

P-183: Refraction Control in Optical Films for LCD

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Abstract

We developed a method for manufacturing of coatable Thin Birefringent Films (TBFTM) with control over values of three principal refraction indices. The control of ratios between principal refractive indices is based on varying formulation of the coatable material and conditions of post-treatment of the coated film. NZ factor of the obtained retarders ranges from 0.0 up to 0.8.

1. Introduction

High contrast ratio at large viewing angles is a very important property of liquid crystal displays (LCD), especially in high definition displays (monitors, TVs) for collective viewing by a group of viewers in domestic, public, or industrial settings. In LCD the viewing angle performance is not improved by polarizers even if they are of very high quality. Typical LCD comprises two dichroic polarizers crossed at 90°. At the viewing polar angles $\theta \neq 0^\circ$ the projections of absorption axes of two orthogonally crossed polarizers on plane that is perpendicular to the light propagation direction form non-normal angle (Figure 1).

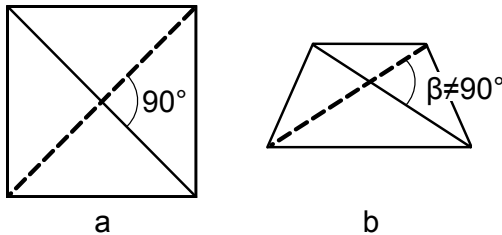


Figure 1. Schematic representation of two crossed polarizers viewed along: (a) the normal; (b) an oblique direction

The light leakage increases with increasing off-axis oblique viewing direction up to polar angle $\theta \approx 70^\circ$. It results in a lower contrast ratio at large viewing angles. The contrast ratio decrease is the most pronounced for incidence plane at an azimuth of -45° and $+45^\circ$. For example, at the viewing angle of 60° the typical polarizer contrast ratio drops down by 70-100 times as shown in Figure 2.

This problem is well known for the O-type polarizers, and it remains true even for the ideal O-type polarizers with infinite contrast ratio at normal [1].

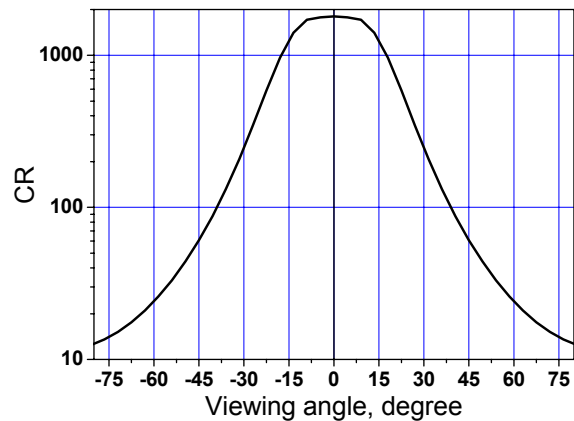


Figure 2. Contrast Ratio of the typical polarizer at 45 degrees to polarizer transmission axis

In order to solve the above mentioned problem one [2, 3] or two [4-6] biaxial retardation films are used as retarders to suppress the dark-state light leakage of two orthogonally crossed polarizers. Various LCD designs require retardation films with certain set of refraction indices or, in other words, certain biaxiality. The biaxial Thin Birefringent Film (TBFTM) is characterized by the value of NZ factor, which is defined as:

$$NZ = \frac{n_y - n_z}{n_y - n_x} \quad (1)$$

where n_x , n_y , and n_z are the principal refractive indices at $\lambda = 550$ nm. Typical relation of the principal refractive indices for biaxial B_A-type retardation films is presented in Figure 3. For B_A-type retarder the lowest (n_x) and highest (n_y) principal refractive indices correspond to the principal dielectric tensor axes A and B, which also belong to plane of the film. In our case, for technological reasons, the A- and x- directions are along the TBFTM coating direction.

In this paper we present a method for control of NZ factor of TBFTM by varying the coating material formulation and/or conditions of TBFTM post-treatment. Further details on TBFTM technology and parameters of retardation films can be found in [2, 4, 7-8].

