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# The Excellent Full-color Micro Display Dominated by RGB Quantum dots

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## Abstract

**This study dominates the red, green, and blue micro-LED pixel by the jet of the quantum dots. The micro-LED array is with the size of 35μm, which is sufficient for high-resolution screen applications. The RGB QDs were jetted into the UV micro-LED array by the Aerosol Jet technology and yield the full-color display. The excellent micro display is with the 165 lm/w of lumen efficiency and 1.52 times of the NTSC color gamut.**

## 1. Introduction

In common, the light utilization efficiency (LUE) of the LCD display system is still lower than 2.8 % [1], most passive components such as color filters can absorbed a large portion of emitted photons [2]. It means that the display needs to be operated at more than ten times of brightness in order to meet the expected output optical power. One solution is to incorporate individually addressable RGB light emitting devices which can replace the color filters.

The RGB quantum dot QD can be a great candidate to yield the full color display and resolve the low light utilization efficiency problem. The QDs possesses unique properties such as high quantum yield, size-dependent emission wavelength, and narrow emission line-width [3-5]. This study report a full-color LED based display by combining UV micro LED arrays with RGB QDs via aerosol jet printing technology [6].

## 2. General Instructions

As shown in figure 1, standard multiple quantum well (MQW) LED were grown on sapphire substrates for the micro LED arrays with the consisting of 128 x 128 arrays of 35 μm micro-emitters and the center-to-center pitch of 40 μm. The UV passive-matrix micro-LED arrays were fabricated on UV wafers with peak wavelength 395 nm, respectively. Prepare the 5 mg/mL of the RGB QDs solution and use the aerosol jet printing method to spray the RGB QDs on the micro LED array sequentially. Finally, the RGB QDs were sprayed onto the surface of the micro LED array using the aerosol jet method in the sequence of red, green, and blue, as shown in figure 1(a)(b)(c)(d).

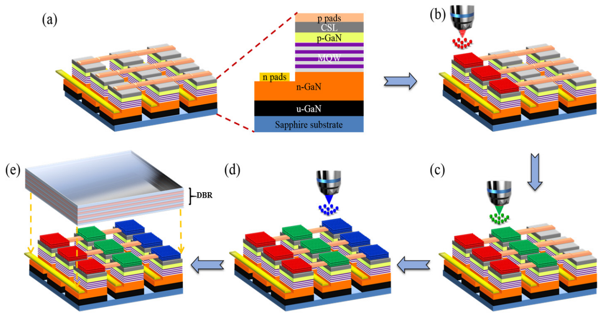


Fig. 1 The process flow of the full-color emission of RGB QDs-based micro LED display.

Figure 2(a) shows the fluorescence microscopy image of sprayed the RGB QDs micro LED array, and the excitation wavelength of the fluorescence microscopy is 365 nm. The size of the pixel is 35μm × 35μm and the pitch between the pixels is 40μm. There are 128 columns of RGB lines and the line width was controlled at 35μm, which can just cover one pixel, as shown in upper right chart of figure 2(a). Figure 2(b) shows the 3D surface images by the Laser Microscope. The thickness of the red, green, and blue quantum dots after the jet process is about 2.1μm, 4.8μm, and 5.5μm, respectively. This red quantum dots is with the strong luminous than the green and blue QDs and the green QDs is stronger than blue QDs in order to yield the uniformity white light, this tunable parameters are indispensably.

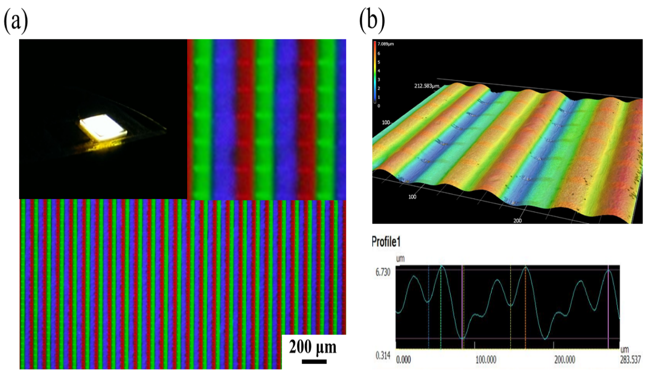


Fig. 2(a) The image of sprayed QDs micro LED array under the fluorescence microscopy.

