P-128: Orientation of a Reactive Mesogen on Photosensitive Surface

Yuriy Kurioz, Oleksandr Buluy, and Yuriy Reznikov
Institute of Physics, National Academy of Science, pr. Nauki 46, 03028 Kyiv, Ukraine

Igor Gerus
Institute of Bioorganic Chemistry and Petrochemistry, 1 Murmans'ka Str., Kyiv, 02094 Ukraine

Richard Harding
Merck Chemicals Ltd, LC Chilworth Technical Centre, Southampton, United Kingdom, SO16 7QD

Abstract:

Reactive mesogens (RMs) are polymerisable liquid crystals that can be formed through the process of in-situ photopolymerisation into thin birefringent films. These films have found applications as optical films (retarders) in the flat panel display industry. Application of the birefringent films requires homogeneous orientation of the optical axis over the film's surface. We report high quality fast photoalignment of reactive mesogens on surfaces of cellulose-cinnamate polymers. Unique photosensitivity of cellulose-cinnamates and high quality photo-orientation of reactive mesogenes on these polymers allow cellulose-cinnamates to be considered as promising materials for producing thin birefringent polymer films by roll-to-roll technology.

1. Introduction

Optical compensating birefringence films are one of the crucial parts of modern LCDs. Application of these films provides high-quality true colour images on a display over a wide viewing angle. Polymer liquid crystals are ones of the most promising optical films extensively used to improve the viewing angle of LCD's. These can be prepared from discotic or calamitic polymerisable liquid crystalline materials via the process of in-situ photopolymerisation of a LC monomer. Recently Merck has reported on development of mixtures of reactive mesogens that can be used to produce optical films with a variety of optical properties [1-2]. Examples of the variety of films that can be produced with these mixtures are shown in Figure 1 [2].

Application of the birefringent RM-films requires homogeneous

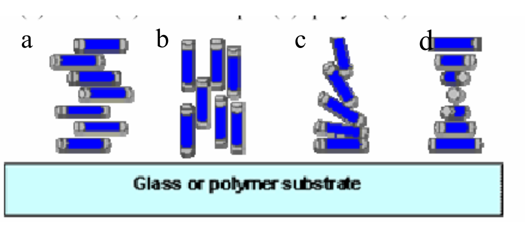

Figure 1. Examples of different reactive mesogen film molecular distributions possible in aligned thin LC layers. These are termed: (a) planar (homogeneous) alignment, (b) homeotropic (c) splayed and (d) cholesteric.

orientation of the optical axis over the film's surface. Usually the RM-films are coated on a polymer substrate and overall alignment of the optical axis in the film is determined by the boundary conditions on the polymer substrate and on the air-RM interface. Producing good alignment on the air-RM interface is achieved by a careful selection of reactive mesogens molecular structure as well as an inclusion of a suitable surfactant. As concern to the alignment of RM on the substrate surface, homogeneous orientation is achieved by using traditional rubbing technique using polyimide layers. Despite a good alignment provided by the rubbing technique, this technology is difficult to apply for roll-to-roll fabrication of RM-films on polymer substrates due to low thermal stability of many polymer substrates.

Photoalignment technology which has been successfully used for orientation of low-molecular weight LCs [3,4] is a promising candidate for application to align RM-films on polymer substrates since all process can be carried out at low temperatures (<80^{o}C). Here we report on the first application of a photoalignment technology to align RM-films.

2. Materials

Our previous studies shown promising features of photoaligning polymers that contain derivatives of cinnamic acid in the side fragments of different main chains (polyvinylalcohol, polysiloxane, cellulose) [5]. The photoaligning properties of these materials are caused by anisotropic dimerization of side fragments at irradiation with polarized UV light and possible trans-cis isomerisation of the cinnamoil fragments. It was found that the cellulose-based cinnamate polymers turned out to have most promising aligning characteristics. In particular, these materials possess unique photosensitivity and provide a high quality alignment of most commercial nematic LC mixtures after UV exposure with a doze ~ 0.1-0.J/cm^2. In our experiments we used cellulose 4-pentyloxycinnamate (PG) which chemical formula is presented in Figure 2.

RMM141 is a mixture of di- and mono-acrylate Reactive Mesogens. The mixture is designed to be dissolved in organic solvent and coated onto substrates with an aligning layer. RMM141 is formulated to produce planar (homogeneous) aligned nematic films. After coating the RMM film can be polymerized in air using a high pressure Hg lamp.

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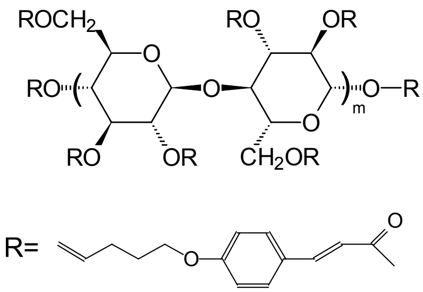

Figure 2. Chemical formula of PG.

3. Preparation of samples

Preparation of the photoaligning layers.

