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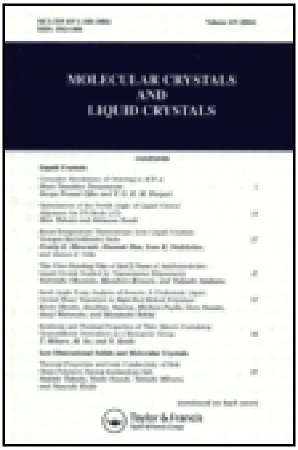

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Electrical Deformation of Thermotropic Liquid-Crystalline Polymer Gels

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ELECTRICAL DEFORMATION OF THERMOTROPIC LIQUID-CRYSTALLINE POLYMER GELS[1)]

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Abstract Liquid-crystalline elastomer carrying cyanobiphenyl side groups was synthesized by radical copolymerization of 6-(4'-cyanobiphenyl-4-yloxy)hexyl acrylate and hexamethylene diacrylate. Liquid-crystalline elastomer was swollen in a low molecular weight liquid crystal. Swollen elastomer in the nematic phase quickly deformed by application of DC voltage. The response time of electrical deformation was determined by image analysis.

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INTRODUCTION

It is well known that polymer gels change their volume and shape reversibly, dependent on several external physicochemical factors, such as temperature, solvent composition, ionic strength, pH, electric field, and light.[2,3)] The response time of volume change was proportional to the square of the linear size of the gel. To improve response time, we proposed a new energy conversion system that is driven by the rearrangement of solvent molecules induced by outside stimulus. Low molecular weight liquid crystals (LLC) can easily rearrange their orientation under an electric field. It is thought that the electrical reorientation of LLC makes it possible to deform the polymer network reversibly. In the previous paper, we demonstrated the electrical deformation of the liquid-crystalline (LC) gel which consists of side-chain type liquid-crystalline elastomer (LCE) having cyanobiphenyl mesogenic group and LLC having same mesogenic group.[4)] The response time of the shape change was less than 1 s. Same phenomena were also reported by Zentel[5)] and Mitchell et al.[6)] However, the response time of shape change have not been investigated in detail. In this work, the response time of the electrical shape change was determined by image analysis

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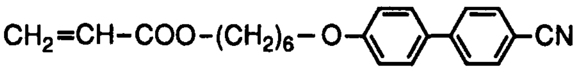
techniques using VTR system.

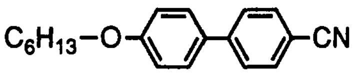
EXPERIMENTAL

Side-chain type LCE was prepared by radical copolymerization of the mesogenic monomer (I) and diacrylate monomer (II) as a crosslinker with α,α'-azobisisobutyronitrile as an initiator.[4] 4-cyano-4'-hexyloxybiphenyl (LLC) (III) was used as a solvent. Optical microscopic observation of anisotropic swelling and electrical deformation was carried out with the electro-optical cell consisting of two SnO_2 glass electrodes and a teflon spacer of 0.23 mm thickness (Figure 1). Temperature of the cell was controlled by a Mettler FP 82 hot stage. The electrical deformation of LC gel was recorded on the microscopic VTR system consisting of an Olympus BH-2 polarizing microscope equipped with a SONY DXC-930 CCD color video camera and a SONY EVO-9650 Hi-8 video cassette recorder.



(I)

$CH_2{=}CH{-}COO{-}(CH_2)_6{-}COO{-}CH{=}CH_2$ (II)



(III)

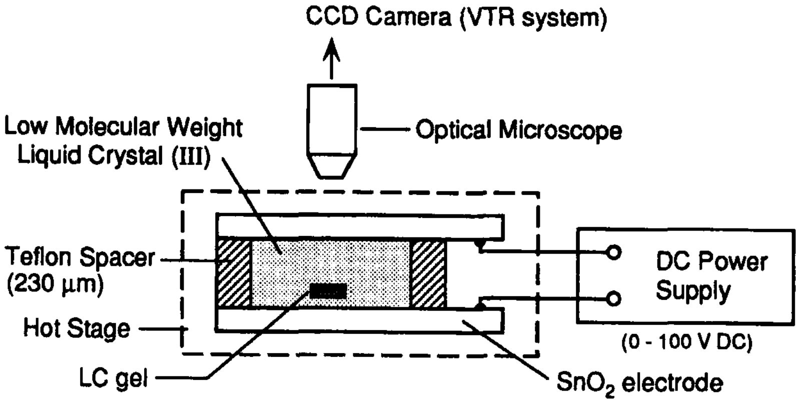


FIGURE 1. Structure of electro-optic cell used in this study.

