APPLICATIONS OF LIQUID CRYSTAL POLYMERS

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Abstract

The main aim of this paper is a general presentation of liquid crystals (LC), of some of the interesting properties and practical applications LC have. There have been presented some of the practical uses of liquid crystals: in medicine (temperature indicators, surface thermography and diagnosis), injection-moulded products, fibres (helicopter winches, racing sheets, halyards, etc.) and in detection of atmosphere contaminations.
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Introduction

The subject of liquid crystals and their use in electronic displays and in non-linear optical systems has become of tremendous importance during the last decade; and the incorporation of liquid crystal units into polymeric materials has led to a group of new materials with diverse properties. Some of these properties have been used in new products and some have yet to be used.

"Polymer liquid crystals or liquid crystal polymers?" is a question that baffled many researchers. Several reasons for using the one or the other were put forward by several authors. Professor Brostow [Brostow, W., 1988], who has given a classification of different architectures, prefers to go in a natural progression from monomer liquid crystals to polymer liquid crystal.

On the other hand, "Polymer liquid crystals" may imply that the subject is about liquid crystals when it is really about polymers. A majority of the contributing authors preferred the term "liquid crystal polymer".

Experimental

Liquid Crystal State

The liquid crystal state (mesophase) exists within some temperature range, $T_m<T<T_c$, where T_m is temperature of melting from solid state into a

mesophase, and T_c is clearing temperature, when the liquid crystal transforms into an isotropic liquid. In the solid state, the centers of gravity of molecules posses long-range positional order, and, also, the molecules orientation points in the same direction providing the long-range orientational order.

When solid melts into a LC at T_m, the positional order is lost although some orientational order of the molecular long axes remains. At still higher temperature T_c, mesophase melts into an isotropic liquid with no positional and orientational order. [www.ipc.uni-stuttgart.de, 2007]

To begin with, we divide liquid crystalline materials into monomer liquid crystal (MLC) and polymer liquid crystals (PLC). We might well be entering now into a similar period with PLC. Conventionally, PLC are considered to be made up of polymer chains in which mesogenic parts (compounds leading to products with LC properties) are grafted, constituting side chains or branches, or in which the mesogenic parts have been incorporated as rigid parts in a main chain, flexible or rigid.

From another point of view, PLC are a new dimension of technological processes by means of which standard manufacturing methods can lead to materials with special properties and various use varying in a large field. [Damian, C., 2003]

However, it is important to take into account not only the synthesis and purification of the compounds resulted, but also the process economy, if products are to be merchandized.

The PLC field is extremely large, from wires and highly resistant fibres, advanced composite materials, elastomers, membranes, thermoplastic or reinforcement materials to compounds with reversible data stock properties, materials used for capsulating medicine with controlled release in the body, etc.

Another important application area of PLC is that of materials with electro-optical properties. These materials are to be found in electronic displays, TVs, etc.

Another area which ensures the future of PLC is genetics. There are many samples of systems which show a similar structure and organization to that of PLC (cell membranes, viruses, etc.), a complete explanation of a mesophase behaviour leading to a better understanding of biological functions. Self-assembling phenomena specific to proteins and viruses have also got similar mechanisms to the ones in the LC system ordering. [Nicolae Hurduc, 1999].

These applications derive directly from the interesting properties of PLC, namely: low viscosity of melting (in the LC state), a high degree of orientation for macromolecular chain, a low degree of shrinkage during the cooling of the melting, mechanical resistance and high modulus (owed to the rigidity of polymer chains), low solubility in different solvents and water, low degree of thermal dilatation, feroelectrical properties, conductive properties, etc.

PLC show a long-range orientational order in one or two directions, thus being somewhere between crystalline and amorphous materials.

In order for a system to turn from a crystalline, ordered phase into a less ordered phase (liquid crystalline) there has to be an external energetical contribution, which can be purely thermal (thermotropic liquid crystals) or mixed, temperature/solvent (lyotropic liquid crystals).

To create a mesophase, a micromolecular or macromolecular compound needs to have rigid atomic groupings, so-called mesogenic groupings. Mesogenic groupings are usually made up of two or more aromatic nuclei, linked differently.

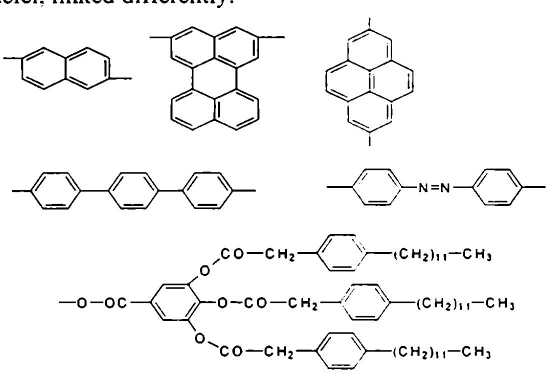

Fig.1: Samples of mesogenic groupings

Results and Discussion

Applications of LC in medicine

An interesting area where LC are present is that of temperature indicators. The way these operate is based on the LC property of interaction with light, according to the propeller pitch by which the mesogenic groupings are ordered.

As the propeller pitch depends on temperature, the colour of the chiral material will change once the temperature will. The chiral material is, usually, microcapsulated in order to avoid the action of environmental factors. To cover a larger temperature area, several mixtures of chiral LC can be used.

An important application of temperature indicators in medicine is the possibility of diagnosing skin cancer, the cancerigenic tissues having a higher temperature than the healthy ones.

