INVESTIGATIONS ON BENT-CORE LIQUID CRYSTAL SYSTEMS

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ABSTRACT

Liquid crystals have become an important part of our daily life. It can be seen in the large liquid crystal displays, privacy windows, and thermometer to mini pocket calculators and in watches. In spite of the discovery of a large number of liquid crystalline phases with ultra-fast switching speeds, the nematic phase is still a backbone of million dollar display industries because of fluidity, long range orientational order and self-healing capability. Recently, the discovery of ferroelectricity and biaxiality in the nematic phase of bent-core liquid crystal, again attracted the interest of not only scientist but also of engineers in the nematic phase, particularly. The ferroelectricity and biaxiality in nematic phase would open a new avenue in the next generation ultra-fast display and photonics devices. Another important aspect of liquid crystals, which make them a hot topic of research, in spite of more than hundred years of its discovery, is its structure-property relationship. The slight change in the structure of the liquid crystal molecule by introducing a small kink in the molecular shape leads to discovery of bent-core liquid crystal that could exhibit many exotic phases with fundamentally new properties and novel phenomena to study. The nematic phase formed by bent-core molecules exhibit

unusual properties and extraordinary effects which are not observed in the calamitic counterparts. The macroscopic properties and phases structure of these liquid crystalline phases not only depend on its shape but also on the flexibility of the central core unit, type of linking groups, terminal and lateral groups *etc*.

The broad objective of this thesis is to investigate the characteristic properties of bent-core liquid crystals having nematic phase and their mixtures with a calamitic liquid crystal, and nanoparticles with different concentrations. The significant contribution of this thesis has been divided into two parts. The first part of the thesis addresses the dielectric and electro-optical properties of six bent-core liquid crystals named GK1 to GK6 possessing nematic phase only with main emphasis on the effect of terminal and lateral groups on the polar properties of bent-core nematics. The dielectric and electro-optical properties of the two achiral four- ring bent-core liquid crystals (GK1 and GK2) possessing an alkoxy ($C_7H_{15}O$-, $C_8H_{17}O$-) chain at one end of the molecules and methoxy (CH_3O-) group at the other end are investigated. Both the compounds exhibit enantiotropic nematic phase over a wide range of temperature. In the dielectric spectroscopic studies of the compounds, only one sharp peak in the loss curve is observed in the entire nematic range. In addition, the dielectric permittivity of the sample is very large. The molecular structures of these two compounds are similar to the compounds studied by Ghosh *et al.*, which are reported to exhibit the ferroelectric-like switching and electro-convection pattern. However, the differences are (a) replacement of the polar halogen substituent at one end of the molecule by a methoxy group and (b) an increased length of the alkyl chain at the other end. These studies confirm the requirement of a polar moiety for the ferro-nematic phase to exist in these four-ring bent-core compounds. Then the mesomorphic behaviour of another four-ring achiral bent-core liquid crystal with the same basic structure but containing a methyl (CH_3-) group in the central phenyl ring is studied. The addition of methyl group in the central phenyl ring not only induces the lowering of the clearing point but also enhances the nematic phase range. The dielectric spectroscopy reveals a low frequency relaxation peak and a very large dielectric permittivity; which is the characteristic of cybotactic clusters. In electro-optic studies, spontaneous polarization peaks is not observed. However, a periodic pattern is observed under the application of an ac electric field. Finally, the compounds show a weak tendency to crystallize; which makes it possible to supercool the cybotactic nematic phase down to room temperature.

Second part of the thesis focuses on the study of dielectric and electro-optical properties of mixture of bent-core liquid crystal with the calamitic liquid crystals, and nanoparticles with different concentrations. Nano-doping of bent-core liquid crystals are of recent interest because the blending of bent-core liquid crystals with nanoparticles opens a new avenue both for fundamental research and in the development of smart materials with desired properties for different types of applications. A four-ring achiral bent-core liquid crystal (GK6) possessing only the nematic phase was doped with titanium dioxide (TiO_2) nanoparticles and its dielectric and electro-optical properties are investigated. The experimental results show both an increase in the moving ion concentration and a drastic increment in the dielectric permittivity of the doped sample. The large increase in the dielectric permittivity at lower frequency is due to the combined effect of space charge polarization and the change in the viscosity of material due to dilution effect. Due to dilution effect, the transition temperature of all the doped samples are decreased by about 10 ^{o}C to 13 ^{o}C. Another way to tune the properties of bent-core liquid crystals is making a binary mixtures. Making binary mixtures are the most simple and cost effective way to obtain a liquid crystal material with desired properties. In fact, the majority of liquid crystal displays are based on multi-component liquid crystals. The dielectric and electro-optical properties of binary mixtures of the bent-core liquid crystal with the calamitic liquid crystal are reported. The main aim is to reduce the instability and obtain a fluid ferroelectric nematic phase at room temperature. Here, we show that by making a proper mixture of bent-core and rod shaped molecules, one can obtain the fluid ferroelectric nematic phase even at room temperature and the fluid liquid crystal nematic phase exhibits a change in birefringence colour with the applied electric field. This occurs due to the decrease in instability of the mixture which depends on the concentration of the bent-core liquid crystal. Dielectric spectroscopy, electro-optical characterization and polarizing microscopy studies confirm that the response is due to the field induced reorganization of the cybotactic clusters in the nematic phase. This study not only suggests a novel technique for obtaining a fluid ferroelectric nematic phase at room temperature but also provides new insights into the real nature of cybotactic clusters.