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The Recent Advances In Nano-Liquid Crystals

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A B S T R A C T :

Highly adaptable and efficient thermo-optical liquid crystals have a bright perspective. Recent years have observed increased application of LCs in fields including medical diagnosis, drug delivery, and even technologically advanced products. LCs are unique in many ways and possess many potential uses. Liquid Crystals (LCs) have recently discovered widespread usage throughout a variety of fields, including biosensors, fermentation control, food and Beverage assessment, waste from industry management, pollution surveillance, and exploring the effects of mining, factories, and dangerous gases in addition to military applications. These carriers are useful for transporting many different kinds of drugs as well as biologically active substances because of several significant properties, such as thermodynamic stability, increased solubility of hydrophobic pharmaceuticals, higher bioavailability, and a regulated releasing pattern. This article briefly outlines present-day research activities in LC-Nano science. The current study focuses on enhancing their manufacturing and evaluation, controlling drug release, and boosting bioactive-laden chemicals' efficacy. Differential scanning calorimetry, polarizing optical microscopy, and morphological analysis are used to examine and characterize new liquid crystal properties. However, not all precisely formulated compounds display liquid crystal characteristics. As a result, their portrayal is as important to their activities. This article delves into the topic of LC-based nanostructure form production, nanomaterial manufacturing, self-assembling, and a variety of applications. We want to investigate various LC preparation strategies, characterization methodologies, and new drug-delivering applications.

Keywords: Liquid Crystals (Lcs); Nano-Partial’s (NP);Lyotrophic Lc’s; Thermotropic Lc’s; Characterization; Future Prospective. Abbreviations: liquid crystals(LCs), Nano-particals(NP),Nematic Lc(NLC), Polarized Optical Microscopy(POM), Differential Scanning Calorimetry(DSC), X-ray diffraction (XRD)

INTRODUCTION:

Bernhard Reinitzer, a chemist from Austria, created cholesteryl benzoate in 1888. It has more than one melting point. He manipulated the temperature among the materials in his studies and noticed the subsequent alterations. Reinitzer is principally responsible for discovering a novel form of matter called the liquid crystal phases. [1-2] Liquid crystals are unique isotropic liquids with crystal features. They have crystal organization and liquid fluidity. [3] We refer to a single chemical compound when discussing liquid crystal materials. However, in practical applications and biological systems, liquid crystals are often mixtures (like E7 or cell membranes of phospholipids). One substance can only do so much; in the real world, one requires things that can stay consistent in many different situations. For example, eutectic mixes of liquid crystals optimize viscosity as well as elasticity while adjusting the nematic phase temperature range as well as response time. [4]

It is possible to synthesize and self-assemble nanoscale structures using liquids and crystalline substances due to their ability to combine molecular and nanoscale mobility with order. Because they are composed of anisotropic compounds, liquid crystals undergo structural and behavioural changes in response to surface interactions and outside influences [5]. LCs have features similar to crystalline solids, such as dielectric, electrical, optical anisotropy, and isotropic liquids, including fluidity and molecular mobility. This unique combination has led to the prominent definition of LCs as "orientationally ordered liquids" or "positionally disordered crystals". [6]

Classification:

Lyotropic and thermotropic are the two types of liquid crystalline solids. Cold, as well as heat, changes the state of thermotropic crystals that are liquid. Both of the most common types of thermotropic crystalline liquids are enantiotropic and mesophase [7.] Four primary varieties of thermotropic liquid crystals have been identified: nematic, cholesteric, smectic, and columnar. Nematic liquid crystals have molecules that align in a parallel fashion, with their orientation influenced by external factors like electric fields [8.] When heated and cooled, the mesophase is called enantiotropic. Lyotropic phases arise when mixed with a suitable solvent. Both temperature and concentration impact the emergence of the mesophase [7.]

