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SCIENCE DIRECT
Dyes and Pigments 65 (2005) 169–174
DYES and PIGMENTS
www.elsevier.com/locate/dyepig

Dielectric spectroscopy analysis of molecular reorientation in dye doped nematic liquid crystals having different preliminary orientation

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Received 19 May 2004; received in revised form 28 July 2004; accepted 9 August 2004
Available online 25 September 2004

Abstract

Reorientation tendencies of liquid crystal (LC) molecules are investigated for two different fundamental orientation configurations that are known as homogenous (HG) and homeotropic (HT). A hybrid LC content, including red and blue dyes together, is employed in these two cells enabling measurements in different spectral regions by two different lasers. Influence of preliminary orientation on the behaviors of molecules under dark and illuminated circumstances is extracted from the performed measurements. Dielectric anisotropy is also studied for the mentioned conditions and its dependency is quantitatively estimated by capacitive measurements.

Keywords: Liquid crystals; Dye doped; Dielectric anisotropy

1. Introduction

LC are highly nonlinear optical materials due to their susceptible property activating under even relatively low optical fields. Several nonlinear mechanisms investigated so far have revealed the promising characters of these materials. The difference in refractive indices, for fields polarized along, and perpendicular to, the director axis brings about a large birefringence property from visible to infrared spectral regime [1]. Because of the large broadband birefringence of nematic LC, it is obvious that these highly sensitive films could be applied in a variety of image processing systems operating with low optical power.

It is also experimentally proved that doping a small amount of dye decreases the required threshold of molecular reorientation further in LC materials [2]. Since many dyes exist that will cover the entire visible spectrum, such dye doped nematic films are highly promising candidates for application as very broadband optical modulators and limiters, and other adaptive optics and coherent wave-mixing devices. Reorientation based effects causing the change of refractive index and observations of several interesting dynamic and storage wave-mixing effects have been studied extensively so far [3–6]. This phenomenon has potential applications such as holographic data storage. Compared with others, LC based systems require lower characteristic voltages to be applied for the realization of molecular response as well as relatively lower light power for efficient modulation of refractive index. Whatever the application is, the preparation of the sample is critical and there are two main preliminary orientation possibilities having mutual benefits. Effect of preliminary orientation, imposed by the surface pattern of the cell substrates, on the molecular reorientation mechanism is of primary importance in the design of LC devices. In the scope of this work, the so called Dielectric Spectroscopy Technique (DST) was applied for analyzing the dependency of

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0143-7208/$ - see front matter
doi:10.1016/j.dyepig.2004.08.001

molecular reorientation on common parameters of the subject such as preliminary orientation, order of laser pumping, applied voltage etc.

2. Method and experiment

There are various works concentrating on the electro-optical characterization of LC [7–10]. DST is a powerful technique successfully applied for understanding the molecular details and effect based tendencies of the investigated case [11]. Dielectric anisotropy, $\Delta\varepsilon = \varepsilon_{\|} - \varepsilon_{\perp}$, where $\varepsilon_{\|}$ and $\varepsilon_{\perp}$ are parallel and perpendicular components of the electric permittivity, respectively, is estimated from capacitance measurements by eliminating dielectric permittivity of medium, ε, from Eq. (1).

$$C = \varepsilon_0 \varepsilon \frac{A}{d} \quad (1)$$

Here C is the capacitance value, ε_0 and ε are dielectric permittivity values of free space and concerned medium, respectively, A is the plate area and d is the thickness of the cell. By using capacitance values, dielectric constants were calculated according to Eq. (1) from where ε is eliminated.

Two samples were prepared both of which were filled with a hybrid composition made up of a nematic host E7 and two dyes that are Methyl red, 0.5% weight/weight and Disperse Blue 14, 0.5% weight/weight. One of the samples is HG, in which overall orientation of molecules is parallel to substrate surfaces, and the other one is HT, in which overall orientation is perpendicular to substrate surfaces. The schematic representation of molecular orientation of dyes and nematic host in HG and HT cells is shown in Fig. 1. Chemical formulae of the samples' components are depicted in Fig. 2. Due to the absorbance nature of our hybrid sample, Fig. 3, it was possible to use two different lasers alternatively; He–Ne (632.8 nm) and He–Cd (441.6 nm). The wavelengths of these lasers correspond to absorbance peaks of the devised sample and alternative usage of two different wavelengths in the experiment provided to demonstrate the exploitation of solely-absorbance originated effects on a single sample by two different pumping sources.

