Liquid Crystal Elastomer Kirigami

Irina Malina Strugaru[1], Quentin Martinet[1], Mickael Ly[1], Bernd Bickel[2], and Jeremie Palacci[1]

[1]Institute of Science and Technology [Klosterneuburg, Austria] – Austria
[2]ETH Zurich – Switzerland

Abstract

Liquid crystal elastomers (LCEs) are soft responsive materials where orientable liquid crystal units (mesogens) are components of a polymer structure. They present exciting opportunities for soft robotics and environmentally-adaptive systems owing to their heat-responsive deformation capabilities: more than 25% uniaxial contraction when heated uniformly from 25C to 80C. The programmability of LCEs is however challenging, as their material properties and heat-induced deformation are prescribed by chemical synthesis and by alignment of the mesogens. In effect, LCE structures are typically programmed by microscopic patterning. Here we use macroscopic topology alterations, namely (kirigami) cuts to control the heat-deformation and mechanical properties of uniaxially-aligned LCEs. The cuts are oriented orthogonal to the alignment of the LCE sheets. We characterize the mechanical response of tethered LCE kirigami under heating and show that it maps to the uniaxial extension of an LCE kirigami at constant high temperature. This allows us to model and quantify the deformation and tensile response of the LCE kirigami with mechanical FEM simulations. We prove that cuts made into LCEs enable us to program their elastic properties and their heat-actuation force. Further we are able to design heat-deployable structures with multiple deformation modes. Finally, we use kirigami patterns to tap into the viscoelastic behavior of the LCE sheets and showcase structures with tunable recoil dynamics. Altogether, we demonstrate that LCE kirigami offer opportunities beyond conventional soft robots or kirigami.