Chapter 6
Conclusions and Further Recommendations

6.1 Conclusions

To summary what we do in this dissertation, the basic electrical characteristics, devices parameters extraction and environmental influence factors of pentacene thin film transistors (TFTs) were investigated. And we also try to realize the active-matrix pixel structure for liquid crystal display driven by pentacne TFTs and carbon nanotube display driven by low- temperature poly-silicon TFTs.

In Chapter 2, we verified the basic grain growth mechanism for pentacene and compared the electrical properties for different device configurations. Beside, we verified the device parameters in top contact TFT utilizing gold as electrodes with different pentacene thickness. Our data show a non-linear relation between threshold voltage and pentacene thickness. The relation follows a square law in our proposed model based on uniformly distributed traps in pentacene film. The trap density also can be extracted and quite match the other researchers. The good fitting suggest that the threshold voltage could be suppressed by enhancing the pentacene film quality or reducing the unintentional dopant. That could be done by purification of pentacene. We also examined the FN tunneling of gold source to pentacene, space-charge limited current (SCLC) from source/pentacene junction to field effect channel and the field effect conduction relationship in pentacene TFTs. The SCLC was found to dominate the current-voltage behaviors in small drain bias regime. The quantity of SCLS current was difficult in pentacene TFTs cause of its three terminal device and complicated behaviors. The further investigation would be needed in the future.

In Chapter 3, the electrical properties of the polycrystalline pentacene TFTs in air and in a vacuum were studied. The pentacene TFTs measured in a high vacuum had superior field-effect mobility, a higher modulated on/off current ratio, a lower threshold voltage, and a better sub-threshold slope than those in air. The poor performance of the device in air follows from the more extensive trapping of carriers in air ambient and the consequent limiting of the charge transport of pentacene transistor. The grain-boundary potential barrier model estimates the potential barrier height and the trap density at the grain boundaries. The model is used to elucidate charge transport in a pentacene TFT under various atmospheric conditions. Moreover, the proposed model offers a satisfactory explanation of the improved performance of pentacene TFTs in a high vacuum and facilitates an understanding of the difference between air and vacuum environments in this regard.

In Chapter 4, an active-matrix liquid crystal display with pentacene TFTs was fabricated and demonstrated. The electronic stability of pentacene TFTs was studied in various environments. The pentacene TFTs were sensitive to humidity/H_2O and easily failed in organic solvent during the subsequent liquid crystal process. A protection layer deposited on the top of the device to overcome issues related to the integration of a pentacene device into the active-matrix display. The photosensitivity characteristics of pentacene TFTs were also investigated. The findings reveal that the pentacene TFTs can drive a normal liquid crystal display with a backlight system. However, an additional light shield layer is recommended. The gate bias stress accelerates the on-current decay of the pentacene TFT; fortunately, the decay is reversible. The reliability and uniformity of pentacene TFTs were investigated in relation to display applications. Although this display required adjustment, a high-resolution transparent display application was realized. In this work, a rigid 0.7 mm glass substrate was adopted. It will be easily transferred to flexible plastic substrates and realized full color display in the future. Therefore the organic TFT has the potential play an important role in future display technology.

In Chapter 5, the high voltage low-temperature-poly-silicon TFTs were used to drive diode carbon nanotube display. Power consumption was reduced in this active-matrix display with hold-type pixel structure since the emission current of the diode carbon nanotube display can be lower compared to pulse-type addressing scheme or traditional passive matrix designs. Scan driver circuits were integrated on the field emission display panel with low-temperature-poly-silicon technology which is consistent with the technology trend of system on panel.

6.2 Further Recommendation

From the investigation in this dissertation, we conclude several further recommendations for future studies.

(1) In Chapter 2, we discussed the definition of threshold voltage and proposed an analytical model to explain the pentacne thickness dependent threshold voltage. The inference was built on the basis of microscopic current-voltage relationship. Some research proposed the switch on voltage that falls into the range of sub-threshold region and means the point starting to accumulate charges to replace the threshold voltage. It is more physical meaningful, however hard to use in circuit simulation. Maybe we could define some point that means the accumulated charge density enough to form an effective conducting channel, like the definition of strong inversion in metal oxide field effect transistor, as the threshold voltage for organic TFTs by calculating the density of states. This work could be done by the measurement of capacitance-voltage and sub-threshold characteristics analysis.

(2) In Chapter 3, the carrier transport in pentacene TFTs was discussed and the potential barrier model was used to analyze the humidity induced increase of trap density. This model and carrier transport could be further verified by measurement of bias temperature characteristics. That could estimate the activation energy of pentacene. Many researches pointed out that the temperature dependent mobility would have different behaviors strongly affected by the polycrystalline pentacene film quality. Thus the bias temperature measurement could improve the understanding of penatcene film structure. Also, the measurement may help us to evaluate the limitation of mobility in pentacene TFTs.

(3) In Chapter 4, an active-matrix liquid crystal display was demonstrated by pentacene TFTs. For commercialization, there are still many things to do. The reliability requirement of traditional amorphous silicon TFTs maybe up to 20,000~30,000 hours for daily use. However, the pentacene TFTs reliability is far away from that. How to improve it become an important topic in the future. Several approaches were proposed to do that. Such as lower down the operation voltage by adapting vertical structure or high dielectric constant gate insulator. Another approach is to improve the pentacene/insulator interface and pentacene film quality because some study reported the defects or interface states degrade reliability of pentacene film.

(4) In Chapter 5, a novel active-matrix pixel structure was adopted to improve the brightness uniformity and lower down the anode voltage of diode carbon nanotube field emission display. However, in real applications, the low voltage and high brightness phosphors for field emission display is still under investigation. Maybe, another pixel approach that including a transistor, a storage capacitor and a triode structure field emission display would solve this problem. A triode structure could sustain higher anode voltage and easy to control the emissive cathode current by

gate bias.