Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl16

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Version of record first published: 21 Mar 2007.

Molecular Crystals and Liquid Crystals. 1971. Vol. 15, pp. 133–140

Printed in Great Britain

Spatial Distribution of Light Scattered by *p*-Azoxyanisole in Applied Electric Field†‡

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Received October 16, 1970; *in revised form January* 15, 1971

Abstract—Regular patterns of domain-like structure have been observed in the nematic range of *p*-azoxyanisole (PAA) when a transverse static electric field is applied.

The spatial distribution of scattered light has been studied using optical Fourier transform techniques.

In this way the relevant characteristics of the domain structure are particularly evident. The behaviour of this structure under different incident and scattered polarization conditions has been observed. A thermal hysteresis has been noted when the nematic range is reached from the liquid isotropic state. In this case, depending on how long the time spent and how high the temperature in the liquid state, the domain-like structure tends to be absent. This memory effect is cancelled out by a successive crystallization.

1. Introduction

It has been noted by many authors that the optical properties of *p*-azoxyanisole in the nematic mesophase are sensitive to an applied electric field.[1,2,3,4] We wish to report the results of some measurements performed on the light scattered by such a liquid crystal under static electric field. Our arrangement differs from the previously reported ones in that we have measured the scattering of the light normal to the applied electric field. The cell we used was a thin flat cell; a collimated coherent laser beam was directed normal to the flat surface of the cell. The liquid crystal was placed between two

† Partially supported by the National Research Council of Italy.

‡ Presented at the Third International Liquid Crystal Conference in Berlin, August 24–28, 1970.

glass plates separated by a mylar spacer. Two electrodes are evaporated on one of the plates and an electric field is applied across these electrodes. The electrodes are parallel and the measurements were performed with different spacings between 1 and 5 mm. The thickness of the cell is 25 μ. An external heater insured a temperature stability of 0.1 °C. The liquid crystal sample was purified by successive crystallizations. Its resistivity is of the order of 10^{10} Ωcm.

2. Experimental Results

The appearance of the liquid crystal film when a static electric field is applied is shown in Fig. 1(a). With a field of about 700 V/cm a periodic structure appears at the negative electrode, which is the upper one in the figure. As the field is increased this structure propagates until the whole cell is filled by this more or less regular pattern. With an electric field greater than 3.0 kV/cm, the periodicity disappears, giving rise to a fast moving threadlike pattern. In this condition the liquid crystal appears as a turbulent medium. This turbulent aspect is present also at lower voltages, but the movement is slower and confined near to the negative electrode. This movement is more evident where the field is inhomogeneous. The regular pattern shows slow random fluctuations, and the above pictures have been taken in a time shorter than the characteristic fluctuation time.

When observed in linearly polarized light the appearance of this structure depends on the direction of the polarization plane.

The experimental set-up is as follows. An Helium–Neon laser giving 5 mW in the red line was used. The beam was expanded and collimated. A polarization rotator was used to allow investigation of the effect of varying the direction of the incident polarization. The angular scanning of the scattered light field in the Fraunhofer range was performed with a photomultiplier whose output signal was directed, through an amplifier and a time-variable integrator, to a recorder. With this arrangement we investigated the behavior of a domain-like structure at different values of the applied electric field as a function of the temperature and of the optical polarization.

In Fig. 1(b) the scattered light distribution in the direction normal to the applied electric field at different values of this field is shown.

