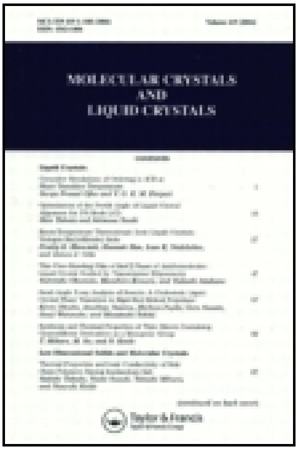

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Electro-Optic Properties of Nematic Liquid Crystal Aligned by Photo-Oriented Films

Boris A. Umanskii [a], Galina N. Dorojkina [a], Nikolai V. Novoseletskii [a] & Sofia I. Torgova [a]

[a] SSC RF "NIOPIK" (Organic Intermediates & Dyes Institute), B. Sadovaya 1/4, Moscow, 103787, Russia

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Electro-Optic Properties of Nematic Liquid Crystal Aligned by Photo-Oriented Films

BORIS A. UMANSKII, GALINA N. DOROJKINA,
NIKOLAI V. NOVOSELETSKII and SOFIA I. TORGOVA

SSC RF "NIOPIK" (Organic Intermediates & Dyes Institute), B. Sadovaya 1/4, Moscow 103787, Russia

In this work we investigated the electro-optic properties of nematic liquid crystals (NLC) aligned by photo-oriented azo-dye films. We found that the response times depend on the terms of orienting film preparation. We have measured the electro-optic characteristics of LC cells with twist orientation, obtained by photo-processed orienting films. We have found that the photo-oriented films prepared with the azo-dyes investigated are thermostable.

Keywords: nematic liquid crystals; azo-dyes; photo-alignment

INTRODUCTION

In order to produce liquid crystal displays (LCDs), it is necessary to obtain the unidirectional LC alignment on the glass plates covered with transparent indium-tin oxide (ITO) electrodes. Such alignment is usually produced by surface rubbing technique of the polymer LC aligning layers. This method, however, gives several problems such as generation of dust particles and electrostatic charges. To resolve these problems rubbing-free techniques are preferable.

The LC alignment obtained by using a linearly polarized UV light exposure, i.e. LC photo-alignment, is one of the most favorable candidates to overcome the problem mentioned above [1-3].

One type of photo-alignment materials is based on photo-isomerization of azo-containing chromophore. Such materials could be individual azo-dyes, polymers with azo-dye moieties and azo-dyes dispersed in polymer matrix. In this work we have deal only with azo-dye and polymer - azo dye mixtures.

In our previous works we had investigated different conjugated and non-conjugated azo-dyes as an orienting agent [4] and we have shown that the type and the quality of the alignment by photo-oriented layers as well as the value of pretilt angle depend on the type and terms of the treatment of the orienting layers [5]. We have also shown that hydrogen bonding plays a very important role in the orienting processes of LC cells. Due to this reason some aprotonic solvents used for spin-coating of individual dyes give only homeotropic LC alignment. We have quantitatively estimated the planar and tilted alignments of NLCs in terms of the degree of orientation S' [6]. We determined, that the dependence of the aligning capability of the photo-oriented layers on the light exposure time was non-linear. Even small anisotropy of the orienting layers gives uniform planar and inclined nematic LC alignment.

In order to get LC orientation with pretilt angle we used "double illumination" method [7]. The films were irradiated with a polarized light beam directed normally to the plate and with non-polarized light at 45° with respect to the glass plates. We have shown that exposition of individual azo-dye to non-polarized light leads to deterioration of orientation homogeneity. While, for the azo-dye - polymer composition the orientation homogeneity was preserved.

We have obtained the homogeneous alignment with different pretilt angles by varying the exposure time of the layers to non-polarized light.

The aim of our work was to investigate the electro-optic characteristics of the LC cells built up with glass plates processed by the photo-alignment method.

EXPERIMENTAL

Materials

The chemical structures of the materials: azo-dyes, solvents and polymers used in our experiments were reported in our previous works [4-6]. As a nematic liquid crystal material were used ZKhM-1630 with positive dielectric anisotropy ($\varepsilon_a = +8.4$) and clearing point ($T_{NI} = 80°C$). This LC material is commercial production of NIOPIK.

The order of the orientation in the uniaxial phases may be evaluated from the polarized absorption, when LC is doped by dichroic dye (DD). KD-184 (λ_{max} =530 nm) was used as a dichroic dye. This DD is commercial production of NIOPIK as well.

Preparation of photo-aligning films and LC cells

Thin films of azo-dyes were prepared on the glass plates with ITO electrode by spin-coating of azo-dye solution in different solvents and curing at 180°C for 1 hour.

