改善低溫複晶矽薄膜電晶體均勻性之元件結構與校正電路之研究

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摘要

在本篇論文當中，我們運用低溫複晶矽薄膜電晶體為元件，分別從元件結構以及其顯示器應用電路設計兩方面來探討均勻性之問題。在此研究中，我們藉由佈局方式簡單地調整元件架構來提升低溫複晶矽薄膜電晶體之均勻性，此外亦提出對元件變異性具有高度補償能力之主動矩陣式有機發光二極體畫素電路以及源極隨耦器形式的類比緩衝電路。

首先，我們從元件結構之觀點來探討低溫複晶矽薄膜電晶體之元件均勻性。我們採用了交叉以及多通道之元件佈局。根據實驗之結果，我們發現交叉方式佈局可以提升相鄰電晶體之均勻性，而多通道結構可以提升低溫複晶矽薄膜電晶體整體之截止電壓及次臨界擺幅之均勻性。針對此結果，我們也進一步進行機制之探討，認為晶粒機率分佈之現象是致使均勻性提升最主要之原因。

在主動矩陣式有機發光二極體畫素電路當中，我們針對各個電晶體尺寸及電容大小進行探討。傳統的畫素架構，經由實際量測結果，可以很清楚的瞭解當驅動電晶體的截止電壓有所不同時，有機發光二極體陽極電壓也會有明顯之差異，因此畫素彼此之間輸出電流有所差異，而導致畫面亮度之不均勻。相較於傳統佈

局的方式，運用前述提出之多通道之結構佈局除了可以有效增大電流，亦可獲得畫素陽極電壓均勻性較佳之結果。

我們先提出一種新型的電路操作模式來校正低溫複晶矽薄膜電晶體之截止電壓變異性之問題。藉由實際量測結果證實，我們所提出的電路架構確實可以有效地縮小輸出電壓變異性之問題，而且可以獲得輸出電壓增大的好處。然而，在重置階段時有機發光二極體亦會有電流通過，而導致整體畫素電路消耗功率將因而提升。因此，我們進一步提出第二種電路操作模式來改善上述的缺點。我們將其中一個電晶體由 N 型換成 P 型，並改由切換訊號控制，在重置階段時此電晶體將阻止不必要的電流流過有機發光二極體，藉以降低整體消耗功率。

在類比緩衝電路設計之研究中，我們了解在液晶顯示器源極驅動器內的類比緩衝器在整合至玻璃基板時，元件的變異性亦極有可能導致實際輸出電壓與目標電壓有所差異。因此，我們亦將多通道結構引入傳統驅動架構中，藉由觀察類比緩衝電路之輸出特性再次驗證多通道結構對薄膜電晶體均勻性提升之能力。由量測結果可以得知具有多通道結構之源極隨耦器形式的類比緩衝電路，其輸出電壓之變異性有明顯地降低，證實多通道結構不論對於前述之畫素電路或是類比緩衝器電路之均勻性均具有明顯改善。如同畫素電路，傳統之類比換衝器無法達到規格需求，因此採用校正電路是必要的。文獻上各種已報導之類比緩衝器電路亦會做整理，在比較各種表現之後，我們認為源極隨耦器形式是較佳之選擇。

傳統的低溫複晶矽薄膜電晶體源極隨耦器具有一個驅動的電晶體，可以明顯的從模擬結果當中得知，輸出電壓並不是固定在預期的輸入電壓減去臨界電壓值，而是呈現一個不飽和的緩步上升現象，我們認為這是因為低溫複晶矽薄膜電晶體的次臨界電流持續在充電之緣故。因此，我們在傳統傳統源極隨耦器加一主動式負載藉以消除輸出電壓的不飽和現象，加了主動式負載後的輸出電壓偏移量與充電時間並無相依性，雖然其偏移量較大，但可藉由灰階校正去補償，所以我們可以得知加上主動式負載後的傳統源極隨耦器對於設計者而言有較佳的助益。