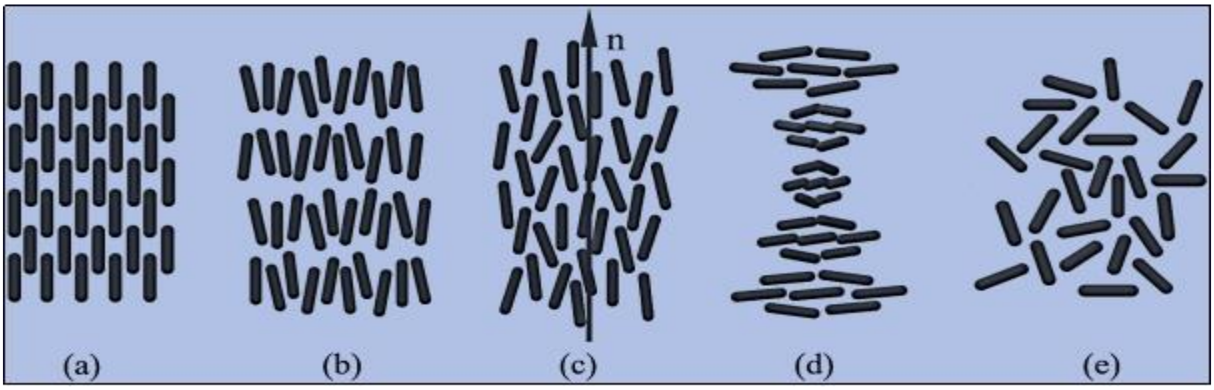

Fig. 1. Molecular arrangement in (a)crystalline phase ,(b) smectic-A phase, (c) nematic , (d)cholesteric phase, and (e) isotropic phase.

Structural characteristics of lyotrofic liquid-

Whenever the concentration of amphiphilic compounds increases, Various new forms emerge, such as typical micelles (oil within water), reversible cubic, reversal cubic, and phases like, hexagonal, lamellar, and hexagonal. There are actually several types of flipped cubic phases such as flipped bi-continuous cubic and flipped micellar cubic. Moreover, sources provided a technique for identifying mesophases using separate capital letters as well as subscripts. For example, the phases L, Q, V, I, and H correspond to the lamellar, cubic, bicontinuous, & hexagonal phases, respectively. Also, subscripts I (1) while II (2) show the normal along with reversing phases, respectively. [8-9]

Structural characteristics of thermotropic lc:

Calamitic molecules resemble rods, whereas discotic molecules resemble discs.[10-11] After the whirling that occurred over the cholesteric, as well as smectic liquid, was removed, the parallel molecule planes began to develop. Friedel addressed the three leading types of liquid-based crystalline phases within organic molecules—nematic, cholesteric, and smectic A. Unlimited folded symmetry axes are a property of smectic A and nematic liquids.[12] A significant twist within the geometry of its cholesteric phase around the point at which it becomes an isotropic liquid. [13]

Properties:

I. Liquid crystals (LCs) need a backlight to display images. Optical diffusers help spread the light from the backlight evenly, preventing viewers from seeing the light source directly. They're also essential in LEDs, ensuring the light is distributed uniformly without bright spots[14]
II. elastic mechanical properties that can lead to new classes of amphiphilic or colloidal interactions[15]
III. Dielectric spectroscopy of nematic liquid crystals (LCs) provides crucial insights into their response to electric fields. This understanding is vital for designing display devices and spatial light modulators[16]
IV. **Dielectric Properties:** At low concentrations, the interaction between particles in liquid crystal (LC) nanocolloids is weak, leading to stable systems. By tuning the surrounding medium's size, shape, and dielectric characteristics, noble metal particles' plasmon absorption bands may be modulated over near-ultraviolet to infrared [17.]
V. Nanostructures can be manipulated using the self-organization and orientational order transfer capabilities of nematic liquid crystals (LCs). When introduced into nematic LCs, the elastic contact force causes the nanostructures to coincide on their long axis towards the orientation of the host LC compounds. External fields and dopant characteristics influence the orientation of liquid crystals[18]
VI. This liquid-crystalline state has properties of liquids as well as solids. That exclusive mixture provides unique properties that neither liquids nor solids can offer.

