

The Development of 403ppi real RGB Printing AMOLED

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Abstract

A 403ppi (pixel per inch) real RGB AMOLED was fabricated without using Fine Metal Mask (FMM). Organic light-emitting layer material was printed on array panel, resulting in a novel process with low cost and high pixel density. The OLED materials printed uniformly and the OLED device performed good property. The profile of the pixel was designed as a hexagonal pattern. Based on this design, it is possible to achieve 403 ppi real AMOLED using pixel printing process. The image quality for this hexagonal pixel arrangement was evaluated by a bmp format Pixel Layout Simulation picture.

Author Keywords

AMOLED, High Resolution, Printing Process, Real RGB.

1. Objective and Background

Recently, active-matrix OLED (AMOLED) has been the mainstreamed display technology for mobile and high-end TV devices in the market with superior display quality. Especially for automotive display, its excellent performance and foldable form may bring best driving experiences. Obtaining high resolution using AMOLED technology with reasonable cost is a big challenging. FMM would be the biggest issue for evaporation process [1]. Currently the best method to achieve high resolution AMOLED without FMM is printing process. However, printing process is more suitable for the resolution lower than 200 ppi, because the inkjet droplet volume of the nozzle head is too large and adjacent smaller pitch pixels are easy bridged. A hexagon shape pixel was designed to increase the resolution with current printing process while each inkjet droplet area contains six sub pixels. Then, high resolution technology will be limited by driver TFT panel process instead of printing process.

In this paper, inkjet printing process will be illustrated, the quality and property of the printing OLED film and device will be discussed. Specific hexagon shape pixel structure including sub pixels and PDL design will be elaborated. And this special pixel structure will be evaluated by a bmp format Pixel Layout Simulation picture. Finally, a 403 ppi printing OLED demo will be demonstrated.

2. Discuss

2.1 Printing process

In our work, the hole injection layer (HIL), hole transport layer (HTL) and emitting layer (EML) were fabricated by inkjet printing process. In order to realize the high resolution pattern, it is necessary to develop small volume and stable ink drop and highly accurate drop placement. The drop volume was mainly determined by the size of printing nozzle and the ink physical property, such as the viscosity, surface tension, which can adjust by ink formulation. We also fine tune the driving waveform to ensure the printing stability and volume minimality. It can also minimize the ink jetting angle to decrease the drop placement shift. To further improve the droplet placement accuracy, the

customized printing algorithm is used, as well as decrease the line mura during printing process.

One of the biggest problems during the printing is to obtain uniform film profile, which directly affects the emission uniformity, efficiency and lifetime. And the key to film uniformity is the drying process of the wet film, which is related with the ink formation, bank property, vacuum dry condition and so on. In our research, we mainly modified the vacuum dry process to improve the film uniformity. By properly regulate the temperature (T), vacuum drying speed (V), vacuum drying time (t) and vacuum drying gap (d), we had film uniformity above 70% for HIL/HTL/EML layer within the $\pm 5\text{nm}$ range.

2.2 OLED device property

In order to reach good device uniformity and high current efficiency, the device architecture is both simulated by setfos software, as well as experimental split test. As the result, second harmonic device architecture design is implemented in our 403ppi high resolution AMOLED display. With this thicker device architecture, defects can easily avoid and higher device performance is achieved. Figure1 illustrates the device architecture and property. The device cavity is weak top emitting, and the efficiency is improved with big view angle.

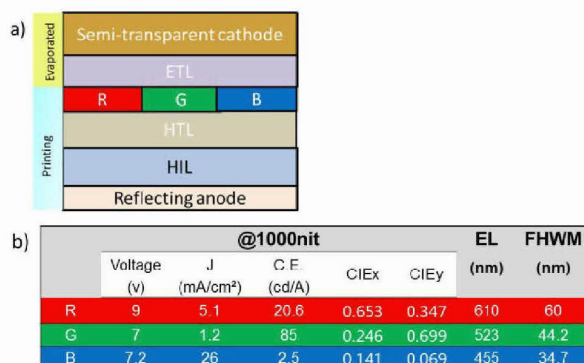


Figure 1. Architecture and performance of OLED devices made by inkjet printing process.

2.3 Pixel design

To achieve high resolution, the PDL was designed as hexagon shape. The detail of the design is shown in Figure 2. Six same color sub pixels were gathered together in one PDL. Each sub pixel in this PDL was formed into one main RGB pixel with the adjacent another two sub pixels of different colors. As shown in Figure 2, six red sub pixels in one PDL separately mix with six green sub pixels and six blue color sub pixels which are in adjacent to PDLs. Each sub pixel is defined as quadrilateral area. The hexagonal PDL was divided into six quadrilateral area. All these six quadrilateral elements were central symmetry in the hexagonal area, and the area value of the six quadrilateral pattern was equally as the 1/6 hexagonal area value.

