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Comparative Study of Liquid Crystalline in Applied AC and DC Voltages By Electrooptical Transmission

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Abstract

The electrooptical transmission of a nematic liquid crystalline in applied AC and DC voltages has been studied as a function of the wavelength in interval 380-780 nm. The main focus of this study is the investigation of the optical transmission properties of nematic sample. We have measured the electrooptical transmission versus applied AC and DC voltages at the determined temperature. The experimental results have been discussed in AC and DC voltages.

Keywords : Electrooptical transmission, AC and DC voltages, nematic liquid crystalline.

Özet

Nematik sıvı kristalde AC ve DC gerilim uygulayarak, elektrooptik geçirgenlik dalgaboyunun fonksiyonu olarak 380-780 nm dalgaboyu aralığında incelendi. Bu çalışmada asıl amaç nematik numunenin optik geçirgenlik özelliğini incelemektir. Belirlenen sıcaklıkta AC ve DC gerilim uygulamasına karşı elektrooptik geçiş ölçüldü ve deneysel sonuçlar her iki gerilim durumu için tartışıldı.

Anahtar sözcükler: Eletrooptik geçiş, AC ve DC gerilim, nematic Sıvı Kristal.

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1. Introduction

It is well known that nematic materials only have orientational order and no positional order. The orientational order of these materials combined with their molecular anisotropy leads to anisotropic physical properties just like those in anisotropic crystalline solid. Materials that exhibit this kind of phase tend to consist of molecules that are long, and have a rigid center that do not allow rotations that result in non-linear molecular conformations. Several experimental methods are sensitive to some characteristic property of nematics and have been used to study mesomorphic transitions [1-5]. Some affects can then be induced by thermally or electrically altering the effective refractive index of the nematics [6,7]. A considerable research has been made in electro-optic displays using nematic samples [8].

On of the most useful properties of nematics is that although they align themselves into crystalline forms, the bonds that hold the crystals together are relatively weak. That means that if one put an extra force on the molecules, it can be often broken down the ordering with fairly small applied force. The most common way of doing this is to use an electric field. Normally, molecules do not have an overall charge. If an electric field is applied, at small fields, the interaction force between the molecules that produces the ordering is bigger than the force due to the applied field. If the field is bigger, by increasing the voltage, then eventually its effect will become comparable with the interactions between the molecules, and then the normal ordering will break down, and the molecules will reorder in a different way. This happens at some threshold voltage. This transition from normal ordering to being deformed by the applied is known as the Freedericksz transition.

One of the properties that have made liquid crystals so important is use to switch light using an applied field. By these properties, the liquid crystals are used commonly as optoelectronic device. These devices use effect which is the province of nonlinear optics. These materials are allowed easy excitation of the electrons in one plane but not in another. Thus it can switch the induce birefringence and by arranging polarizers the amount of transmitted light is switched. The resultant devices can be turned on and off in times of 100 picoseconds, and so it can be used as extremely high speed shutters.

In the present work, we have investigated the electro-optical properties (electro-absorption) of nematic sample using spectroscopic technique [9,10], under an applied *ac* or *dc* electric field.

2. Theory of Electrooptic Effects

In the nematic medium, the molecules are free to move around as in a liquid but tend to remain oriented in a certain direction. The molecules are however not completely fixed orientationally, but perform thermal oscillations around the director. These oscillations become stronger with increasing temperature, up to the point where the orientational order is completely lost in the isotropic liquid. Hence, material parameters of nematics are strongly temperature dependent. The orientational order is characterized by an order parameter S defined as

$$S = \frac{1}{2}\langle 3\cos^2\theta - 1\rangle \tag{1}$$

where, θ is the angle between the longitudinal axis of a molecule and the director. The brackets indicates the average.