Unusual characteristics include Optical activity: This spontaneously twisted nematic liquid crystal exhibits remarkable optical activity throughout the solid and liquid regimes. Temperature sensitivity: Cholesteric liquid crystals modify colour in response to temperature variations. Monocrystal formation: A magnetic field of about a few thousand gausses throughout a centimetre gap and an electric field of around a couple of hundred volts across a 5-25 micrometre gap may yield monocrystals [19.]

CHARACTERIZATION:

There are several approaches for characterizing liquid crystals. Differential Scanning Calorimetry (DSC), X-ray Diffraction (XRD), and Polarized Optical Microscopy (POM) are among the various methods used to study liquid crystals.

Morphological study:

Transmission Electron Microscopy (TEM) and Scanning Electron Microscopy (SEM) study liquid crystal morphological features. SEM analyzes a three-dimensional framework for globular structures, while TEM provides finer resolution for studying the dispersed phase. [20] Changes in internal organization, whether increases or decreases, will result in improved consistency and flow. However, LCs with high viscosity are not suitable for drug delivery.[21]

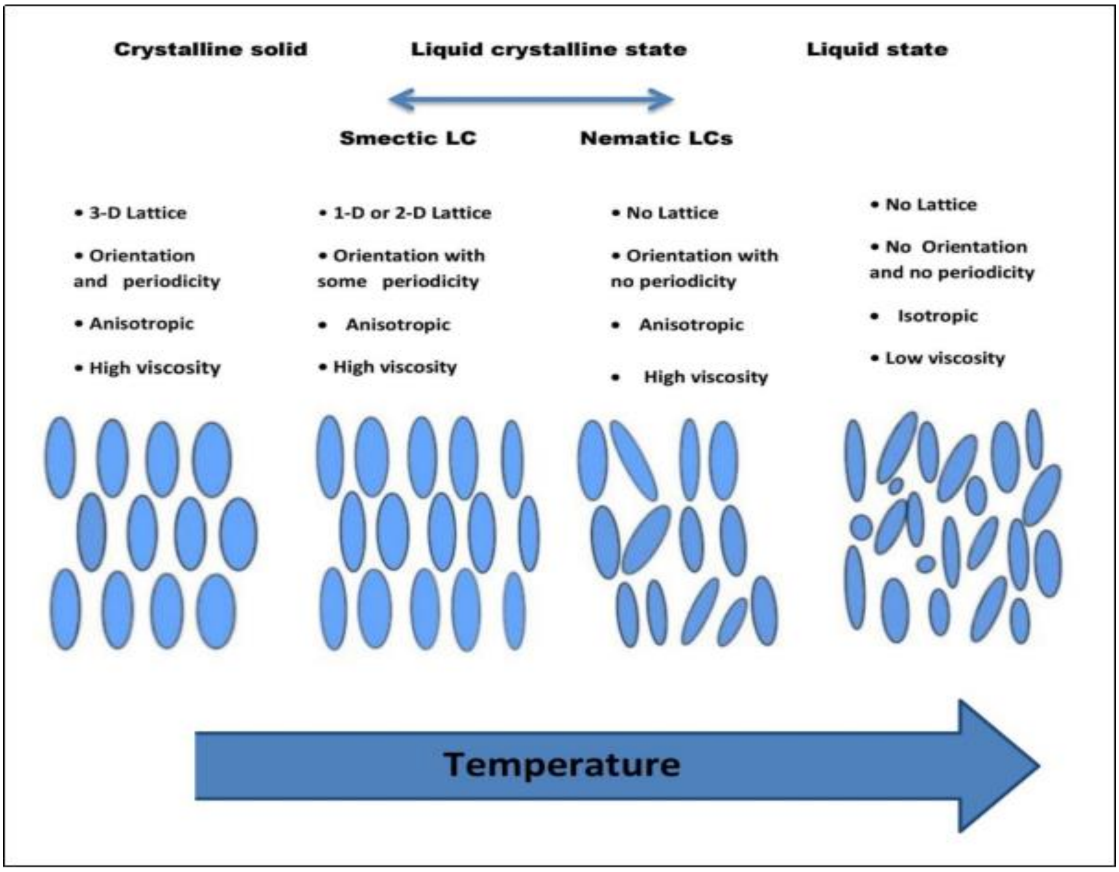

Figure 2 : Differences in the molecular structures of solids, liquids, and cells As the temperature rises.