After that the films were irradiated with linearly polarized UV light beam directed normally to the plate and then with non-polarized light beam directed at 45° with respect to the plate. The samples were exposed to a constant light intensity. The light intensity was 60 mW/cm^2 for polarized light and 160 mW/cm^2 for non-polarized one. The irradiation time for polarized light was 15 min, and from 10 to 120 s for non-polarized light. We used 1000 W super-high pressure mercury lamp as UV light source. Glan prism was used for getting of the polarized light.

The twist nematic (TN) cells were prepared by assembling of two photo-processed glass plates with the direction of light polarization which are perpendicular to each other. Then, after assembling, the TN cells were filled with ZhKM-1630 by capillary method. The cell thickness was about 8 μm.

Measurements

The pretilt angle of the planar cells was measured by the crystal rotation method [8-10].

Electro-optical properties were measured using a He-Ne laser (632.8nm, 1mW) and silicon photodiode. The laser beam was passed through the LC cells normally to the glass plates. The LC cells were driven by a sinusoidal voltage (1 kHz). The intensities of the transmitted light through the sample were measured and recorded as a function of the applied voltage on a XY-recorder. For response time measurements the photo-detector signal fed the input channel of a storage oscilloscope.

RESULTS AND DISSCUSSION

The transmission vs voltage (T-V) curves measured for TN cells with rubbed conventional polyamic acid (PA) films (1) and with photo-processed azo-dye films (2,3) with pretilt angle 6° and 0° respectively are shown in Figure. As it seen from Figure, T-V curves for these LC cells do not differ a lot, and the threshold voltage for photo-oriented cells is higher than for rubbed cell.

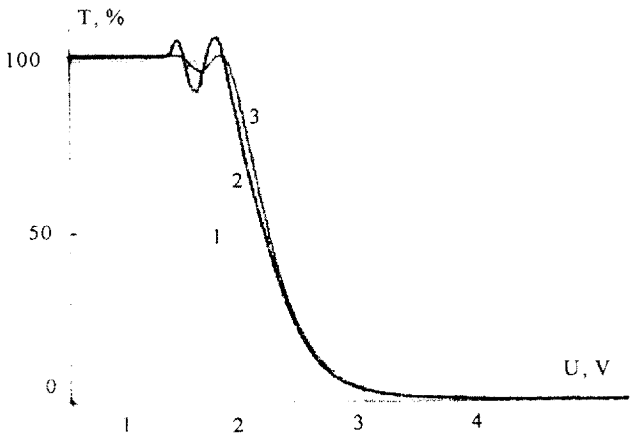

Figure. The dependence of TN cells transmittance T on applied voltage U: 1 – cell with rubbed PA films; 2, 3 – cells with photo-oriented films with pretilt angle 6° and 0° respectively.

The response times for TN cells with different pretilt angles generated by photo-oriented azo-dye films and with rubbed polyamic acid film represent in Table.

Table. The dependence of response times on the type of orienting films and on the pretilt angle.

Orienting films	Photo-oriented azo-dye films					Rubbed PA
Pretilt angle,	0°	2.0°	3.5°	4.8°	6.0°	3.0°
τ_R, ms	24	24	22	22	18	16
τ_o, ms	26	21	18	18	22	11
τ_{on}, ms	50	45	40	40	40	27

In this Table: τ_R – rise time; τ_o – delay time; and $\tau_{on} = \tau_o + \tau_R$ – turn-on time.

From table it is evident, that rise times for LC cells with photo-oriented azo-dye films are higher than for cell with rubbed PA. It can be caused by rather high conductivity of photo-alignment cells and can lead to so called "image sticking" phenomena.

In order to investigate the thermostability of photo-oriented films, the following examinations were carried out:

1. The empty LC cells were annealing at 220 °C during 6 hours;
2. The LC cells filled with LC material were annealing at the temperature which was above the clearing point by 10 °C during 6 hours.

After that the electro-optic characteristics of LC cells under test were measured at room temperature. They haven't change. The main parameters of these films, such as optical anisotropy, pretilt angle and degree of ordering practically have not changed with decreasing the temperature to 220°C. So the thermostability of these LC cells turned out rather high.

CONCLUSION

It was revealed that LC cells with photo-processed azo-dye films have almost the same parameters as LC cells with rubbed PA films. However, the rise times and threshold voltage for these LC cells are slightly worth than for cell with rubbed PA substrates which stipulated by high conductivity of azo-dye layers. Nevertheless, we believe, that azo-dye orienting films have a good perspective for practical application due to their excellent photo-alignment ability and high thermostability.

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