New Type 1/4-Wave Plate Film for OLED Panels

Jiro Ishihara[1], Kenji Yoda[1], Shunsuke Takagi[1], Kazuhiro Osato[1], Yuji Shibata[1], Taku Hatano[1]

[1] Zeon Corporation, Takaoka-shi, Toyama, Japan
Keywords: QWP; ¼-wave plate; OLED; high contrast; low color shift.

ABSTRACT

We will introduce a new type ¼-wave plate film (QWP) for OLED displays. The QWP film consists of two layers with positive and negative intrinsic properties, which results in smaller reflectance and color shift than other type of conventional QWP on OLED. We also have achieved mass-production by new production process.

1 INTRODUCTION

The spread of mobile devices, represented by smartphones and the tablet PCs, is progressing quickly. OLED is growing in prevalence as the display technology for these applications. OLED displays are suitable for mobile devices due to their light-emitting and low power consumption characteristics. Generally, a circular polarizer is required for OLED displays to obtain good black mode performance.

A circular polarizer in combination with an OLED display prevents reflection by absorbing the exit of incident light. Conventionally, a wide wavelength range ¼-wave plate (QWP) was used for the circular polarizer, and the QWP is characterized by the wavelength dispersion of its birefringence. To improve reflection characteristics, there are mainly two ways to control the wavelength dispersion.

One is to use reverse wavelength dispersion material like a copolycarbonate [1]. This single-sheet type QWP has a simple structure, but does not have good reflection characteristics especially in the normal direction because of difficulties to control their wavelength dispersion close to the ideal dispersion.

The other is to laminate two different retarder films with different slow axis angle (e.g. combination of λ/4 and λ/2 retarder [2]). The complete darkness in the normal direction has been achieved by this multi-sheet type of QWP. However, the QWP has some disadvantages such as a narrow anti-reflection viewing angle, large reflective color shift and complicated lamination process.

In the past study, we had developed Cyclo Olefin Polymer (hereinafter referred to as COP) film (Oblique-stretched)×2 and COP film (MD-stretched)×2, but there is a demand for a thinner film with better optical properties and higher processability. In 2015, we had developed the conventional multi-sheet QWP, and have achieved a QWP combined with an oblique stretched COP film as a λ/2 retarder and an oblique stretched polystyrene (PSt) film as a λ/4 retarder. (We reported in SID in 2015. [3])

In this study, we have developed new type multi-sheet QWP with thinner and better optical property. Moreover the new type QWP can be produced using a roll-to-roll, low-cost manufacturing process. Below are the details about the file format, the composition, and the text contents in the manuscript.

2 Result

2.1 Optical Design

We optimized the slow axis angle of each layer to the absorption axis of the polarizer. It is well known that the combination of λ/2 retarder and λ/4 retarder is effective for the wide wavelength range QWP. The appropriate combination of slow axis angle is represented by equation [1] ($\theta_{\lambda/4}$ and $\theta_{\lambda/2}$ are the slow axis angle of λ/4 retarder and λ/2 retarder).

$$\theta_{\lambda/4} = 2\theta_{\lambda/2} + 45°$$

In the case of using two films made from same material, the appropriate slow axis angles of λ/2 retarder and λ/4 retarder are 15deg and 75deg, respectively. However, in case of using two films made from different materials, they generally show different wavelength dispersion and the combination of angles is not same.

We optimized the wavelength dispersion of each layer. Two layers we use are made from different material, Figure1 shows the wavelength dispersion of COP and A-(λ/4). As the graph shows COP and A- have the flat and positive wavelength dispersion, respectively. The material of A- (λ / 4) was selected to have high Re expression and positive wavelength dispersion. As a result, it is possible to make the wavelength dispersion closer to the ideal dispersion with a thinner thickness. We got the negative wavelength dispersion as red line with the retardation of each layer.

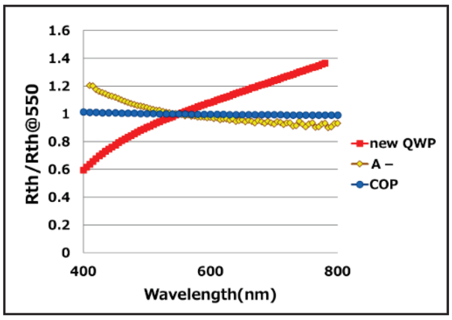

Fig. 1 Wavelength Dispersion of COP and A-

We simulated the appropriate combination of angles and we have found that the combination of λ/2 retarder and λ/4 retarder is optimally in the range of 20-25deg and the range of 85-95. Figure.2 shows the simulation result of the color difference (ΔE*ab) against black(a*=0, b*=0, L*=0). It indicates that the color difference is the lowest around this combinations of angles.

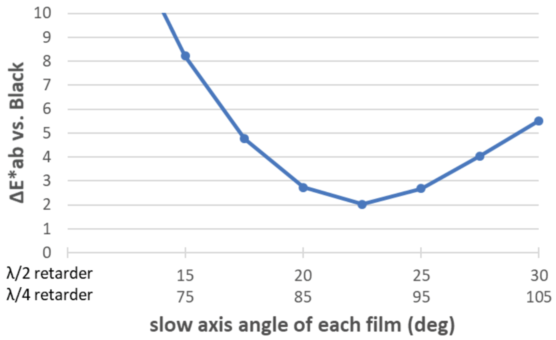

Fig. 2 Simulation result of the color difference against black

In this way, Figure.3 shows the construction of our new QWP. We selected the slow axis angle of λ/4 retarder as around 20 deg and the slow axis angle of λ/2 retarder as around 85 deg.

