Republic of Iraq

Ministry of Higher Education

and Scientific Research

University of Babylon

College of Education for Pure Sciences

Department of Physics

Temperature Effect on Refractive Index and Macroscopic Order Parameter for (MLC) Material

A Research

Submitted to the council of the college of Education for Pure Sciences of University of Babylon in Partial Fulfillment of the Requirement for the Degree of Higher Diploma Education / Physics of Materials and its Applications

by

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2021 A.D. **1443 A.H.**

بسم الله الرحمن الرحيم

{قُلْ هَلْ يَسْتَوِي الَّذِينَ يَعْلَمُونَ وَالَّذِينَ لا يَعْلَمُونَ إِنَّمَا يَتَذَكَّرُ أُولُو الْأَلْبَاب}

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Dedication

To -----------

The memory of my father -------

My mother--------

My Brothers and Sisters

The soul of my brother Dargham

My supervisor

My heart throb, Iraq.

With all the love and appreciation

2021 *ALI*

Acknowledgements

I thank my almighty Allah , in him alone , I put my trust. His mercy and blessing are save , guide and enable me towards ambitions.

I would like to express my deep appreciation and sincere thanks to my supervisor Assistant Prof. **Dr.Zaid Abduul Zahra Hasan** for his guidance and encouragement throughout this work and for his generosity and patience.

I would like to express my deepest thanks to my family and especially my dear mother.

Finally, I would like to express my deepest thanks to friend (Ali Mohammad Hashim), and everyone who helped me achieve the research.

Abstract

This study, we used nematic liquid crystals type (MLC) ,and He-Ne laser with wavelength (632.8nm) to find the temperature effect on the refractive Index and macroscopic order parameter for mixture liquid crystal (MLC) material.

This study shows all refractive indices , order parameter are decrease as the temperature increasing ,also find the order parameter is decrease with the time operation.

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List of Symbols and Abbreviations

Items	Definition
A	Absorbance
D	Thickness of liquid crystal cell
N	Refractive index
P	Chiral pitch
TEM	Transmittance electron microscopy
LCD	Liquid crystal display
X_o	Displacement for the ordinary beam
X_e	Displacement for the extraordinary beam
n_o	Ordinary refractive index
n_e	Extraordinary refractive index
Δn	Birefringence
$< n >$	Average refractive index
θ'	Angle of the wedge formed by the two glass plates
θ_o	Angle formed by ordinary beam with optical axis
θ_e	Angle formed by extraordinary beam with optical axis
L	Distance between the cell and detector
T_C	Clearing temperature
T	Temperature
Q	Microscopic order parameter
LC	Liquid Crystals

5CB	Nematic liquid crystal (4- Cyano -4-pentylbiphenyl)
UCF	Mixture liquid crystal (Phenyl Tolane)
DSCG	Disodium Cromoglycate
PDLC	Polymer Dispersed Liquid Crystal
5PCH	Liquid Crystal Of The nematic Phase
R_{ref}	reference ray

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

Liquid crystals (LCs) are a state of matter that have properties between those of a conventional liquid and those of a solid crystal. For instance, a LC may flow parallel a liquid, but its molecules may be oriented in a crystal-like way ,that exhibit long – range order in one or two dimensions, but not all three [1]. There are many different kinds of LC phases like smectic , nematic and chiral nematic, that can be distinguished by their different optical properties (such as birefringence). When viewed under a microscope using a polarized light source, different liquid crystal phases will surface to have distinct textures. The contrasting area in the textures correspond to domain orientation of the LC molecules in different directions. Within a domain, however, the molecules are well ordered. LC materials are not ever be in same phase (just as water may turn into ice or steam)[2].

Liquid crystals can be divided according to the influence of temperature or concentration on their anisotropic properties into thermotropic , lyotropic and metallotropic phases [3].

Thermotropic and lyotropic LCs consist of organic molecules. Thermotropic LCs width a phase change transition temperature changes.

Lyotropic LCs exhibit phase transitions as a function of both temperature and focus of the molecules in the solvent.

Metallotropic LCs arepossessed of both organic and inorganic molecules; their LC transition depends not only on temperature and concentration, but also on the inorganic-organic composition ratio see Figure (1.1) [4].

Examples of liquid crystals can be found both in the nature like human cell and in technological applications like modern electronic displays[5].

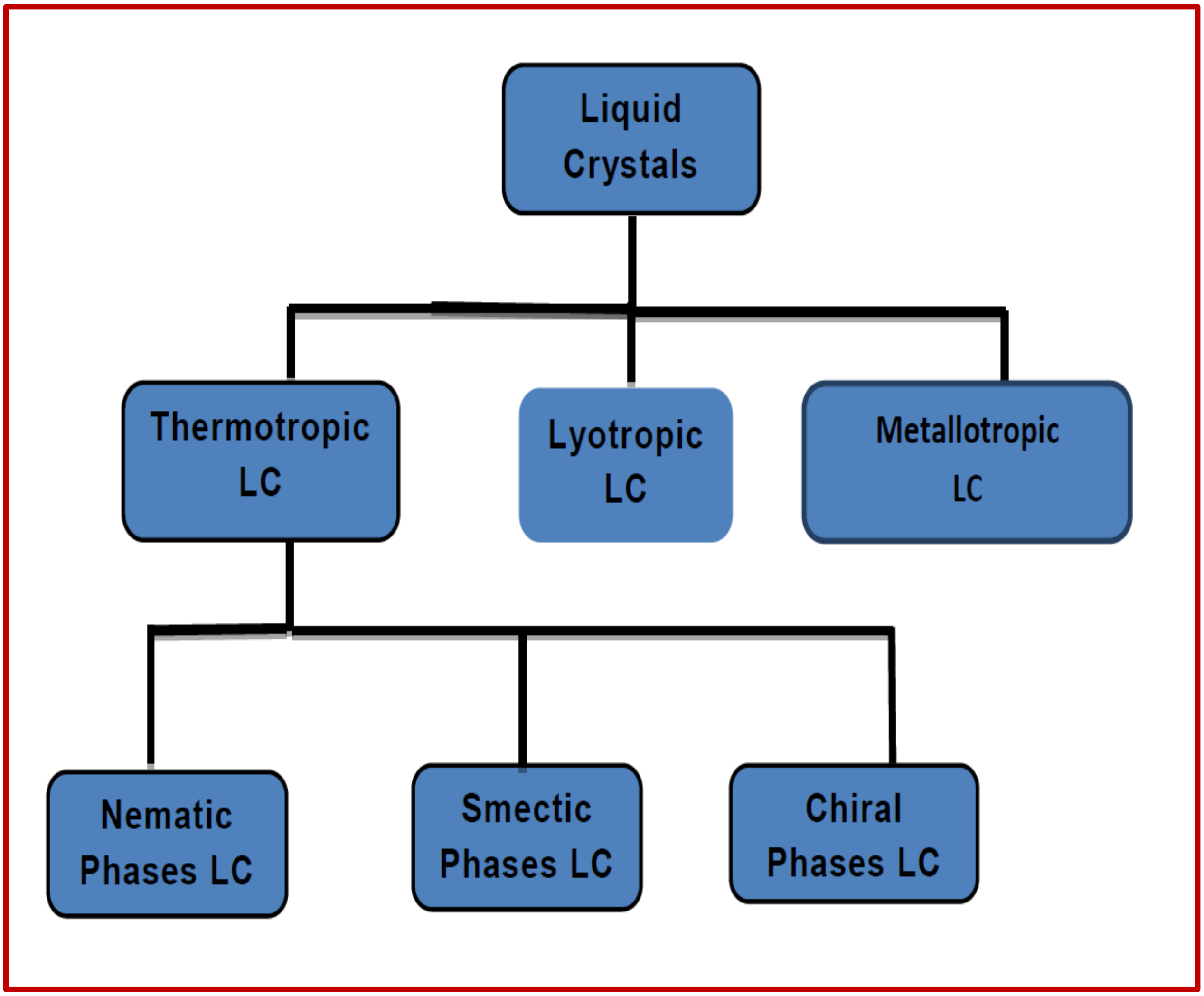


Figure (1.1):The classification of liquid crystals[6]

1.2 Liquid crystal phases

The various LC phases (called mesophases) can be characterized by the type of ordering that it present .

1. Can distinguish positional order whether molecules are arranged in any sort of ordered lattice.

2.Orientational order whether molecules are mostly pointing in the same direction, and furthermore order can be either short-range (only between molecules close to each other) or long-range (extending to larger, sometimes macroscopic, dimensions).

Most thermotropic LCs will have an isotropic phase at high temperature. Heating will eventually drive them into a conventional liquid phase characterized by random and isotropic molecular ordering (little to no long-range order), and fluid-like flow behavior. Under other conditions (for instance, lower temperature), an LC might inhabit one or more phases with significant anisotropic orientational structure and short-range orientational order while still having an ability to flow[7,8].

1.2.1 ThermotropicLC

Thermotropic phases are those occur in a certain temperature range like dependent on compound displaying thermotropic LC conduct is para-azoxyanisole [9].

If the rising of temperature is too high, thermal motion will destroy the delicate cooperative ordering of the phase, pushing the material into a conventional isotropic liquid phase. At too low temperature, most LC materials will form a conventional crystal [7 ,8].

Many thermotropic LCs appear a variety of phases as temperature is changed. For instance, a particular type of LC molecule (called mesogen) may exhibit various smectic,nematic and finally isotropic phases as temperature is increased [9].

1.2.1.1 Smectic phase

Smectic molecules are arranged in horizontal layers and are standing one end either vertically[Figure (1. 2A) and (1.2B)] or a tilt called smectic(C^*) [Figure (1.2C) and (1.2D)][10] .