Differential Scanning Calorimetry (DSC):

The use of Differential Scanning Calorimetry (DSC) for studying transitions between phases within liquid crystals. This happens by determining the differential in heat flow among a sample as well as a reference materials as temperature rises. Both of them the sample as well as reference materials are progressively heated (typically in a linear method). The heat flow towards the sample as well as reference are both measured. The differential heat flow among the two is computed. This distinction gives details regarding the phase transitions that occur throughout a sample.[22]

Polarized optical microscopy (POM):

The optical along with morphology features of LC nanofibers have been investigated by an Olympus BX-51P polarized optical microscope (POM) fitted via optical retarders. The electrospun nanofibers were collected within slides for the microscope and shot using a polarizing microscope equipped with a built-in Canon 6D camera and crossed polarizers surrounding the transmitted form. [22-23]

Small-angle X-ray Scattering. (SAXS)

The diagram of phases was revised through small-angle X-ray radiation scattering after its acquisition obtained via cross-polarized visual inspection by optical microscopy (OM). [24] This approach allowed us to identify locations with many coexisting phases and retrieve critical structural information. These SAXS measures indicated a low degree of orientational ordering and significant translational order among the components. Experimental findings from SAXS measurements support the theoretical prediction of de Vries-like behaviours in such substances.[25]

Transmission electron microscopy (TEM)

The shape and arrangement of various discotic liquid-crystalline transitions have been investigated using a transmission electron microscope. We employ dynamic light scattering, cryo-TEM, and ultrafiltration to examine the distribution of particle sizes and entrapment effectiveness of liquid crystals utilized in the delivery of medications. Kim et al. studied the self-assembly of bent-shaped molecules within water utilizing circular dichroism (CD) as well as transmission electron microscopy (TEM). Investigators discovered that in solutions of water, compounds with nitrile groups collected and compounds lacking them did not, while aromatic bent rod-shaped framework self-assembled within both ends of the rod [26]

Table 1 : Characterization, Types And Properties Investigated

Characterizatio n Techniques	**Properties investigated**	**Types of LCs**	**References**
DSC	Phase transition temperatures, rapid, direct measurement of' specific heat.	All thermotropic mesomorphic compounds. 1,2 dichloroethane at -93 degree.	[27]
POM	Textures of various liquid crystal phases	Any compounds that aremesomorphic	[28]
TEM	Morphologies in the fiber state, positional order inside each layer	thermotropic LCs, lyotropic chromonic LCs	[29]
WAXS	Microphase structures, structure and the phase transitions of thermotropic LCPs	thermotropic LCPs, (P7MB),(P6MB)	[30]
WAXD	Mesomorphic properties : Phase transition, density, depend on molecular weight, structural parameters, microphase.	Wedge-shaped onium salts ABA triblock copolymer	[31]
SEM	investigate the 3D features of globules, Birefringent properties	LC-based sensor	[32][38]
UV/Vis	**Photoresponsive behaviour, absorbance and band gap were measured**	**LCP There are naturally occurring amphotropic liquid crystals made of chemicals called 2,4,6- tris(thiophene-2-yl)-1,3,5- triazines**	**[33][39]**
DMA	**Mechanical strength andphotoresponsive behaviour**	**For making flexible siloxane rubber, liquid crystal tri-block copolymers are used.**	**[34]**
AFM	**structural modification**	**smectic A and nematic Lcs**	**[35]**
XRD	**The molecular components of a mesogen, including their orientation and structural characteristics. Constitution layer by layer**	**nematic mesophases, smectic mesophases**	**[36]**

SAXS	**Its hexagonal framework measures X-ray intensity in relation to the scattering angles.**	**Mesophase compound**	[37]

MATERIAL AND METHOD

Researchers also see the usage of phospholipid-decorated aqueous-LC interfaces for reporting nonspecific interactions among protein-coated nanoparticles.

