Liquid Crystals Today, 2014
http://dx.doi.org/10.1080/1358314X.2014.898880

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Book Review

Liquid crystal elastomers: materials and applications, edited by W.H. de Jeu, Berlin Heidelberg, Springer-Verlag, 2012, 239 pp., £116.39 (hardcover), ISBN 9783642315817

Springer-Verlag has recently published this book as volume 250 in the series *Advances in Polymer Science*; the focus is on the synthesis and characterisation of liquid-crystalline elastomers (LCEs), together with their uses and applications. Since the prediction of such materials by P.G. de Gennes back in the 1970s and their development by H. Finkelmann during the 1980s, these materials have grown and reached maturity, but there is still work to be done to bring them to the industrial arena and use them as actuators, sensors and artificial muscles. For that reason, chemists, physicists and engineers have been working together during the last decades, and this book is showing a very important part of this multidisciplinary field.

In the first chapter, the synthesis of liquid-crystalline networks is described in detail, with emphasis laid on the classification of different polymeric systems as function of the attachment of the mesogens to the polymer backbone. Thus, the characteristic and synthetic routes for the obtaining of side-chain or main-chain LCEs are explained in detail, together with the specific polymerisation techniques used to achieve polymer networks. This first part of the chapter is followed by the characterisation techniques used for the determination of the degree of cross-linking (swelling and stress–strain experiments) and the obtained mesophases (differential scanning calorimetry, polarised optical microscopy and X-ray diffraction). The most important part of this chapter is dedicated to the orientational process of such materials needed for the obtaining of monodomains of LCEs by means of controlled uniaxial deformation, surface effects, magnetic fields or anisotropic deswelling of the samples prior fixation of the material. Finally, the chapter gives examples of the synthetic procedure for the synthesis of LCEs (e.g. nematic, cholesteric, smectic and lyotropic polymer networks).

Chapter 2 is devoted to the use of LCEs as actuators when an external stimulus is applied and the corresponding contraction, expansion or even bending of the sample occurs. In this way, LCE devices, like grippers, motors and valves, can be constructed and integrated in microsystems technology. Besides these real-world miniaturised applications, the chapter also addresses the so-called ferroelectric LCEs. Such materials have the ability to transform mechanical work into electrical energy and vice versa, envisioning a potential route for using such materials for energy conversion devices.

Chapter 3 is dedicated to the use and interaction of light with LCEs. Due to the orientational order imposed during the sample preparation, LCEs are optically birefringent and can be used as bifocal contact lenses. One special case is that of cholesteric LCEs, where the helical axis of the chiral molecules is perpendicular to the film's major surface, and by applying a uniaxial compression, the pitch can be shortened. Thus, the reflected light or cholesteric band edge can be tuned and the emitted light selected. Finally, the chapter also deals with the optomechanical effect from LCEs when light-sensitive molecules are incorporated into the network. When the dye molecules absorb light, they undergo a change in their architecture, which induces a local disorder in the mesophase, and the corresponding change in shape of the sample. If such a sample is clamped at both extremes, a mechanical force immediately appears.

Chapter 4 explains the properties of LCEs swollen by low molecular-mass liquid crystals. The final soft nematic gels exhibit a reduced need of the external applied field when actuation is desired, and an enhanced electro-opto-mechanical effect. The electro-mechanical effect appears when a DC field is applied to a nematic gel. Depending on the nature of the mesogens which constitute the polymer network, the nematic solvent and the degree of orientation of the sample, a shortening in one of the directions perpendicular to the applied field and an expansion in the parallel one can be observed while keeping the volume on the sample constant. In this sense, a soft actuator can be constructed which responds to electrical fields due to the rotation of the domains towards the field direction. Since the director aligns parallel to the electrodes' normal, the incorporation of polarisers after the electrodes allows for the optical observation of such rotational effect. Moreover, an electro-optical device can be designed, and light can be either transmitted in the field-off state or suppressed when electrical field is applied.

Chapter 5 discusses the nature of the nematic-to-isotropic transition in LCEs studied by high-resolution calorimetric and nuclear magnetic resonance experiments. Parameters like the cross-linking density, cross-linking temperature and applied stress field are crucial for the obtaining of a subcritial (discontinuous or first-order transition) or supercritical (continuous or second-order transition) thermomechanical behaviour. Specifically, heat capacity experiments can distinguish between both cases and determine the latent heat for the liquid crystal-to-nematic transition, which is non-zero for a discontinuous behaviour and zero for the continuous one. Deuterium nuclear magnetic resonance spectra from LCEs show the same behaviour as the low molecular-mass mesogens: a splitting of the signal into a doublet, which is related to the order parameter and the alignment of the domains in the sample in the liquid-crystalline phase. When isotropisation occurs, this doublet becomes a single peak. Thus, the nature of the phase transition can be determined when analysing the presence or absence of a doublet and the distance of the peaks at temperature above the clearing temperature. The combination of both techniques allows for the differentiation between a fast-response material (subcritical, nematic-to isotropic) or a smooth change in shape material (supercritical, nematic-to-paranematic).

Chapter 6 introduces the most powerful technique for the analysis and understanding of both mesophases and their degree of order: X-ray scattering. In this chapter, nematic and smectic LCEs are discussed together with the connectivity of the mesogens. Nematic LCEs show a broad peak related to the mesogen-to-mesogen distance in the sub-nanometre scale. The order parameter, which is directly connected to the macroscopic length of the sample, can be calculated from the azimuthal distribution of the signal. The results on nematic LCEs demonstrate that there is no possibility to avoid the internal stress, which creates a mechanical random field and leads to a critical or supercritical thermomechanical behaviour of the samples. Smectic LCEs show sharper peaks, in addition to the mesogen-to-mesogen peak, which are related to the formation of layers and the distance between them in the nanometre scale. The shape analysis of these quasi-long order peaks reveals that such systems are well aligned, but the position of the layers is frustrated due to the random presence of the cross-linker, which acts as an impurity.

This book is an essential text for those who want to learn about the chemistry, physics and applications of LCEs after the retirement from the academia of some of its contributors. The first chapter of the book is the most extended text ever written about the chemistry and characterisation of LCEs. The second chapter is devoted mostly to the fabrication of devices; the LCE-microdevices will receive increased attention in the near future due to the fascinating properties and low cost of these smart materials. The following chapters show very interesting specific examples of the physics of LCEs which could lead to applications in the future. On the whole, the book is a very relevant piece of scientific literature which has been published as a legacy for the next generation of scientists.

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