7. ABSTRACT OF THE INVENTION (to be given along with complete specification on separate page)

The present invention includes a liquid crystal composite comprising a liquid crystal composition as a host and a large concentration of carbon nanotubes as dopants, wherein the carbon nanotubes forms aggregates in the liquid crystal composition. The average length of the carbon nanotubes varies from 0.3 to few μm. This invention discloses a process of transforming commercially available high temperature liquid crystals in to low temperature liquid crystals. It discloses the process of changing the liquid crystal phase with application of bias.

Note:-

***Repeat boxes in case of more than one entry.**

***To be signed by the applicant(s) or by authorized registered patent agent.**

***Name of the applicant should be given in full, family name in the beginning.**

***Complete address of the applicant should be given stating the postal index no./code, state and country.**

***Strike out the column(s) which is/are not applicable.**

5. CLAIMS
I/We claim that

1. A technique for reducing the transition temperature of liquid crystal by the process of forming composite of liquid crystals with high percentage of multi-walled carbon nanotubes comprising: a liquid crystal composition as a host; a large percentage of multi-walled carbon nanotubes as dopants, wherein the average length of the carbon nanotubes varies from 0.3 to few μm.
2. The liquid crystal cell filled with composite according to claim 1, wherein the liquid crystal composition comprises nematic or ferroelectric liquid crystal.
3. The liquid crystal composite according to claim 1, wherein the carbon nanotubes are at a concentration equal to 5 wt % or 10 wt % of the liquid crystal composite.
4. The liquid crystal composite according to claim 1, wherein the carbon nanotubes are not dispersed and form large aggregates.
5. A liquid crystal cell comprising: two electrodes, both electrodes being transparent; and the liquid crystal composite disposed between the electrodes, consisting of (a) a liquid crystal composition as a host; (b) carbon nanotubes as dopants, wherein the average length of the carbon nanotubes varies from 0.3 to few μm wherein the distance between the first and second electrodes is equal to 200 μm or 600 μm.
6. The liquid crystal device as recited in claim 5, where in the host material is nematic liquid crystal with 5 wt% MWCNTs and cell thickness is 200 μm, is found to show high temperature liquid crystal phase at lower temperature on application of bias

Contd.

Contd.

5. CLAIMS
I/We claim that

7. The liquid crystal device as recited in claim 5, where in the host material is ferroelectric liquid crystal with 5 wt% MWCNTs and cell thickness is 200 μm is found to show high temperature liquid crystal phase at lower temperature on application of bias
8. The liquid crystal device as recited in claim 5, where in the host material is nematic liquid crystal with 10 wt% MWCNTs and cell thickness is 200 μm, is found to show high temperature liquid crystal phase at lower temperature on application of bias
9. The liquid crystal device as recited in claim 5, where in the host material is ferroelectric liquid crystal with 10 wt% MWCNTs and cell thickness is 200 μm is found to show high temperature liquid crystal phase at lower temperature on application of bias
10. The liquid crystal device as recited in claim 5, where in the host material is nematic liquid crystal with 10 wt% MWCNTs and cell thickness is 600 μm, is found to show high temperature liquid crystal phase at lower temperature on application of bias
11. The liquid crystal device as recited in claim 5, where in the host material is ferroelectric liquid crystal with 10 wt% MWCNTs and cell thickness is 600 μm, is found to show high temperature liquid crystal phase at lower temperature on application of bias
12. The liquid crystal device as recited in claim 6-11, wherein these devices get shot when bias is increases beyond certain limit called as breakdown voltage.

Contd.

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Contd.

5. CLAIMS
I/We claim that

13. The liquid crystal device as recited in claim 6-11, wherein these devices will also be helpful in switching the material from one phase to another with the help of bias.
14. The liquid crystal device as recited in claim 6-11, wherein these devices show similar effect by doping with Zno and SWCNTs or any other nanomaterial.
15. The liquid crystal device as recited in claim 6-11, wherein these devices may be used to make field sensors, conversion of field in to heat.
16. The liquid crystal device as recited in claim 6-11, wherein these devices will also be possible in liquid crystal elastomers and will improve their electro-mechanical properties.

