Research on the Effect of Anisotropic Module Layers on the White-Angle Difference of OLEDs

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Abstract

This study focuses on the module layer in OLED products, which is a uniaxial anisotropic material that causes birefringence of the emitted light through the layer. After simulation and experimental investigation, it is found that this anisotropic module layer will play a role in the white angle difference (WAD) of the product. Theoretically analyzing the principle, and through systematic testing, it is determined that the effect of the module layer on the WAD of the product can be minimized under a specific optical axis angle.

Author Keywords

OLEDs ; Birefringence ; Optical Axis ; Module Layer ; WAD

1. Introduction

In the era of advanced display technology, organic light-emitting diodes (OLEDs) have risen to prominence and are widely used in cell phones, wearable devices, flat panel displays, automotive displays, laptops and other applications due to their excellent visual characteristics such as high contrast, wide color gamut, wide viewing angle, etc[1,2]. OLED products are composed of a number of film layers, of which the module layer, as the last layer of the display in contact with the outside world, serves to Its role is to protect the display and reduce the deformation of the display after bending, and it should also have high transmittance due to the reduction of the loss of emitted light. However, we have recently found that certain module materials with optical anisotropy will affect the optical performance of OLED displays.

Optical anisotropy is the result of anisotropy of the dielectric constant tensor (dielectric constant) of an organic film, and birefringence occurs after the incident light passes through the anisotropic film layer[3]. This phenomenon affects the white angle difference (WAD) of OLED displays, thus affecting the user experience, so understanding and controlling the relationship between anisotropy for WAD is critical to achieving optimal display quality. However, these anisotropic characteristics have not been fully explored so far, so this study investigates the anisotropic module layers of OLED products in detail. Through a careful combination of theoretical analysis and experimental methods, we endeavor to decipher the precise impact of the anisotropy of the module layers on the white color coordinate shift.. Our study explains the mechanism of the anisotropic layer's influence on the optical performance of OLED panels, verifies the theory through simulations and real measurements, and determines the optimal WAD corresponding to the optical axis angle of the anisotropic layer.

2. Principle analysis

Birefringence is a phenomenon in which a light beam incident on an anisotropic crystal is decomposed into two beams of linearly polarized light that are refracted in different directions, with the unusual light (o light) obeying the law of refraction at all times, and the extraordinary light (e light) not obeying the law of refraction[4]. However, in an anisotropic crystal, there exists a special direction along which light does not undergo birefringence when it propagates in the crystal, and this direction is called the optical axis of the crystal. Figure 1 shows the propagation of light in an anisotropic crystal in three cases. First, light is incident parallel to the optical axis, o light and e light coincide and no birefringence occurs; second, light is incident perpendicular to the optical axis, the propagation direction of o light and e light are the same, but the different propagation velocities produce a phase difference; and lastly, light is incident diagonally with the optical axis, the propagation direction and propagation velocities of o light and e light are different, and the light rays are separated.

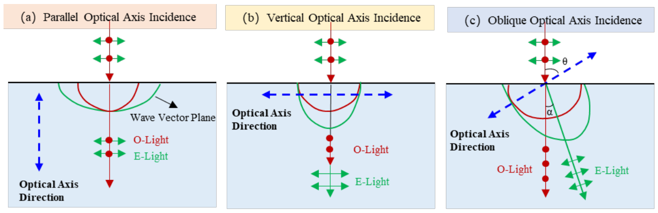

Figure 1. Schematic of light propagation in a birefringent crystal

Analyzed for the case of light incident obliquely to the optical axis, there is an angle (α) of divergence between e- and o-light.

$$\tan\alpha = \frac{1}{2}\frac{n_e^2 - n_o^2}{n_o^2\sin^2\theta + n_e^2\sin^2\theta}\sin 2\theta \tag{1}$$

The phase difference between o light and e light after passing through a crystal of thickness d is δ.

$$\delta = \frac{2\pi}{\lambda}\left(n_o - n_e^{'}(\theta)\right) \tag{2}$$

$$n_e^{'}(\theta) = \frac{n_o n_e}{(n_o^2\sin^2\theta + n_e^2\sin^2\theta)^{1/2}} \tag{3}$$

Where n_e is the refractive index of e-light, n_o is the refractive index of o-light, θ is the angle between the e-light wave vector normal and the optical axis.

From Equation (1) and (2), the dispersion angle and phase difference between o- and e-light are determined by the difference in refractive index and the angle between the incident light and the optical axis, which results in the light intensity being affected to different degrees at different outgoing angles. In other words, anisotropic crystals affect the viewing angle performance of the outgoing light, which is why a module layer with optical anisotropy will have a significant impact on the WAD of OLED products.

3. Results and discussion

We carried out a simulation investigation of the effect of different

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optical axis angles on the WAD of the OELD outgoing light through the numerical simulation software FDTD. The simulation model is shown in Figure 2(a), from bottom to top along the z-axis are the light-emitting layer (EML), polarizer (POL), anisotropic layer, and optical collodion layer (OCA), where the optical axis of the anisotropic layer is in the xy-plane, and the transmittance axis of the polarizer is along the x-axis. The simulation type is 3D, the boundary conditions are set to PML, and the light source is a dipole light source to simulate the change of WAD under the rotation of the optical axis of the anisotropic layer, and the rotation angle is the angle between the optical axis and the transmission axis of the polarizer. The simulation results are shown in Figure 2(b), and the WAD diagram characterizes the relationship between the white color coordinates (u',v') and the angle (0°, 15°, 30°, 45°, 60°, respectively), in which the color coordinates of 0° are (0.194,0.459). From the simulation results, the WAD diagram obviously changes with the rotation of the optical axis, which is consistent with the above theoretical analysis.

