國立交通大學

光電工程研究所

碩士論文

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中華民國九十三年六月

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光電工程研究所
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A Thesis
Submitted to Institute of Electro-Optical Engineering
College of Electrical Engineering and Computer Science
National Chiao-Tung University
in Partial Fulfillment of the Requirements
for the Degree of
Master
In
Electro-Optical Engineering

June 2004
Hsin-Chu, Taiwan, Republic of China.

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摘要

由於通訊產業的蓬勃發展，應用於多種通訊產品之透反式液晶顯示器受到廣泛重視。輕薄、高亮度、可讀性、省電、高色彩飽和度都是可攜式透反式液晶顯示器的重要考量。然而，當透反式液晶顯示器使用背光系統作為光源時，部份的背光就會被反射區所擋住而無法穿透，造成光利用效率降低。為了解決上述的問題，本論文提出一種具微型光管陣列結構之透反式液晶顯示器，以提升光使用效率和增進影像品質。利用一個形狀相似於漏斗的微型光管結構，使的大部分的背光可以穿透過面板，以致於背光的光效率可以大幅提昇。

基於微型光管結構的集光原理，我們利用軟體建立一個模型來描繪具微型光管陣列結構的透反式液晶顯示器之特性。藉由改變上開口的大小、光管的高度和光管側壁的傾斜角，我們可以最佳化微型光管的結構。在此，採用兩種一般商用的被光系統作為模擬時的光源。基於製程上的限制，我們選擇規格為光管高度3um、上開口大小5um和側壁傾斜角60度的微型光管陣列作為最佳化的結構。接著，我們又進一步針對光管上開口的形狀和分佈位置做模擬並討論比較之，而後模擬的結果來繪製光罩。

藉由典型的 TFT-LCD 製程技術，我們製作出一個樣品。其中，製程中有四個最重要的因素能分別決定單一個微型光管的各部位結構。第一，若考慮光管的高度，第一道光罩的曝光時間將扮演決定性的角色；第二，第一道光罩的開口大小將決定光管上開口的大小；第三，烤箱的升溫曲線會對光管的傾斜角造成影響；第四，第二道光罩的曝光時間會影響 Al 覆蓋在光管側壁的範圍。藉由適當調整上述的製程參數後，最佳化的微型光管陣列結構已經被製作，然後，其光利用效率和光分佈可以由光學儀器所量測得到。相較於一般的透反式液晶顯示器，我們的新行結構所量測的光效率增益可以高達 1.81 倍，這和模擬的結果是相符合的。這樣的結果成功的展現出微型光管陣列結構確實可以有效的收集背光並且大大的提升背光使用效率。

對於未來的工作，我們更進一步提出一種新型的反射結構-凹面式反射器，其中，此反射器是建構在微型光管的結構上面，以簡化反射區域的製程。因此，我們可以利用微型光管陣列有效的提升背光源利用率，並藉由其結構來製作凹面式反射區以簡化目前一般的製程，同時又能達到與一般反射區相同的光效率。

Design and Fabrication of the transflective LCD with Micro-tube Array

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Abstract

Transflective LCDs become important with the population of mobile communication where high brightness, high readability, low power consumption and good color saturation are the main concerns. However, when the backlight is used as the light source, the reflective region can be regarded as a block that backlight can not pass through, thus reducing backlight utilization efficiency. In order to resolve the issue in conventional transflective LCDs, a novel structure for transflective LCD technology, micro-tube array, is proposed. The characteristic of this design is to use a micro-tube structure similar to a funnel in shape and to make most backlight pass through the panel so that light utilization efficiency can be increased substantially.

Based on the principle of collecting light, we established a simulation model to characterize the features of the transflective LCD with micro-tube array. The micro-tube array structure was optimized by varying the diameter of the upper aperture (AP), the tube height (d) and the tilt angle of the sidewall (θ_{tube}). Due to the fabrication limitation, we chose the micro-tube array with the specifications of d=3um, θ_{tube}=60°

and AP=5um. Further, various shapes and arrangements of the apertures were also examined and compared. Finally, masks were designed based on the simulation results.

A prototype was fabricated by a typical TFT-LCD process, in which there are four key factors determining the structure of micro-tubes: 1. the exposure time of the 1^{st} mask plays a leading role for tube height (d). 2. the aperture size of 1^{st} mask determines the size of upper aperture (AP). 3. the temperature-rising curve of the oven affects on tilt angle (θ_{tube}). 4. the exposure time of the 2^{nd} mask affects the range of Al-covering on the sidewall of micro-tube. After we modified the mentioned fabrication factors, the optimized prototype of micro-tube array structure was fabricated. The light utilization efficiency of a TR-LCD with micro-tube array was measured with conventional backlight sources. Compare to the conventional TR-LCD, the novel one was a factor of 1.81 in efficiency enhancement, agreed with simulated results. Thus, the result successfully demonstrated that the micro-tube array can collect backlight effectively and greatly improve the backlight utilization efficiency.

We further proposed a concave reflector built on the micro-tube array to simplify the fabrication process of reflective region. Therefore, the image quality and the brightness of TR-LCDs can be much improved.

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