



EuroEAP 2026

**14th international conference on
Soft Transducers and
Electromechanically Active Polymers**

Neuchatel, Switzerland

2-4 June 2026

Technical programme

Book of abstracts

List of participants

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Conference venue

EPFL-Neuchatel
Rue de la Maladière 71
CH-2000 Neuchatel
Switzerland



Wifi: use Eduroam, or “freewifi-epfl”, or scan the QR codes at reception.

Conference Chairperson



Prof. Herbert Shea
Soft Transducers Lab, Institute of Mechanical Engineering
EPFL, Neuchatel, Switzerland

Local organization

EPFL Soft Transducers Lab (LMTS)

Conference Committee

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

Committee President:

- Philipp Rothemund, University of Stuttgart (Germany)

Committee Members:

- Federico Carpi, University of Florence (Italy)
- Edwin Jager, Linköping University (Sweden)
- Cedric Plesse, CY Cergy Paris Université (France)
- Gianluca Rizzello, Saarland University (Germany)

Presentation of the EuroEAP conference series

The 21st century is experiencing a paradigm change from the age of passive synthetic materials to the age of stimuli-responsive and multi-functional materials. Among them, Soft Transducers and Electromechanically Active Materials represent a fast-growing scientific field of research and development. They consist of soft polymer materials, devices or systems that can convert, react or adapt to an external stimulus (such as electrical, magnetic, electromagnetic, mechanical, pneumatic, thermal or chemical) and transduce it into a different form of energy, exhibiting changes (e.g. in terms of shape, size, force, stiffness, surface texture, polarization, colour, etc.), which can be used for diverse needs, including actuation, sensing and energy harvesting. Their numerous and different working principles, as well as their use in practical applications, make this research field inherently and highly interdisciplinary, bridging the gap between chemistry and physics of materials, modelling, electrical and mechanical engineering, manufacturing and user interface science.

These materials and technologies will play an increasingly important role in the future, thanks to their unique combination of stimuli-responsiveness and soft structure. They are already opening numerous possibilities of application in various fields, such as soft robotics, energy harvesting, biomedical devices, human-machine interaction, wearables and smart textiles (to name a few), which so far have been unachievable with conventional and stiff transduction technologies.

The EuroEAP international conference, organized by the EuroEAP Society with a not-for-profit distinctive character and always held in Europe, in charming and easy-to-reach locations, is primarily aimed at sharing and disseminating the latest advances and findings in this emerging field. It gathers experts from all over the world in a highly multidisciplinary event, driven by scientific quality and industrial impact, with an organisation and daily schedule that enable significant opportunities for one-to-one discussions, in a friendly atmosphere.

Since 2011, the conference has been focused on Electromechanically Active Polymers. Today, the event expands its scope to the larger international and diverse research community of soft smart materials and soft transducers.

Prof. Philipp Rothemund
EuroEAP Conference Committee President

Program Overview

Monday, 1 June 2026

Arrival	15:00- 18:00	Registration
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Tuesday, 2 June 2026

Opening	8:45- 9:00	Welcome & introductory remarks Herbert Shea, EPFL
Keynote Lecture	Session 1.1 part I <i>Chair: Herbert Shea, EPFL, Switzerland</i>	
	9:00- 9:40	Kevin Chen, MIT, USA
Invited Lectures	Session 1.1 part II <i>Chair: Federico Carpi, Uni Florence, Italy</i>	
	9:40- 10:10	Pooi See Lee, NTU, Singapore
	10:10- 10:40	Jan Vermant, ETHZ, Switzerland
Break	10:40- 11:00	Coffee break
Short Oral presentations	Session 1.2 part I <i>Chair: Gianluca Rizzello, Saarland University, Germany</i>	
	11:00- 12:00	Oral presentations pt 1 24 presentations of research activities
Poster Session	Session 1.2 part II	
	12:00- 13:00	Posters & exhibitions pt 1
Lunch	13:00- 14:00	Lunch

Short Oral presentations	Session 1.3 <i>Chair: Dorina Opris, Empa, Dübendorf, Switzerland</i>	
	14:00-15:00	Oral presentations pt 2 24 presentations of research activities
Poster Session	15:00-16:00	Posters & exhibitions pt 2 Coffee served during the session
EuroEAP Society meeting	16:30-17:30	Annual meeting of the EuroEAP Society (all welcome, only members can vote)
Social Event	17:45-19:00	Chocolate and Absinth tasting (at conference venue)
Social Dinner	19:00-21:00	Dinner at conference venue (4 th floor)

Wednesday, 3 June 2026

Keynote Lecture	Session 2.1 part I <i>Chair: Philipp Rothemund, Stuttgart University, Germany</i>	
	9:00-9:40	Stéphanie Lacour , EPFL, Switzerland
Invited Lectures	Session 2.1 part II <i>Chair: Anne Skov, DTU</i>	
	9:40-10:10	Georg Duda , Charité, Berlin
	10:10 – 10:40	Lucia Beccai , IIT, Italy
Break	10:40-11:00	Coffee break
Invited Talks	Session 2.1 part III <i>Chair: Cédric Plesse, CY Cergy Paris Université, France</i>	
	11:00-11:15	Bettina Fasolt ZeMA, Saarbrücken, Germany
	11:15-11:30	Thomas Daunizeau EPFL, Switzerland

EuroEAP Society Challenge	11:30-12:00	9 Challenge videos will be shown (3 minutes each)
Short Oral presentations	Session 2.2 part I <i>Chair: Stefan Seelecke, Saarland University, Germany</i>	
	12:00-13:00	Oral presentations pt 3 24 presentations of research activities
Lunch	13:00-14:00	Lunch
Poster Session	Session 2.2 part II <i>Chair: Marco Fontana, Sant'Anna, Pisa, Italy</i>	
	14:00-15:00	Posters & exhibitions pt 3 (Coffee served during session)
Industry Talks	Session 2.3 <i>Chair: Florian Hartmann, MPI Stuttgart, Germany</i>	
	15:00-15:15	Anne Skov , Glysis, Denmark
	15:15-15:30	V. Cacucciolo , Omnigrasp, Italy
Social Event	15:45-18:30	To Laténium museum by bus, back to Neuchâtel by bus
Social Dinner	19:00-22:00	Gala dinner

Thursday, 4 June 2026

Keynote Lecture	Session 3.1 part I <i>Chair: Edwin Jager, Linkoping University, Sweden</i>	
	9:00-9:40	Il-Kwon Oh , KAIST, Republic of Korea
Invited Lectures	Session 3.1 part II <i>Chair: Steven Zhang, MPI-IS Stuttgart, Germany</i>	
	9:40-10:10	Vito Cacucciolo , Politecnico di Bari, Italy
	10:10-10:40	Esther Amstad , EPFL, Switzerland
Break	10:40-11:00	Coffee break
Short Oral presentations	Session 3.2 <i>Chair: Jonathan Rossiter, University of Bristol, UK</i>	
	11:00-12:00	Oral presentations pt 4 24 presentations of research activities
Poster Session	12:00-13:00	Posters & exhibitions pt 4
	13:00-13:10	Final collection and counting of the votes
Awards for Best Poster and Best Society Challenge	Session 3.3 <i>Chair: Daniela Macari, MPI-IS Stuttgart, Germany</i>	
	13:10-13:20	Awards for top three entries in the EuroEAP Society Challenge.
		Award for best poster
Closing Ceremony	13:20-13:30	Conference closure, handover to the next year's chairperson and presentations of the next year's conference venue
Lunch	13:30 - 14:15	

Tuesday, 2 June 2026

Session 1.1

1.1.1 Challenges and opportunities for insect-scale autonomous aerial robots

Yufeng (Kevin) Chen

Department of Electrical Engineering and Computer Science, MIT, USA

Flapping-wing flight at the insect-scale is incredibly challenging. Insect muscles not only power flight but also absorb in-flight collisional impact, making these tiny flyers simultaneously agile and robust. In contrast, existing aerial robots have not demonstrated these properties. Rigid robots are fragile against collisions, while soft-driven systems suffer limited speed, precision, and controllability. In this talk, I will describe our effort in developing a new class of bio-inspired micro-flyers, ones that are powered by high bandwidth soft actuators and equipped with rigid appendages. We constructed the first heavier-than-air aerial robot powered by soft artificial muscles, which can demonstrate a 1000-second hovering flight. In addition, our robot can recover from in-flight collisions and perform somersaults within 0.10 seconds. This work demonstrates for the first time that soft aerial robots can achieve agile and robust flight capabilities absent in rigid-powered micro-aerial vehicles, thus showing the potential of a new class of hybrid soft-rigid robots. I will also discuss our recent progress in incorporating onboard sensors, electronics, and batteries.

1.1.2 Programmable materials for soft actuators

Pooi See Lee (1) (2)

(1) School of Materials Science and Engineering, Nanyang Technological University, Singapore

(2) NRF SGSR CREATE, Singapore

Programmable functional materials play a critical role in the development of high-performance soft actuators which are attractive for soft electronics, soft robotics and wearables. This talk focuses on our materials design strategies, synthetic approaches and the related actuation mechanisms of soft actuators. These soft and

flexible materials and devices can be triggered by different stimuli such as light, electricity or electrochemical potential to deliver programmable functionalities. The actuation modalities and performance can be enhanced with the incorporation of fillers in dielectric elastomer. Preparation of compliant electrodes with polyionic liquid improves the dielectric elastomer actuation properties. Stretchable elastomers that can be 3D printable are developed for actuation and electroadhesion properties. 3D printed manifold electrohydrodynamic actuator has been shown to deliver high output force and high flow rate. These soft actuators are promising for applications in smart grippers, bioinspired robotics, haptics, healthcare and human-machine interface.

1.1.3 Advective Processing of Polymeric Materials for Soft Sensors and Actuators

Tazio Pleij and Jan Vermant

Department of Materials, ETH Zürich, Switzerland

Presentation given by Prof. Jan Vermant

For sensors and actuators, advective processing provides a deterministic route to embed function into soft polymers. Rather than relying on equilibrium self-assembly or chemistry-specific interactions, internal composition, interfaces, and anisotropy are programmed by laminar flow histories. Splitting, rotating, recombining, and stretching material streams define the architecture, making the process reproducible, scalable, and broadly transferable. The key requirement is a controlled elastoplastic or viscoplastic rheological window: materials must flow during processing, yet preserve sharp internal features during deposition and curing.

In hydrogels, advecting dilute and concentrated PEGDA streams enables continuous patterning of cross-link density; photopolymerization then locks in gradients in elasticity, swelling, and mechanical response. For soft sensors and actuators internal functional resolution can be decoupled from external device size. Co-extrusion of rheologically matched dielectric and conductive inks yields capacitive fibers with micron-scale electrodes at high extrusion speeds, producing soft capacitors with nearly linear, hysteresis-free responses. Related continuous co-extrusion enables single-step fabrication of dielectric elastomer actuator fibers.

Session 1.2 – short talks with focus on DEAs

1.2.1 Hetero-cross-linking-induced biphasic bicontinuous dielectric elastomers for high-performance soft actuators

Xiaotian Shi (1) (2), Jiang Zou (1) (2), Guoying Gu (1) (2),

(1) School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai, China

(2) Shanghai Key Laboratory of Intelligent Robotics, Shanghai Jiao Tong University, Shanghai, China

Presentation given by Dr. Xiaotian Shi

Dielectric elastomer artificial muscles are promising for soft robotics because of their light weight, large deformation, and fast response, but their performance is often limited by the low electromechanical sensitivity of materials. Here, we report a semiseparated biphasic bicontinuous dielectric elastomer enabled by a hetero-cross-linking-induced phase separation strategy. This material forms an interconnected dielectric phase within a soft mechanical phase, producing a favorable balance of low modulus, enhanced dielectric constant, and improved breakdown strength. The optimized elastomer shows a Young's modulus of about 10 kilopascals, a relative dielectric constant of 3.6, an electromechanical sensitivity of 360 per megapascal, and 90 percent area strain without prestretching under 35 volts per micrometer. Based on this material, we develop dielectric elastomer artificial muscles in pure-shear, stacked, and rolled configurations. The actuators generate more than 50 percent linear strain, reach an energy density of 375 joules per kilogram, a power density of 2250 watts per kilogram, and a response frequency above 1500 hertz. They also show strong load-driving capability and long-term stability, maintaining actuation for more than 100 million cycles. We further demonstrate robotic arm and soft crawling robot applications, including untethered locomotion. These results suggest a useful route toward high-performance artificial muscles for next-generation soft robots.

1.2.2 Scalable soft actuators via coaxial dielectric elastomer fibers with liquid electrodes

Emmy Y. Markgraf (1), Ryan L. Truby (1) (2)

(1) Northwestern University, Materials Science And Engineering, Evanston, IL, USA

(2) Northwestern University, Mechanical Engineering, Evanston, IL, USA

Presentation given by Ms. Elizabeth Markgraf

Inspired by the movements and mechanics of muscle tissues, soft actuators are critical to the development of bioinspired machines with mechanically adaptable bodies and fast, back-drivable actuation. Electrically controllable soft actuators like dielectric elastomer actuators (DEAs) are especially promising due to their rapid, reversible actuation and efficiency. Manufacturing DEAs typically requires time- and labor-intensive processes to produce. DEAs with fiber-like morphologies, inspired by muscle fibers, have emerged as a route toward high-throughput manufacturing and scalable actuator designs. However, state-of-the-art DEA fibers rely on stiff electrodes that mechanically impede performance. We introduce a manufacturing process for creating DEA fibers that consist of an ionic liquid electrode core and a UV-curable, thiol-ene silicone shell. By harnessing coaxial extrusion and the ability to photocrosslink on-the-fly, we can manufacture DEA fibers in various geometries to display both extensional and contractile actuation. The fibers are capable of being bundled to display different forms of addressable actuation. We also show fiber actuation in different environments, including air, salt water, and cell culture media. We anticipate that our DEA design and manufacturing methods open new avenues for the integration of electrically-controllable, multifunctional actuators in soft and bioinspired robots that can perform in tasks spanning manufacturing to biomedicine.

1.2.3 Visco-pseudo-elastic modelling of elastomeric membranes subject to bi-axial stretching

Alireza Jalalian (1), Gastone Rosati Papini (1), Gianluca Rizzello (2), Giacomo Moretti (1),

(1) University Of Trento, Department Of Industrial Engineering, Trento, Italy

(2) Saarland University, Department Of Systems Engineering,
Saarbrücken, Germany

Presentation given by Mr. Alireza Jalalian

A thermodynamically consistent visco-pseudo-elastic constitutive model is proposed for elastomeric membranes undergoing finite deformations, with particular relevance to dielectric elastomer actuators (DEAs). The formulation relies on a rheological description of the material, which combines a hyperelastic equilibrium response with viscoelastic and rate-independent dissipative contributions, represented through internal stretch variables within a nonequilibrium thermodynamic framework. The model holds for biaxial membrane stretch states, without a-priori assumptions on the deformation kinematics, and it is validated against experiments on a styrene-based rubber subject to large stretches (>2.5). Material parameters are identified from pure-shear experiments using a nonlinear least-square approach, where internal variables evolve along prescribed stretch histories. The identified parameters are validated against independent datasets and further used to predict the response under complex biaxial deformations. Results show that parameters identified from simple monoaxial tests can capture complex multiaxial behaviors, including hysteresis and rate-dependent effects. The proposed framework provides a predictive tool for the modeling and design of DEA-based devices.

1.2.4 High speed robotic xylophone player using hyper elastic

Yueh-Chou Yang (1), Gih-Keong Lau (1), Yu-Chen Chang (1), Hao-Yang Peng (1), Jing-Yi Chen (1),
(1) National Yang Ming Chiao Tung Univ., Bio-Inspired Soft Robotics Lab,
Hsinchu City, Taiwan

Presentation given by Mr. Yueh-Chou Yang

While a human hand can effortlessly strike a glockenspiel, replicating this motion with motor-driven robotic arms poses a significant mechanical challenge. Traditional gear motors suffer from gear assembly wear and noise during the rapid reversal required for a strike. Furthermore, the flywheel inertia of fast-spinning motors often prevents the mallet from lifting quickly enough, resulting in a muffled sound—a limitation that active control mechanisms struggle to overcome. To address these issues, this system adopts a biomimetic approach using Dielectric Elastomer Actuators (DEA) to create artificial muscles. By arranging these actuators in an antagonistic bicep-triceps structure paired with a biomimetic shoulder, the system can stably grip and swing a mallet without the need for noisy, high-maintenance gear systems. A key innovation in this design is the material selection: SEBS (Styrene-Ethylene-Butylene-Styrene) is used to replace commonly used 3M VHB foam tape. Unlike VHB, which suffers from high viscoelasticity and sluggish actuation, SEBS provides hyper-elasticity. This enables the hyper elastic artificial muscles act fast and silently under high voltage pulsed activation. This rapid, spring-like rebound mimics human muscle behavior, ensuring the mallet lifts swiftly off the keys to produce a clear, vibrant tone.

1.2.5 Enabling DEA-driven elastocaloric cooling: a linear demonstrator study

Lukas Moritz Roth (1), Daniel Bruch (1) (2), Paul Motzki (1) (2),

(1) Department Systems Engineering, Saarland University, Saarbrücken, Germany

(2) Department Smart Material Systems, ZeMA - Center For Mechatronics And Automation Technology, Saarbrücken, Germany

Presentation given by Mr. Lukas Moritz Roth

Elastocaloric (EC) cooling utilizes stress-induced phase transformations in shape memory alloys (SMAs) and represents an energy-efficient and environmentally friendly alternative to conventional vapor-compression systems. Dielectric elastomer actuators (DEAs) offer strong potential as direct drive elements for EC materials, enabling compact, lightweight, fully solid-state cooling concepts. A key challenge, however, is the high stiffness and stress requirements of SMAs, which demand large actuation forces that are difficult to achieve with DEAs. In this poster, a simplified linear test platform is introduced as a step toward a DEA-driven EC cooling device. The focus is on approaches to reduce required actuation forces and compensate the intrinsic stiffness of EC elements. The setup consists of a stepper motor-based linear actuator with surplus force capacity and a single SMA wire bundle arranged in series. To lower effective stiffness, a negative bias spring (NBS) mechanism is integrated, providing a region of apparent negative stiffness over a defined displacement range. This reduces the net force demand on the actuator. The NBS can be activated or deactivated, enabling direct comparison between compensated and uncompensated modes. Force reduction is evaluated via real-time motor current monitoring, while the EC response is assessed using infrared thermography. The demonstrator establishes a basis for stiffness compensation concepts and supports future DEA-based actuation.

1.2.6 In-stack breakdown testing: a layer-by-layer approach to reliable dielectric elastomer actuators

Julia Platz (1), Armando Walter (1), Amine Benouhiba (1), Paolo Germano (1), Yoan Civet (1), Yves Perriard (1),
(1) École Polytechnique Fédérale De Lausanne, Integrated Actuators
Laboratory/Center for Artificial Muscles, Neuchâtel, Switzerland

Presentation given by Ms. Julia Platz

VADs require actuators capable of producing pulsatile motion at clinically relevant flow rates, and DEAs offer a soft, lightweight solution. Because VADs are life-support systems, reliability is critical. The current DEAs feature large electrodes (15 000 mm² in area) and consist of stacks with 12 active layers. Such dimensions increase the risk of dielectric breakdown: large electrodes are harder to apply uniformly, raising the likelihood of defects, while high electric fields up to 90 V/μm are needed for sufficient actuation. To ensure reliability, each elastomer and electrode layer should be tested at the intended driving voltage and repaired if necessary before integration into the stack. Previous work addressed breakdown testing by placing an Elastosil sheet with multiple 30×30 mm printed electrodes on a grounded metal plate and contacting each electrode with a moving probe. While effective for testing many electrodes, this method does not support handling and stacking of tested layers at dimensions required for VADs. To overcome this limitation, we propose a method enabling testing and repair of each layer during fabrication within the growing multilayer DEA stack. Each layer is added with the electrode-free side exposed, while a small access hole on the opposite side allows contact with the carbon electrode to apply the test voltage. This ensures that only layers capable of withstanding the target voltage are integrated, reducing the risk of premature breakdown.

