Journal of University of Kerbala

Effect of MWCNT on Electro-Optical Properties of Liquid Crystal

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Abstract

Dispersions of multi wall carbon nanotubes (MWCNTs) in liquid crystals (LCs)type 5CB have attracted attention due to their unique properties and possible applications in photonics and electronics. The results of the investigations of improved the electro-optical properties of liquid crystal optical switch are being presented here. The addition of MWCNT showed fast response time ,fast rise time,and lower threshold voltage.

Key words: Liquid crystal, MWCNT, electro-optical properties, optical switch.

Introduction

Liquid crystals (LCs) turn out to be excellent hosts for multi walled carbon nanotubes (MWCNTs). Having molecular structure similar to MWCNTs, LCs perfectly incorporate MWCNTs into own structure. Particularly, the liquid crystalline orientational order can be imposed on MWCNTs so that aligned ensembles of these particles can be attained [1] . This alignment can be patterned by pattering alignment of LC host. Furthermore, the alignment axis of MWCNTs can be easily driven by the LC reorientation in the external field[2] ; MWCNTs follow reorientation of LC director demonstrating guest-host effect known for molecular solutions and dispersions of anisotropic nanoparticles in LC hosts [3] . Finally, LC can be removed and thus pure aligned MWCNTs can be obtained [4] . This altogether means that LC gives unique opportunity for controllable alignment of MWCNTs.

The LC-MWCNTs systems are not limited to nematic matrices. A series of unique LC-MWCNTs composites based on thermotropic and lyotropic materials with different LC mesophases is developed and characterized[5][6][7][8][9]

A present work is focused on remarkable dielectric, electro-optical and micro-structural peculiarities of LC-MWCNTs dispersions, their correlation and mutual influence.

Nematic LC type 5CB purchase from Sigma-Aldrich co., characteristics of this LCs[3] is presented in Table 1

LC	Nematic mesophase	dielectric anisotropy $\Delta\varepsilon$, optical anisotropy Δn
5CB	295.5- 308.3 K	$\Delta\varepsilon$=13, Δn=0.177 at 298 K

Experimental work:

1- Multiwall carbon nanotubes

MWCNTs have an outer diameter of about 12–20 nm and the length of about 5-10 μm. The specific electric conductivity of the powder of compressed MWCNTs was about 103S/m along the compression axis.

2- Preparation of LC/ MWCNT optical switch

The LC-MWCNT composites was prepared by 20 min stirring of LC and MWCNT mixtures using the ultrasonic bath. The concentration of doping MWCNTs was 0.05 wt %. In the LC-MWCNTs composites. The optical switch for electro-optical and dielectric measurements was made from glass substrates containing patterned ITO electrodes and aligning layers of polyimide. (PVA) for planar alignment of LC 5CB. The polyimide layers were rubbed by a fleecy cloth in order to provide a uniform planar alignment of LC in either field-on state or a zero field (5CB). The cell was assembled so that the rubbing directions of the opposite aligning layers were antiparallel. A cell gap was maintained by the glass spacers of appropriate size (20 μm). Finally, these cells were filled with neat or MWCNTs doped liquid crystals. Fig. (1) shows the optical microscope image for LC/MWNT optical switch, the image shows some aggregation distribution of MWNT dispersed in 5CB LC.

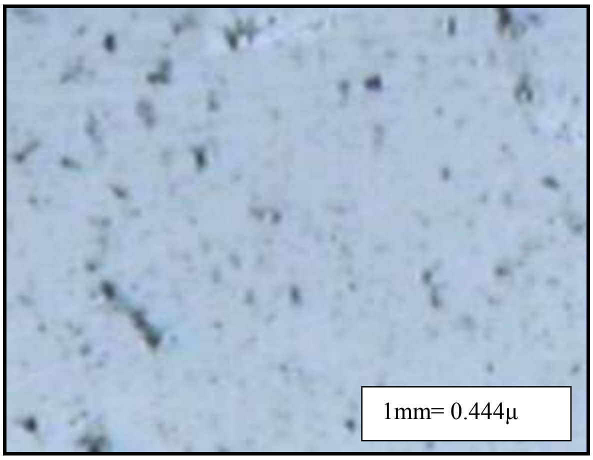

Fig.(1) LC/MWNT optical switch with magnification X10

The LC-MWCNTs composites was monitored by observation of the filled cells placed between crossed polarizers, by optical polarizing microscope.

