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Low Sheet Resistance Counter Electrode in Dye-sensitized Solar Cell

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Abstract: In order to search for the high efficiency and low sheet resistance counter electrode in dye-sensitized solar cell, we used Ti plate as the conducting substrate to prepare the counter electrode by thermal decomposition of H_2PtCl_6. Ti plate counter electrode shows low sheet resistance, good reflecting performance and matching kinetics. The dye-sensitized solar cell with the Ti plate counter electrode shows better photovoltaic performance than that of the cell with the fluorine-doped tin oxide-coated glass counter electrode.

Keywords: Dye-sensitized solar cell, sheet resistance, counter electrode, reflecting performance.

Dye-sensitized solar cell has attracted much attention because of its low cost and high conversion efficiency[1]. It consists of three main components: a dye-coated nano-crystalline TiO_2 layer on conducting glass substrate as photoelectrode, an iodide/ triiodide redox couple as mediator of shutting charge and a counter electrode.

Up to now, the fluorine-doped tin oxide (FTO) -coated glass substrate coated with small amount of platinum is widely used as the counter electrode because of its high catalytic activity for iodide/triiodide redox reaction[2]. However, its high sheet resistance lowers the fill factor of the cell and limits the width of the cell to less than 1 cm[3]. A low sheet resistance counter electrode with high catalytic activity is an important requirement to realize the practical utility of dye-sensitized solar cell.

Titanium has been used extensively as the substrate for electrode due to its excellent combination of corrosion resistance, mechanical properties, low density and low sheet resistance[4]. The performance of the counter electrode in dye-sensitized solar cell using titanium plate(TP) as conducting substrate will be discussed in this letter.

FTO and TP were purchased from Hei Longjiang Hake New Energy Corp, TP and FTO counter electrodes were prepared by thermal decomposition of H_2PtCl_6 in anhydrous isopropanol on TP and FTO respectively. The electrolyte consists of 0.5mol/L potassium iodide and 0.05mol/L iodine in ethylene carbonate/propylene carbonate (EC/PC) (8/2 by

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volume). Electrochemical impedance spectroscopy was carried out with a Solartron 128087S system employing on symmetric thin-layer cell[5]. Sheet resistance was measured by four point method. The reflecting performance of conducting substrate was measured with U-3010UV spectrophotometer. The photocurrent-voltage performance was measured under Xenon lamp (60 mW/cm^2), the area of the photoelectrode is 0.2 cm^2.

Figure 1 showed variation of charge-transfer resistance (R_{ct}) of TP counter electrode with thermalization temperature. Like the variation of R_{ct} of FTO counter electrode with temperature, there exists a temperature where R_{ct} of TP counter electrode is minimum. **Figure 2** showed dependence of R_{ct} of TP counter electrode on platinum loading. R_{ct} of TP counter electrode decreases with the increase of platinum loading up to 10 μg/cm^2, and its variation is small when platinum loading exceeds 5 μ g/cm^2. Considering the cost and the performance of counter electrode, it is favourable that platinum loading is 6 μ g/cm^2.

Figure 1 Variation of R_{ct} of TP counter electrode with thermalizaton temperature, platinum loading is 6μg

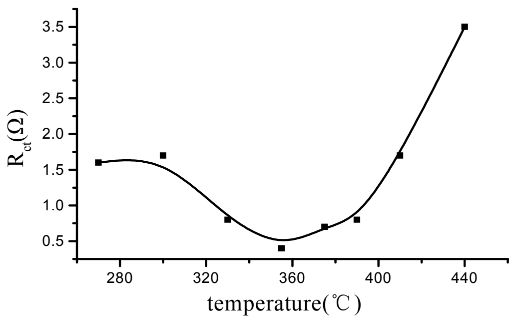
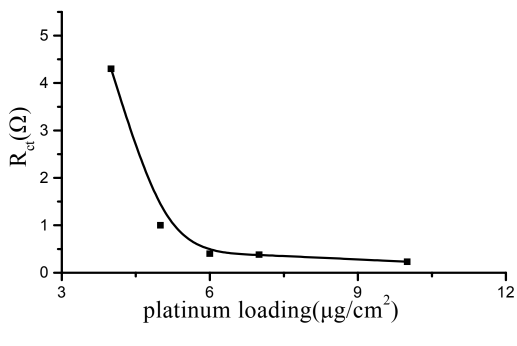


Figure 2 Dependence of R_{ct} on platinum loading for TP counter electrode, thermalization temperature is 355℃.



