

# Performance Enhancement of Quantum-Dot Optical Films (QDOFs) Used in Vehicle Display

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## Abstract

Quantum dots optical films (QDOFs) are prepared by encapsulating coating formulation containing quantum dots with top/bottom substrate films through roll-to-roll lamination. However, quantum dots (QDs) are prone to fluorescence quenching when exposed to water and oxygen surroundings. This article proposes a method to improve the performance of QDOFs by optimizing the coating formulation. This scheme can promote QDOFs' application potential in vehicle display industry.

## Author Keywords

Quantum dots optical films; formulation optimization; reliability test; vehicle display

## 1. Introduction

Colloidal quantum dots (QDs) have excellent optoelectronic properties, such as narrow photoluminescence (PL) bandwidths and high quantum efficiency (>95%), and have been widely used in optoelectronic devices, information displays, and other application fields<sup>1,2</sup>. One of the most successful commercial applications is premixing quantum dots with coating formulation and encapsulating them into quantum dots optical films (QDOFs) through roll-to-roll lamination by upper and lower barrier films, which are applied in the field of LCD backlight display. Traditional LCD displays use blue LEDs as the light source. Under the excitation of blue light, QDOFs emit green light and red light, and generate white light together with transmissive blue light to achieve the full-color performance.

However, QDs are sensitive to water and oxygen, and fluorescence quenching occurs when QDs interact with water and oxygen after certain period<sup>3</sup>, resulting in insufficient performance of optical films. This phenomenon makes conventional QDOFs unable to meet the customer's requirements by reliability test, which restrict QDOFs' application potential in vehicle display.

## 2. Results and discussion

As shown in Figure 1, QDOFs usually have the structure of three layers. The upper and lower layers are barrier layers, and the middle layer is QDs layer. The QDs layer is mainly composed of acrylic resin, green QDs, red QDs and other substances. During the coating process, UV curing is carried out to solidify the QD resin and to make a uniform QD emitting layer. However, the QDOFs have the problem of poor reliability at high temperature and high humidity. Under the condition of 85°C, 85%RH, oxygen and water vapor will continuously penetrate into the film, and then react with ions on the surface of QDs to undergo chemical oxidation and other reactions, thus affecting the optical performance of QDOFs.

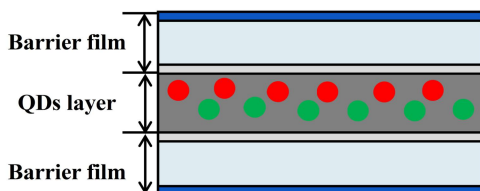


Figure 1. Structure diagram of QDOFs

In order to solve the problem, this paper mainly focuses the optimization of the QDs emitting layer, by adding substances that have better resistance of isolating water and oxygen from the QDs' surface to reduce the reaction possibility between QDs and water/oxygen related oxidative substances, thus this strategy greatly improves the reliability of the QDOFs at high temperature and high humidity like 85°C, 85%RH.

Two samples were prepared to demonstrate the effect on the performance. One was the improved sample with addition of water-oxygen isolating substances, and the other was the control sample. Both samples were placed under the conditions of 85°C, 85%RH for a period of 1000h. As shown in Table 1, the color coordinate x of the control sample was attenuated by 5‰, the color coordinate y was attenuated by 15‰ and the brightness was reduced by 21.9% from the initial value. However, the color coordinate x of the improved sample was attenuated by 2‰, the color coordinate y was attenuated by 4‰, respectively, and overall brightness was only slightly lower by 7.5% from the starting point. From Figure 2, Figure 3 and Figure 4, we can see the specific attenuation rate of two samples. The color coordinates and brightness attenuation rate of the improved sample are obviously better than the control, which proves that the optimization of QD formulation can significantly improve the stability of QD film performance at 85 °C , 85%RH, meeting the reliability test requirements of QDOFs used in vehicle display by downstream clients.

Table 1. Results of reliability test(85°C, 85%RH, 1000h)

	$\Delta x$	$\Delta y$	L
Control sample	-0.0050	-0.0151	78.1%
Improved sample	-0.0022	-0.0043	92.5%

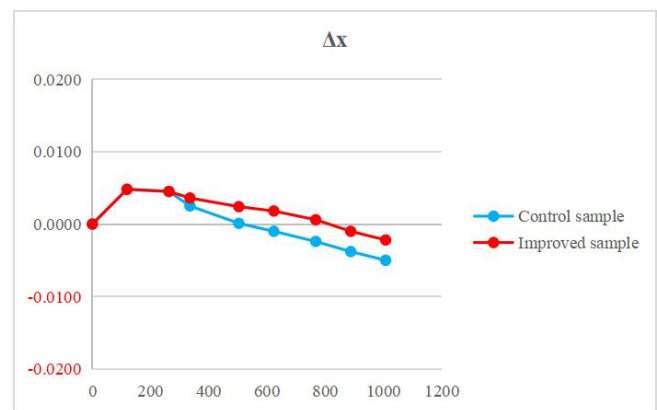


Figure 2. Variation diagram of color coordinate x in reliability test (85°C, 85%RH)

