Technische Universität Dresden, Dresden, Germany
(2) PowerON Group, Auckland, New Zealand

Presentation given by Mr. Junhao Ni

This work reports on an Anthropomorphic Robot Finger which is driven by multilayer membrane dielectric elastomer actuators. The finger includes a rigid skeleton, and two flexible joints (pivots) with attached return springs. Tendons are integrated in the phalanges, guided by pins, and finally, connected to the DEAs. The finger used the fully actuated drive system, each joint is driven by an independent parallel multilayer DEA group. When the DEA is activated, the tendon relaxes, and the return spring pull the finger in order to stretch it. In contrast, when the DEA is turned off, the tendon contracts and the finger flexes. This finger moved 24 degrees under an electric field of 50 volt per micrometer.

3.3.7 Lifetime of multilayer silicone-based dielectric elastomer actuators under DC actuation

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

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

Presentation given by Dr. Herbert Shea

We report an experimental study of the effect of the number of layers on the lifetime of silicone-based dielectric elastomer actuator (DEA) stacks under DC voltage. We observe that DEA lifetime decreases when increasing the number of layers in the stack. Our DEAs consist of uniaxially prestretched silicone membranes (Elastosil 2030/20, 20 ?m initial thickness, 12 ?m thick after prestretch, 12 mm length x 14 mm width) sandwiched between 4 ?m thick carbon black - PDMS composite rectangular electrodes of dimensions 12 mm x 12 mm. A constant DC voltage is applied to the DEAs, whose lifetime is measured at 20°C - 90% RH and at 85°C - 85% RH. At 90 V/?m (2 % actuation strain) and at 85°C - 85% RH, the mean time to failure decreases from 38 hours for 2-layer DEAs to 21 hours for 4-layer DEAs to 5.6 hours for 16-layer DEAs. Decreasing the stiffness of the spring applying the prestretch leads to higher actuation strains at a given electric field, but does not significantly change the DEA lifetime. All devices failed by dielectric breakdown of one layer.

3.3.8 Self-sensing electro-adhesive gripper

Ion-Dan Sirbu (2), Salvatore D'Avella (3), Lorenzo Agostini (1), Paolo Tripicchio (3), Lucio Pancheri (2), Rocco Vertechy (1), Marco Fontana (3),

(1) Università Di Bologna
(2) Università Di Trento
(3) Scuola Superiore Sant"Anna

Presentation given by Prof. Marco Fontana

Electro adhesion is a suitable technology for developing grippers for applications where fragile, compliant or variable shape objects need to be grabbed and where a retention action is typically preferred to a compression force. This contribution presents a self-sensing technique for electro-adhesive grippers (EAG) based on a capacitance measure. Specifically, it is demonstrated that measuring the variation of the capacitance between electrodes of an EAG during the adhesion can provide useful information to automatically detect the successful grip of an object and the possible loss of adhesion during manipulation. A dedicated electronic circuit is developed that is able to detect capacitance variations while the high voltage is active. A test bench characterization is presented to evaluate self-sensing of capacitance during three different states: 1) electro-adhesive pads of the grippers are far away from the object, 2) the electro-adhesive pads are close to the object but the voltage is not active (i.e. no adhesion); 3) the electro-adhesive pads are activated and attached to the object. The measure of capacitance is then correlated with the measurement of shear force. The self-sensing gripper is then demonstrated in a robotic application that employs a robot manipulator arm to pick and place objects of different kind.