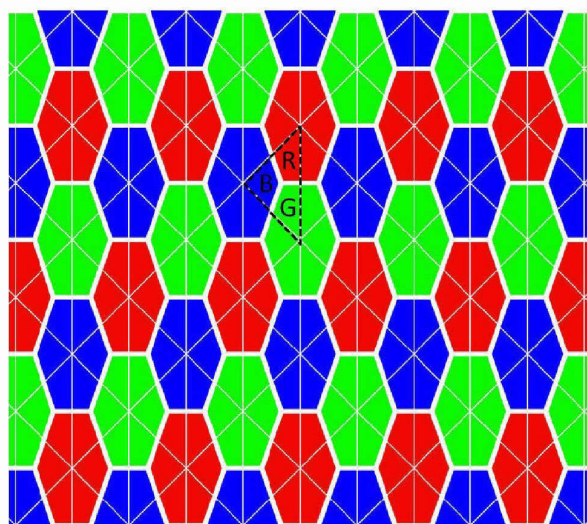


Figure 2. Hexagon shape PDL structure which contains six sub-pixel with the same shape, and the method how RGB color mixed.

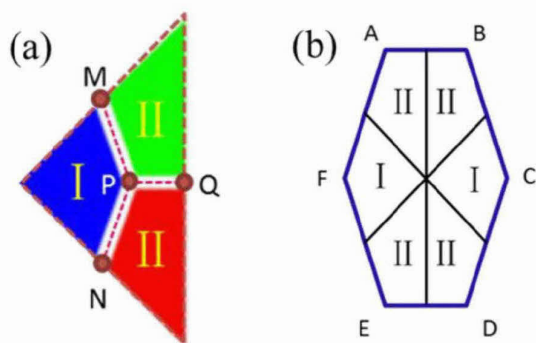


Figure 3. (a) Left image shows the main RGB pixel area put into an isosceles right triangle. (b) Right image shows the structure of a single-colored hexagonal PDL.

Figure 3 describes how the three quadrilateral patterns form one main pixel. These three quadrangle area could be put into an isosceles right triangle shape. The area value of three quadrangle patterns must be equally to $1/3$ of the isosceles right triangle area value, thus formed Pattern I and Pattern II with the cutting line PM, PN and PQ. So one Pattern I and a couple of axial symmetry Pattern II made up the isosceles right triangle that is presented in Figure 3(a). RGB color element will fill this isosceles right triangle which formed one main pixel unit. Likewise, it benefits that isosceles right triangle RGB arrangement mode realizing color grey level will be more effective.

With this RGB configuration rule six quadrilateral patterns made up single-colored frame enclosed by the PDL. Line PM, PN and PQ define the border of hexagonal PDL. Obviously, the length of PM and PN is the same. Assume the length of PM/PN is “a”, and

PQ is “b”. The single-colored Hexagon ABCDEF (six corners of the hexagon) contains two Pattern I and four Pattern II as presented in Figure 3(b). The length of AB & DE are equally to “2a”. The length of BC&CD & FE&FA are equally to “2b”. With this RGB configuration rule these PDLs and sub pixels array to the whole active area. The gray level color can be achieved through adjusting the brightness of these adjacent three sub pixels. And this structure will realize 403ppi real RGB display, of which the image quality is better than the image quality of SPR (sub-pixel rendering) display with the same ppi.

2.4 Pixel film structure

General Figure 4 shows pixel position film sectional view. Pixel open area ① is divided by PDL ③. Single OLED device which can be controlled for every sub-pixel is limited to the SPDL border. OLED device components contain OLED film ⑤, anode ④ and cathode ⑦. Same color OLED film ⑤ in the pixel open area ① is limited to the PDL border. The anode of different sub-pixel open area ② in the same pixel open area ① is divided by sub-pixel define layer (SPDL) ⑥. Anode ④ and OLED film ⑤ is independent respectively which is divided by SPDL ⑥. The anode ④ for every sub-pixel is electrically connected with a driving circuit. Electron is injected from cathode and hole is injected from anode when voltage is applied on. After electron-hole recombination and light emitting in OLED emitting layer, the display image is presented by every sub-pixel area ②.

