色素增感型太陽能電池之電化學與光電特性探討

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摘 要

本研究主要以商業化的TiO2(Degussa P25)作為色素增感型太陽電 池之工作電極， 並以Tetra (4-carboxyphenyl)porphyrin (TCPP) 作為染料， 電解質部分則使用Potassium iodide(KI)、Iodine(I2)並以Propylene carbonate(PC)作為溶劑， 對電極則使用白金(pl atinum，Pt)作為催化劑，研究製程參數對色素增感型太陽能電池 （Dye-Sensitized Solar Cells, DSSC）光電效率的影響，並使 用電化學方法（循環伏安法與交流阻抗分析法）探討氧化還原媒 子(mediators, I-/I3-)之電化學特性，推估擴散係數、擴散極限 電流密度及其電化學阻抗等。 本研究主要針對工作電極、電解質、對電極進行研究。以旋轉塗 佈法將調配好的TiO2 漿料塗佈於ITO 導電玻璃基板上，經450°C 燒結，形成中孔奈米晶薄膜工作電極，探討以不同厚度之TiO2 薄膜製作之工作電極，其光電轉換效率之影響。以不同比例與組 成之[I-]/[I3-]，觀察其電化學特性之變化，並添加具有抑制光電子再結合(recombination)作用的4-tert- butylpyridine(TBP) ，觀察TBP 對本系統光電轉換效率之影響。此外本研究並 以電化學方法，探究白金對電極之電化學行為，以不同厚度的白 金鍍膜，探討對整個電解質系統之擴散極限電流密度與交流阻抗 的影響。 研究結果發現TiO2 工作電極膜厚與旋塗次數成正比，而當工作 電極膜厚達到6.3μm 時(2 層)，具有最佳的光電轉換效率(η) ，當工作電極膜厚再次增加時，光電轉換效率不再增加，但是 短路電流Isc 略降。 電化學分析結果顯示：隨著[KI]增加，擴散極限電流密度 (diffusion-limited current density，Jlim)和Isc 有上升趨 勢，而等效電阻和開路電壓(Voc) 有下降趨勢，當[KI]=0.3M 可 得到最佳的光電轉換效率。同樣的，當[I2]增加時，Jlim 和Isc 有上升趨勢，而其等效電阻、填充因子(FF)和碘錯化物(I3-)之擴 散係數(DI3-)有下降趨勢，在[I2]=0.05M 可得到最佳的光電轉 換效率。當添加TBP 後，Isc 略微下降，Voc 有上升趨勢，而等 效電阻中之電荷轉移阻抗(charge transfer resistance,RCT)明 顯下降，當[TBP]=0.1M 可得到最佳的光電轉換效率。當白金厚度 增加時，對電極之Jlim 有隨之上升，反之其等效電阻逐漸下降， 在白金厚度=10nm 可得到最佳的表現。元件之入射光子- 電流轉 化效率(Incident Photo-to-Current Conversion Efficiency, IPCE)量測顯示當波長在350~400nm 時具有最高的轉化 效率IPCE=20%)。 綜合以上結論，可知本研究之最佳製程參數：TiO2 膜厚6.3μm， [KI]=0.3M、[I2]=0.05M、[TBP]=0.1M，白金厚度10 nm，可得到 最大光電轉換效率η=0.21% ， 此時Voc=0.45V ， Isc=0.885mA ， FF=0.53。研究結果顯示以電化學技術作為DSSC 元件特性之 量測，是一種有效的製程診斷與改進電池效率之工具。

關鍵詞 : 色素增感型太陽電池 ; 二氧化鈦 ; 循環伏安 ; 交流阻抗 ; 擴散極限電流密度

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