As a consequence of the orientational order, the nematics are uniaxially symmetric, with the symmetry axis parallel to the long axis of the molecules. This symmetry will lead to different dielectric constants parallel $\varepsilon_{//}$ and perpendicular $\varepsilon_{\perp}$ to the director. The dielectric anisotropy is defined as

$$\Delta\varepsilon = \varepsilon_{//} - \varepsilon_{\perp} \tag{2}$$

In electrooptical applications of nematics, an electric field is applied to control the orientation of the molecules. Samples with positive dielectric anisotropy tend to align parallel to the field while samples with negative dielectric anisotropy align perpendicular.

A nematic device has a simple construction, which is a sandwich of nematic sample between glasses. The important element in the device is the transparent electrodes on the inner surface of the glass, which is coated with indium-tin-oxide (ITO) thin films. On application of the voltage, the molecules rotate to minimize their energy, which is achieved by the positive ends of the molecules rotating to point in the direction of the negative electrode and vice versa. The propagation of light can be explained by using the description of light as a transverse electromagnetic field. Since the majority of important electrooptical applications are based on the interaction between polarized light and the optical anisotropy of the nematic material. To calculate how the polarization state of a beam of light changes when it propagates through an anisotropic media, the Jones matrix method can be used [11]. The Jones vector representation can also be used to calculate the transmitted intensity of the light passing through an optical system. The Jones vector of the incident light can be written

$$\mathbf{E} = \begin{bmatrix} E_x \\ E_y \end{bmatrix} \quad (3)$$

where, E_x and E_y are the components in the xy-coordinate system. The intensity is calculated as

$$I = |E_x|^2 + |E_y|^2 \quad (4)$$

Let the emerging beam be represented by

$$\mathbf{E}' = \begin{bmatrix} E'_x \\ E'_y \end{bmatrix} \quad (5)$$

The transmittance can then be calculated as

$$T = \frac{I'}{I} = \frac{|E'_x|^2 + |E'_y|^2}{|E_x|^2 + |E_y|^2} \quad (6)$$

If the incident light is normalized, the denominator equals to 1.

3. Experimental Method

The structure formula of *4'-pentyl-4-biphenylcarbonitrile* ($C_{18}H_{19}N$) nematic material is shown in Figure 1, which is obtained Sigma-Aldrich Corporation. The thickness of the sample placed between the reference surfaces was determined with a thin film of *65 μm* thickness. The reference surfaces of sandwich cell samples were cleaned carefully by using alcohol and acetone, and then washed by deionised and bi-distilled water in an ultrasonic bath. Filling of the sandwich cell with sample was carried out by capillary action.

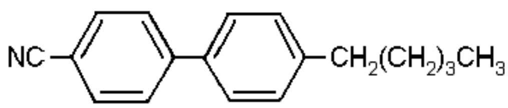

Figure 1. Structure formula of nematic liquid crystal, *4'-pentyl-4-biphenylcarbonitrile* ($C_{18}H_{19}N$)

The transmission measurements were performed in real time, in the wavelength interval of 380-780 nm, using a Perkin Elmer, Lamda 45 UV/VIS spectrometer. In the light transmission technique, the transmitted light intensity by sample was monitored by using the calibration curve between wavelength and electric field, upon increasing voltage, as a function of wavelength. Then transmitted light intensity was re-plotted for each sample against wavelength using the electric field.

Using crossed polarizers we registered the electro-optic effect. By switching on a strong voltage across the sample, the transmitted light was blocked. Switching of the voltage the liquid crystal relaxes back to hybrid structure with a certain characteristic time and with oscillations of the transmitted light intensity [12-14].

Of all the methods used for the identification of nematic phase, polarized light microscopy is the one which provides the most detailed information, especially the molecular orientations [2,15]. The sample was separately placed the spectrometer and another glass plate was used as reference for transmission measurements. Before starting transmission measurements, auto zero count was taken using two glass plates. The structure of the nematic phase was identified by a polarizing microscope (Leica DM LP).

