Experimental Studies on Phase Transition in a Ferroelectric Liquid Crystal

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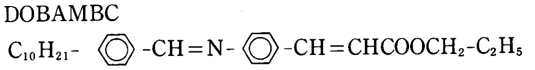
The temperature dependence of the optical transmittance of the ferroelectric liquid crystal CS-1011 has ben studied under the external electric field. The typical D-E hysteresis curves were measured by the optical method.

1 Introduction

Since the discovery of ferroelectricity in the chiral smectic C phase of DOBAMBC (*p-decyloxybenzylidene p'-amino 2-methyl-butyl cinnamate*) by Meyer et al.[1], ferroelectric liquid crystals have attracted great attention for their interesting physical properties[2-5]. . The proposal of various types of electro-optic devices with a high response time also accelerate the synthesis of new ferroelectric crystals. Various types of materials have been developed, however, most of them have been small spontaneous polarizations of the order of $10^{-9}C/cm^2$. Quite recently Sakurai et al. have succeeded in synthesizing a new series of ferroelectric liquid crystals with spontaneous polarization exceeding $10^{-7}C/cm^2$ [6]. The large spontaneous polarization was obtained by decreasing the distance between the chiral carbon and the molecular dipole moment.

Keller et al. also reported a relatively large spontaneous polarization in HOBACPC (*p-hexyloxybenzylidene p'-amino 2-chloropropyl cinnamate*). [7] Molecular structures of the ferroelectric liquid crystals of DOBAMBC and HOBACPC are shown in Figure 1.

DOBAMBC



HOBACPC

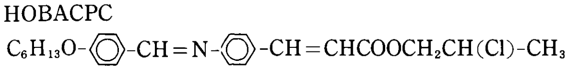


Fig.1. Molecular structures of the ferroelectric and antiferroelectric liquid crystals (a)DOBAMBC and (b)HOBACPC.

From practical view points, ferroelectricity in a wide temperature range around room temperature and the high stability are needed in the ferroelectric liquid crystal with a large spontaneous polarization.

In the Sm C* phase, DOBAMBC has a helical structure, which can be observed as dark and bright stripes appearing with some period.

Meyer et at. observed experimentally the change of the conoscopic image by applying electric field and estimate spontaneous polarization to be $0.04\mu C/cm^2$. They observed the phase transition from the Sm A to the Sm C phase of chiral DOBAMBC liquid crystal. L.J.Yu et al. observed pyroelectricity in this material.[3] Though these two papers indicate that this material has ferroelectric character, there had been no detailed report on the dielectric behavior of this materials. The temperature dependence of the dielectric constant and the spontaneous polarization had been studied by Yoshino et al..[8]

The antiferroelectric liquid crystals have been also studied from both practical and physical points of view. The first observation of the antiferroelectricity of the liquid crystal was made in MHPOBC (Fig.1). [9] An optically pure MHPOBC has its phase sequence of Sm A-Sm C_α*-Sm C*-Sm C_α*-Sm C_A, where Sm C_A* is antiferroelectric phase.

In this paper, we report the transient properties of the transitions of the ferroelectric liquid crystal CS-1011 induced by an electric field.

2 Experimental

Samples CS-1011 used in the present experiment was synthesized by Chisso Co. Ltd.. The transition temperatures are

Sm C*-(55.8℃) -Sm A-(78.0℃) -Ch-(91.3℃) -Iso.

The liquid crystal was placed between two nesa -coated glass plates. The thickness of the cell was 1.5μm. It was aligned by rubbing after coating the plate with a polyimide film. The area of the electrode was 1.2 x 2.2 cm^2. The perspective of the prepared samples are shown in Fig. 2.

In these cells, stripes reflecting helical structures were observed both Sm C* and Sm C_A* eith a polarizing microscope (OLYMPUS M4-400). Figure 3 shows the block diagrams of the apparatus used for observing the domain structures. The pattern of the stripes were monitored by video camera (SHIMAZDU CCD-Z1) and recorded by the computer (NEC PC-9801VM) with the interface (Logitec LGA-91) to process the image.

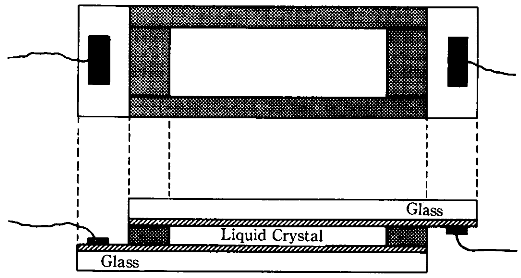


Fig.2. Schematic illustration of liquid crystal cell.

The observed data were stored in the video recorder (NEC VC-F8500) . A light beam of the He -Ne laser (NEC GLG-5000) was used for the measurement of an optical transmittance. The light was detected by the photo diode (TPS708) , and recorded by a XY-plotter (GRAPHTEC WX1100) . The electric field effects were observed by using the low frequency oscillator(NF FG-104TC) and the high voltage amplifier (DEPCO BOP 1000M) with the frequency range from 0.01 to 0.1 Hz.