1.2.7 Influence of unidirectional fiber reinforcement on the electromechanical performance of silicone dielectric elastomer actuators

Xiaohan Han (1) (2), Markus Koenigsdorff (1) (2), Amine Benouhiba (1) (2), Yoan Civet (1) (2), Yves Perriard (1) (2),

(1) Integrated Actuators Laboratory, École Polytechnique Fédérale De Lausanne, Neuchâtel, Switzerland

(2) Center For Artificial Muscles, École Polytechnique Fédérale De Lausanne, Neuchâtel, Switzerland

Presentation given by Ms. Xiaohan Han

Dielectric elastomer actuators (DEAs) offer potential for soft robotic applications requiring large uniaxial deformations, such as facial reanimation. Unidirectional fiber reinforcement is known to suppress lateral contraction and modify the deformation behavior of strip DEAs, but a systematic comparison of how different fiber materials influence their electromechanical performance is still lacking. This study investigates multilayer silicone-based DEAs in five configurations: an isotropic control (ISO), and actuators reinforced with polyethylene terephthalate (PET) or carbon fibers (CF), with and without fiber-direction pre-stretch. Cyclic tensile tests with stretch ratios from 1.1 to 1.5 were conducted under driving voltages up to 6 kilovolts to characterize both passive mechanical behavior and active electromechanical response under isometric and isotonic conditions. Fiber reinforcement increased baseline passive stiffness and hysteresis energy, scaling with fiber rigidity, increasing from ISO to PET, and then slightly to CF. Under isometric conditions at a fixed stretch ratio, fiber-reinforced DEAs exhibited up to 1.5 times higher electroactive force compared to isotropic devices. However, additional pre-stretch along the fiber direction did not lead to further improvements in electroactive force. These results provide practical guidance for material selection and structural design of DEA systems.

1.2.8 Optimizing fiber-reinforced dielectric elastomer actuators with biasing mechanisms for enhanced performance in soft robotics

Carola Böhmer (1), Markus Koenigsdorff (2) (3), Yves Perriard (2) (3), Gerald Gerlach (1),

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

(3) Center For Artificial Muscles (CAM), Ecole Polytechnique Fédérale De Lausanne, Rue De La Maladière 71b, 2000 Neuchâtel, Switzerland

Presentation given by Ms. Carola Böhmer

Dielectric elastomer actuators (DEAs) are a promising class of soft actuators characterized by high actuation speeds and versatile configurations across a wide range of applications. Strip actuators are among the most common DEA designs owing to their fabrication simplicity and geometric flexibility. A key limitation of strip actuators - lateral necking under strain - can be effectively mitigated by incorporating a reinforcement layer that enforces mechanical anisotropy. This constrains deformation to the desired axis, amplifying both actuation strain and force output while simultaneously simplifying control and enhancing self-sensing capabilities. Textile reinforcement layers further improve the actuator strain state toward a pure shear condition, rendering actuation forces independent of the strip's aspect ratio. However, anisotropic reinforcement inherently increases actuator stiffness, which can limit active strain. While negative-rate bias springs have previously been shown to improve active strain in isotropic DEAs, their applicability to fiber-reinforced anisotropic configurations remains largely unexplored. In this study, we systematically investigate the effects of reinforcement composition, geometric aspect ratio, and biasing spring parameters on DEA performance, with the goal of identifying optimal design configurations that maximize active strain and force output for soft robotics applications.

1.2.9 Millimeter-scale folded electrostatic actuators

Yuan Fang (1), Giulio Grasso (1), Florian Hartmann (1),
(1) Biomimetic Materials And Machines Group, Max Planck Institute For
Intelligent Systems, Stuttgart, Germany

Presentation given by Dr. Giulio Grasso

Millimeter-scale electrostatic actuators are a promising solution for miniature robots or multimodal motion systems requiring high actuator density. Current actuator designs are difficult to miniaturize to such sizes, as MEMS fabrication processes or cleanroom environments are required. Moreover, they typically exhibit either limited force output or limited strain: soft electrohydraulic actuators or dielectric elastomer actuators reported in literature achieve only <10% and <30% actuation strains at millimeter scales. To tackle these challenges, we developed a frugal fabrication strategy for electrostatic actuators based on folded structures at millimeter scales. These folded actuators consist of a Parylene-C structure encapsulating interdigitated electrodes. Dielectric and conductive layers are deposited on grooved molds to form 3D structures, and electrodes are patterned through laser ablation. Under high voltage, opposing electrodes collapse, generating large, tuneable actuation strains. Through actuator geometry optimization, we enable mm-scale actuation units (2 mm x 1 mm x 10 mm) that can be arbitrarily stacked or changed in dimensions. A five-unit system weights 20 mg and achieves up to 70% actuation strain and 23 mN maximum output force in a dielectric medium, exceeding 100 times its own weight. Our new actuation platform substantially improves miniature robot strains, showing strong potential for seamless operation across both large-scale and confined environments.

1.2.10 Compact demultiplexer for high-voltage control of dielectric elastomer actuator arrays

Daniel Philippi (1), Sebastian Gratz-Kelly (1), Carmen Perri (2), Paul Motzki (1) (2),

(1) A ZeMA - Center For Mechatronics And Automation Technology, Smart Material Systems, Saarbrücken, Germany

(2) B Saarland University, Dept. Systems Engineering, Saarbrücken, Germany

Presentation given by Mr. Daniel Philippi

Dielectric Elastomers (DEs) are a core technology for soft robotics due to their flexibility and high strain (> 100%). However, combining them into multi-element arrays is challenging because their high operating voltages typically require a dedicated, costly, and bulky high-voltage amplifier for each actuator. To overcome these scalability barriers, this work presents a compact demultiplexer that distributes voltage from a single high-voltage source to multiple individually addressable DE actuators. This significantly reduces overall system complexity, cost (several thousand euros), and footprint (e.g., $28 \times 48 \times 65$ cm per unit). The proposed circuit utilizes commercial off-the-shelf semiconductors in a cascode configuration, capable of switching up to 3 kV. Results demonstrate that this system successfully enables fully independent control of individual actuators using only one high-voltage supply. Future optimizations will incorporate advanced semiconductor technologies like SiC (silicon carbide) or GaN (gallium nitride) to achieve higher switching frequencies and power capabilities. This will allow proportional actuator control via Pulse Width Modulation (PWM) and expand the application scope to other soft robotic architectures, such as HASEL actuators.

1.2.11 Challenges in driving variable resistive and capacitive load at kilovolt ranges

Maribel Cáceres Rivera (1) (2), Alexis Boegli (1) (2), Yoan Civet (1) (2), Yves Perriard (1) (2),

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

(2) Center For Artificial Muscles (CAM), Ecole Polytechnique Fédérale De Lausanne (EPFL), Neuchatel, Switzerland

Presentation given by Ms. Maribel Cáceres Rivera

Driving dielectric elastomer actuators (DEAs) requires kilovolt-level signals to achieve electromechanical deformation, highlighting the critical role of step-up voltage conversion topologies. Under operating conditions, DEAs often exhibit frequent electrical breakdown and low efficiency. Therefore, characterizing their response under different driving methods is important for identifying a reliable and stable topology, especially when electrical parameters such as capacitance, electrode resistance, and leakage resistance vary during actuation. This work compares several driving methodologies: a voltage amplifier (Trek), a modified Marx generator, and a potential current-pulse source. The comparison focuses on current and voltage waveforms, energy transfer, dissipation, size, and the resulting DEA actuation. The studies indicate that the voltage amplifier provides stable and controllable waveforms; the Marx generator offers fast rising edges that produce current spikes; and, on the other hand, the current-peak source enables efficient charging but induces voltage ripples and large currents. These observations help identify suitable topologies for operating a DEA, depending on whether stability, fast actuation, size, or efficiency is critical.

1.2.12 A pulsed high-voltage driver for sub-ms charging of cyclically driven dielectric elastomers with 10 amps peak charging current

Sebastian Becker (1), Benedikt Holz (1), Carmen Perri (1), Paul Motzki (1) (2),
(1) Saarland University, Department Systems Engineering, Saarbrücken,
Germany
(2) ZeMA GmbH - Center For Mechatronics And Automation Technology,
Department Smart Material Systems, Saarbrücken, Germany

Presentation given by Mr. Sebastian Becker

The development of high-performance actuators based on dielectric elastomers (DEs) is increasingly relevant for applications such as soft robotics, microfluidic valves, and haptic systems. Their high energy density, low weight, and compliance make them attractive, but they impose challenges on the driving electronics, requiring high voltages and fast dynamic response. A major challenge arises from the capacitive behavior of DE actuators. Rapid charging and discharging within fractions of a millisecond lead to high transient currents. These peaks enable fast voltage transitions but increase losses, electromagnetic interference, and stress on the power electronics. Thus, the driving stage must balance switching speed, efficiency, and robustness. This work presents a fast-switching high-voltage output stage for DE actuators. The architecture enables precise control of charging and discharging while minimizing switching losses. Optimized circuit topologies and dedicated gate driver strategies ensure high dynamic performance and stable operation, while reducing parasitic effects and voltage overshoot. Experimental results show that the output stage drives DE actuators at high repetition rates with voltage slew rates of up to 125 V/microseconds, maintaining reliable operation and avoiding excessive component stress. This enables fast and precise actuation, e.g., for adaptive valve control, and contributes to efficient driving electronics for electroactive polymer systems.

1.2.13 A dielectric elastomer field-effect transistor enabling flexible circuit integration

Jian Chen (1), Andreas Richter (1), E.-F. Markus Vorrath (1) (2),
(1) TU Dresden, Institute Of Semiconductors And Microsystems
(2) Biomimetics Lab, Auckland Bioengineering Institute, The University Of
Auckland

Presentation given by Mr. Jian Chen

Dielectric elastomers offer a promising platform for soft, compliant electronic components. Here, we present a dielectric elastomer field-effect transistor (DE-FET), a soft voltage-controlled variable resistor that integrates a patterned resistive pathway with a dielectric elastomer actuator (DEA). The device is made from a pre-stretched VHB membrane with a printed carbon-black conductive pattern. Activating the DEA mechanically compresses the conductive path, reducing its resistance and producing transistor-like switching behavior. Compared with previous dielectric elastomer switches, the DE-FET simplifies the architecture by removing one terminal and may enable unidirectional conduction, reducing circuit complexity and supporting soft logic and inverter designs. Experiments show resistance changes over several orders of magnitude, influenced by elastomer viscoelasticity, with response times on the order of seconds. This device demonstrates the integration of actuation and switching in a single soft material system, with potential applications in soft robotics, adaptive sensors, and bio-inspired circuits.

1.2.14 Integrated pneumatic dielectric elastomer switches for soft dielectric elastomer inverters

Chen Jiao (1), Ashwani Sharan Tripathi (1), Andreas Lars Peter Hubracht (2), Bingzhi Wang (2), Uwe Marschner (1), Andreas Richter (1), Jürgen Maas (2), E.-F. Markus Vorrath (1) (3),

(1) Technische Universität Dresden, Institute Of Semiconductors And Microsystems, Dresden, Germany

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Presentation given by Dr. Chen Jiao

Collaborative multi-actuator systems are expected to play a key role in future applications such as robotics, medical devices, and advanced user interfaces. Achieving fully soft, bioinspired systems requires the development of soft electronic circuits. Dielectric elastomers (DEs), as multifunctional electroactive polymers, enable actuation, sensing, and energy harvesting. In this work, a pneumatic dielectric elastomer switch (DES) is developed to convert air pressure into electrical signals. A stretchable conductive track is printed on a silicone membrane, where applied pressure induces out-of-plane deformation, stretching the conductive network and reducing micro-conductive pathways, resulting in a pronounced resistance increase. The DES exhibits stable and repeatable switching over multiple cycles, with resistance changes spanning several orders of magnitude under triangular and square pressure inputs, demonstrating its potential as a soft pressure sensor. Furthermore, the DES is integrated into a planar dielectric elastomer actuator (DEA) system to realize a DE inverter. The DEA generates deformation via Maxwell stress under high voltage, mechanically modulating DES resistance and enabling fully soft electromechanical signal transduction. This system provides a promising platform for soft, programmable transducers in soft robotics and adaptive electronics.

1.2.15 Modeling and control of soft cooperative arrays of dielectric elastomer actuators

Alberto Priuli (1), Saverio Addario (1), Benjamin Zemlin (2), Giacomo Moretti (3), Gianluca Rizzello (1),

(1) Saarland University

(2) HTW Saar

(3) University of Trento

Presentation given by Mr. Alberto Priuli

Recent advances in dielectric elastomer (DE) technology have focused on developing matrix configurations of multiple actuator/sensor units. The intrinsic softness of these systems induces electromechanical coupling between neighboring DEs at the hardware level; this effect, combined with large deformations and material viscoelasticity, significantly impacts system-level performance and poses challenges for modeling and control. Addressing these challenges requires a combination of modeling strategies that balance accuracy and computational efficiency. To this end, we present two complementary modeling approaches for DE arrays with different levels of complexity. A physics-based continuum formulation is first presented that predicts the dynamic response of the entire array, including coupling effects and local deformation patterns, solely from prior knowledge of geometry and material parameters. Second, a reduced-order model is developed for control purposes, capable of tracking key quantities (i.e., DE displacements) while meeting real-time evaluation requirements. Finally, the presented control-oriented model is used to design a cooperative closed-loop motion control policy that exploits interactions between actuators while preserving properties such as passivity, ensuring inherent robustness. Static and dynamic experimental results validate both modeling approaches, while the feasibility of the proposed control policy is demonstrated through simulations.

1.2.16 Model-based design, control, and self-sensing of multi-stable soft robotic manipulators driven by dielectric elastomer actuators

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Presentation given by Mr. Giovanni Soleti

Multi-stable design principles can enhance the performance of compliant systems, including dielectric elastomer actuator (DEA)-based devices, in terms of stroke, energy efficiency, and actuation functionality. In DEA systems, multi-stable biasing mechanisms have mainly been explored at the actuator level, where they can enlarge the range of motion and, in some cases, enable bistable actuation. However, most examples are limited to single-degree-of-freedom (DOF) actuator designs rather than full robotic systems. Consequently, the integration of multi-stability into DEA-based soft robotic manipulators remains underexplored. In this work, we extend this concept to a DEA-based soft manipulator, investigating how multi-stability can enhance system performance, such as robot range of motion. To this end, we propose and compare different modeling approaches to describe the bistable behavior of the system within a control-oriented framework (low DOF). Leveraging these models, we develop strategies for configuration control and tracking of slow trajectories. In parallel, we exploit the self-sensing capabilities of DEAs, from the single actuator level to the full robotic system level, to achieve proprioception and contact detection of the system. These control and self-sensing strategies are then combined to enable sensorless control of the DEA-based soft robot. Finally, we extend the model to three dimensions and propose initial design results for a 3D version of the prototype.

1.2.17 Dynamic modeling and validation of a dielectric elastomer-based tensegrity mobile robot

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(3) Department Of Mechanical Engineering, OTH Regensburg, Regensburg, Germany

Presentation given by Mr. Giovanni Soleti

Tensegrity-based mobile robots combine structural compliance, robustness, and adaptability, which makes them promising platforms for soft robotic systems. Integrating dielectric elastomer actuators (DEAs) into these architectures enables lightweight and efficient actuation while maintaining the inherent compliance of the structure. Nevertheless, control-oriented dynamic modeling of DEA-actuated tensegrity robots remains unexplored. This work presents a modeling framework for a DEA-driven mobile tensegrity robot capable of unidirectional locomotion by exploiting anisotropic friction generated by one-way wheels. The system is described using both continuous and hybrid formulations. The continuous model reproduces the overall dynamics, but relies on large backward friction coefficients to emulate anisotropic contact, leading to high numerical stiffness and poor computational efficiency. To address this issue, a hybrid dynamical model is developed, where unilateral friction effects are imposed through discrete transitions. Experimental validation under different operating conditions shows that the proposed models capture both the robot dynamics and its resonance behavior. The hybrid formulation provides accurate simulations with improved computational efficiency. Furthermore, the comparison between the two formulations indicates that the two models converge to the same response in the limit case of highly anisotropic friction.

1.2.18 Contactless particle manipulation on soft platforms driven by resonant dielectric elastomer actuators

Simon Holzer (1) (2), Markus Koenigsdorff (1) (2), Yoan Civet (1) (2), Yves Perriard (1) (2),

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Presentation given by Mr. Simon Holzer

While precise acoustic manipulation of cells has become an established tool in biological studies, conventional acoustofluidic platforms rely on rigid, opaque piezoelectric transducers. The integration of high-frequency acoustic generation within soft systems remains largely unexplored. This work presents a novel approach in acoustofluidics by using Dielectric Elastomer Actuators (DEAs) operating at resonance. We characterize the high-frequency electromechanical and acoustic responses of circular DEAs under both dry and wet conditions. Through acoustic spectral analysis, we investigate the DEA's resonance modes to efficiently generate acoustic standing wave modes within a liquid medium. As a proof-of-concept for contactless manipulation, the generated acoustic fields are utilized to position microparticles simulating cells into patterns and perform acoustic tweezing via targeted frequency sweeps toward the device center. This approach validates resonant DEAs as a fully integrated and scalable alternative to rigid piezoceramics, opening new possibilities in cell patterning and soft tissue engineering.

1.2.19 Modulable dielectric elastomer minimum energy structure (DEMES) for locomotion and grasping tasks

Mario De Lorenzo (1), E.-F. Markus Vorrath (1), Uwe Marschner (1), Andreas Richter (1),
(1) TU Dresden, Institute Of Semiconductors And Microsystems, Dresden,
Germany

Presentation given by Mr. Mario De Lorenzo

Dielectric Elastomer Actuators (DEAs) are a class of Electroactive Polymers (EAPs) that have become increasingly popular due to their large strain, rapid response times, and force output. Their inherent compliance makes them highly suitable for diverse soft robotic applications enabling biomimetic actuation. Combining a DEA with an anisotropic structure creates a Dielectric Elastomer Minimum Energy Structure (DEMES) capable of interacting with unstructured environments and generating large out-of-plane displacements. Despite the versatility of these soft actuators, DEMES are typically designed for single-purpose tasks requiring extensive time for the design and simulation of each specific robot. This work explores a modular approach using a soft DEMES with PMMA and rod struts as a bone structure to provide anisotropic bending. This configuration acts as a versatile motor unit adaptable to multiple applications. Specifically, locomotion and grasping tasks were demonstrated by 3D printing easily interchangeable support bases. Electromechanical network models, mathematical formulations, and Finite Element Analysis (FEA) in ABAQUS were used to characterize the system and predict its displacement and force output. The modular DEMES exhibited large displacements correlating strongly with theoretical models and generated sufficient mechanical force for effective grasping and unidirectional inchworm locomotion at speeds up to 32 cm/min.