3.3.9 Piezoelectric nanofibers for self-sensing materials and energy harvesting devices

Leonardo Gasperini (1), Giacomo Selleri (1), Davide Fabiani (1),

(1) Unibo, DEI/LIMES, Bologna, Italy

Presentation given by Dr. Leonardo Gasperini

Nowadays, piezoelectric materials are used in a variety of applications, particularly for pressure sensors and energy harvesters thanks to their capability to convert the mechanical energy into an electric voltage. Among them, piezo-ceramic materials (i.e., lead zirconate titanate PZT) show high piezoelectric response, which makes them suitable for energy harvesting applications. Piezoelectric polymers such as polyvinylidene fluoride (PVdF), despite having lower piezoelectric coefficients (d33=25 pC/N), can be easily produced as flexible thin films which can be used for sensing applications or wearable devices. However, if these films are integrated in a composite material, the interface adhesion between the film and the laminate resin could lead to mechanical delamination and potentially catastrophic events. Electrospinning is a promising solution to manufacture piezoelectric nanofibers. They can be embedded in the hosting material that permeates the porous membrane, thus preventing the delamination risk thanks to the intimate contact with the nanofibers. In this way it is possible to create multifunctional materials, whose piezo-sensing capability can be enhanced by polarization processes which align the ferroelectric domains of the nanofibers and maximize the piezoelectric output. Moreover, ceramic PZT nanofibers, with higher piezoelectric response (d33=500 pC/N), can be used for flexible devices for scavenging mechanical energy from vibrations and body movement.

3.3.10 A cooperative flexible array of dielectric elastomer actuator/sensor elements: system design and characterization

Julian Neu (1), Sipontina Croce (1), Jonas Hubertus (2), Günter Schultes (2), Stefan Seelecke (1), Gianluca Rizzello (1),

(1) Department Of Systems Engineering, Department Of Materials Science, Saarland University, Saarbruecken, Germany
(2) Sensors And Thin Films Group, University Of Applied Sciences,

Saarbruecken, Germany

Presentation given by Mr. Julian Neu

Dielectric Elastomer Actuators (DEAs) are a versatile technology for numerous applications and many different fields. DEAs have been successfully integrated into valves, pumps or loudspeakers, where they present advantages compared to conventional actuators, i.e, in terms of large stroke, high energy efficiency, and silent operation. However, most of the recently presented DEAs use stand-alone actuators, or combinations of several decoupled devices. A new approach, that allows to design a completely new type of cooperative actuators, can be obtained by integrating multiple DEA elements onto a single, continuous dielectric membrane. In this way, an array of electro-mechanically coupled DEAs is obtained. Thanks to novel bi-stable polymeric domes used as biasing elements, an overall flexible actuator system capable of large stroke can be achieved. By also combining the actuation features with the inherent self-sensing capabilities of the DEA elements, new complex tasks like conveying objects or generating complex waveforms for haptic devices and wearable textiles are possible. In this work, we present how such type of system is designed and assembled, and show first characterization results of a completely polymer-based and thus flexible 1-by-3 DEA-array.

3.3.11 Inkjet-printed stretchable zipping actuators for on-skin haptics

Giulio Grasso (1), Samuel Rosset (2), Herbert Shea (1),

(1) EPFL, Soft Transducers Laboratory - LMTS, Neuchâtel, Switzerland
(2) University Of Auckland, Biomimetics Laboratory, Auckland, New Zealand

Presentation given by Mr. Giulio Grasso

Zipping electrostatic actuators such as HAXELs and Peano-HASELs enable small scale actuators with high strain and high force. They consist of pouches of thin dielectric films with electrodes patterned at the periphery of the external surfaces. The pouch is filled with dielectric fluid. When a high voltage is applied across the electrodes, the electrodes are pulled together by electrostatic forces, the fluid is displaced, inducing out-of-plane bulging. We present here inkjet-printed stretchable HAXELs: the dielectric layers, the two electrode layers and a sacrificial material for fluidic features are all printed using a JetLab 4xl by

MicroFab, with custom inks. We report 2x3 arrays of 5 mm-wide, 150 ?m-thick actuators that can be laid out in arbitrary configurations. A novel filling process ensures no fluidic cross-talk between actuators. We measure free displacements of up to 200 ?m and blocked forces of up to 40 mN on each actuator. The devices operate even when stretched by 50%. Thanks to their intrinsic compliance, these stretchable HAXELs are well suited for on-skin cutaneous haptics. We report haptics tests of 2x2 arrays mounted on user's fingertips, and find that users easily identify the actuated HAXEL device.

3.3.12 Design and optimization of a fringing field based soft capacitive sensor

Masoumeh Hesam Mahmoudinezhad (1), Iain Anderson (1), Samuel Rosset (1),

(1) Biomimetics Laboratory, Auckland Bioengineering Institute, University Of Auckland, Auckland, New Zealand.

