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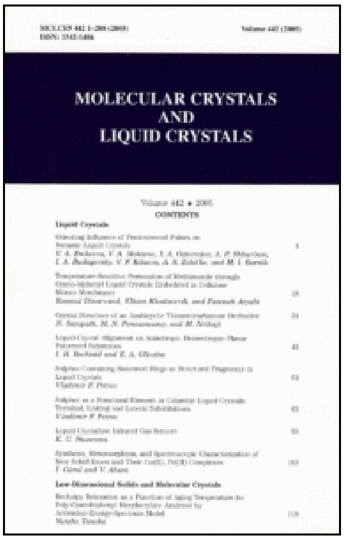

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Electro-Optical Properties of Dye-Doped Nematic Liquid Crystals

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Electro-Optical Properties of Dye-Doped Nematic Liquid Crystals

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The electro-optical properties of dye-doped nematic liquid crystals have been investigated in this work. The absorption and transmittance spectrum of the azo-dye doped nematic liquid crystal are measured. The band gaps of the samples are calculated and the effect of concentration on band gap is studied. The results indicate that energy band gap decreases with the increase in dye concentration.

Keywords Band gap; dye-doped liquid crystal; electro-optical properties

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1. Introduction

It is well reported that photo-physical behavior of a dissolved dye depends on the nature of its environment, i.e., the solvent influences the spectra characteristics of the solute molecules. The solvent effect is closely related to the nature and degree of dye – solvent interactions. The solvent type may also influence considerably the aggregative properties of ionic dyes. The molecular association of dyes in solutions due to strongly attractive electrostatic forces is a well-known phenomenon.

In addition to the solid crystalline and liquid phases, liquid crystals exhibit intermediate phases where they flow like liquids, yet possess some physical properties characteristic of crystals. Liquid crystals are of interest to researchers the world over for various reasons. Nematics are the most widely studied liquid crystals. They are also the most widely used. As a matter of fact, nematics best exemplify the dual nature of liquid crystals–fluidity and crystalline structure.

In this report, we describe the effect of dye concentration on band gap of dye-doped nematic liquid crystal solutions. Also the absorption and transmittance spectrum are measured and the effect of dye concentration are studied. We concluded that the absorption characteristics of azo-dyes may be affected by additional anisotropic interactions between the guest and anisotropic surrounding of nematic liquid crystal. Although the guest host effect have been studied in some detail over the last twenty years [1–6], there is a lot of work to be carried out on the aggregative

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properties of the dye molecules in nematie liquid crystal solvents. In the course of the present study the role of concentration on the guest-host interaction was studied using absorption and transmittance spectrums [7–11].

In liquid crystals, there is a good order in orientation and locality of molecule and they are oriented in a crystal-like way. So their behaviors are similar to solids. This periodicity may be a good reason for origin of the band gap in liquid crystal. On the other hand, due to their fluid behavior their band gan can be measured by optical methods.

2. Experimental Results

A new nematic liquid crystal which has been doped with some azo-dyes is investigated for the first time to determine their electro-optical behaviour. The concentration dependence has been examined for three azo-dyes (Sudan Black B, Sudan III, Sudan IV) [12–14].

Pure nematic liquid crystals was used in our experiments as anisotropic hosts. In this work, a nematic mixture of w1680 with high and positive dielectric anisotropy was also used as anisotropic solvent. The dielectric constant of our liquid crystals are between 8–12 while their dielectric anisotropy are between 10–11 [15,16]. The liquid crystalline material was synthesized in the Institute of Chemistry of the Military Technical Academy, Warsaw, Poland. The dyes were studied in the polar nematic hosts up to a concentration of about 0.1, 0.5, and 1% w/w.

The guest-host cells were made by sandwiching the nematic solutions between two optical glass plates, $2\,\mathrm{cm} \times 1.2\,\mathrm{cm}$. The planar homogeneous orientation of the guest and host molecules was achieved by surface treatment of a cast film of polyvinyl alcohol (Sigma) followed by the rubbing process. The spacing between the electrodes surfaces was 11.2 micrometer was set by use of a Mylar. The plates were sealed together by a sealing material (epoxy resin glue). The introduction of the dissolved dye in nematic liquid crystal solvent was achieved by capillary action. The liquid crystal cells were checked under crossed polarizers, and used in subsequent linear dichroism studies. The temperature of the liquid crystal cells was controlled at 22°C.