1.2.20 Monolithic Dielectric Elastomer Films with Programmed Deformation and Multifunctionalities Enabled by Patterned Electrophoresis of Magnetic Additives

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(2) ZJU-UIUC Institute, Zhejiang University, Haining

Presentation given by Dr. Huifeng Dong

Dielectric elastomers (DEs) are promising artificial muscles for soft robotics and wearable devices due to their large deformation, fast response, high energy density, and light weight. However, conventional DE films exhibit limited deformation modes and lack multifunctionalities. Passive layers, rigid constraints, or multilayered electrode patterning have been used to extend their deformation but often reduce actuation performance and increase structural complexity. Here, we develop patterned electrophoresis of magnetic additives to program deformations in monolithic DE films, achieving bending, twisting, and complex three-dimensional morphing while maintaining high actuation performance. The additives also endow the DE films with multifunctionalities, including magnetic response and electromagnetic wave shielding. By coupling programmed deformations with these functionalities, we demonstrate intelligent soft devices with new functions and controllability such as electric-magnetic co-driven actuation arrays and deformable electromagnetic metasurfaces. This strategy achieves programmable deformations and multifunctionalities in single-layer DE films, opening new possibilities for advanced DE applications.

1.2.21 Transparent electrodes based on reduced graphene oxide for a dielectric elastomer actuator-driven tunable lens

Giacomo Sasso (1) (2), Alec Lamoreux (1), Majid Taghavi (1), Nicola Pugno (1) (3), James Busfield (1), Federico Carpi (2),

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(3) University Of Trento, Department Of Civil, Environmental And Mechanical Engineering, Trento, Italy

Presentation given by Dr. Giacomo Sasso

Dielectric elastomer actuators (DEAs) are widely recognized as a leading class of soft transducers due to their ability to deliver large, fast, and electrically driven deformations in thin elastomeric films. These characteristics make them particularly attractive for adaptive optical systems and multifunctional surfaces, where simultaneous mechanical actuation and light transmission are required. In this work, we investigate the use of reduced graphene oxide (rGO) as a semi-transparent compliant electrode material for DEAs. Thin rGO coatings were deposited via spray processing onto elastomeric membranes, enabling controlled tuning of surface density. The resulting electrodes were systematically evaluated in terms of morphology, optical transmittance, electrical sheet resistance, and electromechanical actuation performance. An increase in rGO surface density led to a reduction in transparency and an increase in conductivity, which directly impacted actuator performance. Devices operated under electric fields up to 50 V/ μm exhibited a substantial enhancement in areal strain, reaching values above 40% for higher electrode loadings. To highlight the application potential of the rGO-based electrodes, a novel tunable lens was developed. The device was made of a 12.5 mm-wide plano-convex PDMS lens coupled to a rGO-based transparent DEA, resulting in a compact form factor. By applying an electric field between 0 and 50 V/ μm , the lens enabled focal tuning ranging from 30 to 36 mm.

1.2.22 Closed loop control of dielectric elastomer generators via self-sensing feedback

Lennart Heib (1), Giacomo Moretti (2), Gianluca Rizzello (1),
(1) Saarland University, Systems Engineering, Saarbrücken, Germany
(2) University Of Trento, Dept. Of Industrial Engineering, Trento, Italy

Presentation given by Mr. Lennart Heib

Dielectric elastomer generators (DEGs) convert mechanical energy from cyclic deformations into electrical energy. Real-time implementation of harvesting cycles requires accurate information of the DEG capacitance, to synchronize charge and discharge events. Existing solutions either rely on a-priori knowledge of the deformation profile or employ dedicated mechanical sensors, both of which limit applicability and increase system complexity. This work presents a self-sensing based closed-loop control strategy for DEGs. By solely relying on voltage and current measurements, we estimate the DEG's capacitance in real time and use it to close the generation loop without dedicated sensors. Accurate capacitive self-sensing requires a large current signal, which is achieved by superimposing a high-frequency, low-amplitude voltage to the priming voltage. The resulting current, however, results in additional resistive losses that reduce the overall energy yield. Starting from established self-sensing algorithms, we explicitly investigate this fundamental trade-off between maximizing self-sensing accuracy and minimizing resistive losses. Then, we investigate new self-sensing algorithms tailored to generators, which allow further reduction of the energy losses. Using both high-fidelity simulations and experimental validation, we analyze how self-sensing parameters and real-time peak-detection strategies affect harvested energy across a wide range of conditions and excitation profiles.

1.2.23 Influence of printed stretchable electrodes on the electromechanical performance of dielectric elastomer transducers

Ozan Çabuk (1), Jürgen Maas (1),

(1) Mechatronic Systems Laboratory, Technische Universität Berlin, Berlin, Germany

Presentation given by Mr. Ozan Çabuk

The fabrication of compliant electrode layers is a key step in the manufacturing and performance optimization of dielectric elastomer transducers (DETs). This work investigates the printability and electromechanical influence of different stretchable electrode materials printed by contactless jetting. Four carbon-black-based silicone inks and one carbon-nanotube-based ink were adapted for printing and evaluated regarding printability, layer quality, electrical resistance, and their impact on DET performance. The electrodes were printed using a Verres MDS 3280 jetting system. Due to adverse rheological behavior and excessive electrical resistance, the carbon-nanotube-based ink and one of the carbon-black-based ink were excluded from further investigations. Three printable electrode materials were chosen to fabricate multilayer DET samples consisting of six elastomer films and five printed electrode layers. Two elastomer film thicknesses, 50 μm and 20 μm , were considered, resulting in 36 samples for electromechanical characterization. The investigated electrodes showed material-dependent differences in printability, layer thickness, resistance, capacitance, mechanical stiffening, dielectric strength, and actuation capacity. The contribution provides a detailed experimental overview of these electrode-related effects on the electromechanical behavior of DETs.

1.2.24 Cost- and process-efficient conductive composites as electrodes for dielectric elastomer devices and their electromechanical analysis

Junhao Ni (1) (2), Arjun Satheesh (3) (4), Yiming Ji (2), Carola Böhmer (1), Andreas Richter (2), Sven Wießner (3) (4), Gerald Gerlach (1), Markus Vorrath (2) (5),

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Presentation given by Mr. Junhao Ni

High-performance dielectric elastomer (DE) devices necessitate synergistic optimization of electrode conductivity and mechanical compliance. However, conventional studies often report material metrics in isolation and do not translate intrinsic electrode properties into deterministic, device-level electromechanical requirements for multilayer DE actuators (DEA). This gap leaves electrode selection largely empirical and can lead to suboptimal device performance. Here, we present a cost- and process-efficient conductive composite ink based on commercially available carbon nanotube (CNT) and polydimethylsiloxane (PDMS). We evaluate electrical resistivity, elastic properties, strain-dependent resistance, and printability-related viscosity of CNT-PDMS inks across 0.5 to 3 wt%. By coupling these material data with charging analysis and an electromechanical model for multilayer DEA, we establish a requirements-driven framework that maps ink properties directly to actuator performance and operating frequency. Our analysis reveals that, once the target frequency is satisfied, minimizing CNT filler content is essential to mitigate electrode-induced stiffening and maximize achievable actuation strain and motion performance. Guided by this criterion, multilayer DEAs are fabricated and experimentally validated. The measured voltage-stretch response agrees well with theoretical predictions, demonstrating the effectiveness of the proposed ink-selection strategy for practical DE devices.

1.2.25 Deconvoluting pdms network architecture via tga-ms evolved gas analysis

Pavle Ramah (1), Liyun Yu (1), Frederikke Bahrt Madsen (1), Anne Ladegaard Skov (1),

(1) Technical University Of Denmark

Presentation given by Mr. Pavle Ramah

Decoupling complex network architectures in crosslinked polydimethylsiloxane (PDMS) elastomers remains a major characterization challenge. This study evaluates thermal degradation behaviour as a tool to differentiate and map structurally distinct silicone network topologies. Five PDMS networks-including traditional, commercial copolymer vinyl-hydride systems, but also networks containing suspected concatenated ring structures-were synthesized. Their topologies were investigated through thermogravimetric analysis coupled with mass spectrometry (TGA/MS). The resulting analytical profile revealed clear structural dependencies, based on the prevalence of characteristic to PDMS molecular or radical degradation pathways. Differential scanning calorimetry (DSC), Fourier-transform infrared spectroscopy (FTIR) of degradation residues, and visual inspection supplemented these measurements to further contrast the networks. Combining evolved gas analysis via TGA/MS with complementary thermal and spectroscopic techniques provides a powerful method to deconvolute intricate elastomer topologies.

Session 1.3: short talks with focus on Electrohydrodynamics & electrostatic actuation

1.3.1 Thermal analysis of electrostatic bellow muscle for space applications

Ion-Dan Sirbu (1) (2), Ubaldo Tosi (1), Arianna Mazzotta (3), Daniele Bertoluzzi (4) (5), Virgilio Mattoli (3), Giacomo Moretti (4), Marco Fontana (1) (2),

Presentation given by Mr. Ubaldo Tosi

Heat dissipation and high-temperature operation are critical challenges for actuators in space. Unlike conventional electromagnetic actuators, electrostatic alternatives ideally dissipate no static power. However, in practice these actuators do produce heat and it is necessary to prove their compatibility with space applications and their advantage over conventional actuators. In this work, we present a thermal analysis of an Electrostatic Bellow Muscle, an electrostatic actuator that deforms out-of-plane, composed of thin layers of polyimide films, electrodes, and rigid structural elements. We investigate the thermal response during operation in vacuum and the dielectric breakdown strength as a function of temperature in a thermal chamber. Thermal response tests are conducted by non-contact measurement of temperature, evaluating the temperature increase when the actuator works against a 1 N load at DC and 1, 10, 50, and 100 Hz. Dielectric strength is measured by applying a voltage ramp to a PI film sandwiched between two electrodes while inside an oven at 25, 60, 100, and 140 degrees Celsius. The results show that temperature increase is negligible during DC and 1 Hz operation, and it is at the most 7.5 degrees at 100 Hz, while PI dielectric strength is approximately constant up to 100 degrees, but it drops sharply at 140 degrees. These results provide a first positive indication of the potential deployment of these novel actuators in space mechatronic systems.

1.3.2 Increasing the power density of electrohydrodynamic pumps by mapping the fluid landscape

Yichi Luo (1), Herbert Shea (1),
(1) EPFL, LMTS, Neuchatel, Switzerland
Presentation given by Mr. Yichi Luo

Electrohydrodynamic (EHD) pumps noiselessly generate fluid flow in dielectric liquids using high electric fields to create, accelerate, and neutralize ions. Such pumps are attractive for wearable actuators, soft robotics, and active thermal management, but their performance remains constrained by limited understanding of how fluid properties influence EHD pumping behavior. We present a systematic comparison of EHD pumping across 11 fluids, including 8 previously unidentified candidates, spanning viscosities from 0.5 to 19 mPa·s and dielectric constants from 2.3 to 64. Tests with more than 30 flexible fiber pumps show that low-viscosity and high-dielectric-constant liquids considerably enhance pumping performance. For 1.2 mm inner-diameter fiber pumps, replacing the commonly used Novec 7100 with propylene carbonate increased fluidic power density by fivefold, reaching 347 W/kg (empty pump mass) at 4.4 kV. The resulting performance enables compact fiber pumps to deliver meaningful hydraulic power, as demonstrated by a hydraulic piston driven by an 18 cm fiber pump. Novec 7100 delivered 12.6 mW when lifting a 1.25 kg load and produced no measurable displacement at 3.75 kg, while propylene carbonate delivered 64.8 mW when lifting a 3.75 kg load.

1.3.3 Thermally Drawn Electrohydrodynamic Fiber Pumps

Lucas Jourdan (1) (2), Herbert Shea (1), Fabien Sorin (2),
(1) LMTS, EPFL, Neuchâtel, Switzerland
(2) FIMAP, EPFL, Lausanne, Switzerland

Presentation given by Mr. Lucas Jourdan

We present a scalable fabrication method based on thermal drawing with co-feeding of metal wires to fabricate electrohydrodynamic (EHD) fiber pumps. Fiber pumps rely on the EHD principle to generate fluid flow with no moving mechanical parts, hence without noise or vibration. The pump consists of a hollow tube and two helically wound metal wire electrodes. When a voltage of a few kV

is applied, the dielectric fluid is ionized and the ions move along electric field lines between electrodes, creating a macroscopic net flow. Recent work from EPFL-LMTS showed over 800kPa/m of pump length, with flow rates over 100mL/min for a typical pitch of 1.6mm (Luo et al, Science Advances, 2026). However, the winding process used to make those fibers (Smith et al, Science, 2023) imposes design constraints and limited length. We adapted thermal drawing, a scalable process used to produce kilometers of optical fibers, to polymers to fabricate EHD fiber pumps. A twisting system integrated into the drawing tower was developed to form the double-helical structure during fabrication. This process decouples the outer diameter of the EHD fiber pump from the pitch of the helical electrodes. We obtained pitches of 4.2, 2.5, and 1.5mm while maintaining a constant outer fiber diameter of 2mm and reaching a fiber length of 8m. Further improvements in double-helix formation at different twisting speeds during thermal drawing will enable the production of meters of EHD fiber pumps opening new opportunities.

1.3.4 Modelling and characterisation of the unzipping dynamics of dielectric fluid actuators

Marco Riva (1), Rajat Chaudhary (1), Sandra Dirè (1), Luca Fambri (1), Marco Fontana (2), Giacomo Moretti (1),

Presentation given by Dr. Rajat Chaudhary

Dielectric Fluid Actuators (DFAs) are a class of variable capacitors consisting of electroactive polymer films and insulating liquid. Upon applying an electric field, DFAs generate mechanical stroke due to electrostatic forces within a flexible multilayer structure. Different dielectric time constants of the polymer and liquid layers, however, lead to charge accumulation at their interface, causing a gradual reduction in Maxwell stress and resulting in stroke relaxation even under constant voltage. We present a continuum framework that extends traditional electrostatic force models from fixed parallel-plate capacitors to full actuator-level behavior. The approach couples distributed electrical dynamics with a lumped mechanical model of the DFA. The framework is validated experimentally using two designs: a multi-layer open V-shaped pouch DFA and a Hydraulically Amplified Self-healing Electrostatic Actuator (HASEL). Despite simplified assumptions such as constant material resistivities and lumped mechanics, the model captures key

trends in unzipping dynamics influenced by geometry and operating conditions, including applied voltage, external loads, and film angle. Overall, this framework establishes a foundation for dynamic electromechanical continuum modeling of DFAs.

1.3.5 A quasi-zero stiffness biasing mechanism for electrostatic bellow muscles

Hadi Taghvaei (1), Pasquale Gallo (1), Marco Riva (1), Matteo Benedetti (1), Marco Fontana (2), Giacomo Moretti (1),

Presentation given by Mr. Hadi Taghvaei

Electrostatic bellow muscles (EBMs) are a class of modular dielectric fluid actuators able to produce large contractions in response to a driving voltage. To produce a stroke, EBMs need to be pre-loaded by an external force, which produces a deformation that is then counteracted by the electrostatic forces. This study presents a quasi-zero stiffness (QZS) biasing mechanism for the EBM, which provides the EBM with a pre-load, hence decoupling its maximum stroke from external forces, and preserving the device from overstretching. The QZS mechanism relies on a set of bending beams arranged around the EBM. Upon zipping, the EBM contraction leads to compression buckling of the beams, which respond with a constant force that allows reopening the device after each actuation cycle without providing additional stiffness. In the presence of large applied loads, the beams are subject to tensile stresses that limit their own extension, protecting the EBM from mechanical failure. We developed an experimental prototype of EBM with QZS biasing system, in which the weight of the biasing mechanism (beams + structural elements) represents $\sim 10\%$ the weight of the actuator. Tests demonstrate that the EBM-QZS system can provide a stroke that is nearly constant in a range of low forces, with a frequency response which is unaffected by the presence of the beams. The EBM device can preserve its structural integrity even in the presence of external forces 40 times higher than the system own weight.

1.3.6 Flow visualization of electrohydrodynamic pumps

Ayana Mizutani (1), Herbert Shea (1),
(1) EPFL, LMTS, Neuchatel, Switzerland

Presentation given by Ms. Ayana Mizutani

Electrohydrodynamic (EHD) pumps generate flow using electrostatic forces in dielectric liquids, enabling fluid transport without moving parts. The channel itself acts as the pump, eliminating external components and enabling lightweight, compact, and silent devices for applications such as soft robotic actuation and electronic cooling. However, despite their ability to generate high flow rates and pressures, EHD pumps suffer from low energy efficiency, and the underlying loss mechanisms remain poorly understood. In this study, we experimentally visualize and quantify the internal flow structures of planar EHD pumps with asymmetrically spaced interdigitated electrode pairs using particle imaging techniques. We identify a flow structure consisting of localized acceleration near the closely spaced electrode pair, deceleration near the widely spaced electrode pair, and recirculating flow regions above the acceleration zone. This structure persists across variations in electrode and channel geometry. By introducing quantitative metrics—including recirculation area, vorticity, circulation strength, and reverse-flow fraction—we show that these structures redistribute momentum away from the net pumping direction and contribute to energy loss. Our study provides the first detailed experimental characterization of internal flow structures in planar EHD pumps, coupled with quantitative pump performance measurements, and highlights their role in limiting efficiency.

1.3.7 Controllable surgical device with electrohydrodynamic pumping actuation

Jacob Rogatinsky (1), Herbert Shea (1),
(1) EPFL, LMTS, Neuchâtel, Switzerland

Presentation given by Dr. Jacob Rogatinsky

Electrohydrodynamics (EHD) describes the movement of an insulating fluid influenced by an electric field due to ionization in regions of high field strength. These charged particles are accelerated by the electric field, transferring

momentum to neutral molecules and generating a bulk flow. Recent works have exploited the EHD phenomenon to pump liquids in fluidic tubing using helically-embedded electrodes. These so-called "fiber pumps" range from several millimeters down to hundreds of microns in diameter and can output hundreds of milliwatts of fluidic power per meter of length. This work introduces a fluidically-driven surgical guide wire actuated by an EHD fiber pump, leveraging fiber pump scalability for integration within the size-constrained device. The 350-micron diameter fiber pump embedded inside the guide wire allows the device's overall diameter to remain under a millimeter. Whereas other surgical robots require bulky external control systems, the guide wire's internalized EHD fiber pump limits the control apparatus to a handheld 1W electrical power supply. The device bends in one direction using a pressurizable end-effector at its distal end, potentially enabling navigation to small peripheral blood vessels in regions like the brain and heart.

1.3.8 Laser induced graphene electrodes for electrohydraulic actuators

Robin Milward Cooney (1), Jan-Niklas Rode (1), Masoumeh Hesam (1), Iain Anderson (1),
(1) Biomimetics Lab, Auckland Bioengineering Institute, Auckland, New Zealand

Presentation given by Mr. Robin Milward Cooney

Electrohydraulic actuators (EHAs) are a promising type of artificial muscle for soft robotic systems due to their silent operation, high power density, and muscle-like deformation. However, compliant electrode fabrication remains a key limitation for repeatable and scalable EHA production. Many existing EHAs rely on manually applied carbon-based coatings or conductive inks, which can introduce variability, increase fabrication complexity, and reduce long-term robustness. This work presents electrohydraulic actuators with laser-induced graphene electrodes patterned directly onto thin-film polyimide substrates. The approach combines laser-scribed conductive electrodes with thermoplastic elastomer seams deposited using a commercial three-dimensional printer to form sealed Hydraulically Amplified Self-Healing Electrostatic (HASEL) actuators. This enables repeatable fabrication without manually applied electrodes while maintaining mechanical compliance and electrical robustness. X-ray computed

tomography was used to characterise the effect of laser processing on electrode morphology and dielectric thickness. The results demonstrate that laser-induced graphene electrodes on polyimide provide a scalable and repeatable fabrication route for electrohydraulic actuators, while also reducing dielectric thickness. This fabrication approach offers a pathway toward more robust and manufacturable soft electrostatic actuators for future robotic and underwater applications.