2.5 Pixel configuration evaluation

It is necessary to simulate the display effect of the designed pixels so that the picture quality and possible defects of the pixel shape can be evaluated. Visual Basic programming language is used to write a pixel simulation program, which converts the designed pixel shape into an analog solution and then outputs the simulated image. Multiple pixels in monitor are used to simulate a real designed pixel. The simulated pixel shape is close to the true shape of the original design pixel in terms of shape, scale, arrangement, etc. Hexagon pixel analog scheme is shown in Figure 5. In this simulation scheme, six pixels are used to simulate one real sub-pixel, 36 pixels are simulated in one PDL region, and the image generated by the analog pixel is in bmp format, and the original image magnified 36 times is shown in Figure 6. Figure 6(a) shows the original picture. The effective graphics information is in top left corner of Figure 6(a). Because analog picture need to be magnified 36 times, most of the original picture should be blank. After simulating the original hexagonal pixels, the analog picture is made up of basic RGB grid point using the computer monitor's pixel unit. The brightness analog picture (Figure 6(b)) is darker than the original picture due to the luminance of the simulation pixel darker than the monitor's real pixel. Figure 6(c) shows the details of simulation pixel of a part of the original picture. It seems that the image quality of hexagon pixel design is favorable and there are no obvious defects as the result of the simulation.

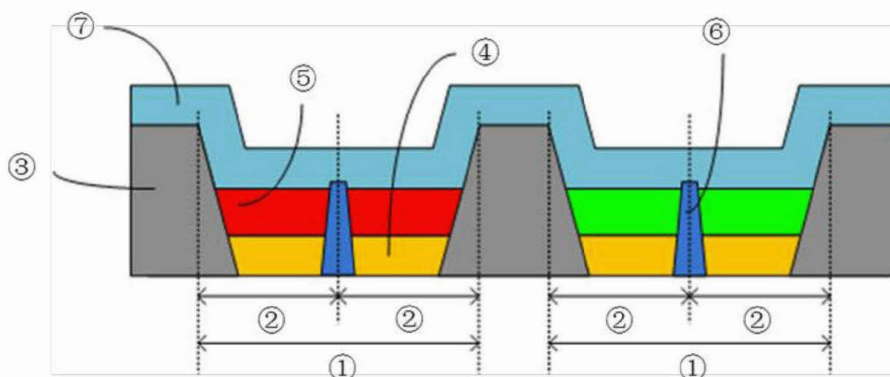


Figure 4. Display area sectional sketch map.

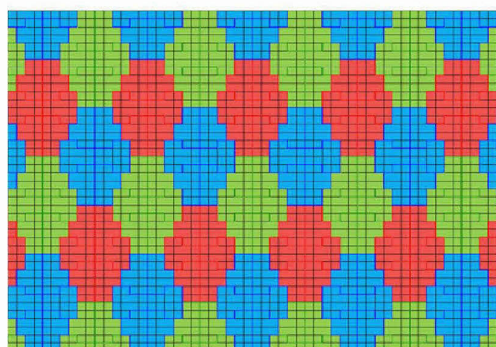


Figure 5. The simulation scheme of hexagon pixel.

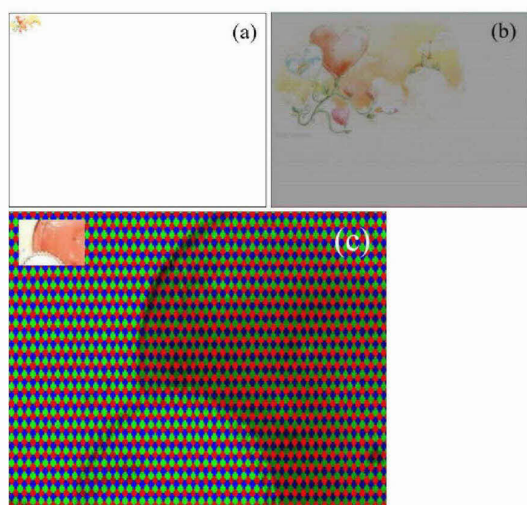


Figure 6. (a) Original picture. (b) Analog picture. (c) Details of simulation.

2.6 Demo display

Figure 7 shows a demonstration of the prototype display panel using the proposed hexagon pixel arrangement, which was designed for 4.92 inch and 1728×972 resolution with 403 ppi. It was the first time we output 403 ppi real AMOLED demo using

pixel printing process. Image quality is fine excluding some process issues.



Figure 7. Demonstration of prototype panel using the proposed hexagon pixel arrangement.

3. Impact

It is the first report that a real RGB 403 ppi panel has been demonstrated with printing OLED process, using the design of hexagon shape pixel and the process of printing OLED, resulting in a scalable, cost-effective manufacturing method for RGB high resolution AMOLED panels.

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5. References

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