Constriction and Expansion of Liquid Crystal Elastomers

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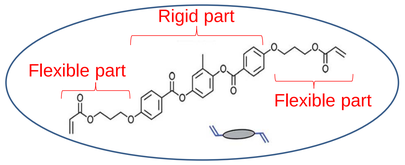
Abstract

The purpose of this study was to demonstrate the expansion and contraction of liquid crystal elastomers (LCEs) during temperature change. Liquid crystals (LCs) demonstrate both liquid and crystal properties and when they are formed into elastomers, they are heat responsive and contract in length when placed in contact with heat. When they cool, LCEs return to their original shape and size. The strain of the LCE samples was calculated as they were heated to 130˚C by 10˚ intervals and the strain was graphed to decrease linearly in length and increase linearly in width. Through this experiment, scientists can better understand the anisotropic properties of LCEs when they work with more advanced models of LCE, such as the CNT-LCE.

Background

Liquid Crystal Monomer



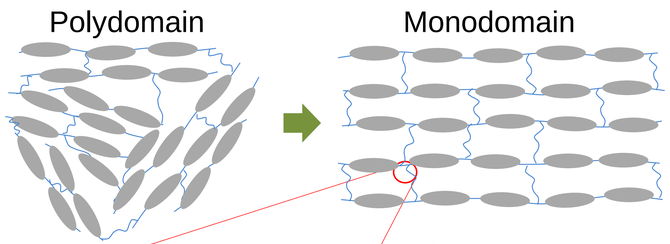
LCs have properties of both Liquid and Crystal when subjected to temperature change

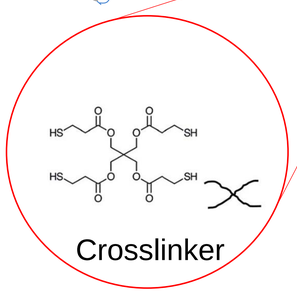
Ref.) *Chem. Soc. Rev.*, **2007**, *36*, 1857.

< Schematic diagram of Liquid Crystal polymer >

A chain of LC monomers connected by covalent bonds

Liquid Crystal Elastomer

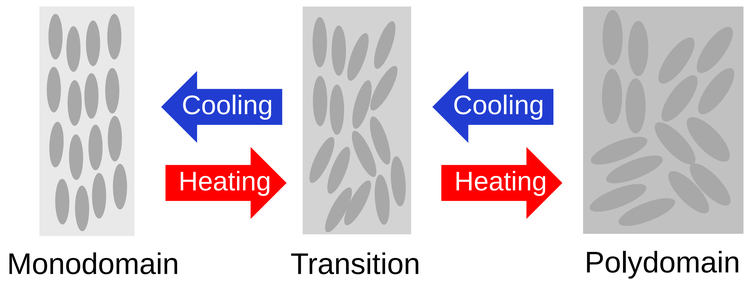




Crosslinker

- LC polymers are crosslinked with other LC polymer chains, creating an elastomer (LCE)
- Coupling of LC and Elastomeric properties induces deformity of the elastomer by LC orientation change
- When stretched or heated, LC orientation also changes

When subjected to external stimuli:



Ref.) *Phil. Trans. R. Soc. A*, **2006**, *364*, 2763.

- LCE contracts in the parallel direction of LC orientation and expands in the vertical direction when being heated up because of the increased disorder of LC orientation.
- The change is reversible, which allows it to be potentially used for artificial muscles.

Experimental Procedure

LCE Preparation

LC (RM257) is dissolved in toluene until transparent at 85°C

↓

Thiol (PETMP and EDDET) and catalyst solution is added

↓

Photoinitiator is added to solution, so later UV light can help activate bonds between LC monomers

↓

DPA, a catalyst, is added to the solution

↓

Bubbles are removed and LCE is poured into a mold and left overnight for the first-step crosslinking reaction

↓

LCE is dried in oven (85°C) for 24 h

↓

Prestretch is applied and LCE is cured with UV light to ensure samples with monodomain configuration

Thermal Test

LCE samples were measured at room temperature and placed on a hot plate

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LCE samples were measured at room temperature and placed on a hot plate

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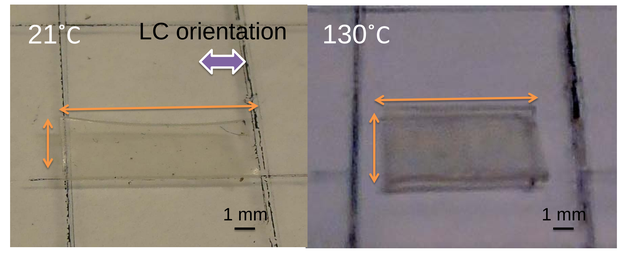
The temperature of the hot plate was increased by 10˚C and the sample re-measured until 130˚C

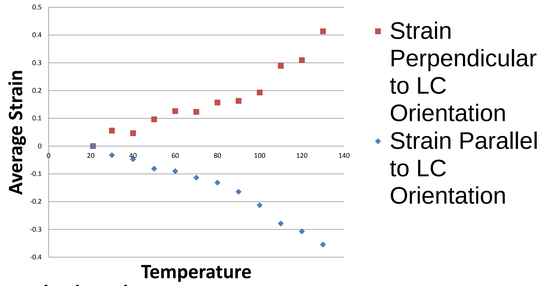
Results and Discussion



<LCE length change with temperature variation>

$$\text{Strain} = \frac{L - L_0}{L_0}$$

Where L_0 is the original length and L is the final length



<Strain variation in response to temperature>

- As the LCE samples heat up by 10˚C intervals, the length contracts and the width expands, thus the strain also decreases linearly with respect to length and increases linearly with respect to width
- When cooled, LCE samples return to their original shape because the UV light has solidified the bonds and the crosslinks in the elastomer

Conclusion

Liquid crystal elastomers exhibit many unique properties, one of which includes contracting in length and expanding in width when exposed to heat. In this study, we made LCE samples and conducted a thermal test on them; we found a linear trend in the sample strain. These findings may be used in further applications of LCEs when experimenting with more complex forms and structures.

References

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