1.3.9 A self-powered soft triboelectric-electrohydrodynamic pump

Steven Zhang (1) (2), Fangming Li (3), Shouwen Sun (3), Xingfu Wan (3), Minzheng Sun (3), Minyi Xu (3) (4),

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(2) School Of Materials Science And Engineering, Georgia Institute Of Technology, Atlanta, USA

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(4) Guangzhou Institute Of Blue Energy, Knowledge City, Huangpu District, Guangzhou, China

Presentation given by Dr. Steven Zhang

Soft pumps have the potential to transform industries including soft robotics, wearable devices, microfluidics and biomedical devices, but their efficiency and power supply limitations hinder prolonged operation. Here, we report a self-powered triboelectric-electrohydrodynamic pump, which combines a soft electrohydrodynamic pump driven by an electrostatic generator, specifically a triboelectric nanogenerator. The triboelectric nanogenerator collects ambient energy and converts it into high-voltage power source, allowing it to self-power an electrohydrodynamic pump and thus eliminating the need for external power supply. Using power management circuit, geometric shape optimization, and stacking methods, we achieve a maximum pressure of 4.49 kPa and a maximum flow rate of 502 mL/min. We demonstrate the pump's versatility in applications such as self-powered soft actuators, oil pumping in microfluidics, and oil purification. The triboelectric-electrohydrodynamic pump holds promising applications, and offers new insights for the development of fully self-powered systems.

1.3.10 StaticDrive: a solid-state mechano-electro-mechanic power transmission

Jian Wen (1), Yuejun Xu (1), Ali Sadeghi (2), Majid Taghavi (1) (3),
(1) Imperial College London
(2) University Of Twente
(3) Queen Mary University Of London

Presentation given by Mr. Yuejun Xu

Triboelectric nanogenerators offer promising energy-harvesting capabilities for powering sensors and electronics but face challenges in powering actuation as the generated power relies on high-frequency mechanical movement with high impedance, and low power output. We introduce StaticDrive, a mechano-electro-mechanic power transmission system that directly powers electrostatic actuators using triboelectric energy. Its high-performance flexible magnetic structure converts arbitrary sliding motion-driven by a joystick- into enhanced electrical output, achieving an open circuit voltage greater than 3.5 kV and a short-circuit current exceeding 90 μ A. When directly connected to dielectrophoretically amplified Liquid Zipping actuators, the generated energy is sufficient to drive actuation. We demonstrate its potential applications in distant manipulation such as precise catheter tip deflection and gripping. StaticDrive provides a compact, adaptable, lightweight and multifunctional solution for mechanical power transmission for low-force manipulation in hard-to-reach environments.

1.3.11 A flexible high-fill-factor haptic interface integrating electrostatic valves

Xintong Tong (1), Herbert Shea (1),
(1) EPFL, LMTS, Neuchâtel, Switzerland

Presentation given by Ms. Xintong Tong

Valves play an important role in pneumatic and hydraulic haptic interfaces, yet thin, compliant, and miniaturized valve solutions for such systems do not currently exist. We report a compliant haptic interface comprising a 2×3 array of six inflatable, bubble-shaped bumps for fingertip exploration. A single air supply actuates all six bubbles through one tube, while integrated electrostatic valves

(ESValves) enable independent control by latching each bump in either the up or down state. Applying a high voltage to the electrodes of a selected bubble generates an electrostatic force that closes the air channel at its entrance, allowing precise control over the inflation and deflation of individual bubbles. This architecture significantly simplifies pneumatic routing and system integration. The device is ultra-thin (390 μm), resulting in a lightweight and flexible valve system suitable for conformal and scalable integration. Locating the valve directly beneath each bubble enables a high fill factor of 60%, $3\times$ higher than previous HAXELs (Hydraulically Amplified Taxels) from our lab, and efficient use of space, while electrostatic actuation provides fast valve closing through a zipping mechanism with low power consumption.

1.3.12 Design, characterisation and control of polymeric electrostatic energy harvesters

Leonardo Zambonato (1), Marco Riva (1), Alireza Jalalian (1), Jo Wilson (3), Andy Hall (3), Gianluca Rizzello (4), Marco Fontana (2), Giacomo Moretti (1),
(1) University Of Trento
(2) University Sant'Anna Pisa
(3) 4C Engineering
(4) Saarland University

Presentation given by Mr. Marco Riva

Electrostatic energy harvesters (EHs) are a promising technology for converting energy from low-frequency and irregular mechanical sources, such as vibrations, human motion, and sea waves, into electrical power. These devices can be implemented in various forms, including dielectric elastomers and dielectric fluid generators (DFGs), enabling adaptation across different scales, operating frequencies, and applications. However, their energy conversion performance strongly depends on both device architecture and control strategy, as geometry, materials, and driving policies directly affect achievable cycles and associated losses. This presentation summarizes our latest research on EHs, addressing both design and control aspects. First, we investigate DFGs, composed of multilayer dielectric polymer-liquid structures. We introduce a custom testbench and a dedicated manufacturing procedure, and present experimental characterization results for DFG units, where capacitance is modulated through the injection and removal of dielectric liquid within a polymeric pouch. We then analyze control

trade-offs for electrostatic generators, with relevance to EHs more broadly, under non-periodic excitations. In particular, we compare conventional peak-triggered operation with smoother current-driven strategies based on continuously varying voltages, evaluating them in terms of feasibility, robustness to stochastic inputs, and overall energy conversion efficiency.

1.3.13 Design and Simulation of a Bio-Inspired Chemotactically Guided Micro-Crawler

Stefan Angerbauer (1), Mario Kunzemann (2), Werner Haselmayr (1),
(1) Johannes Kepler University, Institute For Communications Engineering And RF Systems, Linz, Austria
(2) Johannes Kepler University, Institute for Technical Mechanics, Linz, Austria

Presentation given by Dr. Stefan Angerbauer

Chemotactic signals, i.e., molecular signals that guide the movement of cells through their environment, play an essential role throughout biology. They enable colony formation in bacteria and allow insects such as moths to locate their mating partners. Most importantly, the human immune system strongly relies on chemotactic signaling to coordinate appropriate immune responses. In this paper, we design a micro-robot inspired by the way T cells, a specific type of immune cell, crawl toward a molecular source. We model the entire bio-mechatronic system, including molecular emission by the source, membrane-receptor-based conversion of extracellular signals into intracellular signals, intracellular signaling pathways, and finally the coupling between intracellular signaling and the mechanical subsystem, specifically actin-myosin dynamics and surface adhesion dynamics. In simulations, we identify a suitable parameter set and demonstrate that this bio-inspired synthetic system produces sustained crawling toward the molecular source. The proposed model clearly illustrates the influence of different biophysical effects and can be used to guide the future experimental design of in vivo bio-robots serving, for example, as drug carriers or synthetic immune cells.

1.3.14 Active aeroelastic membranes for bat-inspired flight

Stefania Konstantinidi (1) (2), Yufeng (Kevin) Chen (1), Raphael Zufferey (2),

(1) Soft And Micro Robotics Laboratory, Massachusetts Institute Of Technology, Cambridge, United States Of America

(2) Aerial And Aquatic Robotics And Applications Lab, Massachusetts Institute Of Technology, Cambridge, United States Of America

Presentation given by Dr. Stefania Konstantinidi

Bat wings represent one of nature's most refined aeroelastic structures. Unlike insect and bird wings, or current micro-air vehicles that rely on articulated rigid skeletons and passive membranes, bat flight is powered by soft, active and anisotropic membranes with embedded plagiopatagiales muscles. These muscles are actuated throughout the flap cycle to control the camber of the wing by varying the membrane stiffness, thus actively resisting aerodynamic billowing and modulating the lift. This work introduces an active, bio-inspired wing membrane using dielectric elastomer actuators (DEAs). By integrating DEAs into a biomimetic anisotropic composite wing membrane, we mimic the biological elastin-collagen-muscle network of bat wings. The artificial plagiopatagiales allow the membrane to actively modulate its stiffness and shape under aerodynamic loads. Current prototypes demonstrate controlled camber modulation during gliding, with progression toward powered flapping flight. By shifting actuation from rigid joints directly into the aeroelastic surface, this approach bridges soft materials and aerodynamics, unlocking adaptive flight capabilities for next-generation bio-inspired aerial vehicles.

1.3.15 A soft robotic fish with a dielectric elastomer actuator body and negative stiffness spine

Markus Koenigsdorff (1) (2), Simon Holzer (1) (2), Xiaohan Han (1) (2), Marc-Olivier Arrigo (1) (2), Yoan Civet (1) (2), Yves Perriard (1) (2),

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

(2) Center For Artificial Muscles, Ecole Polytechnique Fédérale De Lausanne, Neuchâtel, Switzerland

Presentation given by Dr. Markus Koenigsdorff

Soft robotics provides a promising approach for underwater exploration by enabling devices that replicate the fluid movements of aquatic life. Dielectric Elastomer Actuators (DEAs) are well-suited for this application due to their high energy density, fast strain rate and silent operation. However, the integration of these typically planar actuators into complex, three dimensional shapes, e.g., for biomimetic robots, remains challenging. This work proposes a robotic fish design that utilizes fiber-reinforced uniaxial DEAs coupled with a pre-compressed buckling beam. The fiber reinforcement allows actuators to be fabricated with curved cross-sections, enabling their direct integration as the robot's outer skin. Additionally, this reinforcement leads to higher electroactive forces compared to isotropic DEAs. To counteract the additional stiffness from the fibers, a negative-stiffness buckling beam is used to mimic the fish's flexible spine. This design results in a highly compliant robot capable of large-amplitude fin displacements, demonstrating a practical pathway for creating three-dimensional soft robotic fishes.

1.3.16 Giant-stroke artificial muscles from fishing line and sewing thread for diverse applications

Shaoli Fang (1), Mengmeng Zhang (1),
(1) The University Of Texas At Dallas, The Alan G. MacDiarmid NanoTech
Institute, Richardson, USA

Presentation given by Prof. Shaoli Fang

High cost and performance limitations like low cycle life and hysteresis have restricted practical uses of large-stroke artificial muscles. We demonstrate that inexpensive, high-strength polymer fibers, such as commercial fishing line and sewing thread, can be transformed via extreme twist-insertion and coiling into fast, scalable, long-life tensile and torsional muscles. These actuators contract by 49 percent, lift loads 100 times heavier than human muscle and actuate at up to 7.5 cycles per second. By harnessing twist transfer mechanics, we developed thermal and electrochemical muscles delivering 98 times the power output of skeletal muscle. For example, a 0.6-gram muscle from 800 micrometers polyethylene line can reversibly lift a 7.2-kilogram weight by 2.2 centimeters twice per second via a 70 degrees Celsius change. We also introduce a mandrel-

free fabrication method overcoming traditional wrapping limits, allowing a spring index over 50 and a 97 percent contractile stroke. Varying plying twist enables transitions between homochiral and heterochiral states. Versatility is shown through energy-harvesting carbon nanotube yarns, self-powered strain sensors, actuating window shutters, and smart jackets that adjust porosity for comfort.

1.3.17 Self-contained reversible pneumatic phase change actuation for soft robotics

Rayan Basodan (1) (2), Byoungyoul Park (2), Hyun-Joong Chung (1),
(1) University Of Alberta, Edmonton, Canada
(2) Canadian National Research Council, Edmonton, Canada

Presentation given by Mr. Rayan Basodan

Pneumatic soft robots offer high force-to-weight ratios, rapid actuation, and high compliance. However, reliance on tethered external infrastructure limits their applications. Phase change liquids have recently been utilized to enable temperature stimulated self-contained pneumatic actuators that circumvent the tethering requirements; however, challenges remain. Difficulties due to managing volatile liquids limit the fabrication methods feasible for making the pneumatic phase change soft robots. Additionally, the permeability of the volatile liquids in the soft materials often used in robotics significantly limits actuation reversibility and longevity. We have developed a facile fabrication method for containing the volatile liquid Novec7000 (34 °C boiling point) in micron thin alginate capsules which enable pneumatic phase change soft robots. These capsules remain intact during extended storage (> 7 months) and can be activated on-demand either mechanically (with 2 to 6 newtons of compressive force) or thermally (above the volatile liquid's boiling point). This approach prevents the loss of volatile liquids for pneumatic phase-change soft robots until actuation is desired. We also developed a composite soft robotic material system that prevents the loss of Novec7000, which allows for reversible actuation. Further incorporation of flexible conductive pathways and heating elements yields self-contained pneumatic phase change soft robots capable of reversible actuation.

1.3.18 Mechanics-informed X-Crossing SMA textile actuators for high-performance wearable assistance

Huapeng Zhang (1), Herbert Shea (1),
(1) Soft Transducers Lab (LMTS), EPFL, Neuchatel, Switzerland

Presentation given by Mr. Huapeng Zhang

We present a fabric actuator based on shape memory alloy (SMA) fibers arranged in a periodic X-Crossing geometry, in which fiber crossings are aligned with the actuation axis to enable constructive force build-up. This actuator architecture overcomes limitations of knitted and knotted SMA fabric architectures, where nonparallel crossings lead to partial force cancellation. The X-Crossing SMA actuator achieves up to 55% contraction strain and 160% stretchability, with a 4.5 g actuator capable of lifting 1 kg. To guide design and control, we developed a variable-stiffness mechanics model that captures stress- and temperature-dependent phase transitions and spatial stiffness gradients in SMA fibers, predicting both material-level stress-strain behavior and device-level force-contraction relationships. The model informs key actuation mechanisms, including the peak in force-contraction curves and a theoretical upper bound of contraction strain, and provides quantitative insights into geometric scaling for performance optimization. The X-Crossing architecture further benefits from enhanced stretchability and frictional self-locking at fiber crossings, improving deformation range and force transmission. We demonstrate wearable applications including lifting assistance with model-informed control and on-body compression. This work features a mechanics-informed design and scalable architecture for high-performance textile actuators in wearable robotics.

1.3.19 Bioinspired phase transition actuators for unthethered wearables

Ingrid M. Graz (1) (2), Rafal Ziembicki (1), Mathias Wendner (1),
(1) School Of Education, Johannes Kepler University Linz, Austria
(2) Institute For Biophysics, Johannes Kepler University Linz, Austria

Presentation given by Dr. Ingrid M. Graz

Soft actuators offer a plethora of advantages, including virtually unlimited degrees of freedom, lightweight and compliant structures, adaptability to complex

environments, and seamless integration into textiles and wearable systems. Driven by mechanisms such as hydraulics, pneumatics, or electrostatic forces, they enable large deformations, high flexibility, and biomimetic motion, making them attractive for wearable assistive and rehabilitation devices. However, many existing soft actuation systems require bulky and heavy peripheral hardware, thereby limiting wearer mobility. Inspired by the rapid volumetric expansion mechanism of the puffer fish, we present bioinspired soft actuators based on liquid-to-gas phase transitions, enabling untethered wearable devices. Powered by conventional batteries, we demonstrate the actuators in contractile textile elements, a scarf that unfolds around the wearer's neck, and a sleeve prototype that translates the wearer's pulse rate into motion and visual feedback. The actuators are characterized using various working liquids and achieve forces of up to 40 N with a compact $3 \times 3 \times 0.5 \text{ cm}^3$ element operating at 36 W. Temperature measurements confirm that actuator heat is effectively shielded from the wearer, ensuring safe operation. Bioinspired phase-transition-based actuation therefore provides a promising pathway toward untethered wearable assistive and rehabilitation systems.

1.3.20 Asymmetric loading effects in electro-ribbon zipping actuators

Siu-Teing Ko (1) (2), Visva Moorthy (1), Lewis Hallums (1) (2), Majid Taghavi (2), Dario Farina (1),

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

(2) Queen Mary University Of London, School Of Engineering And Materials Science, London, UK

Presentation given by Ms. Siu-Teing Ko

The compliance of electro-ribbon zipping actuators makes them promising for applications where adaptability is critical, such as wearable robotics. Their relative force and stroke capacity are constrained by the mechanical properties of the ribbon, including the conductive and insulating layers. However, these metrics are typically evaluated under ideal conditions, mainly symmetrically loaded in isometric and isotonic test configurations, which do not accurately reflect real-world scenarios. In practical wearable applications, actuator geometry is subject to continuous deformation, and load positions can shift dynamically due to user movement and external perturbances. These realistic scenarios introduce

asymmetric load conditions that may significantly alter actuator performance. This work investigates the effect of asymmetric loading on Electro-ribbon actuators, studying how variations in load position influence maximum force capacity, actuation velocity, and stroke length. This analysis will inform the design of these actuators to optimise positioning, load distribution, and overall performance in real-world applications.

1.3.21 A compact phase-change soft actuator

Arianna Mazzotta (1), Herbert Shea (1),
(1) EPFL, Soft Transducers Lab (LMTS), Neuchâtel, Switzerland

Presentation given by Dr. Arianna Mazzotta

This work presents a compact and low-voltage McKibben-type soft actuator powered by on-demand liquid vaporization, generating its driving pressure internally. The actuator consists of a silicone cylindrical chamber filled with a low-boiling liquid and an integrated heater, enclosed in a braided mesh. Upon heating, the liquid vaporizes and pressurizes the chamber. The braided mesh converts the radial expansion into axial contraction. We investigate the factors governing the activation speed of this thermally driven mechanism. A simplified thermal model with power-dependent effective thermal mass is developed and validated experimentally, showing how the activation time depends on input power and on the choice of working liquid. On actuators of 3 cm length and 1.5 cm diameter, 25% axial contraction at 80 kPa is reached in 3 s at 15 V (36 W), in agreement with analytical McKibben predictions. The working liquid plays a critical role: HFE-7000 (boiling point 34°C) reaches the same pressure around 2.5x faster than Novec-7100 (boiling point 61°C), while keeping the liquid temperature below 45°C. To address the slow cooling rate, a liquid recirculation system with twelve 1-mm channels embedded in the chamber walls is being integrated in the actuator design.

1.3.22 Soft Capacitive Pressure Microsensor using Van der Waals sealing of Nanoimprinted Dielectrics

Rishabh Bhooshan Mishra (1) (2), Chenxiang Zhang (3), Juergen Brugger (3),
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- (2) Scuola Superiore Sant'Anna (SSSA), The BioRobotics Institute, Pontedera, Italy
- (3) École Polytechnique Fédérale De Lausanne (EPFL), Microsystems Laboratory, Lausanne, Switzerland

Presentation given by Mr. Rishabh Bhooshan Mishra

Nanoimprinting is considered a versatile, cost-effective technique for high-resolution, high throughput patterning. This study presents a method to fabricate capacitive pressure microsensors using nanoimprinting with soft elastomeric stamp in four main steps. First, a Si-mould is created via photolithography, forming 7 μm diameter circular wells over 0.5*0.5 sqmm area (38.5% filling factor), followed by 0.5 μm reactive ion etching. Second, an elastomeric stamp is prepared by spinning an elastomer on the mould (previa application of an anti-sticking layer) followed by vacuum desiccation to ensure micropatterns filling; after thermal polymerisation the stamp is peeled off. Third, electrodes are deposited on boro-float glass using a shadow mask, followed by SU-8 spinning and soft baking. The elastomeric stamp is used to imprint the SU-8, replicating the mould patterns. Finally, imprinted circular wells are sealed by Van der Waals coupling with a freestanding metalized PMMA nanomembrane to obtain 0.5 μm thin air-pockets. These pockets deform under pressure, causing measurable capacitance variation. Sensor performance, gas permeability and biocompatible encapsulation are extensively studied. Future work will focus on scaling nanoimprinting on large area flexible substrate for soft robotic tactile skin capable of handling delicate objects. The work is partially supported by EU EIC-funded IV-Lab project under the Horizon Europe programme (Grant Agreement No.: 101115545).