Liquid crystal thermometers have a wider range of applicability: medical thermometers, battery testers, fibres which change their colour according to temperature, temperature indicators for children's food, etc. [Muşcutariu, I., 1981]

In medicine, skin thermography has been used since 1956, starting from Roy Lawson's [Lawson, R. M., 1956] notes, in Montreal, on a malignant tissue.

The possibility of using cholesterical LC in skin thermography derives from the special optical properties of the thin films of these mesophases.

Thus, the thin films of cholesterical LC quickly and directly present, by means of their colour, the temperature of the surface where they are put. The change of colour affects the whole visible spectrum from red to purple, if the surface temperature and, consequently, that of the LC changes or is somewhere in a certain value area.

Here are some examples of cholesterical LC applications in surface thermography and diagnosis: vascular diseases, cancer diagnosis, cerebro-vascular diseases, pharmacological tests (the introduction of chemicals in the blood circuit can determine allergic reactions of the skin owed to the histamine release, associated in time with the temperature rise), arthritis, dermatosis, skin grafting, orthopedy, etc.

Injection-moulded products

Liquid crystal polymer materials offer many advantages over conventional thermopastics in injection moulding, including low mould shrinkage, minimum warpage and distortion, fast cycle time, ability to mould thin parts, low moisture absorbtion, and excellent chemical resistance. The mechanical properties are comparable to those of materials filled with short glass fibres.

The important advantages are somewhat conterected, however, by the difficulty of controlling the orientation and anisotropy of the material and the low strenght of the weld lines.

LCP materials have shown excellent performance in surface mounted components. The applications require materials having high mechanical strengh and modulus, durability and toughness, chemical resistance, flame retardance, suitable coefficient of thermal expansion, dimensional stability and easy of processing.

LCP materials offer several advantages over metals and traditional thermoplastics for use in compact disc scanning heads.

A bakery pan for use in magnetic conveyor systems has been produced by injection-moulded LCP including integrated ferrous or magnetic material members [U. S. Patent, 1990].

Fibres

High performance polymeric fibres have the potential to revolutionize the use of composites and other fibre applications. Although the properties differ somewhat between different types of polymeric fibres, they have many positive qualities in common: low density, very high specific tensile properties, high toughness, good chemical resistance.

The unique properties of the lyotropic PLC fibres make them suitable for a number of applications. Generally available are Kevlar (Du Pont) and Twaron (Akzo), poly-(p-terephthalamide) (PPT) [Collyer, 1990].

PPT is used in ropes for helicopter winches, racing sheets, halyards, etc. where high specific modulus and tensile strength are required. Ribbon parachutes made from PPT have only half the weight of the corresponding polyamide design.

Fabrics made from PLC fibres are used as garments in helmets and military jackets. These types of helmets are said to be able to stop a flying bullet in a very short distance. Figure 2 shows the effect of a bullet on the material.

The excellent tear resistance and thermal insulations properties also make PPT suitable for gloves and clothings for hostile environments.

Some applications of PLC fibres are: protective fabrics (ballistic vests, gloves, clothing); strong fabrics (tarpaulins, conveyer belts); coated fabrics (inflatable boats, sails); industrial fibres (cables – oil rig mooring, ropes – marine use, filament wound pressure vessels, sails, sewing threads); rubber reinforcements (radial tyres – trucks, automobiles); belts (conveyor, power transmission); plastics reinforcement (space applications, aircraft-interior, aircraft-propeller, boats, canoes, kayaks, military-helmets, sporting goods); cement reinforcement (building materials, pipes); friction uses, asbestos replacement (brake linings, clutch facings, gaskets packing, etc.)

Fig.2: Twaron (Akzo) fabric panel after a shooting test with a 9-mm parabellum. Missile and deformed bullet nose are shown for comparison

The detection of atmosphere contaminations

The diffusion of impurities in a cholesterical LC influences the propeller pitch and the wave length of the reflected light colour. Fergasson [Fergasson, J. L., 1968] suggested for the first time the use of this effect as a means of detection of atmosphere contamination.

If the steams of different organic solvents in the polluted atmosphere come in contact with and diffuse in LC creating mixtures of different concentrations, they colour differently.

If the steams are dissolved in CLC the colour change is reversible when the solvent lowers through evaporations. When there is a reaction between the solvent and LC, the change of colour is permanent.

The sensitivity to impurities of LC layers is very high (10^{-6}). The method, however, raises some questions if the detection time prolongs and this is because CLC in contact with the air, even in the absence of polluted steams, can change chemically both through oxidation and reactions determined by solar radiations. [Kallard, T., 1970]

References

BROSTOW, W., Kunststoffe-German Plastics, 1988, 78, 411

COLLYER, A. A., Mater. Sci. Technol., 1990, 6, 981-992

DAMIAN, C., Influența spațiatorului asupra comportării termice a unor polimeri cu proprietăți de cristal lichid. - referat, Facultatea de Chimie, Universitatea „Al. I. Cuza", Iași, 2003

FERGASSON, J. L., Appl. Optics, 1968, 7, 1721

KALLARD, T., Liquid Crystals and Their Apllications, Optosonic Press, New York, 1970

LAWSON, R. M., Can. Med. Assoc. J., 1956, 75, 309

MUŞCUTARIU, I., Cristale lichide şi aplicații, Ed. Tehnică, București, 1981

NICOLAE HURDUC, DUMITRU PAVEL, Cristale lichide polimere, Ed. Junimea, 1999

U. S. PATENT 4922811, May 8, 1990. Bred pan fabricated of liquid crystal polymer

www.ipc.uni-stuttgart.de/~giesselm/AG_Giessel.., 2007