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FIELD INDUCED STUDIES IN CARBON NANOTUBES DOPED NEMATIC LIQUID CRYSTAL MIXTURE

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ABSTRACT

Carbon nanotubes (CNTs) doped nematic liquid crystal (NLC) mixture of varying concentrations of CNTs in 0.0, 0.2 and 0.5 wt./wt.% ratios have been prepared and studied. The effect of electric field on current behavior and optical properties in pure NLC and CNTs-NLC mixtures has been investigated. Dispersion of CNTs in NLC mixture increases the current nearly 3 times. The lower concentration of CNTs leads to better optical responses.

Keywords: Nematic liquid crystal; carbon nanotubes; threshold voltage

1. INTRODUCTION

Over the past years, doping of nanoparticles (NPs) in liquid crystals (LCs) has provided an intriguing and viable way of manipulating the properties of LCs [1]. It has been wildly accepted that doping of nanomaterials such as gold, silca, CdTe quantum dots, $BaTiO_3$, Au, ZnO, TiO_2, MgO, SiO_2 etc. in liquid crystals have significant effect and potential applications in displays [2-7]. Proper selection of nanomaterials, concentration, homogeneity and their compatibility with liquid crystals show a remarkable effect on liquid crystal characteristics particularly alignment of liquid crystals, conductivity, transmission properties and threshold voltage [4, 8-12]. Since the discovery of CNTs, physical and chemical properties of CNTs have been studied and reported. In this paper, an attempt has been made to study the electric field induced effects on current characteristic, optical responses and threshold voltage in pure and CNTs doped NLC mixtures.

2. EXPERIMENTAL PROCEDURE

A room temperature nematic liquid crystal 8CB (4-cyano-4''-octylbiphenyl) and CNTs were procured from Kingston Chemicals, UK and Sigma Aldrich, India respectively. 8CB has a phase sequence

$$Crystal \xleftrightarrow{22.5°C} SmA \xleftrightarrow{33.5°C} N* \xleftrightarrow{49.5°C} I$$

The chemical structure of 8CB is shown in Fig. 1.

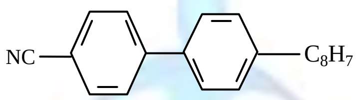

Fig 1: Chemical structure of 8CB

Preparation of LC cells

LC sample cells of thickness 12µm were prepared using indium tin oxide (ITO) coated transparent glass substrates (sheet resistance 24Ω/□). Three samples assigned as pure and CNTs-NLC cells were prepared in varying concentration of CNTs (0.0, 0.2 and 0.5 wt./wt/% of 8CB). The mixture of CNTs and 8CB were initially homogenously mixed and then heated to the isotropic temperature of NLC followed by ultrasonication (frequency 36 kHz). The prepared homogenous mixtures were then filled into empty LC cells by capillary action. These filled cells were placed in specially designed hot stage coupled with computer controlled temperature controller (LINKAM- TP94, THMSE 600). The transmission studies were taken using photomultiplier tube and output responses were also recorded on digital storage oscilloscope (Tektronix TDS 2024B).

3. RESULTS AND DISCUSSION

To explain the behavior of dielectric material in electric field several theoretical models have been proposed [13-15]. The conductivity of dielectric materials is given by

$$\sigma = ne\mu \quad (1)$$

Where µ is the mobility of charge carries and results the conductivity of dielectric material. The conductivity and mobility are related by $\mu \sim E^{1/2}$ and $\mu \sim E^{-(1/2)}$ in high and low temperature range respectively. Therefore it may be assumed that for high temperature range, current density (*J*) varies with electric field (*E*) as

$$J = \sigma E \approx E^{3/2} \exp(\beta\sqrt{E}) \quad (2)$$

and for low temperature range

$$J = \sigma E \approx E^{1/2} \exp(\beta\sqrt{E}) \quad (3)$$

From equations (2) and (3), it is concluded that *J* is dominated by exponential factor in equations (2) and (3) and hence current density in whole temperature range may be written as [16]

$$J \sim \exp(\beta\sqrt{E}) \quad (4)$$

The current-electric field behavior for pure and CNTs doped mixtures are plotted in Fig 2 and 3 and show that the current vary linearly with electric field for pure and CNTs doped sample cells. The solid lines in both Fig (2&3) represent a fitting and are in good agreement with theoretical equation 4. It can be seen that after CNTs dispersion the current increases nearly 2-3 times than pure NLC material. This increase in conductivity in CNTs-NLC mixtures is mainly due to additive of small amount of extrinsic impurity (n-type) CNTs.