1.3.23 A modeling framework to evaluate electrohydrodynamic pumps efficiency

Cesare Cariddi

Robophysics Laboratory, Politecnico Di Bari, Bari, Italy

Soft EHD (electrohydrodynamic) pumps enable silent, power dense, and highly integrated fluidic actuators. Recent results on EHD fiber pumps with 1.2 mm inner

diameter reported output pressures close to 10 bar per meter length, and power density close to 200 W/kg. Despite their integration advantages and high power density, EHD pumps are all severely limited by the low electro-fluidic efficiency (5%) hindering untethered robotic applications. This study uses an analytical modeling approach to investigate energy loss mechanisms within EHD pumps to identify key parameters affecting overall efficiency. We broke down the electro-fluidic transducer into two major parts: the first one connecting voltage and electrical current to the motion of charged ions, and the second one describing how force and velocity of the moving ions result in flow rate and pressure of the bulk liquid. We used a highly simplified fluid dynamics model to describe ions to bulk liquid energy transfer. Preliminary results from our model show that: (1) reflow is highly likely to occur and governed by channel geometry, liquid viscosity and pressure gradient; (2) viscous losses near channel walls can easily account for > 90% of total energy loss, making it the major suspect for the low efficiency of EHD pumps. Once fully validated experimentally, this modeling framework will shed light on the electro-fluidic power transfer inside EHD pumps and provide design rules for higher efficiency pumps.

1.3.24 Experimental evaluation of working fluids for soft robotic phase change actuation

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Presentation given by Mr. Mathias Wendner

Soft robotics relies on compliant actuators for adaptive motion. While pneumatic systems are widely used, they often require bulky external hardware that limits portability and autonomy. Liquid-gas phase change actuators (PCAs), which use resistive heating of low-boiling-point fluids by means of resistor heating, offer a compact and untethered alternative for soft robotic and wearable applications. In this work, we investigate the influence of different working fluids on PCA performance and efficiency. Using actuators of different sizes, we evaluate how fluid properties affect key metrics including response time, force output, thermal behavior, efficiency, and long-term stability. Results reveal fluid-dependent trade-

offs for application-specific PCA design. Fluids with slower but more stable actuation are suitable for sustained biomimetic motion, whereas faster-response fluids enable compact and dynamic systems. Based on these findings, we demonstrate three application-specific systems: a soft robotic finger using isopropanol for stable cyclic actuation, an untethered McKibben actuator using ethanol for balanced performance, and a water-driven gripper for efficient high-force actuation. Overall, this work highlights fluid selection as a key parameter for tailoring PCA performance for soft robotic and wearable technologies.

Wednesday, 3 June 2026

Session 2.1

2.1.1 Soft neural electrodes: expanding possibilities in neuroprosthetics and neural research

Stéphanie Lacour
EPFL, Switzerland

Soft microfabricated electrodes are unlocking new possibilities in neural engineering by providing adaptable, biocompatible interfaces that seamlessly integrate with biological tissues. This talk explores recent advancements in these electrodes, focusing on two key applications: auditory prostheses and brain organoid research. In auditory systems, soft, multichannel implants are especially suited for conforming to the complex, curved surface of the cochlear nucleus, enabling precise stimulation for patients who are not candidates for traditional cochlear implants. In brain organoid research, innovative electrode designs such as stretchable MEAs and the self-actuating "e- Flower" electrode provide high-resolution recordings of neural activity, even under mechanical strain. These applications highlight the transformative potential of soft electrodes to bridge the gap between engineered devices and complex neural systems, advancing both clinical therapies and fundamental neuroscience.

2.1.2 Material-driven Musculoskeletal Regeneration

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Musculoskeletal disorders remain one of the leading causes of disability worldwide, while current clinical treatments often fail to restore fully functional tissue. Material-driven regenerative strategies offer the opportunity to actively guide endogenous healing processes by integrating biomaterials science, mechanobiology, and immunomodulation. Our research focuses on understanding

how physical and biological cues interact during successful regeneration of mesenchymal tissues such as bones, cartilage, or muscles following injury. In this context, biomaterials are no longer considered passive scaffolds but dynamic instructive systems capable of directing cell fate, vascularization, and tissue organization. Combined with bioreactor systems and pre-clinical model systems, these approaches enable the investigation of how immune responses and mechanical loading can help to steer tissue repair. Recent developments in hydrogel systems, bio fabrication, and mechanically adaptive implants have demonstrated that targeted modulation of the healing niche can stimulate endogenous repair cascades while reducing the need for extensive cell transplantation. The long-term vision is to engineer regenerative therapies that restore tissue function through precisely designed material environments tailored to patient-specific biological and mechanical conditions. Such concepts may fundamentally transform medicine by shifting treatment paradigms from replacement toward cure.

2.1.3 Towards fully integrated perceptive soft robots enabled by 3D soft optical sensing

Lucia Beccai
IIT, Italy

A wide range of technologies exists today for soft tactile sensors and skins, yet fully integrated, distributed, and robust sensing in deformable robots remains a challenge. Soft waveguide-based optical transduction is especially promising for creating sensory skins and individual sensors. My team has developed optical devices for tactile sensing, multi-touch detection, and strain sensing, applicable both in robotics and human-computer interaction. However, overcoming robot-sensor assembly complexity and mechanical discontinuities requires moving beyond traditional system-engineering approaches toward fully embedded 3D sensing. In this perspective, we develop sensors via additive manufacturing, investigating the role of layers' orientation for material mechanical and optical properties and surface patterning for improved sensing performance, and implement 3D monolithic perceptive units (MPUs). Our approach is to co-design sensing, actuation, and robot body through a workflow combining design, fabrication, and SOFA-based simulation. I will present a monolithic perceptive gripper inspired by the elephant trunk tip, integrating pneumatic actuation, tactile sensing, and proprioception within a single 3D-printed structure. Finally, I will

show how the system distinguishes exteroceptive and proprioceptive information during reaching and delicate pinching tasks, highlighting the potential to scale this approach toward full elephant-inspired continuum manipulators

2.1.4 Repair of dielectric elastomer actuators - enabling manufacturing acceptance and mass production

Bettina Fasolt (1), Bruch Daniel (2), Motzki Paul (1) (2), Seelecke Stefan (2),

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(2) Department Of Systems Engineering, Department of Material Science And Engineering, Saarland University, Saarbrücken, Germany

Presentation given by Dr. Bettina Fasolt

The electromechanical response of dielectric elastomer actuators scales quadratically with the applied electric field, resulting in more efficient actuation at higher voltages. The main limitation, however, is dielectric breakdown. In commercially available dielectric films, premature local breakdown may occur below the manufacturer-specified field due to production-induced inhomogeneities. Such defects represent a major obstacle for reliable DEA mass production, particularly for multi-layer actuators, where a single failure can disable the entire system. A test and repair process was developed to improve material yield, reduce waste, and ensure actuator functionality. First, a DE layer is tested in a breakdown tester and early breakdown spots are identified. Second, a method for the repair of these spots is introduced. A final validation of the repaired DE layer for quality control concludes the process, ensuring higher yield of functional actuators in an early manufacturing stage. Investigations quantify the influence of repaired areas on the stress/strain behavior of silicone DEA and evaluate their actuation performance. In long-term cycling experiments the operation of repaired actuators over many cycles is confirmed. Additionally, a production-oriented concept is introduced that enables scaling of the testing and repair workflow and its integration into an industrial manufacturing line, from electrode deposition to stacked actuator fabrication.

2.1.5 Capturing the hidden physics of robotic and natural touch

Thomas Daunizeau

EPFL, LMTS, Neuchatel, Switzerland

Contact mechanics govern how living organisms and robotic systems interact with their environments, enabling complex behaviors such as gripping, climbing, and locomotion. Yet, because contact interfaces are inherently concealed, measuring and studying them remains a major scientific challenge. Addressing this gap is critical to advancing tribology and equipping robots with the rich tactile sensing necessary for real-world deployment. In this talk, I introduce a series of vision-based soft tactile transducers that convert physical contact into high-resolution visual data. Specifically, we leverage three complementary sensing modalities: thermochromic sensing to reveal contact geometry and material properties via thermal signatures; total internal reflection to resolve microscale contact and surface roughness; and photometric stereo using selective reflectance coatings to provide 3D contact topography and silhouette imaging at micrometer-millisecond resolution. These sensors are supported by novel opto-mechanical designs and image processing methods, while fabrication with dielectric-doped silicone ensures compatibility with electroactive (EA) systems. This yields a comprehensive framework, demonstrated by characterizing the mechanics of zipping in EA grippers and capturing elusive biological interactions, such as human finger ridge vibrations and locust jumps.

EuroEAP Society Challenge 2026

	Project title	Team leader	Institution
1	Contactless particle manipulation on soft platforms driven by resonant dielectric elastomer actuators	Simon Holzer	EPFL
2	ElastoSwitch	Carmen Perri	Saarland University
3	Multi-element vibro-tactile feedback armband based on pneumatic pre-loaded dielectric-elastomers	Daniel Philippi	Saarland University
4	A Soft Robotic Fish with a Dielectric Elastomer Actuator Body and Negative Stiffness Spine	Markus Koenigsdorff	EPFL
5	Tubular DEAs as Blood Pump	Amine Benouhiba	EPFL
6	Cooperative Dielectric Elastomer Actuators Conveyor Matrix	Stefan Seelecke	Saarland University
7	Flexible, wearable, honeycomb-patterned shear sensor	Andres Osorio Salazar	EPFL
8	Measuring and optimizing energy efficiency of soft electrostatic actuators	Steven L Zhang	MPI-IS
9	High speed robotic xylophone player using hyper elastic	Yueh-Chou Yang	Nat. Yang Ming Chiao Tung Univ.

Session 2.2 – short talks with focus on electroadhesion, sensors and wearables

2.2.1 Reinforced dielectric elastomer grippers for firm and articulate handling of medical fluid bag

Shih-Lun Liu (1), Gih-Keong Lau (1),
(1) National Yang Ming Chiao Tung Univ., Bio-Inspired Soft Robotics Lab,
Hsinchu City, Taiwan

Presentation given by Mr. Shih-Lun Liu

It is challenging for robotic grippers to pick and place deformable objects, such as medical fluid bags, because motor-driven robotic grippers often have poor force control and risk damaging them. For example, when applying excessive grip force, the gripper jaws may puncture the plastic membrane, leading to fluid leakage. In contrast, the human hand is dexterous in handling these highly deformable objects. While grasping a fluid bag gently, the hand can lift, flip, and hold it firmly during tasks like spiking and priming an infusion (IV) bag. To solve this problem, we developed a gentle, dielectric-elastomer-actuated gripper with integrated pre-tensioned serpentine springs. The fingertips of the gripper are embedded with electro-adhesive films to enhance grasping. Upon activation, the electro-adhesive film adheres to the deformable surface, allowing the bag to be lifted with minimal grip force.

2.2.2 Long-jaw electroadhesive gripper for firm grasping and flipping of books

Yen-Po Cho (1), Gih-Keong Lau (1),
(1) National Yang Ming Chiao Tung Univ., Bio-Inspired Soft Robotics Lab,
Hsinchu City, Taiwan

Presentation given by Mr. Yen-Po Cho

Soft and hard grippers alone cannot handle a book. While soft electroadhesive grippers have demonstrated pick and place of fruits and can, they cannot flip the posture of object picked due to high flexibility that risk to peel the electroadhesion

pad from the edge. In comparison, motor-driven hard grippers can pick a hard cover book by strong grip force, but it failed to secure a paperback book which may deform or flex under the gravity and grip. They can fork lift the books but risk losing the hold when flipping the books upright. In particular, the eccentricity-induced torque may loosen the gripper hold of a book. Such slippage at the interface between the gripper and book reduces the payload to a fraction of the grip force. To solve the problem, a book gripper were proposed to combine the mechanical grip force and electro-adhesion to firmly hold a book at any posture. With its inherent stiffness and mechanical grip force, the gripper can grasp a book upright and turn or flip to horizontal posture. Further, the electro-adhesion help increase the payload of up to 560 g at 300 g grip force. This ratio of payload to grip force is 1.86, far greater than typical friction coefficient (0.15-0.8) of common plastic and metal materials. As such, the grippers can gently handle the hardcover of relative heavy book.

2.2.3 High force, fabric-based electroadhesive clutch system for adaptive automotive airbags

Paul Gilmore,

Toyota Motor North America, Toyota Research Institute Of North America,
Ann Arbor, MI, USA

The electroadhesive (EA) clutch is a voltage-controlled variable stiffness device capable of large forces and compact profile. Among several clutch adhesive materials, P(VDF-TRFE-CTFE) is an attractive option due to facile processing and high EA stress, but clutches made with this material have had long disengage times. Adding nanomaterials into the polymer is one approach to address this problem, but too much (>10 wt%) can cause both brittleness and worsened adhesion to the substrate. Here, we achieve fast disengage times using ultra-low loading (0.5-1.5 wt%) of titanium dioxide nanoparticles. The improvement is attributed to increased nanoscale surface roughness, which alleviates the typical tradeoff between EA stress and disengage time. This new material results in 100x decreased disengage time, high EA stress (up to 67 N/cm²), and has the same favorable mechanical and bulk electrical properties as the plain polymer. Next, we address the engineering aspects for clutch-system integration. Due to the high EA stresses now possible, the substrate yield strength and attachment strength are often found to be limiting factors rather

than EA stress. We analyze and increase the substrate yield strength and clutch attachment strength to fabrics. Using these advances, we demonstrate the clutch as an active tether in vehicle airbags to control the deployed shape. This functionality has the potential to improve safety by adapting the airbag for different crash scenarios.

2.2.4 Towards soft and stretchable gecko-inspired skin with electroadhesion

Lihaoya Tan (1), Jianan Yi (2), Andreas Richter (2), Jonathan Rossiter (3), Ernst-Friedrich Markus Vorrath (2), Andrew Conn (3),

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(2) Dresden University Of Technology, Institute Of Semiconductors And Microsystems, Germany

(3) University Of Bristol, School Of Engineering Mathematics And Technology, UK

Presentation given by Prof. Andrew Conn

Gecko-inspired adhesion has attracted significant interest in soft robotics due to its passive and safe operation, residue-free attachment, and controllable adhesion. It has also been integrated with other mechanisms, such as electroadhesion, to develop smart adhesive systems. However, existing approaches that combine conductive materials with gecko-inspired microstructures often involve complex and time-consuming fabrication processes. Here, a novel method based on direct ink writing is proposed to fabricate a monolithic soft hybrid interdigitated electrode with gecko-inspired skin (SIDEGS), aiming to improve both fabrication efficiency and adhesion performance. Unlike conventional designs where electrodes are placed beneath the gecko-inspired skin backing layer, our structure directly embeds a carbon powder-silicone composite into the microstructures, allowing the adhesive microstructures themselves to function as the electrode architecture. Finite Element Method Magnetics (FEMM) simulations indicate that, under 1 kV, this design increases the electroadhesion force by approximately 4.7 times compared to the conventional electrode-on-backing configuration. These results suggest that the proposed SIDEGS design can enhance electroadhesion and thus improve overall hybrid adhesion performance. This

work offers a promising route for the efficient fabrication of soft, stretchable, and intelligent adhesive skins for soft robotic applications.

2.2.5 Wall perching of flapping drone using belly-mode shear electro-adhesion

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Presentation given by Prof. Gih-Keong Lau

Head-on ceiling electro-adhesion had enabled perching of small flapping drones with masses below 20 grams; however, its payload capacity is limited due to the peeling failure of the electro-adhesive pad under increasing load. Inspired by woodpecker trunk perching, this work proposes a shear-mode belly electro-adhesion strategy for wall perching of flapping drones, enabling significantly higher payload capacity up to 70 grams, approximately doubling the area-specific adhesion force compared to conventional normal-contact designs. The proposed system integrates a shear electro-adhesive pad mounted on a rotating leg mechanism, which reduces mass eccentricity during wall perching. A T-shaped tail structure provides a lower anchoring point to mitigate top-edge peeling of the adhesive interface. In addition, the belly-mounted configuration lowers the center of gravity, improving flight stability relative to head-on perching architectures. Although the belly placement increases aerodynamic drag, forward flight performance is maintained through tail elevation trimming. Experimental results demonstrate successful forward flight, approach maneuvers, and stable belly perching onto vertical walls. This work highlights shear electro-adhesion combined with bio-inspired structural design as an effective approach for improving payload capacity and perching stability in flapping-wing robotic systems.

2.2.6 Real-time detection of electroadhesion device release by capacitance self-sensing

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Presentation given by Dr. Chiara Scagliarini

Industrial electrostatic grippers can greatly benefit from integrated sensing strategies that monitor electroadhesion (EA) status during operation, as they would enhance reliability and automated control of grasping tasks. However, combining rigid sensors or vision systems often used to track object handling with Electroadhesion Devices (EADs) can undermine the advantages that make such systems competitive in terms of compliance, soft touch, weight, and power consumption. EADs built-in sensing capabilities offer a compelling alternative for adhesion-task inspection. Their intrinsic capacitance variation upon mechanical coupling can be used to infer key parameters, such as contact quality and grasping status, without the need for additional sensors. Here, we use an online identification approach to achieve real-time capacitance estimation of an interdigitated EAD geometry (15 cm² area), solely relying on current and voltage signals measured during high-voltage activation. The self-sensing EAD system succeeds in both inferring the adhesion state of the EAD and discriminating between two types of contacting materials, by operating EA while contextually reading capacitance. Capacitance decreases up to 80% and 50% were recorded when disengaging from conductive and dielectric targets, respectively. These results show promise for the implementation of self-sensing strategies in EA grippers, to achieve contact detection and selective grasping with no external sensors.

2.2.7 Core-shell polyionic liquid fiber strain sensors

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Presentation given by Mr. Leo Kershaw

We report core-shell ionic conducting fibers (ICFs) based on a novel ionic liquid grafted silicone (IL-g-silicone) for high-performance, textile-integrable strain sensing. The IL-g-silicone features a bottlebrush architecture comprising a flexible siloxane backbone grafted with imidazolium moieties and weakly coordinating anions. This combination affords one of the highest ionic conductivities reported for anhydrous PIL homopolymers (5.9×10^{-5} S/cm at room temperature). Core-shell ICFs were fabricated via coaxial wet-spinning of the IL-g-silicone core and a UV-curable PDMS shell, yielding mechanically soft and highly extensible fibers (Young's modulus 0.209 MPa, strain at break 510%). The PDMS shell dominates the mechanical response and endows the fibers with low hysteresis and excellent fatigue resistance, with $\sim 94.5\%$ stress retention and 91.3% strain recovery after 300 cycles to 100% strain. The ICFs were configured as ionic conducting fiber strain sensors (ICFSSs) which exhibited piezoresistive sensing behaviour. The ICFSSs showed gauge factors of 1.82 (0-50% strain) and 2.52 (50-100% strain), minimal hysteresis, and high repeatability. The ICFSSs were subsequently integrated into a wearable textile device and demonstrated the ability to accurately track a range of bodily motions. These results establish core-shell PIL-based ICFSSs as a scalable and durable platform for garment-integrated ionotronic sensing.

