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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

In this thesis, we study a newly developed oxide semiconductor Zn-Si-O (mole ratio of ZnO: SiO_2 =0.8:0.2) and its application in organic optoelectronic devices. To illustrate Zn-Si-O is a promising materials for inverted organic devices, several works have done: First, electrical and optical properties of Zn-Si-O thin films are investigated to show its potential for application in both inverted organic light emitting diode (OLEDs) and inverted organic solar cells (OSCs) as cathode buffer layer. Second, interfacial studies for both electrode/Zn-Si-O and Zn-Si-O/organic semiconductor interface have done by several experimental techniques. Research results show that low energetic barrier for both interface is achieved. Third, four kinds of devices are studied: inverted single junction OLEDs, inverted tandem OLEDs, bulk heterojunction organic solar cells and hybrid solar cells. Performance of these devices with Zn-Si-O show significant improvement comparing to conventional oxides (ZnO, ITO) counterparts. Finally, surface electronic structure tailoring of Zn-Si-O by post plasma treatment is studied. Its influence to energy alignment of Zn-Si-O/organic semiconductor interface and performance of organic devices has been discussed. The detail results are summarized as follow.

A general introduction to review the background of cathode buffer layer issues in organic electronic devices is done in Chapter 1. The objectives of this thesis are also introduced in this Chapter.

Electrical and optical properties of Zn-Si-O are measured and the main results are shown in Chapter 2.1. The experiment results show that Zn-Si-O has large optical band gap (3.8eV) and high transparency in visible region, which make it suitable for application in optoelectronic devices. The electron mobility of Zn-Si-O is 1.21 $cm^2/V\cdot s$ which is 6 orders of magnitudes larger than conventional organic electron transport material Alq_3. More important, Zn-Si-O shows an ultra-low work function 3.4 eV which is exceptionally small among the conventional oxide semiconductors. With such a small work function, a low energetic barrier between Zn-Si-O and organic semiconductors can be expected.

Voltage-current characteristics of Zn-Si-O/electrode (Al, ITO and Au) interface are investigated in Chapter 2.2. Ohmic contact is formed for Zn-Si-O/Al and Zn-Si-O/ITO and an unexpected small Schottky barrier is found for Zn-Si-O/Au interface. The specific contact resistances of Zn-Si-O/Al and Zn-Si-O/ITO are measured by CTLM method and the value are 4.0×10^{-3} Ωcm^2 and 6.7×10^{-3} Ωcm^2, respectively.

Application of Zn-Si-O to both single junction and tandem inverted OLEDs are studied in Chapter 3.1 and Chapter 3.2. For single junction inverted OLED, Zn-Si-O is found to be an effective electron

transport and electron injection layer for inverted OLED. Benefiting to its low work function, lower energetic barrier is formed at Zn-Si-O/Alq_3 interface compared to conventional oxides cathode ZnO and ITO. With Zn-Si-O as ETL/EIL, both current efficiency and power efficiency are higher due to better hole-electron balance. For inverted tandem OLED, Zn-Si-O work as both electron injection layer and charge generation layer. Combining with high work function oxide, MoO_3, an effective charge generation layer (CGL) with bi-layer Zn-Si-O/MoO_3 is achieved. Although the work function difference between MoO_3 and ZSO is large, a quasi-Ohmic contact is formed. Research results show that interface state is formed, due to the reduce of MoO_3 by deposited Zn-Si-O on it under high vacuum. A tandem OLED is successfully fabricated utilizing this bi-layer CGL and low voltage loss of just 0.4 V is achieved which is smaller than conventional organic CGL.

Application of Zn-Si-O to bulk heterojunction polymer solar cells (PSCs) are studied in Chapter 4. Zn-Si-O is found to be an effective electron extraction layer (EEL) for inverted OSCs. Although there is a band offset at the interface of Zn-Si-O/PCBM interface which will hamper the electrons transfer from PCBM to Zn-Si-O, we can obtain high efficiency inverted OSCs by introducing a bilayer structure EEL by combining ZnO film and ultra-thin Zn-Si-O film (5nm). With such a bilayer EEL, both J_{sc}, V_{oc} and fill factor (FF) are enhanced. With the improvement mentioned above, the power conversion efficiency of OSCs with ZnO/Zn-Si-O (5nm) as EEL is 4.17% which is higher than the ZnO (3.47%) and ITO (1.98%) counterpart.

Influence of post plasma treatment to Zn-Si-O/organic semiconductor interfacial energy alignment is studied in Chapter 5. We studied the surface electronic structure of a-ZSO and the energy alignment of Alq_3/amorphous ZSO (with and without oxygen/Ar plasma treatment) interface by in situ UPS. It was found that the work function of the amorphous ZSO film increased from 3.4 eV to 4.0 eV. Additionally, the offset between LUMO of Alq_3 and the CBM of ZSO increased by 0.4 eV after oxygen plasma treatment. The smaller band offset of Alq_3/as-deposited ZSO and Ar-ZSO interface results in lower electron injection barrier and exciton dissociation rate, which resulting in better performance when it was used as electron injection layer of OLED. In contrast, the oxygen plasma treated ZSO is more efficient for application in hybrid solar cells due to the higher exciton dissociation efficiency at the interface. These researches provide a surface cleaning method to air exposed Zn-Si-O thin films which is important for practical produce and extend the application field of Zn-Si-O to organic-inorganic hybrid solar cells.