PETRU PONI

EXECUTIVE AGENCY FOR HIGHER EDUCATION, RESEARCH, DEVELOPMENT AND INNOVATION FUNDING

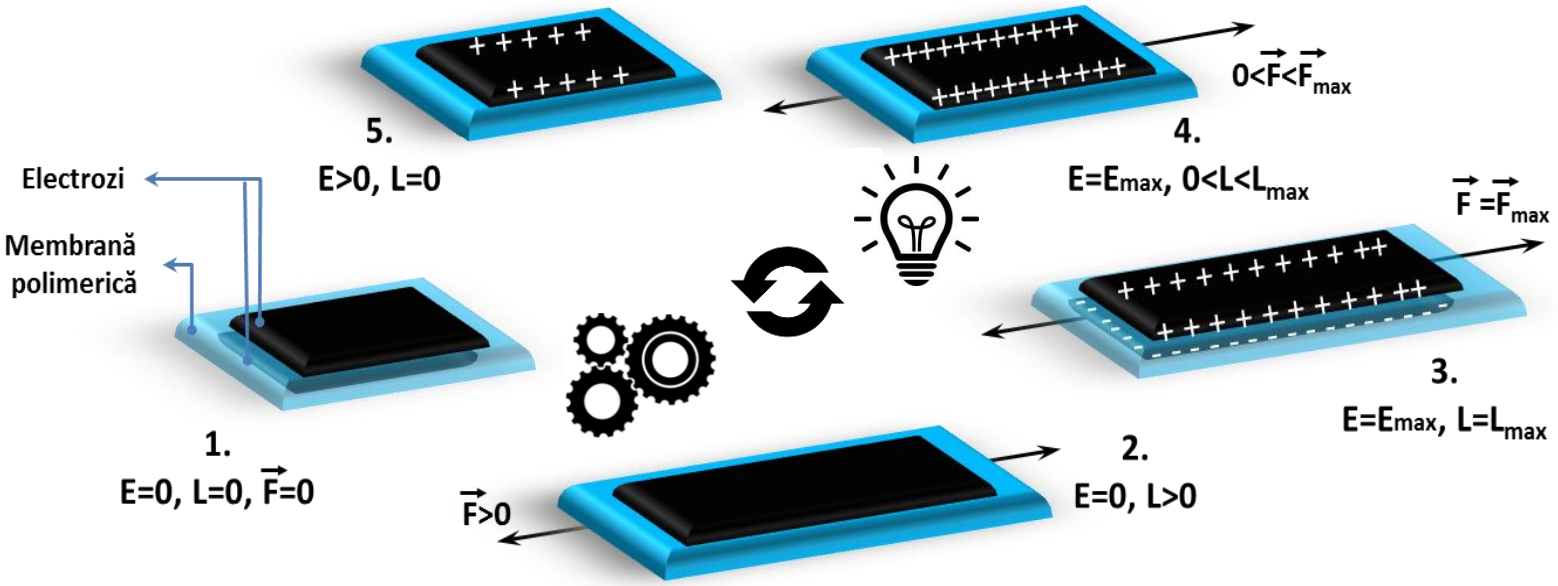
GreENergy

Energy harvesting structures optimized through green silicone chemistry

Contractor: "Petru Poni" Institute of Macromolecular Chemistry
Project type: experimental demonstrative, PN-III-P2-2.1-PED
Contract number: PN-III-P2-2.1-PED-2016-0188/CNCS/CCCDI-UEFISCDI (Grant 68PED/2017)
Implementation period: 1.01.2017-30.06.2018
Project budget: 600 000 lei
Project leader: Dr. Maria Cazacu