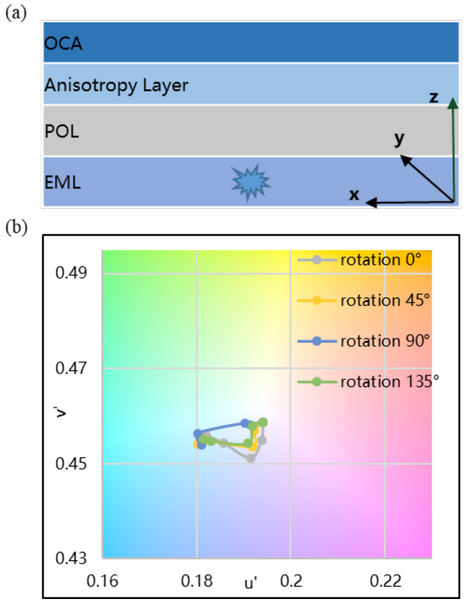

Figure 2. (a) Simulation Model Stacking Diagram (b) Simulation WAD Diagram

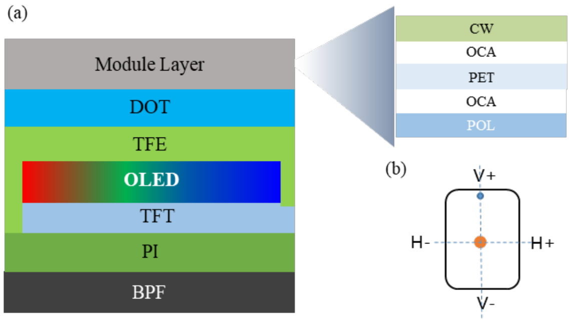

Figure 3. (a) OLED panel structure (b)Test direction schematic

We then conducted a systematic test, the measured OLED panel structure and the stacked structure of the module layers are shown in Figure 3(a), the PET layer, CW layer in the module layer all have optical anisotropy, but compared with the PET layer, the CW layer is less anisotropic, therefore, we only focus on the PET layer to investigate the influence of the optical axis on the WAD of the OLED panel. We conducted tests in four directions as shown in Fig. 3(b), namely, left-right (H-,H+) in the horizontal direction, and top-bottom (V+,V-) in the vertical direction, in order to compare the symmetry of the WAD of OLED panels, and the difference of the WADs in the horizontal and vertical directions.

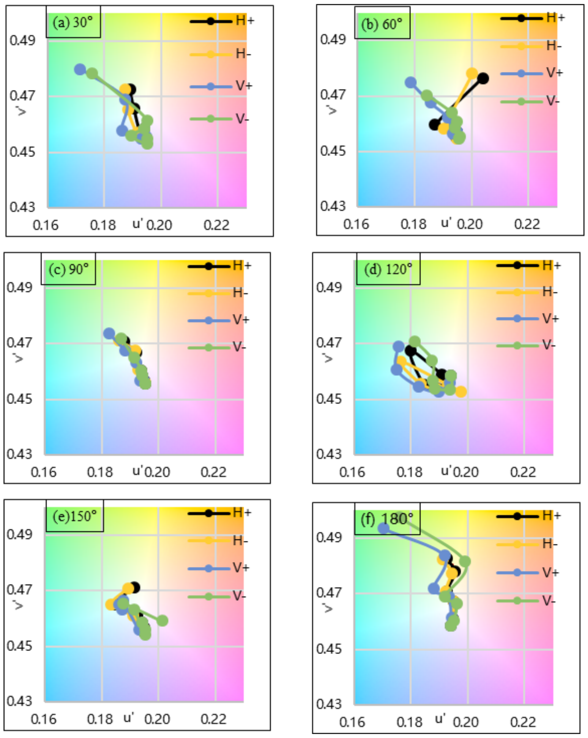

Figure 4. WAD diagram of OLED panel at different rotation angles of PET layer

Our test method is to rotate the PET layer at different angles and then laminate it on the same OLED panel, and then test the WAD maps in four directions. By comparing the WAD maps at each angle, we can obtain the WAD symmetry and the difference between the WADs in the H direction and the V direction, and determine the rotation angle of the PET layer corresponding to the optimal WAD map. As shown in Figure. 4, we compare the WAD maps at six angles, and we can see that when the PET layer is rotated at an angle of 90°, the WAD map of the OLED panel is optimal, i.e., the angular color deviation is minimized, and at this time, the WAD symmetry and the difference between the WADs of the H and V directions are all optimal.

4. Conclusion

This study mainly analyzes the effect of anisotropic crystals on the light output of OLED theoretically and verifies it by simulation. And through experimental tests, the optical axis angle of the module layer that minimizes the effect on the WAD of the OLED panel is determined. This research result provides an important theoretical basis and practical guidance for the optimization of WAD of OLED panel, which helps to promote the further development of OLED technology in related fields, and has a positive reference value for the subsequent research on the design and application of the module layer of OLED products.

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