

STORM-BOTS

**Soft and Tangible Organic
Responsive Materials progressing
roBOTic functionS**



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Words from the coordinator

Current conventional hard robots can handle rigid and heavy objects with high precision but tend to fail when they interact with delicate or deformable objects. Even more, for applications such as haptics or minimally-invasive surgery, movements within tight spaces are required, however simple miniaturization of conventional robotic elements is not always viable. New organic materials, showing controlled deformations in response to external stimuli, can be key to developing new technologies that make robotics move into the realm of soft and small. Liquid crystal (LC) based crosslinked materials are ideal for this purpose as they can present large, anisotropic, and reversible mechanical responses when exposed to a suitable trigger such as heat, light, humidity, or an electric or magnetic field.

We, the STORM-BOTS consortium, have the expertise and the commitment to collectively consolidate advances in the LC-based actuator field, generate new fundamental insights, and apply these new principles to drive a paradigm shift in the fields of robotics and engineering. Within the framework of STORM-BOTS, we will train through research a new generation of scientists in the multidisciplinary field of LC-based responsive elements for robotics and haptic interfaces, with the overall goal of creating an enabling technology that will decisively contribute, from Europe, to re-shape robots and functional surfaces of tomorrow.

While elaborating this newsletter we received with great sorrow the sad news that our project partner Prof. Mark Warner passed away last December. He was a great colleague, mentor and friend of many of us and we will terribly miss him.

Carlos Sánchez Somolinos

Spanish National Research Council – CSIC



Project summary

Soft responsive materials and new fabrication schemes are key ingredients to develop new disruptive technologies for robotic elements and devices, that are expected to revolutionize the fields of minimally invasive surgery, targeted drug delivery, material sampling and manipulation, responsive functional surfaces and human-machine interfaces. The use of soft responsive, instead of hard inert, matter in these areas provides unique features such as the material being able to sense the environment and autonomously perform complex tasks – “the material is the machine”. In this scenario, liquid crystal elastomers are receiving an increasing deal of attention as they exhibit large, programmable mechanical deformations in response to different stimuli. Europe has played a leading role in liquid crystal science since its birth. To be at the forefront also tomorrow, we aim at harnessing the full potential of liquid-crystal-based responsive surfaces, soft actuators and smart machines.

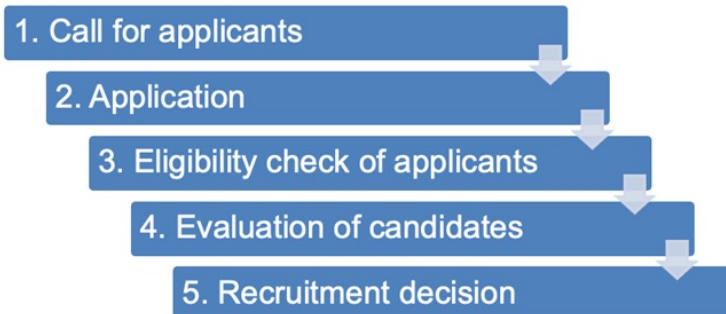
STORM-BOTS counts on academic and non-academic leaders from top research institutions and with unique scientific and technical expertise, in order to provide this next generation of scientists and engineers with the best possible research environment for developing new materials and manufacturing tools to enable advanced robotic functions. Based on innovative individual research projects, the students will be provided with a transnational, comprehensive, highly integrated, multidisciplinary and multi-sectoral training programme. Encompassing aspects from chemistry, physics, materials science, advanced manufacturing and robotics, local and network-wide training activities will give these students the opportunity to become involved in trailblazing research, acquiring the necessary skills for a future career in the field.

The STORM-BOTS project delves into this field of robotics by running a state-of-the-art training programme for 13 young researchers.



Our Early Stage Researchers

NETWORK LEVEL



BENEFICIARY LEVEL



During the STORM-BOTS Kick-off meeting that took place on February 17th 2021, the recruitment strategy was widely discussed. A Recruitment Plan was drafted and approved, establishing a coordinated process for the recruitment.

Recruitment process

The procedure followed the guidelines of the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers.

The call was jointly published in the STORM-BOTS website with a downloadable Guide for applicants, EURAXESS and other scientific and employment websites, with the aim of promoting and reaching the widest number of candidates possible.

A Selection Committee for each position was set up at each host institution, led by the supervisor, but the Recruitment Committee composed by all the supervisors and co-supervisors of the Network supervised the whole process. The Recruitment Committee approved the final ranked list of selected candidates and reserve list for each position.

To comply with the principles of fairness and equitability of the process, all applicants received a written assessment made by the respective Selection Committees.