PG was dissolved in dichloroethane with typical weight concentration c = 5 g /L. The photoaligning films were produced by spin-coating of the solution over glass or polymer substrates covered with ITO during 5 s at the revolution speed, v = 7000 rpm. We also used polymer colour filters as the substrates. The deposited films were dried at 80°C during 1-1.5 hours to remove the solvent. The produced PG films had a thickness of about 0.1 μm. The substrates covered with the PG films were illuminated by UV light from a high pressure *Hg*-lamp (electric power 500 W) from the side of PG film through water IR-filter. Homogeneous UV-light field was formed in the plane of the substrate by a quartz condenser and a polarizing Glan-Thomson prism. We irradiated the films in two stages. During the first stage the film was exposed for 2 s with not-polarized UV light (no Glan-Thomson prism, intensity $I = 20 mW/cm^2$). This treatment decreased solubility of PG by toluene which is used as a solvent of the reactive mesogene. During the second stage the film was irradiated by polarized UV light (intensity $I = 2.5 mW/cm^2$) with different exposure times t_{exp}:1; 3; 5; 7; 10; 15; 20; 25; 30; 60 and 90 seconds**.**

Photalignment of RM-mixture

A solution of RMM141 in toluene (c = 300g /L) was spin-coated (v = 3000 rpm) on the substrate with irradiated PG film. Observation of the spin-coated RM liquid layers between crossed polarizers showed preferably unidirectional alignment of the optical axis over the substrate surface with some orientation defects. A number of these defects decreased with time, probably due to evaporation of the solvent. Annealing of the film at 60°C accelerated the improvement of the alignment; the defects usually disappeared after 30 s of the annealing.

After achievement of a good alignment of the RM mixture the last one was polymerized using not-polarized light from a high pressure UV Hg-lamp ($20 mW/cm^2$) during 50-60 s. The thickness of the produced polymer film was ~ 2.7 μm.

4. Alignment quality

To characterize the quality of the RM alignment we put the substrate with the photo-oriented RM -film between crossed polarizers and adjusted the sample position to get a minimal transparency of a probe beam of He-Ne laser (λ = 0.638 μm). In this geometry we measured the intensity of the probe beam behind analyzer, $I_\perp$. Then, we rotated the analyzer for 90° and measured again the intensity of the probe beam, I_{II}, behind the analyzer. The ratio $\alpha = (I_{II} - I_\perp)/(I_{II} + I_\perp)$ which is called as *aligning quality parameter* is equal to zero in the case of macroscopically random alignment and $\alpha = 1$ when the director is oriented unidirectionally [5,6].

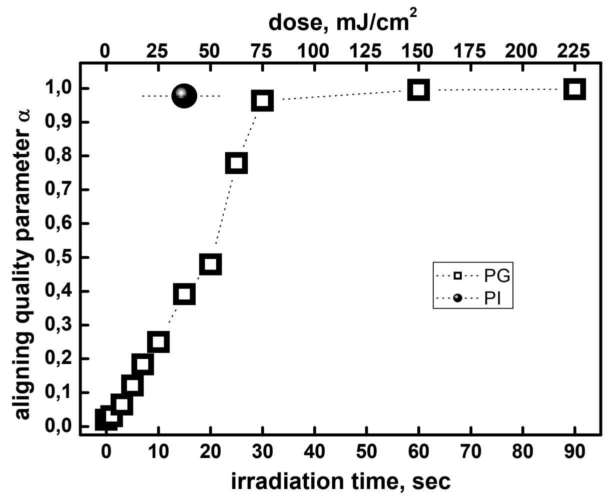

Figure 3. Dependence of the aligning quality parameter RMM141 on PG surface on exposure time and irradiation. For comparison, the aligning quality parameter of RMM141 on rubbed polyimide surface is depicted by the circle point.

The dependence of the quality parameter α on exposure time, t_{exp} and dose, D, are presented in Figure 3. The value α for a rubbed polyimide layer is also presented in the same figure. One can see that at $t_{exp} \approx 30$ s (irradiation dose, $D = It_{exp} = 75$ mJ/cm^2) the quality parameter $\alpha \approx 0.98$ almost coincided with the aligning quality parameter of rubbed polyimide.

The alignment of the RMM films were obtained on the color filters also. The photo of the aligned films on color filter is presented in Figure 4. The alignment treatment was the same as described above.

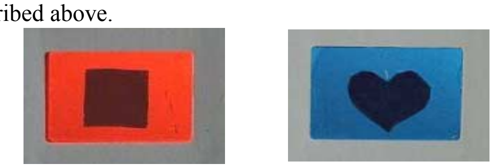

Figure 4. Orientation RMM-141 films on surface of PG coated onto the color filters; $t_{exp} = 30$ s, $I_{exp} = 2.5 mW/cm^2$

5. Conclusions

The results obtained have clearly demonstrated a large potential of the photoalignment technology to align mesogens. The quality of the alignment of RMM141 on the photoalignment layer PG is not worse than the alignment of RMM141 on a standard rubbed polyimide film. The small irradiation dose needed to get a high-quality alignment (~ 75 mJ/cm^2) makes the technology extremely promising for application in roll-to-roll process.

6. References

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