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Role of specific and nonspecific intermolecular interaction in electro-optical response of doped 6CHBT nematic liquid crystal with azo dyes

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ABSTRACT

Investigations done so far have shown that dopant material have a considerable effect on the electro-optical responses of dye-doped liquid crystal. But the type of inter or intra-molecular interaction roles in electro-optical properties and nonlinearity of doped liquid crystalline systems has uncovered. In this work, to study of the kind of molecular interaction effects on electro-optical properties of doped LC, two dyes with dissimilar interactional and functional groups were used as LC dopants. Therefore, doping these dyes into liquid crystals allows us to understand and analyze the effect of interaction type on electro-optical responses of the pure and doped samples. The electro-optical Kerr behavior, the pre-transition temperature and third order nonlinear susceptibility of pure and doped LC by two dyes with different interactional groups were having studied. The obtained results revealed that the electro-optical response of nematic liquid crystal can be strongly enhanced or decreased, depending on dopant's nature, concentration and type of specific and nonspecific interaction between doped dye and liquid crystal molecules. In other words, it will be shown that dopants molecular interactions with each other and liquid crystal molecules are important factors for controlling of electro-optical responses of dye doped liquid crystal system.

1. Introduction

Through several studies, it has been proved that liquid crystals doped with dopants such as dyes and nanoparticles have given rise to a number of novel practical applications and pointed the way toward innovative improvement of the physical and electro-optical properties of liquid crystals. Enhancement of the electro-optical properties of liquid crystal is dependent on the type, concentration and intrinsic characteristics of the dopants used [1–3]. Generally, various kinds of guest-host systems are used to enhance their optical and electro-optical properties and improve the performance of optoelectronic devices [4–8]. The linear and nonlinear optical properties of the host material can be affected considerably, by doping with a small amount of dye [9–13]. From the standpoint of optical properties, doping of liquid crystals by appropriately dissolved concentrations and types of dyes clearly deserves special attention [12–14]. So, it seems that more precise investigation is required for a better understanding of the influence of interactions type and dopants' concentration, which are considered to be responsible for electro-optical responses of doped systems.

Due to high values of solubility, order parameter, permanent dipole moment and dichroic properties in liquid crystal displays (LCDs) and also the highest efficiency for LC nonlinearity enhancement, azobenzene dyes are attractive as dopants of LC [15,16]. Since intermolecular interactions between azo dyes and liquid crystal environment contain either nonspecific (dipole-dipole) or specific (e.g. hydrogen-bonding) interactions, consequently, it becomes necessary to investigate the effect of functional groups of azo dopants. It is well known that functional groups are determinative factors for the type of intermolecular interactions and host environment parameters' can considerably be influenced by these functional groups.

There are various techniques for measuring the molecular anisotropy and intermolecular ordering in anisotropic matrix. Among these techniques, the Electro-optic Kerr effect is a powerful method for the measurement of the optical nonlinearity [17–20]. The Kerr effect is a type of quadratic electro-optic effect. It also exists in crystals with Centro-symmetric point groups. It is caused by an electric-field-induced ordering of polar molecules in an optically isotropic medium. Consequently, refractive index change is induced by the external electric

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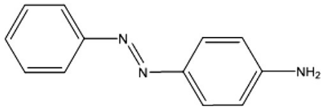
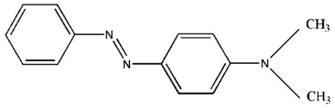
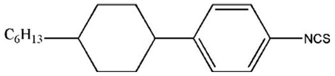
Table 1
Dyes and liquid crystal structure.

Molecular structure	Molecular weight, g/mol	Molecular name
	197	Aminoazobenzene (A-Dye)
	225	Dimethyl-aminoazobenzene (B-Dye)
	301	4-(trans-4′-n-Hexylcyclohexyl)-isothiocyanatobenzene (6CHBT)

field (E). On the other hand, the LC composite is optically isotropic when there is no voltage applied, but will become anisotropic in the present of electric field. The magnitude of Kerr effect is measured by the Kerr constant, B, and expressed as [18–20]:

$$B = \frac{\Delta n_{\text{induced}}}{\lambda E^2} \tag{1}$$

Here, B is the Kerr constant, $\Delta n_{\text{induced}}$ ($\Delta n_{\text{induced}}\Delta n_{\text{induced}} = n_{\parallel} - n_{\perp}$) is the induced birefringence, E is the amplitude of the electric field and λ is the probe wavelength. The Kerr constant also affects the third order non-linear susceptibility tensor, $\chi^{(3)}$, which is an important parameter for optical material, as can be seen by following Eq. [21]:

$$B = \frac{24\pi}{n\lambda}\chi^{(3)} \tag{2}$$

The temperature dependence of Kerr constant and transition temperature in isotropic phase of liquid crystal can be expressed by Eq. (3), based on the Landau-de Gennes theory [21,22]:

$$B = \frac{\varepsilon_\circ \Delta n_\circ \Delta\varepsilon_\circ}{4a\lambda\sqrt{\varepsilon}}(T - T^*)^{-1} \tag{3}$$