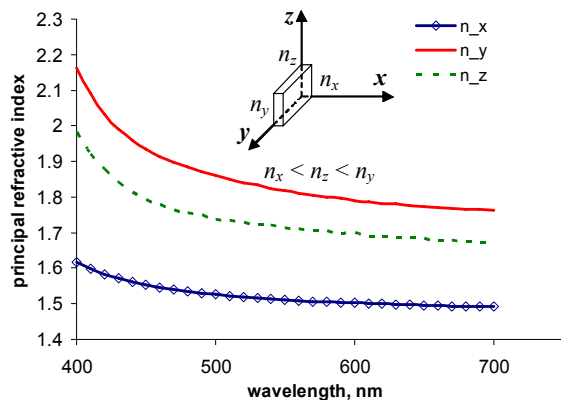


Figure 3. Typical spectral dependencies of principal refractive indices for biaxial B_A -type film

2. Results and discussion

2.1 Materials and method

Crysoptix TBFTM retarders are produced by coating liquid self-assembling materials on glass or plastic substrate with subsequent drying, wherein the liquid coating material is transformed into molecularly oriented nanofilm [7-8].

The TBFTM biaxial retarder manufacturing is a four step process including: (i) a chemical modification; (ii) lyotropic liquid crystal (LLC) formation; (iii) mechanical orientation of liquid crystal molecular units during deposition; and (iv) evaporation of the solvent (drying). The chemical modification step introduces hydrophilic groups on the periphery of the molecule in order to impart amphiphilic properties to the molecule. Amphiphilic molecules in water stack together into supramolecules. At specific concentration, solution of supramolecules converts into a liquid-crystalline state and forms LLC. The LLC is coated onto a substrate in such a way that the shear force direction determines the molecular orientation in the resulting thin liquid film. The solvent evaporation step allows to fix the oriented supramolecules and to produce the birefringent film.

Coating materials are based on *Crysoptix* sulfonated aromatic compounds [7,8]. Coating solutions were prepared with different counterions: Li^+ , Na^+ , K^+ , and Cs^+ . The H^+ -forms of the core compound, i.e. corresponding sulfoacids were dissolved in DI-water containing $LiOH$, $NaOH$, KOH or $CsOH$ and concentrated on rotary evaporator. Typical pH of concentrated LLC was close to neutral. The weighted concentration of the main material was kept the same for all solutions. The TBFTM biaxial B_A -plate retardation films were formed by coating the LLC onto clean soda-lime glass substrates, and subsequent drying [2].

2.2 TBFTM NZ factor control

Typical spectral dependencies of principal refractive indices for biaxial B_A -type films are presented in Figure 3. The NZ factor of TBFTM is controlled by changing parameters of TBFTM formulation and/or conditions of TBFTM post treatment. The first method of the NZ factor control is based on the effect of counterion on optical performance of biaxial TBFTM. The counter-ion radius varied from 0.068 to 0.165 nm. Figure 4 shows TBFTM NZ factor as a function of type of counter-ion.

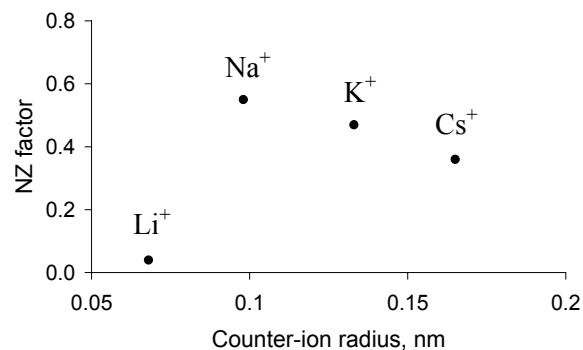


Figure 4. NZ factor of TBFTM as a function of counter-ion radius

The second method of the biaxiality control is based on changing conditions of TBFTM post-treatment at a solvent evaporation stage. We have examined TBFTM retardation films (in all counter-cationic forms) dried in air at room temperature and the films dried in air at the elevated temperature of 230°C for one hour. The NZ factor dependence on post-treatment conditions is presented in Table 1.

