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RESEARCH ARTICLE

THE OVERVIEW OF DIELECTRIC PROPERTIES OF LIQUID CRYSTALS WITH THE FUNCTION OF FREQUENCY AND TEMPERATURE

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Abstract

In this review article, we have analysed the overview of the dielectric parameters of liquid crystals (LCs) such as nematic, smectic with the function of frequency and temperature.LCs are isotropic with anisotropic dielectric nature. When the dielectric anisotropy was affected by the cause director reorientation in an applied electric field, deepening our understanding of dielectric response has been a leading theme in the development of LC science. Herein, we have studied the dielectric permittivity, dielectric loss and relaxation behaviour of nematic and smectic LCs. The molecular theory of LC has been explained by Maier and Saupe and then used it to explain how nematic order influences dielectric relaxation in LCs.

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Introduction:-

Liquid crystal (LC) is a good candidate for the basic understanding and applied aspects of soft condensed matter [**1, 2**]. It exhibits a wide temperature range and thermal properties which make them very useful for different potential applications. Many researchers have been made to study the dielectric properties of LC in different phases such as nematic, smectic C (SmC) and smectic C* (SmC*) [**3-8**] for an application point of view. The research of liquid crystals (LCs) envelopes a broad area: physical, chemical and biological properties. They have been emerged to be instituted in diverse medical, technological, therapeutic and scientific purpose. The discoveries and invention of new science in this part is being revealed and the prospects for additional applications are being investigated. However, the physical properties of LCs are still open and need to be investigated. The development of LC research has been involved in academic, medical and technology. LCsare exclusive material in their properties and applications. The continuous researchand new applicationsinvolved in this field will bring LC intothe light of audience and modern technology.

In school days, we are familiar three states of matters solid, liquid and gaseous before the discovery of LCs. A solid may be crystalline or amorphous with a spatial and orientational atomic order of long range and the latter of short-range order only. When a solid is heated above its melting point, it becomes an isotropic liquid with neither spatial nor orientational order, which transforms back into a solid after cooling. There are many existing phase ofLC transitions with symmetrical and mechanical properties intermediate between those of an isotropic liquid and a crystalline solid[**9**]. LC phase is known as mesophase. The different mesophase occurs in the function of temperature and concentration of solvent. A basic unit displays longrange positional and orientational order in case of the crystalline nature of the materials. In an isotropic liquid, a basic unit neither positional nor orientational order.

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Bridging the gap between highly ordered crystalline state and isotropic liquid, we find a surprisingly fascinating LC process called mesophase. Themany fascinating phases occurs in LCs with the arrangementof the molecules. The variation in the molecular arrangement of LC phases according to the temperature is shown in **figure 1**.The fact that LCs are likeisotropic liquids with only a small amount of additional order is the key to understanding thedielectric and electro-optical properties for the many applications.

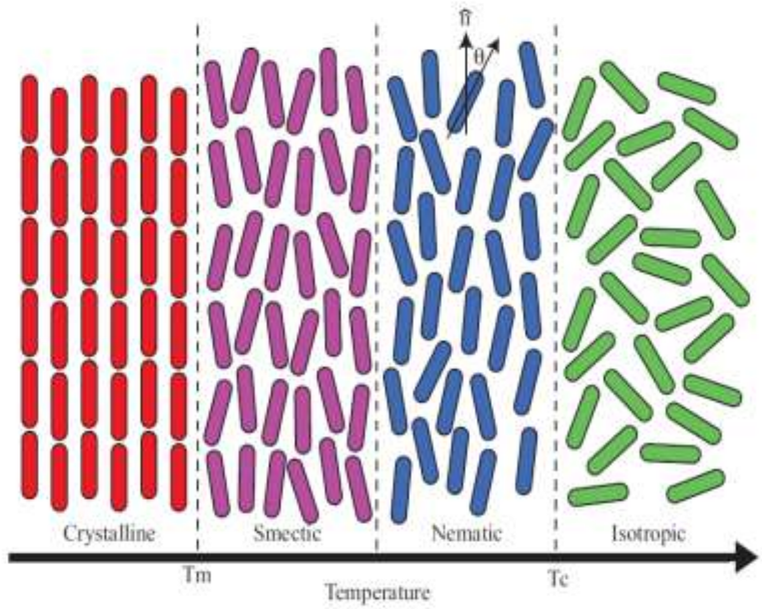

Fig. 1:- Liquid crystals molecular arrangement exhibiting different levels of orientation and positioned order in the crystal, smectic, nematic and isotropic phases as a function of temperature.