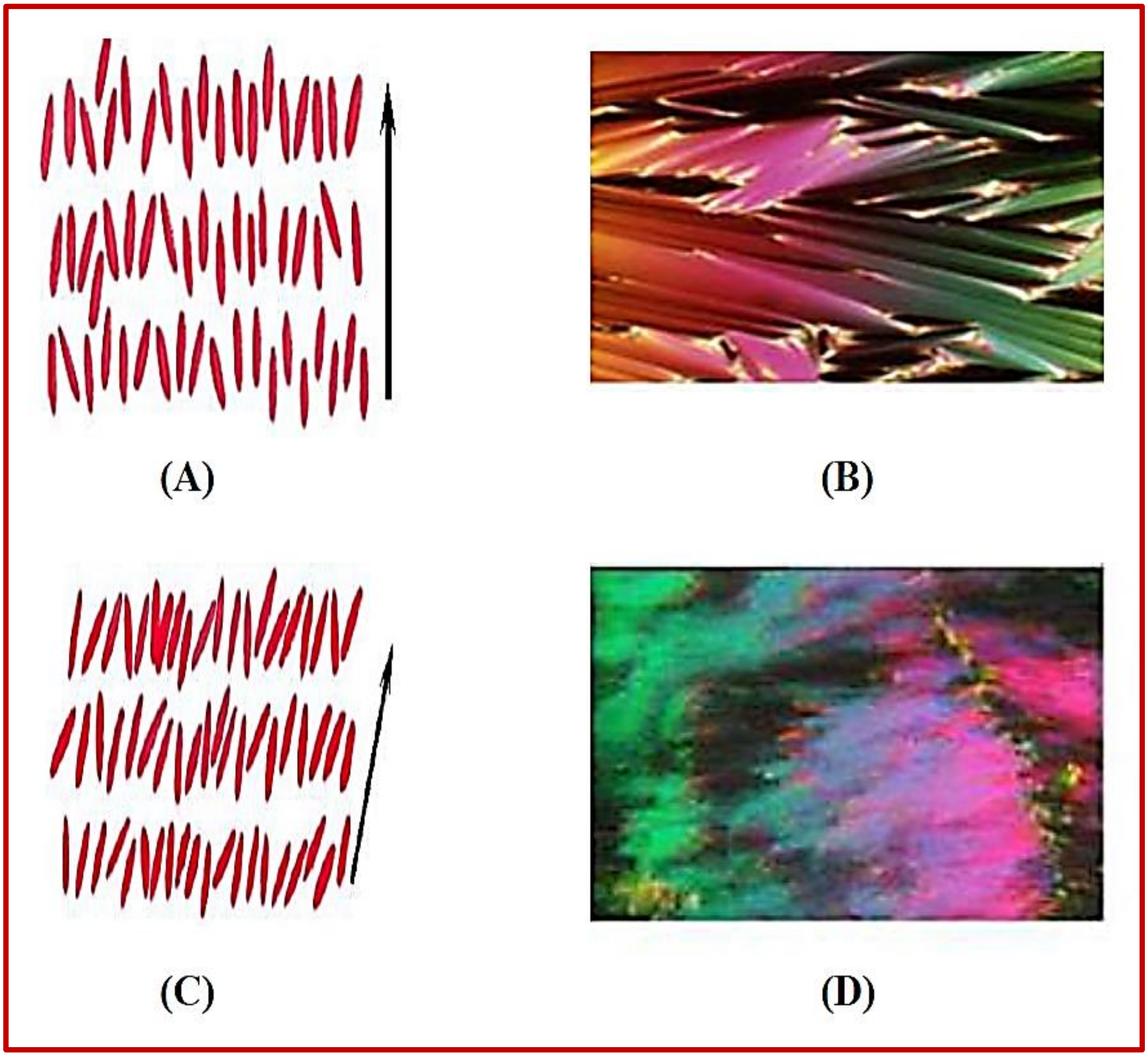


Figure (1.2) : Picture of the smectic C phase (A) ,Photo of the smectic C phase using polarizing microscope (B),Picture of the smectic C * (C) and Photo of the smectic C * (D) [10]

The smectic-C mesophase has a chiral state designated C* [Figure (1.3 A)]. Consistent with the smectic-C, thedirectormakes a tilt angle with respect to the smectic layer. The difference is that this angle rotates from layer to layer forming a helix. In other words, the director of the smectic-C* mesophase is not parallel or perpendicular to the layers, and it rotates of one layer to the next.

One can notice that the twist of the director, represented by the green arrows, in each layer in the following diagram [Figure (1.3A) and (1.3B)] .

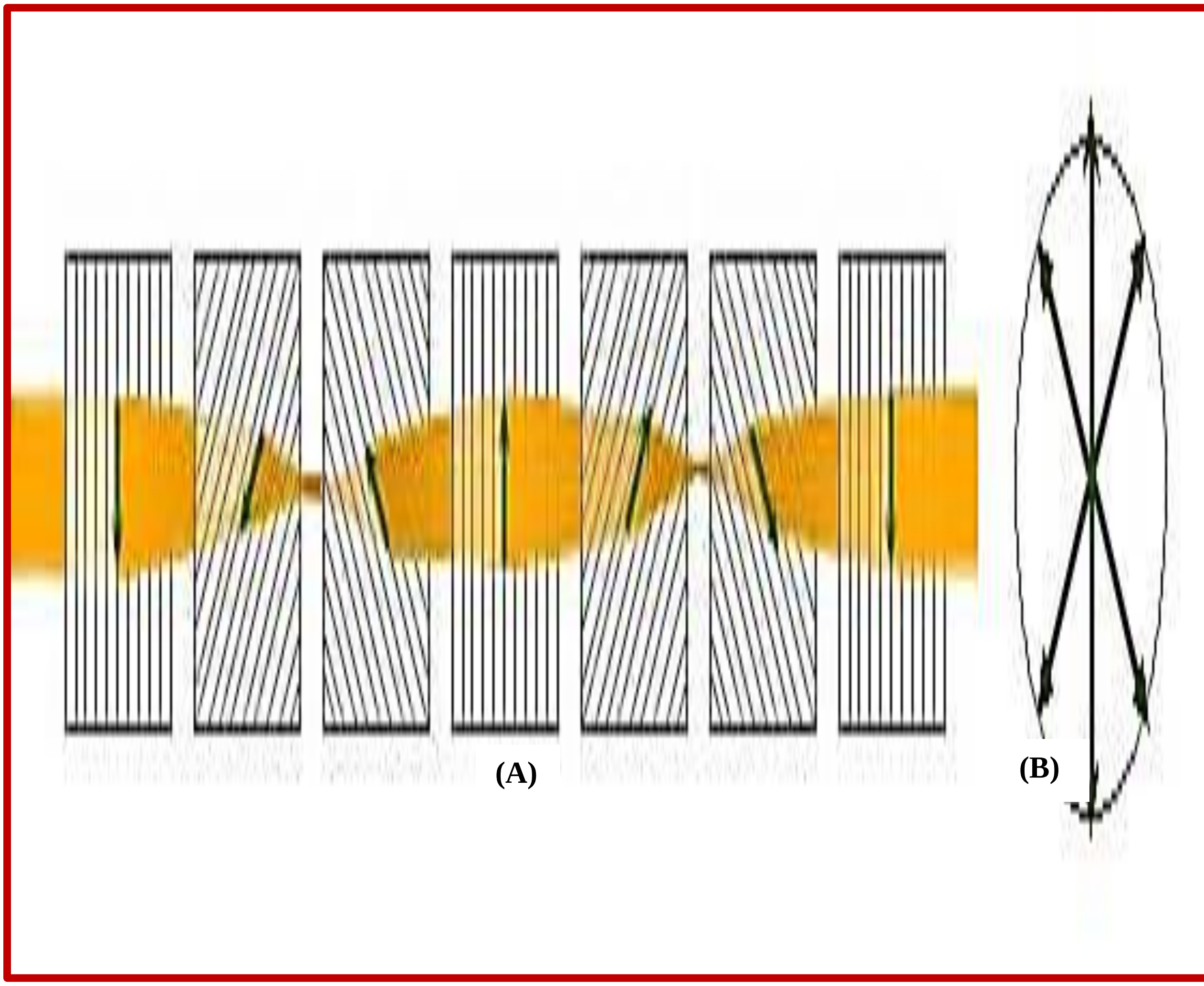


Figure (1. 3):(A) A schematic performance of a smectic C* phase , and a view of the (B) same phase, but along the axis [10]

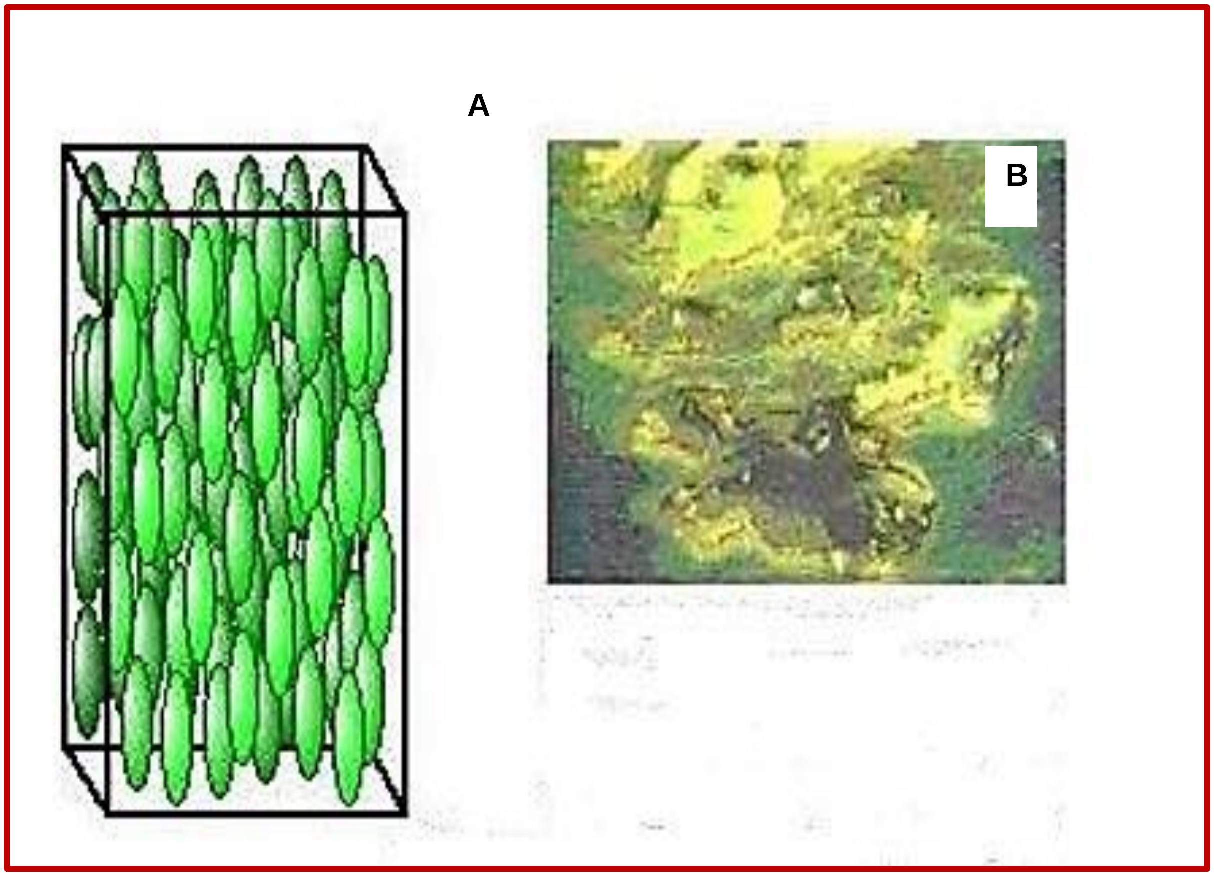
1.2.1.2 Nematic phase

One of the most common LC phases is the nematic. The word nematic comes of the Greek ,which means "thread". This term originates from the thread-like topological defects observed in nematics, which are formally called 'disclinations'. Nematics also exhibit hedgehog topological defects. In a nematic phase, the rod-shaped organic molecules have not positional order, but they self-align to have long-range directional order with their long axes roughly parallel Figure (1. 4 A) and (1.4 B) [11]. Thus, the molecules are free to flow and their center of mass positions are randomly distributed as in a liquids, but still maintain their long-range directional order.

