Adaptive Micro-Display Pixel with Quantum Dot and Guiding Layers for Compact Arrangement

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Keywords: Micro-LED, Quantum Dot, Color Conversion

ABSTRACT

Color conversion material such as quantum dot can be used extensively for high density and small pixel display. However, process of color conversion materials could impose limitations on the pixel characteristics. This article shows the use of guidance layers to alter pixel density, for the possibility on generating compact subpixels.

1 Introduction

In order to obtain colour displays, most LED (e.g. micro-LED) structure will introduce short wavelength emitters (e.g. Blue LED or UV-LED) as light source, then apply color conversion material (CCM) such as quantum dots, for generating colors [1-5]. Due to the process capability, a specific spatial configuration between pixels is required to ensure the stability of the process for generating pixels. In addition, optical requirements suggest that materials such as black photo-resistance [6-7] need a critical design to guarantee the crosstalk-free between pixels (Fig.1).

However, the integration of such a structure will inevitably limit the pitch between pixels and affect overall performance for compact pixel alignment. In addition to the above problems, the sub-pixel layout of each color also faces a variety of challenges. These include the conversion efficiency of CCM (in the followings the quantum dots are introduced as example) for individual spectrum, the brightness of each color, the required thickness [8] and the layout for subpixels. In addition to the structure mentioned above to avoid crosstalk, quantum dots must also be manufactured in a separate layer, so that problems of alignment tolerance become critical. All of these factors reduce the ability to create higher density pixels for non-native color micro-display.Based on the above explanation, the overall pixel layout and the resulting optical efficiency need to be refined by improving the process or by designing the new optical structure. The following report explains with demonstrations for the proposed micro-display pixels.

2 Methods

In general, the configurations designed for each pixel are determined by the brightness and colour conversion efficiency of each subpixel. Fig.2 shows the image of pixel and sub-pixel in full-color micro-LED sample. As indicated in this figure, the pixel consists of 4 sub-pixels with GGRB layout. It is clear that the pitch between sub-pixels is generally larger than the size of the sub-pixel, because of the limitations of the QDPR process and the layout of the micro-LED pixels. In order to overcome the reality of not being able to make an extreme compact pixel's layout on the physical substrate, a concept similar to AR at the pixel level is introduced [8].

In this design, *the physical and virtual subpixels are arranged together to obtain the so-called adaptive pixel arrangement*. This makes it possible to get compact pixel arrangements, or even a mixed spectrum pixel setup. On the basis thereof, Fig. 3 is an illustration of the proposed pixel structure [9], which is compatible with pixel smoothing techniques [10-13]. This demonstration uses the blue micro-LED as the excitation source (but not limited to), with a quantum dot color conversion layer coating on the output side of the micro-LED for green and red sub-pixels. An area of transparent material is assigned to the blue light emitter location. Now, the tricky part is that this location need not align exactly with the position of the blue pixel. Note that a *light conducting structure* with the aperture on the upper layer determines the position of the blue subpixel. As can be seen from the schematic diagram, position of the red/green sub-pixels is directly defined by the process of quantum dots, while position of the blue sub-pixel can be determined by the adjustable aperture of the light conduction structure. Therefore, by calibrating the position of aperture (statically/dynamically), the configuration and density of pixels can be change. In general, proposed method may reach the sub-pixels mixings.

3 Results and Discussions

Based on the arguments above, this section demonstrates the concept of adaptive pixel design. The methodology can be considered as an augmented virtual image based on a pixel, which means that the virtual pixel can be superimposed on the physical pixel, as illustrated in Figure 4.

The present technique overlaps the aperture of the light conducting structure upon the position of the quantum dots. By doing this, one can produce a colorful mixture between blue pixel and red/green pixel. In particular, the shape and size of virtual pixels can be arbitrary, and this concept could be applied to different light emission mechanism.

Fig. 5 show the comparison of micro-LED displays before and after the sub-pixel position adjustment. Notice that the size of a virtual adaptive pixel is different to the initial pixel size. By using this concept and reorganizing the positions of the sub-pixels, the pixel density is modified. Resolution and luminosity per pixel zone can be changed. This concept can also be used to create a mixed color sub-pixel, such as the purple color produced by mixing blue and red, shown in the demonstrated figures.

It is necessary to discuss the part of the light conducting material to implement this concept to other light source configurations. By doing this, one can perform the blending of other color light, or move the sub-pixel of other colors. For example, to move a red pixel, the criteria are to select the material and coatings that correspond to the specific wavelength for the light conduction structures. Possible application can be considered as shown in Fig.6, along with pixel smoothing techniques, but the efficiency is the issue needed to be an exam.

4 Conclusion

This article describes a special adjustable pixel that can adjust the position of the sub-pixel by changing the position of the light emitted from the excitation source, thus making each sub-pixel closely aligned. By applying this idea and arranging the sub-pixels correctly, the pixel density can be increased and the luminosity of the panel can be improved. The proposed method makes it possible to modify the pixel geometry, reduce the effect of process limitation, improve pixel resolution and change the brightness distribution. In addition, this proposal is not limited to components with blue micro-LED as the light source, but can be applied to components with different type of light sources (e.g. micro-OLED).

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Acknowledgements

The authors would like to thank to Dr. Ching-Nan Chuang for the pilot run of the QDPR material. Conclusive discussion with Dr. Fleming Fu-Ming Chung, Dr. Chuan-Chung Chang, Dr. Hung-Ta Chien and Mr. Kevin Huang are addressed. We also like to express our gratitude to Prof. Dong-Sing Wuu, Dr. Kai-Ping Chang and Mr. Chih-Wei Lo from National Chung Hsing University for the fabrication of the QDPR samples and the integration of the micro-LED demo kits. Financial support from Coretronic Corporation for QDPR project code and business grant are most appreciated.