More than 160 candidates applied in the two calls launched in March and June, and by the end of November 2021 all 13 ESRs were recruited and integrated into the network.

Early Stage Researchers >



ESR 1

Eliza Sopubekova

Electrically driven polymers for active antennae • Eindhoven University of Technology (NL)



ESR 2

Rahul Singh Yadav

Liquid crystal chemoresponsive actuator • University of Zaragoza (ES)



ESR 3

Erick René Espíndola Pérez

Multimaterial 4D printed components and devices • Spanish National Research Council (ES)



ESR 4

Paolo Sartori

4D Printed biomimetic soft robotic functions • Spanish National Research Council (ES)



ESR 5

Lovish Gulati

Magnetic field assisted assembly and alignment of LCEs • Max Plank Society (DE)



ESR 6

Reza Norouzikudiani

Finite element models for dynamical actuation of LC sheets • Sant'Anna School for Advanced Studies (IT)



ESR 7

Michał Zmyślony

Putting Gauss Curvature to Work • University of Cambridge (UK)



ESR 8

Mert Orhan Astam

Electrically driven liquid crystal actuator • Eindhoven University of Technology (NL)



ESR 9

Duygu Sezen Polat

Liquid crystal actuator with electrical feedback mechanism • Eindhoven University of Technology (NL)



ESR 10

Yasaman Nemati

Magneto-photoresponsive actuators with complex and reconfigurable shape • Tampere University (FI)



ESR 11

Zixuan Deng

Light-Fuelled Robotics Going under Water • Tampere University (FI)



ESR 12

Giulia Spallanzani

Electrically driven sensor skins for LCE-based soft robotics • Netherlands Organisation for Applied Scientific Research (NL)



ESR 13

Tommaso Da Col

Definition and validation of adaptive LCE-based instruments • PRECEYES (NL)

What has happened so far

Kick-off meeting

The kick-off of the Project took place online on February 17th, 2021. Representatives of all the STORM-BOTS beneficiaries attended the meeting. It was a great opportunity to get to know each other, discuss the details of the Recruitment Process and

review the different aspects of the project: training, dissemination & communication, management and finances. In addition, the members of the Supervisory Board, the Recruitment Committee and the rest of governing bodies were appointed.



Training activities

Liquid Crystal Elastomers course at TU/e

The scientific training for the ESRs began soon after their recruitment. Starting on September 2021, Prof Dick Broer and Dr Danqing Liu gave a four-session Course on Liquid Crystal Elastomers, where several aspects related to LCEs were explored in depth with the STORM-BOTS ESRs who at that time were already recruited in Eindhoven, both by TU/e and by Preceyes: Tommaso (ESR-13), Eliza (ESR-1), Mert (ESR-8) and Duygu (ESR-9).



Wettability course

On October 2021 Dr Nadia Grossiord from SABIC delivered a three-session course on Wettability and Solubility Parameters organised by the Eindhoven University of Technology for PhD students, including the STORM-BOTS ESRs already enrolled at TU/e: Eliza (ESR-1), Mert (ESR-8) and Duygu (ESR-9)

The students were not intimidated by all the thermodynamics and equations involved but rather enjoyed going through the different aspects of the course: theory behind wettability and overview of methodology, practical examples and solubility parameters.



Other training activities

- Significant participation of STORM-BOTS members at the **11th International Liquid Crystal Elastomer Conference - ILCEC 2021**. Some of the partners's scientists in charge were invited speakers, and many of the ESRs participated as attendees.
- As part of their transversal skills training, the ESRs at CSIC, Erick (ESR-3) and Paolo (ESR-4) attended the course **From the paper to the dissemination video** organised by the Institute of Nanoscience and Materials of Aragon (INMA).
- The ESRs at Tampere University, Yasaman (ESR-10) and Zixuan (ESR-11), attended the online **Summer course on Liquid Crystals of the Bاندول LC School** organized by Prof. Jan Lagerwall.

Dissemination activities

4D printing for soft robotics on TV

4D printing of Liquid Crystal Elastomers developed at the Advanced Manufacturing Laboratory (AML) at CSIC was highlighted in the first episode of the science divulgation show “Agujero de Gusano” at Aragon TV.

Soft Robotic functions for biomedical applications is just an example of the technology to be developed in STORM-BOTS.



Support session for Doctoral Networks

A support session for the preparation of Horizon Europe – Doctoral Networks 2021 proposals was held last September at CSIC, organised by the Spanish National Research Council's European Unit with the aim of supporting researchers who want to apply to this Marie Curie call.