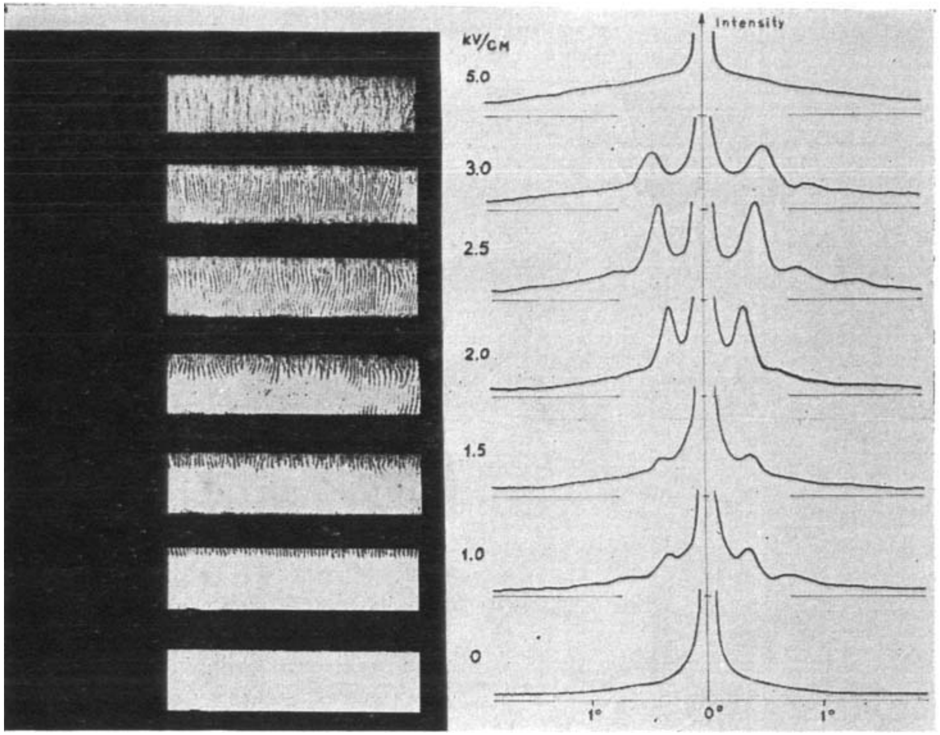

Figure 1. (a) Aspect of a PAA film for different values of the applied electric field. Electrode separation 1 mm, T = 120.0 °C, Sample thickness 25 μ. Polarization vector $\mathbf{E}_i$ parallel to static electric field. (b) Angular distribution of scattered light intensity in a plane normal to the applied electric field.

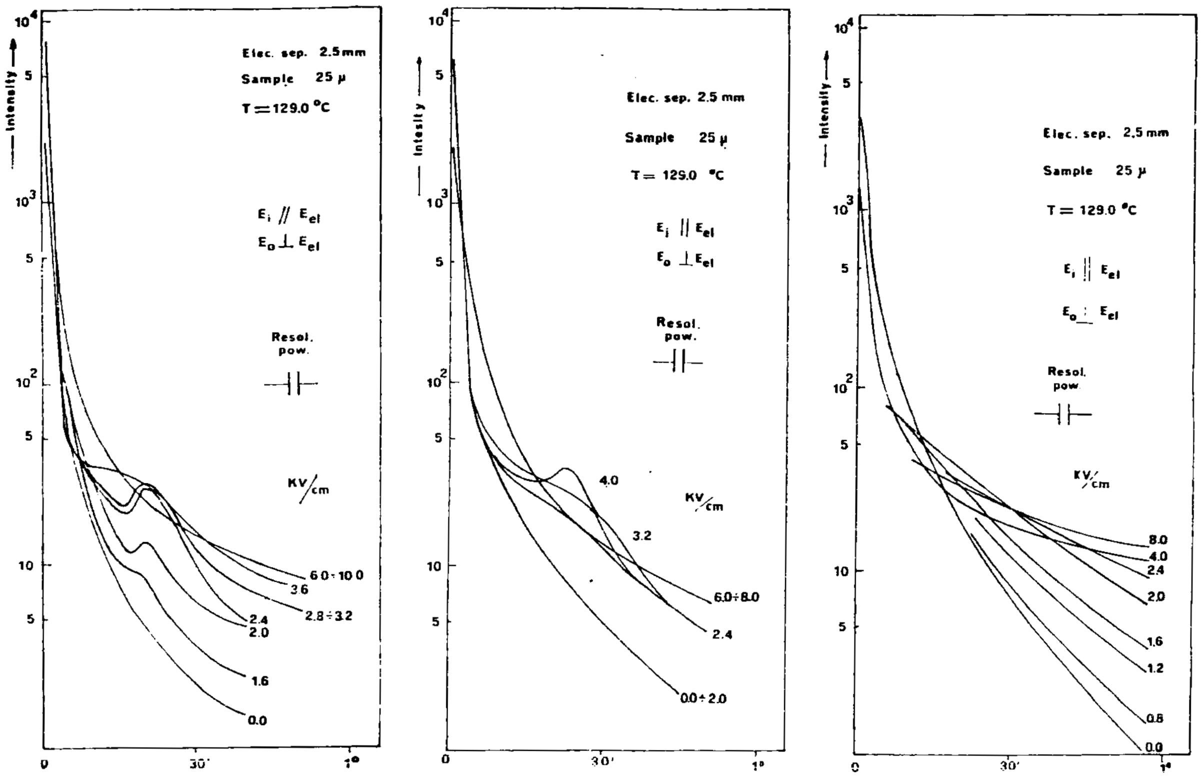

Figure 2. Distribution of polarized scattered light for different values of applied electric field. (a) The temperature of 129.0 °C has been reached from the solid state. (b) The same temperature has been reached by cooling from the isotropic liquid state. In (c) the same as in (b) but after a longer permanence in the isotropic state.

