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From the Current Literature

LIQUID CRYSTALS IN DISPLAY DEVICES

A. A. GROSHEV and V. B. SERGEEV

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LIQUID crystals as substances possessing the properties of liquids (fluidity, drop formation) and a regular molecular structure (anisotropy of the dielectric, magnetic, electric properties etc.) have been known since the end of the 19th century[1]. The feasibility of practically employing liquid crystals in various branches of science and technology, which was uncovered in the last few years, has increased the interest in the study of the structure and properties of these high-molecular organic compounds, as manifest by the large number of published reports, international conferences[2], and the first scientific conference on liquid crystals in the USSR[3].

The liquid-crystal state is observed primarily in two classes of organic substances, aliphatic high-molecular monocarbon acids and their salts, and aromatic compounds. These substances are characterized by the presence of one or several benzene rings, the production of the mesophase becoming more favored with increasing number of these rings[4].

The existence of a mesophase between the solid and liquid state is usually observed in a definite temperature interval. With increasing temperature, the substance changes from the state of a solid crystal into the mesomorphic state, and then becomes an isotropic liquid. This transition is usually abrupt, can be repeated many times, and is reversible. The region of existence of the mesomorphic state of a substance depends on its chemical composition. Thus, for p-azoxynisole it is observed in the range 116–133°C.[5a] A substance with a temperature range from 11 to 41°C has by now been synthesized[6]. Liquid crystals with a temperature range from −32 to 100°C are reported in[7].

A distinguishing feature of the molecular structure of a liquid crystal is that the molecules are elongated, i.e., anisometry of the molecules, and this obviously predetermined their mutual arrangement. There are three types of liquid-crystal structure: smectic, cholestric, and nematic. The smectic crystals have a layered structure. The elongated molecules are arranged perpendicular to the surface of the layer. The cholesteric crystals are also layered, with the long axes of the molecules making an angle with the layer surface. The inclination angle of the molecules varies from layer to layer along a spiral whose axis is perpendicular to the layers. Nematic liquid crystals have no layered structure; they show only a parallel orientation of the molecules along the long axes, corresponding to the direction of the optical axis of the substance[8]. Only cholesteric and nematic liquid crystals are presently used in practice.

In the free state, the liquid crystals have low transparency, owing to the continuous variation of the refractive index over the volume of the material. Under the influence of an electric or magnetic field, or of solid surfaces on thin films of liquid crystals, it is possible to attain a definite orientation at which the liquid crystal becomes transparent.

Several electro-optical effects are observed in liquid crystals and are based on the variation of the optical properties under the influence of the electric field. These effects allow us to construct certain information display devices.

Dynamic scattering of light occurs when a thin layer of a nematic crystal, placed between two transparent electrodes coated on the internal surfaces of two glass plates, begins to scatter the incident light when an electric potential is applied. This is due to the motion of the liquid-crystal molecules, induced by the dissociating action of the passing ions. Ion production can also be attributed to the disintegration of neutral impurity molecules in the presence of an electric field or to Schottky emission[5a,b]. When the intensity of the electric field is changed from 0.5 to 5 V/μ, the liquid crystal changes color from transparent to milk-like white[9]. The light flux is attenuated by a factor 30–35 and the power consumption is 100 μW/cm^2[10,11]. The electric field corresponding to threshold excitation and saturation of various liquid crystals of different types is not constant and can take on values 0.7 and 2 V/μ, respectively. The time of excitation of the dynamic scattering process is inversely proportional to the current. The damping time is proportional to the square root of the resistivity and to square root of the liquid-crystal film thickness[12]. The time of excitation of the dynamic scattering is 1–10 msec, while the damping time is 10–30 msec for substances in which the mesophase exists from 60°C upward, and 10–100 and 300–1000 msec respectively for substances in which the mesophase exists at room temperature. There circuit-engineering solutions that make it possible to shorten appreciably the damping time of the process by suppressing the dynamic scattering electrically[5c,13].

In the second "host-guest" electric effect, on the basis of which it is possible to construct a colored display system, the molecules of the liquid crystal ("host") orient the molecules of a dichroic additive ("host"), the absorption spectrum of the latter being a function of their orientation relative to the polarization direction of the incident light[14a]. If there is no electric field, the rod-like polarized dye molecules are oriented by the nematic molecules and the incident white light is absorbed by definite sections of the spectrum, imparting to the panel the color characteristic of the dye. When an electric potential is applied, the nematic molecules become reoriented, dragging with them the dye molecules, as a result of which the light absorption becomes negligible and the panel becomes transparent[9].

The excitation time following the switching of the light is 1—5 msec, and the recovery time is 100 msec at a temperature higher than 45°C and an applied field 0.5 V/μ.

The image-memory effect, or the effect of optical storage, can be produced in a mixture of nematic and cholesteric liquid crystals. When an electric signal producing a field on the order of 3 V/μ is applied, optical scattering is produced by a thin mixture of these crystals. When the electric field is removed, this state is preserved for a long time without drawing additional energy. To return the substance to the initial state it suffices to apply an acoustic signal of approximate frequency 3 kHz and amplitude 5 V/μ and duration 30—500 msec[15].

The foregoing electro-optical effects will make it possible to develop a new generation of information display system with essentially new properties and highly effective technical characteristics. Among these characteristics are:

1) independence of the image contrast of the external illumination, since these devices are not sources of light but modulators of an arbitrary image-signal light flux;

2) possibility of reproducing the information in halftone;

3) presence of adjustable memory without power consumption;

4) images in color;

5) possibility of producing panels directly controlled by logic circuits without additional exciters, owing to the low power consumption and absence of high voltages[11];

6) high resolution, reaching 20 el/mm[16a];

7) planar construction, greatly decreasing the dimensions of the apparatus;

8) long service life, reaching 10 000 hours[17b];

9) low cost of initial materials and simple manufacturing technology.

Display devices using liquid crystals are constructed in the form of dia-projectors to operate in transmitted light or epi-projectors to operate in reflected light. They come in three main groups:

a) panels with fixed image formate;

b) matrix panels;

c) panels with continuous structure and controlled with an electric field.

Panels with fixed image format produce images in the form of mnemonic diagrams, letters, or numbers[18]. Matrix panels with rectangular rasters are intended to reproduce simple moving images in real time without using an intermediate carrier[5c,14b,17a]. Panels with continuous structure, controlled by an electric field, make it possible to produce images in which the dimensions, shapes, and positions of the elements can be varied. Such panels can be used for voltmeters without moving mechanical parts, null indicators, and traveling-beam panels[16b].

Further research on display devices is aimed at producing flat-screen television sets[19]. In addition to work on flat screens, research is carried out on color television screens with liquid crystals[20], and three-dimensional television panels[21].

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