2.2.8 A Fibre-electronic Somatic Interface for Non-wearable Sleep Monitoring

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Presentation given by Dr. Xin Chen

We present an intelligent fibre-electronic system that transforms ordinary mattresses into autonomous physiological interfaces, seamlessly combining multimodal sensing, adaptive processing, and digital-twin intelligence for continuous, non-invasive health monitoring. The system employs a multimodal thermally drawn fibre that integrates piezo-resistive and piezo-electric components and demonstrated refined performance, achieving 30% better sensitivity for the piezo-electric device compared to state-of-the-art. The fibres were then integrated in a mattress and their response tested, enabling the training of a machine learning algorithm to recognize a variety of physiological and positional patterns. An experiment was then performed to follow such parameters over-night, highlighting the ability for sleep monitoring with 90% accuracy compared to a commercially available benchmark. This approach narrows the performance gap between laboratory-based measurements and home-based monitoring, offering a distributed, scalable solution for continuous sleep assessment. Looking ahead, incorporating advanced algorithms for sleep staging, anomaly detection, individualized modeling, and testing our system with a larger cohort of individuals may further enhance diagnostic accuracy and clinical relevance.

2.2.9 Piezoresistive thread for smart orthosis application

Alexandre Khaldi (1), Cyril Lahuec (1), Fabrice Seguin (1), Laurent Dupont (1),
Achraf Mesnaoui (1),
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Presentation given by Dr. Alexandre Khaldi

In both clinical and home-based rehabilitation settings, patient progress is commonly assessed by measuring joint angles, range of motion, muscular activity,

or adherence to prescribed exercises. While portable robotic systems and wearable motion sensors exist, they are often intrusive, difficult to calibrate, or uncomfortable for long-term use. Electroactive textile-based polymeric transducers represent a promising alternative due to their flexibility, conformability, and potential for seamless integration into garments. In this study, we report the functionalization of a monofilament textile transducer composed of a thermoplastic elastomer (TPE) fiber and a conductive poly(3,4-ethylenedioxythiophene) (PEDOT)-based coating. The developed protocol ensures uniform coating, good adhesion, and mechanical compatibility with the elastic core. We characterize the electromechanical response of the transducer under cyclic deformation, focusing on its sensitivity and working range for monitoring finger flexion.

2.2.10 Reducing hysteresis in capacitive dielectric elastomer sensors through control of adhesive layer viscoelasticity

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Presentation given by Mr. Artem Prokopchuk

Dielectric elastomers (DEs) are versatile, highly deformable materials used in actuators, sensors, and generators across robotics, energy, (bio-)medical, and industrial applications. However, a common challenge in DE devices is hysteresis, which affects the stability and accuracy of their electrical response. For sensing applications, fast and reliable sensor response is crucial to accurately track system changes. In multi-layer devices, there is a contradiction between the high mechanical compliance of adhesive layers and their viscoelastic behavior, including residual viscosity and time-dependent deformation after curing. This work investigates how modifying the stiffness of glue layers in a multi-layer DE sensor influences both hysteresis and the underlying viscoelastic response. By

comparing sensors fabricated by layering with two different materials for the glue layer: (i) softer Ecoflex 00-50 (Smooth-On, Inc., Shore 00-50) and (ii) stiffer Elastosil RT 601 (Wacker, Shore A 45), we demonstrate that increasing the stiffness of the adhesive layers alters their viscoelastic properties, leading to reduced energy dissipation and diminished hysteresis. As a result, the sensors exhibit more stable and reliable capacitance changes. These findings highlight the importance of considering both stiffness and viscoelastic behavior in material selection for optimizing dielectric elastomer sensors.

2.2.11 Force and stiffness sensing in electro-ribbon actuators

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(1) Queen Mary University Of London
(2) Imperial College London

Presentation given by Mr. Yuejun Xu

Physical interaction in soft robotics requires accurate sensing of displacement, force, and stiffness, yet conventional sensors can not provide multivariate sensing and struggle with dynamic interactions. We present a vision-based multivariate sensing approach for electro-ribbon actuators that leverages a physics-based inverse model. By tracking actuator deformation and solving for large-deformation mechanics, the method simultaneously estimates contraction and output force, enabling identification of state-dependent stiffness in real time. Experiments demonstrate low-bias and high-fidelity force estimation under both isometric and dynamic loading conditions. Using the jointly estimated force and displacement, we further achieve closed-loop stiffness shaping by regulating the force-displacement response to follow a programmable virtual spring. We validate the versatility of the approach in two systems: a soft gripper that infers object size and relative stiffness, and an antagonistic rotary joint that supports trajectory tracking, load identification, and variable stiffness modulation.

2.2.12 Multidirectional soft deformation sensor

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Presentation given by Ms. Svetlana Shachneva

Soft robots exhibit large, multidirectional deformations, making sensing of their evolving shape essential for effective feedback control. State-of-the-art soft strain sensors are predominantly based on capacitive or resistive sensing principles. They cannot distinguish between deformation directions, or they require multiple electrical connections and complex signal processing. Here, we present a soft sensor that measures multidirectional strain using a single connection. The sensor is a soft, stretchable capacitor comprising hydrogel electrodes and an elastomeric dielectric. At high measurement frequencies, the magnitude and phase of its impedance exhibit different deformation dependencies, allowing us to distinguish multidirectional deformations. We demonstrate that the impedance response of this system can be described using the Telegrapher's equation. We experimentally validate the operation principles of a sensor that measures multidirectional strains up to 100%. Impedance-based sensors could improve the speed of feedback control of soft systems, thus increasing their agility and adaptability. Potentially, they could also be used to study the biomechanics of various biological systems.

2.2.13 Real-time tracking of elbow flexion using in situ calibrated soft piezocapacitive sensors

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Presentation given by Dr. Renzo Ramiro Ramirez Herrera

Continuous joint kinematic monitoring outside clinics is crucial for rehabilitation. Conventional inertial measurement units offer portability but suffer from

magnetic disturbances and lose precision over time due to integration drift, while optical systems are mostly confined to laboratories. We propose a magnetometer-free wearable system using dielectric elastomeric sensors (DES) to track elbow flexion. The DES are coupled to the upper limb via 3D-printed supports, while an adjustable linkage applies a mechanical pre-strain, so that the sensor is slightly pre-stretched during full elbow extension. An onboard inertial measurement unit is worn continuously but utilized only temporarily during initial setup, for initial calibration. During a guided calibration process, a custom algorithm synchronizes capacitive data with inertial reference angles, to perform a polynomial regression. Once calibration coefficients are extracted, the inertial unit is computationally deactivated, and continuous tracking relies exclusively on DES. The proof-of-concept was evaluated against a marker-based optical tracking framework. Results demonstrated a good kinematic agreement among the calibrated DES, the inertial reference, and the optical ground truth during repeated flexion cycles, suggesting that this architecture provides a viable approach for real-world kinematic tracking.

2.2.14 Flexible, wearable, honeycomb-patterned shear sensor

Andres Osorio Salazar (1), Federico Maria Reato (1), Maël Dagon (1), Anil Can Kahraman (1), Paolo Germano (1), Yoan René Cyrille Civet (1), Zoltan Pataky (2) (3), Yves Perriard (1),

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(3) Faculty Diabetes Center, Faculty Of Medicine, University Of Geneva, Geneva, Switzerland

Presentation given by Dr. Andres Osorio Salazar

We present a novel parallel plate capacitive shear sensor developed within the framework of the Intelligent Plantar Pressure Offloading project for the prevention of diabetic foot ulcers and amputations. In diabetic patients, peripheral neuropathy reduces plantar sensitivity, leading to calluses, ulcers, and amputation. Ulcer formation is driven by normal and shear stresses, which generate friction and tissue wear. Measuring both stress components enables a more

comprehensible control algorithm for the smart insole, actively reshaping its actuation layer to offload critical regions. Our sensor differs from existing solutions in two key aspects: (1) an extended measurement range for planar shear stresses up to 100 kPa, and (2) an optimized 3D geometry maximizing the shear-to-normal sensitivity ratio to reduce tilt-induced shear measurement errors. The device consists of four pads arranged in a cross configuration, forming separate capacitor electrodes facing a common counter-electrode embedded in a flexible structure. It comprises a bulky upper layer and a honeycomb-patterned lower layer that separate the capacitor plates, and allows shearing but restricts normal-direction deformation.

2.2.15 Segregation-Driven Confinement for Enhanced Piezoresistivity in Graphite-Flake Elastomer Composites

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Presentation given by Ms. Lingyu Liu

Piezoresistive graphite flake (GF) composites provide electronic "ON-OFF" responses to strain for dielectric elastomer switches (DES) [1,2]. We recently demonstrated how to use confinement to orient GFs within thin films to create strong piezoresistivity [3]. Here, we introduce segregated structures using insulating, spherical particles to create this confinement even in thicker composite films. We found that the electrical resistance of GF-composites in thick films increases by 10^2 at 40% strain. Composites that additionally contained 1, 2, 5 vol% of PMSQ particles enhanced their relative resistance changes approximately 8-40 times. PMSQ acts as a hard filler, and its addition reduces the effective percolation threshold, an effect that is exploited in segregated Conductive Polymer Composites (sCPC) [4]. It is surprising that such fillers increase piezoresistivity: lowering the effective percolation threshold should increase the number of conductive pathways and reduce piezoresistivity. We used WAXS to show that fillers increase the alignment of GF under strain. We hypothesize that PMSQ particles act as rigid pivots that guiding the flakes. The constrained motion around these pivots forces GF edges apart, increasing their separation and

overcoming the reduced piezoresistivity expected from the lowered effective percolation threshold. Our results enable the enhancement of the piezoresistive response in thick films that are particularly suitable for DES.

2.2.16 Investigation of different non-metallic conductive polymers for in-situ sensors on flexible energy devices

Alexandra Perryman (1), Sarah-Jane Dunlop-Potts (1),
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United Kingdom

Presentation given by Ms. Alexandra Perryman

An application of strain gauges is lifetime structural monitoring. Traditional strain gauges have ranges of 1-5% which are not designed for large movement. The primary design of motivation for new sensors was to monitor larger movement, such as on underwater cables while they are in service. Whether that be in shallow or deep waters, as they will be subjected to a constant force from the tide in shallow waters and tidal drift in deep water. This contributes to the constant low-level strain that is turned into permanent strain over the sensor's lifetime. The key part of the strain sensor development is the electrode layer. Balancing the level of resistance and strain required a fine level of control of electrode properties. The conductive filler, Ketjenblack 300-J, a carbon black powder was mixed into Ecoflex, the polymer matrix, to achieve the optimal balance between conductivity and strain, based upon the percolation threshold. Target properties were tested via uniaxial strain testing and resistance via probe measurement. Targeting 100% strain and resistance of 1000 ohms to match traditional strain gauges. To date, the most optimal electrode produced is a 6% Powder by weight with an initial resistance of 7.6K ohms, average, with 100% strain, that increased to 1200K Ohms after 10^7 cycles.

2.2.17 Influence of printing substrate and strain history on the formation of conductive network in liquid metal-silicone fibers

Inga Põldsalu (1), Martina Medini (1), Christopher D. Woolridge (1), Robyn E. Worsley (1), Magdalena Skowrya (1), Frederikke Bahrt Madsen (1), Anne Ladegaard Skov (1),
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Presentation given by Dr. Inga Põldsalu

Liquid metal-silicone composite fibers are attractive as stretchable conductors and sensors for electroactive polymer systems, yet their resistance is often assumed to be an intrinsic material property. Here, we show that a conductive network of liquid metal droplets within a silicone matrix is strongly influenced during extrusion printing and can be further modified by later stretching. Fibers containing liquid metal droplets dispersed in silicone were printed either onto rigid substrates or into a compliant Carbopol support. Fibers printed onto rigid substrates consistently showed lower resistance than fibers printed into Carbopol. Micro-computed tomography revealed clear differences in droplet arrangement: rigid-substrate printing promoted greater apparent connectivity, especially near the contact surface, while Carbopol-printed fibers contained more isolated droplets and fewer continuous pathways. Cyclic tensile loading caused further conductivity increases. Repeated stretching at fixed strain reduced signal drift and produced a more stable response. When fibers were stretched beyond the previously applied strain, resistance decreased again, indicating the formation of additional conductive pathways. These results show that conductivity is not fixed after fabrication but instead depends on printing conditions and strain history. This understanding offers a route to tune liquid metal-silicone fibers as soft electrodes and strain sensors for electroactive polymer devices.

2.2.18 Mechanochromic elastomer-based tactile graphic tablet for handwriting analysis

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(2) Queen Mary University Of London, School Of Engineering And Material Science, London, United Kingdom

(3) University Of Trieste, Department Of Engineering And Architecture, Trieste, Italy

Presentation given by Mr. Alessandro Pagani

Early diagnosis of neurodegenerative disorders, as well as monitoring of disease progression and rehabilitation outcomes, can benefit from quantitative digital biomarkers of neuromuscular function. In this context, handwriting analysis provides a rich, non-invasive source of motor and cognitive information, capturing fine features of sensorimotor control. This study presents a vision-based tactile graphic tablet for the quantitative assessment of handwriting and drawing behaviour. The device integrates a flexible interface embedding a mechanochromic elastomer that changes structural colour under mechanical deformation. By tracking pixel colour (hue) variations with an internal camera, the system reconstructs contact position and applied pressure with high spatial resolution and low hardware complexity.

2.2.19 Self-sensing bending and coiling pneumatic actuators

Valentina Potnik (1), Giacomo Sasso (2), Gabriele Frediani (1), Federico Carpi (1),

(1) University Of Florence

(2) Queen Mary University Of London

Presentation given by Ms. Valentina Potnik

We introduce self-sensing bending and coiling soft pneumatic actuators. Bending pneumatic actuators have been developed through various approaches. However, a few incorporate self-sensing capabilities and self-sensing coiling actuators have

not yet been reported. Existing coiling actuators are rare and are fabricated using textile-based techniques, where both radial and axial dimensions change during actuation. We present a strategy for developing self-sensing bending and coiling actuators with bidirectional motion, depending on which chamber is pressurised. When both chambers are actuated simultaneously, the actuator elongates. The actuators operate at low pressures and the prototypes are manufactured using off-the-shelf materials. The system consists of an airtight elastomeric tube encased in a nylon filament, which prevents expansion. Self-sensing capability is achieved with an internal piezoresistive stretch sensor formed by a conductive elastomeric film coated along the inner wall of the tube. This film deforms with the actuator and enables measurement of resistance changes corresponding to the forces generated at different pressures. The actuator, with a length of 500 mm, is applied to grasping tasks in water. Two grasping modes are demonstrated: first, the floating actuator performs a circular motion to gather debris into a concentrated area, second, by attaching a metal hook to its end, the actuator functions as a gripper to collect impurities from the water surface.

2.2.20 An electrically driven multimodal soft robot enabled by a monolithic heterolayer elastomer

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Presentation given by Dr. Lyting Wang

Soft robots powered by active materials hold great promise for navigating complex environments through adaptive, multimodal locomotion. However, prevailing designs typically rely on a single active material within multi-component architectures, which often leads to high structural complexity and "soft-stiff" interfacial challenges arising from the integration of rigid parts. Here, we present an electrically driven, entirely soft robot—the MHE-Robot—based on a monolithic heterolayer elastomer (MHE) that integrates two soft active materials, a processable high-performance dielectric elastomer (PHDE) and a liquid crystal elastomer (LCE), into a lightweight laminated film. In this unique "soft-soft" structure, the LCE functions as a reconfigurable and powerful compliant skeleton

to program the structure into predefined equilibrium states, while the PHDE serves as a fast-responsive artificial muscle driving dynamic motion. Through independent control of the two active materials, this synergistic actuation mechanism enables versatile multimodal locomotion and substantial load capacity. The MHE-Robot demonstrates bidirectional crawling at 2.3 centimeter per second, leaping over 2.5 body lengths, stable climbing on a 20° slope, and controlled rolling. The MHE-Robot can smoothly transition between various locomotion modes and carry loads up to five times its own weight.

2.2.21 Wearable pneumatic tactile displays for softness rendering in virtual abdominal palpation

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Italy

Presentation given by Dr. Gabriele Frediani

Simulating soft object interactions is essential for creating immersive and realistic virtual reality environments, particularly in applications such as medical training, where the perception of tissue softness is critical. However, current haptic technologies still face limitations in reproducing the mechanical compliance of fingertip interactions. Soft actuators offer a promising solution, thanks to their intrinsic compliance, lightweight design, and ability to conform to the skin, enabling more natural cutaneous stimulation. Taking advantage of these properties, we recently developed compact, wearable tactile displays based on pneumatic actuation. To evaluate the performance of this technology in a realistic scenario, we developed a virtual abdominal palpation system integrating hand tracking with wearable pneumatic fingertip displays. We present preliminary psychophysical tests on healthy participants that show high accuracy in discriminating between regions of a simulated abdomen with different levels of softness.

2.2.22 Woven Textile Actuators for Wearable Robotics and Haptics

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

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Presentation given by Prof. Edwin Jager

Soft robotics exploits deformable materials and structures to achieve compliance and adaptability, enabling safe and close interaction with humans. Combining electromechanically active polymer actuation with textile technology enables soft, large-area actuators with one-, two-, or three-dimensional form factors (fibres, fabrics, and garments), which are highly relevant for wearable soft robotics. This study investigates in-air actuating polypyrrole (PPy)-based trilayer tape yarns (TYs) and the effects of their integration into woven fabric actuators. Individual TYs are developed, comprising two PPy layers sandwiching a poly(vinylidene fluoride) (PVDF) membrane containing ionic liquids (ILs). The influence of the fabric structure on displacement and blocking force is systematically examined. Individual TYs achieve a maximum displacement of 30.6 ± 3.6 mm (± 1.5 V) at 2.5 mHz and a blocking force of 0.20 ± 0.07 mN (± 1.0 V, 2.5 mHz). The TYs are subsequently integrated into plain-weave actuating fabrics, enabling the parallel assembly of multiple actuators without loss of displacement. The blocking force of woven actuators increases linearly, reaching 1.13 ± 0.18 mN for five TYs, facilitated by integrated conductive yarns. Multi-area fabric actuation is demonstrated, together with a wearable, on-body application of the fabric actuator.

2.2.23 A Pneumatic Wearable Sleeve for Pain relief through artificial tactile stimulation

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Presentation given by Dr. Orkesh Nurbolat

Chronic pain and localized musculoskeletal discomfort affect millions of people worldwide, creating increasing demand for non-chemical and non-electrical therapeutic approaches that are easy to use and have minimal side effects. This work presents a wearable sleeve designed to explore the feasibility of relieving pain through artificial tactile stimulation using pneumatic McKibben actuators. The device consists of a size-adjustable soft textile sleeve with integrated channels that allow miniature McKibben actuator units to be wrapped around the target area. Each actuator can be controlled individually, while the overall system is programmable through embedded electronic control hardware. By generating localized and controllable mechanical pressure, the device aims to investigate the potential of wearable soft pneumatic actuation for pain relief. Preliminary prototype development demonstrates the feasibility of achieving repeatable pressure actuation using compact pneumatic hardware while maintaining flexibility, comfort, and conformability to the human body. Potential applications include wearable wellness systems, stress relief, rehabilitation support, and assistive healthcare technologies. Future work will focus on further miniaturization of the device, improved integration of the pneumatic system, and clinical evaluation of its therapeutic effectiveness.