Most nematics are uniaxial they have one axis that is longer and preferable .However, some liquid crystals are biaxial nematics, meaning that to orienting around their long axis, they also orient along a secondary axis [12].

Aligned nematics have the optical properties of uniaxial crystals and this makes them very useful in liquid crystal displays (LCD_s) [13]

Nematics have fluidity similar to that of the ordinary (isotropic) liquids but they can be easily aligned by an external magnetic or electric field.Nematic molecules possess a high degree of long-range order with their long axes approximately parallel, but without the distinct layers of the smectic crystals.



Figure(1.4):Aschematic representation of the nematic phase (A) and a photo of a nematic liquid crystal (B) [11]

1.2.1.3 Chiral phase

The chiral nematic phase exhibits chirality (handedness). This phase is often called the cholesteric phase because it was first observed for cholesterol derivatives [14] . Only chiral molecules (for example , those that lack inversion symmetry) can give rise to such a phase. This phase exhibits a twisting of the molecules perpendicular to the director, with the molecular axis parallel to the director. The limite twist angle between adjacent molecules is due to their asymmetric packing, which results in longer-range chiral order. In the smectic C*phase (an asterisk denotes a chiral phase), the molecules have positional ordering in a layered structure (as in the other smectic phases), with the molecules tilted by a finite angle with respect to the layer normal. The chirality induces a finite azimuthal twist from one layer to the next, producing a spiral twisting of the molecular axis along the layer normal [9,15,16].

The chiral pitch Figure (1.5), p, indicates to the distance over which the LC molecules undergo a full 360° twist (but note that the structure of the chiral nematic phase repeats itself every half-pitch, since in this phase directors at 0° and ±180° are equivalent). The pitch (p), typically changes when the temperature is altered or when other molecules are added to the LC host (an achiral LC host material will form a chiral phase if doped with a chiral material), allowing the pitch of a given material to be tuned accordingly. In some liquid crystal systems, the pitch is of the same order as the wavelength of visible light. This causes these systems to exhibit unique optical properties, like Bragg reflection and low-threshold laser emission [17] , and these properties are exploited in a number of optical applications like the LC displays [13,16] . For the case of Bragg reflection only the lowest-order reflection is allowed if the light is incident along the helical axis, whereas for oblique incidence higher-order reflections become permitted.

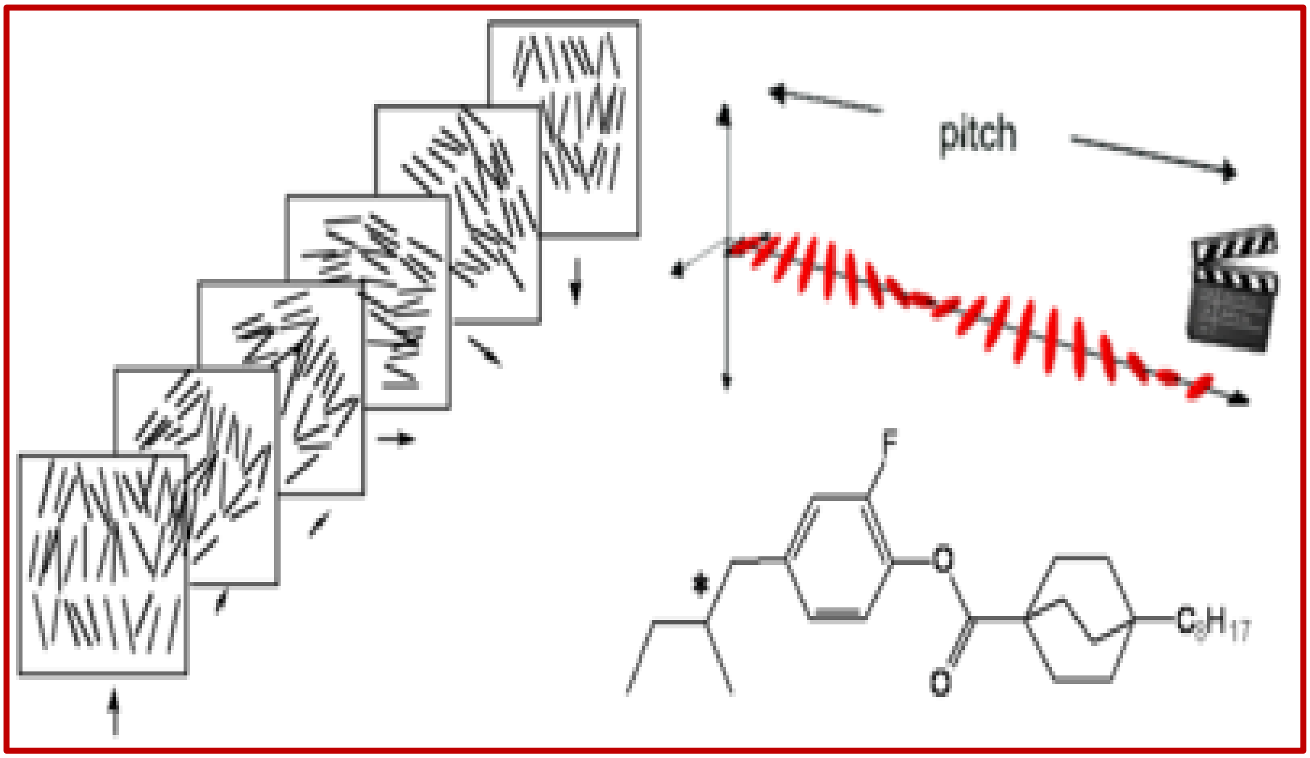
Cholesteric liquid crystals also appear the unique property that they reflect circularly polarized light when it is incident along the helical axis and elliptically polarized if it comes in obliquely [18]. Adding a chiral dopant to a nematic liquid crystal will induce a helical twist to create a chiral nematic phase. Remember it is the phase that is chiral not necessarily the molecule itself.

A cholesteric liquid can diffract light differently depending upon the pitch of the liquid crystal according to the equation

$\lambda = np$ ....(1.1)

Where λ is the wavelength of light, n is the refractive index and p is the pitch due to the periodic pitch there is a lattice spacing, therefore it is potential to diffract light causing different colours [19].

The pitch is very sensitive to temperature, cholesteric LC have temperature dependent optical properties [20].



Figure(1.5):A schematic representation of the liquid crystal in a cholesteric state the direction twists at different levels [10].

1.2.2 Lyotropic LC

Lyotropic molecules consist of a nonpolar hydrocarbon chain with a polar head group. In a solvent, like water, the water molecules are sandwiched between the polar heads of adjacent layers while the hydrocarbon tails lie in a nonpolar environment Figure (1.6).

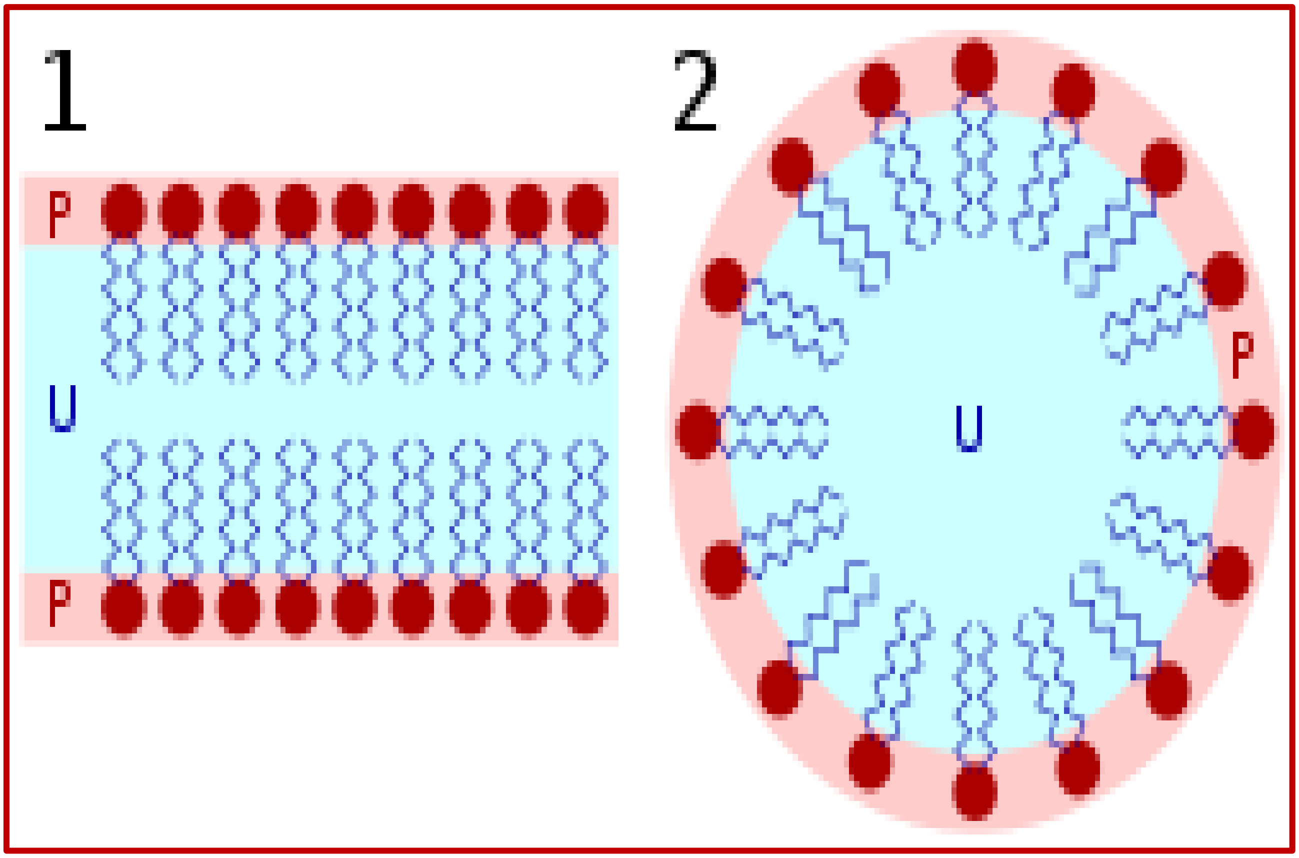


Figure (1. 6): A schematic representation structure of lyotropic liquid crystal. The red heads of surfactant molecules are in link with water, whereas the tails are immersed in oil (blue): (1)bilayer and (2)micelle [21].

If smectic and nematic liquid crystals are subjected to changes in temperature, they change their form and their light transmission properties splitting a beam of ordinary light into two polarized components to produce the phenomenon of double refraction. This results in the appearance of the characteristic iridescent colors of these kinds of liquid crystals. This type of liquid crystal finds use in thermometers, egg timers, and other heat sensing devices [22].