6. DATE AND SIGNATURE (to be given at the end of last page of specification)

Khosla Samriti 28/4/15

Sood Nitin 28/04/2015

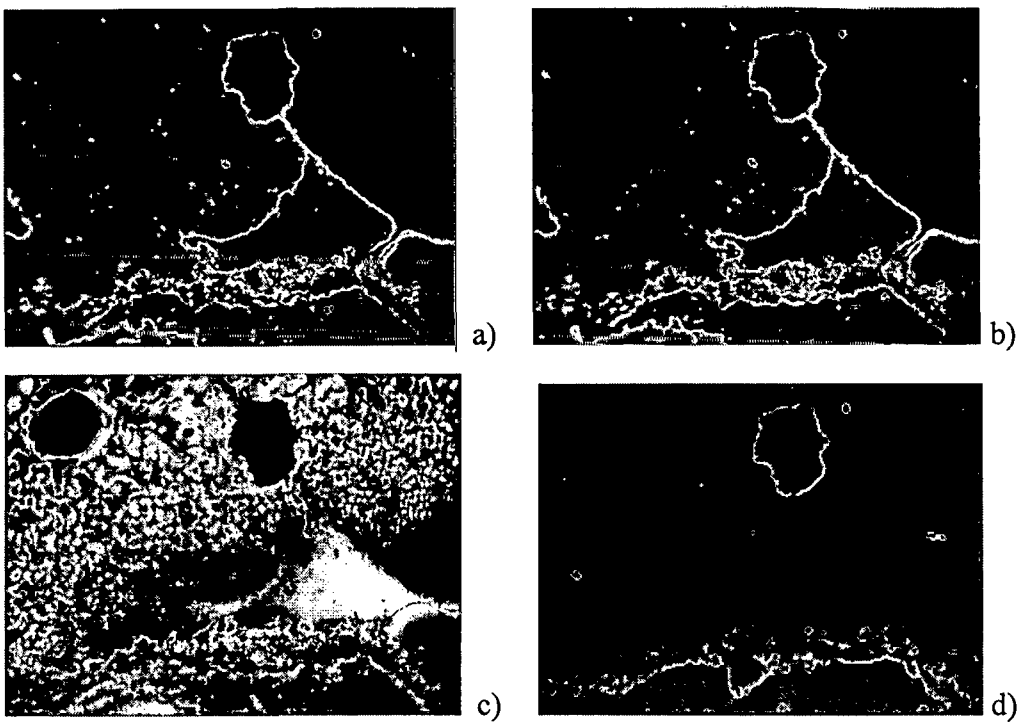


Fig 2:-Optical microphotographs of 5% doped NLC-I mixture at 0V with increasing temperature a) 35 ^{0}C b) 40 ^{0}C c) 45 ^{0}C d) 50 ^{0}C.

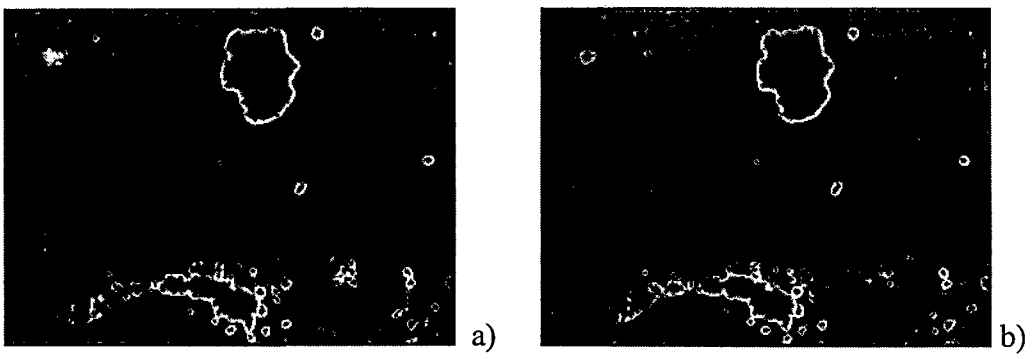


Fig 3:-Optical microphotographs of 5% doped NLC-I mixture at 2V with increasing temperature a) 40 ^{0}C b) 50 ^{0}C


a)

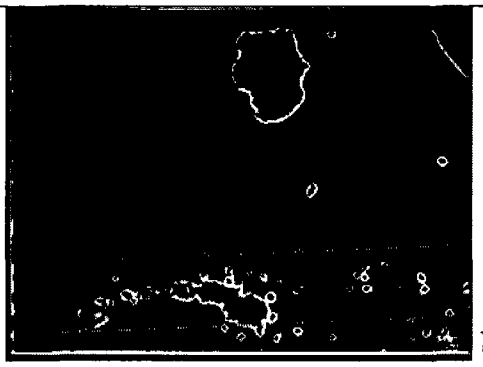

b)

Fig 4:-Optical microphotographs of 5% doped NLC-I mixture at 6V with increasing temperature a) 40 ^{0}C b)50 ^{0}C


a)


b)


c)

Fig 5:-Optical microphotographs of 5% doped NLC-I mixture at 8V with increasing temperature a) 40 ^{0}C b) 45 ^{0}C c) 50 ^{0}C

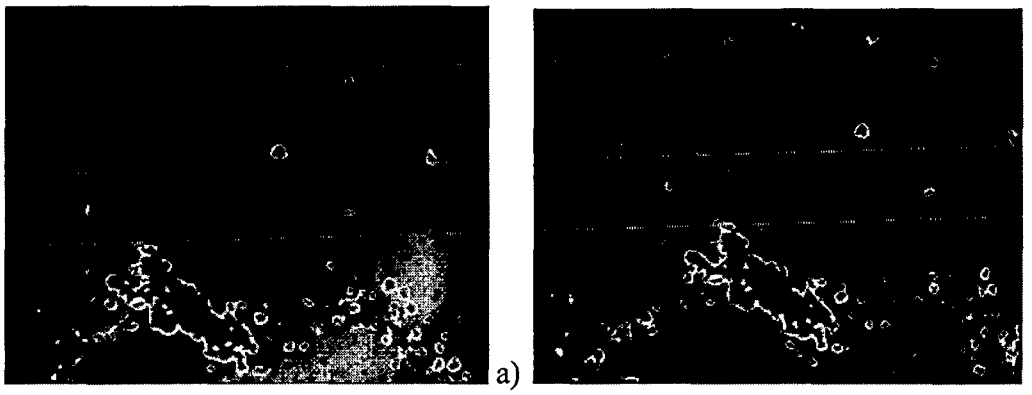


Fig 6:-Optical microphotographs of 5% doped NLC-I mixture at a) 10V and b) 12V respectively

