Active-Matrix OLED (AMOLED) Microdisplay for Augmented-Reality Applications with Improved Color Space

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ABSTRACT

Our contribution describes the optimization of OLED microdisplays to increase the color gamut and to reduce the OLED complexity. We show that these improvements can be reached by a 3-color RGB-white OLED approach that features a single layer multicolor emitting zone, respectively.

1. INTRODUCTION

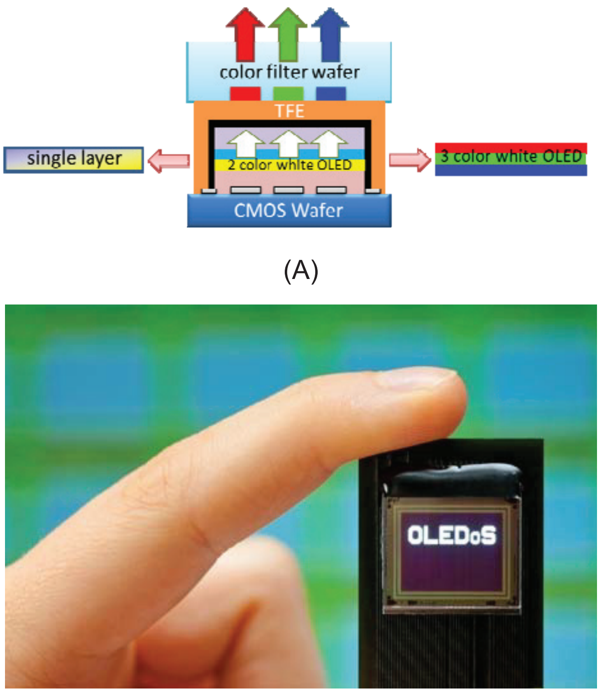
The technical simplicity of an OLED structure and consequently simple fabrication, as well as superior picture quality are important factors for future mass market lifestyle applications such as video glasses or head-mounted displays in combination with wearable computer systems. Today's OLED displays in smart phones already feature up to 97% of the AdobeRGB color gamut [1] with Full-HD resolution and negligible color shift under various viewing angles. In OLED microdisplays, these aspects are more challenging due to the dimensions of the emitting pixels of a few µm only. The combination of lithographically structured color filters on top of a white OLED is state of the art while sub-pixel patterning of active OLED pixels is already under development [2].

In our contribution, we show two aspects of OLED stack-optimization results to be applied in active-matrix OLED microdisplays. On the one hand, the color gamut drastically depends on the color filter properties, their alignment to the emitting OLED pixel and the spectral distribution of the electroluminescence (EL). On the other hand, the simplification of the OLED architecture is a key to reduce production time and costs.

2. OLED MICRODISPLAY

AMOLED Microdisplays, discussed in this contribution are based on a CMOS Si-backplane, followed by a vacuum-deposited small-molecule white OLED with molecular doped charge transport layers. On top, a thin-film encapsulation protects the OLED from oxygen and moisture. Further, a glass wafer, containing pre-structured color filter sub-pixels is laminated. Details about the process chain can be found in previous publications [3].

The standard OLED stack is a 2-color (blue-yellow) fluorescent white system as shown in Figure 1. The color separation takes place via absorption of the undesired parts of the white EL-spectrum. The generated EL from the emitting molecules, in combination with micro-optical interference effects as well as the transmission function of color filters define the achievable color gamut of the display. A major problem is the splitting of the yellow EL-peak into green and red light. This approach requires very distinct spectral transmission functions of the CF materials.



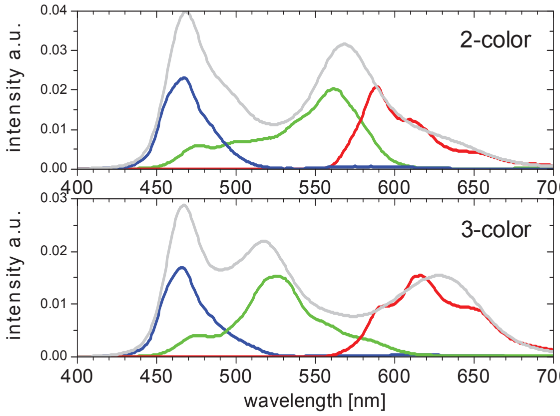
(A)

(B)

