

論文 / 著書情報
Article / Book Information

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論文要旨

THESIS SUMMARY

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Department of, Graduate major in		
学生氏名：	陳 杰	
Student's Name		

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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

The development of clean and renewable energy is now necessary to build a sustainable society. Solar cells, which convert light energy into electricity without producing pollution, show excellent potential as next-generation energy convertors. However, the high cost of commercial silicon solar cells restricts the use of solar energy. Thus, reducing the cost of solar cells has become a critical issue in enabling their commercialization. In recent years, dye-sensitized solar cells (DSSCs) and perovskite solar cells (PSCs) have attracted much attention due to their high cost-effectiveness arising from their ease of manufacture. For these solar cells, interface engineering is vital to achieve high power conversion efficiency, because interfaces determine the external voltage and photogenerated electron-hole pair collection.

DSSCs have a sandwich structure, which comprises a dye-sensitized metal oxide semiconductor working electrode (TiO_2), a redox electrolyte (I^-/I_3^-), and a platinum counter electrode. When an electron moves through the TiO_2 working electrode, it can directly react with the ions in the electrolyte due to the direct contact between the electrolyte and TiO_2 , which results in charge recombination. Thus, reducing the interfacial contact between the TiO_2 working electrode and electrolyte is important to reduce this recombination. For DSSCs, the additive 4-tert-butylpyridine (tBP) is usually added to the electrolyte to increase the open-circuit voltage (V_{oc}) and efficiency of the DSSCs, which is explained by the band-edge shift of the TiO_2 anode and function of blocking layer. However, the other effects of tBP are not well studied, such as a decreased short-circuit current (J_{sc}) and increased fill factor (FF).

In recent years, PSCs have attracted much research interest due to their high efficiency and potential. However, the unstable perovskite absorber and hole transport material (HTM) result in poor stability. To improve the stability, carbon nanotubes (CNTs) with high chemical stability, hydrophobicity, and high conductivity were considered for an alternative electrode to form HTM-free PSCs. However, it is difficult to form a good interface between a perovskite layer and CNTs due to the tubular structure of CNTs. Thus, improving the perovskite/CNT interface should be important for obtaining highly efficient CNT-based HTM-free PSCs. A detailed introduction, electrical characterization methods, and the objectives of this study are given in Chapters I and II.

Chapter III described an investigation of the changes in all the photovoltaic parameters on using tBP additive, regardless of increases in V_{oc} and FF or decreases in J_{sc} . To achieve this, the detailed attachment between the TiO_2 working electrode and tBP was varied by changing the amount of dye

adsorption of the DSSCs using an electrolyte with or without tBP, and the dye adsorption was quantitatively evaluated after UV-vis measurements. Employing the tBP additive could efficiently increase V_{oc} from 0.515 to 0.737 V. Electrochemical impedance spectroscopy (EIS) confirmed that this increase in V_{oc} could be attributed to the band-edge shift caused by deprotonation of the TiO_2 working electrode. However, intensity-modulated photovoltage spectroscopy (IMVS) and intensity-modulated photocurrent spectroscopy (IMPS) did not reveal the function of the blocking layer: DSSCs with tBP showed higher recombination currents. Further investigation by EIS confirmed that this problem was related to the high transport resistance (R_t) in TiO_2 after using the tBP additive, which acted as a barrier to electron collection at short-circuit. Furthermore, the DSSCs with tBP additive obtained low diffusion resistance (R_d) in electrolyte which might be one reason of serious recombination, because the fast ion migration could increase the ion density at TiO_2 /electrolyte interface. And the improved FF is attributed to the decrease of reverse saturation current caused by the band-edge shift of tBP.

Chapter IV explained how oxygen-containing functional groups including carboxyl ($-COOH$) and carbonyl ($-C(=O)-$) were decorated on the CNTs to increase their interaction with the perovskite layer. The morphology of the perovskite material improved significantly after long-term storage. Consequently, the PSCs using CNTs decorated with oxygen-containing functional groups obtained a higher efficiency after long-term storage in an ambient medium with a relative humidity of 20%–50%, which was confirmed by an enhanced interface between the perovskite layer and CNTs, verified by EIS. In one case, an efficiency of ~3.21% was increased to ~11.19%. When employing the same fabrication process, the PSCs using raw CNTs without oxygen-containing functional groups could not achieve interfacial improvement, so that the efficiency was not improved, although a similar perovskite crystal morphology was obtained after long-term storage. Consequently, the efficiency of PSCs using raw CNTs decreased from ~7.66% to ~5.34% under the same ambient conditions.

Based on the efficiency enhancement described in Chapter IV resulting from the interfacial improvement after long-term storage, the fabrication of a good initial interface is further probed in Chapter V. Herein, dimethyl sulfoxide was added to PbI_2 solution to form a porous PbI_2 film, which was further treated by press process; the initial interface between the CNTs and PbI_2 film was thus improved, and the CNT-based HTM-free PSCs achieved an initial efficiency reaching 11.03%.

In conclusion, the interfaces are vital to the performance of DSSCs and CNT-based PSCs. EIS is a powerful tool for studying the electrochemical system in DSSCs and PSCs; it confirmed both the band-edge shift and increase in R_t caused by tBP in DSSCs and the decrease in charge transfer resistance at perovskite/CNT interfaces caused by oxygen-containing functional groups in CNT-based HTM-free PSCs.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note: Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1 copy of 800 Words (English).

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