Coatable Retarder Technology for LCD Home TV

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Abstract

Crysoptix KK has developed low-cost coatable retarder technology. A full range of coatable retardation films with tunable value of biaxiality (NZ factor) has been developed for the first time. Tunable NZ factor allows efficient compensation of modern VA and IPS mode LCD with just single retardation film.

1. Introduction

Cost reduction is dominant for LCD TV industry today. The market demands low-cost high-efficiency solutions. In this situation, simple innovations in existing technology fail, and a new technology is required for manufacturer to keep good positions in the market.

Modern LCD TV polarizer comprises an optical retardation film enhancing the viewing angle contrast ratio. Current retarders are made from stretched polymer films, which are relatively expensive. Crysoptix KK has recently developed [1-3] and promotes new low-cost coatable retarder technology. The technology is based on application of self-organized organic compounds.

Besides the low cost and technological simplicity coated retarder is slimmer, more resistant to heat and gives better optical compensation as compared to existing polymer retardation films.

2. Experimental

Crysoptix full range of coatable thin birefringent films (TBF^{TM}) provides efficient compensation of LCD. Retardation properties of said retardation films are presented in Figure 1.

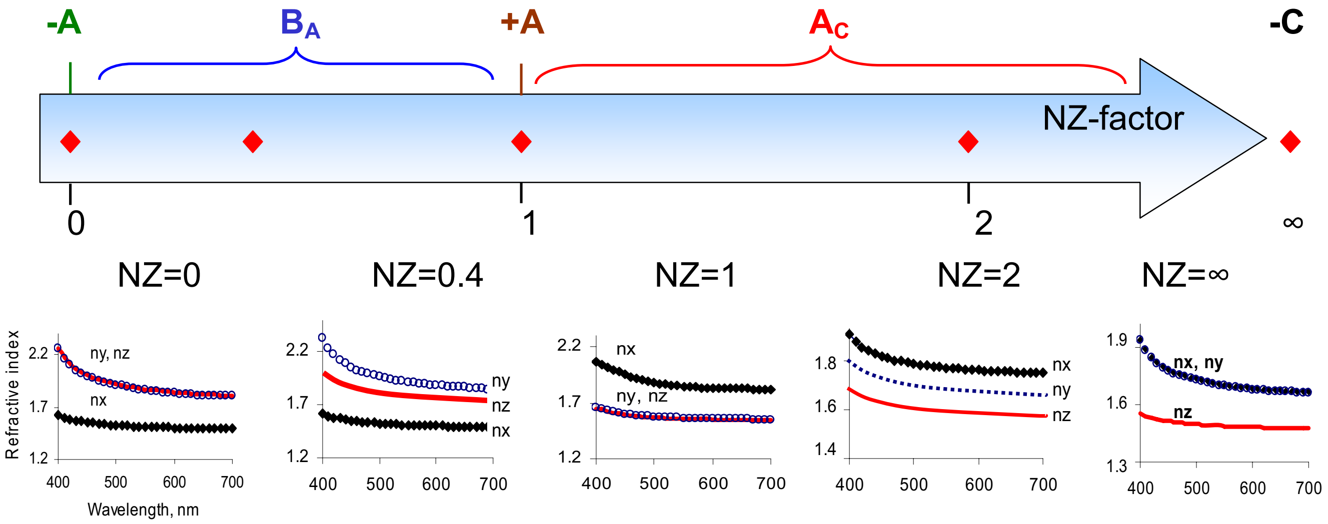


Fig. 1. Spectra of principal refractive indices for Crysoptix coatable retardation films: negative A-plate, biaxial B_A-plate, positive A-plate, biaxial A_C-plate, negative C-plate (shown from left to right).

2.1 Theoretical background

Typical retardation film is characterized with optical properties such as retardation value, three principal refractive indices and their spectral dependence. In optical design, a relationship between principal refractive indices, the NZ factor, is important and becomes principal measure of retarder biaxiality:

$$NZ = \frac{R_{th}}{R_o} = \frac{n_s - n_n}{n_s - n_f},$$

where R_{th} – out-of-plane retardation, R_o – in-plane retardation, n_f– lower in-plane refractive (fast axis), n_s – higher in-plane refractive index (slow axis), n_n – out-of-plane (along normal direction) refractive index.

The NZ factor of Crysoptix retardation films covers the range from zero (for negative A-plate) to infinity (for negative C-plate). One can find detailed retarders classification elsewhere [1].

Moreover, it is possible to tune the NZ factor of biaxial films and achieve practically any NZ factor value, which is optimal for a particular optical design.

2.2 Coatable technology

Crysoptix KK offers a new optical film manufacturing technology, which is applicable for large-scale mass production.

