A Study on the Optical Characteristics of Biaxial Film by using Dual Rotating Retarder Polarimeter and a Novel Simulation Model

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Abstract

We have studied the optical properties of the biaxial film such as fast axis, retardance and the change of polarization state between crossed polarizer using dual rotating retarder polarimeter. We have developed a novel simulation model, which could explain well the experimental results, and found that it could be used to optimize the compensation film in LCD for improving wide-viewing property.

1. Objectives and Background

Recent years, many reports revealed that the light leakage of LCD in oblique direction could be improved by adding optical compensation films between crossed polarizers. It is very important to understand the change of the polarization state of output light through LCD cell and compensation films because the light leakage can be estimated from the distance between the polarization state of the light in front of analyzing polarizer and those of the compensation point in Poincare sphere. The change of polarization state through some uniaxial films can have been explained by the fast axis orientation and the retardance value of the film in oblique direction.

Among the several instruments used in optical film industry, we have used the dual rotating retarder polarimeter (Fig. 1) (Axoscan, Axometrics co. Ltd,) because it can directly measure the polarization state with Stokes Vector (S0, S1, S2 and S3 correspond total intensity, linearity, orientation and circularity of the polarized light). We confirmed the reliability of this instrument by comparing the measured and the calculated polarization state though well defined uniaxial stretched COP (Cyclo Olefin Polymer) film and TAC (Tri Acetyl Cellulose) film.

The importance of biaxial film in wide viewing compensation polarizer has been increased because it can improve the cost structure of the compensation polarizer by replacing two or more pieces of uniaxial compensation films. Therefore, it is needed to understand the change of polarization state by a biaxial film for designing wide viewing compensation polarizer.

However, it was very difficult to predict and even to explain the change of polarization state through a biaxial film because of the very complex calculation steps. Therefore, we have developed a new model to calculate the fast axis orientation and the retardance through biaxial media in oblique direction by using the three-dimensional refractive index system and its orthographic projection.

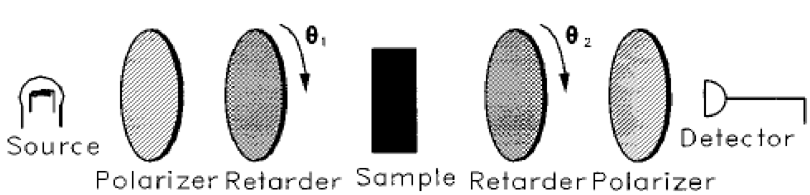

Fig. 1 Schematic diagram of Dual Rotating Retarder Polarimeter

2. Results

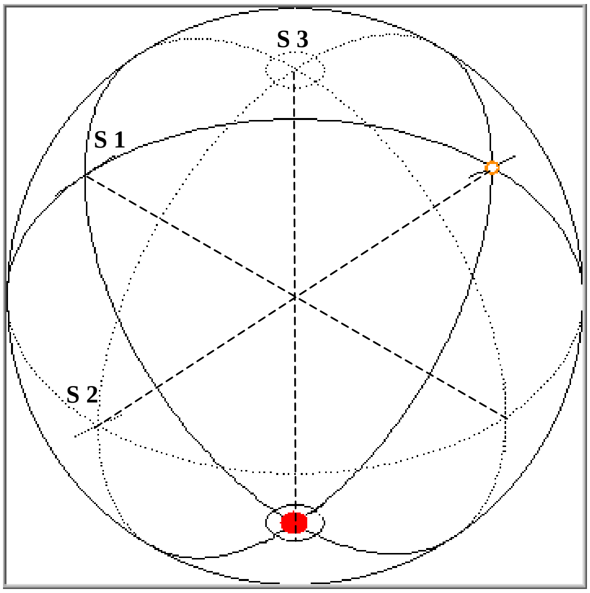

Fig. 2 The change of the polarization state in QW (quarter wave) uniaxial COP film
- Incident Light : + 45 ° linear (blanked circle)
- Output Light : Left Circular (filled circle)

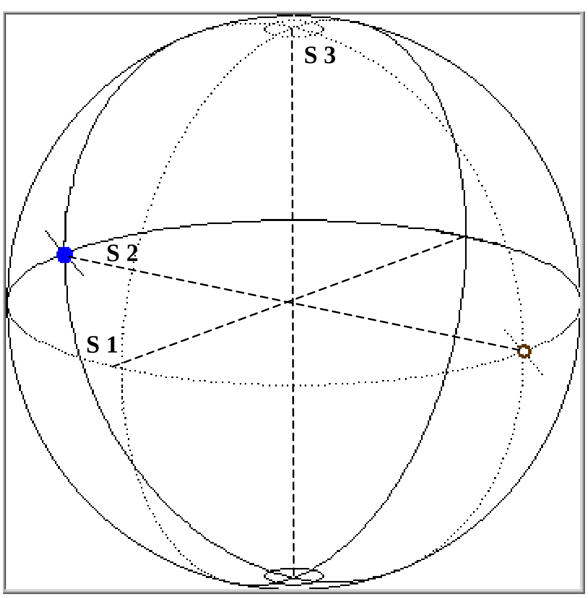

Fig. 3 The change of the polarization state in HW (half wave) uniaxial COP film
- Incident Light : + 45 ° linear (blanked circle)
- Output Light : − 45 linear (filled circle)

First, we have confirmed that the dual rotating retarder polarimeter is the good method to explain the change of the polarization state of the light through any kind of retardation films by using the uniaxial stretched COP film.