3- Electro-optical measurements

The electro-optical measurements were carried out using the experimental setup described in Fig.(2). The cell was set between two crossed liner polarizers so that the angle between the polarizers is 90^0,while the angle between the polarizer axes and the rubbing direction of the polymide layer was 45°. The sinusoidal voltage 0-3 V (at frequency 250 Hz) was applied to the cell using function generator (Tektronix TMB83 FG 501A,2MHz). The photo detector used was from (RS stock no.308-067) , consists of a high performance silicon photodiode combined with a high gain low noise amplifier . The Oscilloscope was Tektronix TDC 2024B, 200MHz used to display the output signal. The time of voltage application, was about 20 sec . The transmittance of the samples was calculated as $\eta=(I_{out}/I_{in})*100\%$
where I_{in} and I_{out} are intensities of the incident and transmitted light, respectively.

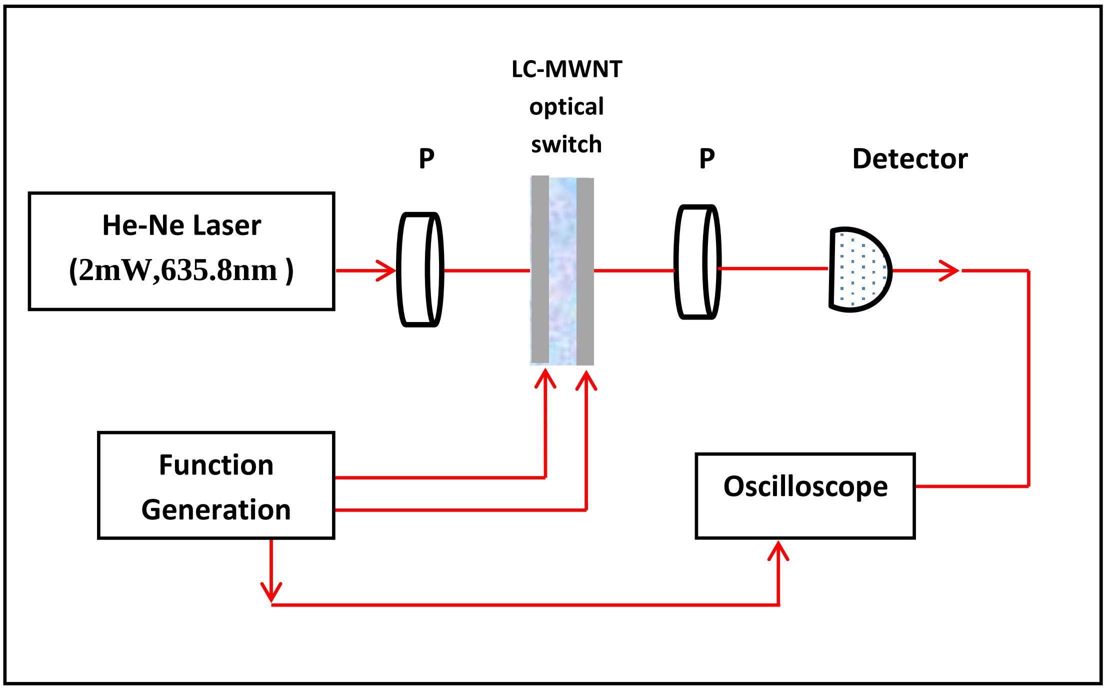

Fig.(2) Experimental setup for measuring the electro-optical properties of the LCD devices with an applied AC voltage

Results and discussion

1- Frequency response

The frequency that the device of LC/MWNT have maximamam transimetance as an optical switch is 250 Hz .

2- Threshold voltage

The threshold voltage of the LC/MWNT is measured when it start to response. The frequency of AC applied voltage from the function generator hold at 250 Hz. Fig. (3) shows the relation between applied voltage and output voltage record from the detector as a function of the transmission of the LC/MWNT optical switch, the dashed line point for the threshold voltage is 0.9 volt, while for pur LC optical switch is 1.4volt.