Here,$\Delta\varepsilon_\circ$ is the low frequency dielectric anisotropy, a is the temperature independent coefficient, $\Delta n_\circ$ is the birefringence corresponding to complete alignment and T^* is the second-order pre-transition temperature. From this expression, it is clear that there is a liner relationship between reciprocal of the Kerr constant and temperature.

In this paper, two dopants with similar structure and different interactional capabilities have been used, in order to understand the difference of interaction types on electro-optical response. Therefore, due to reasons mentioned already, Aminoazobenzene and Dimethyl-aminoazobenzene dyes, which have capability of specific and nonspecific interactions, respectively, have been used at varying concentrations in 6CHBT liquid crystal. This study was undertaken to deduce electro-optical properties of pure and also doped 6CHBT LC with two azo dyes, including various interactional groups. In addition to these achievements, second-order pre-transition temperatures in different compositional percentage of dyes into liquid crystal host were reported separately, for the first time. Also, third order nonlinear susceptibility was obtained through employing electro-optical Kerr data. Finally, obtained results have been discussed by comparing them in different concentrations of doped systems.

2. Experimental

2.1. Materials

The used dyes, Aminoazobenzene and Dimethyl-aminoazobenzene (Table 1) were supplied from Merck (pro analysis) and used without further purification (guests). These dyes (A and B dyes) have a rod like shape and the direction of the dipole moment of them is largely parallel to the long molecular axis [4].

The maximum absorption bands of Aminoazobenzene and Dimethyl-aminoazobenzene dyes in 6CHBT are 385 and 406 nm, respectively. The liquid crystal material (6CHBT), with positive dielectric anisotropy, was synthesized in the Institute of Chemistry of the Military Technical

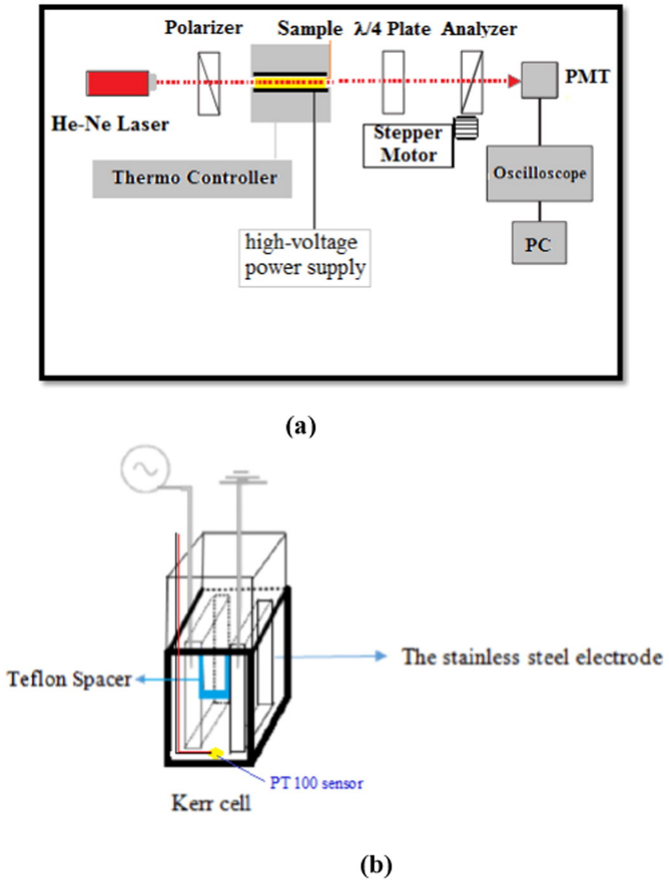


Fig. 1. (a) Schematical Kerr effect setup for measuring the Kerr constant and third order non-linear susceptibility (b) Kerr cell.