Also be accomplished using a magnetic field which make them useful in calculator or other LCD displays. Temperature sensitive liquid crystals are used in mood rings. When lyotropic liquid crystals are subjected to disturbances, like stirring or squeezing, the layers of crystals are disturbed altering their light transmission characteristics to produce colour changes similar to the smectic and nematic liquid crystals described above. [23].

1.3 The structure and Transition Temperature equations

6-[4-(4-Cyanophenyl)phenoxy] hexyl methacrylateis a commonly used nematic liquid crystal with the chemical formula ($\mathbf{C_{23}H_{25}NO_3}$) , is one of the mixture liquid crystals. The liquid crystal M LC under goes a phase transition from a crystalline state to nematic state at 5 ^{o}C and it goes from a nematic to an isotropic state 42 ^{o}C see Figure (1.7) .

$C_{23}H_{25}NO_3$

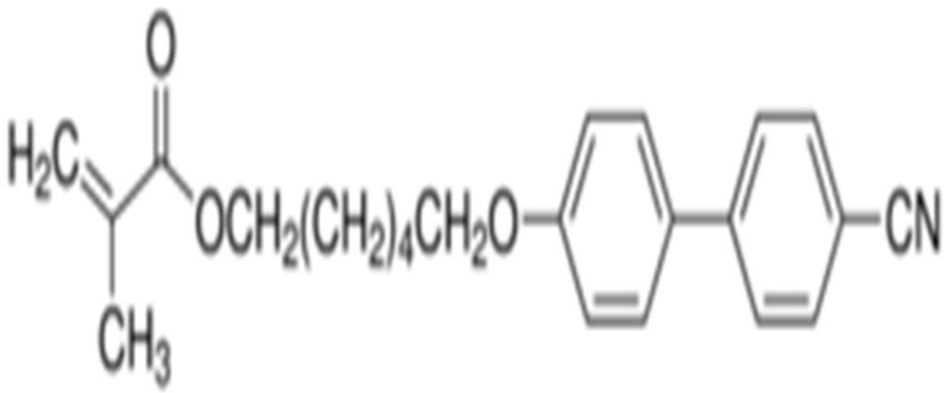


Figure (1.7) The structure formula for M L C Liquid crystal [24]. The transition temperature of M LC liquid crystal is Cr 5 ^{o}C N 40℃ Iso.

1.4 Application of Liquid Crystals

Spectroscopy methods (Mass spectroscopy, gas chromatography, infrared spectroscopy) can give precise and quantitative detection, however they are bulky, complex to provide real-time, portable detection Electro-chemical sensors and optical sensors can be designed to detect gas analyte fastly and effectively.

Liquid crystal sensor is another option for chemical detection which is usually based on simple mechanisms and instrumentations [25].Compared to the bulky and complex spectroscopy, these LC sensors can not only provide real-time, portable detection at reasonable sensitivity, but also can be easily operated and manufactured .These types and mechanism for sensor in gas shown in Table (1.1) [26].

Table (1.1):The characteristics of four types of LC sensors with a comparison between them [26]

Types of liquid	Analytes	Mechanism for sensoring	Medium or support system	Special fabrication method	Special instrumentation for detection
Nematic LC	Organic vapors (organoamines, organophosphorus) Some biological proteins.	Binding of analytes to receptors change LC orientation above the surface	Nanometer roughness Au on the top of glass substrate. SAM with receptors hosted on the top of Au layer.	Nanometer roughness Au layer created by oblique electron beam evaporation	None (naked eye)
Cholesteric LC	Organic vapors of common solvents (acetone, hexane, benzene, and pyridine).	Orangic vapors can be incorporated between the layers of cholesteric liquid crystals, change their pitch length and therefore their color.	Cholesteric liquid crystal film was cast on glass disk, or mixed with PVC or silicon rubber powder in order to immobilize the LCs	None	Spectrometer (400~800nm) is needed.
Discotic LC	Organic vapors (alkanes, alcohols, esters and some aromatic compounds)	Absorption of volatiles will effect orientational and positional fluctuation of discotic LC molecules on the surface, therefore change the conductivity	Interdigitated electrode (gold on silicon). Molecules were self-organized to homeotropic aligned layer through thermal annealing.	Interdigitated electrodes made by traditional photolithographic method	Electrometer is needed to measure conductivity change.
Lyotropic LC	Biological ligands such as microbe, toxin, antibody	Binding of ligands to the receptors hosted in lyotropic liquid crystal would cause deformation of LC and alternation of the transmission of polarized light	Concentration control of lyotropic LC in solvent to make a lamella phase.	None	None (naked eye)

Liquid crystals are widely used in the liquid crystal displays, which rely on the optical properties of certain liquid crystalline substances in the presence or absence of an electric field. In a typical device, a liquid crystal layer (typically 10 µm thick) sits between two polarizers that are crossed (oriented at 90° to one another). The liquid crystal alignment is chosen so that its relaxed phase is a twisted one. This twisted phase reorients light that has passed through the first polarizer, allowing its transmission through the second polarizer (and reflected back to the observer if a reflector is provided). Thus, device exhibit transparent. When an electric field is applied to the LC layer, the long molecular axes tend to align parallel to the electric field thus gradually untwisting in the center of the liquid crystal layer. In this state, the LC molecules do not reorient light, so the light polarized at the first polarizer is absorbed at the second polarizeras shown in Figure (1.8), and the device loses transparency with rising voltage. In this way, the electric field can be used to make a pixel switch between transparent or opaque on command. Colour LCD systems use the same technique, with color filters used to generate red, green, and blue pixels [27]. Like principles can be used to make other liquid crystal based optical devices [28].

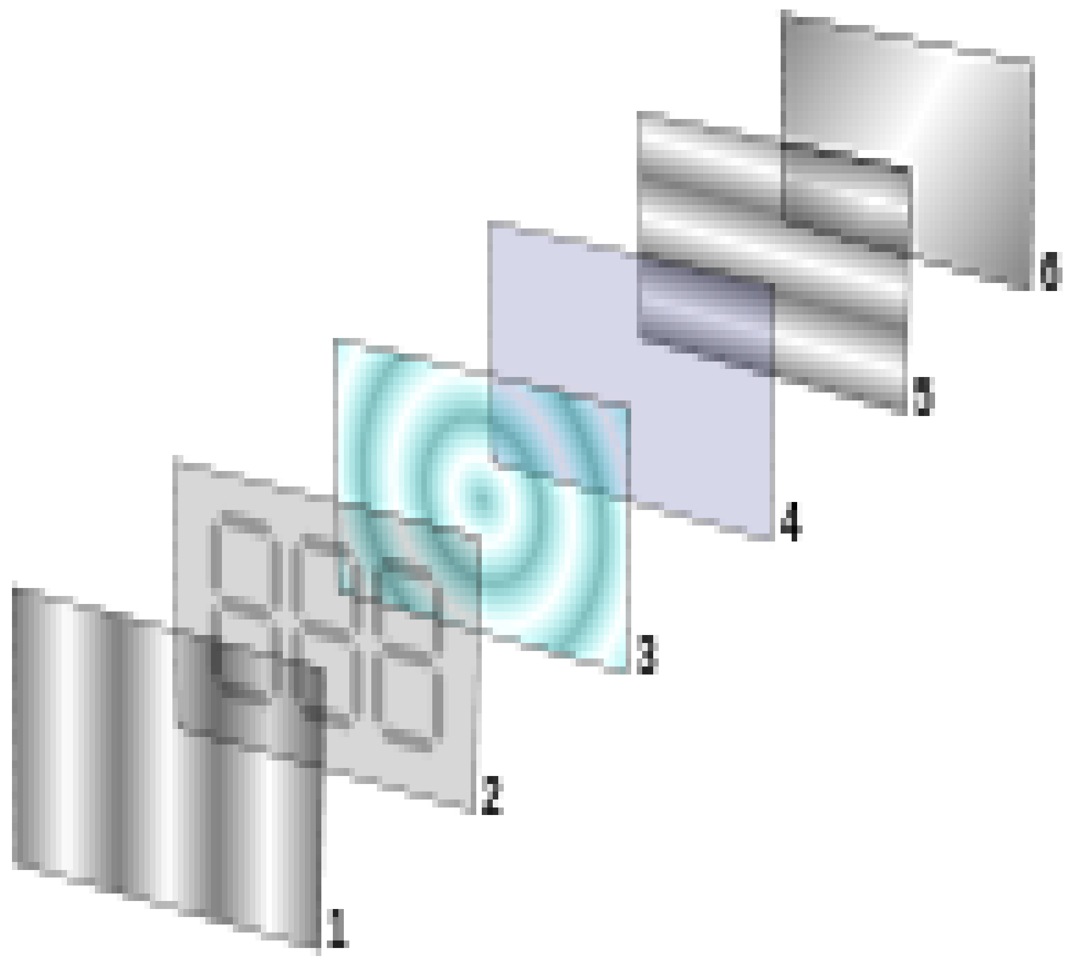


Figure (1.8): Structure of liquid crystal display: 1 – vertical polarization filter, 2 and 4 – glass with electrodes, 3 – liquid crystals, 5 – horizontal polarization filter, 6 – reflector [29] .

Liquid crystal tunable filters are used as electro optical devices, for example, in hyperspectral imaging .Thermotropic chiral LCs whose pitch varies strongly with temperature can be used as crude liquid crystal thermometers, since the color of the material will change as the pitch is changed. Liquid crystal color transitions are used on many aquarium and pool thermometers as well as on thermometers for infants or baths [30]. Other liquid crystal materials change color when stretched or stressed. Thus, liquid crystal sheets are often used in industry to look for hot spots, map heat flow, measure stress distribution patterns, and so on. Liquid crystal in fluid form is used to detect electrically generated hot spots for failure analysis in the semiconductorindustry [31]. Liquid crystal lasers use a liquid crystal in the lasing medium as a distributed feedback mechanism instead for external mirrors. Emission at a photonic band gap created by the periodic dielectric structure of the liquid crystal gives a low-threshold high-output device with stable monochromatic emission [17,32].

Polymer Dispersed Liquid Crystal (PDLC) sheets and rolls are available as adhesive backed Smart film which can be applied to windows and electrically switched between transparent and opaque to provide privacy [33].

Many common fluids, like soapy water, are in fact liquid crystals. Soap forms a variety of LC phases depending on its concentration in water [34].

1.5 Literature survey

Reinitzer (1888)[23]found the cholesteryl benzoate does not melt in the same manner as other compounds , but has two melting points . At 145.5 °C it melts into a cloudy liquid, and at 177.5 °C it and the melts again and the cloudy liquid becomes clear .

Kates (1973)[34] studied the effect of rotating magnetic field of an nematic LC at a certain rotation frequency, he observed a periodic distribution orientation for the molecules.

Lopes *et al*. (1989) [35] studied the birefringence in mesophaseof most organic compounds under two fields magnetic field and temperature , they observed a birefringence is increase with orientation molecules .