We designed LC-based sensors for surfactants, phospholipids, bile acids, proteins, as well as synthetic polymers using the following kinds of substances:

- Emulgade® SE-PF
- Tetradecyl tetradecanoate
- Polyethylene glycol (PEG)-15 hydroxystearate
- PEG-12 cetostearyl ether
- 2-Hydroxypropyl-β-cyclodextrin (HP-β-CD)
- Carbopol 980 NF

The water in sample processing, HPLC, and LC-MS/MS, in addition to the isopropyl alcohol that was utilized for HPLC, all had excellent HPLC quality.[40]

Synthetic approaches to preparing polymeric liquid crystals:

Kevlar is a simple nylon-type polymer. This polymer is synthesized by heating a dicarboxylic acid with diamine. Many polymers, such as various types of poly(acrylates), are produced through transesterification. Another standard method for preparing poly(acrylates) is radical polymerization. This process uses an initiator, like AIBN or hydrogen peroxide, under thermal conditions or through photo-induction. [41]

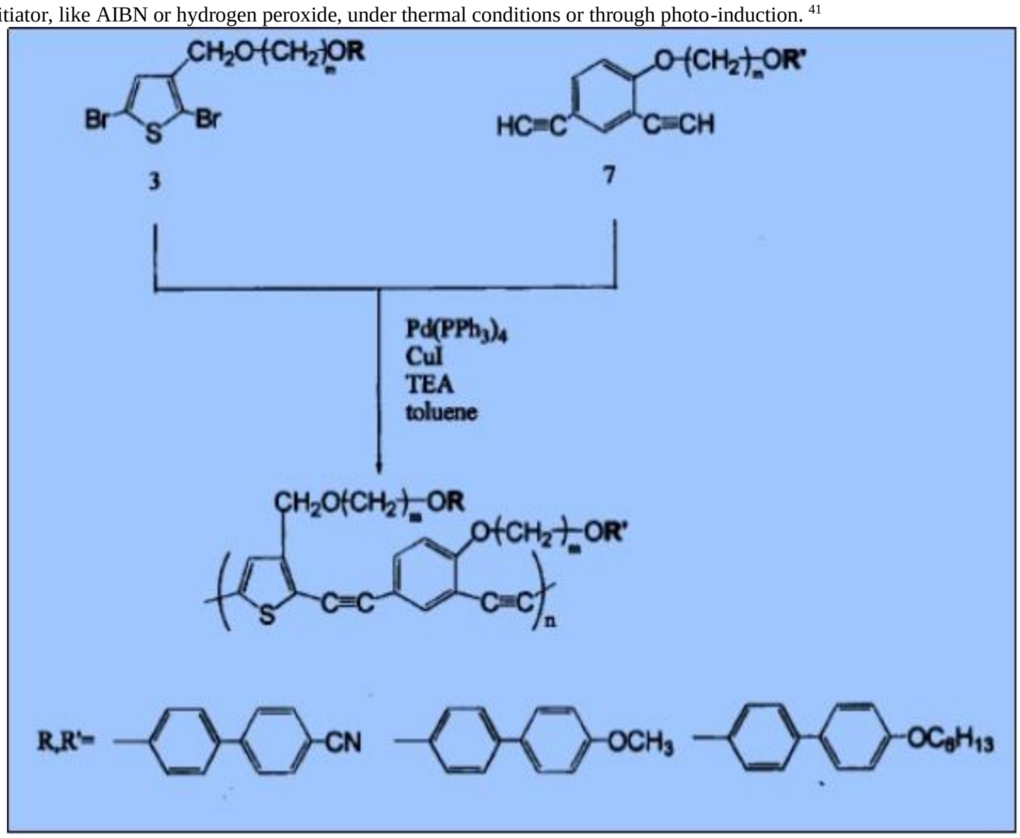

Figure 3: standard method for preparing poly(acrylates) for preparing polymeric liquid crystals (Kevlar)