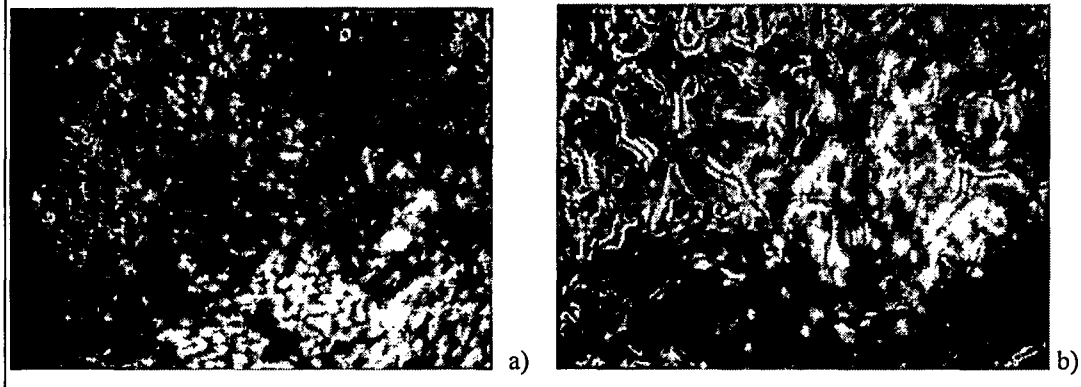
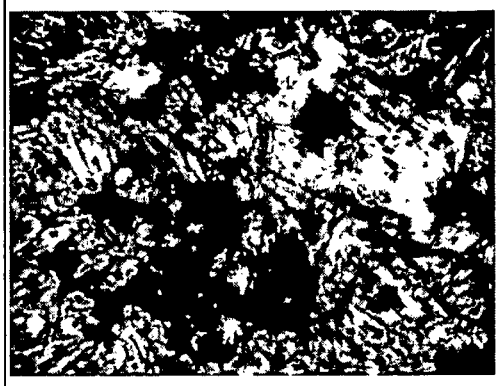
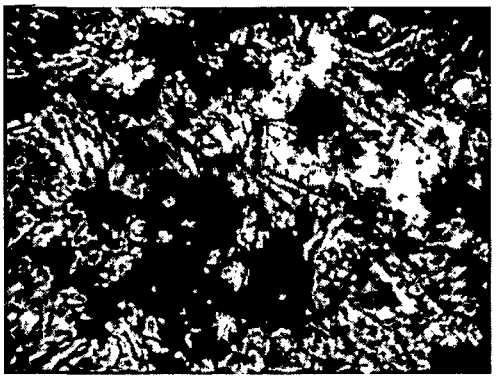


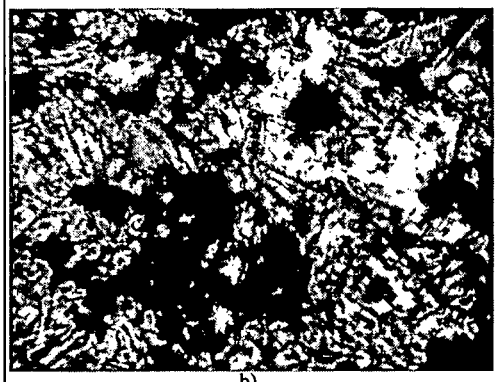
Fig 7:-Optical microphotographs of pure NLC-II with 0V bias at a) 50 ^{0}C b) 56 ^{0}C



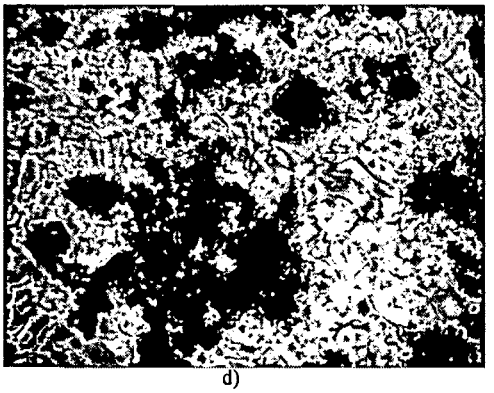
a)



b)



b)



d)

Fig 8:-Optical microphotographs of 5% doped NLC-II at 45 ^{0}C a) 0V b) 2V c) 4V d) 6V