但即使消除了輸出電壓不飽和現象，元件的變異性問題卻依然存在。因此我

們提出一種校正電路，藉以解決變異性過大的問題，此電路包含了四個開關、一個儲存電容以及兩個低溫複晶矽薄膜電晶體。藉由此操作，輸出電壓端的電壓值相當近似輸入電壓值。此外，我們亦發現主動式負載之閘極偏壓對電路輸出偏差具有顯著的影響，可藉由適當的偏壓設計達到具高度均勻性、良好輸出特性以及低功率消耗之類比緩衝電路。

Study on the Uniformity Improvement of Low-Temperature Polycrystalline-Silicon Thin Film Transistors with the Device Structures and Compensated Circuits

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ABSTRACT

The uniformity issues of the low-temperature polycrystalline silicon thin film transistors (LTPS TFTs) were investigated from the individual aspects of device structure and the display driving circuits design in this dissertation. In this work, the device structure is adjusted to improve the uniformity of LTPS TFTs by changing layout method. Furthermore, active matrix organic light emitting diode pixel circuits and a source follower type analog buffer circuit with highly compensating capability are also proposed.

First of all, the device uniformity of LTPS TFTs is studied from the view point of device structure. The interdigitated and multi-channel structure with slicing layout

method is adopted in this work. According to the experimental results, it is observed that the interdigitated layout the multi-channel structure can promote the matched transistors and overall uniformity of threshold voltage and subthreshold swing of LTPS TFTs. The possible mechanisms of the improving uniformity of multi-channel structure are discussed and it is considered that probability effect is the most major reason.

In the active matrix organic light emitting diode (OLED) pixel design, each function of transistors and capacitor are investigated. Through the measured results in the typical pixel circuits, there is clear difference existing in OLED anode voltage when the threshold voltages of driving transistors are varied. Therefore, the output currents are varied from pixel to pixel leading the non-uniform brightness. Compared with conventional layout method, the multi-channel structure with slicing layout of driving TFT in previous work can enhance the output current and promote uniformity of the pixel anode voltage effectively.

A pixel circuit with new operation mode is proposed to compensate the variation of threshold voltage in LTPS TFTs. By means of experimental results, it is verified that the proposed pixel circuit can solve the problem of output voltage variation effectively and higher output voltage can be obtained. However, the power consumption is increased because current flow through OLED device in the reset period. Therefore, a modified circuit design is further proposed to overcome the issue. By modifying pixel design, an n channel TFT is replaced by a p channel TFT controlled by the switching signal in order to block the current flow through OLED during pre-charge period and the overall power consumption can be lowered.

In the analog buffer circuit, the device variations may lead to the difference between input voltage and output voltage when the analog buffer is applied to the source driver of liquid crystal displays or integrated into glass substrate. Meanwhile, the output variations of the conventional source follower with multi-channel structure are also introduced. It can be observed that the output variations are apparently reduced comparing with conventional source follower. It is proved that the uniformity of previous pixel circuit or analog buffer circuit can be improved by multi-channel structure. The traditional analog buffer circuit can not achieve the specific requirement like the one of pixel circuit. Therefore, the compensation circuit for analog buffer is necessary. In this dissertation, all kinds of analog buffer circuits are introduced and compared, while the source follower type is considered as the better choice.

The conventional source follower consists of one driving transistor. It is observed from the simulation results that the final output voltage is not kept constant, but exceeds the value of Vgs - Vth expected in principle. It is ascribed to the sub-threshold current which charges the circuit continuously. As a result, it will be sensitive to the charging time for various product specifications. Therefore, an active load is added to eliminate this unsaturated phenomenon of the output voltage and the deviation of output voltage has no relation to the charging time. Although this offset voltage deviation is larger, it can be compensated by external gamma correction. Therefore, the conventional source follower with an active load has better performance for the designers.

Nevertheless, the simulation results show that the circuit suffers from huge variations and output voltage is not the same due to the variations of TFTs even eliminating the output voltage unsaturated phenomenon. Therefore, a new analog buffer which consists of four switches, a capacitor, and two LTPS TFTs is proposed for the compensation of the device variation. The operating principles are described as follows. The output voltage is compensated by the voltage stored in Cvt and almost equals to input voltage. Besides, the bias voltage of an active load has great influence on output voltage deviation. By means of proper bias voltage design, a highly uniformed, excellent output characteristic and low power consumption analog buffer circuit can be obtained.

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