View Angle Emission Pattern in ITO-TPD-Alq_3-LiF-Al Organic Light-Emitting Diodes

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Abstract : This report makes an important correction to estimating angular dependent emission pattern of Organic Light-Emitting Diodes (OLEDs). Today, experiments on measuring angular light intensity of OLEDs are conducted without considering the difference between the view angle identified by photodiode and the actual angle being measured. ITO-TPD-Alq_3-LiF-Al Organic Light-Emitting Diode was used to find out the degree of the error. In this case, the difference in average was about 1°, which is highly significant. Since the difference varies from case to case, the need for adjustment must be evaluated for each case.

Key Words : Angular dependence of emission pattern, Organic light-emitting diodes, Alq_3

1. Introduction

Thanks to lower power consumption, superior display quality, and self-emitting characteristic, organic light-emitting diodes have recently started to replace many of the earlier technologies in the flat panel display market. Naturally, understanding of emission pattern of particular devices is considered important part of current research as angular dependence of emission pattern is applied in calculating device efficiencies. Photodiode is generally used to measure angular light intensity of the device at a given distance and power. This common method, however, involves erroneous identification of the view angle being measured by photodiode with the estimated value. In this paper, we hereby present correction to the error by using specific data from ITO-TPD-Alq3-LiF-Al device.

2. Methodology

2.1 Experiment

A 5 mm wide ITO strip line was manufactured by etching, which used the solution of hydrochloric acid (HCl) and nitric acid (HNO_3) in 3:1. At room temperature, the substrate was exposed for about 10~20 minutes with the distance from the solution being 1cm. The following procedure was cleaning the patterned ITO glass substrate with distilled water. The substrate was resonicated in chloroform ($CHCl_3$), ethyl alchohol (C_2H_5OH), and deionized water for each about 20 minutes at 50 °C. After sonication, ITO was dried by N_2 gas heater, thereby successfully fabricating ITO-TPD-Alq_3-LiF-Al device.

Then, the ITO-TPD-Alq_3-LiF-Al device was positioned on the axis of the rotating sensor at a distance of 2 cm from the device. The silicon photodiode was set to rotate every 10 degrees from 0° to 60° to measure the light intensity at each angle θ'. The 0° rotation position was on the normal line to the emission surface. The wavelengths of the emission were increased from 400 nm to 700 nm; intensity was measured at about every 0.77 nm.

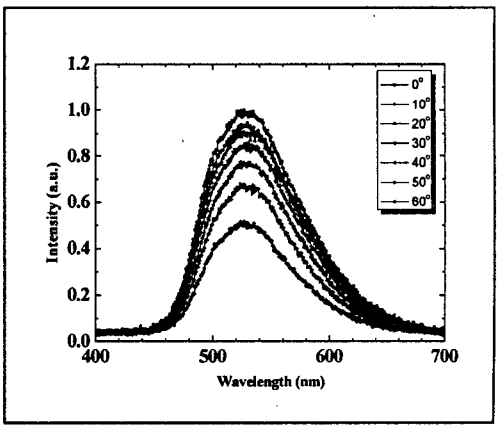

Figure 1. EL spectrum of emission at each view angle from 0 to 60 degrees.

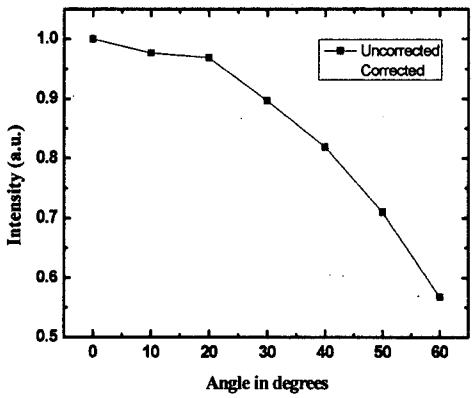

Figure 2. Angular dependent emission pattern of ITO-TPD-Alq_3-LiF-Al device from the experimented data.