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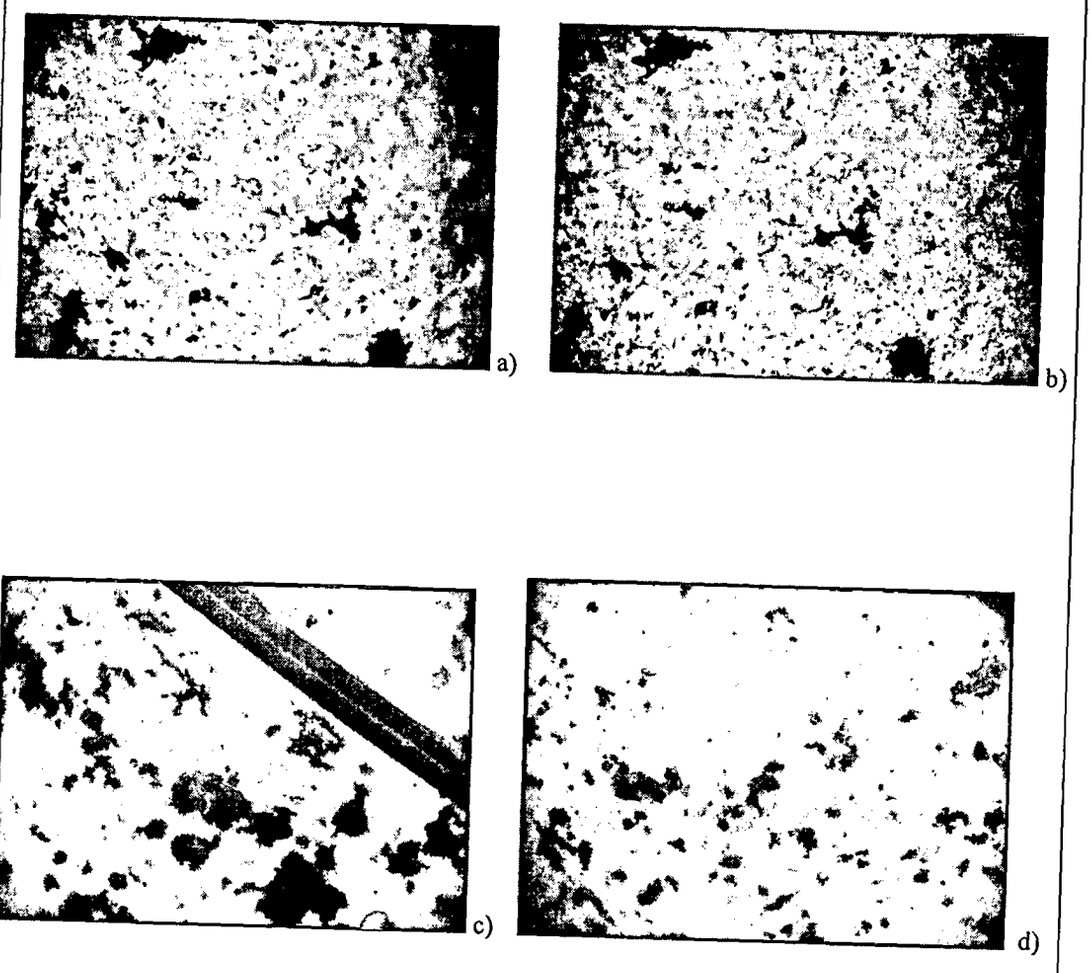


Fig 9:-Optical microphotographs of 5% doped FLC-I material a) 0V 35 ^{0}C b) 6V 35 ^{0}C c) 12V 35^{0}C d) 12V 40 ^{0}C

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4. DESCRIPTION

A. BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to liquid crystals, and more particularly, to a method for obtaining high temperature liquid crystal phases at lower temperature or reducing the transition temperature of liquid crystals with the help of bias and nanotubes.

2. Description of the Prior Art

The use of liquid crystal in display devices requires the presence of liquid crystal phases at room temperature. Because of the problems such as the high cost and complex method of synthesis for production of material with room temperature liquid crystal phases, a method to convert high temperature liquid crystal in to room temperature liquid crystals has long been a critical issue and is highly desirable in the liquid-crystal display (LCD) technology. Manufacturers and researchers have made many efforts to eradicate the problem. Unfortunately not a single efficient method to convert the high temperature liquid crystals into room temperature liquid crystals, after their synthesis has been developed so far.

To solve the problems, current strategy is used in which we dope LC materials with a high concentration of carbon nanotubes (CNT) so that CNTs form aggregates inside the materials. It would lead to the appearance of high temperature phases at room temperature when a sufficient voltage is applied.

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B. Detailed Description

The liquid crystal (LC) materials were doped with very high concentration of multi wall carbon nanotube (MWCNTs) and were filled in the planar cells. A high voltage was applied to the cells which get short at some particular voltage (Breakdown Voltage). Below this breakdown voltage, we observed that with application of bias the nanotube aggregates tries to join and elongate. These cluster behaved as local heater till the application of breakdown voltage after which the cell breaks. This phenomenon resulted in the reduction of transition temperature of liquid crystal phase. However, in order to observe the effect noticeably, the minimum thickness of the cell is kept at 200 μm. The liquid crystal materials were doped with a minimum 5% wt/wt concentration of CNTs. In this framework, the effect is reported for the two types of materials: a) Nematic liquid crystal (NLC) and b) ferroelectric liquid crystals (FLC). The observations were also made on other materials and similar effects were observed. The details of the investigations are as follows.

i) Materials Used

The MWCNTs used to disperse in liquid crystal were synthesized at the National Physics Laboratory, New Delhi, by a chemical vapour deposition method. The diameter of the synthesized MWCNTs ranged from 30–50 nm with a typical length ranging from 0.3 μm to several μm. The MWCNTs were doped in concentration of 5 and 10% wt/wt ratio into Liquid crystal material. The composites were prepared by simple mixing of MWCNTs in host Liquid crystals.

The host liquid crystal material used in the present study are high temperature Nematic Liquid Crystal 1-(trans-4-Hexylcyclohexyl)-4-isothiocynatobenzene and high temperature Ferroelectric Liquid Crystals KCFLC 10S and DOBAMBAC. The Nematic Liquid Crystal material used here was obtained from Sigma Aldrich. The Ferroelectric Liquid Crystals, KCFLC 10S and DOBAMBAC, were obtained from Kingston Chemical UK and Frinton Inc. USA respectively. The electro-optical textures of the cells were observed by an optical microscope (Dewinter Biowizard).

