國 立 交 通 大 學

光電工程研究所

博 士 論 文

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感測元件上之運用研究

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摘　　要

本論文提出一種可製作出高效能有機薄膜晶體的介電材料。我們利用射頻濺鍍法沉積低溫氮化鋁薄膜，該低溫沉積的氮化鋁薄膜具有相當高的輸水特性，與並五苯有機薄膜有相近的表面能特性。在研究中，我們首先調變沉積溫度來降低氮化鋁的表面粗操度與結晶率，當氮化鋁的表面粗操度與結晶率隨沉積溫度而降低時，氮化鋁的介電層漏電流、在元件的操作區間內可降低到 10^{-9}A/cm^{2} 的水準，且介電層厚度也可以近一步降低到 100 奈米以下。我們亦嚐試調控濺鍍時的氬氣與氮氣混合比率來近一步降低氮化鋁介電層漏電並提升可靠度。研究中發現，較高氮氣的比率可以降低漏電流，且我們進一步發現一個可能與氮空缺相關的缺陷分佈將往深層能階移動，這個近似 Poole-Frenkel 的缺陷態一但位於較深的能階，則氮化鋁的漏電則可以進一步獲得控制。在掌握了氮化鋁的介電特性之後，我們在該低溫介電層上進行有機薄膜電晶體的製作，我們所製作的氮化鋁有機薄膜電晶體可以操作在相當低的電壓（小於 5V），但具有相當高的場效載子漂移率（大於 1.6 cm^{2}/V-sec）與相當優良的次臨界擺福（小於 0.2 V/decade），與國際上有機薄膜電晶體的領先研究團隊的成果相當。另一方面，我們也利用有機薄膜電晶體作為光與氨氣體的感測器。在有機薄膜光偵測器的研究中，我們嘗試用紫外光來改變介面態、來影響元件對光的響應。我們發現存在於有機薄膜與介電層間的帶電缺陷態可能有助於提升對光的響應，在光激發下有助於提升光電流生成而在光激發除後將會延長元件回覆時間。在實驗中所獲得的有機薄膜光感測器

的響應可高達 10 安培每瓦（A/W），與目前所知的高光響應有機電晶體相當。在有機薄膜氣體感測中，我們初步地研究了氨氣與有機薄電晶體的反應。我們發現提高環境氨氣濃度將會降低電晶體輸出電流並提高元件臨界電壓，並討論金屬接面端與有機薄膜本身在氨氣環境下的電阻變化。我們亦發現元件的尺度與通道比例可能是影響氣體感測靈敏度的一個因素。最後我們提出一種新穎垂直通道的電晶體結構，並研究改善該新穎元件的關閉區域漏電流並提升元件開關比例的方式。

Study on High Performance Organic Thin Film Transistor and its Application on Sensor Devices

Student: Kuo-Hsi Yen Advisor: Hsiao-Wen Zan

Degree of Ph.D. in Electro-Optical Engineering

Abstract

In this thesis, we proposed a dielectric layer for the application of high performance organic thin film transistors (OTFTs). By using the radio frequency (RF) sputtering system, we deposited the alumni nitride (AlN) film as the dielectric layer under a very low temperature. The low-temperature deposited AlN film is highly hydrophobic and its surface energy is similar to that in pentacene film. In our study, we varied the AlN film deposition temperature to lower the AlN film surface roughness and suppress its crystallization. When the surface roughness and the crystallization decreased with the lowering of deposition temperature, the dielectric leakage current of AlN film can be as low as 10^{-9}A/cm^2 when the devices were operated and biased. The AlN dielectric thickness can also be reduced to less than 100nm. Furthermore, we also adjusted the argon (Ar) and nitrogen (N_2) ratio during the AlN film sputtering to lower the dielectric leakage and to increase the AlN film reliability. It was also found that higher N_2 ratio in sputtering process may lower the AlN dielectric leakage. A nitrogen related vacancy defect may also distribute toward a deeper energy level under higher nitrogen ratio. When the Poole-Frenkel liked defect distribution is situated on deep energy level, which helped to further decrease the AlN dielectric leakage. After we gained the experiments of AlN dielectric leakage control, we fabricated the OTFTs on the AlN dielectric layer. The fabricated OTFT with AlN dielectric layer (AlN-OTFTs) can be operated under a low voltage (less than 5V) with high field effect mobility (more than 1.6cm^2/V-sec), and its subthresold swing is still good (less than 0.2V/decade). Besides

the development of high performance AlN-OTFTs, we also applied the OTFTs to act as optical and gas sensors. In the study of optical OTFT sensors, we used the ultra violent light (UV-light) to modify the interface states, which may influence the device optical response. It was also found that the charged defect states between the organic film and dielectric layer may help to increase the photo-responsivity in optical OTFT sensors. That will enhance photo-current generation under illumination and prolong the device recovering time when the illumination was removed. The observed photo-responsivity in our organic photo detector can be as high as 10 A/W, which value was similar to that in high performance organic photo detector. In the study of organic thin film gas sensors, we studied the interaction between NH_3 and OTFTs primitively. It was found that the OTFT output current will be reduced and the threshold voltage will be increased with the increasing of NH_3 concentration. The contact resistance between metal electrode/organic interface and channel resistance were also discussed under different NH_3 concentration. The device geometry and channel length may be important factors that influenced the sensitivity of organic gas sensor. Finally, we proposed an novel vertical channel OTFTs. We studied the device leakage properties and improved device leakage current in the device off state region.

誌　　謝

什麼是人生最大的快樂？對我而言，就是能做自己想做的事，從一無所知到小有收穫；而什麼是人生最大的幸福？對我而言，就是遇到再大的困難與挫折時，身邊永遠都有可信可愛的家人、老師、與朋友，陪著我一起走過這些難忘的歲月。在博士班的日子裡，最感謝我的父母，給我一個安穩且無後顧之憂的環境，讓我一無返顧、無止盡的追求學問與解答，並且時時提醒我要照顧好身體。感謝我的指導教授－冉曉雯老師，以最大的信任、耐心、與關懷，不斷的給我機會，讓我進步並受益滿懷，並讓我到世界各地與傑出的研究人員互動。感謝蔡娟娟老師，深刻的引導我一窺業界深厚的研究經驗，給我機會到國外進行研究交流。實驗室的學弟妹們，有你們日以繼夜的努力，才會有今天實驗室的規模！更感謝幾位實驗室剛成立時，最辛苦的幾位伙伴：傑斌、溥寬、睿志、文馨、與俊傑等，你們的付出我們才有許多振奮人心的研究成果。還要感謝其他協力實驗室的夥伴們：勳哥、小銘、宏澤、明達、坤益、貓貓、小白、以及工研院的夥伴們。給我許許多多技術上與儀器上的資助，我們的論文才得以順利進行。當然，還有中正大學的老朋友們，這幾年在新竹與我共同走過。以及，曾經與我一起熬夜患難的朋友，感謝你們！

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