The incident light was polarized parallel to the applied field. It is possible to see that the periodicity of the domain-like structure gives two peaks in the scattered light at small angles. The position of the peaks is related to the spatial frequency of the structure; it is seen that it increases with the applied field. In the range in which all the cell is filled by the regular pattern, this dependence is linear. Together with the two main peaks, some other peaks are present, corresponding to higher harmonic frequencies. At applied field greater than 3.0 kV/cm, the peaks disappear according to the visually observed behavior of the structure, and the scattered distribution becomes smoother and broader. This behaviour is present in the nematic range, disappearing at the upper transition temperature. We have observed that when cooling the sample from the isotropic liquid to the nematic state, the periodic structure becomes less and less pronounced. This effect is more evident the longer the time the sample is maintained in the isotropic state, or the higher the temperature. Once the sample is cooled to the solid state, this memory effect is erased; when heated domains again appear. This effect is visible in Fig. 2.

In Fig. 2(a) the orthogonally polarized scattering is shown for different applied voltages, when the indicated temperature is reached from the solid state. Pronounced peaks are visible. In Fig. 2(b) and 2(c), the same temperature is reached after the liquid crystal was maintained in the isotropic liquid state for one and three hours, respectively. The polarization states are the same as before. In the parallel polarized scattering (not shown here), there are no peaks, and the curves are the same, whatever the thermal history of the sample.

In Fig. 2 the polarization of the incident light was parallel to the applied static field. In Fig. 3 the polarization is normal. In the two upper sets of curves the nematic phase is reached from the low temperature range. The periodic structure is observed in both the emerging polarization directions. In the lower sets the peaks disappear when the same temperature is reached after the liquid crystal was left in the isotropic liquid state some hours and then cooled.

Figure 4 shows the scattered intensity at spatial frequencies higher than the spatial characteristic frequencies of the domain-like structure. In this region the scattering has a spatial exponential

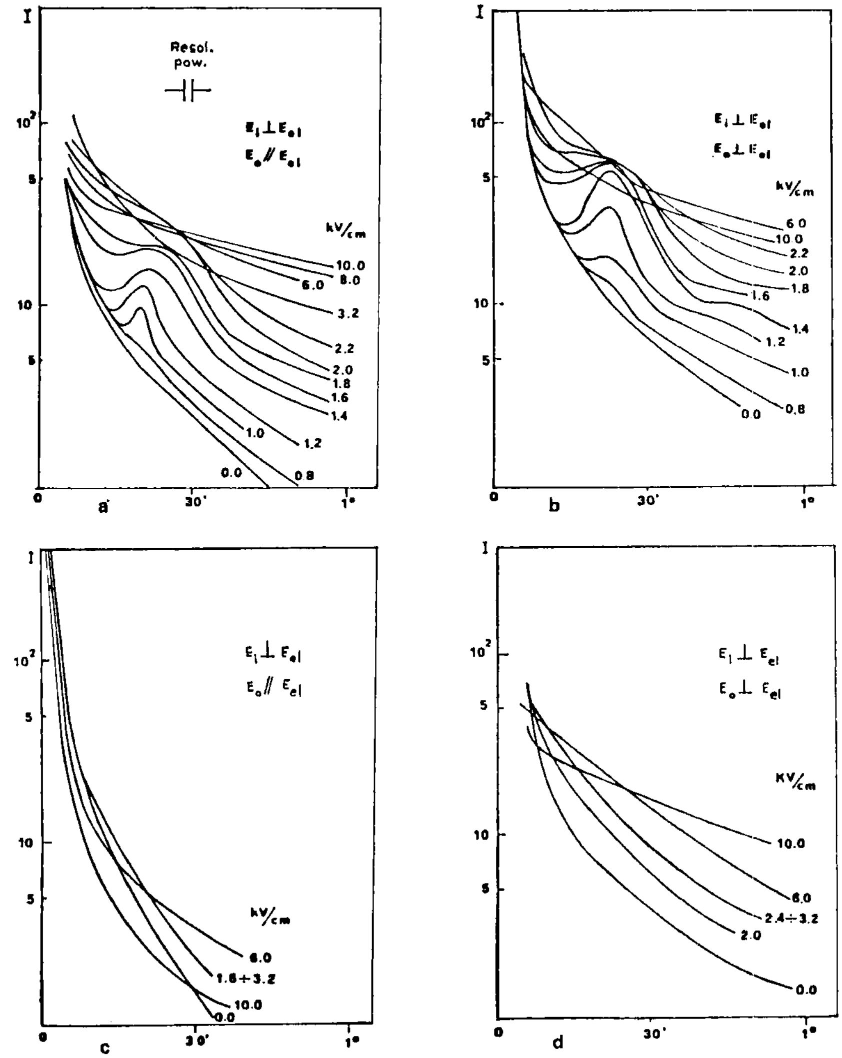

Figure 3. (a, b) Angular distribution of the scattered light at different values of the static applied field. Electrode separation 2.5 mm; Sample thickness 25 μ. $T = 129.0\,°C$. Polarization relations are shown in figures. (c, d) The same as (a, b). The temperature of observation has been reached after some hours of permanence in the isotropic liquid state.

