EFFECT OF NANO-MATERIALS ON THE ELECTRO-OPTICAL PROPERTIES OF DEFORMED HELIX FERROELECTRIC LIQUID CRYSTALS AND THEIR APPLICATIONS

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF NANO-MATERIALS ON THE ELECTRO-OPTICAL PROPERTIES OF DEFORMED HELIX FERROELECTRIC LIQUID CRYSTALS AND THEIR APPLICATIONS"** being submitted by **Jai Prakash** to the Indian Institute of Technology Delhi for the award of the degree of "**DOCTOR OF PHILOSOPHY**", is a record of the authentic research work carried out by him under our supervision and guidance. He has fulfilled all the requirements for submission of this thesis, which to the best of our knowledge has reached the required standard.

The material contained in this thesis has not been submitted in part or full to any other University or Institute for the award of any other degree.

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ABSTRACT

Liquid crystals (LCs) have shown their importance as a promising materials in various display as well as non-display (optical devices based on LC) applications in modern technology. Most of the displays currently available in the market are based mainly on LCs. Present work is an attempt to bring the attention of researchers in exploring the potential of nano-materials doped LC or ferroelectric LCs (FLCs) in other disciplines apart from parent area of LCs, i.e. optical devices, photoluminescent LC displays (LCDs), faster LCDs and memory devices. In the present study, effect of nano-materials on the electro-optical properties of deformed helix FLC (DHFLC) and their applications has been discussed. These studies can be applied in various disciplines of science and engineering for the fabrication of several devices.

Chapter 1 presents the introduction of LC, its classification and various applications along with a brief review of the present status of the field.

Chapter 2 describes the techniques used in the fabrication of sample cells, instruments involved in the characterization of these cells. To carry out the LC research, the systematic study of LCs is very important to know the physical, chemical, electro-optical and dielectric properties of LC. The methods used for the determination of material constants of LCs have also been described in this chapter.

Chapter 3 demonstrates the critical conditions for bistability in DHFLC. The bistability in surface stabilized FLCs (SSFLCs), in which the thickness of the sample

cell is kept less than the pitch value of the material, is a consequence of broken symmetry and is an inherent feature of the SSFLC geometry. The bistability phenomenon in DHFLCs is not like the conventional FLC material where it is due to surface stabilization effect. As the pitch value of the DHFLC material is in submicron range, the bistability in DHFLC is entirely a different concept related to helix deformation and molecular reorientation process. However, a bistable switching and a memory element with a reasonable working voltage and response time have been observed in DHFLC. In this chapter, we have presented introduction, history, and salient features of DHFLC material including basic mechanism of DHF effect. The dynamics of bistability in DHFLC have been demonstrated in detail. The threshold voltage studies and the molecular reorientation processes have also been presented to explain dynamics of bistability in DHFLC.

Chapter 4 presents the effect of surface anchoring on optical bistability in DHFLC. The important part in the construction of LCDs relies on the process of alignment. The surface anchoring effect plays a key role in the field of LC in order to get alignment (whether it is homogeneous, homeotropic, or hybrid). There are several alignment techniques to align LC molecules. The surface anchoring effect in FLCs are difficult to study due to complexity in surface interactions caused by the introduction of spontaneous polarization and layer structure. In this chapter, it has been shown that an ultraweak anchoring lowers the saturation voltage and favors the best memory effect in DHFLC. The lowering of the saturation voltage has been confirmed by taking the variation of tilt angle for different DC voltages in weakly anchored DHFLC cells. This chapter also proposes the perfect memory effect in broad frequency range in DHFLC material without any surface treatment which has been shown for the first time. The current chapter also describes the dependence of response time on the surface anchoring and the cell thickness.

Chapter 5 covers the effect of doping of nanoparticles (NPs) on the memory of DHFLC material. The NPs doped LCs have been studied extensively for observing the different aspects such as electro-optical, dielectric, memory effect, phase behavior *etc*. Much of the reported work has been focused on nematic LCs. In this chapter, a long lasting nonvolatile memory effect in gold NPs (GNPs) doped DHFLC material has been demonstrated. The long lasting memory effect in DHFLC cells has been observed by using dielectric and electro-optical methods. The memory effect in such systems has been explained on the basis of the electric field induced charge transfer effect and the stabilization of helix deformation process.

Chapter 6 describes the effect of carbon nanotubes (CNTs) on the response time of DHFLC. The doping of CNTs in LCs has been pursued for improving their electro-optical properties, dynamic response and other physical parameters. This chapter deals the results of the fast electro-optic response of multi walled CNTs (MWCNTs) doped DHFLC material. The fastening of the response in MWCNTs doped DHFLC has been explained on the basis of decrease in rotational viscosity, increase in anchoring energy, loosening of molecular packing. This chapter also proposes the increase in conductance in MWCNTs doped DHFLC.

Chapter 7 gives the effect of doping of GNPs on the photoluminescence of DHFLC. The main drawbacks of the LC based display devices are their low brightness and energy efficiency due to the use of polarizers and absorbing color filters. The enhanced electromagnetic fields generated near the metallic NPs surfaces can enhance the fluorescence of chromophores (light emitting centers) in close proximity to the surface as well as metal itself. The present chapter describes the characterization of newly synthesized DHFLC material, namely LAHS19, using different experimental techniques. The chapter too illustrates the enhancement of luminescence intensity in GNPs doped DHFLC material on the basis of interaction of DHFLC molecules with GNPs. The enhanced photoluminescence in GNPs doped DHFLC material would provide a cutting edge tool in the realization of enhanced photo luminescent LCDs.

Chapter 8 presents the application of LC in optical devices (we have taken the example of phase shifting interferometer). The realization of LC based phase shifting interferometer has been described. Phase-shifting interferometry is a common optical technique for non contact surface profilometry. The application of LC technology to a lateral shearing phase-shifting interferometer has also been described. The difference between a traditional shear plate and the LC version is the additional phase that is accumulated owing to the LC layer. The present chapter describes the realization of LC based phase shifting interferometer because the contrast of the fringes presented in earlier LC based phase shifting interferometer was poor. The improvement in the contrast of fringes was achieved by coating the LC cell surfaces with reflecting material. The voltage dependent phase shifting has been presented in nematic LC based phase shifting interferometer.

Chapter 9 summarizes the important findings and results obtained from electro-optical properties of pure and nano-materials doped DHFLCs as discussed in chapters 3 – 7. The conclusion of application of LC technology to the realization of phase shifting interferometer (as presented in chapter 8) has also been discussed in this chapter. The future scope has been explored on the basis of above work from both basic and applied research points of view and presented in this chapter.

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