Photoalignment Properties of Brilliant Yellow Dye

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ABSTRACT

Photoalignment properties of commercially available Brilliant Yellow (BY) diazo dye are investigated. By using ozone pre-cleaning procedure we succeeded in deposition of highly uniform BY films on different kinds of inorganic and organic substrates used in LCD manufacturing. Excellent photoalignment of nematic, smectic ferroelectric and reactive liquid crystals (LC) on BY films is observed. This alignment shows extraordinary high photo-and thermal stability. The distinguished alignment properties of this dye extend the field of the sulfuric azo dyes effective for photoalignment.

1. INTRODUCTION

The alignment of liquid crystal (LC) molecules is an important research/development subject, because it is a key process in fabrication of LC displays and devices. Right from the beginning polyimide (PI) rubbing technique has been routinely used to align liquid crystals. It produces quite reliable alignment commonly acceptable for state-of-the-art devices. However, it can not satisfy strong demands of advanced technology. A principal drawback of this procedure is mechanical contact with the aligning substrate, which may destroy alignment layer and surface electronics. Besides, it causes surface charging and dusting. The LC alignment produced by rubbing is not perfectly uniform, especially on microscopic level. Because of this, alignment methods avoiding mechanical contact with the aligning substrates are being actively studied. Among the most promising candidates for future industry is photoalignment. This technique excels in high uniformity, wide-range and smooth variation of the parameters of LC alignment.

The phenomenon of liquid crystal photoalignment became a subject of extensive research after the effect was discovered for the azobenzene units attached to a substrate [1] and dispersed in a polymer matrix [2]. Since then, huge variety of alignment materials has been developed [3]. Nevertheless, azo dye materials remain among the best candidates for technological application. The sulfuric azo dyes show the best promise. Earlier we discussed extraordinary good photoalignment properties of the sulfuric disazo dye SD-1 (Fig. 1a) [4-7]. It possesses nice film forming properties and high photosensitivity. The SD-1 films provide alignment characterized by strong anchoring, high thermal and photostability, excellent electrooptic performance. As we show in the present paper, similar characteristics demonstrate commercially available dye Brilliant Yellow (BY) having substantially different structure. This implies that the field of highly effective sulfuric azo dyes is broader than we conceived.

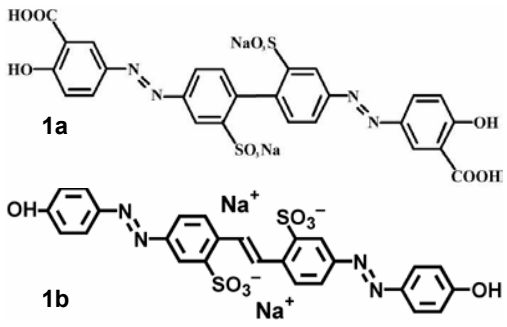

Fig 1 Chemical structure of bisazo dye SD-1 (1a) and BY (1b)

The alignment properties of BY have been first discussed in [8, 9]. The authors realized good alignment of nematic LC on BY films deposited on polyvinyl alcohol layers. At the same time, they faced difficulties in transferring this alignment to bare glass substrates. In our studies this problem was solved by proper treatment of the substrates and solvent optimization. In fact, we applied procedure earlier optimized for SD-1 dye. By using ozone treatment we succeeded in obtaining uniform BY films on a big number of substrates used in LCD devices (glass, ITO/glass, silicon

wafers, plastic films). The best films were obtained by using DMF to dissolve BY.

2. EXPERIMENTAL

The chemical structure and UV/Vis absorption spectrum of BY and also SD-1 are presented, correspondingly, in Fig. 1 and Fig. 2. Because of additional double bond (C=C bond in the molecular core), BY molecule possess stronger π conjugation than SD-1 molecule that results in batochromic shift of the spectrum.

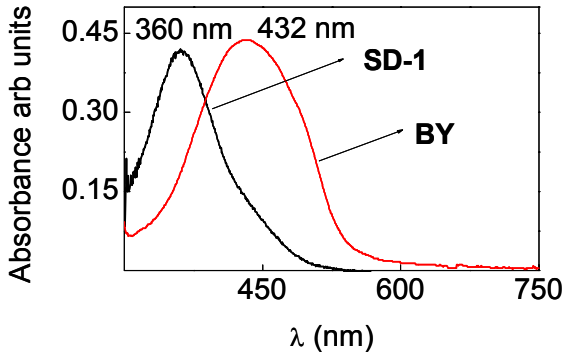

Fig 2 The UV-Vis absorption spectra of BY and SD-1 in the films, showing the absorption maxima at 432 nm and 360 nm, respectively.

