A continous flow synthesis of actuators based on liquid crystalline elastomers

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The use of liquid crystalline elastomers for actuator applications has been reported for several years. When the mesogens in a crosslinked liquid crystalline polymer change their orientation during a phase transition from the LC phase into the isotropic phase, the polymer backbone has to follow this motion, which results in a deformation of the material. This makes these compounds interesting canditates for the production of actuators.
To realize strong shape changes, it is necesary to orient the mesogens into a liquid crystalline monodomain before the polymer is crosslinked. This orientation step is very crucial in the preparation of good LC based actuators. Untill now, methods like the drawing of fibers or the streching of pre-crosslinked films have been used mainly, yielding macroscopically structured actuators.
Using microfluidics, we realized a continous flow synthesis of spherically shaped particles from a crosslinked liquid crystalline polymer. In this approach, a mixture of a liquid crystalline monomer [1] with crosslinker and UV-initiator are melted and injected through a very thin needle into a co-flowing stream of silicon oil. For this we used a very simple setup, self-build from needles and PTFE tubing [2]. The resulting droplets are then cooled into the liquid crystalline phase and exposed to UV light while still flowing. This initiates polymerization as well as crosslinking, producing solid particles which leave the reactor dispersed in oil.
The size of the particles can be controlled by several parameters, mainly the viscosity of the silicon oil and the flow rate ratio between oil and monomer. Thus we obtained particles with a diameter between 200 and 500 micrometers with a size variation coefficient as low as 1%.
Due to the parabolical flow velocity profile in the tubing, the mesogens in the monomer dropletts are preferentially oriented parallel to the flow direction when the polymerization takes place. This gives the particles characteristics of a liquid crystalline monodomain.
Upon heating them into the isotropic phase under a microscope the particles change their shape from a spherical to a rod like conformation. Thereby length changes of more then 70% can be observed. The actuation is completely

reversible and very fast, which was shown by rapidly cooling particles in the streched conformation by a flow of cold air. We also show that the intensity of the shape change strongly depends on the flow rate at which the particles were polymerized. The same conformational change can be achieved by swelling the particles with a suitable solvent, which also induces a phase transition.

(1) Donald L. Thomsen III, Patrick Keller, Jawad Naciri, Roger Pink, Hong Jeon, Devanand Shenoy, Banahalli R. Ratna, Macromolecules 2001, 34, 5868-5875
(2) Michel Bouquey, Christophe Serra, Nicolas Berton, Laurent Prat, Georges Hadziioannou, Chemical Engineering Journal 2008, 135S, S93–S98

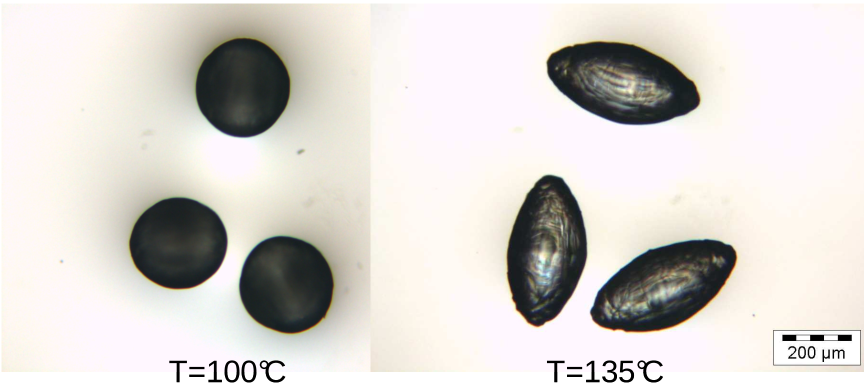

Fig. 1: Microscopy images of the particles deformation