1.5" Full Color ECR(Enhanced Contrast Ratio) OLED Using Black Layer Technology

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Abstract

Hyundai LCD Inc. and LUXELL Technologies Inc. have jointly developed a 1.5" passive matrix full color OLED display (132×RGB×96, 111ppi) with characteristics of enhanced contrast ratio using black layer technology. This prototype ECR OLED was fabricated with the structure of ITO/HIL/HTL/RGB EML/HBL/ETL/LiF/Black Layer/Cathode and showed significant improvement of contrast ratio comparing with that of non-filtered OLED as well as compatible with circular polarizer OLED

1. Introduction

More people are getting interested in organic light emitting diode(OLED) since its performance and reliability has been remarkably improved to apply for flat panel display since Kodak's introduction in 1987 [1,2].

OLEDs are now widely recognized as a new emerging display technology as a substitution for dominated LCD in FPD market and many commercial OLED products were already adopted in mobile phone as a sub-display or main display of major display manufacturers in the world, and enlarge their potential application as future flat panel display.

In recent years, OLED technology has been shifted from R&D phase to production level as enhancing its reliability while strengthening its intrinsic advantages such as high brightness, fast response time, wide viewing angle, and low operating voltage. Balance of production cost and display performance most likely become a key issue of OLED industry in the near future and ECR OLED including Black Layer will be among candidates to give a contribution to achieve it.[3]

The technical advantage of Black Layer Technology is to achieve a polarizer-free OLED panel with same visual quality. Implementing Black Layer to conventional OLED, we fabricated an ECR (enhanced contrast ratio) OLED with cathode deposition process and polarizer attachment process was eliminated. Another merit in OLED production is low process cost. Just adding silicon monoxide deposition process in cathode deposition process to form three-layered metal and metal silicon oxide, high-cost polarizer can be substituted with low-cost Black Layer without reducing contrast ratio and reflectance ratio.

We have prepared a full color ECR OLED display by using Black Layer Technology. The display has resolution specification of 132×RGB×96 pixels with uniformed pixel size of 0.228 × 0.228 ㎟ as summarized in Table 1.

Display Type	Passive Matrix
Glass Size	38.571 x 31.413 ㎟
Active Area	30.071 x 21.863 ㎟
Viewing Area	32 x 23 ㎟
Pixel Pitch & Size	0.228 ×0.228 ㎟
Dot Gap	25㎛(C) x 25㎛(R)
Aperture Ratio	59.7%

Table. 1. Specification of Full Color Passive matrix OLED panel

2. Experiment

An indium-tin-oxide(ITO) glass substrate on 0.7 t soda lime glass with 1300 Å and 0.5 Ω/□ of sheet resistance was used as transparent anode. Stripe type

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column of anode pattern was formed in the active area by photolithography method and it has 228 μm pitch along with optimized (60degree) taper angle after patterning of insulating layer and cathode separator later on. Surface treatment of ITO film on glass substrate is one of important method to build up reliability and performance of panel. Oxygen plasma treatment was done prior to vacuum deposition of organic layers.

The ECR OLED was fabricated in multi-chamber vacuum deposit system with thermal sources and encapsulated under nitrogen environments with device structure composed of a glass substrate with a patterned ITO anode.

Organic layers are fabricated by thermal deposition rate control using thickness sensor. Device is composed with multi layers: a 4,4',4''-Tris(N-(2-naphthyl)-N-phenyl-amino)-triphenylamine(2-TNATA) hole-injection layer, a N,N'-Di(naphthalen-1-yl)-N,N'-diphenyl- benzidine (a-NPD) hole-transport layer, a R,G,B emitting layer, and a Tris-(8-hydroxy-chinolinato)-aluminium(Alq3) electron-transport layer. LiF buffer layer is used between the organic stack and the cathode to improve the device performance. The cathode using Al black layer technology is composed of four layers. It consists of three different deposition rates of Al:SiO buffer layer, and 1000 Å of thick aluminum layer. Aluminum and Silicon monoxide is co-deposited to form 1st to 3rd layer of Black Layer by thermal evaporation.

3. Result & Discussion

It is a textbook knowledge that the speed of light in vacuum is independent of the wavelength of light. The velocity of propagation of electromagnetic waves through a solid depend on the wavelength of the radiation and is given by the complex refractive index

$$N = n - ik ,$$

where the real part, n is related to the wave velocity, and k is the extinction coefficient, related to the damping of the oscillation amplitude. The extinction coefficient determines the extent to which light is slowed down in the material.