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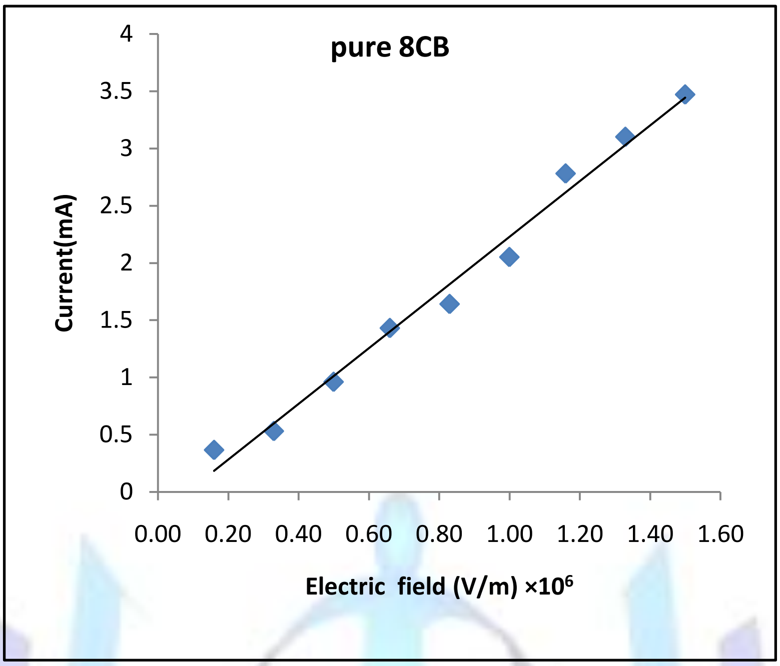

Fig 2: Electric field dependence on current for pure NLC mixture at 30^{0}C

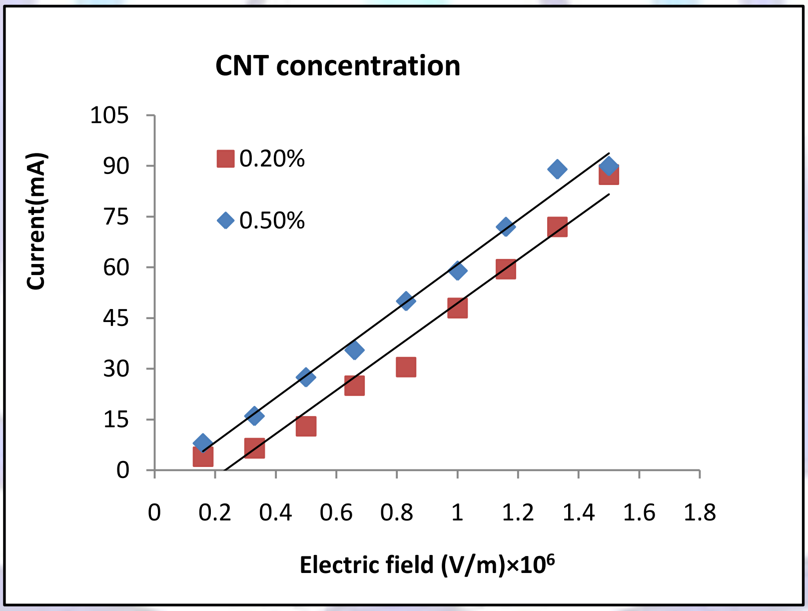

Fig 3: Electric field dependence on current for different CNTs-NLC mixtures at 30^{0}C

A slight increase in current has been observed in 0.50% CNTs doped cell than 0.20% concentration cell. It was also noticed that higher concentration of CNTs (>0.50%) doping in NLC mixture an accumulation of CNTs appears and results a damage of cells. The lower concentrations of CNTs produces more ordered arrangement into NLC order, however in our results upto 0.05% concentration current is increasing it may be due to both the CNTs and liquid crystals long range order and they try to orient in similar direction. The higher value of current is due to the conducting nature of CNTs. The temperature dependence on current characteristics at different CNTs concentration is represented in Fig 4. It is clearly seen that current more or less decreases with increasing the temperature and higher for 0.50% CNTs doping. This slight decrease in current may be due to that LC molecules are more distorted due to interaction with CNTs molecules and thermal agitation effect.