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RESULTS AND DISCUSSION

Small pieces of LCE were allowed to heat up to 100 ° C in (III) with a nematic-isotropic transition temperature ($T_{N\text{-}I}$) of 75.9 ° C. LCE swelled isotropically about 5-6 times by weight at an equilibrium state in (III). Isotropic gel was changed to anisotropic gel (LC gel) by cooling from 100 ° C to 50 ° C. The degree of swelling of the gel slightly decreased by the cooling. When the temperature was raised again and held at 76 ° C, (III) underwent the phase transition from nematic to isotropic, but the LC gels remained unchanged in the nematic phase as it did. Figure 2 shows the microscopic picture of the LC gel in the electro-optic cell. The electro-mechanical effect was examined at this biphasic condition. Rapid bending of the LC gel was observed when DC voltage was applied to the direction perpendicular to the plane of Figure 2. The amount of deformation produced by applying 70 V DC is indicated by the arrow in Figure 2. The response time of the shape change under a DC electric field was determined by image analysis techniques. Figure 3 shows the time profile of the electrical deformation of LC gel. As shown in Figure 3, the shape change of LC gel was completed in 300 msec. It was seen from the image analysis that the electrical shape change of the LC gel was 10-100 times slower than the electrical orientation change of LLC. The original shape was recovered by the removal of the electric field. The deformation was completely reversible and could be repeated many times by repeated DC application. The relationship between the electrical reorientation of LLC and the electrical shape change of the LC network is under investigation in detail.

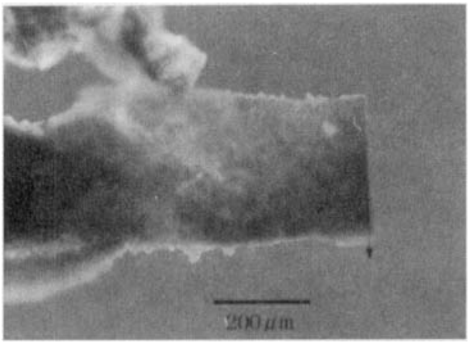

FIGURE 2. Optical microscopic picture of LC gel in the electro-optic cell at 76 ° C. LC gel was immersed in isotropic LLC (III). Electric field induced shape change was indicated by the arrow.

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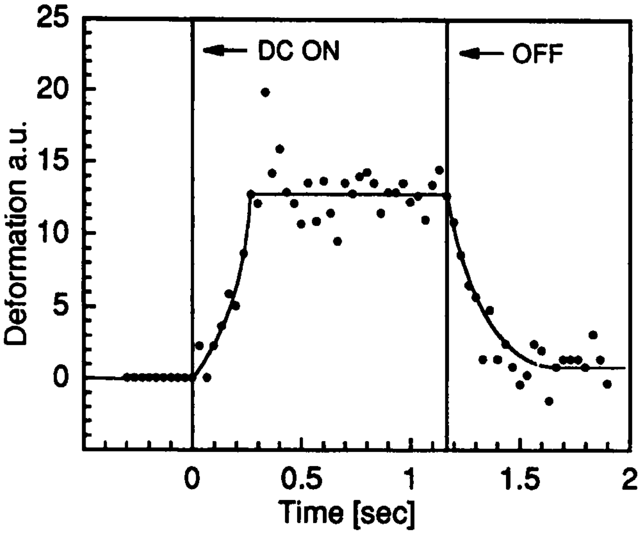

FIGURE 3. Time profiles of electrical shape change of LC gel. 10 a.u. (arbitrary units) is equivalent to 21.4 mm.

ACKNOWLEDGMENT

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