3. Results and Discussion

From the standpoint of optical properties, the doping of liquid crystals by appropriately dissolved concentrations and types of dyes clearly deserves special attention. The most important effect of dye molecules on liquid crystals is the modification of their nonlinear optical properties. These molecules are generally elongated in shape and can be oriented and reoriented by the host nematic liquid crystals. Light propagation through a medium depends on whether the light – matter interaction is linear or nonlinear.

Visible absorption and transmittance spectrums of Sudan black B, Sudan III, Sudan IV doped in w1680 are shown in Figures 1–3 respectively for 0.1%, 0.5%, and 1% of dye amount in liquid crystal. Philips UV-Vis spectrophotometer (model pu8750) is used for the spectrometry. As it is clear, the transmittance is increasing by decreasing the dye concentration.

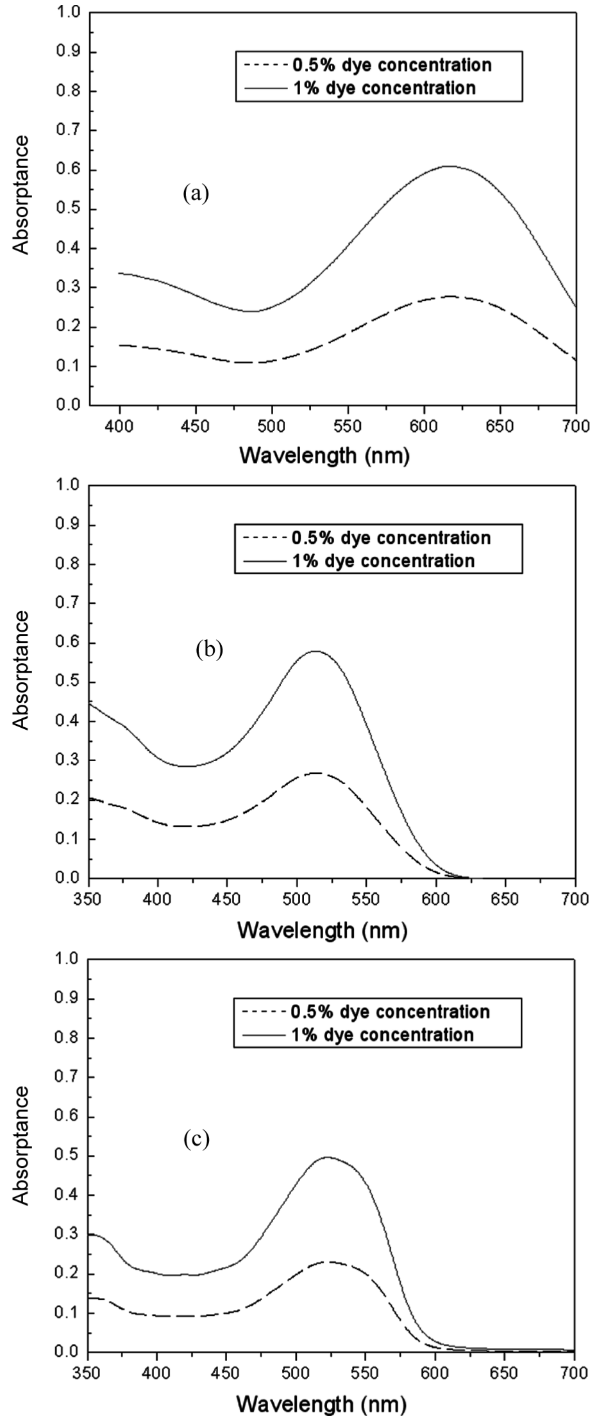

Figure 1. Absorption spectrum of dye-doped nematic liquid crstal with different dyes: (a) Sudan black B; (b) Sudan III; and (c) Sudan IV.