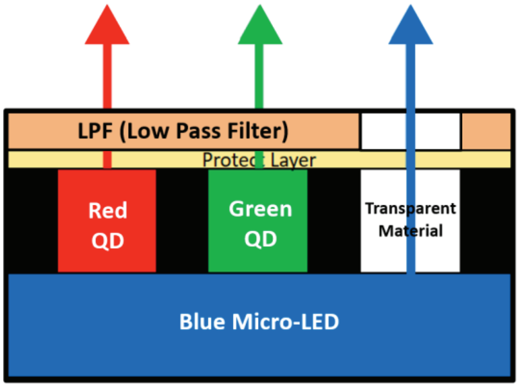

Fig. 1 Conventional design of full-color micro-LED.

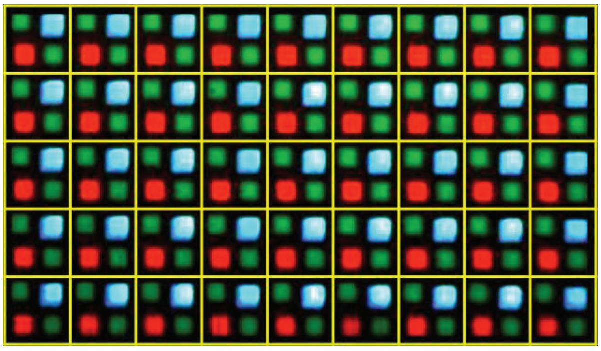

Fig. 2 The image of pixel and sub-pixel in full-color micro-LED sample.

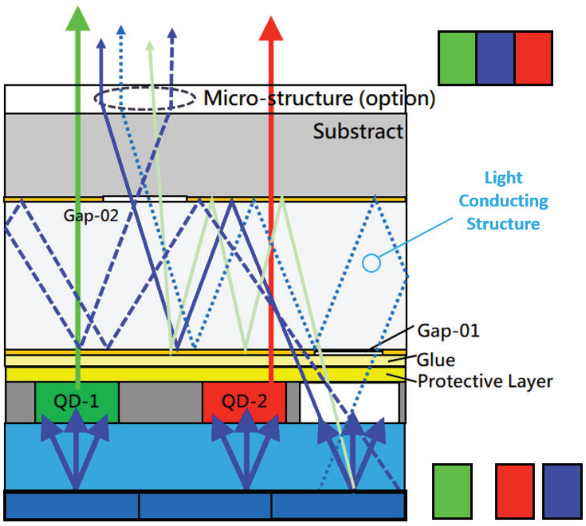

Fig. 3 Schematic of sub-pixels compact arrangement case. The exit of blue ray is determined by the gap of the light conduction layer.

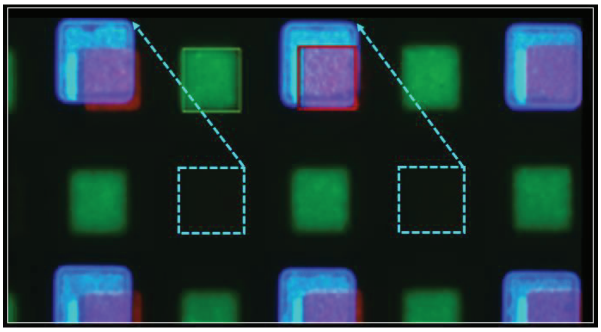

Fig. 4 Overlapping between blue and red sub-pixels generating purple sub-pixels.

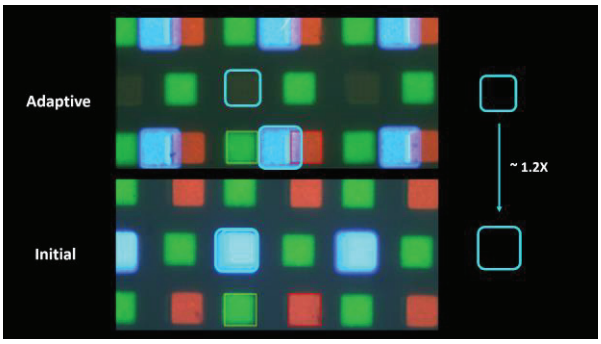

Fig. 5 The comparison between initial state and adaptive arrangement state. Compact arrangement will increase the density of pixel and provide space for other pixels.

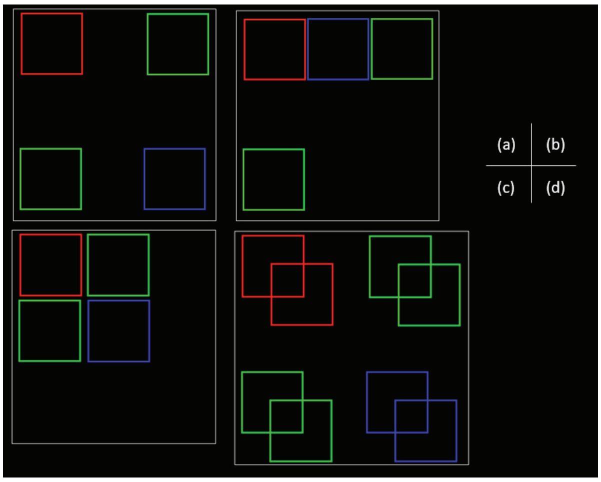

Fig. 6 Four possible scenarios (a)-(d) for adaptive arrangements with different conducting layers and coating design. Further introducing the pixel smoothing or wobulation by different means is possible.