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The phase sequence of the host liquid crystal Materials used is as follows:-

Nematic Liquid Crystal (NLC)

NLC-I

Crystal---Room Temperature---Nematic---50C---Isotropic

NLC-II

Crystal----56 ^{0}C ----Nematic-----76 ^{0}C ------Isotropic

Ferroelctric Liquid Crystals (FLC)

KCFLC10s (FLC-I)

Crystal----64.5 ^{0}C ----Smectic C*----99^{0}C --- Smectic A ---112 ^{0}C -----Isotropic

DOBAMBC(FLC-II)

Crystal---76 ^{0}C----- Smectic C*-----94 ^{0}C-----Smectic A-----117 ^{0}C-----Isotropic

ii) Cell/Device Fabrication:

The cells were made with ITO coated plates and the thickness was maintained with the help of spacers. For planar alignment in cells, we considered two Indium tin oxide (ITO) coated glass substrates (obtained from Bharat Electronics Ltd., Bangalore). The substrates were initially rinsed in acetone (extra-pure). This procedure was immediately followed by the deposition of thin coating of ~5-10% PVA (polyvinyl alcohol) prepared in de-ionised distilled water. The glass plates were baked at 130^{0}C for one hour and then rubbed uni-directionally using nylon cloth to get well aligned mono-domain. The conducting sides of the substrates were joined together and separation between the substrates was maintained by using the spacer of different thicknesses (from 200 to 600 μm). Two sides of the cell were sealed using Norland NOA65 an UV polymer, and then cured in presence of UV light.

Remaining two sides of the cells were sealed using an optical adhesive after filling the sample in the cell and was again cured in the presence of UV light. The cell assembly is shown in Fig. 1. The electrodes were connected at the ITO coated substrate surface using indium solder for a better contact. The electric field was applied to the sample across these electrodes. The temperature of the sample was regulated at ±1^{0}C variation during the measurement by using Temperature programmer cum hot stage.

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The composite material was filled in these planar cells using capillary action. The cells were made without any precaution to disperse CNT thereby resulting in formation of clusters.

iii) Results

MWCNTs strongly attract each other by Vander Waals forces. So, when no precautions are taken, they form more or less developed system of aggregates in a liquid host. Weak aggregation of CNTs is observed in the polar aprotic solvents like dimethylformamide, *N*-methyl-2- pyrrolidone, the chlorinated hydrocarbon dichloroethane, and the polar protic compound ethyl alcohol. In LC matrices the nanotubes aggregate quite intensively. This is considered to be a challenge for the majority of applications demanding LC-CNTs composites with high and uniform dispersion of CNTs. As a result, earlier the presence of aggregates was considered as a disadvantage and extensive research was done to disperse them. In the present work we have obtained a great advantage of the phenomenon as discussed below in details.

Nematic Liquid Crystals

NLC-I

Figure 2 shows the optical microscopic images of MWCNT doped NLC medium with increasing temperature without any external bias. These images clearly depict the agglomerations of MWCNT in NLC medium. We observed that at a temperature of 50 ^{0}C [transition temperature] phase of LC changes from nematic to isotropic. The CNT clusters, however, remain intact and hence we do not find any noticeable effect of MWCNTs cluster.

Fig 3 shows the optical images of the samples on application of a bias of 2V. In this case we observed that the change in phase of LC takes place at a slightly lower temperature [45 ^{0}C]. However, no effect of bias on MWCNTs cluster is observed Similarly, the increase of external bias up to 6V [Fig 4] results in change of LC phase at an even lower temperature i.e. 40 ^{0}C with CNTs still present in the form of clusters.

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Fig 5 shows the optical microphotographs of CNT-LC mixture at 8V with increasing temperature. This shows the appearance of high temperature phase at 35 ^{0}C, a further reduction in transition temperature. In this case, we also observe that MWCNTs starts to elongates along the applied field [Fig 5(c)] and a little dispersion of MWCNTs in LC medium is obtained at a temperature of 50 ^{0}C. Fig 6(a,b) shows the optical microphotographs of CNT-LC mixture at 10V and 12V respectively. It represent the appearance of LC phase at room temperature and also the clusters of MWCNTs gets completely disperse in LC medium. A futher increase in bias leads to the leakage of cell.

NLC-II

Fig 7 shows appearance of nematic phase at 56 ^{0}C in 200 μm cell of pure NLC-II. The application of bias did not effect the transition temperature of this sample. In case of 5% doped cell of NLC-II, we observe the lowering of trasntion temperature with appearance of nematic phase at 45^{0}C on application of 6V bias [Fig 8 (a-d)].

Ferroelectric Liquid Crystals and MWCNTs dispersion

FLC-I

The investigations performed on ferroelectric liquid crystals (FLC) cells of thickness 200 μm are presented in Figure 9(a-d). FFigure 9 shows the microphotographs of MWCNT-FLC composite at different bias volatages. It is clear from these images [Figure 9] that as we increase the bias the doped material changes its phase. At 12V, the high temperature phase appears at a temperature as low as 35^{0}C. Finally at even higher bias the dispersion is obtained. On further increase of bias the cells breaks. The effect of MWCNTs on FLCs seems to be the similar as observed in previous section for NLC Material.

FLC-II

In FLC-II, effect of CNT doping wassimilar as for FLC-I.

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The increase in thickness of the cell, for all samples, increases the breakdown voltage both in NLC and FLC composites. The increase in cell thickness also allowed us to use more wt./wt. percentage of nanutube at same breakdown voltage as compared to the one at small cell gap. **A similar behavior is expected in other nematic and ferroelectric liquid crystal.**

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v) DESCRIPTION OF THE DRAWING

Fig.1:- A view of Cell Geometry.

Fig 2:-Optical microphotographs of 5% doped NLC-I mixture at 0V with increasing temperature a) 35 ^{0}C b) 40 ^{0}C c) 45 ^{0}C d) 50 ^{0}C.

