Discovering Geometry and the Materials Applications

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Abstract

Geometry is concerned with the properties of configurations of points, lines, and circles, while topology is concerned with space, dimension, and transformation. Geometry is also materials independent and scale invariant. By introducing holes and cuts in 2D sheets, we demonstrate dramatic shape change and super-conformability via expanding or collapsing of the periodic hole arrays without deforming individual lattice units[1,2]. When choosing the cuts and geometry correctly, we show folding into the third dimension, known as kirigami. The kirigami structures can be rendered pluripotent, that is changing into different 3D structures from the same 2D sheet[3-5]. We explore their potential applications in energy efficient building facade, super-stretchable and shape conformable energy storage devices and medical devices, as well as bioinspired robotics.

Programmable shape-shifting materials can take different physical forms to achieve multifunctionality in a dynamic and controllable manner. Through designs of geometric surface patterns, e.g. microchannels, we program topological defects, and thus, the orientational elasticity in liquid crystal elastomers (LCEs), to direct folding of the 2D sheets into 3D shapes[6]. Taking this knowledge of guided inhomogeneous local deformations in LCEs, we then tackle the inverse problem – pre-programming a sheet to take an arbitrary desired 3D shape[7]. We show how blueprints for arbitrary surface geometries can be generated using approximate numerical methods, and how local extrinsic curvatures can be generated to assist in properly converting these geometries into shapes. We successfully produce flat sheets of LCEs with precise and local control of the molecular orientation, which, upon thermal activation, take arbitrary desired shapes, such as a face (Figure 1). The general design principles will allow for exploration of unmet needs in flexible electronics, aerospace, medical devices and cosmetics. Lastly, I will show the prospective of taking geometry to create smart fabrics.

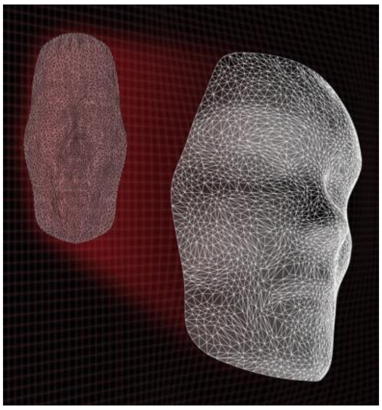

Figure 1: Illustration of the design of local geometries in a 2D sheet of liquid crystalline elastomer for heat actuated formation of a face.

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