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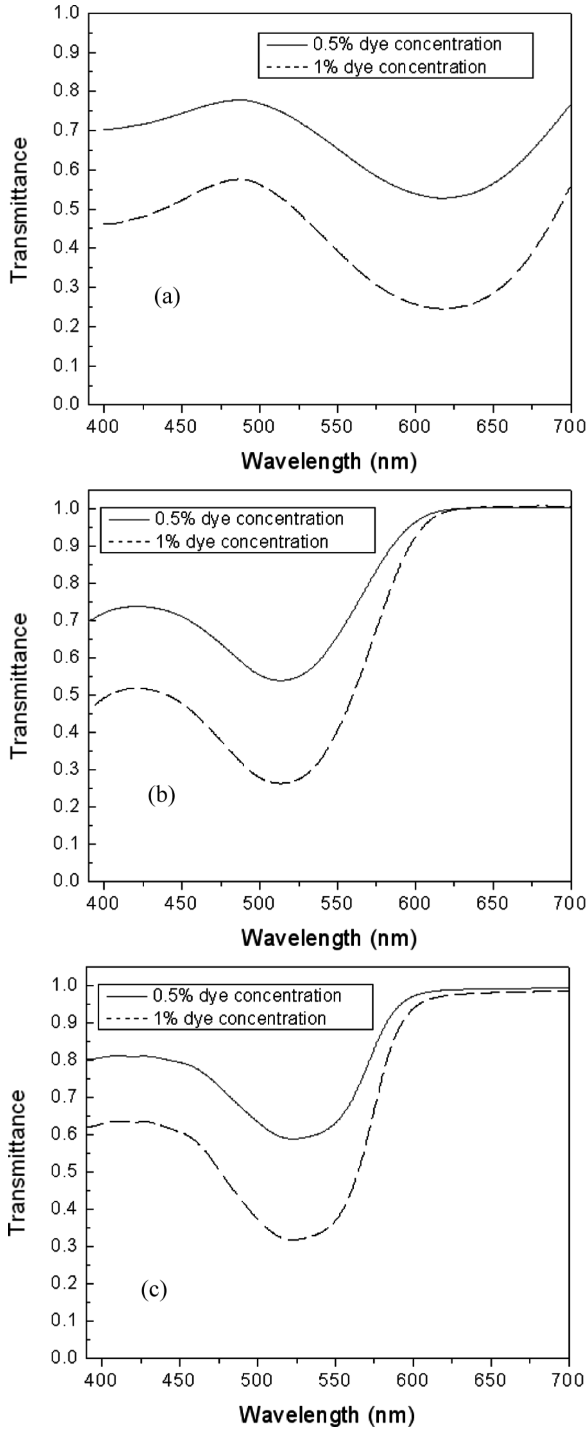

Figure 2. Transmittance spectrum of dye-doped nematic liquid crstal with different dyes: (a) Sudan black B; (b) Sudan III; and (c) Sudan IV.

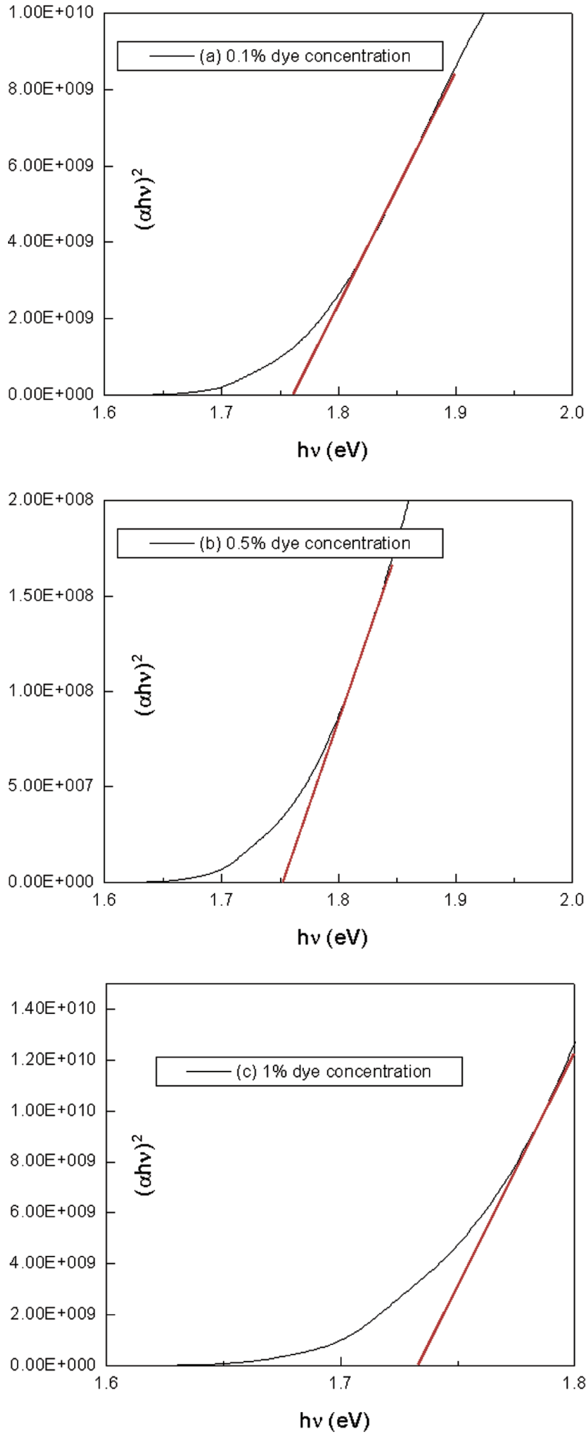

Figure 3. Band gap measurement for Sudan black B using Tauc relation.