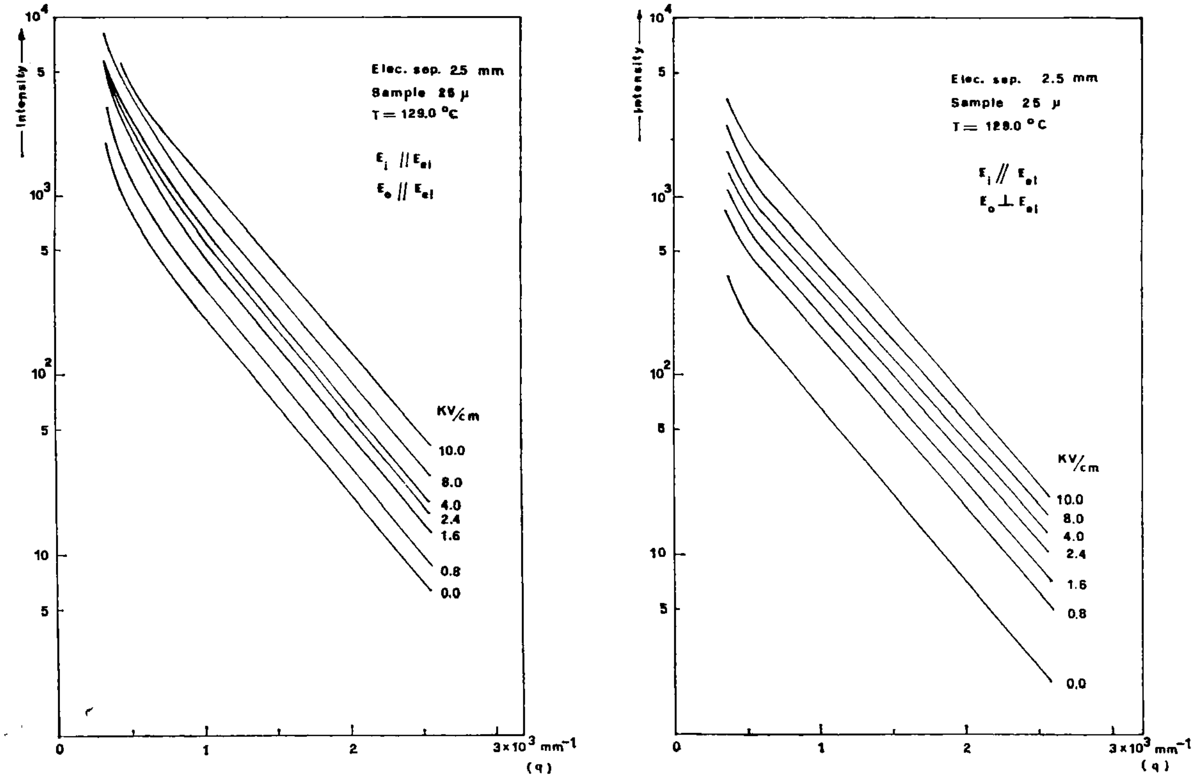

Figure 4. Angular distribution of the scattered light at different values of the static electric field. Plane polarized light. The nematic phase has been reached from the solid state.

distribution, whose decay constant does not seem to depend on the applied voltage, neither on the polarization of incident and scattered light. The total scattered intensity depends on the thermal history of the sample.

3. Conclusions

The previously exposed measurements can be summarized as follows:

First, with an intermediate electric field, a periodic structure appears in *p*-azoxyanisole in the nematic range. This periodic structure is present in a plane parallel to the applied field. The observed results are in agreement with the hypothesis of a periodic orientation of the optical axis of the molecules. This arrangement gives rise to a phase and amplitude grating which acts differently with the two polarizations. The theory of this effect will be presented elsewhere. The exponential decay of the scattered intensity at high spatial frequencies allows the determination of the typical length of the scattering centers.

Another important observation which can be drawn from the measurements is the existence of a thermal hysteresis. A similar effect has been reported in cholesteric liquid crystal using different techniques[5] for measurement.

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