By selecting the extinction coefficient and thickness of the media, it is possible to control the phase shift between the incident and the lagging waves. If now the original wave is broken down into two parts by a semi-transparent film (Fig. 1), the phase shift between the two parts will increase with the thickness of the solid. If the lagging wave is now reflected by a reflective surface in the opposite direction, it will interfere with the original wave reflected from the first surface. The phase shift of 180 ° between the two reflected waves will mean the destructive optical interference. Selecting the amount of the reflected and transmitted light through the first layer, it is possible to make the two reflected waves being of the same magnitude, but propagating out of phase, which means their cancellation

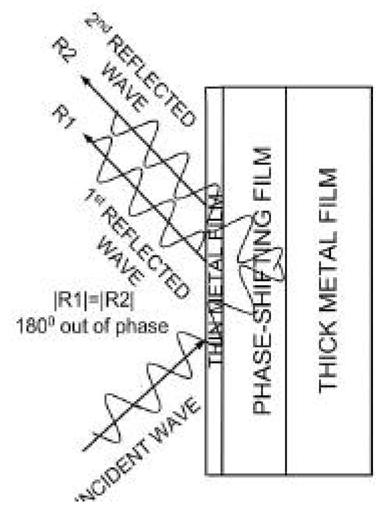

Fig. 1. Basic principles of operation of the optical interference contrast-enhancing stack.

Luxell Technologies Inc. used this principle to develop a new concept [4] of eliminating the reflected light from an electroluminescent display. The concept interposes a destructive optical interference stack (Black Layer™) between the light-emitting part of the device and the Al electrode. Later the stack was applied to OLED devices [5]. This contrast-enhancing stack (CES) has a combination of an ultra-thin (~20-50 Å) semi-absorbing metal layer, a phase-shifting layer of a transparent conducting oxide (such as ITO, ZnO:Al, SiO-based materials, etc.), and a thick reflective metal layer (such as Al). The ultra-thin metallic film causes partial reflection of the ambient light. The whole stack is treated as an optical interference filter. A computer analysis is based on the calculation of the characteristic matrix of each layer, a component of this stack [6-8]. Thickness of the individual films is chosen such as to provide a

180° phase shift between the two reflected waves of the same magnitude, which causes the cancellation of the reflected light

Full color ECR OLED display using Black Layer Technology was fabricated using normal 1.5" conventional OLED.

We measured reflectance of OLED via vertical reflectance measurement method. The source and detector part lean to 8 degrees from orthogonal line and reference reflectance material is MgF2 coating plate, which has normal reflectance of 91.5%. The reflectance of ECR OLED was compared with normal OLED as selecting Al plate as a reference material.

Reflectance of ECR OLED is only 16.5% of conventional OLED's which is relatively similar with that of OLED optically filtered by circular polarizer devices in the region of 380~790 nm because of optical interference effect as described in Figure 2.

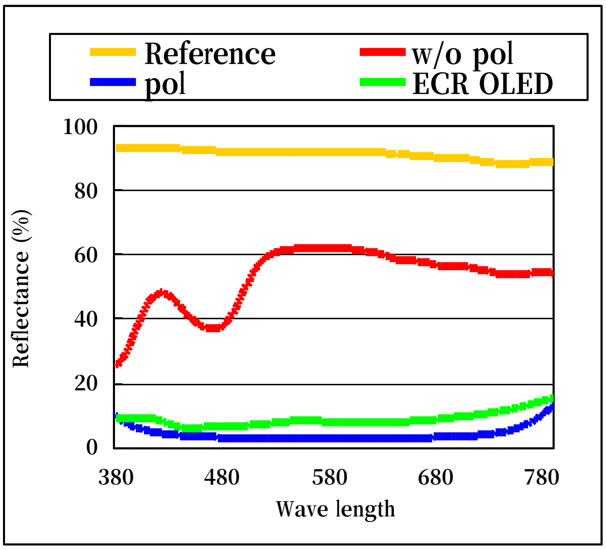

Fig. 2. Reflectance comparison of the normal OLED panel without Black Layer and with Black Layer.

The contrast ratio is measured using OLED panel with proper module IC. We arranged a chessboard image and measured the brightness of full-on and full-off area using BM-7.

Sample	Average Reflectance(%)
Reference	91.2575
Without polarizer	52.7371
With polarizer	4.0945
ECR OLED	8.7172

Table 3 : Comparison of the reflectance : the normal OLED with or without polarizer and ECR OLED

Contrast ratio of ECR OLED, 40:1 is also competitive to that of circular polarizer OLED, 38:1. These results suggest possibility of replacing circular polarizer with Black Layer as long as process tolerance can be acceptable in the manufacturing process of OLED.

Sample Table	With Pol.	Without Pol.
Normal OLED	38.57	5.56
ECR-OLED	-	40

Table 4 : Comparison of the contrast ratio : the normal OLED with or without polarizer and ECR OLED

4. Conclusion

We have fabricated full color ECR OLED display integrating Black Layer Technology.

The reflectance of ECR OLED is only 16.5% of conventional OLED's. The contrast ratio of ECR OLED and conventional circular polarizer OLED is 40:1 and 38.57:1 respectively.

This ECR OLED is first pixilated full color OLED device using Black Layer in the designed product.

Replacement of expensive circular polarizer by Black Layer in OLED display will contribute to OLED's market penetration considering product cost along with reasonable performance.

5. Acknowledgements

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6. References

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