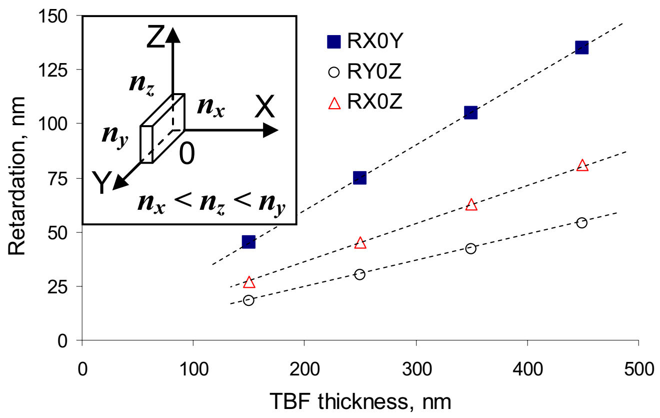


Fig. 2. Optical retardation vs. thickness for BA-LT-1000 biaxial B$_A$-plate retardation film. The insert shows relationship between principal refractive indices in B$_A$-plate retarder.

The base material can be synthesized at chemical plant and then mixed with solvent (water for most products) at the mixing plant. Typically we verify a composition of the synthesized material with high-performance liquid chromatography (HPLC) data and make coated samples with Mayer Rod coating technique for optical tests.

By varying the thickness of coated layer, we can control the value of retardation (Figure 2). A certain optical retardation can be calculated by multiplication of corresponding indices difference and TBF^{TM} thickness d:

$$R_{X0Y} = (n_x - n_y) \cdot d,$$
$$R_{Y0Z} = (n_y - n_z) \cdot d,$$
$$R_{X0Z} = (n_x - n_z) \cdot d.$$

The Mayer Rod coating technique serves well for lab prototyping of the film samples.

Application of large-scale printing processes such as slot-die coating machine and flat-bed – for glass substrate, and roll-to-roll – for plastic substrate, allows producing high quality smooth coatings of a wide range of thicknesses. Thus Crysoptix KK materials can be coated on triacetyl cellulose (TAC) or polyethylene (PET) substrates using the roll-to-roll slot-die coater.

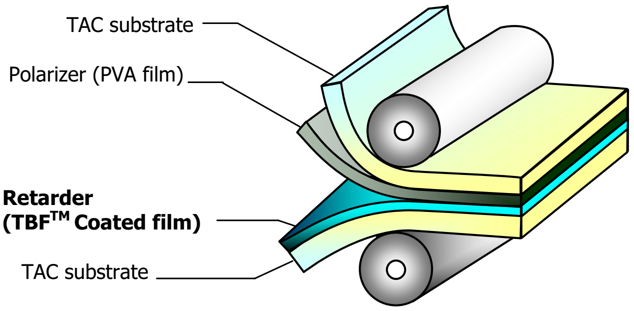


Fig. 3. Roll-to-roll technology allows coating of retarder material on plastic substrates and subsequent lamination with polarizer.

After coating on TAC the retardation film can be laminated with other functional layers such as polarizer film.

2.3 Thermal stability

The retardation change in optical films under heating influences the light leakage of LCD design in black state [4].

We have investigated our films in temperature range typical for LCD operation. The results are presented in Figure 4. Due to crystalline nature of base material in Crysoptix biaxial BA-LT-1000 retarder there is no retardation change in temperature range from 25 to 60 °C. In case of positive A-plate for the mentioned temperature range the retardation change is 5%, and in A_C-plate – 7%.

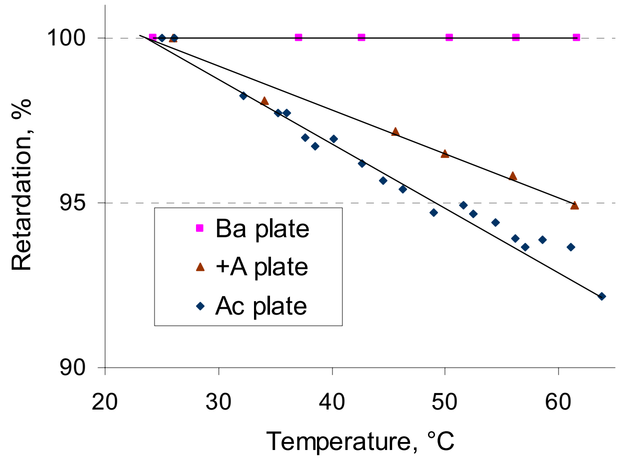


Fig. 4. In-plane retardation change during heating the biaxial B_A-plate, positive A-plate, and biaxial A_C-plate retarders.