In this article, we havestudied the overview of the wide rich work of published literature covering the dielectric and electro-optical properties of LCs. We are concise as well as selective in our discussion which focuses on the physical properties of LCs with influences on the variation of frequency and temperature. It is significant to point out here that the dielectric parameter such as dielectric permittivity, dielectric loss, dielectric strength and relaxation frequency vary with the function of frequency and temperature. In addition, the physical parameters are also studied the alignment of sample cells. Thermal dynamic parameters of LCs, such as elastic constant show, threshold voltage, relaxation time, rotational viscosity, etc, still provide a potential for development.These physical propertiesprovide important information about the molecular dynamic orientations and position and their interactions in the LC molecules. The temperature variation of elastic constant, relaxation time and rotational viscosity are of massive significance for the modern displayand photonic technology[**10-12**].There is remarkable investigating the behaviour of binary mixtures of LC as a result of the knowledge they offer in various field, such as examining the phase transition phenomena, understanding the interaction of molecules, and providing the idea about microscopic structure of the arranged state and order parameter fluctuations. Thus, the dynamics of thermal properties and structure formationin mesogenic compounds are the basics aspect to the understanding of LC technology. This review paper aims to present the dielectric properties of LCs with temperature and frequency variations.The general introduction of LCs begins, accompanied by a discussion on the applications of LCs and, consequently, on the impact of external entities in various phases in LC.Then progress has been made with the developmental status of the liquid crystal technology for the application point of view and, potentially, a conclusion is drawn with their future prospects.

Dielectric spectroscopy

The bound electric charge measure contained within the atomic structure is characterized by the dielectric material.Ideal dielectric materials do not produce free charges.However, bound charges in the material have the ability to polarize with the external applied electrical field.LCs are dielectric materials that exhibit structural changes as a result of dielectric polarization.In general, dielectrics can be modeled using the Lorentz Model of Matter and the dielectric and optical properties of isotropic and anisotropic compounds can be derived from this theory.Lorentz theorized that matter can be modeled as oscillating masses on springs with driving forces equivalent to external electric fields.The dielectric properties have significantly increased with the function of temperature of various phase onLCs. The spectroscopy of LC is tool togive the dynamical molecular relaxation behavior of liquid crystalline materials. It is well known that the dielectric permittivity in the SmC* phase is first defined by the director's reorientation and dipolar polarization of the molecules due to the collective dielectric relaxation. The collective dielectric relaxations are two mode one is goldstone mode (GM) and soft mode (SM), which arises by the fluctuations in the director and magnitude of the tilt of the molecules, respectively. The other collective dielectric relaxation process is due to the domain mode [**13**], which is appears in high spontaneous polarizationvalue of the FLC materials.The molecular reorientationaround the long and short molecular axis are studied in all mesophases are investigated in the literature [**13**].

The dielectric relaxation can be described in terms of the complex dielectric permittivity,

$$\varepsilon^*(\omega,T)=\varepsilon'(\omega,T)-i\varepsilon''(\omega,T) \quad (1)$$

here ε' represents the real part of the complex dielectric permittivity and its spectrum is called the dispersion curve. ε'' is the imaginary part of the complex dielectric permittivity and its spectrum is called the absorption (dielectric loss) curve. ω is the angular frequency of the applied electric field.

In order to characterize the temperature dependence of the observed dielectric relaxationof complex dielectric permittivity ($\varepsilon^*(\omega)$) can be described by the Debye formula as follows,

$$\varepsilon'(\omega)=\varepsilon_\infty+\frac{\varepsilon_0-\varepsilon_\infty}{1+\omega^2\tau^2} \quad (2)$$

$$\varepsilon''(\omega)=\frac{(\varepsilon_0-\varepsilon_\infty)\omega\tau}{1+\omega^2\tau^2} \quad (3)$$

where ε_0 is the static dielectric permittivity ε_∞ is the dielectric permittivity in high frequency limit.

The generalization of Debye formulations described a dielectric relaxation process with a discreet relaxation time distribution associated with a single relaxation process distribution.However, if the dielectric relaxation process shows a continuous distribution of relaxation time, the Cole-Cole relaxation time distribution can be described as:

$$\varepsilon^*(\omega)=\varepsilon_\infty+\frac{\varepsilon_0-\varepsilon_\infty}{\left\{1-(i\omega\tau)^{1-\alpha}\right\}} \quad (4)$$

where α is the distribution parameters.