Fig 3:-Optical microphotographs of 5% doped NLC-I mixture at 2V with increasing temperature a) 40 ^{0}C b) 50 ^{0}C

Fig 4:-Optical microphotographs of 5% doped NLC-I mixture at 6V with increasing temperature a) 40 ^{0}C b)50 ^{0}C

Fig 5:-Optical microphotographs of 5% doped NLC-I mixture at 8V with increasing temperature a) 40 ^{0}C b) 45 ^{0}C c) 50 ^{0}C

Fig 6:-Optical microphotographs of 5% doped NLC-I mixture at a) 10V and b) 12V respectively.

Fig 7:-Optical microphotographs of pure NLC-II with 0V bias at a) 50 ^{0}C b) 56 ^{0}C

Fig 8:-Optical microphotographs of 5% doped NLC-II at 45 ^{0}C a) 0V b) 2V c) 4V d) 6V

Fig 9:-Optical microphotographs of FLC material a) 0V 35 ^{0}C b) 6V 35 ^{0}C c) 12V 35^{0}C d) 12V 40 ^{0}C

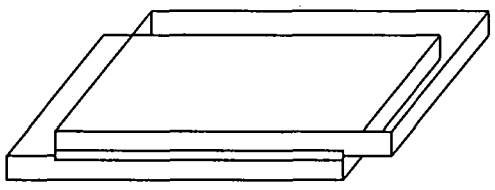


Fig. 1- Cell Geometry

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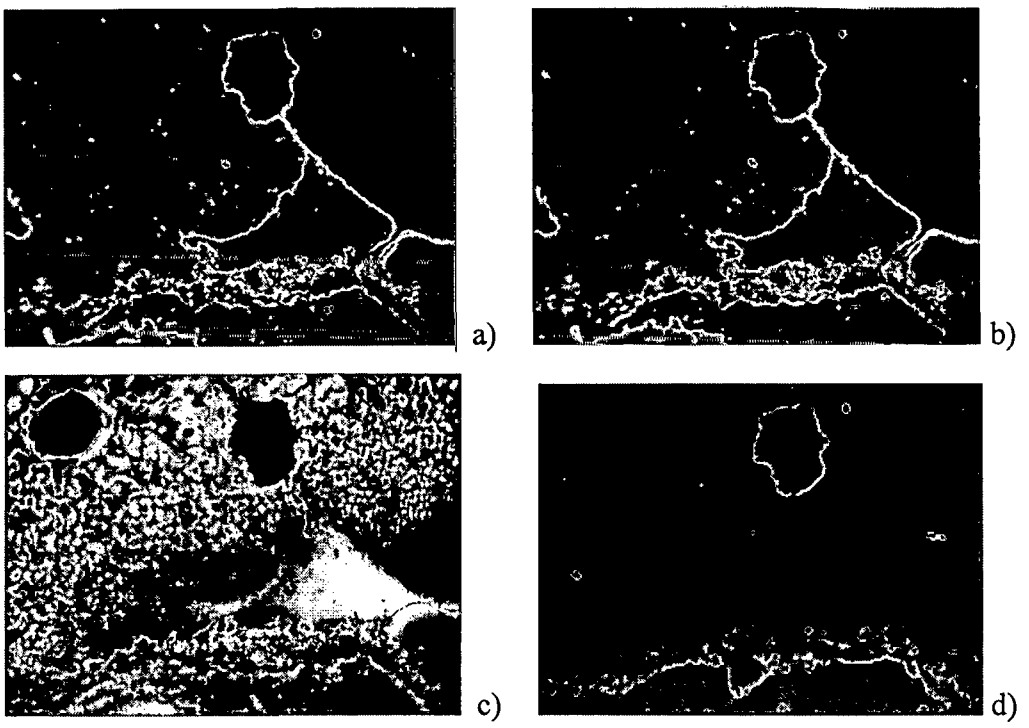


Fig 2:-Optical microphotographs of 5% doped NLC-I mixture at 0V with increasing temperature a) 35 ^{0}C b) 40 ^{0}C c) 45 ^{0}C d) 50 ^{0}C.

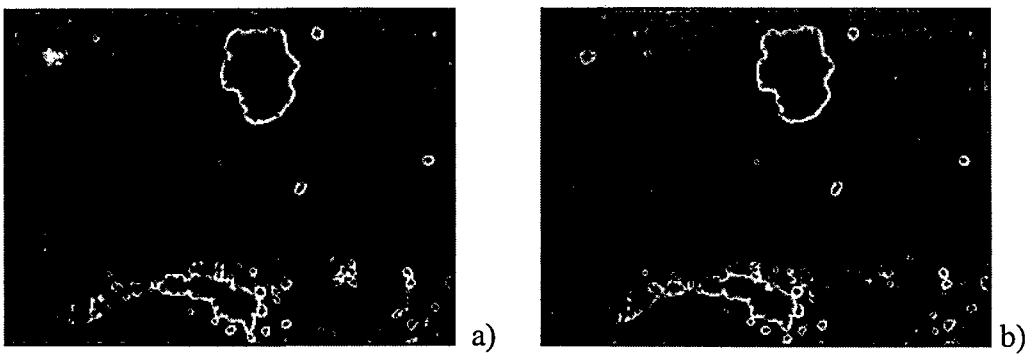


Fig 3:-Optical microphotographs of 5% doped NLC-I mixture at 2V with increasing temperature a) 40 ^{0}C b) 50 ^{0}C


a)

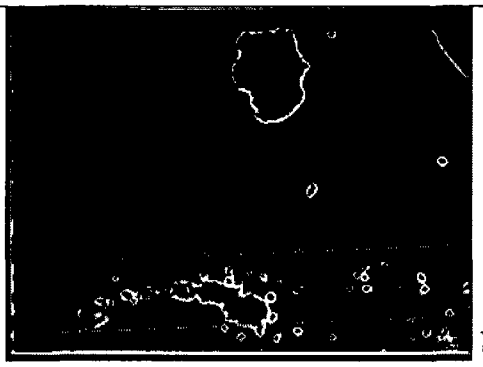

b)