From the computed data, a graph of light intensity and wavelength for each view angle was computed (Fig. 1). As noticed from the graph, maximum values of light intensity for each view angle had congruent wavelength at about 535 nm. These data was plotted in a graph showing the emission pattern according to view angle (Fig. 2).

2.2 Calculation

To find out the difference and determine the degree of error, the relationship between the two values must first be acquired. Whereas θ' is the view angle recognized by the sensor and θ actual view angle being measured, the relationship can be derived from trigonometry, using Sine and Cosine Law:

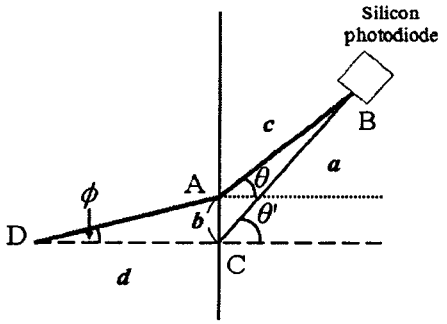

Figure 3. Variables identified for the calculation. A ray, coming from the device (D), is refracted at the interface of the device and air; silicon photodiode (B) detects the light.

$$\theta = \tan^{-1}(\tan\theta' - \frac{b}{a}\sec\theta')$$

Results are obtained through substituting the data from the experiment. ϕ values were obtained from Snell's Law, $n\sin\phi = \sin\theta$, while 1.5 was substituted for refractive index n, since glass, which is 1mm thick, is the dominant determinant. Obviously, b was obtained from $d\tan\phi$ whereas $d = 1\text{mm}$ as the thickness of glass was solely considered.

3. Result and Discussion

As a result, the error between θ' and θ was computed from the equation; the difference is as significant as about 1 degree (Table 1).

Table 1. Results from the derived equation.

θ'(˚)	θ (˚)	*Error* (˚)
0.00	0.00	0.00
10.0	9.67	0.33
20.0	19.4	0.63
30.0	29.1	0.88
40.0	38.9	1.06
50.0	48.9	1.12
60.0	59.0	1.04

To visualize the degree of error, a graph of angular dependent emission pattern of ITO-TPD-Alq$_3$-LiF-Al organic light-emitting diode was drawn from 0˚ to 60˚ to compare the uncorrected and corrected curves (Figure 4).

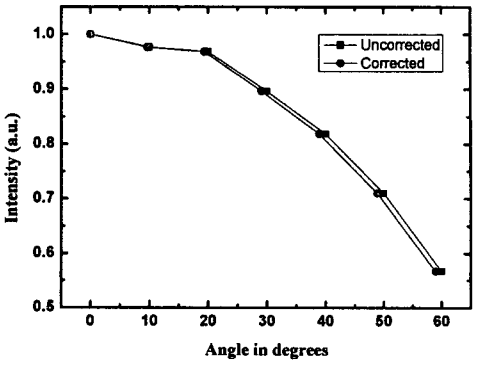

Figure 4. Angular dependence of emission pattern of ITO-TPD-Alq$_3$-LiF-Al device, showing uncorrected curve directly acquired from photodiode (blue), and corrected curve (green).

4. Conclusion

This research examined the degree of error between the view angle identified by the sensor and the actual angle being measured. The significance of the error was determined based on the experiment conducted by a sample device, ITO-TPD-Alq$_3$-LiF-Al organic light-emitting diode. In this case, the computed error was quite large and needed correction. The need for adjustment of view angle may be different in each model. Although this specific device contains considerably large error, other devices may not. As a general rule, the emission will be diffused more widely for thicker layers. Thus, devices with thinner layers (smaller d) will have smaller error; devices thicker than ITO-TPD-Alq$_3$-LiF-Al device will have errors larger than 1 degree. Other variables such as the distance between the sensor and the device (a), and refractive index (n) must also be concerned. Because many variables play important roles simultaneously in determining the level of the inaccuracy, error evaluation is required for each case.

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