During the measurements incoming laser beam was arranged to cover the whole surface of the sample cell by a diverging lens and opaque masking permitted to precisely illuminate only the filled portion, which is roughly at the order of 0.25 cm^2. Thickness of the cells is ~8.7 μm and Indium Tin Oxide (ITO) coated substrates enabled to apply voltage to samples. Experimental set-up is shown in Fig. 4. Impedance/gain phase

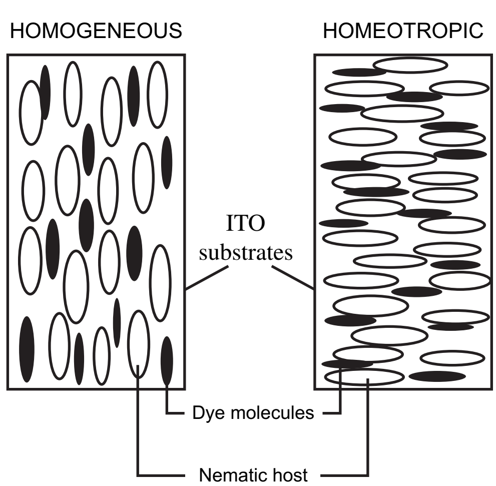

Fig. 1. The schematic representation of molecular orientation of dyes and nematic host in HG and HT cells.

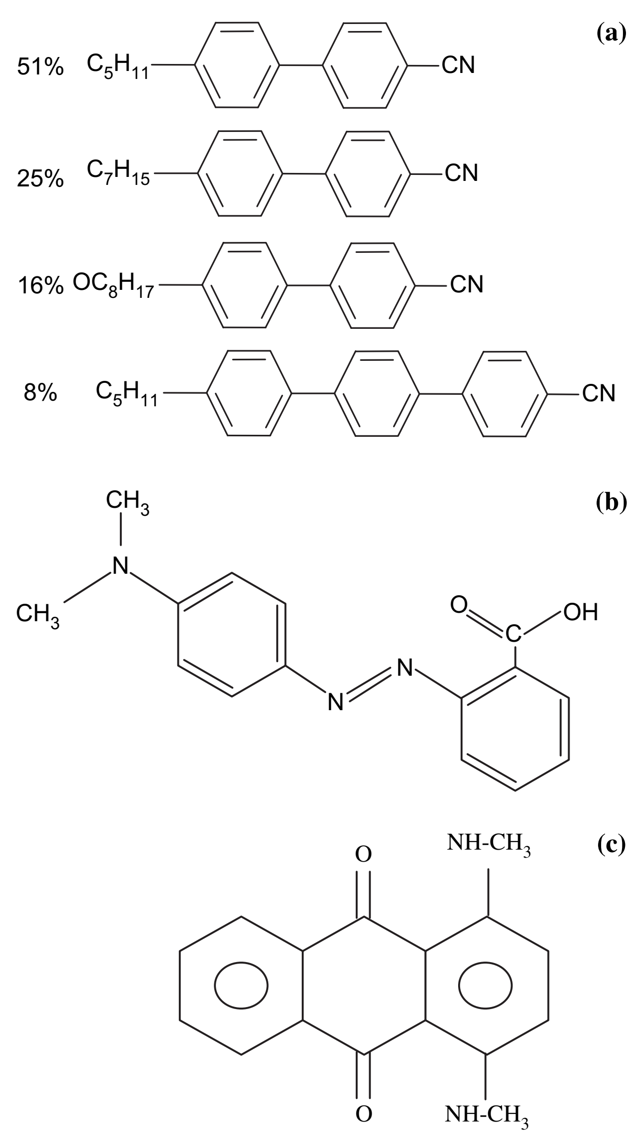

Fig. 2. Chemical components of the devised hybrid sample. (a) Nematic host E7, (b) Red dye (Methyl red), (c) Blue dye (Disperse Blue 14).