Barbara(1989)[36] proved the external electric and magnetic fields effect the orientation of liquid crystal molecules, 4 – n-pentyl – 4' - cyanobiphenyl (5CB) with special attention focused on geometries where one field is applied along the direction of initial orientation and a second field is applied perpendicular to this direction to break the uniaxial symmetry of the sample .This studies show that the effect of fields on fluctuations of the nematic director should dominate the experimental observations. .

A.Firouzi *et al.* (1997)[37] showed macroscopically oriented silicate – surfactant liquid crystals are produced by slow cooling of lamellar and hexagonal mesophases during their isotropic –anisotropic phase transitioning an 11.7 T magnetic field. These results demonstrate the utility of liquid crystal processing strategies for organizing inorganic – organic hybrid materials over mesoscopic and macroscopic length scales.

Ostapenko *et al*. (2008) [38] reported measurements of magnetic field induced nematic order in the bent – core liquid crystal 4 – chlororesorcinolbis [4 – (4-n-dodecyloxybenzoyloxy)benzoate]. Using the 31Tsolenoid at the National High Magnetic Field Laboratory, this study is observed, at temperatures less than 1^o above the clearing point, a first – order transition to the nematic phase. The critical magnetic field at which this occurs increases with temperature.

Ostapenko *et al*. (2009)[39] studied the effect of magnetic field caused birefringence of a 14% solution of disodium cromoglycate (DSCG)in water at temperature above the nematic – isotropic coexistence region, this study is resulted to when is increase the temperature above the coexistence region ,is deviated from this linear dependence. The data shows that Δn goes to zero, whereas Landau – de Gennes predicts that Δn should decrease asymptotically.

Ren Guang– Jun, *et.al*, (2009)[40] showed search is a matrix method for analyzing the optical rotation effect of a liquid crystal is presented, and the matrix expression of optical rotation of liquid crystal is given.The magnetic optical rotation characteristic of liquid crystal is studied by testing rotation angle and transmission of liquid crystal. The optical rotation direction of liquid crystal is independent of the magnetic field direction .

Nina Podoliak*et al*. (2010)[41]studied the induced magnetic field on liquid crystal, they showed that a small bias magnetic field not only breaks the symmetry of the ground state, but also plays a crucial role in facilitating .

Peter*et al*. (2011) [42] worked in the thermotropic liquid crystal 4- (trans – 4ˋ- n –hexylcyclohexyl) – isothiocyanato- benzene (6CHBT) was doped with differently shaped magnetic nanoparticles with the aim to raise the sensitivity of the liquid crystal on the external magnetic field. The shift in the temperature from isotropicto nematic phase was observed in the liquid crystal doped with rod like particles.

Akihiko and Tomomi, (2012)[43]showed theoretically study phase separations in mixtures of a low molecular – weight-liquid crystalline molecule (LC) and a rigid – rod such as polymer (rod) under an external field, such as magnetic or electric fields. By taking into account two orientational order parameters of the rod and the LC.

Giorgia *et al*. (2013)[44]studied the microscopic single domains nucleating and growing within the coexistence region of the isotropic and Nematic phase in magnetic field. By rapidly switching on the magnetic field the period needed to align the nuclei of sufficiently large size is measured, and they found the decrease with the square of the magnetic field. When the field is removed the disordering time is observed to last on a longer time scale. The growth rate of the nematic domains at constant temperature within the coexistence region is found to increase when a magnetic field is applied.

Khan *et al*. (2014) [45] published the search about using the liquid crystal in biosensor for urea detection. This study is to find the a transmission electron microscopy (TEM) grid filled with 4 – cyano – 4' - pentylbiphenyl (5CB) on an octadecyltrichlorosilane – coated glass substrate in aqueous media was developed to construct a urea biosensor by coating poly(acrylicacid-b-4-cyanobiphenyl-4-oxyundecylacrylate)(PAA-b-LCP) at the aqueous / 5CB interface and immobilizing urease covalently to the PAA chains. This new and sensitive urea biosensor is relatively cheap , allows easy naked eye detection , and may be useful for screening the urea level in the human body.

Zaid et al. (2015) [47]Using the four – parameter model for describing the temperature effect on refractive indices of mixture liquid crystal (UCF) based on the vuks equation , at wave length (632.8 nm) . They obtained excellent agreement between the experimental data and theory. find the ordinary refractive index ($n_{\circ}$) and birefringence (Δn) are increased as the temperature is increased . Also find the average refractive index < n > decreased linearly when the temperature increased , and find the order parameter (S) decreased as the temperature is increased.

Zaid (2016) [48] Used nematic liquid crystals type (5PCH) and wavelength (632.8 nm) that find the temperature effect on the optical properties , this study shows the direct proportionality between the temperature and the ordinary refractive index ($n_{\circ}$) , from one side and the indirect proportionality between the temperature with the extraordinary refractive indices (n_e) and optical anisotropy (birefringence Δn) .

1.6 Aim of the study

Study the temperature effect on the Refractive Index , Macroscopic Order Parameter and time operation for MLC Material liquid crystals.

CHAPTER TWO

THEORETICAL BACKGROUND

2.1 The effect of external field on the properties LC

The structural state of a liquid crystal is very sensitive to external forces as well as boundary conditions at surface . Many external stimuli are known affects the physical and optical properties, these are static and alternating electric fields, static and rotating magnetic fields, mechanical forces and torques , ultrasonic field , and even a moderately intense electromagnetic field as has been shown recently by saupe [46]. A large amount of work has been reported in this area recently but it cannot be said that there is general agreement on the interpretation of results .We shall discuss the effect of temperature**.**

2.2 The refractive indices

When the laser beam is polarized at 45 degree to the director of the crystal , it will pass through the sample and splits itself in an " ordinary ray " and an "extraordinary ray " . Because of LC birefringence nature , the two beams will leave the cell in two different directions . By measuring the deviation angle of these two rays with respect to the situation in which the UCF or 5CB liquid crystal is absent it will be easy to find the two refractive indices of the liquid crystal by means of the refraction laws .

The point where the reference ray R_{ref}(Figure2.1) ,emerges from the empty cell , encounters the observation plane π , which is perpendicular to R_{ref} ,is determined experimentally by translating the detector along the x-axis by means of the millimetric translator until the peak of the spot is exactly in the center of the detector . After that , the cell is filled with the liquid crystal and the two refracted beams R_O and R_e will appear .The detector is now translated in order to bring the center of the peak corresponding to the ordinary beam . The displacement (X_o) from the reference point (O) is recorded .This procedure is repeated for extraordinary light spot , recording its distance (X_e) from point (O) . From the geometrical considerations (Figure2.1) ,we can calculate the two refractive indices the ordinary refractive index (n_o) and the extraordinary refractive index (n_e)from the following formulas [50].

$$n_o = \frac{\sin(\theta' + \theta_o)}{\sin\theta'} \quad \text{(2.1)}$$

$$n_e = \frac{\sin(\theta' + \theta_e)}{\sin\theta'} \quad \text{(2.2)}$$

Where θ' is the angle of the wedge formed by the two glass plates , θ_o and θ_e are the angles formed by the beams R_o and R_e with respect to the beam R_{ref} emerging from the wedge when the M LC LC is absent. Note that the lateral shifts of the beams R_o and R_e with respect to R_{ref} at the output of plate B are smaller (Figure 2 . 1). These shifts are much smaller than experimental accuracy on the measurements of X_o and X_e and, thus it can be neglected. From elementary geometry, it follows that [50].

$$\tan\theta_o = \frac{X_o}{L} \quad \text{(2.3)}$$

L : The distance between the wedge liquid crystal cell and the detector

$$\tan\theta_e = \frac{x_e}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.4)$$

$$\therefore\ \theta_{\circ} = \tan^{-1}\left(\frac{X_{\circ}}{L}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.5)$$

$$\theta_e = \tan^{-1}\left(\frac{X_e}{L}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.6)$$

So that ,

$$n_o = \frac{\sin[\theta' + \tan^{-1}(\frac{x_o}{L})]}{\sin\theta'} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.7)$$

$$n_e = \frac{\sin[\theta' + \tan^{-1}(\frac{x_e}{L})]}{\sin\theta'} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.8)$$

The average refractive index $< n >$ is [50].

$$< n > = \frac{(2n_0 + n_e)}{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.9)$$

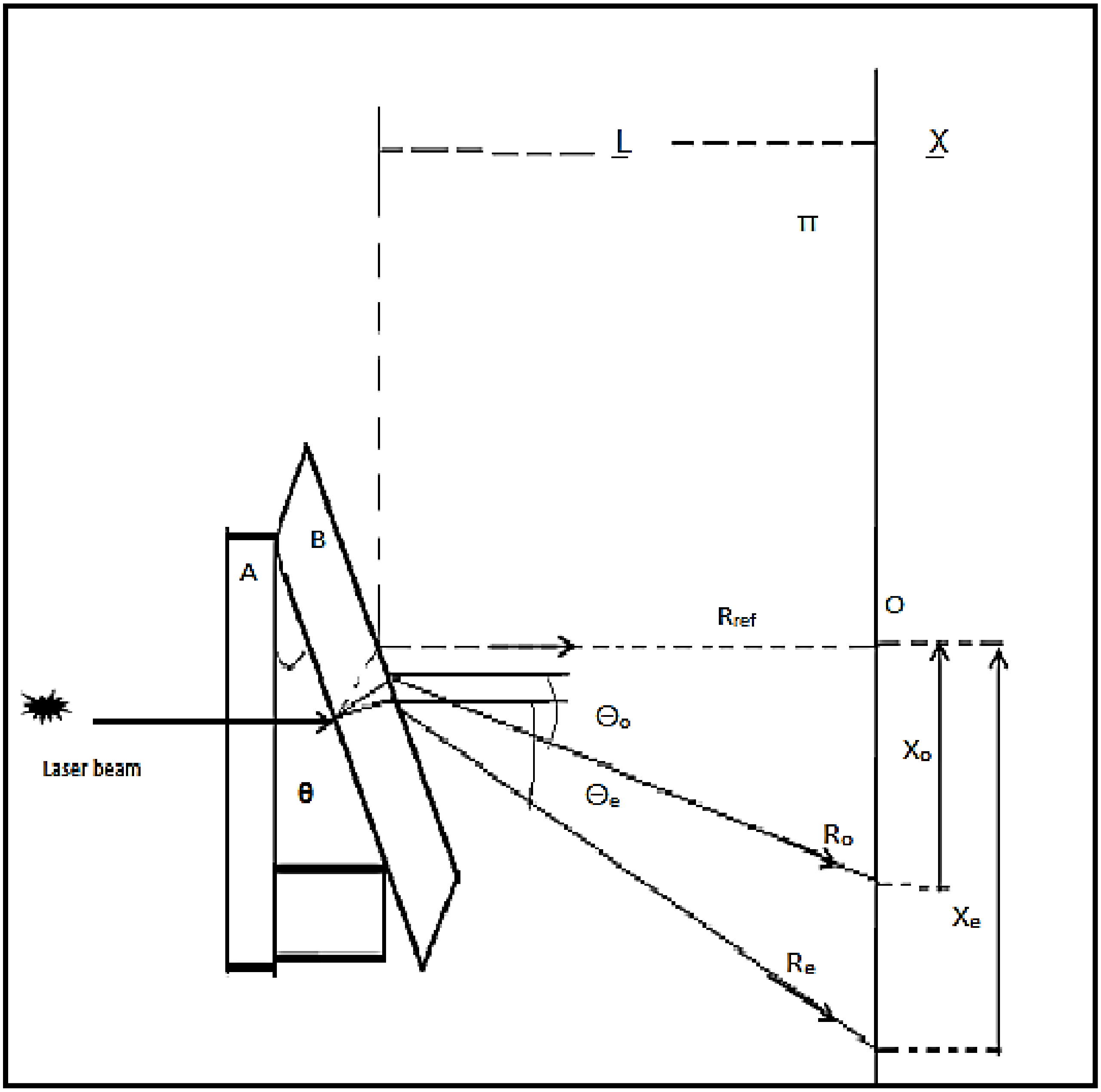


Figure (2. 1) : Liquid crystal wedged cell, the He – Ne laser beam encounters first the substrate A. When the cell is empty only ray R_{ref} emerges. When the wedge is filled the ordinary and extraordinary ray R_o and R_e appear .The angles formed by R_o and R_e with R_{ref} are called(θ_o, θ_e)[50]

Δn is the birefringence corresponding to complete alignment for uniaxial alignment [51 ,52].