Presentation given by Ms. Masoumeh Hesam Mahmoudinezhad

Nowadays, robots are increasingly replacing humans to do repetitive and accurate tasks. In some robotic applications like the manipulation of fragile objects, soft sensors can play a crucial role by providing tactile sensation. A good tactile sensor should be sensitive to any deformation, insensitive to other environmental parameters like temperature, and not show time-dependent drift. Soft capacitive sensors are ideal candidate for this application. However, the usual dielectric elastomer sensor configuration is not very sensitive in compression. Here, we present a sensor based on an interdigitated electrode (IDEs) patterned on a commercial PCB and a deformation-sensitive composite. The sensor is easy to fabricate and has a fast response with great sensitivity of 252 percent to 10N compression load. The sensor can measure different compression load ranges with high sensitivity. This design does not need a compliant electrode or any complex fabrication methods such as a lithography. We will discuss the optimization of the sensor's parameters to maximize the sensitivity for different applications.

List of participants

N.	Last name	First name	Organization	Country
1	Aabloo	Alvo	University of Tartu	Estonia
2	Adeli	Yeerlan	Empa(Swiss Federal Laboratories For Materials Science And Technology), EPFL	Switzerland
3	Agostini	Lorenzo	Università di Bologna	Italy
4	Anderson	Iain	University Of Auckland	New Zealand
5	Andrejczuk	Rafal	TU Dresden	Germany
6	Bakardjiev	Petko	Tu-Dresden	Germany
7	Baltes	Matthias	IMSL - ZeMA gGmbH	Germany
8	Banerji	Saoni	University Of Tartu	Estonia
9	Bertolucci	Federico	University Of Bologna	Italy
10	Boese	Holger	Fraunhofer Institute For Silicate Research	Germany
11	Bruch	Daniel	IMSL - Saarland University	Germany
12	Bruns	Arne	University Of Auckland	United States
13	Bui	Khoa	Laboratoire De Physicochimie Des Polymères Et Des Interfaces (LPPI)	France
14	Çabuk	Ozan	Technical University of Berlin	Germany
15	Cacucciolo	Vito	Politecnico di Bari	Italy
16	Cao	Danfeng	Linköping University	Sweden
17	Carpi	Federico	University of Florence	Italy
18	Chang	Longfei	Hefei University Of Technology	China

19	Cheng	Zhongyang	Auburn University	United States
20	Ciarella	Luca	TU Dresden	Germany
21	Civet	Yoan	EPFL	Switzerland
22	Conn	Andrew	University Of Bristol	United Kingdom
23	Credi	Caterina	National Institute Of Optics - National Research Council	Italy
24	Croce	Sipontina		Germany
25	Danner	Patrick Marcel	EMPA	Switzerland
26	De Menech	Quentin	Ecole polytechnique fédérale de Lausanne (EPFL)	Switzerland
27	De Rossi	Danilo	University of Pisa	Italy
28	Diteesawat	Richard Suphapol	University Of Bristol	United Kingdom
29	Ehrlich	Johannes	Fraunhofer Society	Germany
30	Fasolt	Bettina	ZeMA Zentrum für Mechatronik und Automatisierungstechnik gGmbH, Germany	Germany
31	Floreano	Dario	EPFL	Switzerland
32	Fontana	Marco	Scuola Superiore Sant'Anna C.F. 93008800505	Italy
33	Frediani	Gabriele	University of Florence	Italy
34	Ganesan	Manikandan	Linköping University	Sweden
35	Gasperini	Leonardo	Unibo	Italy
36	Gerhard	Reimund	University of Potsdam, Faculty of Science	Germany
37	Grasso	Giulio	EPFL	Switzerland
38	Gratz-Kelly	Sebastian	Saarland University	Germany
39	Graz	Ingrid M.	Johannes Kepler University (JKU)	Austria
40	Haberland	Norbert	Datwyler Switzerland	Switzerland

