Direct printing the director field of liquid crystal elastomers to program Gaussian curvature under the nematic-isotropic phase change.

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Abstract

Active materials aim to transform the material itself into a mechanism, in this area the nematic-to-isotropic transition of the liquid crystal elastomer is an interesting candidate to create this material mechanism and this is due to the contraction/expansion experienced in the nematic-isotropic transition experienced by this type of materials. To accomplish this, it is necessary to set the director field of the nematic phase before crosslinking the elastomer to encode a given structure or mechanism. In this area, there are interesting advances in the forward design, this means if a director field is set, predicts the deformed configuration of the structure of the material when it is driven to the isotropic phase(1), and the inverse design of the director field, given a target shape in the isotropic state what it is the director field in the nematic phase(2). In both cases, the director field is a scalar field that must be imprinted in the material, usually in thin films. In this area exists different technologies, but the most common are optical and mechanical alignment, the last one aligns the oligomers or polymer chains by mechanical shearing, so to pattern the director field molds are used but recently has been shown the possibility to get high levels of alignment by extruding the material through a nozzle, this open the possibility to directly print the director field(3)(4), this impose a challenge because the description of the director field is a continuum or discrete scalar field of directions, this have to be translated to a discrete print path with a constant or constrained width.

In this work we present the procedures for a given director field to find the proper discretization of it to be able to print it, by constructing a stripe pattern from the director field with a constant spacing given by the nozzle of the 3d printer, for this we use the procedural phasor noise technique(5), and order the be able to print a printing path is extracted from this stripe pattern. The 3D printing technique used is direct ink writing(6) implemented in the laboratory with UV light source to crosslink the oligomers at the moment the material leaves the printer nozzle, allowing to set the director field of the nematic phase in the direction of motion of the nozzle. This manufacturing tool allows us to experimentally study the mechanical effect of creating different point defects or discontinuities in the director field, yielding out-of-plane deformation with a characteristic Gaussian curvature. Also, we present our implementation of the inverse design of shells following the works of Hillel et al.(2) but setting the director field by 3D printing.

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