For uniaxial crystal $n_{\shortparallel} = n_e$, $n_{\perp} = n_o$ and

$$\Delta n = n_e - n_o \qquad \text{-------------------- (2 . 10)}$$

$$Q = \frac{n_{\parallel} - n_{\perp}}{\Delta \boldsymbol{n_o}} = \frac{n_e - n_o}{\Delta \boldsymbol{n_o}} = \frac{\Delta n}{(\Delta \boldsymbol{n})_{\boldsymbol{o}}} \qquad \text{------------------ (2 - 11)}$$

The value of macroscopic order parameter (S) becomes (1) at (0 ^{0}C) ($\Delta n = (\Delta \mathbf{n})_{\mathbf{o}}$) . This can be determined by extrapolating $(\boldsymbol{\Delta}\mathbf{n})_{\mathbf{o}}$ for T = 0 ^{0}C.

This extrapolation is done on the linear portion of the graph drawn between birefringence (Δn) with lin $[\, 1 - \frac{T}{T_C} \,]$ [53 , 54].

CHAPTER THREE

EXPERMENTAL PART

3.1 Introduction

To take measurements the temperature, make to provide the experimental tools:

1. He – Ne laser: This device has the properties.

Table (3 – 1): He – Ne laser device properties

The properties	Magnitude and unit
Wavelength	632.8 nm
Output power	1.5 mW
Polarization Ratio	Linear
Working life	> 10000 h
Power Stability	5 %
Tube working voltage	120 V
Divergence Angle	< 1.3 mrads

2. DC Power Supply

This DC power supply is work by voltage (0 – 30) V , and is given the DC current (5 Ampere).

3. The Detector

Using this detector , we can find the peak for Gaussian shape for the spot position , also , using this device we can observ any change .

4. The liquid crystal cell

This cell is composed of two glass plate putting in two windows made from Aluminum plate Figure(3.1).The cell windows (2mm) thickness, kept in a wedge – shaped configuration by means of two spacers of different thickness. The readings were taken in a laboratory at the College of Science ,University of Baghdad .

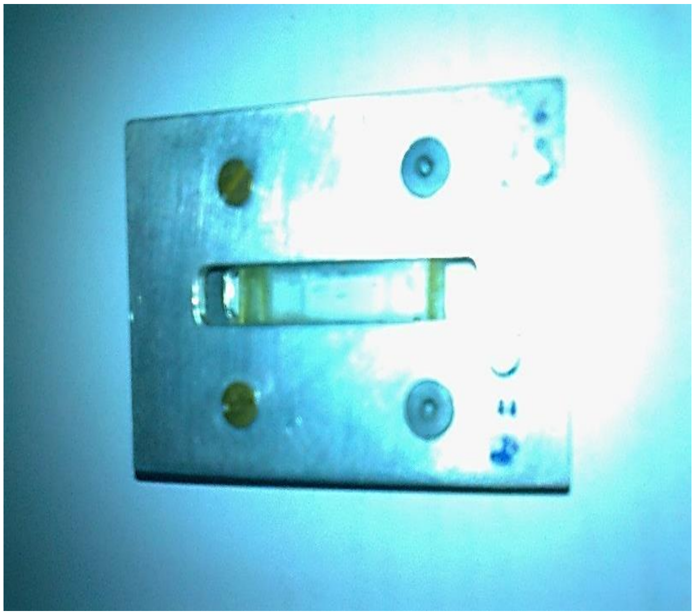


Figure (3. 1) : The liquid crystal cell

3.2The temperature effect

In order to study the effect of temperature on the behavior of the liquid crystal, a thermos – optic system should be used. The system contains:

1. Hot stage system is contain on heater.

2. Thermometer device to count the temperature steps .

3. He – Ne laser device.

4. Detector device.

5. Liquid crystal cell .

After the collected the experimental tools, make to design the thermo – optic system is shown in Figure (3.2).

Figure (3.2): Schematic of Thermo – Optic set up [55] .

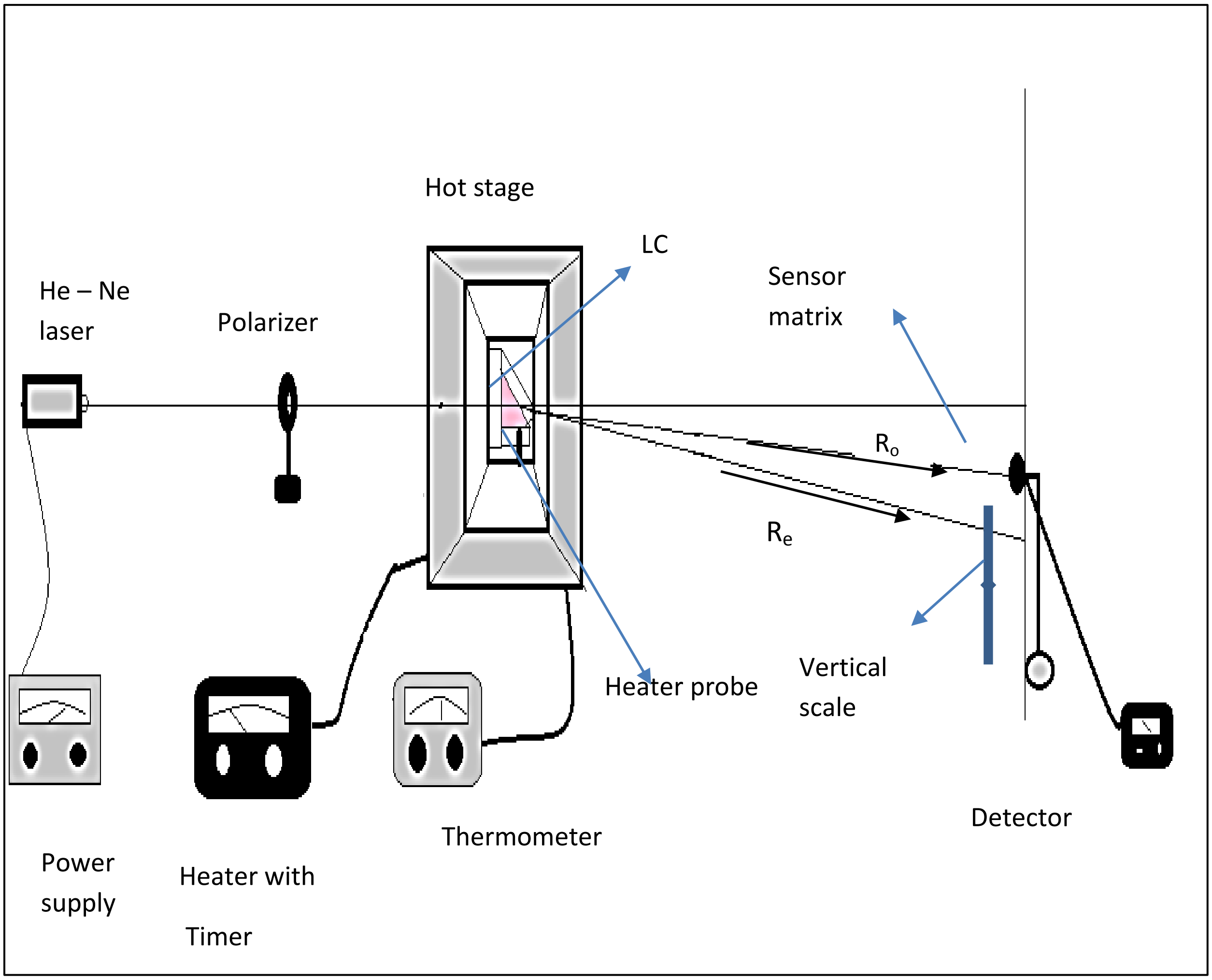


Figure (3.3) : Schematic diagram of the thermo – optic system [55] .

When the laser beam polarized at 45 ° with respect to the director of the crystal passes through the sample, it splatted in an " ordinary ray "and an " extraordinary ray" .Because of the LC birefringence the two beams will exit from the LC cell and travel in two different directions, it is easy to find the two refractive indices of the liquid crystal by means of the refractions laws ,by measuring the deviation angle of these rays with respect to the situation in which the (M L C) LC is absent. To study the temperature effect on the refractive indices should put the

LC cell in hot stage figure (3.2), the hot stage is controlled by thermometer and timer.

In Figure (3.3), the ordinary and the extraordinary spots are shown as detected by the detector. Two different situation are presented in the figure , so that it is easy to find the position of the two beam maxima. The point where the ray reference R_{ref} emerge from the empty wedge, the observation plane π , which perpendicular to R_{ref} . This point is determined experimentally by moving the detector along the X – axis of the spot is exactly in the center of the detector. After that the cell is filled with the (MLC) an the two refract beams (R_o) and (R_e) will appear.

The distance between liquid crystal cell and the detector (L) was also calculated . The equations (2.7) and (2.8) are used to calculate the ordinary refractive indices (n_o) and extraordinary refractive indices(n_e) .

Each measurement has been repeated many times by changing the temperature of the sample in order to reconstruct the temperature dependence of the refractive indices, the time interval between two runs was (20 min), in order to reach a good stability .

The equation (2.10) is applied to find the birefringence .

Chapter Four

Results and Discussion

4 .1 Introduction

The study of the effect of the temperature an these parameters (n_o and n_e) is also presented in this chapter.

All studies were done at a certain wavelength.