Fig 4:-Optical microphotographs of 5% doped NLC-I mixture at 6V with increasing temperature a) 40 ^{0}C b)50 ^{0}C


a)


b)


c)

Fig 5:-Optical microphotographs of 5% doped NLC-I mixture at 8V with increasing temperature a) 40 ^{0}C b) 45 ^{0}C c) 50 ^{0}C

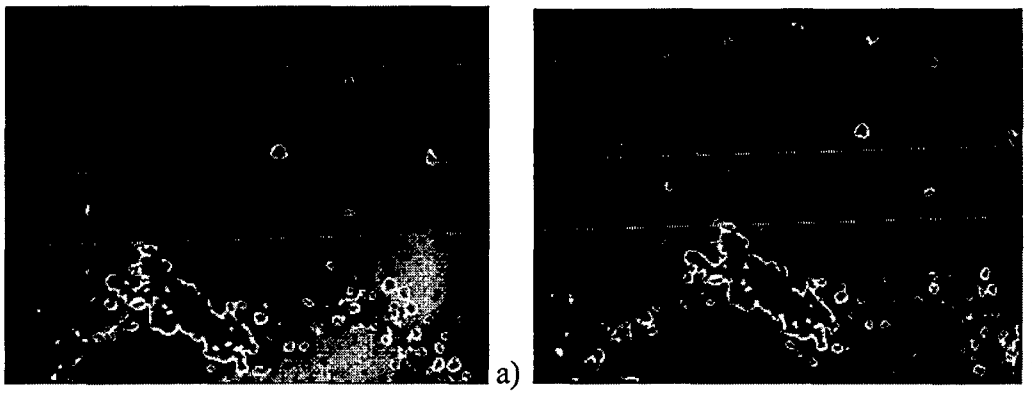


Fig 6:-Optical microphotographs of 5% doped NLC-I mixture at a) 10V and b) 12V respectively

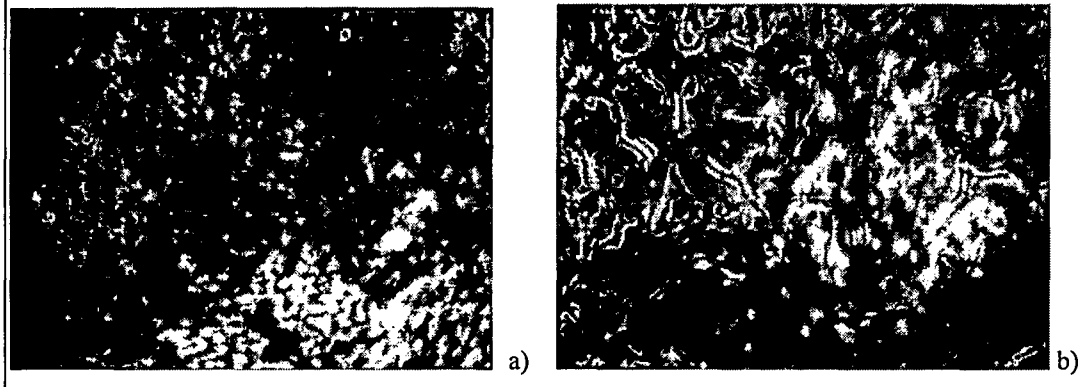
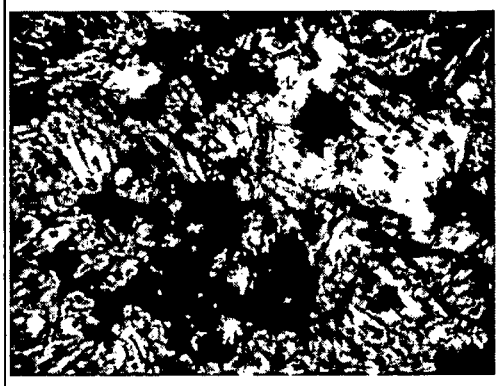
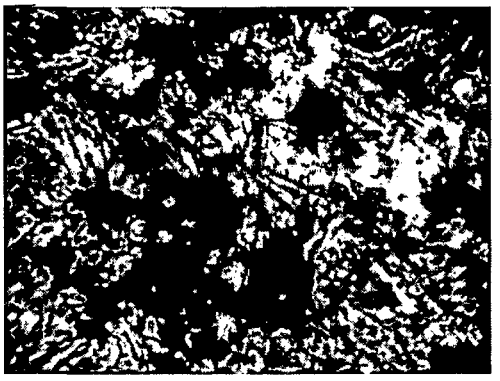


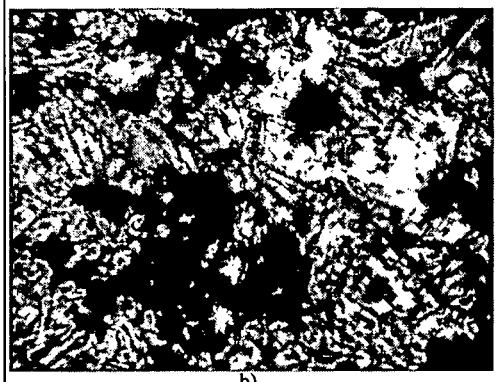
Fig 7:-Optical microphotographs of pure NLC-II with 0V bias at a) 50 ^{0}C b) 56 ^{0}C



