

DOCTORAL THESIS

Charge injection, transport and thin film transistor applications of phenylamine-based organic semiconductors

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**Charge Injection, Transport and Thin Film Transistor
Applications of Phenylamine-Based Organic Semiconductors**

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A thesis submitted in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy

Principal Supervisor: Dr. SO Shu Kong
Hong Kong Baptist University
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Abstract

This thesis presents the charge injection and transport properties of amorphous organic semiconductors. Understanding these two properties is of vital importance for improving the performance of organic optoelectronic devices, which are receiving wide recognition in the past decade. Four techniques were cross-examined in this thesis for studying the properties, namely, time-of-flight (TOF), current-voltage (J - V), dark-injection space-charge-limited current (DI-SCLC), and thin film transistor (TFT) techniques. The materials under investigation belong to the family of phenylamine-based (PA) compounds, i.e. N,N' -diphenyl $-N,N'$ -bis (1-naphthyl) (1,1'-biphenyl) 4,4'-diamine (NPB) and 4,4',4''-tris(n -(2-naphthyl) $-n$ -phenyl-amino) triphenylamine (2TNATA). With high lying highest occupied molecular orbital (HOMO) level of -5.4eV , NPB was used for the charge injection analysis.

For charge injection, transition metal oxides (TMOs) were used as the hole injection layer (HILs) for NPB. We demonstrated the injection performance of TMO/NPB contact was significantly improved upon oxygen exposure to the TMO films. For J - V experiment, nearly overlap between the measured and theoretical J - V curves can be observed from the samples with oxygen exposed TMOs. Moreover, clear DI-SCLC transient peaks were observed over a wide range of electric fields from the samples. The two features cannot be observed from the samples with no gas exposed TMOs. This indicated TMOs with oxygen exposure can form nearly Ohmic contact with NPB, while the TMOs with no gas exposure cannot. The improvement was attributed to a reduction in the energy barrier at TMO/NPB interface, which was a consequence of the work function enhancement of TMO by the oxidation of oxygen. To demonstrate the importance of TMO as HILs on improving the performance of organic electronic devices, TMOs were introduced into NPB based organic thin film transistors (OTFTs). The insertion of TMO between Au and NPB in the OTFTs improved their performance.

For charge transport, an OTFT configuration was used to be a tool for carrier mobility evaluation in amorphous organic semiconductors. NPB and 2TNATA were the

target amorphous organic materials for investigation. The field effect (FE) mobility was found to about one order of magnitude smaller than that obtained from independent time-of-flight (TOF) technique using a thick film of $\sim \mu\text{m}$. Independent J - V experiments showed that contact effect was not the origin of the discrepancy. Temperature dependent measurements were carried out to study the energetic disorder of the material. It was found that the energetic disorder increased in the neighborhood of a gate dielectric layer and was one of the origins causing the discrepancy between TFT and TOF mobilities.

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