使用金屬和新穎材料電極之有機薄膜電晶體電性行為與蕭基接面特性之研究

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摘 要

本論文製作許多以五環苯(Pentacene)為半導體層之有機薄膜電晶體，在改變不同五環苯製程條件和電極材料…等，藉由電性量測和物性觀察，探討對電晶體特性的影響和可能機制，並研究不同金屬電極的電晶體特性表現和接觸阻抗(Contact resistance)。以達成具有低接觸阻抗、優越特性的五環苯有機薄膜電晶體。

首先改變沈積溫度、沈積速率、以及薄膜厚度，五環苯製程條件，研究觀察有機薄膜電晶體特性變化，以獲得合適之條件，應用在後續的研究中，並探討可能機制。其中高溫和低速率的沈積有利於獲得高結晶性、低缺陷的五環苯主動層，也就是較高的載子遷移率(Mobility)和電流開關比(On/off current ratio)。另外，五環苯有機薄膜電晶體在存放一特定時間後的特性退化，也有所探討。

獲取合適五環苯製程條件後，由於五環苯有機薄膜電晶體使用金屬電極，

也就是所謂的蕭基接面，很大的接觸電阻是被預期的，因此，藉由改變相同金屬功函數(Work function)之電極材料，如鈀(Pd)和金(Au)，和接觸層(Adhesion layer)厚度，觀察五環苯有機薄膜電晶體的特性差異，得知五環苯和不同金屬材料之接觸特性差異與載子入射能障(Injection barrier)對特性的影響，以獲得具優越特性的金屬電極材料和合適的接觸層厚度；其中較薄之接觸層和使用鈀作為接觸金屬將獲得較佳之元件特性。並為進一步的提高五環苯有機薄膜電晶體特性，閘極介電層的表面處理也有所探討和呈現；藉由特定材料(HMDS)做表面處理後，使元件之載子遷移率提升數倍。

在論文的最後，由前述之結論為基礎作進一步的嘗試，將多壁奈米碳管(Multi-walled carbon nanotubes, MWCNTs)作為五環苯有機薄膜電晶體之電極材料，因其與五環苯間良好的接觸性質和增大的接觸面積等，使可獲得低接觸電阻、高載子遷移率的優越結果；其中最高的載子遷移率可達 0.16 cm^2/Vs，電流開關比達到 10^7等級。

Study on the Electrical Properties and Schottky Contact Characteristics of Organic Thin Film Transistors with Metal/Novel Material Source and Drain

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Abstract

In this thesis, pentacene thin-film transistors (pentacene TFTs) were fabricated to study the influences of pentacene deposition condition and contact material on the device performance and contact resistance. On the foundation of the results of electrical characteristics and surface morphology, the probable mechanisms of the effect of deposition conditions and contact materials on the performance were intensively discussed in attempt to achieve superior performance and low contact resistance of pentacene TFTs.

By varying deposition temperature and rate, and thickness of pentacene active layer, we found that higher deposition temperature and lower deposition rate could lead to highly crystalline order and less defects in pentacene active layer, which result in turn result in higher

mobility and on/off current ratio.

Schottky contact between pentacene and metal electrodes results in a large unwanted contact resistance. Therefore, we used Au and Pd, which have the approximate work functions, as the contact materials. For firmly sticking Au and Pt to the substrate, Ti adhesion layer is needed. However, this additional layer will induce large injection barrier of Schottky contact because of the huge work function difference between Ti and pentacene. Thus, we also studied the effect of the adhesion layer thickness on the performance in order to get the optimized composition. From the results, pentacene TFTs with Pd as the contact material and thin Ti adhesion layer depicted superior performance because of the better contact properties and the reduced injection barrier of Pd than Au. In addition, in order to improve the performance of pentacene TFTs, HMDS surface treatments on gate dielectric was also conducted.

In the final part of this thesis, we introduced multi-walled carbon nanotubes (MWCNTs) to be the contact material and studied the effects of MWCNT S/D on the performance. From the results, we found that superior performances and lower contact resistance were achieved, because of its excellent contact properties and lager contact area to pentacene. The highest mobility and on/off current ratio, and lowest contact resistance were 0.16 cm^2/Vs, 10^7, 10^8 Ω-μm, respectively.