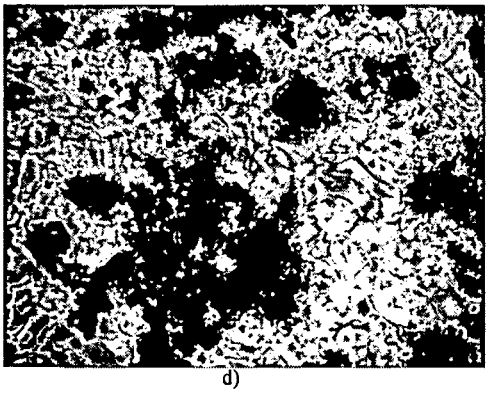
a)



b)



b)



d)

Fig 8:-Optical microphotographs of 5% doped NLC-II at 45 ^{0}C a) 0V b) 2V c) 4V d) 6V

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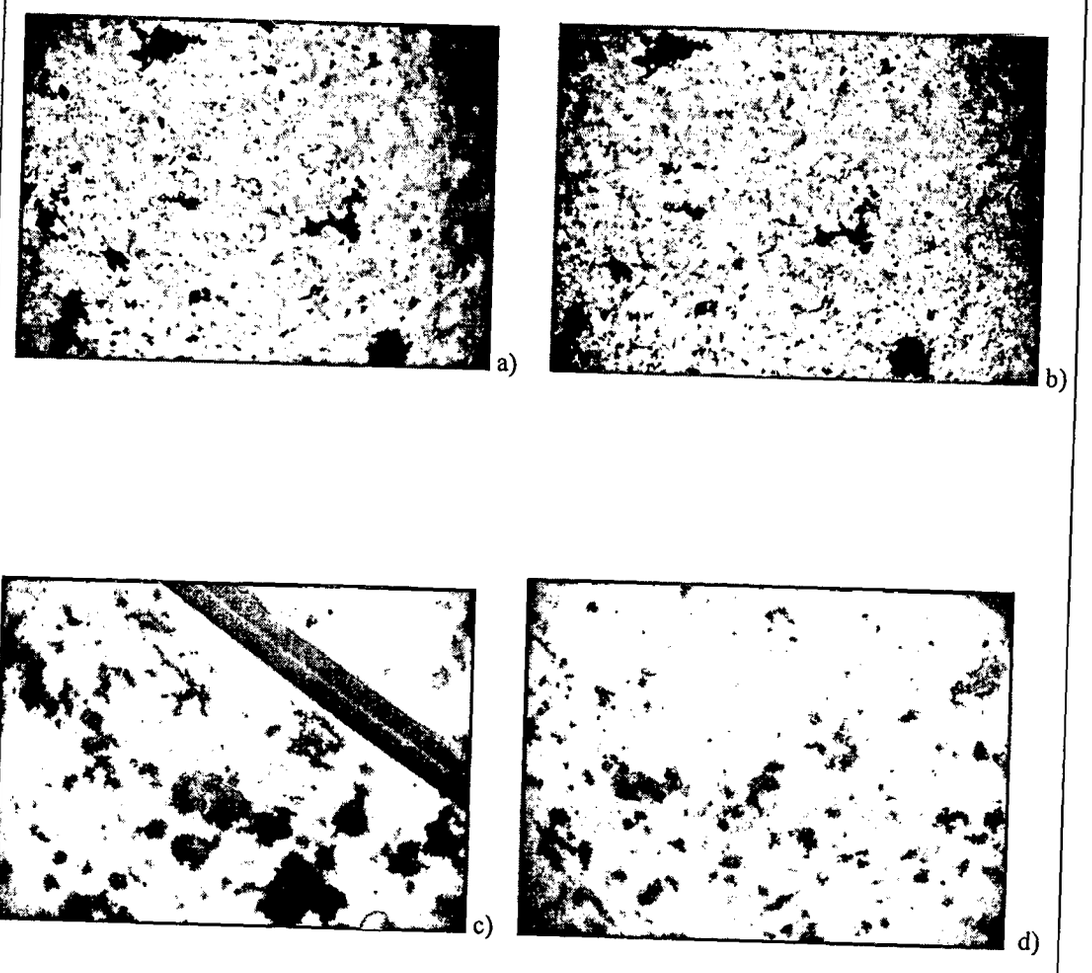


Fig 9:-Optical microphotographs of 5% doped FLC-I material a) 0V 35 ^{0}C b) 6V 35 ^{0}C c) 12V 35^{0}C d) 12V 40 ^{0}C

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Conclusions:- The object of the present invention is to identify the process to convert high temperature liquid crystal materials in to low temperature liquid crystals. By this process we shall obtain the liquid crystal phase at room temperature for a materials which otherwise show this phase at high temperature. According to our embodiment, a high concentration (5-10 wt% of liquid crystals) of multi-walled carbon nanotubes is added in commercially available high temperaure liquid crystals materials without taking any precaution to disperse them in host liquid crystals. The material is then filled in the liquid crystals cell of high thickness (200 and 600 μm). It results in formation of agglomerates in liquid crystals cells which usually are not desirable as they do not appreciably affect the properties of liquid crystals. But in this process we have found the usefulness of these aggregates. In these heavily doped samples, on application of bias, we observed the appearance of Liquid crystal phases at room temperature which were observable only at high temperature in case of pure Liquid crystal materials.

By using this technique we were able to convert high temperature Liquid crystal into low temperature Liquid crystals. The synthesis of room temperature Liquid crystal is supposed to be a complex and costly process. This method has resulted in the formation of room temperature Liquid crystal at very low cost, less time and very simple method.