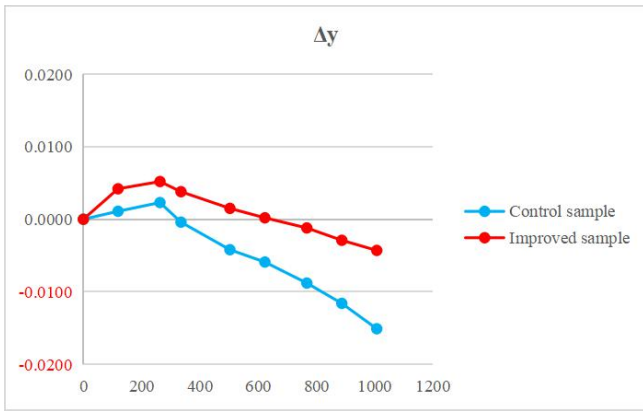


Figure 3. Variation diagram of color coordinate y in reliability test (85°C, 85%RH)

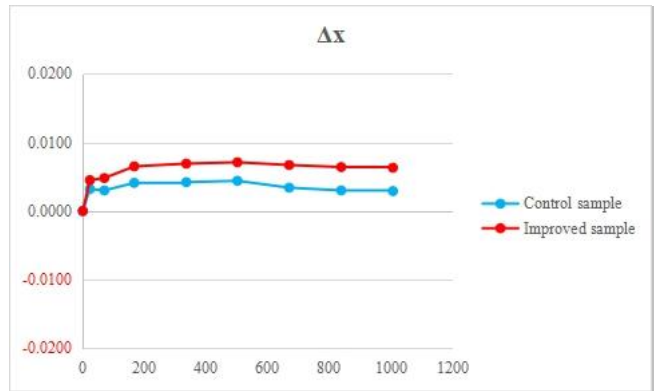


Figure 5. Variation diagram of color coordinate x in reliability test (95°C)

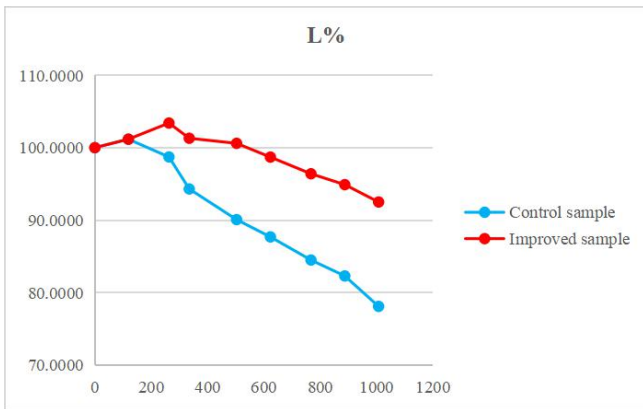


Figure 4. Variation diagram of luminance L in reliability test(85°C, 85%RH)

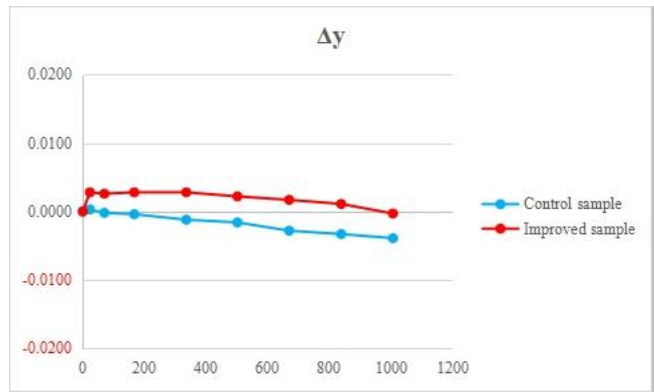


Figure 6. Variation diagram of color coordinate y in reliability test (95°C)

Both samples were also placed under the conditions of 95°C for a period of 1000h to evaluate their high temperature performance. As shown in Table 2, the color coordinate x of the control sample was risen by 2.9%, the color coordinate y was attenuated by 3.9% and the brightness was reduced by 6.6% from the initial value. However, the color coordinate x of the improved sample was risen by 6.3%, the color coordinate y was attenuated by only 0.3%, and the brightness was reduced by 2.6%. From Figure 5, Figure 6 and Figure 7, we can see the specific change curve.