Experimental preparation : material used:

4–n–pentyl–4'–cyanobiphenyl (5CB) was used as a LC. Polyacrylonitrile (PAN) was used as an electrospinning host material (150,000 wt) Bogi A, Faetti S (2001) Elastic, dielectric and optical constants of 4′-pentyl-4-cyanobiphenyl.[42] . An N, Xu Q, Xu L, Wu S (2006) Orientation structure and mechanical properties of polyacrylonitrile precursors.[43]

Electrospinning system:

An electrospinning system created a precursor solution of PAN/5CB. The Inovenso electrospinning device was used with a standard deep green syringe needle of 0.8 mm outer and 0.5 mm inner diameter. A 20-μm thick aluminum foil and glass substrates served as collectors. The needle as well as collector distances remained constant at around 23.0 centimeters. We collected the LC composite using a range of electrospinning powers, from 12.0 kV - 24.0 kV. It was E-fields that went with them were between 521.7 and 1043.5 V/cm. Concerning the concentration along with electrospinning voltages, the precursor flow rate was varied between 0.15 to 3.00 ml/h.[44]

Mechanical agitation :

To create lyotropic liquid crystal (LLC) nanoparticles, mechanical agitation, such as highpressure homogenization, sonication, or shearing, is often required. The viscous bulk phase, which can be made from lipids, surfactants, and stabilizers, is then introduced into an aqueous solution, together with mechanical agitation [45-46]

FORMULATING APPROACH:

Liquid crystals are formulated using various techniques, including top-down, bottomup, spray drying, and sonication. In the top-down method, a viscous mixture of stabilizers and lipids is dispersed into water using high-pressure homogenization (HPH). This is followed by sonication and shearing to create nanosized formulations like cubosomes and hexosomes. HPH is widely used in industrial-scale production of liquid crystal-based products.[47]