2.2.24 Real-time bidirectional control of conductive electroactive polymer actuators using a portable and miniaturized human-machine interface

Taha Ajnada (1), Sofiane Ghenna (1), Thanh-Hang Tran (1), Alexandre Auptel (1), Loic Bellone (1), Florian Gonzalez (1), Grégory Turbe (1), Loic Venet (1), Farouk Benmeddour (1), Sébastien Grondel (1), Eric Cattan (1), (1) Univ. Polytechnique Hauts-de-France, CNRS, Univ. Lille, UMR 8520 - IEMN, Valenciennes, France

Presentation given by Ms. Thanh-Hang Tran

A portable joystick based control interface for electroactive polymer (EAP) micro actuators is presented, targeting applications such as endoscopic camera steering and soft micromanipulation. The system converts manual joystick commands into precise bipolar voltage stimuli using an STM32 Nucleo G491RE microcontroller and a custom bipolar conditioning stage. The hardware includes an OPA4277PA operational amplifier and a MAX660 charge pump voltage converter, delivering a symmetric output between plus 2 volt and minus 2 volt, with a sensitivity of 10 millivolt. The embedded software implements a real time signal mapping strategy using the internal dual channel digital to analog converters of the STM32. The interface is integrated into a three dimensional printed enclosure, making it suitable for clinical or portable environments. Experimental results show a stable bipolar square wave and smooth reversible bending of EAP micro beams, with a response time below 1 second. The system successfully controls a three finger micro gripper, demonstrating coordinated grasping and release of micro objects. While the current open loop design is effective, inherent material drift, known as the memory effect, highlights the need for future closed loop control. Nevertheless, the proposed interface bridges the gap between laboratory setups and practical user centered tools for soft robotics and medical applications.

Session 2.3 – Industry Talks

2.3.1 Low Performance, High Impact: The Success Story of a Failed Dielectric Elastomer

Anne Ladegaard Skov (1)(2)

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(2) Glyscious, 2860 Gl Holte, Denmark

In 2015, we set out to develop a high-performance dielectric elastomer (DE) by incorporating high-permittivity glycerol into a silicone elastomer as one of our lead materials, in collaboration with Danfoss PolyPower. Under ideal (low-voltage, relatively dry) laboratory conditions, we succeeded. The DE showed excellent electromechanical properties and looked every bit like a promising actuator. Unfortunately, the moment we exposed it to more realistic testing conditions (high voltage and significant humidity), reality intervened. The DE absorbed water readily, leading to substantial dielectric losses and increased electrical conductivity, and any hopes of practical dielectric actuation failed rather spectacularly. Rather than declaring defeat, we took a closer look at what the material was actually good at. Its softness, conformability, permeability, and strong interaction with moisture, fatal flaws in DE contexts, turned out to be highly desirable features for wound and skin care. In this talk, we describe how a “bad” dielectric elastomer found a much better use as a wound dressing and how its properties could be further tuned to make an effective drug-delivery patch. This failed dielectric elastomer led to new research focusing on properties beyond dielectric behavior, and Glyscious was established in 2020.

2.3.2 Vacuum-free suction cups for energy-efficient pick-and-place using electroadhesion

Vito Cacucciolo (1)(2)

(1) Omnigrasp, Italy

(2) Politecnico di Bari, RoboPhysics Laboratory, Bari, Italy

Omnigrasp is developing electroadhesion-based suction cups that consume less than 5% of the power required by vacuum systems. Bridging the gap between laboratory research and industrial needs for this Electroactive Polymer (EAP) technology presents a series of unexpected challenges. Making the technology scalable, reliable, and durable requires solving problems distinct from those encountered when developing initial proof-of-concept prototypes. We were surprised to find that standard handling could dislodge wires from the devices and to realize the critical importance of visual feedback for device operation. Furthermore, team composition and funding are critical; transitioning from TRL 4 to 6 and beyond demands diverse expertise and varied funding sources. In this presentation, I will share some insights from Omnigrasp's ongoing journey from lab to industry.

Thursday, 4 June 2026

Session 3.1

3.1.1 Auxetic meta-architectures for embodied mechanical intelligence in wearable haptics

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Human dexterity stems from a complex interplay of adaptability and sensing. In wearable systems, this is needed for interfaces in VR, AR, and teleoperation, yet conventional technologies are often limited by rigid architectures and poor spatial coverage. This keynote presents a unified framework for auxetic meta-engineered wearable haptic systems that leverage embodied mechanical intelligence to overcome these barriers. At the finger scale, we introduce a glove-type interface utilizing negative Poisson's ratio architectures for conformal coverage across all joints. This ensures precise positioning of haptic regions despite anatomical variability, providing high-resolution multimodal feedback including pressure, vibration, and tunable stiffness. This enables intuitive grasping and bidirectional haptic communication, allowing users to perceive remote robotic states. We extend this paradigm to a wearable fabric platform using shape-memory alloy-knotted architectures for reversible 3D expansion. Featuring microscale Parylene-engineered electrical segmentation, this textile allows for spatially programmable actuation zones. This enables the encoding of rich spatiotemporal information for both cutaneous and kinesthetic feedback, supporting applications from hands-free navigation to adaptive motion training. These systems establish a new class of body-conformal interfaces where auxetic meta-structures serve as active enablers of distributed sensing and actuation.

3.1.2 Electrofluidic fiber muscles: modular, self-contained soft fiber actuators driven by electrohydrodynamics

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Presentation given by Prof. Vito Cacucciolo

EFMs (Electrofluidic Fiber Muscles) combine an antagonistic pair of thin fluidic actuators with millimeter-thick, integrated EHD (Electrohydrodynamic) fiber pumps, generating pressure and motion directly from electrical input, without external pumps or reservoirs. Their soft fiber form factor makes them easy to scale and integrate into robots and wearables. By studying the coupling between EHD pumps and McKibben actuators, we found that overfilling the system to an optimal bias pressure has three major implications: (1) external reservoirs can be removed, enabling closed-circuit operation, with the extending McKibben serving as a reservoir for the contracting one; (2) the muscles can operate at high electric fields without cavitation (localized liquid boiling), a major failure mode; and (3) the actuators can use the steepest part of the nonlinear McKibben pressure-strain curve. Together, these effects significantly increase performance, with EFMs reaching 50 W/kg of average power density. EFMs are modular: force scales with bundled actuators. Since fiber pumps and fluidic actuators are separate components, connected only through dielectric fluid, response time can be tuned through the pump-to-actuator ratio. We demonstrated EFMs in three robotic tasks: a fast lever at 180 mm/s that launches objects in under 0.3 s; a strong bundle lifting 4 kg (200x its weight) with a 30-mm stroke; and a woven muscle bending a robot arm by 40 degrees, compliant enough for a human handshake.

3.1.3 3D printing of soft piezoresistive sensors

Esther Amstad

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Nature fabricates lightweight materials with exceptional combinations of mechanical properties and functionalities through benign, energy-efficient

processes. These capabilities emerge from an interplay between structural organization across length scales spanning from the nanometer to the millimeter and locally varying composition. We remain far from achieving similar structural and compositional control over such a broad range of scales in synthetic materials. As a consequence, most man-made polymers still exhibit properties and functionalities that fall short of those found in natural materials, limiting their use in demanding applications such as soft robotics. In this talk, I will present granular polymers, including piezoresistive hydrogels and elastomers, that can be 3D printed into load-bearing architected materials with spatially varying mechanical properties, enabling programmed modes of deformation. I will show how these materials can be functionalized to become piezoresistive, allowing their use as stretchable sensors for humidity, temperature, and pressure. Such sensing capabilities have the potential to endow structures with proprioception, thereby opening new avenues for the design of closed-loop robotic systems. Finally, I will demonstrate how piezoresistive sensors can be integrated into actuators to create grippers that operate with high energy efficiency under closed-loop control.

Session 3.2 – short talks with focus on materials and biomedical applications

3.2.1 SupreSIL® - Silicones with highly increased pot-life for novel fabrication possibilities of silicone devices

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Presentation given by Dr. Jonas Groten

Silicone elastomers are key materials for dielectric elastomer sensors and generators because they combine high elasticity, low mechanical losses, fast response, and excellent environmental stability. Their softness and reversible deformability enable large capacitance changes under strain, while their insulating character provides a robust dielectric layer between compliant electrodes. These

properties make silicones attractive for flexible and stretchable devices. Conventional reactive silicone systems are limited by finite pot-life. Once mixed, crosslinking starts immediately, causing time-dependent changes in viscosity, wetting, and flow behavior. With SupreSIL®, we demonstrate a silicone-based one-component system in which crosslinking is suppressed during processing and triggered only in the final curing step. This extends pot life and provides a stable processing window with constant material properties. This enables new manufacturing routes for dielectric elastomer devices, including inkjet and aerosol jet printing, where droplet formation, line definition, and layer homogeneity are sensitive to material changes. The extended pot life allows precise patterning of thin dielectric layers and multilayer architectures while reducing defects such as nozzle clogging, thickness variations, and interfacial inhomogeneities. This concept offers a pathway toward scalable, additive, and high-resolution fabrication of dielectric elastomer sensors and generators.

3.2.2 Crosslinker Role Reversal in Hydrosilylation-Cured Silicone Dielectric Elastomers: Impact on Network Architecture and Electromechanical Performance

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(2) Department Of Chemistry, Technical University Of Denmark, Kgs. Lyngby, Denmark

Presentation given by Dr. Liyun Yu

Dielectric elastomers (DEs) require precise control of network architecture to achieve optimal electromechanical performance. We investigate how crosslinker microstructure and functional group influence curing kinetics, network topology, and properties relevant to silicone DEs prepared via Pt-catalyzed hydrosilylation. Two end-linked polysiloxane systems were examined using silicon-hydride and vinyl crosslinkers with reversed functional roles. NMR revealed distinct sequence distributions: the hydride crosslinker exhibits a block-type microstructure, while the vinyl crosslinker shows a more alternating pattern. Rheology demonstrated that the hydride-based system cures rapidly in a single-stage process, forming a

densely crosslinked, heterogeneous network, partly promoted by hydride self-condensation. The vinyl-based system exhibits a two-stage curing process with an extended induction period due to transient Pt-vinyl complex formation, resulting in a more uniform and lightly crosslinked network. Hydride-crosslinked elastomers exhibit higher Young's modulus (Y) (1.15MPa) and tensile strength (1.10MPa), characteristics that can enhance actuation stability. Conversely, vinyl-crosslinked elastomers exhibit lower stiffness (Y of 0.65MPa) and higher elongation at break (222%), which is advantageous for large-strain actuation. This study establishes clear structure-processing-property relationships linking crosslinker microstructure to functional performance in silicone DEs.

3.2.3 Fluorine-free transducers

Dorina Maria Opris (1) (2), Yauhen Sheima (1), Patrick Danner (1) (2), Johannes Szczepanski (1) (2), Jana Wolf (1) (2), Thulasinath Raman Thulasinath (1), Yulia Yutz Yutz (1),

(1) Empa

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Presentation given by Prof. Dorina Maria Opris

High-dielectric-permittivity elastomers are essential for the next generation of soft transducers, particularly in automotive technology, biomedicine, robotics, energy storage, and electronics, where poly(vinylidene difluoride) (PVDF) and its copolymers are frequently employed as dielectrics. However, these materials are part of a broader class of per- and polyfluoroalkyl substances (PFAS), which are increasingly subject to regulatory scrutiny, particularly regarding emissions and end-of-life disposal. Indeed, these polymers may be discontinued, prompting several industry sectors to seek environmentally friendly, cost-effective materials that are compatible with scalable manufacturing processes and recyclable. We have developed a new class of dielectric elastomers that exhibits high dielectric permittivity and meets the stringent demands of ultrathin-film fabrication and device integration. This makes it particularly well-suited to replacing PVDF in several transducer applications. We synthesized solvent-free dielectric inks with tunable viscosity that are suitable for various processing methods. We have produced high-dielectric-permittivity films and prototypes incorporating our material to demonstrate its functionality. By combining novel material innovation

with process engineering and prototype manufacturing, we bridge the gap between research and industry.

3.2.4 Ionic liquid grafted silicone for high permittivity elastomers

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Presentation given by Mr. Zhanhong Yang

This work develops silicone elastomers with improved dielectric performance for soft actuator applications by covalently grafting imidazolium-based ionic liquid groups onto polydimethylsiloxane (silicone) chains. A series of anions was introduced via an anion exchange reaction to tune thermal and dielectric properties, with all grafted silicones showing thermal stability above 200 C. Depending on the anion identity, the glass transition temperature spanned from -39 to +17 C, the low-frequency permittivity ranged from 1.1 E5 to 3.8 E6, and ionic conductivity varied from 1.0 E-7 to 3.5 E-5 S/cm. The optimal silicone, combining both the lowest glass transition temperature and the highest low-frequency permittivity, was incorporated into a condensation-cured silicone network, yielding elastomer films with a dielectric constant of 8.9 @ 1 Hz, Young's modulus of 0.4 MPa, stretchability of over 300%, and a breakdown strength of 63.6 MV/m. Dielectric losses remained below 0.01 @ 1 kHz, indicating efficient energy storage and reduced dissipation under electrical loading. The covalent anchoring of ionic liquid groups prevented ion migration and preserved mechanical integrity, avoiding common issues observed in systems containing free ionic liquids. The resulting soft elastomers show strong potential for soft robotics, wearable technologies, and low-voltage actuation, where stable dielectric behavior and high electromechanical efficiency are essential.

3.2.5 High dielectric permittivity polar polysiloxanes with tunable chain length and reactive end-groups

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(2) ETH Zürich, Departement Of Materials, Zürich, Switzerland

Presentation given by Ms. Jana Wolf

High-dielectric-permittivity polysiloxanes hold great potential for applications as solid electrolytes in batteries and as dielectrics in elastomer transducers (DET). A major challenge is synthesizing materials that combine high dielectric permittivity with good mechanical properties, which requires polymers with well-controlled chain length and defined end-groups for precise cross-linking and property tuning. Here, we present a synthetic route to a polar polysiloxane meeting these requirements. The synthesis relies on anionic ring-opening polymerization (AROP) in the presence of an end-blocker, yielding polymers with controlled chain length, reactive end-groups, and only a negligible amount of cycles. Subsequent thiol-ene addition introduces polar side-chain groups that increase dielectric permittivity while preserving the reactive end-groups. The degree of polymerization, cyclic siloxane content, and end-functionalization efficiency were characterized by ^{29}Si NMR. Rheological analysis was performed to assess viscosity, which increases substantially upon functionalization of polyvinylsiloxanes. Depending on chain length, the resulting polar polysiloxanes can be either blade cast or melt pressed, offering a versatile platform for high-permittivity elastomer fabrication. The material's mechanical and electrical properties were systematically evaluated and actuator prototypes were fabricated and tested.

3.2.6 Towards improved electromechanical properties in soft silicone films using two-dimensional materials

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Presentation given by Dr. Robyn Worsley

Soft silicone polymers are promising candidates for dielectric elastomer actuator fabrication. To increase performance, many attempts are made to enhance the relatively low dielectric constant of silicone, e.g., through the addition of higher-permittivity fillers, yet studies focused on dielectric strength improvement are limited. The two-dimensional crystal family offers flexible platelet-shaped fillers which can be micron-sized laterally, but only a few nanometres thick, with local atomic and electronic configurations, including surface disorder and potential defects, varying significantly compared to the bulk crystal. Such characteristics can facilitate the trapping of mobile charges, preventing premature dielectric breakdown when these materials are incorporated in composite systems. Platelet alignment to create an oriented, tortuous network, enabled by the high filler aspect ratio, may further hinder charge transport. In this study, two-dimensional hexagonal boron nitride is investigated as a flexible, charge-trapping nanoplatelet filler, to improve silicone breakdown strength and permittivity, without compromising on softness. A focus is placed on achieving well-dispersed platelets at low loadings, with functionalisation and alignment explored; graphene is further considered as an alternative filler. Initial data indicates a dielectric strength of 213 V/ μm for a boron nitride nanoplatelet loading of ~ 5 wt.%, compared to 188 V/ μm for the 'unfilled' reference formulation.

3.2.7 Role of interfacial polarization in polar polysiloxanes

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Presentation given by Dr. Thulasinath Raman Venkatesan

Polar groups are incorporated into polysiloxanes to enhance dielectric permittivity and electro-active performance. Understanding their influence on dielectric behavior is crucial for designing advanced materials. In this study, dielectric spectroscopy was used to investigate dipolar and charge relaxation processes in nitrile-substituted polysiloxanes. The results reveal multiple glass-transition temperatures (T_g) in the random homopolymer, indicating localized phase separation between polar side groups and the non-polar backbone, and resulting in interfacial polarization (IP). IP occurs above the T_g -related relaxations and is attributed to real charge accumulation at interfacial regions. These insights were further utilized to induce pyroelectric behavior in other-wise amorphous polysiloxanes, a property typically associated with crystalline materials. This was achieved by incorporating metal oxide fillers, resulting in polymer adsorption at filler surfaces. This in turn increases the interfacial area, and stabilizes IP. Applying thermal stress between the T_g and interfacial relaxation temperature range results in a stable secondary pyroelectric current. A pyroelectric coefficient of 2.58 ± 0.80 $\mu\text{C}/\text{m}^2\text{K}$ was obtained, the highest value reported to date for amorphous polymers. These findings demonstrate a new pathway for designing fluorine-free pyroelectric polymers.

3.2.8 Well-defined concatenated silicone network elastomers for soft transducers

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Presentation given by Mr. Ádám Lukács

Silicone elastomers are prime candidates for dielectric elastomer actuator (DEA) components, due to their high softness and stretchability. These properties also position them as ideal materials for other flexible electronics and mechanical energy storage applications. Concatenated silicone ring network elastomers exhibit excellent softness and stretchability due to purely physical cross-links that slide under stress. Previously, concatenated ring network elastomers were synthesized in bulk, allowing only for limited control and variability of network properties through changes in reaction conditions. To achieve a more controlled network, this work explores the concept of building up concatenated networks in three distinct steps: 1. Synthesis of large single rings. 2. Threading of rings with telechelic linear polymers. 3. Performing ring-closure on the threads of linear polymers to construct a concatenated ring network. The ring-closing reaction is achieved via alkene metathesis, resulting in a residual double bond in the polymer backbone. This could be further exploited, for example, to introduce dipolar functional groups via post-curing functionalization reactions, thereby increasing the otherwise low dielectric permittivity of silicones and improving DEA performance. Apart from the overarching concept, the current state and difficulties of this synthetic approach are also presented, highlighting the challenges of obtaining pure single rings and subsequent threading attempts.

3.2.9 Dielectric silicone composites incorporating a densely packed 3D Cd(II) coordination network for soft electromechanical transducers

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Presentation given by Dr. Mihaela Dascalu

A three-dimensional (3D) Cd(II)-based coordination polymer was synthesized using 1,3-bis(carboxypropyl)tetramethyldisiloxane as a ligand in combination with the heterocyclic co-ligand 4,4'-azopyridine. The structure of the compound was elucidated by elemental analysis, spectroscopic methods, and single-crystal X-ray diffraction. Structural analysis revealed the formation of a dense three-dimensional network promoted by the high flexibility of the ligand, resulting in low porosity. Thermal and humidity behavior were also investigated. The presence of a permethylated disiloxane segment in the structure is responsible both for the hydrophobic character of the compound and for its compatibility with silicone matrices. On this basis, the coordination polymer was incorporated in different proportions into a silicone matrix to obtain composite materials. Films obtained by crosslinking the latter exhibited enhanced mechanical and dielectric properties compared to the neat silicone matrix. According to theoretical evaluations based on the mechanical and dielectric parameters, these silicone composites show potential for application in electromechanical transducers operating in generator mode.