GreEnergy - *Scope*

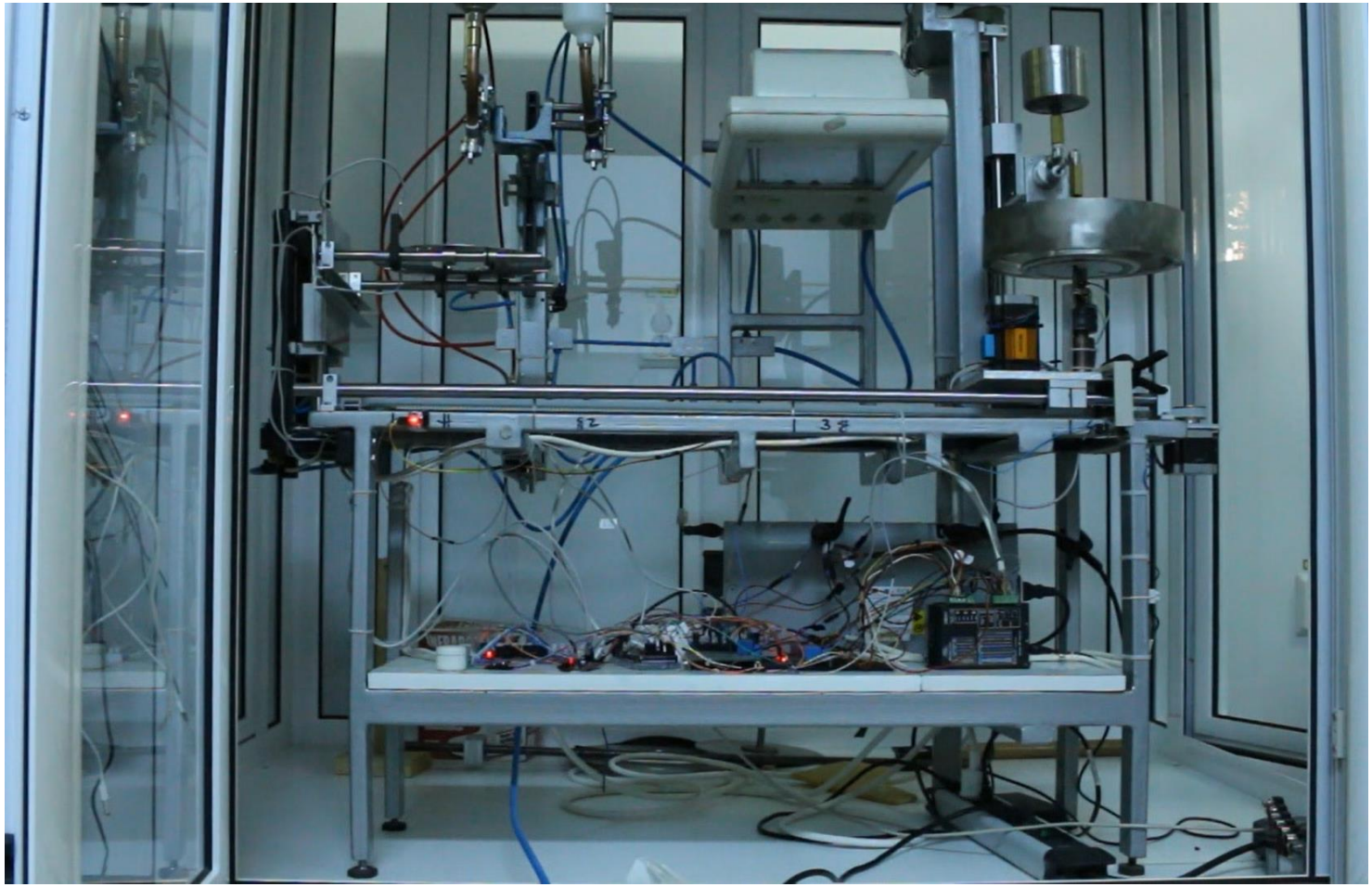
The **project aim** is to develop, through a relatively green approach, a laboratory technology for getting active elements able to efficiently convert mechanical energy into electrical energy. These are based on dielectric elastomers (DEs) coated on both sides with stretchable compliant electrodes forming a capacitor or dielectric elastomer generator – DEG.



The project responds by excellent science (future and emergent technologies) to one of the grand challenges facing EU society, i.e., secure, clean and efficient energy. Dielectric elastomers (DE) have emerged as promising smart energy-transduction materials offering many advantages over other technologies, having good performance as generator (high energy density and efficiency) and better material properties (low cost, high compliance, durability and environmental tolerance).