Table 1. The NZ factor dependence on post-treatment conditions

Counter-ion	Ion radius, nm	NZ factor	
		$T_{drying}=23^{\circ}C$	$T_{drying}=230^{\circ}C$
Li^+	0.068	0.04	0.54
Na^+	0.098	0.55	0.81
Cs^+	0.165	0.37	0.53

The counter-ion species and film post-treatment conditions are supposed to affect the resulting TBFTM structure which determines the NZ factor of the retardation films. The observed changes in the TBFTM biaxiality may be better understood by taking into account that the base coating material consists of linearly conjugated plank-like molecules. The conjugation length and, hence, a polarizability, is different in three principal directions (see Figure 3) - in other words the molecule's electronic structure is anisotropic. When dissolved, the molecules are self-assembling in supramolecules (stacks) and forming LLC at certain concentration. Under the action of a shear force during the coating step the stacks of the film are aligned along the coating direction in a plane parallel to the substrate surface [2].

On the basis of the experimental data of principal refractive indices as a function of counter-cation type we conclude that the NZ factor depends on the value of the principal refractive index n_z (Figure 5). Hence, the biaxiality of the TBFTM retarders depends on the degree of supramolecules' orientation/disorientation in YOZ-plane (Figure 6). A degree of ordering can be related to a density of supramolecular packing. Thus the retardation film in Li^+ cationic form is characterized by the minimum degree of supramolecular orientation, while the maximal degree of orientation is achieved by the TBFTM in Na^+ cationic form dried at elevated temperature of 230°C.

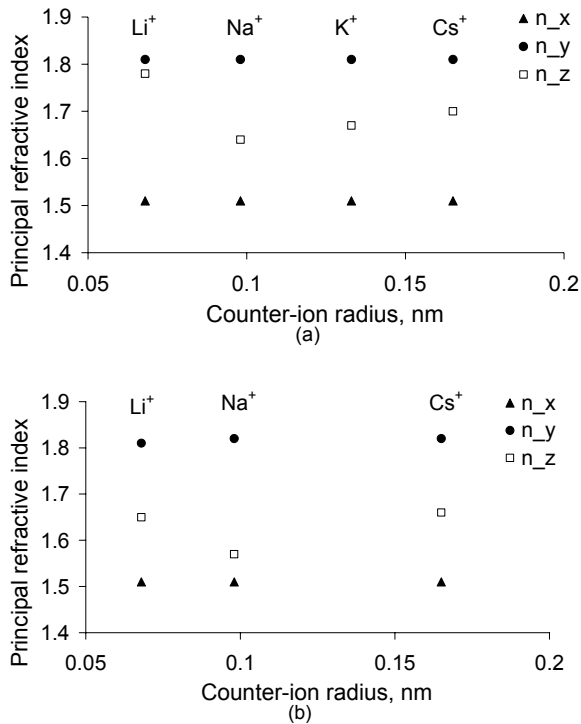


Figure 5. Principal refractive indices of TBFTM produced from LLC coating materials in different counter-cationic forms: (a) dried in air at 23°C, and (b) dried at elevated temperature of 230°C

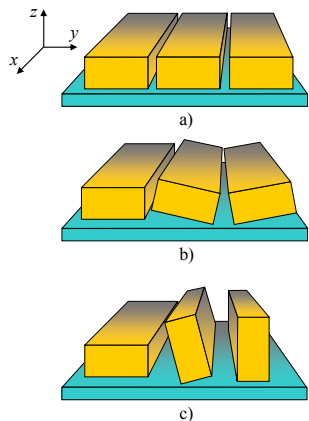


Figure 6. Optimization of various degrees of supramolecules orientation /disorientation in YOZ-plane: (a) maximal orientation, (b) intermediate state, and (c) maximal disorientation

Hence the TBFTM NZ factor control can be realized by changing the TBFTM formulation or by varying the TBFTM drying conditions (see Figures 4, 5, and Table 1). One of these methods or their combination allows producing a set of retardation films with the predetermined NZ factor providing the most significant optical compensation of polarizers in LCD.

3. Impact

The developed approach of controlling NZ factor of optical films allows designing biaxial retarders according to LCD manufacturers' requirements. Specific formulation and choice of appropriate post-treatment conditions enable to control NZ factor of the target optical film in substantial range, without changing a base chemical material.

4. References

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