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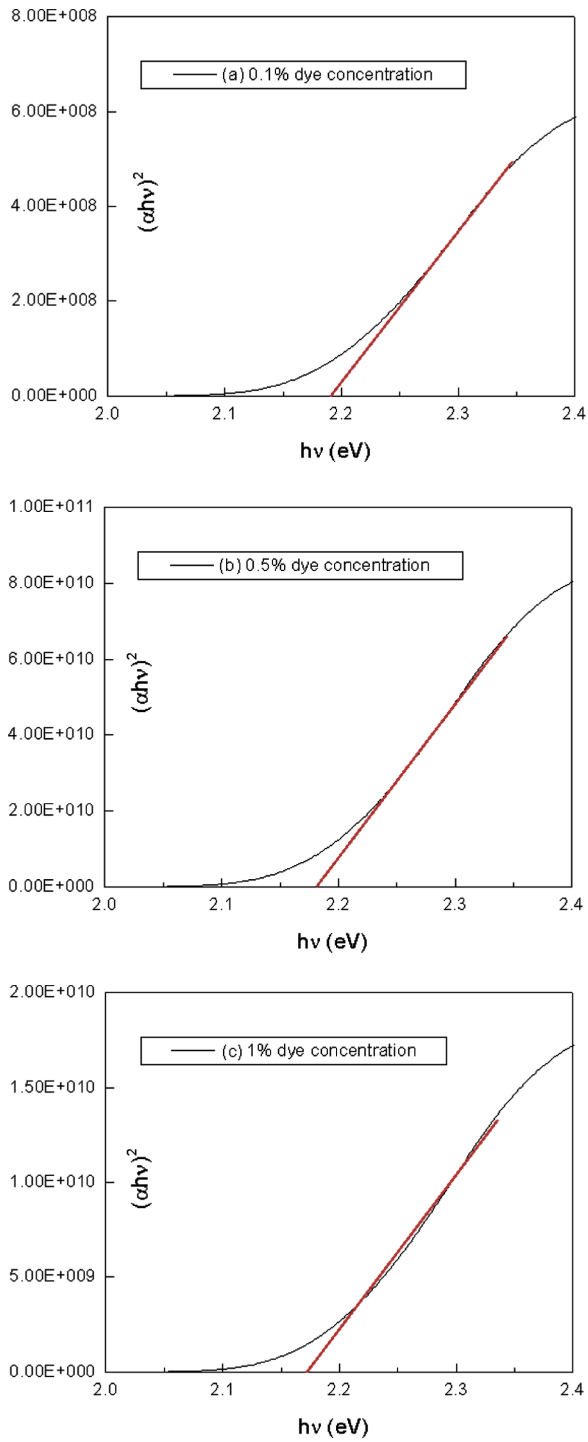

Figure 4. Band gap measurement for Sudan III using Tauc relation.