GreEnergy - *Scope*

The project will deliver a laboratory-scale technology able to produce DEs energy harvesting elements adjustable on request, built up from alternating, highly stretchable and compliant dielectric/electrode layers, based on different silicone formulations.



GreEnergy - *Stages, activities and related deliverables*

Stage 1 – Design and optimization of the dielectric and electrode	
Activities	**Expected results**
A1.1. Optimization of the dielectric material structure and composition	● At least four polymers of pre-established molecular masses; ● at least two chemically modified polydimethylsiloxanes with polar groups ●At least a filler, i.e., TiO2 nanotubes ● Dielectric films with different size and geometry ● Product sheets concerning to dielectric films ● Electrode free-standing films ● Product sheets concerning to electrode films ● Elements for energy conversion units ● Product sheets concerning to energy conversion units ●Two articles at least submitted to publication
A1.2. Filler`s preparation	
A1.3. Optimization of the dielectric film forming and crosslinking process and geometry	
A1.4. Evaluation of the mechanical and dielectric behavior of the dielectric films prepared	
A1.5. Optimization of the electrode structure and composition	
A1.6. Characterization of the free-standing film electrodes	
A1.7. Optimization of the electrode deposition on the dielectric	
A1.8. Evaluation of the mechanical and electric behavior of the electrode-dielectric-electrode assembly	
A1.9. Dissemination of the scientific results: presentation at conferences and articles writing	

Stage 2 - Laboratory validation of the experimental laboratory demonstrator	
Activities	**Expected results**
A2.1. Setting configuration and commissioning the installation for casting successive dielectric elastomers films and compliant electrodes and demonstration	● Laboratory installation to produce elements for energy conversion units ● Laboratory setup for energy harvesting test ●1 article submitted to publication
A2.2. Upgrading and realizing the required configuration of the facility for the evaluation of the energy conversion capacity of the obtained units	
A2.3. Demonstration of the method/procedure functionality	
A2.4. Dissemination of the scientific results: presentation at conferences and articles publishing	

GreEnergy - *Scientific results*

Published articles

1. The effects of incorporating fluorinated polyhedral oligomeric silsesquioxane, [F3C(CH2)2SiO1.5]*n* on the properties of the silicones, M. Iacob, A. Bele, A. Airinei, M. Cazacu, *Colloids and Surfaces A: Physicochemical and Engineering Aspects* 522, 66-73 (2017), DOI:10.1016/j.colsurfa.2017.02.045. *WOS:000404491600008; JUN 5 2017; IF: 2,714; SRI: 0.561*
2. All-silicone elastic composites with counter –intuitive piezoelectric response, designed for electromechanical applications, C. Racles, M. Dascalu, A. Bele, V. Tiron, M. Asandulesa, C. Tugui, A. Vasiliu and M. Cazacu, *J. Mater. Chem. C*, 5, 6997-7010, (2017), DOI: 10.1039/C7TC02201H.*WOS:000406107600012; JUL 28 2017; IF: 5.256; SRI: 1.104*
3. Iron oxide nanoparticles as dielectric and piezoelectric enhancers for silicone elastomers, M. Iacob, C. Tugui, V. Tiron, A. Bele, S. Vlad, T. Vasiliu, M. Cazacu, A. L. Vasiliu, C. Racles. Smart Materials and Structures, 26, 105046 (2017), DOI: 10.1088/1361-665X/aa867c.*WOS:000411444100003; OCT 1 2017; IF: 2.909; SRI: 0.767*
4. Stretchable energy harvesting devices: attempts to produce high-performance electrodes; C. Tugui; C. Ursu; L. Sacarescu; M. Asandulesa; G. Stoian; G. Ababei, M. Cazacu; ACS Sustainable Chemistry & Engeering, 5, 7851-7858 (2017), DOI: 10.1021/acssuschemeng.7b01354.*WOS:000410006200045; SEP 1 2017; IF: 5.951; SRI: 1.181*
5. Assessment of chemicals released in the marine environment by dielectric elastomers useful as active elements in wave energy harvesters, M. Zaltariov, A. Bele, L. Vasiliu, L. Gradinaru, N. Vornicu, C. Racles, M. Cazacu, J. Haz. Mat. 341, 390-403, (2018), DOI: 10.1016/j.jhazmat.2017.07.068. *WOS:000412378700043; JAN 5 2018; IF: 6.065; SRI: 1.173*