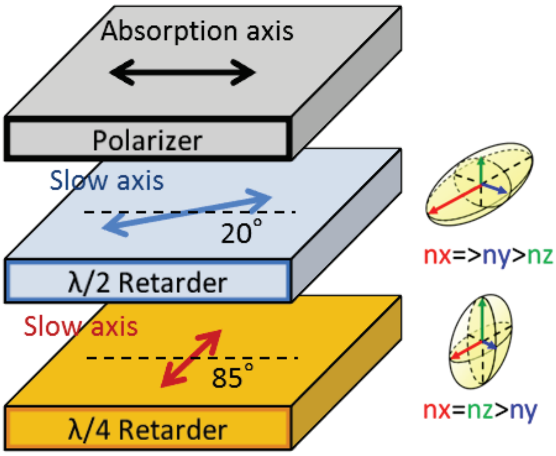

Fig. 3 Construction of Our New QWP

2.2 Manufacturing

We designed two optical layers in one sheet. Thereby, this one sheet can be used in roll-to-roll process of polarizer maker. Figure4 shows schematic diagram of our new QWP. We coat negative intrinsic birefringent material on COP. After that, we co-stretch the two layer films. By combining stretching and coating technology, we can control the slow axis angle of each layer.

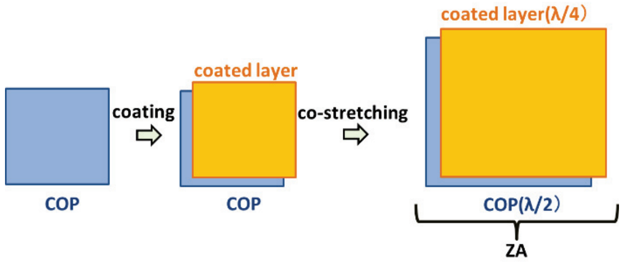

Fig. 4 Schematic Diagram of Our New QWP

Figure5 shows the film roll of our new film produced by the mass production machine. Now we can produce the film width of 1330mm.

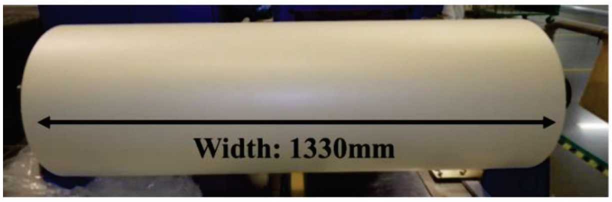

Fig. 5 Film Roll Produced by Mass Production Machine

2.3 Measurement results of reflection characteristics

We measured the reflection characteristics on OLED panel with circular polarizer and compared to our new QWP with other types of QWP. One is the conventional multi-sheet QWP based on COP and the other is the conventional single-sheet QWP based on polycarbonate derivative. Figure6 and Figure7 show their reflectance and color shift (Δab).

Our new QWP achieves smaller reflectance and smaller color shift in all directions than other type of conventional QWP.

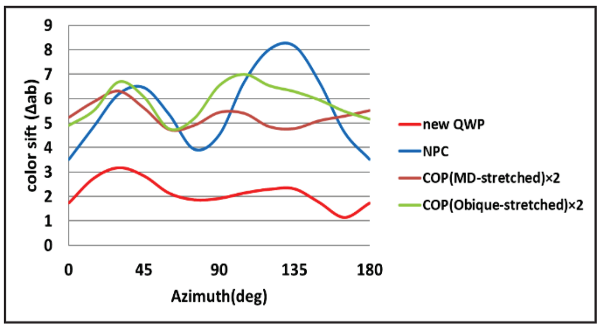

Fig.6 Measured Color Shift (Δab) at Polar Angle 45°

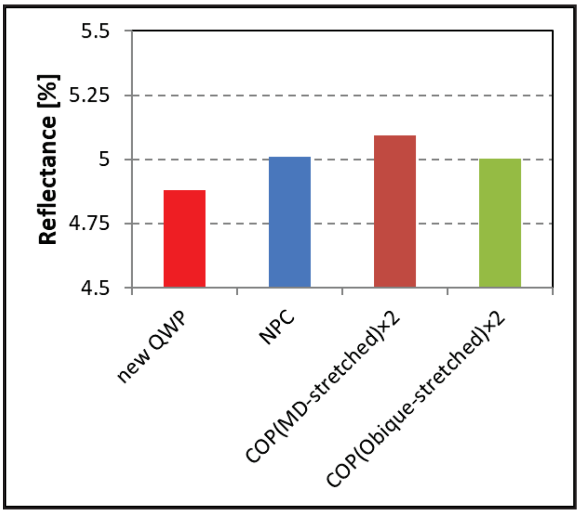

Fig. 5 Measured Reflectance in Normal Direction
Averaged reflectance of all azimuth angle at polar angle

3 CONCLUSION

We have successfully developed a unique production process of new type QWP for OLED displays which enables low reflectance and color shift, and achieved to make two optical layers in one sheet.

1) By controlling the slow axis angle of λ/2 retarder film and λ/4 retarder layer made from different material, we have achieved the completely low reflectance at normal direction, reduced the color shift and thickness.

2) Our new film can be manufactured by roll-to-roll process using our oblique and co-stretching technology.

REFERENCES

[1] A. Uchiyama, T. Yatabe, Japanese Journal of Applied Physics 42, 6941 (2003).
[2] Japan patent disclosure JP1993-100114.
[3] K.Osato, “Novel 1/4-Wave Plate Film for OLED Panels” SID2015, P140.