4 .2 The effect on the refractive indices

a : The ordinary refractive index (n_o)

According equation (2 - 7) , can be found the ordinary refractive indices , these data′ s is representation in figure (4 - 1) for mixture liquid crystal (MLC)

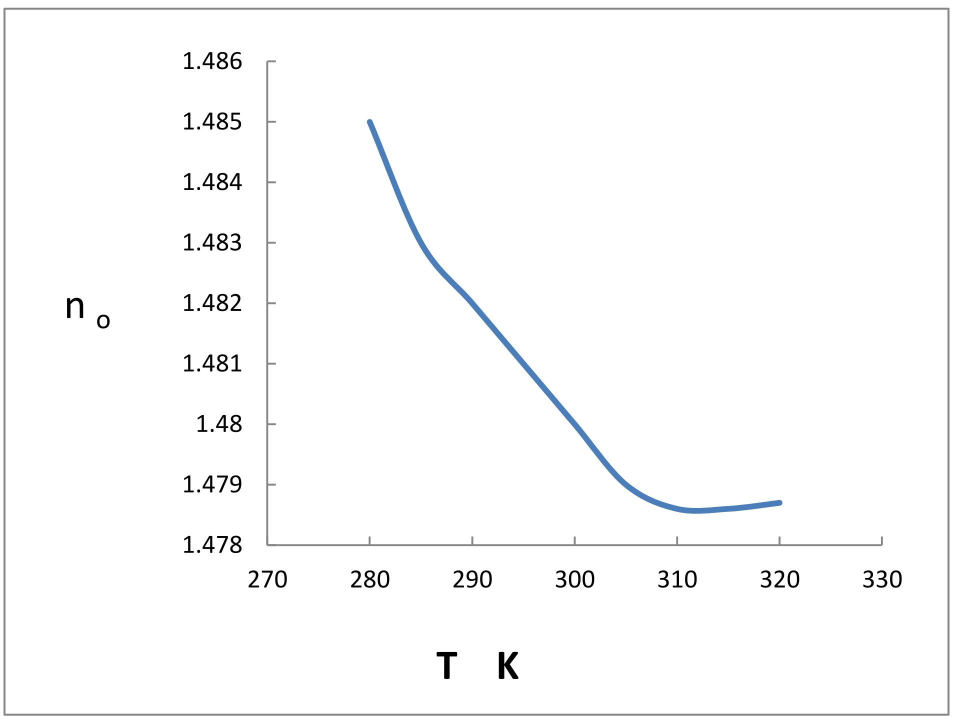


Figure (4 - 1) : Temperature – dependent ordinary refractive index (n_o) for mixture liquid crystal (MLC), at wave length (632.8 nm).

The figure (4 – 1) show that the ordinary refractive index decrease with increasing the temperature, this behavior agrees many researches[Jun Li . *et.al* (2004)][81]and [F.Bloisi , *etal*.,(1997)][82].

To explain this behavior the random motion of the rod like molecules increases when the temperature increase, therefore, the ordinary beam velocity decrease.

b: The extraordinary refractive index (n_e)

From applying equation (2 - 8), are can notice that the extraordinary refractive index (n_e) decreases with increasing the temperature [figure (4 - 2) for the mixture liquid crystal (MLC)

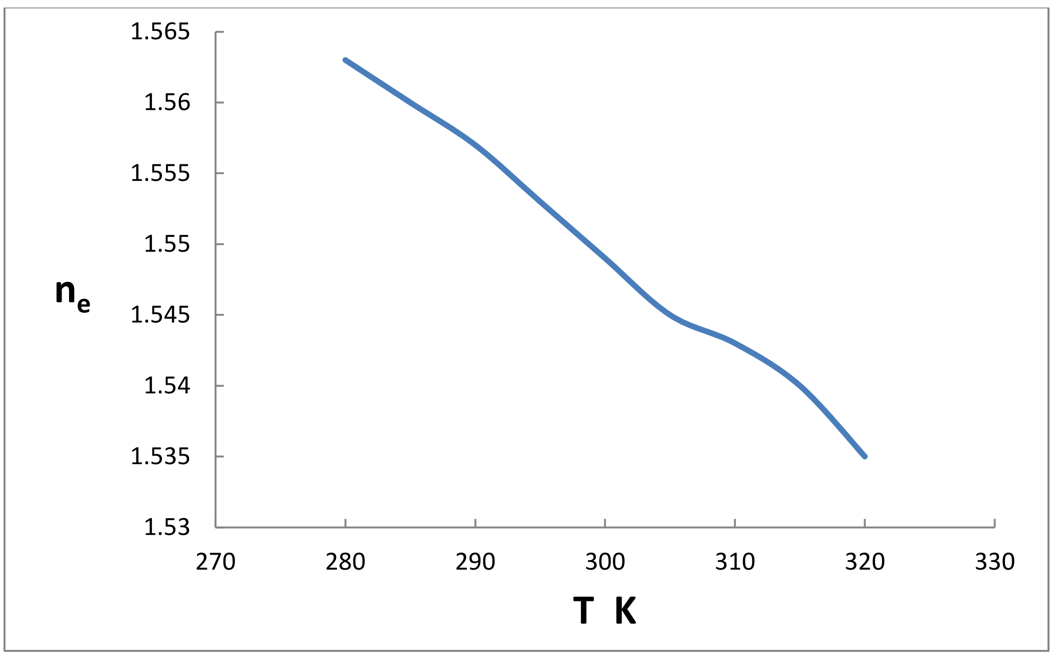


Figure (4 - 2) :Temperature – dependent extraordinary refractive index (n_e) for mixture liquid crystal (MLC) at wavelength (632.8 nm) , According to the equation ($n_e = \frac{c}{v_e}$) , the extraordinary velocity increases with increasing the temperature causing reducing the value of the (n_e). This results goes well with other researches [Thomas,T.,*et.al* (2006)] [83] .

c :The average refractive index < n >

By using equation (2 - 9) ,and using the ordinary and the extraordinary refractive index values , the average refractive index values can be calculated, these data are represented in figure (4 - 3) for mixture liquid crystal (MLC)

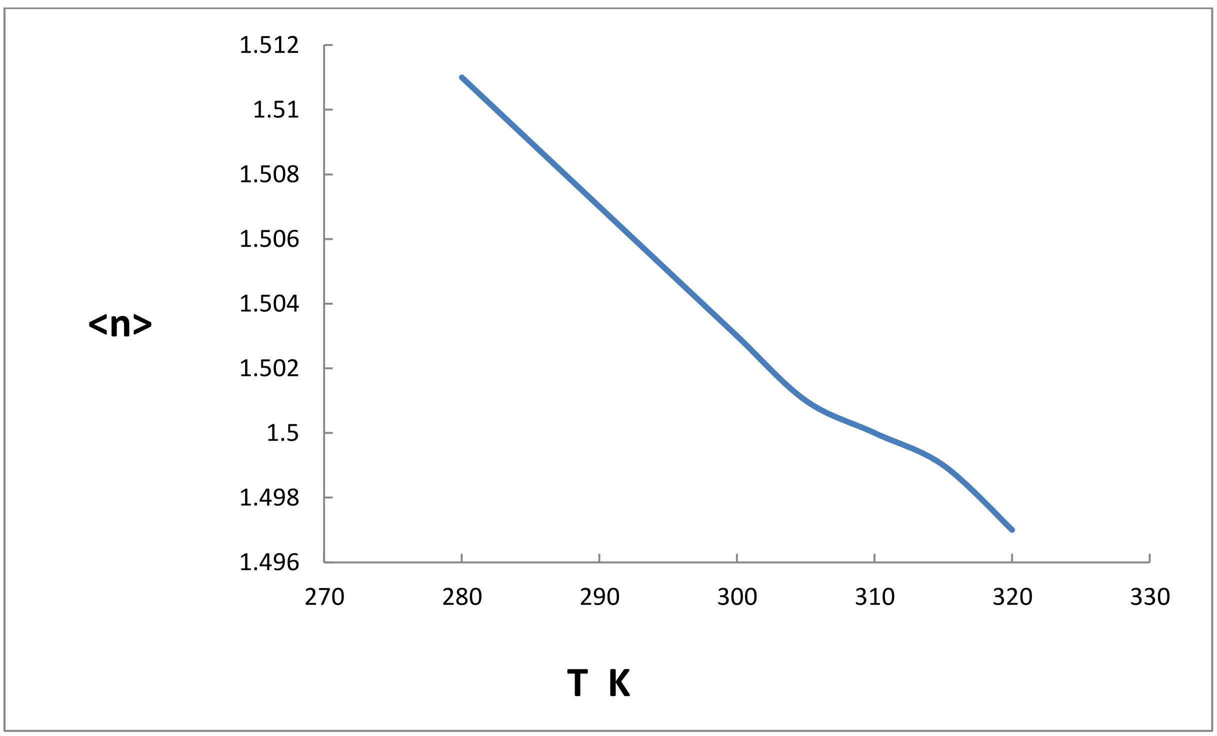


Figure (4 - 3) : Temperature – dependent on average refractive index < n > for mixture liquid crystal (MLC) at wave length (632.8 nm).

This figure show that , the average refractive index is decrease linearly as the temperature increase. This behavior is agreed the other researchers [Soorya , T.N. , *et.al* (2006)] [84] and [Yuan Chen ,*et.al* (2013)] [85].

d : The birefringence (Δ n)

According the values of extraordinary refractive index (n_e) and ordinary refractive index (n_o) in equation (2 - 1 0), one can find the optical anisotropy (birefringence) values at different temperatures value, the data is presented in figure (4 - 4) for the mixture liquid crystal (MLC) .This behavior shows indirect relation and agrees with researches [Sudipta Kumar S.,*etal*.,2013] [86].

The figures show that birefringence (Δn) decreases with increasing the temperature value , and because of this sensitivity , the liquid crystals used as thermal sensors.