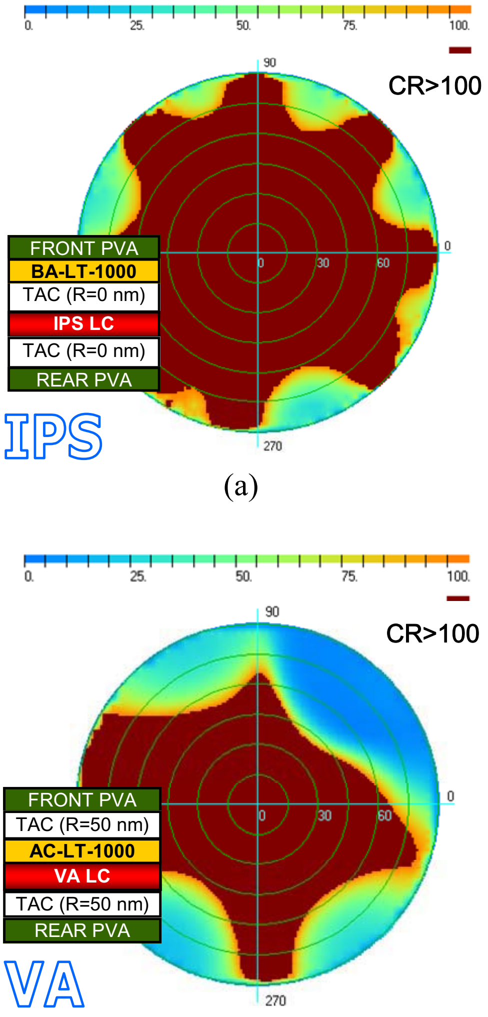
3. Results and discussion

The flexibility of NZ factor choice makes optical design of LCD easier and more efficient.

The IPS mode LCD compensated with single B_A-plate retarder and VA mode LCD compensated with single A_C-plate retarder are shown in Figure 5.

Figure 5a, demonstrates simulation results for the IPS LCD viewing angle performance for the LCD compensated with biaxial B_A-type plate TBF^{TM} having the following parameters: n_x=1.51, n_y=1.81, n_z=1.68 (NZ=0.5) at λ=550 nm, thickness d=0.5 μm. Optical stack scheme inserted in the figure 5a provides a high contrast ratio – more than 100 in 60° viewing cone.

Figure 5b shows the performance of a single domain VA mode LCD. Here the LCD is compensated with biaxial A_C-type plate TBF^{TM} having following parameters: n_x=1.72, n_y=1.68, n_z=1.62 (NZ=2.2) at λ=550 nm, d=1.3 μm and spectra shown in Figure 3b. The optical stack inserted in the figure 5b results in a high contrast ratio – more than 100 in 45° viewing cone, and more than 50 in 60° viewing cone. The contrast drop at +45° diagonal corresponds to the LC molecules' reorientation axis and can be easily overcome by multi-domain pixel design, where the contrast ratio will be enhanced to values of 100 in 60° viewing cone.



(a)

(b)

Fig. 5. Simulated viewing angle contrast ratio map at λ=550 nm for IPS (a) and VA (b) mode LCD compensated with Crysoptix biaxial retarders.

The properties of the most advanced Crysoptix product – biaxial B_A-plate retarder BA-LT-1000 – are specified in Tables 1 (coating solution), 2 (coating requirements) and 3 (coated film).

TABLE 1. Technical specifications of coating solution for Crysoptix BA-LT-1000

Characteristic	Value
Solvent	water
Typical solid concentration range	10-15 wt.%
Typical viscosity range	Shear thinning liquid ~0.1-0.2 Pa·s at shear rate of 100 s^{-1}
Appearance	Colorless viscous opalescent pearly liquid

TABLE 2. Coating requirements for Crysoptix BA-LT-1000 lab sample preparation

Parameter	Recommendation
Substrate preparation	No alignment layer, no rubbing, only cleaning procedure
Solution/substrate/ ambient temperature	20-25 °C
Coating speed	150-300 mm/sec
Drying Condition	Normal (drying in open air)
Lab sample wet thickness range*	1.5-3 μm
Lab sample dry thickness range*	200-300 nm
Coating method	Coating at high shear rates

**For film coated with Mayer Rod technique*

TABLE 3. Technical specifications of coated TBF™ for Crysoptix BA-LT-1000 at λ=550 nm

Characteristic	Value
Transmission	91%
n_x	1.51
n_y	1.81
n_z	1.68
Δn_{yx}	0.30
Δn_{yz}	0.13
Δn_{zx}	0.17
Depolarization (Mayer Rod hand coating)	~ 0.2%/μm
Typical thickness by Mayer Rod, nm	200-300
Wet environmental stability test	1000 hours at relative humidity 90% and temperature 60 °C
Adhesion test (Gardner P-A-T Paint Adhesion Test Kit PA-2000)	high

The coated TBF™ post-treatment by dipping into bath with barium salts (e.g., barium nitrate) converts the retarder in the water insoluble form. Such retarder laminated with TAC passes wet environmental stability test [2].

4. Summary

New Crysoptix technology opens an opportunity to reduce material consumption and the cost of LCD optical films, in particular retarders. Crysoptix retarders exhibit high resistance to heat deformation and provide enhancement of the viewing angle performance.

The first product – biaxial B_A-plate (BA-LT-1000) TBF™ has successfully passed the pilot stage at the chemical plant and is currently in the pilot stage at the coating factory.

Crysoptix is open for cooperation with coating partners and polarizer makers as well as with LCD integrators.

5. References

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