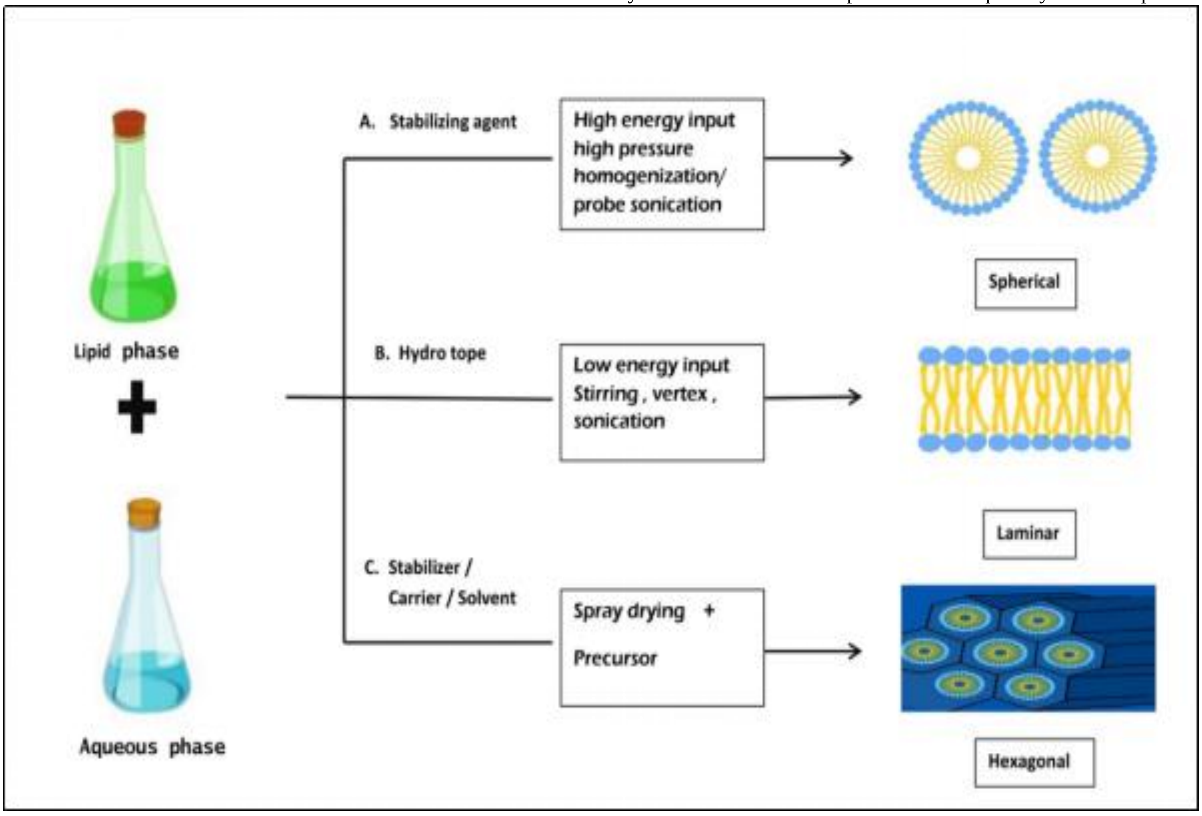

Fig. 4. Various techniques are utilized in the formulation of liquid crystals.

FACTORS AFFECTING PHASE TRANSITION:

Outside factors include temperature, pressure, light, as well as magnetic fields; inside factors include amphiphilic molecules, water content, along with third additives; while prescription factors include optical properties. Studies have shown that phases can change because of many things.[48]

The main things that affect how well NPs dissolve and how stable NPs/LC dispersions are are
There are five things that affect how well NPs interact with LC:

I. The size, density, and flexibility in the structure of the NPs shell;
II. The quantity of NPs;
III. The temperature,
IV. The chemical make-up and
V. 5.Phase state of the LC host.

or NPs/LC combinations to stay stable, they need to have strong bonds with LC molecules. [49]

ADVANTAGES:

A. Compared to traditional methods, this technique offers several advantages for synthesizing non-spherical nanoparticles: lower dispersion, easier control over geometric features, and the ability to create particles with extremely high aspect ratios using the long channels of hexagonal columnar micelles.[50]

B. Utilizing optical power below a milliwatt range along with dc voltages of roughly 1 V, an orientational photo-refractive (PR) effect within LCs doped along with impurity was found. The induced electro-optical characteristics altered dramatically, making doped LCs suitable platforms for studying nano-dopant features.[51]

C. Liquid crystals (LCs) are a recent breakthrough in drug delivery methods. Because of their capacity to maintain drug release, they have grown in popularity as injectable formulations. [52]

D. LCs offer excellent solubilization and protection against enzymatic degradation, making them a viable drug delivery method. [53]

E. LCNPs have consistently outperformed other carriers in vivo, demonstrating remarkableefficacy across various applications. Through better drug delivery towards the skin, eyes, and with brain to more effective pharmacokinetic features such as prolonged circulation as well as tissue accumulation, LCNPs show substantial promise for the therapeutic management of a variety of disorders, including malignancies as well infections. [54]

DISADVANTAGES:

A. Internal organizational adjustments can improve consistency and flow. Highly viscous LCs are unsuitable for medication delivery.[21]

B. Heat treatment can solve the two primary problems of formulation techniques: vesicle formation and reduced surfactant solubility above a given temperature.[55]

C. There are several restrictions on using LCNs to administer medications. For example, loading hydrophilic medicines into the bilayer mesophase gets more challenging aswater content increases. It is also challenging to regulate the rate of drugs being released through hydrophilic routes because of their small size and restricted diffusing paths.[56]

APPLICATION:

A. Optically active molecules within LC form spiral patterns perpendicular to their long molecular axes. Consequently, LC displays helical characteristics.[57]

B. Due to its intrinsically quick (in µs range) electro-optical response, ferroelectric liquid crystals (FLCs) are seen as attractive materials for a variety of photonic and display applications. Ever since tilted chiral smectic, LCs were found to exhibit Ferroelectricity.[58]