STORM-BOTS participated as a successful case of a proposal for an Innovative Training Network within the MSCA H2020 Actions. We were honoured to participate and happy to share our experience with other researchers.



Lab tour for high school students

Introducing the research work to young students and arousing their interest in science, especially in materials science, nanotechnology and robotics, is one of the STORM-BOTS goals.

Last September Zixuan Deng (ESR-11) participated in a lab tour at Tampere University (Finland) and gave 22 high school students a demonstration on light-fueled liquid crystal soft robotics. He also explained how experimental work and research are carried out on a daily basis. Students were fully engaged in the activity and gave very positive feedback.



Upcoming Events

For the second year of STORM-BOTS implementation, we are planning a large number of activities aimed to the successful accomplishment of the ESRs' goals:

Local training activities will certainly continue, such as a **lab tour** for the ESRs organised by the project's industrial partner Preceyes.

Two **network-wide symposia** organised by CSIC and the University of Cambridge, will be of key importance. They will be the perfect time and place to exchange ideas and tools for the successful development of the ESRs' individual projects and their Personal Career Development Plans.

The **secondments** will also be of great relevance, complementing the ESRs' training by exposing them to different disciplines and different sectors (academic and industrial) in an international environment.

Among other activities the researchers will set up a **Virtual Journal Club** programme in which they will meet periodically and present a paper of their choice, and of course they are expected to continue working on their research and scientific **publications**, and to soon start presenting their work at relevant international scientific **conferences**.

- **Local training**
- **Network-wide Symposia**
- **Secondments**
- **ESRs' Virtual Journal Club**
- **Scientific publications**
- **International Conferences**



Prof Mark Warner, Fellow of the Royal Society (1952–2021)

It is with great sadness that we must report the death of Mark Warner, a key researcher in the STORM-BOTS project, and the pre-eminent theorist in the global liquid crystal elastomer (LCE) community.

First and foremost, Mark was a soft-matter statistical-physicist, meaning he worked on deriving the properties of soft phases of matter from its microscopic constituents. He first came to Cambridge from his native New Zealand as an undergraduate in 1970. As a young researcher in the 1980s, he worked on the statistical theory of polymers and elastomers with Sir Sam Edwards, and on liquid crystals with Paul Flory. Over the subsequent decades he coupled these two subjects to build the theory of liquid crystal elastomers, the remarkable materials at the heart of our project. His theoretical efforts culminated in his celebrated “trace formula” for the energy of an LCE, which predicts and explains the many captivating and dramatic behaviors of LCEs that so many of us were subsequently seduced by.

In particular, Mark’s trace formula captures how liquid crystal (LC) phase changes within LCEs can generate massive actuation responses in response to heat, light or swelling, making LCEs artificial muscles. The formula also captures how the LC director rotates within an LCE in response to mechanical stress, generating extremely soft modes of deformation, and microstructural instabilities, which now find applications in damping. Beyond nematics, Mark also ex-

plained that smectic elastomers have yet more exotic 2D elasticity, owing to their high layer modulus, and that cholesteric elastomers have vivid optical properties, and change colour on stretching. These early insights were expounded in his book “Liquid Crystal Elastomers” (co-authored with Eugene Terentjev), which has become the standard text in the field, and many of them were verified experimentally by Heino Finkelmann, with whom he worked very closely, and ultimately shared the Europhysics prize.

In Cambridge, Mark was also a much-loved lecturer and supervisor, who inspired generations of undergraduates. Later he became extremely concerned with improving the rigor of school physics, to enable students from all backgrounds to enter the subject. He founded the Isaac-physics online platform to provide appropriate content to school pupils: since its inception the Isaac-physics has helped 350,000 students, who have solved 76,000,000 problems between them.

Those of us who knew Mark remember a kind, and generous man who loved walking and swimming, and read widely on history and philosophy. He was relentlessly curious, always asking simple questions, and profoundly unpretentious. It was thus with some embarrassment that he accepted a string of honors and prizes, including fellowship of the Royal Society, the Europhysics prize, the Humboldt prize, and the Bragg medal for physics education.



Mark also loved the LCE community. He was a prodigious mentor and a great believer in the iconoclastic value of young researchers. Indeed, it was his gentle encouragement and support that enticed many STORM-BOTS PIs into the LCE field, and he was extremely enthusiastic about extending this support to the next generation through the project. He was truly the best of us, and we will miss him terribly. However, nothing would make him happier than our training of a new generation of LCE scientists, and our stewarding of LCEs towards useful application.

John Biggins

on behalf of the STORM-BOTS Consortium



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Beneficiaries



MAX-PLANCK-GESELLSCHAFT



Partner Organisations

