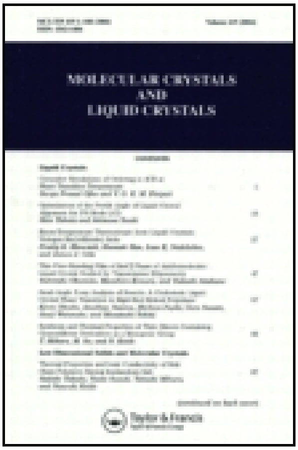

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Alignment of Nematic Liquid Crystals by Photo-oriented Layers

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Alignment of Nematic Liquid Crystals by Photo-oriented Layers

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In the present work the optical anisotropy of various azodyes used as orienting layers for liquid crystals (LC) was investigated. The anisotropy was induced by linearly polarised light. It was experimentally shown that the orientation by photo-oriented layers is in some cases better than the one obtained by routine rubbing. The dyes investigated were either introduced into polymer films or used as single substances. It was shown that the value of pretilt angle depends on various factors but mainly on the nature and the treatment of the orienting layers. Angles from 0 up to 7° were obtained. The value of the angle can be imposed by the proper choice of the film-preparation process.

Keywords: alignment; photoorientation; liquid crystal; anisotropic layers

INTRODUCTION

The problem of obtaining planar alignment of nematic liquid crystals (LC) with the use of thin photo-oriented layers (PL) was under study during the last years[1,2,3]. Recently this problem was extended to obtain various pretilt angles. This problem is of urgent importance for multidomain screen design. The azodyes layers are known to be the promising materials for application[5,6].

In this work we study the properties and orienting capabilities of the photoinduced anisotropic layers for inclined LC alignment. It should be stressed that there are two aspects of this problem: the homogeneity of the orientation of nematic LC molecules and the definite value of the pretilt angle of LC in the bulk. To obtain the desirable alignment of orienting layers one needs to choose the molecular design of azodye and the proper treatment of these layers.

In the present work, several conjugated and nonconjugated azodyes were studied (Fig. 1). The investigated substances were either introduced into polymer-polyamide acid (PAA) (composition layers) or used as single compounds.

We used the well known method[7] for the photo-oriented layer preparation: thin layers were exposed to polarised (first stage) and nonpolarised (second stage) light.

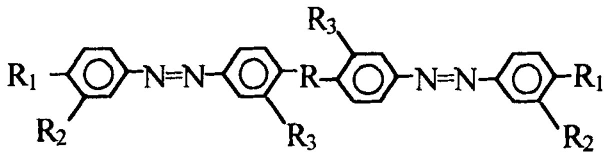
The main goals of the present work were:

- to examine the alignment capability of the anisotropic layers
- to obtain and to estimate the nematic LC pretilt angles induced by these layers.

EXPERIMENTAL

The azodyes of 1 and 2 series were used as materials for preparation of photooriented layers.

Series 1



Series 2

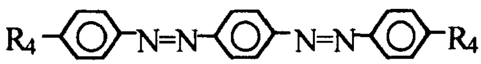


TABLE 1 Structures of investigated dyes

N	R	R_1	R_2	R_3	R_4
I	-	-OH	-COONa	$-SO_3Na$	-
II	-CHCH-	$-OC_2H_5$	H	SO_3Na	-
III	-S-	$-OC_2H_5$	H	SO_3Na	-
IV	-	-	-	-	OH

Thin (100 - 150 nm) layers of single azodye or polymer - azodye compositions were prepared by deposing 1- 2% solutions of azodyes and polymer-azodye compositions in DMF on a glass plate with ITO by means of spin-coating. The layers were dried at 80°C for 15 min. Two glass plates prepared in such manner were assembled as the LC cell with a gap of 15 μm.

In order to orient the layers the empty cell was exposed to 250 W high- pressure mercury lamp radiation. The Glan prism was used to obtain a specific light polarisation. We found that the optimal exposure time for photo-oriented layers preparation was 15 min at 20-30 mW/cm^2 light intensity (for polarised light). The exposure time for nonpolarised light was 0 - 120 sec. The cell was filled with LC by capillarity.

The commercially available nematic liquid crystals ZhKM-1630 and ZhKM-3141 (produced by SSC RF NIOPIK) were used.