Especially, we have used two optically well-defined films, quarter wave plate and half wave plate. They are commonly used in LCD and OLED industry. It is very well known that the quarter wave plate(λ/4 plate) can change the linear polarization state to the circular polarization state. And it is also well known that the half wave plate(λ/2 plate) can change the linear polarization state to the opposite linear polarization state.

Fig. 2 is the experimental results by using the dual rotating retarder polarimeter. The sphere in the figure is Poincare Sphere, in which x, y, z coordinates correspond three Stokes vector, S1, S2, and S3. If the incident light is 45 ° linear polarized light (S2=1), the quarter wave plate rotates it to the circular polarized light (S3=1) and the half wave plate rotates it to the −45° linear polarized light (S2=−1). The variation of the output polarization state is due to the wavelength of the incident light. These results can explain our knowledge very well.

Second, we have checked the change of the polarization state through some uniaxial media. Fig 4,5 are the experimental results for the positive A plate and negative C plate, which are used for compensation of viewing angle of contrast in Liquid Crystal Display.

In Fig. 4, if the incident light is 45° linear polarized light (S2=1), the positive A plate rotates input polarization state clockwise about its fast axis orientation, 0 ° by its retardance In Fig. 4, if the incident light is the same as Fig. 5, the negative C plate rotates input polarization state clockwise about its fast axis orientation, 90° by its tilt-induced retardance. The distribution of the changed output polarization state is due to the wavelength variation from 400nm to 800 nm.

In brief, a uniaxial media rotates the input polarization state clockwise about its fast axis orientation by its retardance, and it is easy to estimate the change of the polarization state in a uniaxial film

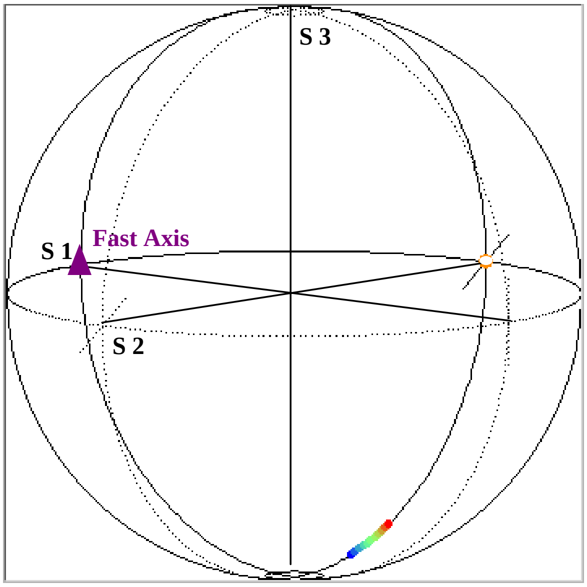

Fig. 4 The change of the polarization state in uniaxial COP Film (R0=100) - Positive A Plate
- Film Rotation Angle : 0 °
- Film Tilt Angle : 0 °
- Fast Axis Orientation : 0

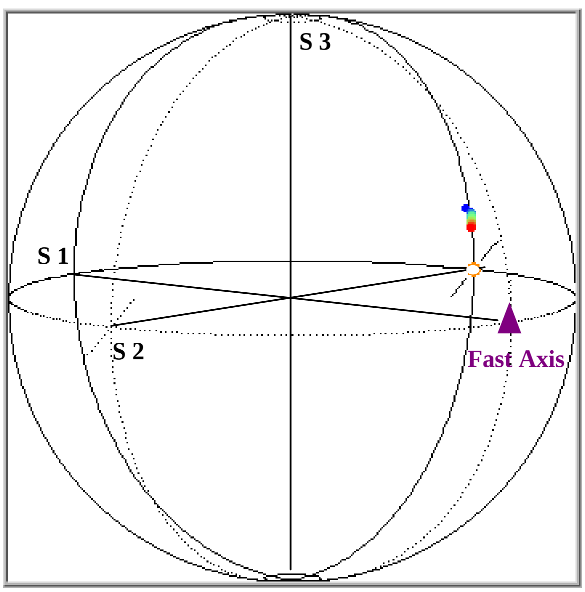

Fig. 5 The change of the polarization state in TAC Film (Rth= −55) - Negative C Plate
- Film Rotation Angle : 0 °
- Film Tilt Angle : 50 °
- Fast Axis Orientation : 90

because the fast axis orientation and the retardation value can be simply predicted.