The temperature dependence of the dielectric parameters improves before the transition temperature under the bias voltage and relaxation frequency, indicating the electronic effect of the LCs. The collective dielectric relaxationbehaviour of SmC* and SmA phase of liquid crystal with the function of temperature gives the dynamical information of the bulk sample for display applications [**13**]. However, in electroclinic effect of liquid crystal, thebehaviour of the softmode (SM)and goldstone mode (GM)near the transition temperature ofSm C*-Sm A phase has been investigated in many researchers. Ferroelectric liquid crystals (FLCs) have the same phase sequence, as FLCs withthe only difference that the Sm A phase has wide temperature range around the room temperature and a high electroclinic coefficient to get more induced tilt angle. A fundamental investigation and development and market overview of LCs display was published by B. Bahadur [**1**] who discussed a theory of basic understanding of LC for application of display devices. The main idea of these pioneering understanding was to control the director of the LC and improve the material parameters of LC by using different alignment cells and intermolecular interactions and coupling force between them. Many researchers investigated the dielectric parameters such as dielectric permittivity, dielectric loss, dielectric strength and relaxation behaviour of LC for different phase with variation of frequency and temperature [**13**]. Significantly results have been found for the improvement of dielectric permittivity and dielectric anisotropyof LC. The dielectric permittivity is very high at lower frequency and almost constant for higher frequencies in Sm C*, Sm A, and chiral nematic phases [**13**]. The GM dielectric relaxation frequency is almost independent of the temperature in deep Sm C * phase[**13**]. The GM is depending upon the phase fluctuation of FLC molecules and it occurs in low frequency region.However, as the temperature reaches the near transition temperature of T_C, the relaxation frequencydepends on the temperature.The dielectric permittivity of the SM constantly decreases, and the level of relaxation increases as it departs from the SmA phase transition temperature [**13**].

The temperature dependence of dielectric properties of nematic LC for using of the wide temperature range for displays devices and capacitor temperature sensor were investigated by Belyaev [**14**]. They have focused on the problem on the enhancement of dielectric parameters for LC display applications in extreme ambient conditionsand expansion of LC devices functionality. The dielectric parameters of LC are strongly affected for the application of display and sensor technology. The real and imaginary part of complex dielectric permittivity investigated with the function of temperature by using planar and homeotropic geometry. A LC capacitor temperature sensor was proposed which consists of two pairs of planar and vertical alignment areas.Its output signal depends on both dielectric anisotropy of the LC and medium ambient temperature.The dielectric anisotropy is characteristic property of LC by tune geometrical parameters with external applied electric filed. The LC sample cell is addressed with a short (~100 μs) electrically symmetric input pulse with an amplitude less than the threshold voltage of the Fredericks effect (~0.5 V), period ~0.5 s [**14**]. Maximum effective dielectric anisotropy was analysed of nematic liquid crystal and observed at perfect boundary conditions of the sample cells. A polyimide film provided the planar alignment, and an organosilicon film provided the vertical alignment [**15, 16**]. V. S. Chandel et al [**17**] studied the dielectric properties of 4-methyl n (2’-hydroxy, 4’-n-hexadecyloxy) azobenzene with the variation of temperature and frequency. The values of dielectric permittivity were observed to remain almost constant in the temperature range from 30°C to 71°C, and their value shows a sudden change at 72°C, which shows the crystal to the nematic phase transition in the material.The relaxation frequency exhibiting at 1MHz in dielectric loss curve. The low frequency dispersion has investigated for different nematogen [**18, 19**] and was assigned to the reorientation of the molecular long axis [**20, 21**]. These results are good agreement with Maier and Saupe theory of relaxation in the nematic phase in the low frequency region [**22**]. In dielectric loss curve only single peak observed showing single relaxation of LC molecules. As the temperature increased, the peak of the loss curve shifted to a higher frequency region [**23**].

Conclusions:-

The dielectric response of liquid crystal of various phases such as nematic, SmC, and SmC * has been reviewed with frequency and temperature function.In this article it illustrates that the dielectric relaxation effects in LCs remain an active dielectric study field.The LC ordering field contributes to a qualitative slowing of the dielectric relaxation of the longitudinal dipoles of the LC molecules, as described by Maier and Saupe theory.Recently, a number of new studies connecting the impact of dielectric relaxation behavior to the dynamics of LC molecules.

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