Liquid Crystal Elastomer Fibers for Application in Soft Robotics and Medical Technology

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Abstract: Liquid crystal elastomers (LCE) are an emerging material class known for their ability to reversibly contract and perform work. Therefore, especially in soft robotics and as artificial muscles this material class offers great potential to replace electromotoric-driven motion. Currently LCE are mainly fabricated as thin films, limiting their potential applications. Here, we present a wet spinning process that allows the continuous production of liquid crystal elastomer fibers (LCEF).

LCEF were prepared via hydrosilation of the elastomer PMHS and liquid crystal (LC) MBB using a mixture of 11UB and vinyl-terminated PDMS as crosslinks. During wet spinning, a heated oil bath was used to initiate the first thermal crosslinking step to achieve fiber shape stability. Fibers were then drawn with a ratio of max. 2.3. Shear stress during this process was used to align the LC, generating an anisotropic state. After drawing, a second thermal crosslinking step was applied to fixate LC orientation along the fiber axis. This orientation is required to achieve contractile behavior of the LCEF after surpassing nematic-isotropic transition temperature (T_{NI}) [1]. At this temperature, LC are enabled to reorientate/ realign, aiming for a state of maximum entropy or perfect isotropy. The rotation of the LC is transferred onto the elastomeric backbone, in which polymer chains will therefore lose their stretched state, resulting in a macroscopic contraction of the fiber.

Table 1: comparison of mechanical, contractile properties and specific power of LCEF with literature values of SMP, LCE, and human muscle [2,3]

	contraction [%]	E-modulus [MPa]	contractile strength [MPa]	spec. power [W/kg]
Human muscle	20 – 50	10 – 60	0.1 – 0.35	50 – 284
SMP	> 300	0.5 – 1	~ 2 – 3	~ 5 – 10
SMP-fibers	> 300	~ 0.5	2.3	6.5
LCE	19 – 45	-	0.01 – 0.12	0.1 – 0.4
LCEF	5 – 10	2.5	0.23	1 – 4

The as spun LCEF were characterized regarding mechanical properties, contraction, and mass-specific power and compared to LCE-films, shape-memory polymers (SMP), SMP-fibers, as well as human muscle (Table 1). Furthermore, LCEF were braided and twilled to investigate influence of these textile processes regarding mechanical and contractive behavior.

Results underline the high potential of LCEF to act as artificial muscles with a property profile similar to native muscle tissue. Comparison with LCE-films from literature showed further development potential of the spinning method to increase LC orientation and therefore contractile capability of the fibers.

Ongoing research is focusing on improvements regarding material composition and integration of a percolation network to enable Joule heating of the LCEF. This will enable the textiles to get electrically stimulated, paving the road towards applications in soft robotics and especially medical technology, e. g. prosthetics.

Keywords: *Liquid Crystal Elastomer Fiber, Wet spinning, Artificial Muscle, Soft Actuator*

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