C. LC-based biological sensors have multiple uses other than clinical diagnosis, such as drug analysis for pharmaceuticals, food hygiene, fermentation surveillance, control of the environment, and military applications.[59]

D. Biosensor: A hybrid approach integrating LC and nanostructures may easily provide adequate optical, electrical, and magnetic properties, resulting in a sensor that has excellent sensitivity, wide detecting range, low detecting range, as well as reliability. Due to their ease of management, nanotechnology-assisted LC-based biological sensors could represent a promising alternative for building small sensing devices within pointof care (POC) uses. LC reacts with carbon nanostructures, molybdenum diselenide, along with tungsten diselenide.[60]

E. Skin disease treatment: A liquid crystal emulsion containing cyclosporine is a liquid crystal emulsion-type pharmaceutical composition. It can also be used to enhance transdermal absorption of a medication, like for testing skin disorders.[61] Developments in H-PDLC films—a hybrid technology combining holography and PDLC films—hold great promise for applications across fields as diverse as data collection and storage, diffractive optical components, photonic crystals, fiber optics, three-dimensional displays, and reflection.[62]

F. NLCs have been successfully employed to modulate refractive index for various applications by altering molecular orientation using external fields or UV light.[63]

In drug delivery system:

1. Oral DDS nanostructures have unique features that allow them to hold many bioactive compounds, including hydrophilic, hydrophobic, and amphiphilic ones. LCNs have also emerged as viable. Drug carriers that improve the solubility of insoluble medications. Research in living organisms demonstrated that the bioavailability of conjugated rapamycin was 3.35 times higher than that of the unconjugated drug [64].
2. Because of their structural resemblance to skin microstructures, LC mesophases can facilitate the dermal delivery of bioactive compounds. Because of their similarities, mesophases can pass through the stratum corneum with relative ease. More specifically, the cubic structuring of mesophases closely resembles the in vivo cubic structure of the epidermal barrier on the skin's surface.[65]

CHALLENGES:

The problem regarding liquid crystals includes the accumulation of electric and residual DC charge upon their surface throughout prolonged picture projection. This charge draws the ionic impurity inside the liquid's crystal material and material layers, leading to selective surface adsorption. In addition, liquid crystals possess an elevated concentration of ionic impurity within their aligned layers, plus the molecules they contain consist of conjugated functional groups and lone pairs that could cause problems with display applications. These difficulties eventually affect the performance of liquid crystals within device applications[66] . Much larger antenna arrays than those in labs, such as the Square Kilometer Array, provide a formidable challenge to NLC-based technologies.[67]

FUTURE PROSPECTIVE:

LCNs have several distinctive features, including the simplicity with which they may be modified with functioning target and imaging molecules. Furthermore, such dispersions possess a viscosity exactly like water, which is useful for administering them via a vein and enables dual loading of medicine along with imaging agents. In addition, their surfaces may include cancer-specific targeted moieties. Monoolein-based hexosomes, For instance, are laden with low-soluble docetaxel plus stabilised with Pluronic linked with rhodamine plus folate, despite keeping their LC phase structure [68] .CDL-coated nanoparticles are exhibiting promising outcomes in Preclinical tests due to their increased bio-compatibility and precise targeting of certain tissues[69] .Research conducted in vivo has revealed enhanced antitumor effectiveness, which may be ascribed to elevated cytotoxicity, heightened expression of apoptotic markers, and reduced side effects. The efficacious treatment of metastatic breast cancer by LCNs as dual drug delivery vehicles appears to be supported by the aforementioned results.[70]

CONCLUSIONS:

Liquid crystal research is quite extensive. There are several liquid crystal designs readily accessible, making them suitable for a wide range of applications. Numerous new paths have emerged in recent years, and certain of them may evolve into extremely successful research fields along with applications. Due to its special qualities, liquid crystals have the potential to use widely in fields, including phototonic applications, clinical diagnostics, biomedicine, pharmaceutical composition, as well as sensing systems.As a "non-reactor" allowing the fabrication of uniformly sized and shaped nanomaterials, the LLC phase themselves is becoming increasingly utilized.

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