

Abstract

Liquid crystal elastomers (LCEs) are a group of smart materials that can reversibly change their shape, color, refractive index, and other physical properties under external stimuli. The properties of these materials are closely tied to their molecular alignment. Research on LCEs includes the synthesis of new compounds that enable materials to respond to different ranges of stimuli or exhibit specific parameters (e.g., optomechanical), the development of methods to control geometry and alignment, and the integration of LCEs into systems, such as e.g. actuators or optical components.

This dissertation describes light-driven systems based on thermoresponsive, dye-doped LCEs. It presents new methods for fabricating and aligning the elastomer-based components, as well as millimeter-scale devices that use LCEs as actuators heated through absorption of light. The work consists of a cycle of five articles dedicated to this topic.

The automated station for producing LCE films with predefined alignment (RoboLEC), described in the first publication, enables the fabrication of dye-doped materials suitable for use in light-driven systems. The user loads glass slides coated with a photoalignment layer, uploads images that define the alignment direction, and supplies a UV-curable adhesive with microspheres of a specified diameter to set the sample thickness. The process runs fully automatically, and the number of samples is limited by the supply of these materials.

The second article presents an overview of LCE results obtained within the research group in which I conducted my research. In addition to previously published outcomes, it introduces a previously unreported robot that mimics water-strider locomotion and moves on the water surface. Its leg motion is driven by an LCE “muscle”. Muscle deformation is induced by laser pulses at a frequency of a few hertz. Although the robot is about 6,000 times slower than its natural counterparts, to the best of my knowledge it is the first report of a water-strider robot at natural scale.

The third article describes a robot that imitates snail locomotion at natural scale. The device travels over surfaces coated with synthetic “mucus” (e.g., glycerine), enabling motion at various orientations relative to gravity, including vertical and upside-down. Locomotion is driven by a deformation wave propagating along the robot’s body, generated by laser scanning of the LCE.

The fourth and fifth articles present a rotary and linear motor, respectively. In both designs, motion is driven by scanning a laser beam over LCE elements, which allows the operating direction of each motor to be controlled. The rotary motor employs an LCE ring whose alignment forms a +1 topological defect, whereas the actuators in the linear motor feature a periodically varying, stripe-domain alignment along their length, produced using the novel rubbing-overwrite method described in the fifth publication.

Key words: liquid crystal elastomers, smart materials, photoresponsive polymers, actuators, soft robots, light-driven systems, motors