3 Results and Discussion

The ferroelectricity of this liquid crystal were investigated well by using the dielectric measurement. D-E characteristics were also studied by the hysteresis curves.[8]

In this paper, we examined the D-E characteristics by the optical method at the temperature around

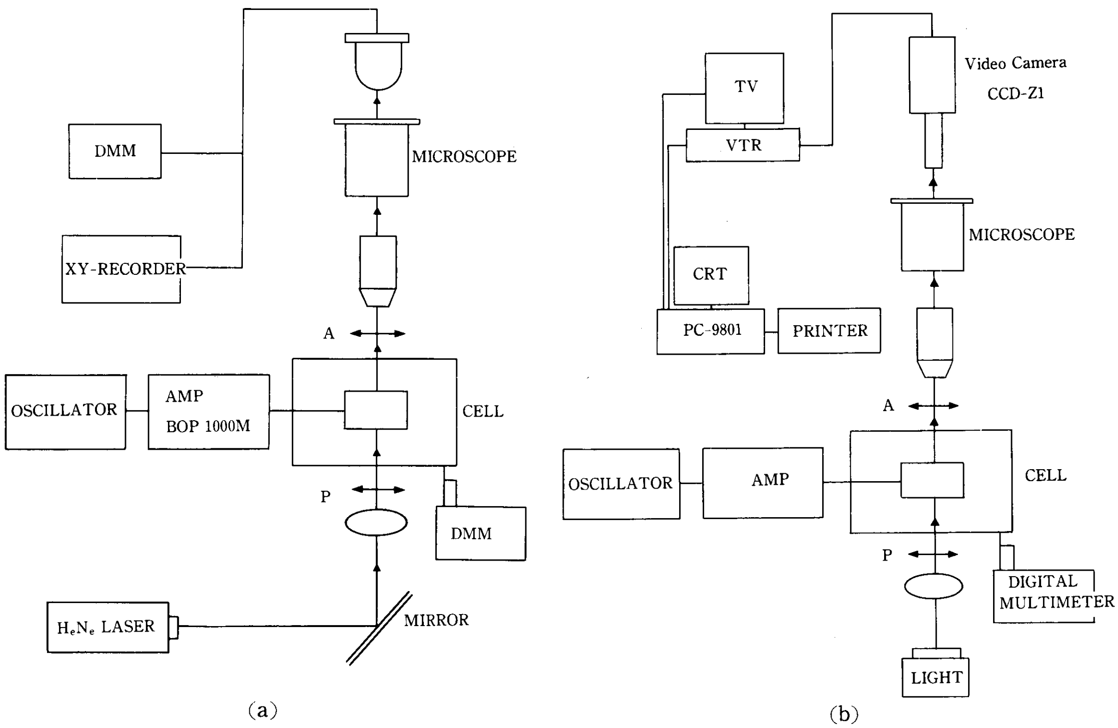


Fig.3. Block diagram of the (a)transmittance experiment, and (b)the system for taking photograph.

