Electrooptical Effects and Experimental Probes of the Structure of Blue Phase III
V. Dolganov, R. Fouret, C. Gors

To cite this version:

HAL Id: jpa-00248426
https://hal.archives-ouvertes.fr/jpa-00248426
Submitted on 1 Jan 1997

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
Short Communication

Electrooptical Effects and Experimental Probes of the Structure of Blue Phase III

V.K. Dolganov (1,*), R. Fouret (2) and C. Gors (2)

(1) Institute of Solid State Physics, Russian Academy of Sciences, 142432 Chernogolovka, Moscow Region, Russia
(2) Laboratoire de Dynamique et Structures des Matériaux Moléculaires, Université de Lille I (**), 59655 Villeneuve d'Ascq, France

(Received 4 January 1996, revised 25 June 1996, accepted 14 November 1996)

PACS.61.30.-v – Liquid crystals
PACS.64.70.Md – Transitions in liquid crystals

Abstract. — Optical transmission spectrum measurements in an electric field are used to study the short-range structure of the blue phase III (BPIII). The data are compared with the theoretical models for BPIII. Our results can be explained by the models in which BPIII has the simple-cubic local structure or cubic bond orientational order.

1. Introduction

Blue phases (BPI, BPII, BPIII) [1] exist in chiral liquid crystals in a small temperature interval below the clearing point. BPI and BPII possess a periodic long range orientational order with cubic symmetry. As the chirality is increased the anomalous BPIII appears between cubic BP and isotropic phase. The properties of BPIII differ essentially from BPI and BPII, in particular, it exhibits a broad diffraction band typical of amorphous system [2,3].

In an attempt to understand the structure of this anomalous phase several models have been proposed:
1) an icosahedral model [4–7], in which BPIII is characterized by a quasiperiodic icosahedral symmetry;
2) a cubic domain model [8], in which BPIII consist of randomly oriented small domains a local symmetry O^2;
3) a cubic domain model [9], in which BPIII consists of randomly oriented small domains a local symmetry O^5;
4) a double-twist model [10], in which BPIII is viewed as a collection of double twist cylinders;
A schematic representation of these structures may be found in review by Wright and Mermin [1];

(*) Author for correspondence (e-mail: dolganov@issp.ac.ru)
(**) UFR de Physique

© Les Éditions de Physique 1997
5) the fluctuation mechanism of the BPII-BPIII transition was proposed [11,12]. It was suggested by Longa and Trebin [12] that, although there is no translational periodicity in BPIII, a cubic bond orientational order remains.

In recent years several experimental attempts have been performed to determine the structure of BPIII [13–15]. An increase of the intensity and sharpening of the reflection band were observed in an electric field for system with $\Delta \varepsilon < 0$ [16–18]. It was suggested [18] that the surface ordered BPIII and an electric field increased the penetration depth of ordering. Under these assumptions the surface effects could be understood using the double-twist model. As was shown recently [19], the chiral cubic bond orientational order model was consistent with a number of experiments. The main problems of determination of the BPIII structure are associated with weak intensities of the higher harmonics of the basic wave vectors for any of the existing models. As the result the existing experimental data do not allow one to draw unambiguous conclusion about the structure of bulk BPIII.

Recently we performed a simple experiment [20] to detect the structure of BPIII through measurement of the transmission spectrum in an electric field. From this experiment the recurrence vector (or the multiplicity $N$, i.e. the number of the reciprocal lattice vectors with given $\tau$) could be estimated ($N < 9$) for the main reflection band of BPIII. This essentially ruled out the body-centered cubic model $O^5$ ($N = 12$ for the main reflection band (110)) and icosahedral model, in which a set of the wave vectors from centre to the vertices had the least multiplicity $N = 12$. The simple-cubic local structure $O^2$ ($N_{100} = 6$) was consistent with current experiment [20]. For the double-twist tube there is no recurrence vector (multiplicity $N$) and more experimental tests of the validity of the double-twist model are needed. In this paper we report the results of angular transmission measurements on BPIII in an electric field.

2. Experiment

The sample are a chiral-nematic mixture of the chiral compound S811 and the nematic EN18 [16–18,21]. The mixture forms three blue phases BPI (41.80–42.15 °C), BPII (42.15–42.32 °C), BPIII (42.32–42.45 °C) and has negative dielectric anisotropy [16]. The liquid crystal sample is contained between glass slides coated with transparent conducting layers. In order to avoid electrohydrodynamic instabilities a sinusoidal electric field with a frequency of 4 kHz is used. No surface treatment was used for alignment of the sample at the boundaries. The temperature of cell is stabilized with an accuracy of 0.005 °C. The spectra given in this paper consist of the spectrum of the light passing through the sample ($T$) or diffracted ($I$) by it normalized by the lamp spectrum ($T_0$ or $I_0$).

Figure 1 shows the change of the transmission spectra in an electric field. The data were obtained for incident light direction along the field direction (Fig. 1a) and for the tilt sample (Fig. 1b; the tilt angle 40°). A comparison of the transmission and reflection spectra of BPIII in the electric field is shown in Figure 2 (incident light direction along the field direction (1), backscattering geometry (2)). In the present measurements the field strengths are less than the threshold for the field-induced transition to a three-dimensional hexagonal blue phase of to a deformed BPII [22].