For the estimation of the quality of LC alignment and orienting capability of photo-oriented layers we calculated the degree of orientation $S' = (A_{II}-A_{\perp})/(A_{II}+2A_{\perp})$, where A_{II} and $A_{\perp}$ are the absorbences for linear polarised light with the polarisation parallel and perpendicular to the LC director or to the preferable orientation of the long axes of azodye molecules in the photo-oriented layers. A_{II} and $A_{\perp}$ were measured with the help of a UV - VIS spectrophotometer "Specord-M40" equipped with neutral polarizers. In order to measure S', the nematic LC was doped with the special spectral mark, namely: the dichroic dye KD-184 (produced by SSC RF NIOPIK). The mark was dissolved in the nematic LC with a concentration of 0.2% (wt). The absorption spectrum of this mark differs from that of the orienting materials. The absorbance of layers (at λ_{max} =390 - 400 nm) and of the mark (λ_{max} =530 nm) was measured.

The pretilt angles were measured using the crystal rotation method[8].

RESULTS AND DISCUSSION

On the first stage of the experiment the photosensitive layers were exposed to polarised light. In Fig. 1 the dependence of A_{II}, $A_{\perp}$, ΔA ($\Delta A = A_{II} - A_{\perp}$) and S' on the exposure time of the polarised light for dye II - polymer composition is shown.

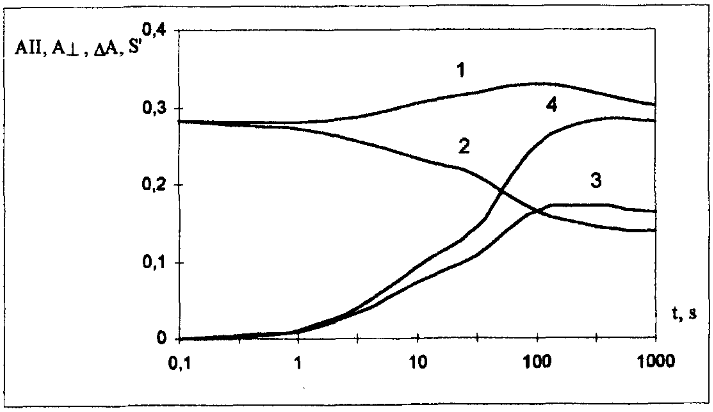


FIGURE 1. The dependence of absorbance $A_{II}(1)$, $A_{\perp}(2)$, $\Delta A = A_{II} - A_{\perp}$ (3) and the degree of orientation of oriented layer S'(4) on the exposure time (t) for the azodye II - polymer composition.

The maximum value of ΔA was achieved for exposure time 5 minutes. Further irradiation reduces ΔA. We suppose that this was caused by partial photodegradation of azodye II. Nevertheless, in this case the best alignment of nematic LC was obtained by the use of photo-oriented layers which were irradiated during 15 minutes.

In Table 2 the dependence of S' of the photo-oriented layers and LC on the nature of the orienting layers is presented. For the preparation of orienting layers we used both single dyes and polymer - dyes compositions. The optimal ratio between polymer (PAA) and dye was 1:1. This ratio was chosen after a preliminary study of the pretilt angle dependence on the dye concentration.

TABLE 2 Degree of orientation of photo-oriented layers and of nematic LC.

Composition of Orienting film	Degree of orientation		
	Photooriented layers	ZhKM-1630	ZhKM-3141
100% I	0.28	0.84	0.65
50% I + 50% PAA	0.17	0.76	0.68
100% II	0.1	-	-
50% II + 50% PAA	0.15	0.76	0.65
100% III	0.009	-	-
50% III + 50% PAA	0.01	0.71	0.61
100% IV	0.01	-	-
Rubbed polyimide film	-	0.76	-

It is evident from Table 2 that in case of dye I and II (good orientation) the polymeric matrix plays a smoothing role. In the case of weak orientation (dye III) the influence of polymer matrix is practically absent. Moreover even weak oriented layers lead to high degree of orientation of the LC.

The dye IV was only partially dissolved in LC and cannot be used as an orienting agent. Nevertheless, we believe it is a promising one because this molecule has a very long chain of conjugation. Its modification to the insoluble form and further application seems to be very interesting. We have chosen I, II and III azodyes for our experiments.

It was found that both, the degree of ordering S' and pretilt angle θ depend on the exposure time of the layers to nonpolarised light.

In Fig. 2 the dependences of S' of the nematic LCs and the photo-oriented layers as well as the pretilt angles θ on the exposure time for ZhKM-1630 and ZhKM-3141 are shown.

