

有機薄膜電晶體垂直結構與汲極/源極電極配置之研究

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中文摘要

在此論文中，我們提出兩種結構來製造有機薄膜電晶體元件。首先，第一種元件是垂直薄膜電晶體。在我們提出的製程與結構中，免除以往高解析度製程設備才能製作短通道元件的問題，利用簡易的黃光對準設備與遮光罩的配合，即可達到短通道的元件。並從中觀察到非飽和電流的現象。藉由元件特性的分析，我們觀察到高電場下金屬與有機介面的 Fowler-Nordheim 效應主導垂直元件特性。為改善垂直薄膜電晶體的特性，我們更改底端源極金屬的電極形狀，在閘極控制的能力提升下，該元件在小電壓下(少於 $-5V$)之電流開關率由 10^2 提升至 10^4 。

第二種結構為上下電極式有機薄膜電晶體，其結構類似於第一種，只是在汲極與源極間無重疊的區域，並且製程上更為簡易，透過遮光罩與蒸鍍機的合作完成有機薄膜電晶體低成本製造的目標。該元件在特性上優於下電極有機薄膜電晶體，在通道縮短的情況下電動遷移率較緩於下電極有機薄膜電晶體。為更瞭解該元件的電流傳輸，我們透過電阻的分析來建立模型。藉由接觸電阻，垂直電阻，薄膜電阻與類蕭特基電阻的組合，成功建立與量測實際值相當吻合的上下極式元件模型。

Study of Vertical OTFTs and the related S/D Electrode Design

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Abstract

In this thesis, two architectures are proposed for fabricating the organic thin film transistors (OTFTs). One is the Vertical Organic Thin Film Transistor (VOTFT). In the proposed process and structure, with the simply photo-aligner and shadow mask, the short-channel VOTFTs are achieved. According to the output characteristics of VOTFTs, the unsaturated drain current is observed. A Fowler-Nordheim tunneling transportation dominates the carrier transport in VOTFTs. To further improve VOTFT property and gate-control ability, the source electrode is modified as the mesh-like shape. In the modified VOTFTs, the drain voltage is significant reduced (less than 5V), and the on/off current ratio is also increased from 10^2 to 10^4 .

Secondly, the proposed structure is TBC-OTFTs (Top-Bottom Contact OTFT). It is similar the VOTFTs but the Source/Drain electrodes are not overlapped. Fabricated by shadow-mask only, the TBC-OTFTs show better performance than the bottom-contact OTFT. To further study the current transport in the TBC-OTFTs, the resistance-analysis is introduced to model the proposed structure. With the

combination of the contact resistance, the vertical resistance, the film resistance, and the Schottky-like resistance, the constructed model is plotted as the function of gate-voltage. Comparing the modeling result to the experimental plot, it is founded that the experiment data is good agreed with the proposed model.



誌謝

把這篇論文獻給這個土地上為軟性電子打拼的人

兩年以來，從 OTFT 與 OLED 分不清楚到完成論文，從老師提出軟性電子的相關想法到我的響應開始，隨後國錫的加入到現在，能目睹這團隊的人、事、物從無到有並兩年內追上世界腳步，我很開心能夠參與盛事，當中要感謝的人很多。

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Table Captions

Chapter 1

Table 1.1 Comparisons of TFTs using different materials

Chapter 2

Table 3.1 Contact resistance in TC, BC, TBC, and OTFTs



Figure Captions

Chapter 1

Fig. 1.1 Mobility of the organic semiconductors has been improved by five orders of magnitude over the past 15 years.

Fig. 1.2 Prominent (a) p-type and (b) n-type organic semiconductor materials.

Fig. 1.3 Energy band diagram of pentacene.

Fig. 1.4 Scanning electron microscopy (SEM) image of a pentacene thin film grown on SiO₂ and a Au electrode. The grain size is much smaller on Au than on SiO₂ far from the Au edge. The pentacene grain size on SiO₂ in the region close to the Au edge is similar to that on Au and increases with increasing distance from the edge.

Fig. 1.5 Energy band diagrams (a) for a p-channel (pentacene) and (b) for a n-channel (NTCDA) OTFTs. The left side shows the devices at zero gate bias, while in the centre and in the right part the accumulation and depletion mode operation regimes are presented.

Chapter 2

Fig. 2.1 Structure and process flow of vertical organic thin film transistors

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Fig. 2.3 Top view microscope image of VOTFTs with meshed source electrode

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Fig. 2.5 Process flow of TBC OTFT

Fig. 2.6 Device resistance R as a function of channel length L at V_{DS} = -1V to -5V

Chapter 3

Fig. 3.1 Output characteristics of Group-A VOTFTs

Fig. 3.2 Transfer characteristics of Group-A devices

Fig. 3.3 Output characteristics of Group-B devices

Fig. 3.4 Transfer characteristics of Group-B devices

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Fig. 3.18 R_{on} modeling in (a) TBC bot-source (b) TBC top-source

Fig. 3.19 Total resistances from modeling and experiment are plotted (a) TBC bot-source (b) TBC top-source

