

# TEmpuRA

Theory for Electrostriction of PolymeRic Actuator

## MAIN PARTICIPANTS

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Other participants: Nozomu HATAKEYAMA, Ryuji MIURA, Akihira MIYAMOTO (NICHe), Hiroshi YABU (AIMR, TU), Tetsuya UCHIMOTO (IFS), Gael SEBALD (ELYTMax), Jean-Marc CHENAL (MATEIS), Jean-Fabien CAPSAL, Laurence SEVEYRAT, Veronique PERRIN (LGEF), Jean-Yves CAVAILLE (ELYTMax@INSA)

## OVERVIEW (keep within this page)

**Starting year:** 2014

**Current researchers (permanent/non-permanent):** 3 person-month/year

<b>Positioning</b> <i>(Multiple selection allowed – total 100%)</i>	<b>Transportation</b>	<b>Energy</b>	<b>Eng. for Health</b>	Include partner from <input type="checkbox"/> Outside ElyT <input type="checkbox"/> Industry
				Main funding source(s) <input checked="" type="checkbox"/> Public project(s) <input type="checkbox"/> Industrial <input type="checkbox"/> Own resources
				IFS CRP/LyC project? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No
<b>Materials and structure design</b>		50%		For main projects: Agency / year / name of project <i>(up to 3, past projects in gray)</i>
<b>Surfaces and interfaces</b>				Estimated annual budget:
<b>Simulation and modeling</b>		50%		
<b>Other:</b>				
<b>Highlights &amp; Outstanding achievements</b> <i>(3-5 bullet points)</i> <ul style="list-style-type: none"> <li>• We have demonstrated that in polyurethane, electrostatic pressure and polarization body forces cannot explain the strong electromechanical behavior.</li> <li>• Our hypothesis is that electrical charge diffusion and their Coulombic interactions are the main mechanisms</li> <li>• This might explain both the slow mechanical response and large deformation, as well as the bending observed on homogeneous films.</li> <li>• 3 peer reviewed co-authored articles</li> </ul>				

## PROJECT DESCRIPTION

### Background

Conversion of energy is a hot topic in robotics and microfluidics especially in term of electromechanical coupling for actuators and energy harvesting (which includes sensors, useable for non-destructive techniques). Because of the lack of theoretical guideline, they result from a time-consuming systemic screening. The project aims at providing a complete model accounting for 3 contributions, (i) electrostatic surface forces coming from the two electrodes interactions, (ii) possible body forces resulting from dielectric interactions between dipoles and local electric field gradients and (iii) interactions between electric charges able to diffuse. This needs theoretical approaches and numerical simulations by (i) molecular dynamics (thanks to the NICHe team) and (ii) at a mesoscale to compare with experimental data (thickness changes, bending, etc.). Most of our works were performed on polyurethane and from now we plan to test some model materials with given internal architecture and well-known electrical and mechanical properties.

### Key scientific question

Physical mechanisms at the origin of soft polymer deformation observed under electric fields, and their time dependence. Numerical simulation of the observed behavior on given polymers.

### Research method

Up to now, we worked on polyurethane, which is known to exhibit a strong deformation under electric field. In order to understand better the mechanisms of these behaviors, we will develop new model materials, fully characterized from both macroscopic and microscopic point of view (viscoelastic and dielectric responses, conductivity under high electric field, electromechanical responses, microscopy and SAXS observations). In parallel, we aim at testing several hypothesis involving electrical charges diffusion, in relation with the deformation kinetics and amplitudes, as determined with our experimental set-up.

### Research students involved *(gray color for previous years)*

#### Master/Bachelor students (years):

- N. Boucida (M2 stay at IFS/ELyTMax), April-September 2016
- Zhouyang He (M2 student of INSA, Mat. Sc. and Eng.), possible stay at TU (2021)

### Visits and stays *(gray color for previous years)*

#### FR to JP (date, duration):

- |               |                |         |
|---------------|----------------|---------|
| • K. Yuse     | June-July 2019 | 8 days  |
| • K. Yuse     | Nov-2019       | 5 days  |
| • JY Cavaillé | Feb-March 2019 | 2 weeks |
| • JY Cavaillé | Apr-2019       | 1 week  |
| • JY Cavaillé | June-July 2019 | 2 weeks |
| • JY Cavaillé | Oct-Nov 2019   | 2 weeks |
| • JY Cavaillé | Decembre-2019  | 1 week  |