4. Results and Discussions

Transmittance of *4¢-pentyl-4-biphenylcarbonitrile* ($C_{18}H_{19}N$) sample was investigated at room temperature by using technique described above. The transmitted intensity was saved as a function of wavelength and then the data were re-plotted against wavelength by using the calibration curve between wavelength and electric field. The plots of transmitted light intensity versus wavelength for applying AC and DC electric field of $C_{18}H_{19}N$ sample are shown in Figures 2,3, respectively at different wavelengths. It is seen that the transmitted intensity increases at certain onset AC and DC voltages, which corresponds to the molecular orientations.

The transmitted intensity by sample is the same up to 3 volts for DC voltage. This indicates that there some sort of threshold behavior present for the sample meaning that the transmitted intensity by the sample remains unchanged until a threshold voltage is reached. This is supported by the Figures 4,5. This electro-optic characteristics of sample are the same like the characteristics of surface stabilized devices, when placed between crossed polarizers. The bistability of the system caused threshold behavior and

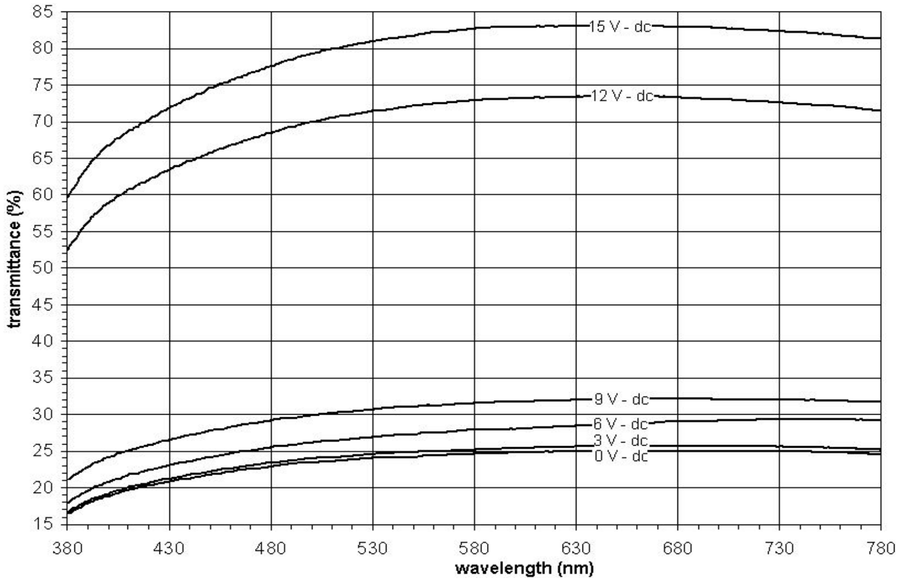

Figure 2. Transmitted intensity versus wavelength under different DC voltages.