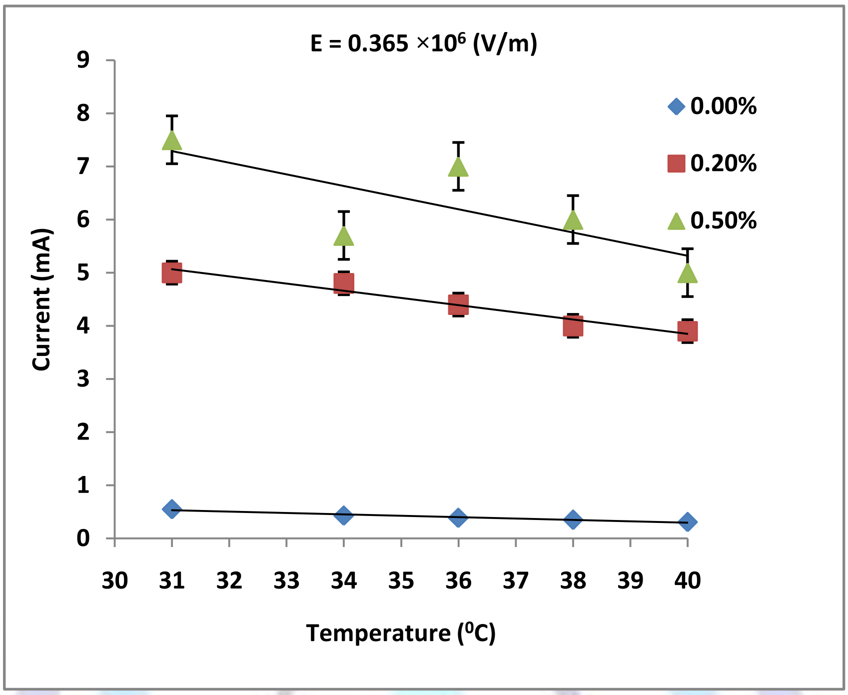

Fig 4: Temperature dependence on current in pure and CNTs doped sample at 30⁰C

Optical properties

Transmittance (the ratio of I_{out}/I_{in}, where I_{out} and I_{in} are the transmitted and incoming light passing through the cell respectively) and threshold voltage (V_{th}) are an important characteristic parameter to optimize the display for applications. The output transmission as a function of applied voltage for pure and CNTs-NLC cells is shown in Fig. 5. It is observed that at low concentration of CNTs (0.20% wt/wt.), sample cell show maximum value of transmission than higher concentrated CNTs doped sample cell. It may be due to the less distortion in 0.20% than 0.50% CNTs doped samples.