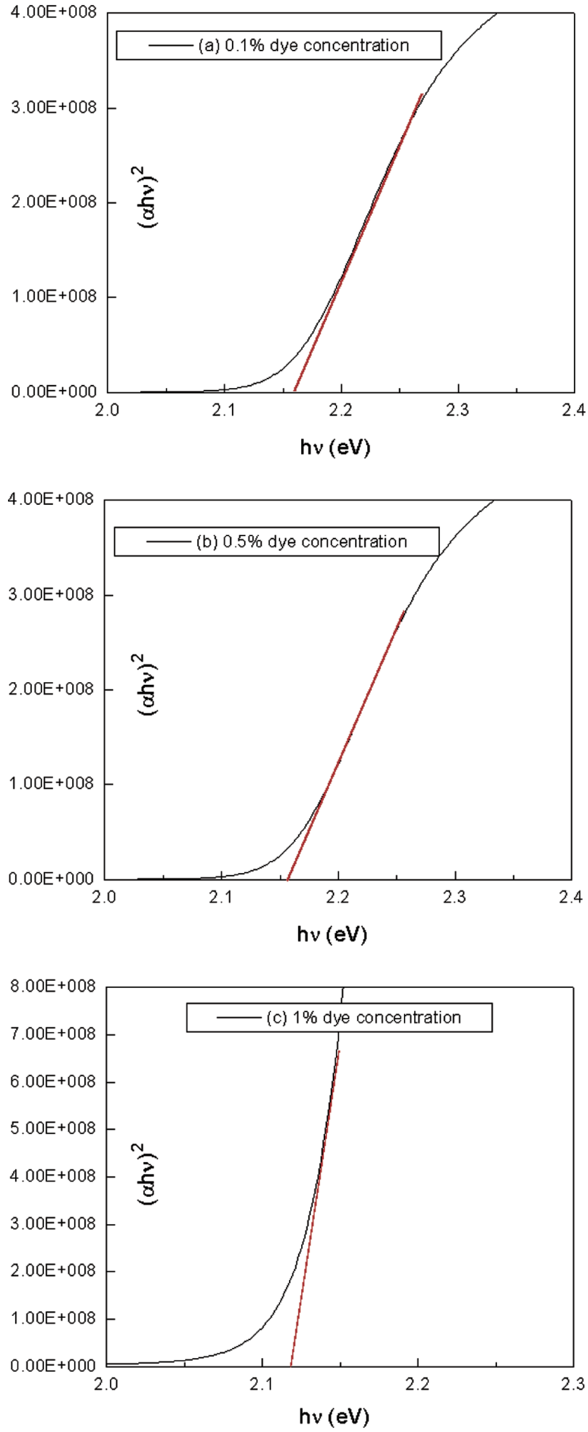

Figure 5. Band gap measurement for Sudan IV using Tauc relation.

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Table 1. Band gap values for different dye-doped nematic liquid crystal

Dye name	Band gap for 0.1% dye concentration (eV)	Band gap for 0.5% dye concentration (eV)	Band gap for 1% dye concentration (eV)
Sudan black B	1.76	1.75	1.73
Sudan III	2.19	2.18	2.17
Sudan IV	2.165	2.16	2.125

UV-Vis spectroscopy gives an idea about the value of optical band gap energy (E_g) and thus provides an important tool for investigation. The absorption of light energy by Sudan dyes in the visible regions involves promotion of electrons in π orbital from the ground state to the higher energy state which are described by molecular orbitals. In the solid state physics, the transition occurs between the valence band (V_B) and conduction band (C_B), E_g is the band gap or energy difference between the valence band and conduction band.

The absorption coefficient for direct gap materials is given by Tauc relation [17–20],

$$\alpha = B\frac{(h\upsilon - E_g)^{0.5}}{h\upsilon} \tag{1}$$

where hυ is the photon energy, E_g is band gap energy, and B is the constant which is different for different transitions. α is estimated from the transmittance spectrum using the relation $\alpha = (\frac{1}{d})Ln(1/T)$, where T is transmittance and d is the thickness of sample, in this study d is 11.2 μm.

By plotting a graph between $(\alpha h\nu)^2$ as a function of hν, a straight line is obtained. The extrapolation of straight line to $(\alpha h\nu)^2 = 0$ axis gives the value of the energy band gap of samples. In Figures 3–5, graphs are plotted between $(\alpha h\nu)^2$ and hν, for band gap determination of 0.1%, 0.5%, and 1% dyes (Sudan Black B, Sudan III, and Sudan IV respectively) doped nematic liquid crystal. The band gap values of the dyes are summarized in Table 1 for 0.1%, 0.5%, and 1% weight concentration. As it can be seen in graphs, energy gap decreases with the increase in dye concentration.

All of the chosen dyes have generally high solubility. Sudan black B has high stability and also the advantage of a high dichroic ratio because of its rod-like molecular shape. Apart from Sudan black B, two of the azo dyes investigated in this work would not be suitable for commercial applications because they are phenols. Thus, they are not electrochemically or photochemically stable enough for LCD applications. The structure of Sudan black B is approximately rod-like, so that the transition moment vector of this dye may be considered to be parallel to the long molecular axis.

4. Conclusion

The absorption and transmittance spectrum of the Sudan black b, Sudan III, and Sudan IV doped nematic liquid crystal are measured. For the samples, the

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absorption will increase by increasing dye concentration and it is reverse for transmittance. The band gaps of the samples are calculated and the effect of concentration on band gap is studied. The results indicate that band gap decreases with the increasing in dye concentration. Between these dyes Sudan black B is good candidate for commercial uses because of its stability and small bang gap.

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