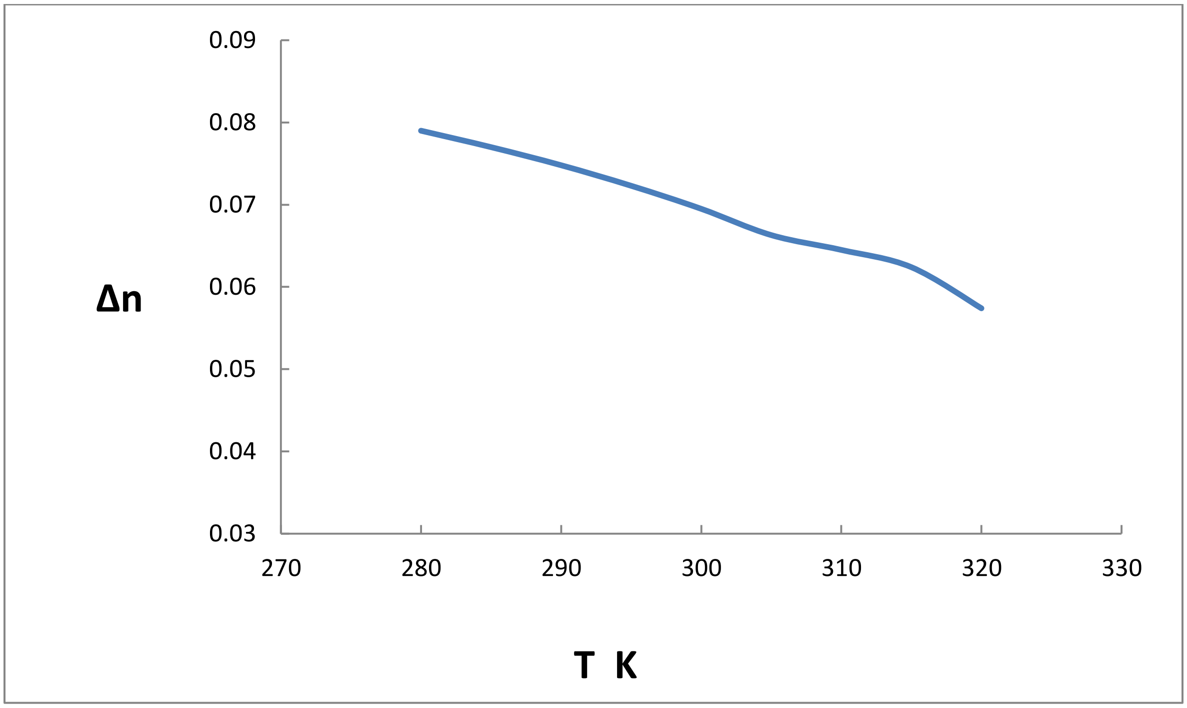
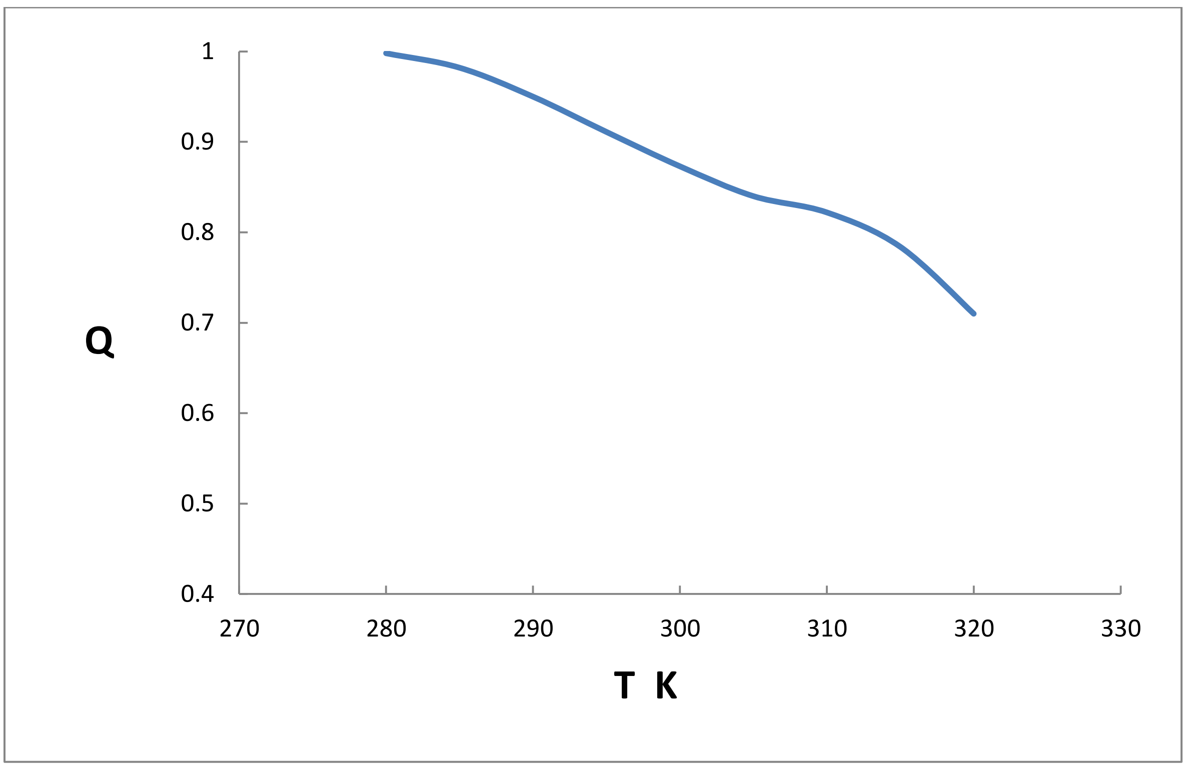


Figure (4 - 4) : Temperature – dependent on birefringence (Δ n) for mixture liquid crystal (MLC) , at wave length (632.8 nm) .

4.3 The effect on order parameter (Q)

Using equation (2 - 11) , the order parameter (Q) can be found the relation of (Q) with the temperature is presented in figure (4 – 5) for the mixture liquid crystal (MLC) .

The figure show the order parameter (Q) decreases as the temperature increases , due to random movement of the rod like molecular for these liquid crystals, therefore the order parameter vanishes at the clearing temperature (T_C) where the liquid crystal phase goes to the liquid phase,. This results agrees with researches [T.K.Devi ,*etal*.,2014] [87].

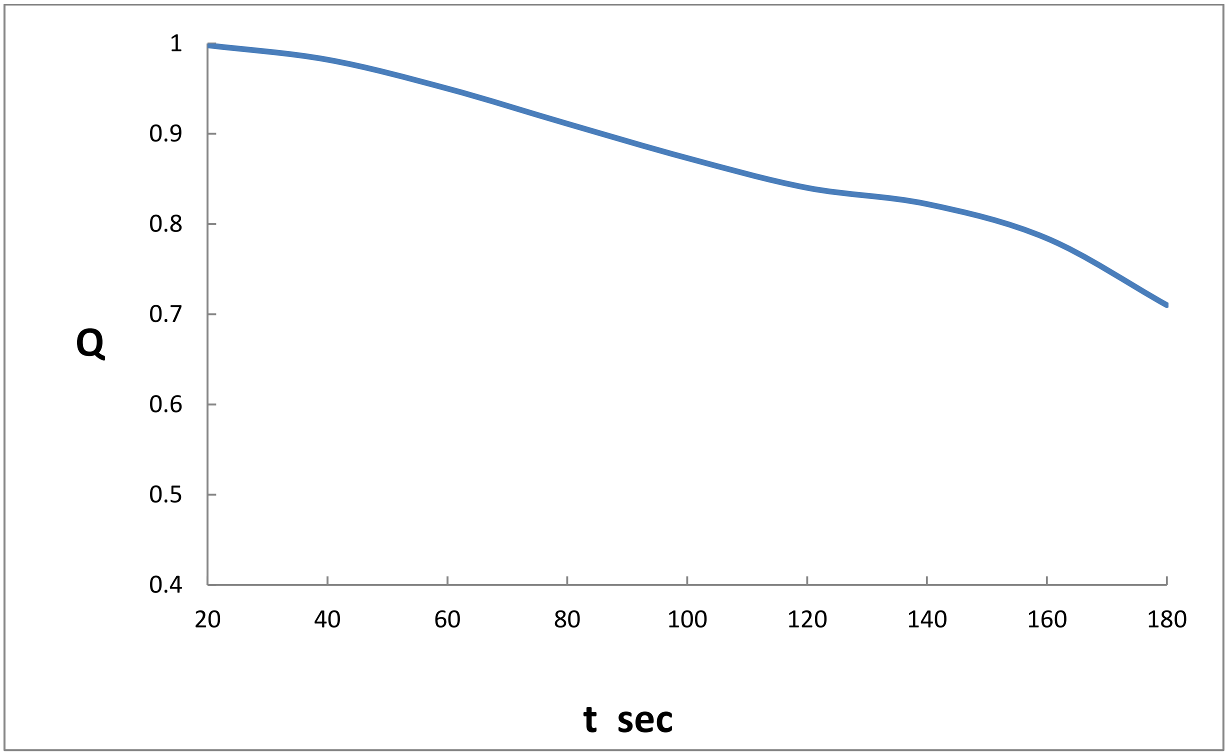


Figure(4 – 5): Relationship between order parameter (Q) and temperature (T) for mixture liquid crystal (MLC),at wave length (632.8 nm) .

4.4 The time Operation

can be found the relation of the order parameter (Q) with the time operation in present the temperature the figure (4 – 6) show that for the mixture liquid crystal (MLC) .

The figure explain the order parameter (Q) decreases as the time operation increases , due to random movement of the rod like molecular for these liquid crystals increases, therefore the order parameter vanishes at the clearing temperature (T_C) where the liquid crystal phase goes to the liquid phase.



Figure(4 - 6): Relationship between order parameter (Q) and time work (t) for mixture liquid crystal (MLC),at wave length (632.8 nm) .

(4.5) Conclusions

The result of this study shows the effect of temperature on Refractive Index And Macroscopic Order Parameter such as:

1- The rising of temperature is too high, thermal motion will destroy the delicate cooperative ordering of the phase, pushing the material into a conventional isotropic liquid phase. At too low temperature, most LC materials will form a conventional crystal ,The refractive indices for mixture liquid crystal (MLC) decreases as well as increasing the temperature, due to the random motion for the rod-shaped organic molecules have not positional order

2- When the temperature increase the order parameter is decrease.

3- The study is show the order parameter is decrease as well as the time operation increasing.

(4.6) Future Work

1 – Study the magnetic field effects on Refractive Index And Macroscopic Order Parameter For (MLC) Material.

2 – Study the electric field effects on Refractive Index And Macroscopic Order Parameter For (MLC) Material.

3 – Study the piezoelectric effects on Refractive Index And Macroscopic Order Parameter For (MLC) Material.

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الخلاصة

هذا البحث تم دراسة تاثير درجة الحرارة على معامل الانكسار لمادة الخليط البلوري السائل (MLC) ومعدل الانتظام باستخدام البلورة السائلة النماتية من نوع (MLC) وليزر (Ne– He) بطول موجه (632.8 nm) .

توضح هذه الدراسة جميع معامل الانكسار ، كذلك معدل الانتظام تتناقص مع زيادة درجة الحرارة ، بالإضافة ايضا وجد ان معدل الانتظام يتناقص مع زمن التشغيل .

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة بابل
كلية التربية للعلوم الصرفة
قسم الفيزياء

تأثير درجة الحرارة على معامل الانكسار ومعدل الانتظام لمادة البلورة السائلة نوع

(MLC)

بحث مقدم الى مجلس كلية التربية للعلوم الصرفة في جامعة بابل جزء من متطلبات نيل
درجة الدبلوم العالي تربية / فيزياء المواد و تطبيقاتها

علـي حسـين كـريم مرموس

بكالوريوس تربية فيزياء \ جامعة الموصل

٢٠١٢-٢٠١٣

إشراف
الأستاذالمساعد

د. زيد عبد الزهرة حسن

١٤٤٣ هـ ٢٠٢١م