Table 2. Results of reliability test(95°C, 1000h)

	$\Delta x$	$\Delta y$	L
Control sample	0.0029	-0.0039	93.4%
Improved sample	0.0063	-0.0003	97.4%

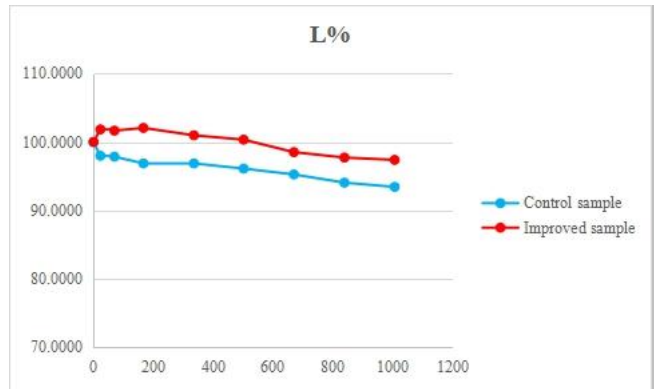
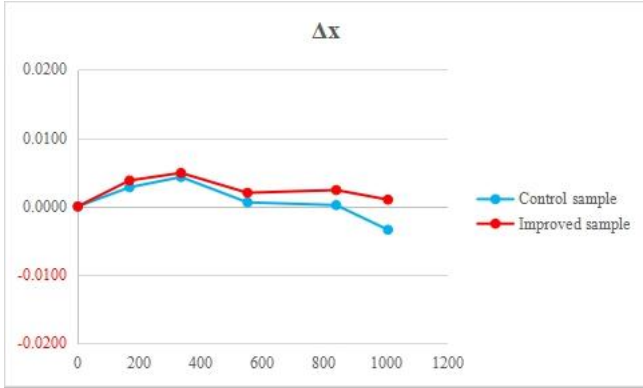


Figure 7. Variation diagram of luminance L in reliability test(95°C)

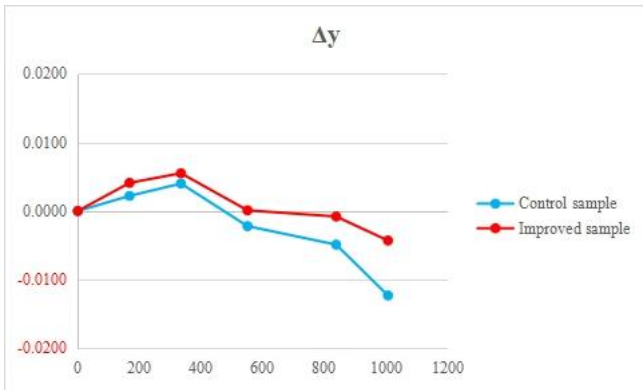
Considering the practical application scenario of QDOFs, the high temperature, high humidity and blue light test was carried out. As shown in Table 3, the color coordinate x of the control sample was attenuated by 3.4%, the color coordinate y was attenuated by 12.3% and the brightness was reduced by 3.2% from the initial point. However, the color coordinate x of the improved sample was risen by 1%, the color coordinate y was attenuated by 4.3% and overall brightness was only reduced by 0.1%. From Figure 5, Figure 6 and Figure 7, we can see the specific change curve.

**Table 3.** Results of reliability test(50°C, 80%RH, 22mW/cm<sup>2</sup> 1000h)

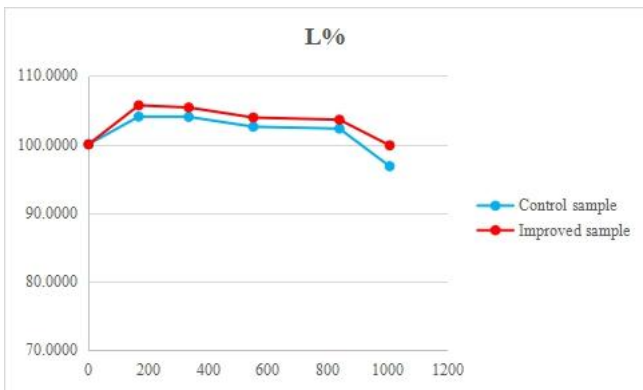
	$\Delta x$	$\Delta y$	L
Control sample	-0.0034	-0.0123	96.8%
Improved sample	0.0010	-0.0043	99.9%



**Figure 8.** Variation diagram of color coordinate x in reliability test (50°C, 80%RH, 22mW/cm<sup>2</sup>)



**Figure 9.** Variation diagram of color coordinate y in reliability test (50°C, 80%RH, 22mW/cm<sup>2</sup>)



**Figure 10.** Variation diagram of luminance L in reliability test(50°C, 80%RH, 22mW/cm<sup>2</sup>)

**3. Conclusion**

This article proposes a method to effectively improve the performance of QDOFs by optimizing formulation. However, it still needs to be further improved in worse working conditions, such as navigation, aerospace and so on.

**References**

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