EFFECTS OF AN ALTERNATING ELECTRIC FIELD ON THE TRANSPARENCY OF A THIN FIELD OF THE SMECTIC PHASE OF \( p \)-TYPE \( n \)-OCTYLMETHYLBENZOIC ACID

A. P. Kapustin, Z. Kh. Kuvatov, L. S. Mamaeva, and A. N. Trofimov

An experimental study was made of the transparency of the smectic phase of \( p \)-type \( n \)-octylhydroxybenzoic acid as a function of the intensity and frequency of an electric field. A significant thermal hysteresis was found: at a given temperature, the smectic phase obtained by heating from the solid crystalline state is less sensitive to the electric field than the phase produced by cooling from the isotropic liquid. The transparency changes are explained on the basis of the appearance, growth, and destruction of domain structure in the electric field.

The transparency of a liquid crystal film is closely related to structural features and the molecular ordering of the mesophase and to the effects which occur at the interface between the solid (glass) and the liquid crystal. By studying the transparency of substances which form liquid crystals and carrying out visual and optical observations, one can establish the phase-transition temperature \([1]\) and determine the effects of electric and magnetic fields on molecular orientation, domain formation, etc. \([2-5]\). Study of these topics is of considerable scientific and practical importance.

We report here an experimental study of the effect of an electric field of various frequencies and intensities on the transparency of a thin film of \( p \)-type \( n \)-octylhydroxybenzoic acid, \( \text{CH}_3(\text{CH}_2)_7-\text{C}_8\text{H}_4-\text{CO}_2\text{H} \).

EXPERIMENTAL METHOD

We studied the transparency of a liquid-crystal film on an apparatus based on an MF-2 microdensitometer, using transmitted natural light. The liquid crystals were placed between two flat glass plates coated with thin transparent conducting films. The plates were isolated from each other by mica spaces 0.05 mm thick and mounted in a special holder. An alternating electric field was applied to the plates from a sonic-frequency generator through a transformer; the light was transmitted parallel to the electric field.

The temperature in the chamber holding the sample could be adjusted to vary the sample temperature up to 200°C. The temperature was measured by a copper–constantan thermocouple within 1°C. An M-25/3 mirror galvanometer was used as a null indicator in a bridge circuit.

The relative change \( I/I_0 \) in the light intensity transmitted through the sample was measured by the MF-2 microdensitometer; here \( I \) is the light intensity at the given temperature and field; and \( I_0 \) is the intensity of the light which passes through the isotropic liquid phase of the sample at the experimental temperature; in operation with fields \( (T = \text{const}) \), it is the light intensity in the absence of a field.

Visual and optical observations and photomicroscopy of the samples by means of an MBI-6 microscope were used to inspect the sample in natural and polarized light.

TABLE 1.* Values of the Domain-Structure "Constant" when this Structure First Appears in the Smectic Phase Produced by Cooling (Second region, T = 105°C, sample thickness d = 0.05 mm)

<table>
<thead>
<tr>
<th>U, v</th>
<th>30</th>
<th>38</th>
<th>42</th>
<th>55</th>
<th>70</th>
<th>80</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>f, Hz</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>300</td>
<td>400</td>
<td>500</td>
<td>840</td>
</tr>
<tr>
<td>L,μ</td>
<td>11</td>
<td>9.0</td>
<td>8.0</td>
<td>7.0</td>
<td>6.5</td>
<td>5.5</td>
<td>5.0</td>
</tr>
</tbody>
</table>

*The domain-structure "constant" is the overall width of a domain, including its boundary.

RESULTS

1. Determination of the Phase-Transition Points

It has been shown that p-type n-octylhydroxybenzoic acid forms smectic and nematic phases [6]. A transparency method [1] was used to determine the temperature ranges in which these phases exist; these transparency measurements were carried out during both heating and cooling of the sample. From Fig. 1 we see that the temperature dependences of the transparency corresponding to the different ranges differ only quantitatively, not in shape. This result is probably due to the thermal hysteresis and structural differences of the liquid crystal phases corresponding to the same temperature.

From these curves and from visual and optical observations we determined the following transition points: 99°C for SC = SLC, 108°C for SLC = NLC, and 148°C for NLC = IL. A sharp change in the sample transparency occurs at each transition point. The decrease in curve 1 at 71°C corresponds to a polymorphic transition in the solid crystalline phase. Microscopic observations clearly revealed a restructuring of the texture near this point.

2. Effect of an Electric Field on the Transparency

Because of the thermal hysteresis, the liquid crystals may be in different states at a given temperature, depending on the conditions under which the mesophase was formed. We therefore studied the effect of an alternating electric field on the transparency of the smectic phase (T = 105°C) of the substance produced by heating from the solid crystalline state and that produced by cooling from the isotropic liquid.

Figure 2 shows the experimental dependences of the transparency on the frequency of the electric field. Comparison of the corresponding curves shows that the smectic phase produced by cooling is more sensitive to changes in the intensity and frequency of the electric field than is the phase produced by heating.

The behavior of the transparency as a function of the electric field can be explained qualitatively on the basis of the visual and optical observations.

In polarized light, a fresh solid crystalline sample appears to be a polycrystalline substance consisting of a large number of regions — grains — differing in molecular orientation. The grain boundaries are highly nonuniform and are generally preserved in the smectic phase as well as in the solid phase during recrystallization. By carrying out recrystallization in an electric field, one can cause the grains to coalesce, thereby obtaining smectic samples consisting of several large regions within which the optic axes of the molecules are predominantly parallel.

In the smectic phase an electric field of a certain intensity and frequency produces a domain structure consisting of long, narrow domains running parallel to each other (Fig. 3). The molecular dipole moments in neighboring domains are antiparallel [4].

The transparency changes are closely related to the appearance, growth, and disappearance of domains in the electric field and to other phenomena which accompany these changes.

If we choose the intensity and frequency of the electric field as variable parameters characterizing the state of the liquid-crystal sample, we can arbitrarily distinguish several regions on the U, f "state diagram" on the basis of the visual and optical observations.

For the sample produced by cooling we can distinguish five regions (Fig. 4).