3. Discussion

The transformation of the transmission spectra (Fig. 1) is largely governed by the orientation of the BPIII in an electric field $E$ and an increase of the domain size (a sharpening of the reflection peak). The orientation of the BPIII in an electric field is characterized by the orientational distribution function for the reciprocal lattice vector $F(\theta, E)$, where $\theta$ is the
Fig. 1. — Transmission spectra in the temperature range of BPIII (42–40 °C). The sample thickness is 31.5 μm. (a) Incident light direction is along the field direction. The field strengths, from top to bottom, are (V/μm) 0.00, 3.06, 3.12. (b) The tilt of the sample is 40°. The field strengths, from top to bottom, are (in V/μm) 0.00, 3.06, 3.11. For purposes of clarity, curves (b) were shifted to bottom of the Figure (the shift was 0.015).

Fig. 2. — Transmission (1) and diffraction (2) spectra of the BPIII for the electric field $E = 3.00$ V/μm.

angle between the normal to the plane of the sample and the reciprocal lattice vector. The whole of the transmission spectrum $T/T_0$ is determined by a superposition of diffraction bands at $\lambda = \lambda_0 \cos \theta$, where $\lambda_0$ is the Bragg wavelength for backscattering. Figure 3 shows the intensities of the reflected spectra for a back-scattering configuration ($\theta = 0$) and $(T_0 - T)/T_0$ at $\lambda_0$ (incident light direction along the field direction). The data for the peak intensities agree with the dependence observed by Kitzerow et al. [17]. The voltage dependence of the peak
intensity is determined by the changes of the $F(\theta, E)$ and the width of the reflection band. The voltage dependence of integral intensities of the reflection spectra for a backscattering configuration is proportional to the voltage dependence of $F(E)$ at $\theta = 0$. The fact that $(T_0 - T)/T_0$ correlates with the reflection data for the integral intensities allow us to conclude that the voltage dependence $(T_0 - T)/T_0$ reflects well the voltage dependence of the orientational distribution function.

A possible method of testing for a double-twist BPIII structure is by angular transmission measurements on a field-aligned sample. For the double-twist tube the wave-vector is associated with a diameter of a tube. Application of a field causes the cylinder axis to align perpendicular to the field direction for system with negative dielectric anisotropy [16]. The position of the band in the diffraction spectrum remains practically constant ($\Delta \lambda < 5$ nm) over a wide interval of the fields. So the cylinders are not distorted by the electric field. The behaviour of the transmission intensity has to depend essentially on the angle between the cylinder axis and incident light direction. It is necessary to consider two cases:

(i) in the plane of the sample the tubes are parallel to each other in an electric field; 
(ii) in the plane of the sample there is no preferable orientation of the tubes in an electric field.

In the first case (i) the tilt of the sample in the plane of the cylinder axis has to cause a short-wavelength shift of the field-induced band, the tilt in perpendicular direction does not have to cause the shift of the band. We have found that the field-induced band was shifted ($\Delta \lambda = 37$ nm, Fig. 1), however, the shift did not depend on the direction of the tilt. So the behaviour of BPIII is different to the case (i).

In the case (ii) the field-induced spectrum has to be a superposition of the diffraction bands in the wavelength range from $\lambda_0$ to $\lambda_\phi = \lambda_0 \cos \phi$ ($\phi = 24.7^\circ$ is the angle between the field direction and the incident light beam in the sample, the tilt of the sample is $40^\circ$, the refractive index is 1.54). One might expect the large width of the field-induced band for the tilt sample (from $\lambda_0 = 463$ nm to $\lambda_\phi = 421$ nm). In fact, we observe the band at the boundary of this
region (Fig. 1b) and so the behaviour of BPIII in an electric field is different to the second case (ii). Consequently our angular measurement seems inconsistent with the double-twist model for BPIII. As for mixture with positive dielectric anisotropy a stable lattice orientation with axes [100] or [111] parallel to the electric field direction followed for cubic structures from theoretical considerations [23]. Despite of these theoretical predictions [110] || $E$ orientation was unaffected by electric fields [24, 25]. Because of these disagreements with the theory it is difficult to predict the preferred orientations in an electric field for different models in mixtures with $\Delta \varepsilon > 0$.

Our results and measurements that have been recently performed [20] are consistent with the cubic $O^2$ model or the cubic bond orientational order. The cubic bond orientational order twists along a fourfold [001] or a threefold [111] symmetry direction [19]. This result is also consistent with the number of the reciprocal-lattice vectors ($N < 9$) for BPIII [20]. However, the possibility that cholesteric BPIII is characterized by the cubic order deserves further experimental and theoretical consideration.

Acknowledgments

The research described in this publication was made possible (V.K.D.) in part by Grant from RFFI 95-02-05343, No. RE 4300 from ISF and from French National Education Minister.

References