To prepare alignment films, BY material was dissolved in DMF solution with fixed concentration of 1 % by weight. The solution was spin coated at 800 rpm for 10 seconds and then at 1500 rpm for 40 seconds onto substrates preliminary treated for 20 min with the ozone plasma in UVO-cleaning machine. Subsequently, the films were dried at 90°C for 30 min. On the following stage, the films were irradiated with a polarized UV light from the high pressure mercury lamp. The light intensity in the films position was about 3mW/cm^2. Alternatively, the films were shined with the Ar laser light (λ=457 nm) with intensity 20 mW/cm^2. The parallel and 90° TN cells were prepared and filled with liquid crystals designed for different LCD modes. The cell gap was varied between 5 and 18 μm.

3. ALIGNMENT RESULTS

3.1. Nematic mixtures

Figure 3 shows the macroscopic photographs of the parallel cell filled with different nematic LC mixtures. One can see excellent alignment in all cells. Figure 4 shows that alignment quality of TN cells is good too. The azimuthal anchoring coefficient W_a determined by measuring deviation angle in TN cell filled with LC E7 is about 3 x10^{-2} erg/cm^2. The TN cells were used to test alignment photostability. In these tests the filled LC cells were partially irradiated with unpolarized UV light (8mW/cm^2 for 1 hour). We have not detected difference in alignment quality and twist angle for the irradiated and non-irradiated parts. The cells endure heating to 150° for 1 hour that also suggests good thermal stability of LC alignment.

Figure 5 shows alignment in case of photoalignment processing with Ar laser light. One can see that alignment quality is equal to that which was observed for the substrates processed by UV light (Fig. 3).

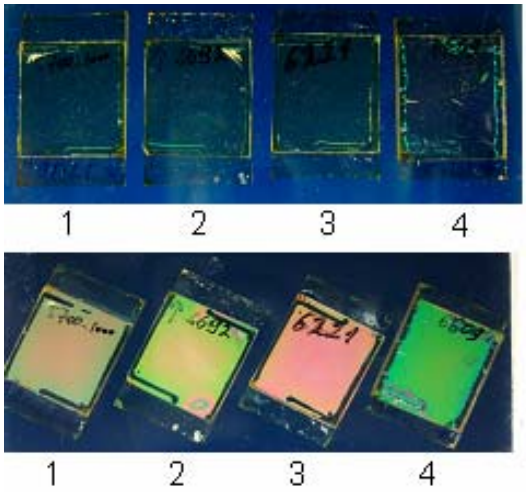

Fig 3 Photographs of the symmetric cells based on BY alignment layers and filled with different nematic liquid crystals: STN LC ZLI 5700-100 (1), IPS LC MLC 6692 (2), AM TN LC MLC 6221-000 (3), VA LC MLC 6609 (4). The easy axis of LC forms angle 0° and 45° with polarizer in upper and lower row, respectively. Cell gap is 18 μm.

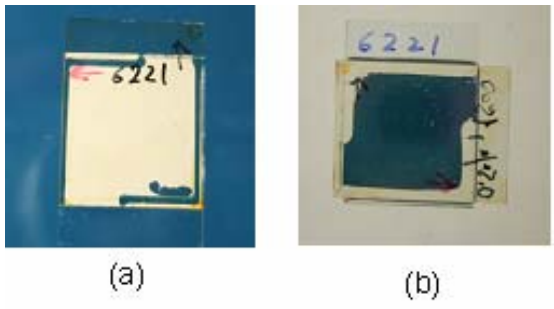

Fig 4 Photograph of TN cell filled with LC E7 viewed between two polarizers. (a) – polarizers are crossed; (b) – polarizers are parallel. Cell gap is 5 μm.

3.2. FLC mixtures

The alignment tests were also carried out for ferroelectric LC. In these tests we used FLC mixture FLC-510 developed in Lebedev Physical Institute of the Russian Academy of Sciences. As it is evident from Figure 6, BY photoalignment films provide extremely uniform alignment of this mixture. The microscopic uniformity is also good (Fig. 7). Besides, this cell exhibits excellent electrooptic performance. The alignment quality even improves after the field treatment. The anchoring energy obtained from hysteresis curve was about 0.185 erg/cm^2. This is slightly better than for the cells based on SD-1 alignment films.