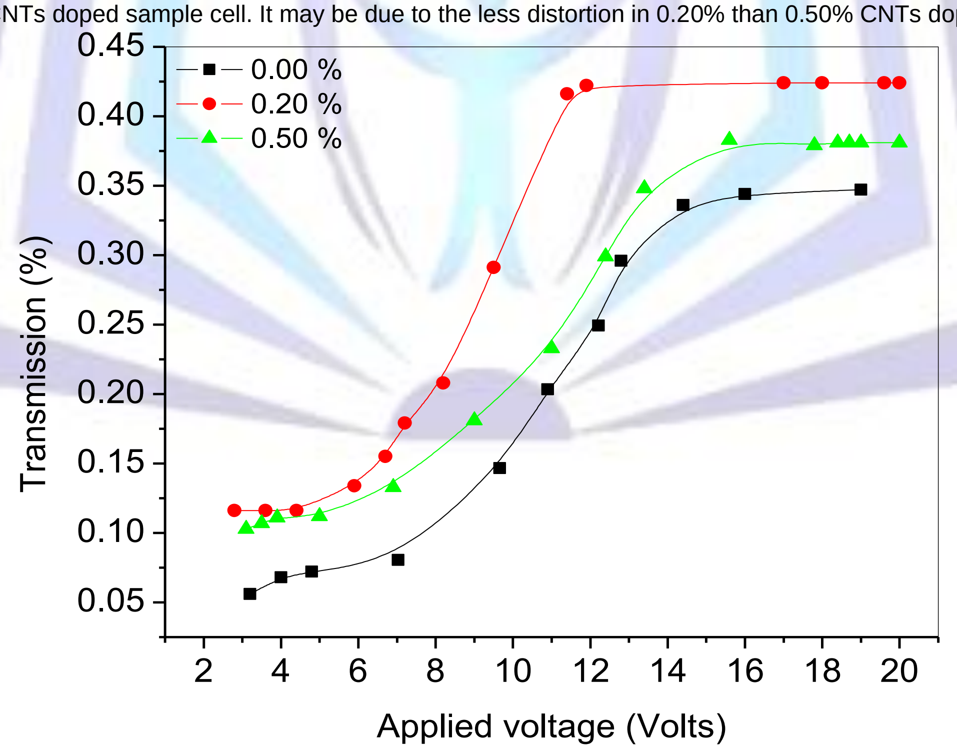

Fig 5: Transmittance-voltage curve for pure and CNTs doped samples at 30 °C.

The value of V_{th} as obtained from Fig. 5 is shown in Fig. 6. V_{th} decreases with increasing the temperature in all cells. The decrease in threshold voltage with temperature may be due to decrease in the order parameter of liquid crystal with temperature [17].

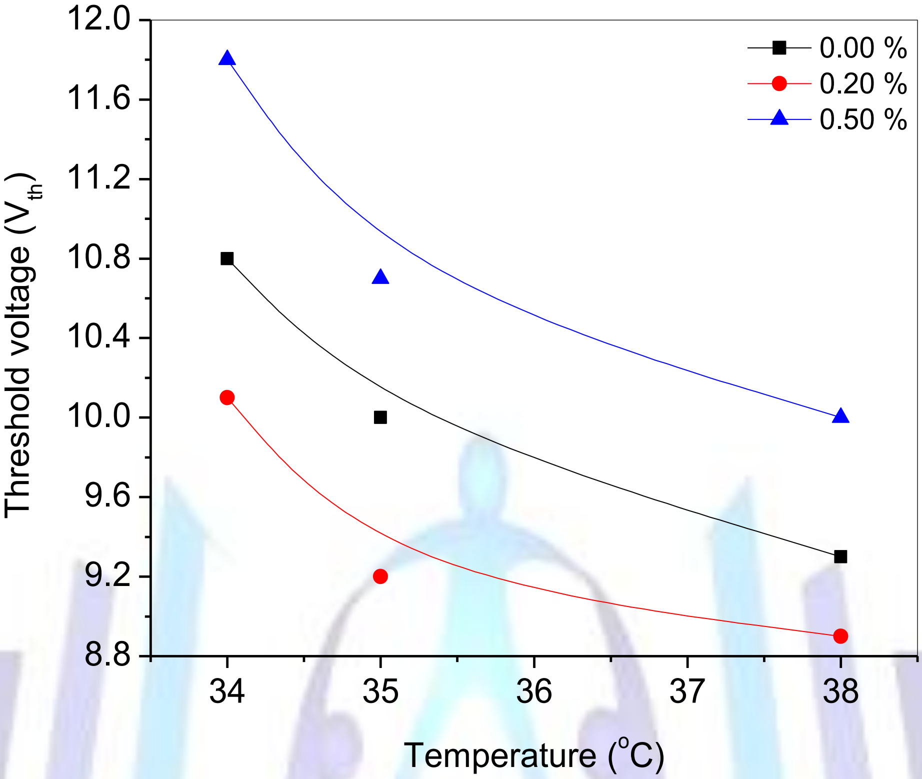

Fig 6: Temperature dependence on threshold voltage for pure and CNTs doped cells

4. CONCLUSIONS

Pure nematic liquid crystal and CNTs-NLC mixtures have been prepared and studied under electric field. Doping of CNTs increases the current 2-3 times in CNTs-NLC mixture and follows a liner relationship with applied electric field. This increase in current is expected due to the conductive nature of CNTs. A decreasing behavior in current was also notice with increasing the temperature. Higher value of optical transmission and lower threshold voltage was observed in 0.2% CNTs doped sample cell.

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