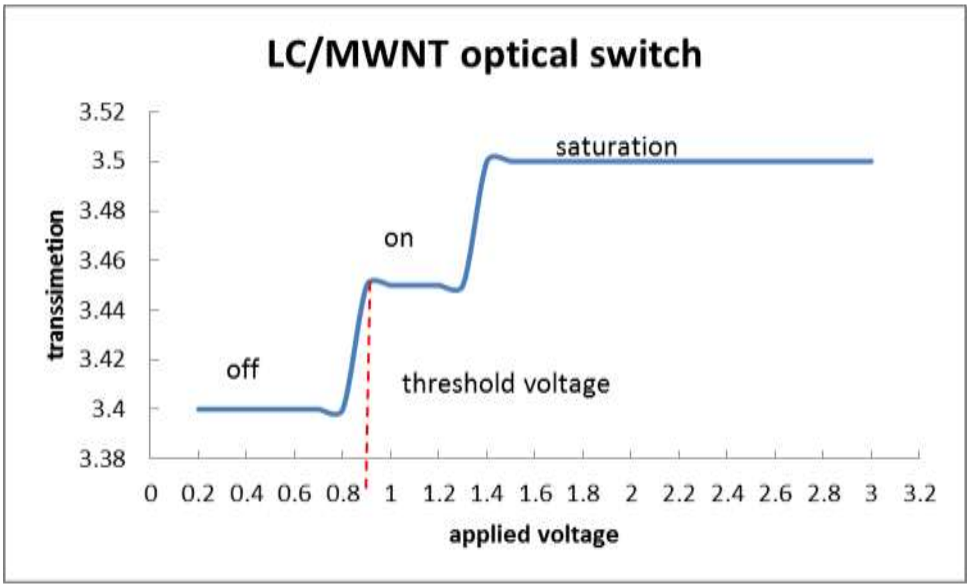

Fig.(3) Threshold voltage of LC/MWNT optical switch

3- Rise Time

We calculate the rise time from the signal of the response voltage of the LC optical switch device that get from the Oscilloscope as shown in Fig. (4), the rise time was 2.5 ms

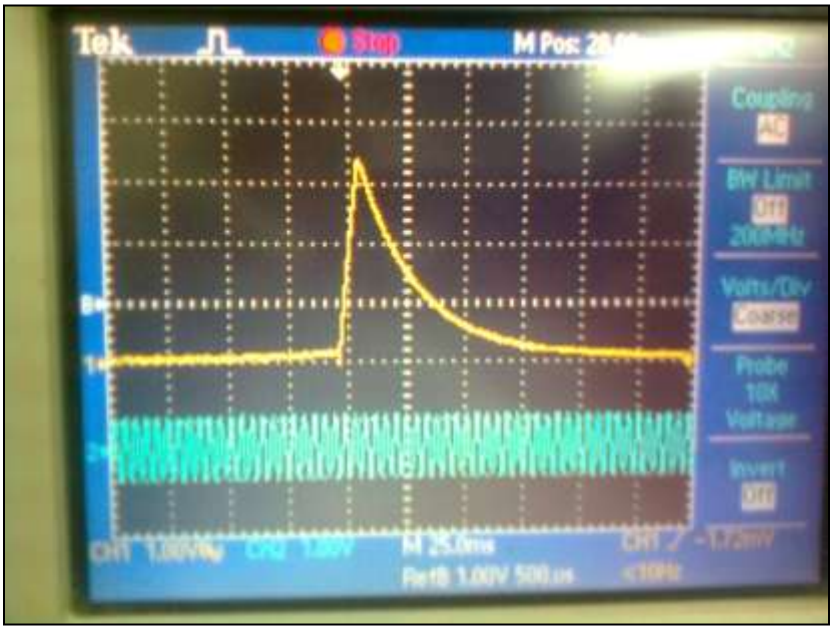

Fig.(4) The signal of LC/MWCNT optical switch

4- Fall time
   Fall time 90% - 10% of the steady state of signal= 50 ms
5- response time
   response time 0% - 62.5% of the steady state of signal= 5ms.

The intensity of transmission decreased by(Iin/Iout)x100% is(3.6/3.4)x100% =12.24%

Conclusion:

The LC -MWCNT optical switch has been studied to understand the stability of these systems in the nematic phase, the composite system results in an improvement in relaxation decay time for larger Vac, which might be an application for LC display technology. It has been shown that the phenomena of self-organization in LCs orients MWCNTs and that MWCNTs dispersed in LC can act as seeds for oriented domain growth. Herein the anisotropic nature of controlled nanotube orientation deposition can align nematic 5CB LC. The electro-optic properties of LC-MWCNT optical switch show enhancement ,threshold voltage decreased by 60% , The response time of LC/MWCNT composite optical switch reduced due to the addition of MWCNT in 5CB LC showing an improved switching behavior. Decreasing the threshold voltage from 1.5 V of pure 5CB to 0.9 V for doped 5CB with MWCNT. The rise time from 7.5ms for pure 5CB to 2.5 ms for doped 5CB with MWCNT. The fall time from 58.75ms for pure 5CB to 50ms for doped 5CB with MWCNT. Fast response time from 12.5ms for pure 5CB to 5ms for doped 5CB with MWCNT.

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