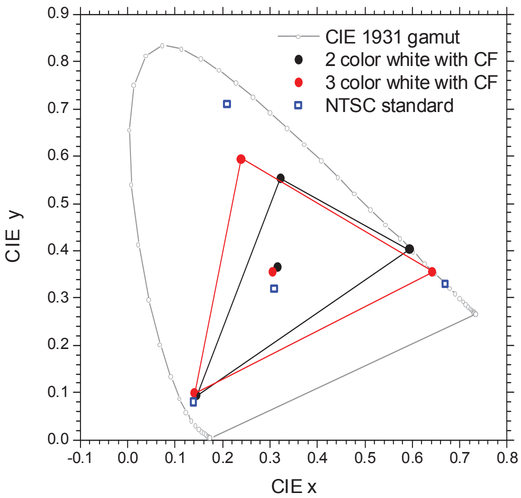
Fig. 1 Schematic cross-section of an OLED microdisplay with either 2- or 3-color white OLED, thin-film encapsulation (TFE), and the top-most color filter wafer (A) and working OLED microdisplay comprising 2-color white OLED, mounted onto PCB (B).

3. RESULTS

Beside the optimization of the color filter design, e.g. varying the CF material or its thickness, one strategy to extend the color gamut of the microdisplay is to replace the state of the art 2-color white OLED by a 3-color white approach. Later on, the color filter can further be optimized to extend the color gamut (e.g. 100% NTSC). First results of optical simulations of a complete AMOLED microdisplay layer structure confirm the idea. The EL spectra in Figure 2 (A) show the impact of the color filter on the spectral width and overlap in emission of adjacent sub pixels. As depicted in Figure 2 (B), the gamut drastically increases from 48% to over 70% of NTSC just by matching the transmission functions of the CF materials with the emission peaks of appropriate OLED emitter materials.



(A)

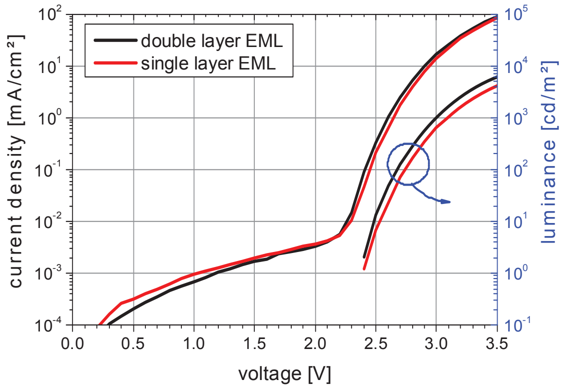


(B)

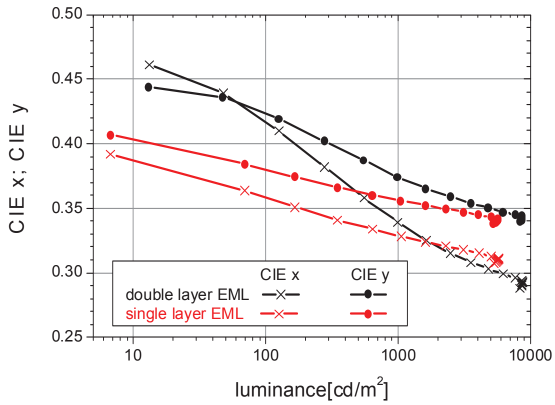
Fig. 2 Comparison of calculated EL spectra (A) and the corresponding color gamut (B), either with state-of-the-art 2-color (black dots) or new 3-color (red dots) white OLED. These approaches are able to cover 48% and 70% of the NTSC space, respectively. The increased distinction of red and green color can directly be observed.

Changing from a 2-color to a 3-color white OLED, the overall luminance is maintained, assuming well balanced charge transport and exciton management.

Further it has to be noticed, that a 3-color, 3-layer emitting zone requires a rather complex OLED process. Therefore, we first evaluated a 2-color white OLED with either a double- and a single emission layer to study the concept of stack simplification on a less complex emitting layer. The single layer contains both emitting dopants in one host while the double layer is a stack of a yellow and a blue emitting layer, both of host-dopant architecture.



(A)



(B)

Fig. 3 Current-voltage-luminance characteristics (A) and color coordinates (B) of double-layered compared to single-layered emission zone for 2-color white light generation.

As shown in Figure 3, there is no remarkable difference in the current-voltage characteristics between both approaches and only a slightly lower luminance at a given current is observable which is partially due to the different color coordinates. Further, the single layer design leads to an increased color stability with varying driving voltage.

We expect the single emitting layer to show less color shift by further optimization of emitting layer and adjacent blocking layer. The double layer system is much more sensible against the charge balance inside the emitting zone, resulting in a strong shift of e.g. CIE x between 10 and 10000 cd/m^2. This concept would be preferable to realize 3-color white OLEDs comprising a single-layer emission zone.

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