The photovoltaic behavior of the cell with FTO electrode (FTO cell) and TP electrode (TP cell) as counter electrode were shown in **Figure 3**, and the detailed information such as current density, open circuit voltage, fill factor and conversion efficiency were listed in **Table1**.

Figure 3 Photocurrent-voltage performance of dye-sensitized solar cell under 60 mW/cm^2 illumination

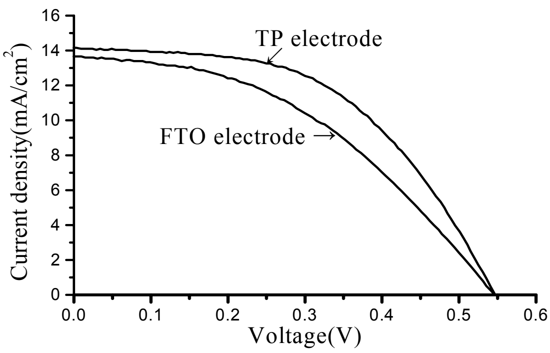


Figure 4 The photo-reflecting performance of counter electrode

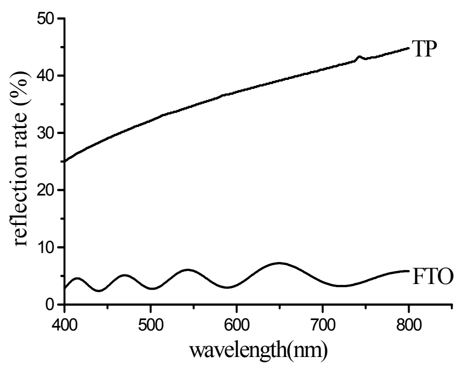


Table 1 The conversion efficiency, fill factor, current density and voltage of the cell

Counter electrode	*Conversion efficiency (%)*	*Fill factor*	*Current density (mA/cm²)*	*Voltage (V)*
FTO electrode	5.5	0.42	13.6	0.54
TP electrode	7.4	0.57	14.2	0.54

It is obviously that TP cell shows better photocurrent/voltage performance. The differences in the fill factor mainly resulted from the slope of I-V curve (**Figure 3**). The I-V curve of TP cell at the potential near the open circuit voltage was more vertical than that of FTO cell. The internal resistances(R_i), which include resistance of working electrode, solution, counter electrode and wires, can be estimated from the slope of I-V curve of two cells at the potential near the open circuit voltage. The R_i were 73 Ω and 113 Ω for TP and FTO cell respectively. After removing the IR drop of 40 Ω in FTO cell, the I-V curve of FTO cell was very similar to that of TP cell. The improvement of TP cell in fill factor was caused by the decrease of R_i. The 40 Ω difference of R_i between two cells mostly came from the difference between FTO and TP counter electrodes. The R_i of counter electrode is composed of charge-transfer resistant and sheet resistant. Charge-transfer resistance of FTO and TP counter electrode measured by impedance method were 0.2 Ω and 0.4 Ω, which were small compare to the R_i. The square resistance of FTO and TP measured by four point method were 20 Ω and 0.8 Ω. The sheet resistance calculated from square resistance and the dimension of counter electrode with about 2 cm long and 1 cm wide were 40 Ω and 1.6 Ω. That is to say, the difference of R_i was mainly caused by sheet resistance.

TP cell also showed higher short circuit current. This may result from good reflecting performance of TP counter electrode. The photo-reflectivity of TP and FTO counter electrode were shown in **Figure 4**. TP counter electrode showed better photo-reflectivity, especially in red and infrared regions. The photons, that not absorbed by dye on TiO_2 working electrode reached TP counter electrode, reflected by it, and went through the working again. Light reflecting increase the light path and absorbance, and therefore shorten the circuit current.

In conclusion, TP counter electrodes increase the fill factor by low sheet resistance and high catalytic activity for iodide/triiodide redox reaction, and the short-circuit current by high reflecting rate, therefore the total conversion efficiency was increased. It is suitable for counter electrodes in dye-sensitized solar cells, especially in large area cells.

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