6. Ceramic nanotubes-based elastomer composites for applications in electromechanical transducers, A. Bele, C. Tugui, L. Sacarescu, M. Iacob, G. Stiubianu, M. Dascalu, C. Racles, M. Cazacu, Mater. Design., 141, 120 – 131, (2018), DOI: 10.1016/j.matdes.2017.12.039, *DEC 20 2017; IF: 4.36; SRI: 2.065.*

Patents

1. C. Racles, M. Cazacu, *Procedeu de obtinere a siliconilor colorati transparenti,* Patent Nr. 01085 / 11.12.2017;
2. A. Bele, M. Cazacu, M. Neagu, M. Popescu, C. Racles, *Modular instalation and process to obtain multi-layer polymeric generators*, Patent Nr. A/00127 / 26.02.2018.

Articles published in extenso

1. Codrin Tugui, Mihaela Dascalu, Maria Cazacu, Materiale siliconice pentru energie: performante si limite, Stiinta Moderna si Energia, 36th edition, 17-18 May 2018, Cluj-Napoca.

Oral presentations

1. Silicone-based materials for electromechanical applications; A. Bele, M. Dascalu, C. Racles, M. Cazacu; 11th International Workshop on Silicone Polymers 2-6 July 2017, Snekkersten, Denmark.
2. Iron oxide nanoparticles for energy conversion devices; M. Iacob; Stiinta Moderna si Energia 35th edition, 18-19 May 2017, Cluj-Napoca;
3. Maria Cazacu, Materiale siliconice pentru energie: performante si limite, Stiinta Moderna si Energia, 36th edition, 17-18 May 2018, Cluj-Napoca – comunicare in plen;
4. Mihaela Dascalu, Abordari pentru cresterea performantei electromecanice a elastomerilor siliconici, Stiinta Moderna si Energia, 36th edition, 17-18 May 2018, Cluj-Napoca – comunicare in plen.

GreEnergy - *Scientific results*

Scientific stages

1. Adrian Bele, EuroEAP - Scientific mission grand (SMG): Green silicone based interpenetrating polymer networks as dielectric elastomers for electro-mechanical applications. Department: Danish Polymer Center, Technical University of Denmark, Copenhagen, Denmark, 27.06.2017 - 12.08.2017.

Posters at international events

1. Maria Cazacu, Codrin Tugui, Bele Adrian, Elena Hamciuc, Polysiloxane-polyimide semi-interpenetrated networks with dual electromechanical response, EuroEAP 2017: 7th International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles, 6-7 June **2017**, Cartagena, Spain;
2. Codrin Tugui, Maria Cazacu; Comparative approaches to high performance stretchable electrodes, EuroEAP 2017: 7th International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles, 6-7 June **2017**, Cartagena, Spain.
3. Adrian Bele, Codrin Tugui, Mihaela Dascalu, Carmen Racles, Maria Cazacu, Functionalized silicones showing giant actuation strains, EuroEAP 2017: 7th International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles, 6-7 June **2017**, Cartagena, Spain.
4. Mihail Iacob, Maria Cazacu, Tudor Vasili, Carmen Racles, Iron oxide nanoparticles as fillers for silicone elastomers to improve their dielectric permittivity and induce piezoelectric effect; EuroEAP 2017: 7th International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles, 6-7 June **2017**, Cartagena, Spain.