The micro-LED array emits the photons of 395 nm which can excite the RGB QDs deposited on the surface of the individual LED. However, due to the thin thickness of the QD layer, the UV photons from the underneath LED can't be absorbed completely. If this type of device is going to be used for display or lighting applications, extra care needs to be taken to these leaked UV rays. The best way to deal with this situation is to lay down a layer of distributed Bragg reflector (DBR) to increase the recycling of the UV photons. In our design, a 17.5-pair HfO2/SiO2 multiple-layer structure was integrated into the micro-LED array. This DBR provides 90% of reflectance at 395 nm and high transmission (around 90%) at 450 nm (Blue), 520 nm (Green) and 630 nm (Red) bands as shown in Fig. 3.

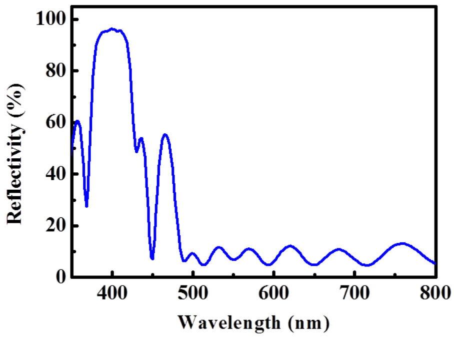


Fig. 3 The reflectance spectrum of 17.5-pair HfO2/SiO2 distributed Bragg reflector (DBR).

The spectra with the driving current of each LED is 20 mA the used with and without DBR were taken as shown in Fig. 4(a). From the measurement, a pronounced UV peak (at 395 nm) is an indicator of less-efficient pumping, while the red, green, and blue signals are not strong. After DBR is added, the strong reflection band successfully let the 395nm peak be suppressed and increase the visible intensities by 194 % (blue), 173 % (green) and 183 % (red).

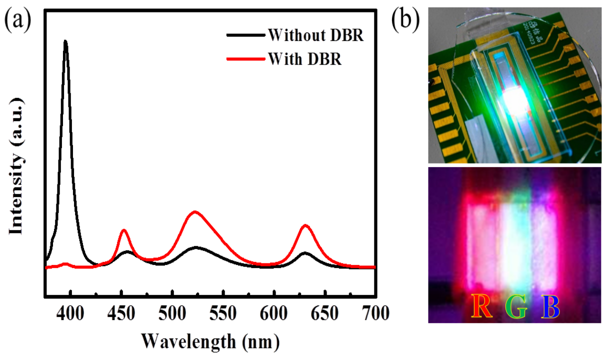


Fig. 4(a) The emission spectra with and without the DBR structure. (b) The sprayed RBG QDs micro LED display device in action and representative image of RGB pixels in bottom image.

Additionally, the color coordinates of three QDs were measured by a spectrometer and plotted on the CIE 1976 chromaticity diagram as shown in figure 3. The CIE coordinates of the QDs related emissions were compared to the National Television System Committee (NTSC) standard color triangle. The saturated colors provided by narrow line-width emission of QDs ensure the maximum coverage on the CIE diagram. The area inside the yellow dash triangle shows the maximum color gamut that can be projected by the RGB QDs, which is 1.52 times of the NTSC color gamut (dash-dot line). When the colors of the QDs are changed, so does the triangle in the plot.

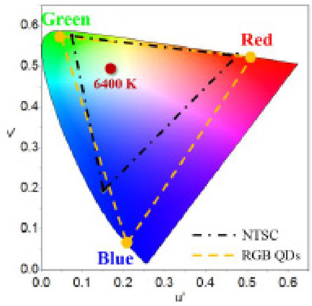


Fig. 3 The CIE 1976 color space chromaticity diagram of the QD display technology and NTSC.

## 3. Conclusions

In conclusion, this study demonstrates a pitch 40μm micro-sized LED array with independently addressable RGB pixels by applying Aerosol Jet technology with colloidal quantum dots. The initial results show promising the excellent white light generation such as the 165 lm/w of lumen efficiency and 1.52 times of the NTSC color gamut. This is the first time that a high-resolution pixelated array can be demonstrated for display technology. This technology shall be disruptive with the generation of light-emitting devices in the future.

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