## COMMUNICATIONS AND VALORIZATION

### Journal publications *(gray color for previous years)*

	Authors	Title	Journal	Vol.	pp. / ID	Year	DOI
1	Gildas Diguët, JY Cavaille, Gael Sebald, Toshiyuki Takagi, Hiroshi Yabu, Ai Suzuki, and Ryuji Miura	Physical behavior of electrostrictive polymers. Part 1: Polarization forces	Computational Materials Science				Under revision
2	M.H. Jomaa, L. Roiban, D. Dhungana, J. Xiao, J.-Y. Cavallé, L. Seveyrat, L. Lebrun, G. Diguët, K. Masenelli-Varlot	Quantitative Analysis of grafted CNT dispersion and of their stiffening of polyurethane (PU)	Composites Science and Technology	171	103-110	2019	doi: 10.1016/j.compscitech.2018.12.012
3	M.H. Jomaa, L. Seveyrat, L. Perrin, L. Lebrun, K. Masenelli-Varlot, G. Diguët, J.-Y. Cavallé,	Difference between electrostriction kinetics, and mechanical response of segmented polyurethane-based EAP	Smart Materials and Structures	26	035049	2017	doi: 10.1088/1361-665X/aa5c4b

### Conferences & Seminars *(gray color for previous years)*

	Authors	Title	Conference	Date	City	Country	DOI (if applicable)
1	Ai Suzuki, Masayuki Miyano, Ryuji Miura, Gildas Diguët, Jean-Yves Cavaille, Gael Sebald	Estimation of Multiple Coefficients to Express Longitudinal and Transverse Electrostriction in the PTMO Crystal	17th ICFD	2020 Oct. 18-30	Sendai	Japan	
2	K. Yuse, G. Coativy, G. Diguët, V. Perrin, L. Seveyrat, S. Livi, J.-Y. Cavallé	Role of Charge Carrier Transport on the Understanding of Polyurethane Actuation	17th ICFD	2020 Oct. 18-30	Sendai	Japan	
3	Ai Suzuki, Masayuki Miyano, Ryuji Miura, Gildas Diguët, Gildas, JY Cavaille, Sebald Gael	Quantum chemical calculation study for the polarization evaluation of the semi-crystalline poly tetramethylene oxide elastomer	Meeting of The Institute of Electrical Engineers of Japan	2019 Dec. 16	Tokyo	Japan	IEJJ Digital Library, [A] Basic / Materials / Common Division Dielectric / Insulation Materials Study Group 2019-12-16, Paper No. DEI19109

4	Kaori Yuse, Gildas Diguët, JY Cavaille	Electrical Conductivity Versus Electrostriction in Di-Block Polyurethane: New Insights	16th ICFD	2019 Nov. 6-8	Sendai	Japan	
5	Ai Suzuki , Masayuki Miyano , Ryuji Miura Jean Yves Cavaille , Gildas Diguët , Gael Sebald	Polarization and Elasticity Characterization in Crystal and Amorphous States of Polytetramethylene Oxide Elastomer	16th ICFD	2019 Nov. 6-8	Sendai	Japan	
6	Gildas Diguët & Kaori Yuse	Seminar on Electrostriction	Morita's Lab	2019 July 8	Todai, Tokyo	Japan	
7	A. Suzuki, M. Miyano, R. Miura	Theoretical estimation of dielectrics constant of electroactive polymers	15 <sup>th</sup> ICFD	2018 Nov 7-9	Sendai	Japan	
8	A. Suzuki, R. Miura, N. Hatakeyama, J.-Y. Cavaille, G. Diguët, G. Sebald	Multiscale Modeling of Electromechanical Coupling in Electroactive Polymers	14th ICFD	2017 Nov. 1-3	Sendai	Japan	
9	Nazim Boucida, <u>Jean-Yves Cavaillé</u> , Jean-Marc Chenal, Gildas Diguët, Gael Sebald	Nano-structured polymer based materials for energy conversion and actuation,	ISMANAM	2016 July 3-8	Nara	Japn	Invited lecture