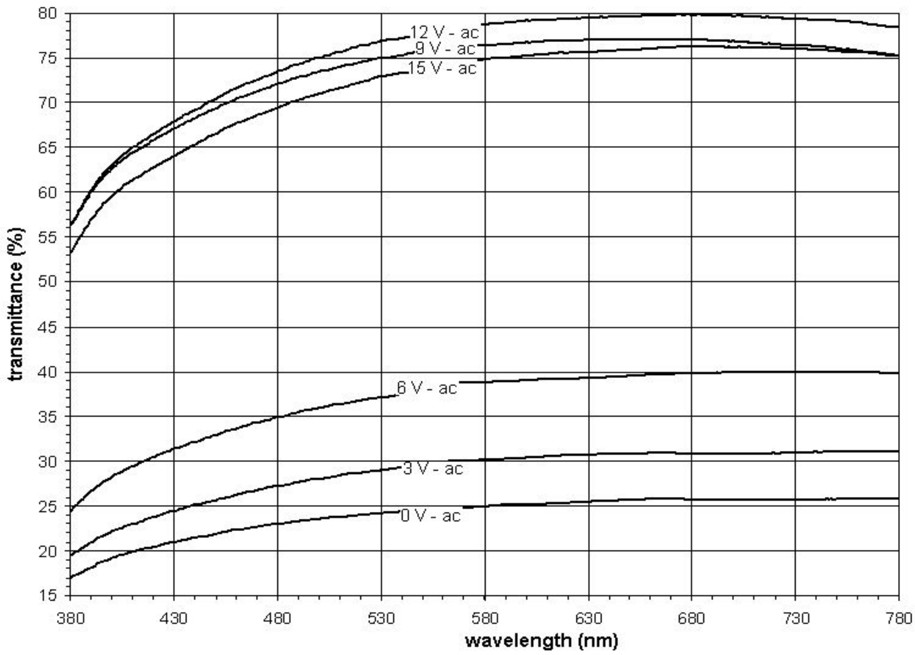

Figure 3. Transmitted intensity versus wavelength under different AC voltages.

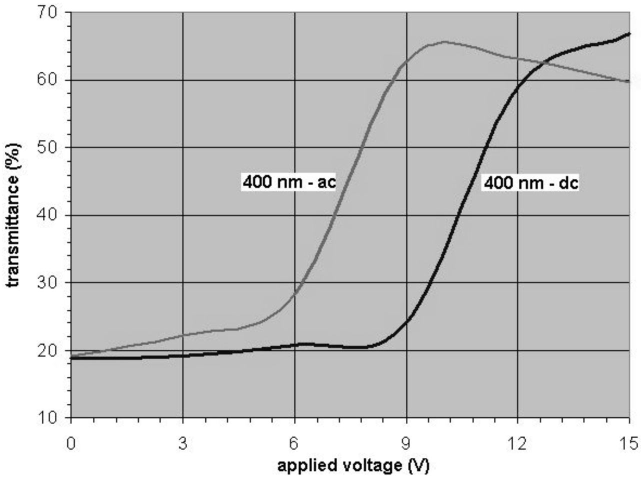

Figure 4. Transmitted intensity versus applied voltage at 400 nm for AC and DC voltages

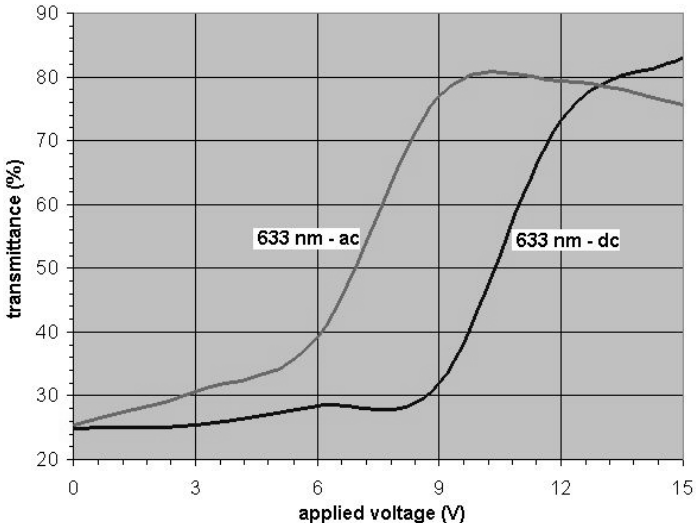

Figure 5. Transmitted intensity versus applied voltage at 633 nm for AC and DC voltages.

hysteresis. In the operation of this bistable device, the switching between two stable states is driven by the interaction between the applied electric field and polarization. Looking at these figures we can see easily that the threshold value for DC voltage is 5 V. The threshold value for AC voltage is lower than DC voltage. Another interesting aspect in Figures 2 and 3 is sudden rising of transmitted intensity up to 9 Volt for DC while 6 Volt for DC voltage.

In summary; we introduced a spectroscopic technique to study transmission of a nematic sample by monitoring the transmitted light intensity as a function of wavelength, under applied AC and DC voltages. The experimental results of this study are appropriate to the previous measurements performed by means of conventional spectroscopic technique [16,17].

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