應用微型光學元件於提升
攜帶式液晶顯示器之影像品質

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摘　要

隨著數位資訊時代的來臨與網際網路的普及，消費性電子產品不斷朝向可攜式化、輕薄短小化、省電、低功率輸出的方向前進。微型光學元件(Microoptical Components)由於具有平面化、高設計自由度、與易於製造等優勢，遂成為目前相當重要的光學應用技術。而攜帶式液晶顯示器(Portable liquid crystal display)其優點為薄型化、重量輕、多樣性、高可讀性及低耗電量，目前已被廣泛使用於多種可攜式產品上。然而，攜帶式液晶顯示系統仍面臨了許多的問題，諸如影像亮度(brightness)、影像對比度(contrast)、與系統效率(efficiency)等。為了改善這些問題，本論文提出了三種不同的微型光學元件應用於多樣的攜帶式液晶顯示系統，使其影像品質與顯示功能獲得提昇，讓攜帶式液晶顯示器能被更廣泛且成功地應用在不同的領域。本論文並發展利用半導體微影蝕刻、塑膠翻印壓膜、灰階光罩及光阻熱熔等微光學的各種製程技術，來更精密的控制元件之光學品質、有效的減少其製程步驟與降低成本。

攜帶式液晶顯示面板在反射模式所顯示的影像仍存在著亮度偏低、對比度不足、均勻性不佳等缺點，而本論文研究則成功的開發出「光控制薄膜(Light control film)」來聚集多種角度之環境入射光，並控制面板反射光的角度，使反射光有效的分佈於觀賞視角內以大幅提升顯示器反射影像之亮度、對比度、視角及均勻性。經由適當的光學設計，此薄膜可避免產生表面漫射(Surface scattering)、色散(Color dispersion)、或是雲彩花紋(Moiré pattern)等現象。

此外，光控制薄膜是利用半導體製程(Semiconductor process)與翻印壓膜(Stamp molding)的技術將結構製作於厚度僅為 100 微米的塑膠薄膜上，使用者可輕易的將此薄膜貼附於攜帶式顯示器的表面，即可達到影像品質之提升。

透反式液晶顯示器的穿透影像具有開口率低、光使用效率低、反應時間不匹配、及色彩飽和度不同等問題。因此，本論文提出一種具「光反射影像增強層(Image-enhanced reflector)」之透反式液晶顯示器，使得穿透與反射光有近乎相同的光路徑，進而提升光使用效率、開口率、反應時間與色彩飽和度。此外，目前的膽固醇(Cholesteric)液晶顯示器雖具有高亮度、記憶穩態及低耗電量等優點，但卻多為單色顯示且只能操作在反射模式；本論文研究亦利用光反射影像增強層使膽固醇液晶顯示器能在穿透與反射模式底下均顯示相同的影像色彩；並提出了使用高雙折射率的液晶搭配彩色濾光片的製程來達到世界首創的全彩透反式膽固醇液晶顯示器。此研究中更發展了半色調網點光罩(Half-tone mask)的技術來製作光反射影像增強層，此技術可利用單一光罩曝光即製作出連續表面之微型光學元件，大幅減少了製程的步驟，避免光罩對準的誤差且可進一步的提升微型光學元件的光學品質。

當透反式液晶顯示器使用背光系統作為光源時，大部份的背光都會被反射區所擋住而無法穿透，造成背光源的光利用效率降低。為了解決上述的問題，本研究發展出「微型光管陣列(Micro-tube array)」結構，以提升背光使用效率並增進影像品質。此結構利用形狀相似於漏斗的微型光管陣列，將被遮蔽的背光有效的匯集至穿透區域，以致使背光的光利用效率可以大幅提昇，進而提升整體的顯像品質。本論文也成功的利用了 TFT-LCD 製程搭配光阻熱熔技術製作出微型光管陣列結構，證明了此結構是可以量產實現化的設計與技術。

論文中展現了微型光學元件於液晶顯示器產業的重大應用潛力，提供系統設計者更多的技術來源與設計創意空間來開發更佳的顯像技術；而結合光學設計與半導體製程的微光學元件技術，也將在未來高科技產業中具有益形重要的地位。

Applications of Microoptical Components for Image Quality Enhancing on Portable Liquid Crystal Displays

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Abstract

As the popularization of multimedia and Internet applications, the market of liquid crystal display (LCD) for portable applications is increasing worldwide due to their remarkable merits of thin, light, and low power consumption. Nevertheless, they still have several issues like low brightness, poor contrast, and low system efficiency. Microoptics, having the advantages of planar structure, low cost and designed flexibility, are being developed and well applied as a key technology for portable LCD applications to much increase their overall performance.

In this thesis, three novel microoptical components were designed to further improve the issues of portable LCDs. Based on the design of microoptics, various fabrication technologies, including semiconductor process, plastic molding, half-tone mask, and thermal reflow technology are used to develop several planar microoptical components to enhance image performance of portable LCDs in various aspects, such as brightness, optical efficiency, contrast ratio, and image quality.

The reflective images of conventional reflective LCDs still suffer from inadequate brightness and contrast ratio. Therefore, we proposed "light control films (LCFs)" which can be easily laminated onto the top surface of reflective LCDs to direct the incident light from multi-direction for much enhanced brightness, contrast ratio, viewing angle, and uniformity. By using optimized optical design, dispersion, moiré patterns, and surface scattering, are all invisible. Furthermore, we utilized

semiconductor processes and injection/stamping molding to fabricate the designed patterns on thin transparent plastic substrate ($<100\mu m$), thus the LCFs can be produced economically and reproducibly in large volume.

The concerns of transmissive image of transflective LCDs are low optical efficiency, slow response time, and different color saturation. An "Image enhanced Reflector (IER)" was proposed to built upon the transmissive region to guide the backlight to follow the similar paths of reflective light. Consequently, it can yield high optical efficiency, same response time, high area utilization, and matched color saturation. Moreover, IER structure can be further applied on cholesteric LCDs to display same color images both in reflective and transmissive modes, and maintains good readability in any ambience. By using high birefringence LC material ($\Delta n > 0.6$) with conventional color filter process, a full color transflective cholesteric LCD can be achieved. Additionally, the half-tone mask technology, which can use single mask exposure to form microoptical elements with continuous profile and high optical performance, was developed and used to fabricate the IER structure.

In conventional transflective LCDs, the reflective region blocks most of the backlight for illuminating LCD's, thus much reducing the backlight utilization efficiency. "Micro-tube array (MTA)" was demonstrated to collect the backlight into the transmissive area to increase the backlight utilization efficiency. Thus, the image quality of portable LCDs can be further improved with lower power consumption. A typical TFT-LCD process with thermal reflow technique, which has convenient and cost-effective process, was utilized to fabricate the micro-tube array structure.

This dissertation has successfully demonstrated the great potentials of microoptics, and explored for the portable LCDs applications. By using semiconductor process to fabricate microoptical components, the microoptics is appealing for variety of novel applications in the near future.