GreEnergy - *Scientific results*

5. Adrian Bele, Lyiun Yu, Maria Cazacu, Carmen Racles, Anne Skov, Binary silicone elastomeric systems with stepwise crosslinking as a tool for tuning electromechanical behaviour, EuroEAP 2018: 8th International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles, 5-6 June **2018** Lyon, France;
6. Codrin Tugui, Maria Cazacu, Assembling and comparative evaluation of stacked actuators based on different active elements, EuroEAP 2018: 8th International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles, 5-6 June **2018**, Lyon, France;
7. Mihail Iacob, Vasile Tiron, Codrin Tugui, Mihaela Dascalu, Maria Cazacu, Natural sodium bentonite - a filler with unexpected effects on silicones, EuroEAP 2018: 8th International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles, 5-6 June **2018**, Lyon, France;
8. Mihaela Dascalu, Mihail Iacob, Codrin Tugui, Adrian Bele, Carmen Racles, Maria Cazacu, An attempt to improve the performance of silicone dielectric elastomers through the filling strategy, EuroEAP 2018: 8th International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles, 5-6 June **2018**, Lyon, France;
9. Carmen Racles, Mihaela Dascalu, Adrian Bele, Codrin Tugui, Maria Cazacu, Polysiloxanes modified with Disperse Red 1 forming stimuli responsive free-standing thin film, EuroEAP 2018: 8th International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles, 5-6 June **2018**, Lyon, France;
10. Adrian Bele, Maria Cazacu, Marian Neagu, Mircea Popescu, Carmen Racles, Ghiocel Emil Ioanid, Instalatie modulara si procedeu pentru obtinerea generatoarelor polimerice stratificate, The 22nd International Exhibition of Inventics “INVENTICA 2018”, 27 –29 June **2018**, Iasi – Romania.

GreEnergy - *Scientific results*

PhD Thesis

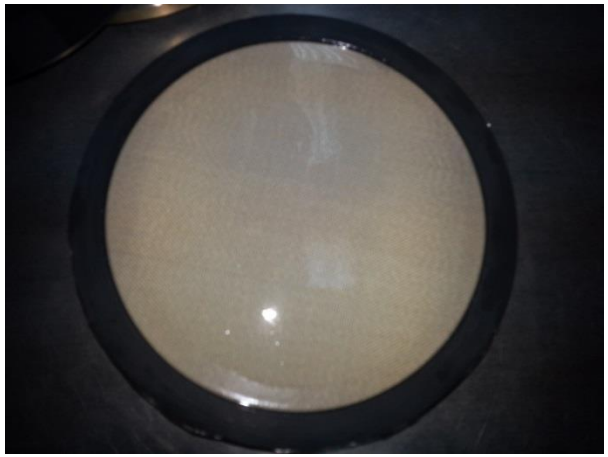
1. TUGUI Codrin, Electroactive silicone and silicone-organic networks, 21.07.2017. The aim of the thesis was to identify appropriate partners (inorganic and/or organic networks) and to modify and combine them with the siloxane network, in order to obtain new dielectric elastomers with superior electromechanical properties compared with existing materials.

2. BELE Adrian, Smart silicone materials, 25.10.2017. The aim of the thesis was to improve the electromechanical properties of silicone based dielectric elastomers by chemical modification of the polymers backbone or to obtain polymeric composites

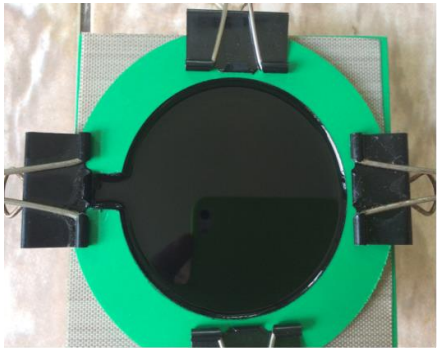
GreEnergy - *Scientific results*

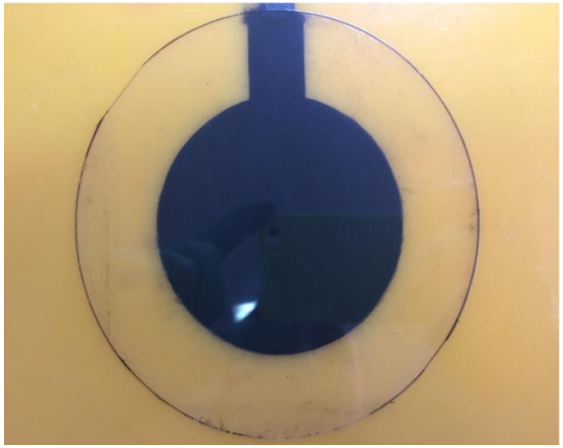
Pictures of obtained samples throughout project stages