41	Haim	Simon-emmanuel	University of Grenoble Alpes	France
42	Henderson	Jillian	Wave Energy Scotland	United Kingdom
43	Henke	Ernst-Friedrich Markus	TU Dresden	Germany
44	Hesam Mahmoudinezhad	Masoumeh	University Of Auckland	New Zealand
45	Hodges	Jonathan	Wave Energy Scotland	United Kingdom
46	Hubertus	Jonas	University Of Applied Science Of Saarland	Germany
47	Jager	Edwin	Linköping University	Sweden
48	Kang	Zhaoqing	Technical University Of Denmark	Denmark
49	Koenigsdorff	Markus	Technische Universität Dresden	Germany
50	Konstantinidi	Stefania	Ecole Polytechnique Fédérale de Lausanne (EPFL)	Switzerland
51	Kovacs	Gabor	CTsystems AG	Switzerland
52	Krüger	Tim	TU Berlin	Germany
53	Kunze	Julian	IMSL - ZeMA gGmbH	Germany
54	Macari	Daniela	Max Planck Institute For Intelligent Systems	Germany
55	Martinez	Jose G.	Linköping University	Sweden
56	Martinez	Thomas	EPFL	Switzerland
57	Mehraeen	Shayan	Linköping University	Sweden
58	Meyer	Andreas	iMSL - ZeMA gGmbH	Germany
59	Michel	Silvain	Empa Materials Science And Technology	Switzerland
60	Moretti	Giacomo	Saarland University	Germany
61	Motzki	Paul	IMSL - ZeMA GGmbH	Germany
62	Nalbach	Sophie	IMSL - ZeMA gGmbH	Germany

63	Neu	Julian	Saarland University	Germany
64	Nguyen	Giao T. M.	CY Cergy Paris Université - France	France
65	Ni	Junhao	Technische Universität Dresden	Germany
66	Ortega	Amaia	Linköping University	Sweden
67	Ortega	Jeanette	Institut Für Textiltechnik Of The RWTH Aachen University	Germany
68	Owusu	Francis	EMPA	Switzerland
69	Perri	Carmen	Polytechnic Of Bari	Italy
70	Plesse	Cedric	CY Cergy Paris University	France
71	Prechtl	Johannes	Saarland University	Germany
72	Prokopchuk	Artem	Technische Universität Dresden	Germany
73	Qiu	Yaxin	Linköping University	Sweden
74	Raman Venkatesan	Thulasinath	UP Transfer GmbH An Der Universität Potsdam	Germany
75	Ramirez Herrera	Renzo Ramiro	University of Florence	Italy
76	Richter	Andreas	Technische Universität Dresden	Germany
77	Rizzello	Gianluca	Saarland University	Germany
78	ROMERO NEGRETE	CHRISTIAN PAUL	University Of Bristol	United Kingdom
79	Rosset	Samuel	Auckland Bioengineering Institute	New Zealand
80	Rossiter	Jonathan	University Of Bristol	United Kingdom
81	Rothemund	Philipp	Max Planck Institute For Intelligent Systems	Germany
82	Sandacz	Zoe	Parker Hannifin/University Of Minnesota	United States
83	Sasso	Giacomo	Queen Mary University of	Italy

			London	
84	Seelecke	Stefan	Saarland University	Germany
85	Shea	Herbert	EPFL	Switzerland
86	Simonetti	Giovanni	University of Florence	Italy
87	Sîrbu	Ion-Dan	University Of Trento	Italy
88	Skov	Anne Ladegaard	DTU	Denmark
89	Stiubianu	George	Institute Of Macromolecular Chemistry Petru Poni Iasi	Romania
90	Syzoniuk	Oleksandr	University Of Tartu	Estonia
91	Taghavi	Majid	Imperial College London	United Kingdom
92	Tan	Lihaoya	University Of Bristol	United Kingdom
93	Tugui	Codrin	"Petru Poni" Institute of Macromolecular Chemistry	Romania
94	Vancaeyzeele	Cedric	CY Cergy Paris Université	France
95	Vertechy	Rocco	University Of Bologna	Italy
96	Von Szczepanski	Johannes	Empa	Switzerland
97	Walker	Christopher	Auckland Bioengineering Institute	New Zealand
98	Weissmüller	Jörg	TUHH	Germany
99	Wiesmath	Anette	Datwyler	Switzerland
100	Willian	Tobias	Universität des Saarlandes	Germany
101	Wilson	Katie	PowerON Limited	New Zealand
102	Wu	Yihan	University Of Auckland	New Zealand
103	Yi	Jianan	Dresden University Of Technology	Germany
104	Yu	Liyun	Technical University Of Denmark (DTU)	Denmark