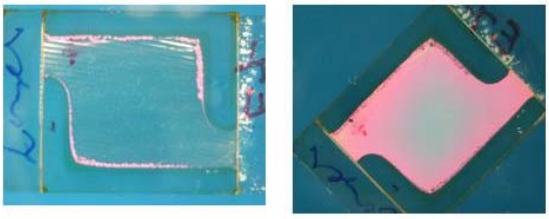

Fig 5 Photographs of the symmetric cells filled with room temperature nematic liquid crystal E7 aligned using BY photoalignment layer irradiated by polarized Ar laser light (λ=457 nm, 20 mW/cm^2, 30 min). The induced easy axis forms angle 0^o (a) and 45^o (b) with polarizer. Cell gap is 18 μm.

Fig 6 The photographs of the symmetric cells filled with ferroelectric liquid crystal FLC-510 viewed between pair of crossed polarizers. The BY photoalignment layers are cured with polarized UV light (3mW/cm^2 (365 nm), 30 min).

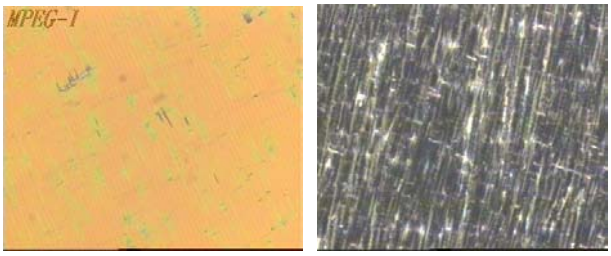

Fig 7 The microphotographs of the FLC cell presented in Fig. 6. Pictures (a) and (b) corresponds to bright and dark state, respectively. After field application alignment uniformity even improves.

3.3. Mixtures of reactive mesogens

Last years saw enhanced interest to liquid crystalline materials capable to polymerize under light or heating. These materials are called reactive mesogens (RM) or polymerizable LCs. Aligned in liquid crystalline state, films of these materials transform to solid anisotropic films after polymerization. Such the films are extensively studied as passive optical elements and surface electronic devices. The alignment of these materials set special requirements. Earlier we established that SD-1 photoalignment films can be effectively used for this purpose [6]. Figure 8 shows that films of BY also demonstrate high alignment ability with regard to reactive mesogens. They yield RM alignment of high uniformity, which can be easily patterned.

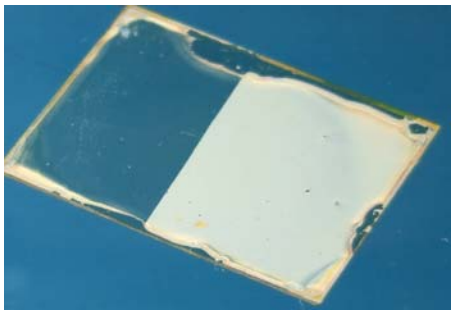

Fig 8 The photograph of the film of planar RM RMM256C from Merck deposited on isotropic plastic strip containing BY photoalignment layer. Cell is viewed between crossed polarizers. Optic axis in the right and left film's domains forms, respectively, angle 0^o and 45^o with polarizer.

4. ALIGNMENT MECHANISMS

BY is suitable compound for studying photoalignment processes in azo dyes, because its absorption maximum is located between several conventional emission lines. The alignment and photoalignment peculiarities of BY molecules will be extensively discussed in the forthcoming paper. Now, we just briefly mention main results. Irradiation of BY films with polarized light causes orientational ordering of dye molecules. This orientation is not based on *trans-cis* isomerization as in azopolymer films [10]. This photochemical

process is suppressed, presumably because of dense molecular packing and so lack of free volume for conformational change. The relaxation of excitation energy of BY molecule is realized through rotationally oscillatory levels without involvement of conformational changes. In case of 365 nm polarized excitation, BY molecules prefer out-of-plane reorientation, while in case of 457 nm excitation clear in-plane reorientation is observed. This suggests that out-of-plane reorientation requires higher energy (by analogy with LC anchoring energy). The strong aggregation processes in BY films are observed. J aggregation dominates in thin films, while H aggregation predominates over J aggregation in thicker films. The H aggregation hinders photoordering process and, as result, weakens LC anchoring with the film thickness increase.

5. CONCLUSION

In summary, Brilliant Yellow provides excellent photoalignment for different kinds of liquid crystals. Taking this into account, as well as high photo- and thermal stability of the induced alignment, one can offer this dye for various display applications. The example of BY shows that the field of highly effective photoalignment azo dyes is much broader that it was earlier conceived. This gives more freedom for the further optimization of photoaligning azodyes.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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