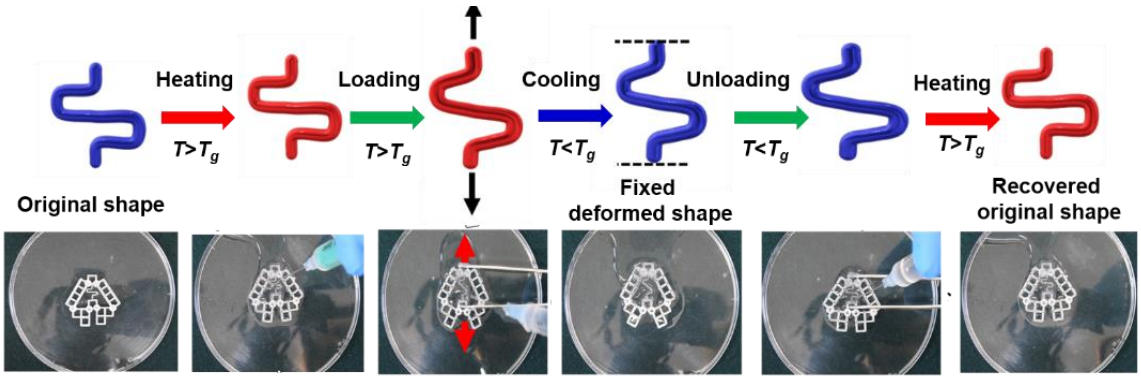
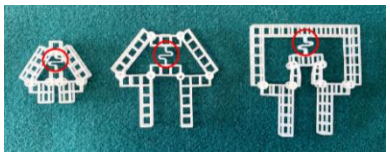
Comprehensive studies of the thermomechanical properties of innovative smart polymers for the development of actuators with multiple shape memory functions

Shape memory polymers (SMPs) are stimuli-responsive multifunctional materials that can change their shape in a predefined manner under an applied external stimulus, e.g. temperature changes. The mechanisms of SMP's shape memory behaviour differs from those in shape memory alloy (SMA) and are related to the fact that the elastic modulus of polymers dramatically differs at the temperatures above and below their glass transition temperature (T_g). Since the SMP's rigidity varies depending on the temperature, they can work as both sensors and actuators, enabling miniaturization, crucial for biomedical and aerospace applications.
The aim of the project is a comprehensive study of particularly noteworthy new generation of multiple-shape memory polymers that demonstrate the ability to memorize more than two various shapes in order to design self-adaptive devices and shape memory micro-actuators with triple or quadruple shape memory effects. Polyurethane shape memory polymer (PU-SMP) and thermoset shape memory epoxy (SMEp) produced by additive manufacturing (AM) towards applications in engineering, robotics, textiles, aerospace, biomedicine are considered.



The innovative solution uses a small, highly sensitive SMP element connected to a much larger one with an appropriate design in such a way that even a slight change in the shape of the sensor-actuator caused by a local change in temperature will result in the desired multiple effect of changing the shape of the self-adaptive device.



The idea is shown in more details on left; the sensor-actuator is in the red circle. The SMPs to be considered are AM photopolymers with various polymerization degrees obtained by different exposure time and PU-SMP combining two filaments with different glass transition temperatures T_g.

Using a new generation of the obtained multiple-shape memory polymers that demonstrate the ability to memorize more than two various shapes enables design micro-actuators with triple or quadruple shape memory functions. The stepped actuation of the actuator is achieved by triggering at different temperatures through step-by step heating. In the frames of the proposal the research explores the processability of SMPs with various T_g, including those close to body temperature for 4D printing of thermo-sensitive self-adaptive medical actuators with precise shape-morphing capabilities and applications in smart biomedical devices.

Development of the Project Idea in the frame of the Project Implementation

- 3D printing of SMP in order to obtain dual, triple or quadruple shape memory functions of the smart shape memory actuator under external stimuli
- Special design targeting on enlarging the Shape Memory Effect (SME) depending on the function applications
- Design of SMP actuators with multiple shape memory functions and investigation of their behavior under various thermal and mechanical loading conditions
- Comprehensive program of investigation of thermomechanical couplings of the SMPs during various loadings, including cyclic, carried out in various conditions
- Development of constitutive model for the investigated SMPs and its validation by using materials structure parameters and obtained experimental results

The knowledge about the multiple-shape memory polymers and their based micro-actuators with triple or quadruple shape memory effects will be discussed at seminars, lectures, science-popularizing events that PI and Research Team are often invited to, published in open access journals of the JCR list, presented at state and international conferences and schools,; e.g. Spring School for Young Researchers - New Trends in Experimental Mechanics http://ntem1.ippt.pan.pl/, organized for EuraSEM by Principal Investigator and Coinvestigator 1. The project webpage will be designed and up-dated. Implementation of the project will also strengthen scientific cooperation in Poland, e.g. with the University of Silesia and with international partners such as the Universidad Politécnica de Madrid in Spain, the Institute of Macromolecular Chemistry in Romania, the AICHI Institute of Technology, Toyota-city and the SMP Technologies Inc., Tokyo in Japan.