Finally, we have measured the biaxial COP film which is widely used in compensation film industries. In order to measure the characteristic optical property of a biaxial media, a biaxial COP film has been rotated and tilted.

Fig. 6 is the experimental results for the negative B plate. It rotates the −45 ° linear polarized light about its fast axis orientation, 59 ° and the rotation degrees are exactly same as its retardation value. From these results, we can be sure that a biaxial media, like a uniaxial media, also rotates the incident polarization state clockwise about its fast axis orientation by its retardation value.

But, in a biaxial media, the retardation value of the film induces the change of the fast axis orientation in oblique direction. This makes it difficult to understand the changes of the polarization state in a biaxial film.

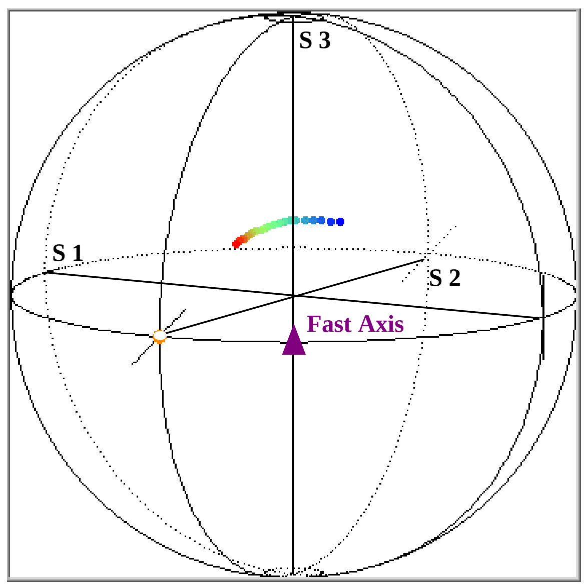

Fig. 6 The change of the polarization state in biaxial COP Film (R0=100, K=125)
- Negative B Plate
- Film Rotation Angle : 40 °
- Film Tilt Angle : 50 °
- Fast Axis Orientation : 59 °

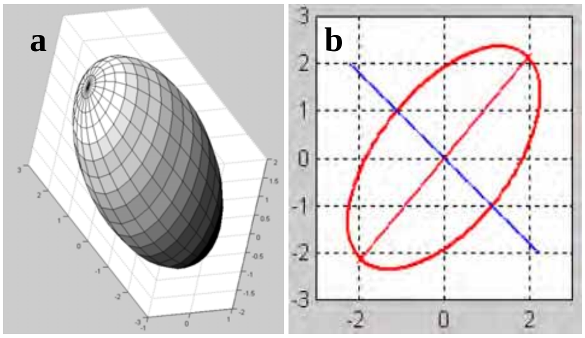

Fig. 7 The novel simulation model in 3D refractive index and its orthogonal projection

To explain these specific phenomena of a biaxial film, we have invented a model in three-dimensional refractive index system. Using its orthogonal projection (Fig. 7b) of three-dimensional Rugby ball (Fig. 7a) like model, we can obtain the induced refractive index, *ne* and *no*. From the difference of these two values, the total retardation value is obtained easily. And the orientation direction of *no* means the fast axis orientation of a biaxial film in oblique direction.

Table 1. The fast axis orientation

Sample Film	Film Rotation	Film Tilt	Experimental data	Simulated data
A	-45 °	50 °	-52.9 °	-52.5 °
A	-60 °	30 °	-62.6 °	-62.7 °
B	-30 °	30 °	-33.9 °	-33.5 °
B	-90 °	50 °	-90.0 °	-90.0 °

Table 2. The retardation value

Sample Film	Film Rotation	Film Tilt	Experimental data	Simulated data
A	-45 °	50 °	102.5 nm	104.5 nm
A	-60 °	30 °	104.9 nm	106.0 nm
B	-30 °	30 °	93.7 nm	95.5 nm
B	-90 °	50 °	128.3 nm	128.9 nm

A : R0=100 nm, K=95, biaxial COP
B : R0=100 nm, K=125, biaxial COP

Table 1, 2 The comparison result of the data of experiments and simulations in some biaxial films.

Table 1, 2 are the comparison results between experimental data and simulated data of some biaxial films. The simulation value of fast axis orientation and retardation value fit the experimental data very well.

With this novel model, we can get the fast axis orientation and retardation value of any kinds of biaxial film in any oblique direction.

3. Conclusion

The dual rotating retarder polarimeter is very powerful instrument for studying a change of the polarization state in an optical film. Using this tool, we can certificate the polarization state changes in uniaxial media and biaxial media. A single optical film like stretched COP, TAC, and etc rotates the incident polarization state clockwise about its fast axis orientation by its retardation value in oblique direction.

And to predict the fast axis orientation and the total retardation value of any kinds of optical films, the novel simulation model in three-dimensional refractive index has been invented.

4. Acknowledgements

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5. References

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