3.2.10 Silicone rubber batteries, simple elastomeric generators

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Presentation given by Mr. Christopher Woolridge

Electroactive polymers-particularly dielectric elastomer actuators and generators (DEAs/DEGs)-have been widely studied for energy harvesting and storage.

However, practical use is limited by the need for ultrathin, defect-free films, compliant electrodes, and high electric fields, leading to complexity, cost, and reliability challenges, as well as constrained energy output. Here, we present a simpler alternative: silicone rubber batteries, where energy storage relies on the intrinsic elasticity of silicones rather than high-field electrostatics. Mechanical energy is stored through stretching and converted into electrical energy via a straightforward electromechanical transduction mechanism. A proof-of-concept device using a 3D-printed stretching system with gearbox and DC motor shows that two stretched silicone bands can power small electronics, such as LEDs and mobile phones, at moderate strains (~170%), well below material limits. The device was tested, yielding a mechanical-to-electrical efficiency of ~27%. Rubber batteries offer a low-cost, electrode-free alternative to DEA/DEG systems, with further improvements expected from advances in mechanical design and energy conversion. They show strong potential for distributed, accessible energy storage, complementing or competing with lithium-ion technologies.

3.2.11 Stimuli-responsive silicone composites for reversible optical vapor sensing based on a cobalt(II) 2D coordination polymer

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Presentation given by Dr. Maria Cazacu

By incorporating a two-dimensional (2D) cobalt(II)-based coordination polymer as an active chromic phase into a silicone matrix, flexible and stimuli-responsive composite films were obtained. The 2D polymer exhibits reversible solvato- and vapochromic behavior, driven by changes in the coordination environment of metal center induced by interactions with guest molecules. The structural characteristics of the 2D polymer, containing siloxane moieties in the ligand structure, facilitate its homogeneous dispersion within the silicone matrix, while the crosslinking of the latter provides mechanical robustness and efficient vapor permeability, preserving the optical responsiveness of the active phase. The resulting composites function as soft and deformable sensing platforms capable of producing rapid, repeatable, and fully reversible color changes upon exposure

to organic vapors. The optical signal remains stable over multiple adsorption-desorption cycles without observable degradation. Integration of the composites into a simple optical sensing platform, employing a dedicated signal-analysis algorithm, enabled the detection of organic vapors at ppm-level concentrations. This approach provides a scalable route toward multifunctional soft sensing materials that combine stimuli-responsive coordination chemistry with elastomeric matrices, opening perspectives for flexible and low-power vapor detection in environmental monitoring and soft transducer applications.

3.2.12 Soft iontronic materials for Physical AI

Aslan Miriyev
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Physical artificial intelligence (PAI) involves sensing, actuation, and signal transmission through the material structure of robot bodies, mirroring the versatile role of biological tissues. Achieving such material-level multifunctionality in synthetic systems is one of the core challenges in PAI. Ionic materials are uniquely positioned to address this challenge. They can transform electrical energy to mechanical and vice versa while operating under low voltages and currents, are multifunctional, serving as actuators, sensors, supercapacitors and conductors, and are compatible with 3D-printing-mediated fabrication of complex, hierarchical structures. We present three examples of 3D-printable soft iontronic materials as building blocks for all-ionic robot bodies. Ionogel/SWCNT mixed ionic-electronic composites (ISMCs), fabricated via vat photopolymerization (VPP), enable decoupled pressure and temperature sensing in a single printed element. In addition, ionic wires (i-Wi), stretchable VPP-printed ionogels and eutectogels, transmit AC and DC signals under large deformations while serving as strain and temperature sensors. We also present fully sustainable gelatin/ethaline eutectogels, printed via direct ink writing, functioning as biodegradable wearable sensors for joint motion monitoring. Together, these results advance the foundation for PAI robotic bodies built entirely from ionic matter.

3.2.13 Electrically and magnetically responsive soft actuators using mof-derived porous magnetic materials

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Presentation given by Mr. Donghyeok Yun

In this study, we fabricated an ionic electroactive polymer actuator using a MOF-derived porous magnetic material as an electrode component. The magnetic material was prepared from a metal-organic framework by oxidative decomposition at 300 C, followed by heat treatment at 700 C under an inert atmosphere. After the thermal conversion, the MOF precursor formed a porous carbon-based structure containing magnetic species. This structure was introduced into the electrode layer to provide both ion-storage sites for electrochemical actuation and magnetic responsiveness for external-field actuation. The fabricated actuator showed bending motion under a low applied voltage, which is attributed to ion migration and accumulation at the electrode-electrolyte interface. A blocking force was also measured to evaluate the output performance of the actuator. In addition to electrical actuation, the actuator responded to an external magnetic field, indicating that the magnetic components derived from the MOF precursor remained effective after the electrode fabrication process. These results confirm that electrical actuation and magnetic-field-induced motion can be implemented in a single iEAP actuator by using MOF-derived porous magnetic electrode materials.

3.2.14 How eap help for an experimental validation of the bending moments theory

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Presentation given by Ms. Thanh-Hang Tran

The experimental comparison between the quasi-static moment associated with the blocking force and the dynamic moment generated during free deformation remains challenging and can only be achieved under specific experimental

conditions. Although bending moment modeling is well established in the literature through both blocking-force and curvature-based approaches, experimental validation remains limited due to the difficulty of accurately measuring the radius of curvature, particularly for passive materials. In contrast, actuator materials subjected to external stimuli (electrical, thermal, etc.) can generate large deflections, enabling more reliable curvature measurements. Materials capable of producing small radii of curvature under large displacements are therefore particularly suitable for such investigations. This investigation required prior consolidation of the stiffness characterization of a clamped-free cantilever beam. In this study, ionic electroactive polymers were used to experimentally establish, for the first time, a relationship between the blocking-force moment and the free bending moment for different applied voltages. This investigation required prior consolidation of stiffness characterization data for a clamped-free cantilever beam, using independent bending moment measurements to support and validate this relationship experimentally.

3.2.15 Optimizing ionically conductive gels for direct-ink writing processes and wearable textile actuators

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Presentation given by Ms. Louise Anne Furie

Ionically conductive gels have emerged as promising materials in the development of next-generation energy storage systems, ionotronics, and wearable sensors. When integrated into conjugated polymer actuators, these gels function as an internal ion reservoir, providing the electrochemical environment necessary for stable operation in ambient air—a traditional bottleneck for soft robotic systems. In this work, we present a versatile suite of ionically conductive gel formulations based on a blend of a commercial elastomer and polyethylene oxide (PEO). To bridge the gap between material synthesis and functional application, we focused on tuning the viscoelastic properties of the gels. By

systematically varying the polymer ratios and additive concentrations, we achieved a rheological profile optimized for direct-ink writing (DIW). This additive manufacturing approach allows for the high-resolution deposition of gels directly onto textile substrates, facilitating the seamless integration of active components into garments. The resulting gels demonstrate a favourable balance of mechanical robustness, flexibility, and ionic conductivity. This work provides a scalable pathway for the fabrication of textile-integrated wearable actuators, moving soft robotics closer to practical, everyday applications in healthcare and human-machine interaction.

3.2.16 Effect of bias force and potential on actuation performance of electroactive yarns for soft robotic applications

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Presentation given by Mr. Abd Ul Qadeer

In soft robotic system, flexibility, lightweight, and mechanical comfortability are the key requirements for actuators. EAP (Electroactive polymer) based textile actuators are suitable candidates as they are lightweight being textile-based and produce mechanical displacement due to the EAP material. The performance of these textile-based actuators depends on their constituent electroactive yarns and other parameters like bias force and potential. In this study highly stretchable conventional yarns were coated with a conductive poly-3,4-ethylenedioxythiophene: polystyrene sulfonate (PEDOT: PSS), dimethyl sulfoxide (DMSO) and polyethylene glycol 400 (PEG 400) mixture to make them conductive. To make them electrochemomechanically active, polypyrrole was electropolymerized on these yarns. Then their actuation performance was systematically evaluated in liquid and air using a two-electrode setup. In this simple and symmetric actuation setup two identical PEDOT/PPy coated yarns were used as an anode and cathode, respectively. The actuation response was measured under different bias force and applied potential. The results suggest that

the linear actuation output of actuators is affected significantly by these parameters. These findings contribute to improving the actuation performance and provide support to understanding the fundamentals of EAP-based textile actuators for their integration into soft robotic systems.

3.2.17 Balancing printability and mechanical properties in gelatine-alginate hydrogels for soft microrobotics

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Presentation given by Ms. Karin Trakell

Soft microrobots are promising for biomedical applications due to their compliance and small size. Hydrogels are attractive candidate materials for such soft microrobots because of their biocompatibility, possibility of 3D printing, and tuneable mechanical properties. However, their use is challenged by the need to balance printability with softness. This research explores different hydrogel formulations as materials for the development of 3D-printable, biocompatible soft microrobots. The focus is to identify a hydrogel that retains soft, compliant mechanical properties after printing and crosslinking. An optimal balance is sought between suitable rheological properties, which govern extrusion and printed strand shape, and soft mechanical properties, for compliant hydrogels. Different concentrations of gelatin and sodium alginate are evaluated for printing fidelity and mechanical properties. Preliminary results suggests that these formulations show potential for printed, soft microrobots. A printed strand uniformity of 57% relative to the 0.2 millimeter thickness model was achieved, with the same formulation exhibited a Young's modulus of 185 kPa and an elongation at break of 55%. This work contributes to printable hydrogel systems for soft, biocompatible microrobots.

3.2.18 Vacuum-enhanced dielectric elastomer actuator counterpulsation for cardiac assistance: in vivo evaluation in a porcine model

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Presentation given by Dr. Amine Benouhiba

Cardiac assist devices based on dielectric elastomer actuators (DEAs) offer a promising alternative to conventional mechanical circulatory support by providing soft and adaptive mechanical assistance. However, existing DEA-based systems face significant limitations in energy efficiency and effective hemodynamic modulation. This study presents a novel vacuum-enhanced DEA-based counterpulsation device and evaluates its performance in a porcine in-vivo model. We investigated two distinct implementation configurations: a direct attachment to the descending aorta and an integration into a bypass circuit mimicking an ascending aortic attachment. The device was actuated in synchronization with the cardiac cycle to provide real-time mechanical unloading. The results demonstrate that the vacuum-enhanced DEA system significantly improved diastolic augmentation (Mean: $39.1 \pm 11.7\%$; Range: 29.2 to 55.0%) and achieved superior left ventricular unloading, marked by a remarkable reduction in end-diastolic pressure (Mean: $-126.1 \pm 65.6\%$; Range: -188.3 to -67.1%). Furthermore, the device reduced stroke work (Mean: $-12.3 \pm 14.0\%$; Range: -24.2 to 4.4%) and increased stroke volume (Mean: $3.9 \pm 2.2\%$; Range: 2.5 to 7.1%) compared to baseline (device off). These findings establish vacuum-enhanced DEA actuation as a highly viable and impactful approach for next-

generation cardiac assist devices, paving the way for further clinical optimization and application.

3.2.19 Energy-based control of a dielectric elastomer cardiac assist device

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Presentation given by Dr. Ning Liu

We present our work about the port-Hamiltonian modeling and control of a dielectric elastomer actuator designed for use in a cardiac assist device. The proposed nonlinear model captures the actuator's hyperelastic material behavior, viscoelastic damping, and electromechanical coupling, and remains valid for large deformations up to 0.4. An original Interconnection and Damping Assignment Passivity-Based Control strategy is developed to achieve closed-loop stabilization at a desired position. The accuracy of the multiphysics model and the performances of the proposed controller are experimentally validated.

3.2.20 Design and prototyping of a soft dielectric-elastomer-driven pump for insulin delivery

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Wearable insulin pumps demand quiet, low-volume fluid delivery through soft interfaces that conform to the body, yet commercial devices use electromagnetic or piezoelectric drives in rigid enclosures, limiting skin compliance and miniaturization. Dielectric elastomer actuators (DEAs) offer a soft-matter

alternative, converting an electric field directly into large membrane strain while remaining compliant, silent, and lightweight, but existing DE-driven pumps target soft-robotic power transmission rather than the low flow rates and biocompatible materials needed for medical delivery. Here, we present a soft pump for insulin dosing comprising three fluidic chambers in series, each sealed by Elastosil silicone membranes functioning as single-layer DEAs. The pump body is moulded from Sylgard 184 PDMS using laser-cut acrylic frames, and passive silicone flap valves provide flow rectification. Phase-shifted excitation (1-4 kV) produces sequential membrane compression and a travelling volume wave generating unidirectional flow without moving parts. Chamber geometry and membrane dimensions are informed by a lumped-parameter model coupled with finite element analysis in ABAQUS. Fluid tests on a single-chamber prototype confirm reversible, leak-free actuation and measurable fluid displacement, though the current valve geometry does not yet achieve sufficient sealing for consistent unidirectional flow.

3.2.21 Enhanced steerable thin-film electrode technology for safer cochlear implantation

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Presentation given by Prof. Eric Cattan

During cochlear implant surgery, standard electrode arrays are surgically inserted into the scala tympani to stimulate the spiral ganglion cells and rehabilitate hearing in deaf patients. However, due to the stiffness and passive nature of the standard electrode arrays insertion into the tympanic ramp may result in trauma or incomplete insertion. To address this issue, we developed an original steerable thin film electrode array (TFEA) coupled with an EAP. By adjusting the thicknesses of the materials, the proposed TFEA offers tunable stiffness, and the microfabrication process using SU-8 or polyimide negative photoresist thin films is both cost-effective and simple. Twenty gold electrodes distributed over the 25

millimeters length with a surface area of 0.16 millimeters square are obtained. With these surfaces, it's possible to stay in the safe neural stimulation limits with charge densities below of the Shannon limit. A strain gauge has been fabricated to integrate the TFEA and control the actuation. In addition, we modified the curvature of a TFEA during insertion into a 3D printed cochlea model, using micro-actuators at low electrical voltage. The control of the curvature reduces the contacts with the cochlea walls as much as possible. Successful insertion, with a curvature angle close to 360 degree, was achieved. This novel prosthesis has the potential to improve insertion control and reduce the risk of trauma during cochlear implantation.

3.2.22 Innovative Bilayer Actuators with Antagonistic Ionic Mechanisms for Cochlear Implants

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Presentation given by Ms. Elsa Lamberet

The increasing prevalence of hearing loss has led to a growing number of cochlear implant procedures. Current cochlear implant electrodes rely on passive insertion and lack adaptive mechanical control, which can lead to insertion trauma, suboptimal placement and ultimately up-to 30% failure rate. Conjugated polymer (CP) actuators have been explored for biomedical applications such as catheters, neural interfaces, and cochlear implants, allowing electrically controlled curvature for improved device positioning. In this work, we propose an innovative bilayer architecture operating in aqueous electrolyte, based on two distinct in plane CP layers exhibiting antagonistic cooperative ionic mechanisms: a DBS-doped polypyrrole (PPy) layer (cation-driven) and a Acesulfame Potassium-doped PPy layer (anion-driven). This configuration enables single-sided integration, while leaving the opposite side fully available for auditory nerve stimulation electrodes. While DBS-doped PPy is widely used due to its proven biocompatibility, the key innovation was to develop a stable anion-driven layer in

physiological media. We present here electropolymerized PPy layers with antagonist matching performances in NaCl aqueous solution (curvature radius up to $R = 10$ millimeters for both layers). Initial results demonstrating cooperative actuation in this novel architecture will be presented. This approach paves the way for active positioning control in cochlear implants.

3.2.23 Smart glove for monitoring the assembly of an engine coolant pump

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Presentation given by Dr. Bettina Fasolt

Manual assembly sequences are critical for efficiency and product quality. While camera-based monitoring is common, it fails in space-limited environments. To enable monitoring in confined workspaces, this work introduces a smart glove that identifies handled components, measures grip forces, and issues warnings if incorrect parts are picked or components are missed during assembly. Developed for engine coolant pump assembly, where missing gaskets or small parts are often detected only during leak testing, the glove integrates four dielectric elastomer (DE) force sensors on the upper phalanx. These sensors quantify grip forces and track finger use, integrated into the glove with minimal impact on movement or comfort. The system delivers immediate haptic feedback when force thresholds exceeds or finger use deviates from expected patterns. Unlike acoustic warnings that may be missed in noisy environments, vibrations provide direct, intuitive correction. The actuator comprises four stacked, oval-shaped DE layers designed to fit the human arm. The glove's textile provides mechanical bias through its elastic behavior, and a buckled-beam-spring increases stroke. Miniaturized electronics, including capacitive sensing, a microcontroller, wireless communication, a power supply, and high-voltage circuitry, are seamlessly integrated into the glove cuff together with the haptic element, enabling compact, wireless, real-time monitoring in manual assembly processes.

3.2.24 An antagonistic hydraulic McKibben actuator system: energy recycling for wearable soft robotics

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Presentation given by Mr. Jakob Dirnberger

Hydraulic actuation systems based on McKibben artificial muscles have become a cornerstone of soft robotics due to their high efficiency, strong force output, and lightweight design. Despite these advantages, their deployment in real-world applications remains limited, as many systems still rely on tethered compressors or motor-pump units. This work presents an untethered actuation system consisting of two antagonistic McKibben muscles that function as both actuators and fluid reservoirs. The actuators are made of rubber hoses and Kevlar braided sleeves and are driven by a compact motor-pump unit. Several parameter configurations were evaluated under unidirectional and bidirectional operation. Measurements of pressure, force, contraction, and electrical characteristics provide a comprehensive characterization of the system's behaviour and confirm its potential as an efficient solution for soft robotic applications. The results demonstrate, that the system can achieve a maximum output force of 600 N and an efficiency of up to 12%, indicating performance comparable to more complex and expensive setups. The potential of this hydraulic actuator is further highlighted through a 3D-printed exoskeleton demonstrator. This example illustrates how lightweight, untethered systems can still deliver substantial force. Such capabilities point toward promising applications in fields like healthcare, where robust and flexible support systems could help address growing workforce shortages.

3.2.25 Capacitive self-sensing for closed-loop grasping control of an electroadhesion suction cup gripper

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Presentation given by Mr. Simone De Carolis

Electroadhesion suction cup (EASC) grippers are soft, silent, and energy-efficient, yet they operate largely open-loop: without feedback, contact position depends entirely on pre-tuned parameters. This work characterizes dynamic capacitance measurement as an intrinsic self-sensing signal for contact monitoring of an electroadhesion suction cup gripper, requiring no additional components. The capacitance signal captures three distinct physical regimes of the EASC gripper: near-field proximity effects, detectable within 1-2 millimeters of the target surface, progressive capacitance increase during electrostatic zipping as contact area grows, and sensitivity to object material and thickness once contact is established. Capacitance is measured at kilohertz rates, enabling feedback latencies below 1 millisecond and proximity anticipation windows of 1 to 10 milliseconds during approach at velocities between 0.1 and 1 meter per second. Each sensing regime is quantitatively mapped, identifying signal ranges and sensitivities relevant for proximity detection and contact monitoring. These results establish capacitive self-sensing as a fast, hardware-efficient feedback strategy for electroadhesion grippers, laying the groundwork for closed-loop grasping control of EASCs.

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