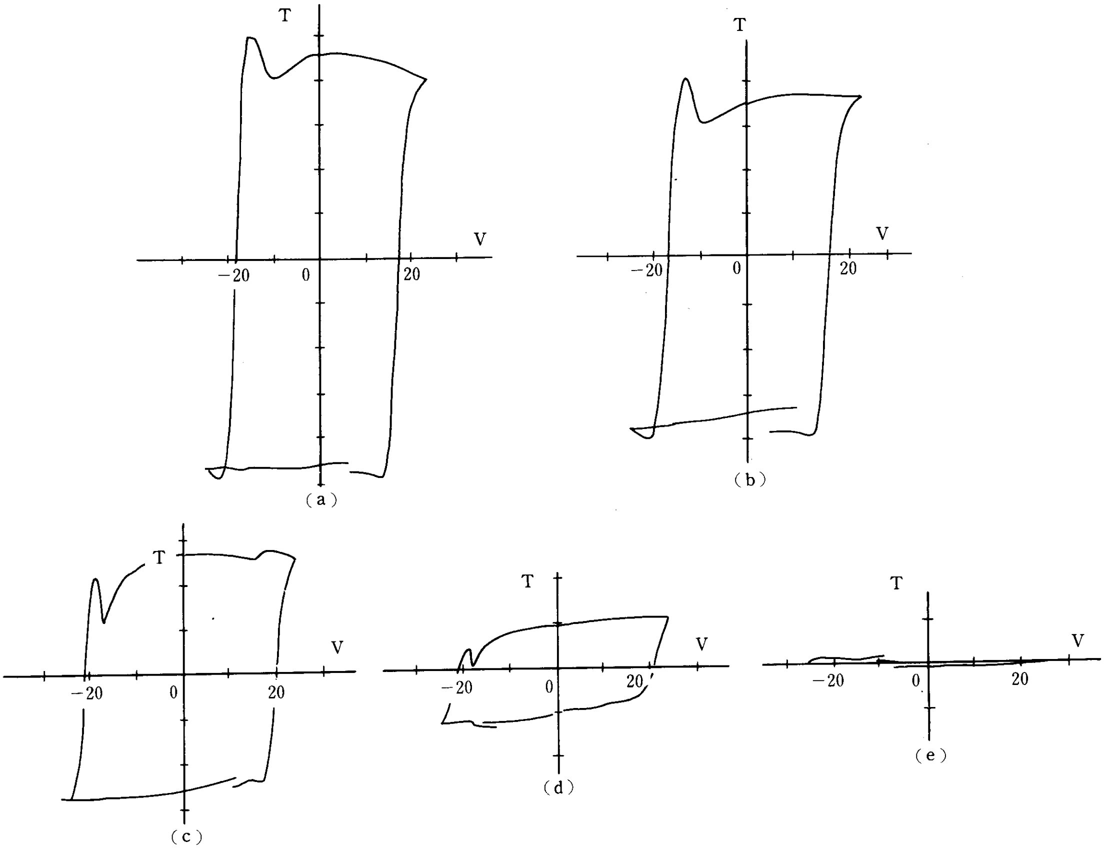


Fig.4. Dependence of the transmittance on the temperature (a)22.3℃, (b)29.0℃, (a) 40.7℃ (b)43.5℃, and (c)44.3℃.

the phase transition from Sm C* to Sm A phase. The polarization reversal of the sample were observed by the change of the optical transmittance. The signals detected by the photodiode were recorded by XY -plotter, where the electric fields with the triangle wave-form were applied.

Firstly, we show the field dependence of the optical transmittance of the sample at the different temperatures. Fig.4 shows the D-E characteristics at various temperatures. The frequency of applied external electric field was fixed to 0.1 Hz during the measurement. The frequency was limited to lower than 0.1 Hz due to the responsibility of the recorder. The electric field was applied only when the loops were recorded in order to prevent from the decaying the optical transmittance by applying the fields. In the liquid crystal cells, the uniform state of the dipole moment are stable at no applying electric field. However, the Chevron state becomes stable when the electric fields are applied to the sample. These switching of the liquid crystal show the decay of the optical transmittance. It was considered that the uniformity of the switching destroyed, because the iteration of the switching makes the some defects in the sample. This effect is very serious in the application as the electric device. (Fig.5) . Fig.6 shows the D-E characteristics of the optical transmittance at the various frequency. The destructed loops were observed at low frequency. D-E characteristics were not able to observe at the temperature 44℃ where the phase transition occurred.

In this paper, we showed the experimental results of the transmittance of the liquid crystal CS-1011. Dynamical study of the ferroelectric domain were observed by using the polarized optical microscope.

Acknowledgement

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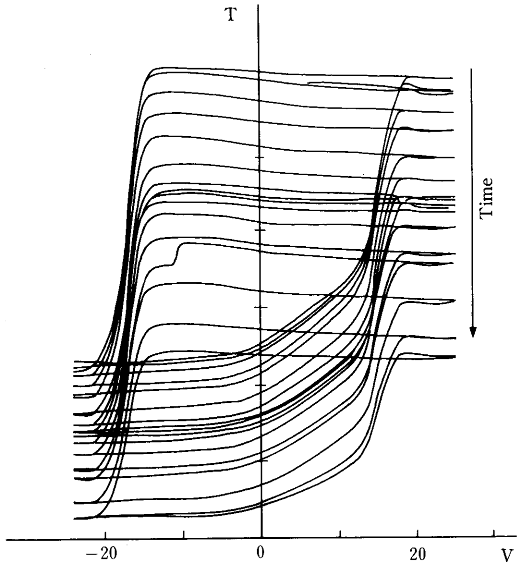

Fig.5. Time dependence of the transmittance at T=20.3℃.

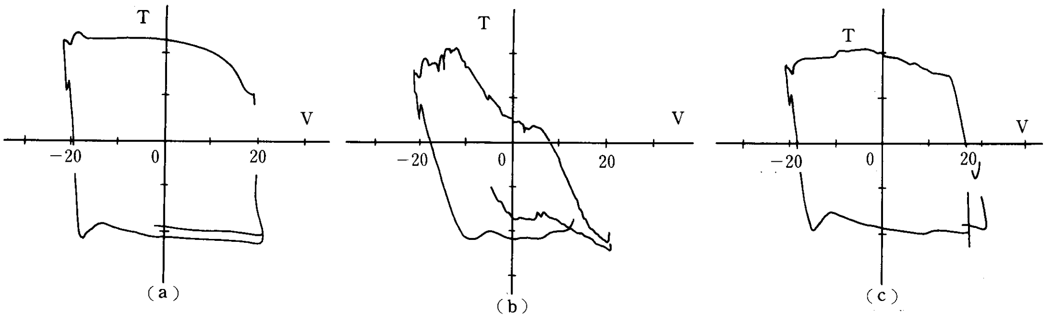

Fig.6. Dependence of the transmittance on the frequency (a)0.1 Hz, (b)0.01 Hz, and (c)0.05 Hz.

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