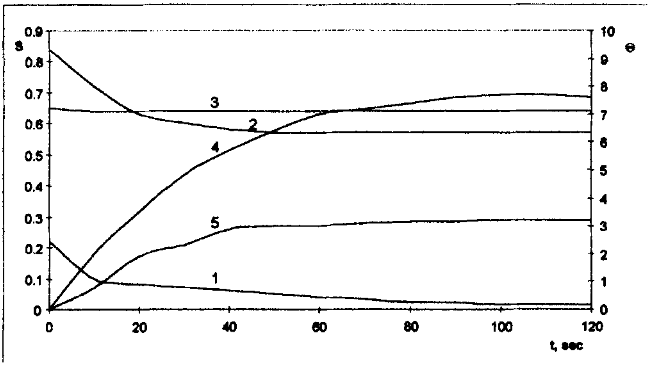


FIGURE 2. Dependence of S'_{PL}(I), S'_{LC} (2-ZhKM-1630, 3 - ZhKM-3141), pretilt angle θ (4 - ZhKM-1630, 5 - ZhKM-3141) on the exposure time (nonpolarised light). Azo-dye I.

One can see that exposure time exert different influence on the degree of ordering S'_{LC} and pretilt angles θ for ZhKM-1630 and ZhKM-3141. In the case of ZhKM-1630 (Fig. 2) the pretilt angle increases, while the degree of orientation decreases with increase of the exposure time. Moreover ZhKM-1630 has the pretilt angles two times more than ZhKM-3141, and the letter possesses the lower orientation capability. This can be explained by the different molecular interactions of these LCs with the orienting layers.

In the case of composite layers the result was opposite (Fig. 3). ZhKM-3141 had two times more pretilt angles than ZhKM-1630. In both cases (for single azo-dye layers and composite ones) the pretilt angle had increased to a certain value and remained unchanged under further irradiation. The degree of orientation of nematic LC remained constant. Similar results were obtained in the case of ZhKM-1630 aligned by azodyes I, III - polymer composition, but the pretilt angle was practically near zero.

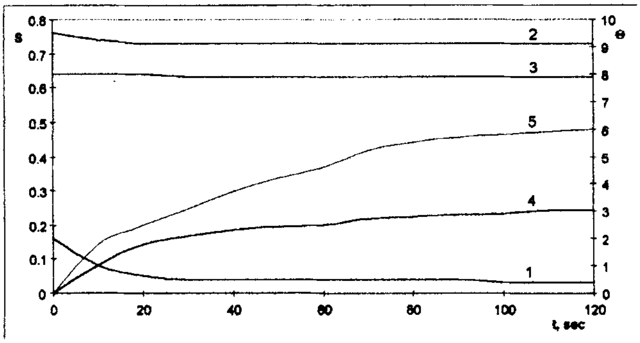


FIGURE 3. Dependence of S'_{PL} (1), S'_{LC} (2 - ZhKM-1630, 3 - ZhKM-3141), and pretilt angle θ (4 - ZhKM-1630, 5 - ZhKM-3141) on the exposure time (nonpolarised light). Azo-dye II-polymer composition.

It is necessary to underline the dual influence of the polymer matrix on the quality and on the type of nematic LC alignment. Comparing the nematic LC orientation induced by single dye layers (I - II) with the one induced by polymer composite layers (Fig. 2-3, Table. 2) it is evident that in the case of planar orientation:

1) composition on the base of dye I has lower aligning capability than single dye I;

2) composition on the base of dye II has higher aligning capability than single dye II.

3) both of these compositions have the same aligning capabilities.

The influence of polymer matrix on the nematic LC orientation and pretilt angle formation will be the subject of further study. We can expect that the various azodyes – polymers compositions would allow us to obtain the required nematic LC alignment.

CONCLUSIONS

1. The planar and tilted alignments of nematic LCs have been estimated in terms of the degree of orientation S'.
2. It was determined, that the dependence of the orienting capability of the photo-oriented layers on the light exposure time was non-linear. Even small anisotropy of the orienting layers gives the uniform planar and inclined nematic LC alignment.
3. It was found, that the exposure of the photo-oriented layers to nonpolarised light causes the appearance of pretilt angles. In the case of single azodyes it led also to deterioration of orientation homogeneity. For the azodye - polymer composition the orientation homogeneity was not changed.
4. It was found a dual influence of the polymer matrix on the quality and on the type of nematic LC alignment.

Acknowledgments

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