- **Dielectric films (activity A1.3)**



- **Electrod films (activity A1.5 and A1.6).**

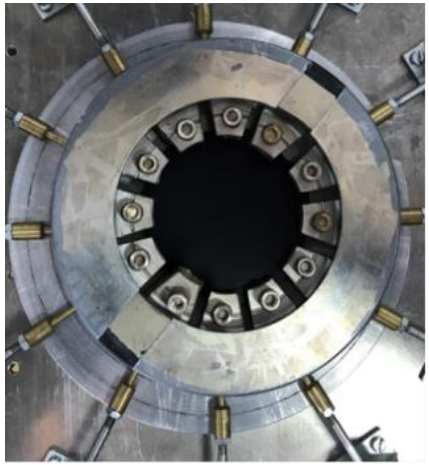


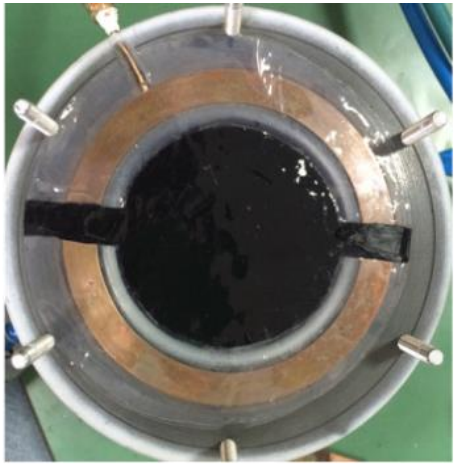


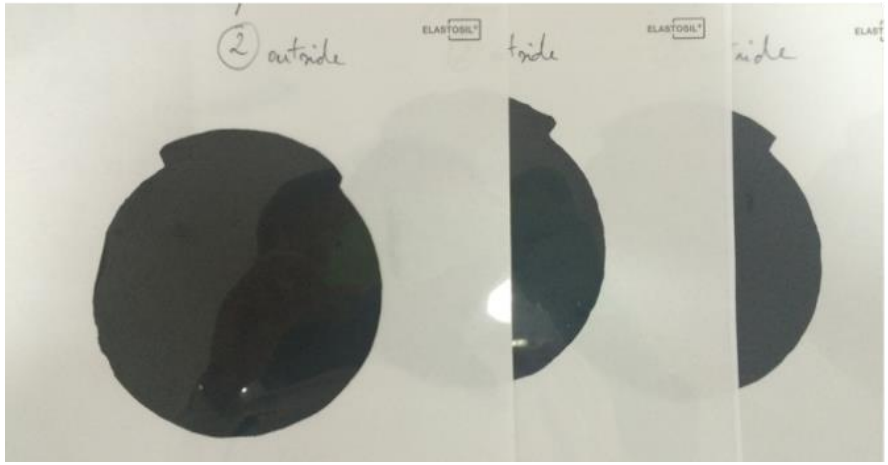
GreEnergy - *Scientific results*

Pictures of obtained samples thought project stages

●Elements for energy conversion units (activity A1.7).







GreEnergy - *Project Team*

PROJECT DIRECTOR
Dr Maria Cazacu,
Senior researcher (CSI)

Team membre
Dr Carmen Racles,
Senior researcher (CSI)

Team membre
Dr Mihaela Dascalu,
Postdoc

Team membre
Dr George Stiubianu,
Postdoc

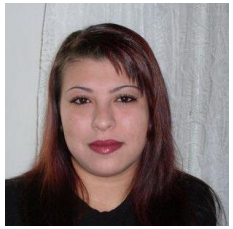
PhD student
Adrian Bele

PhD student
Codrin Tugui

PhD student
Mihail Iacob

Mechanical engineer
Mircea Popescu

Electrical engineer
Alin Negau



Technician
Roxana Solomon