

Shape memory polymers (SMPs) are stimulus-responsive polymer materials which could recover their original shapes from the predetermined temporary shapes by means of a suitable environmental stimulus, such as heat, light, electricity, magnetic field or water etc. In comparison with other types of polymer materials such as electroactive elastomers and hydrogels, SMPs have unique and desirable shape memory capabilities owing to the pre-stored mechanical energy during the deformation stage. In terms of thermodynamics, SMP macromolecules are normally composed of two or more segments, at least one of which is the permanent segment and the others of which is reversible one. A relaxation could happen in the reversible segments at temperatures above the shape memory transition temperature. The potential of SMPs is determined by the number of temporal shapes they can efficiently be disclose and the ability to tune the shape memory transition temperature(s) for the targeted applications. Currently known SMPs are capable of successfully storing three, four and even five different shapes, i.e. they are multiple-SMPs.

Having reached the limits of the possibilities of existing approaches in the creation of SMPs, the development of SMPs went in such directions as: two-way shape memory effect (SME); multiple-shape memory effect; temperature memory effect; alternative SME actuation mechanisms; molecular origin of SME; surface shape memory effect, etc.

This project is aimed at creating an entirely new approach to the creation of polymer blends, which in turn will open up new possibilities in the design of multiple-SMPs with tailored shape memory and mechanical properties and in the understanding the mechanism of the polymer shape memory effect. We think that the blending of immiscible polymers could lead to an innovative approach to creating a new type of multiple-SMPs. Nowadays, the mixing of immiscible polymers remains a great challenge. This is because the entropy of mixing for macromolecules is inherently very low therefore, in most cases, the mixing of two or more polymers results in phase separation on the macroscopic scale. This fatal problem poses a significant barrier to producing many scientifically and technologically relevant homogeneous blends. To circumvent the macroscopic phase separation of polymers, several strategies have recently appeared to prepare polymer blends using supramolecular complexation, porous coordination polymers, fluid interfaces. However, it remains difficult to improve versatility, mass-productivity and/or compatibility.

Solid state mixing of immiscible polymers at the molecular level using severe plastic deformation (SPD) methods, i.e. a group of techniques involving very large strains and high pressure could represent an attractive pathway to multiple-SMPs formation especially as far as easy processing is concerned. Our pilot experiments showed that mixing of immiscible polymers is possible when using one of SPD methods - equal-channel multiangular extrusion. In particular, a pair of immiscible polymers which had never been molecularly compatibilized before, even in the melt - acrylonitrile-butadiene-styrene copolymer and semi-crystalline poly(ethylene terephthalate) - were blended under SPD to form a bulk material of multiple shape memory polymer.

This strategy offers several advantages for the preparation of polymer blends: a high versatility of applicable polymers and the possibility of achieving compatibilization at the molecular level without the need for any additives.

It is expected that many different combinations of a variety of polymers can be mixed by SPD. Subsequently, on their basis, a new type of SMPs will be formed. This study will concern various pairs of immiscible polymers. Various SPD methods will be used. The structure and properties of materials will be investigated using various techniques, including electron microscopies, solid-state nuclear magnetic resonance spectroscopy, broadband dielectric spectroscopy, polarized infrared spectroscopy, dynamic mechanical analysis, etc. Mechanisms of solid-state mixing of immiscible polymers will be established and physically based constitutive models for the mixing process of immiscible polymers in the solid state under SPD conditions will be formulated.