Trade Science Inc.

Nano Science and Nano Technology
An Indian Journal

Short Communication

NSNTAIJ, 3(2), 2009 [61-63]

V^{5+} and Fe^{3+} doped TiO_2 composite nano-crystalline solar cell research

Ding Shi-Wen*, Zhang Hong-Jun, Zhang Yuan-Yuan
College of Chemistry and Environmental Science, Hebei University, Baoding Hebei 071002, (CHINA)
E-mail: dingsw-hbu@163.com

Received: 25th August, 2009 ; Accepted: 4th September, 2009

ABSTRACT

Prepared V^{5+}, Fe^{3+} doped TiO_2 and pure TiO_2 in co-precipitation method, and prepare nanocrystalline TiO_2 film with the three kinds of titanium dioxide in different order. The titanium dioxide crystal structure is mainly the anatase and few rutiles. According to atomic force microscope (AFM) examination, the shape of TiO_2 is spherical shape and particle size of it is about 3-6nm. Assembles the solar cell and Surveys their electro-optical performance. The results showed that the Fe-Ti-V electrode performance is better then others, the short-circuit current is 1.1mA • cm^{-2} and the open-circuit voltage (V_{OC}) is 83mV.

KEYWORDS

TiO_2;
TiO_2 film electrode;
Doped.

INTRODUCTION

Increasing energy demands and concerns over global warming have led to a greater focus on renewable energy sources in recent years. The conversion of solar energy is likely to play a key role as one of the technologies that can replace fossil fuels in the generation of mass energy. However, the current high cost of solar panels made from traditional inorganic semiconductors imposes a restriction on their mass usage. TiO_2 has the superior physics and chemistry nature, thus it becomes a hot research spot. Since the first efficient dye-sensitized solar cell was reported by Gratzel et al. in 1991 this kind of new solar cell has attracted world wide attention for its low production cost, easy handling and relatively high light-to-electrical conversion efficiency. Dye-sensitized solar cells (DSSC) are composed of nanocrystalline TiO_2 film, electrolyte containing a redox couple and counter electrodes. The function of nanocrystalline TiO_2 film is to absorb the appropriate wavelength of sunlight .Photo excitation of the valence band results in the injection of an electron into the conduction band of the oxide. The people have done massively about the TiO_2 research, such as titanium dioxide nanotubes[1,2], doped titanium dioxide[3,4].

In this work, we prepared a nanocrystalline TiO_2 film which has three different titanium dioxide compositions, and use it to assemble solar cells.

EXPERIMENTAL

Chemicals and instruments

Anhydrous lithium iodide (LiI), iodine (I_2), $TiCl_4$, ammonia, $FeCl_3$, NH_4VO_3, ethanol, are analytical reagents, F-doped SnO_2 coated glass（FTO–glass）as transparent conductive glass for photoelectrodes, All experiment water used is double-distilled water.

UT58E Digital multitester, Y-2000 X-ray

Diffractometer (Dandong),Atomic force microscopy AJ-III (Shanghai AJ Nano-Science Development Co.Ltd.), BRANSON-BUT-2030-25-06-type Supersonic clearer, Shanghai Wei Yu BME100L high shear mixed emulsion machine, Tianjin Optics Instrument plant GY-1 Bromine-tungsten lamp.

Preparation of electrode

Instill 22ml$TiCl_4$ to 200 mL deionized water by the speed of 1d/s, and lay it until it changed to clarify. Dissolves NH_4VO_3 2×10^{-3}mol in 50ml distilled water. Mixes two kind of solutions together, and pour the solution in three-neck bottles. Heat it until boil. Under the conditions of 100 degrees for 20 minutes, add the ammonia water which the volume fraction is 50% adjustment to the neutral or the weak alkalescent, then heats up 3 hours before the cessation of heating reaction. Washing the reaction products with distilled water until it is no impurities such as NH_4^+ and Cl^-, then we obtain the Vanadium-doped titanium dioxide. Prepare Iron-doped titanium dioxide and pure titanium dioxide with the above similar method.

Take 3g above different titanium dioxide to join separately to the 297ml distilled water, emulsifies 10 minutes by a speed 5000r/min.

Spraying the emulsion on the conductive glass which has been cleaned as follow:

First, only spurts the pure titanium dioxide on the conductive glass (Figure 1a).

Second, like Figure 1b in the shape of a sandwich, iron-doped in the bottom, pure titanium dioxide in the middle, vanadium-doped titanium dioxide at the top, the thickness of each layer is the same.

The third likes the second (Figure 1c), but in contrast with the second, vanadium-doped titanium dioxide in the lower, pure titanium dioxide in the middle, iron-doped titanium dioxide at the top, the thickness of each layer is also the same.

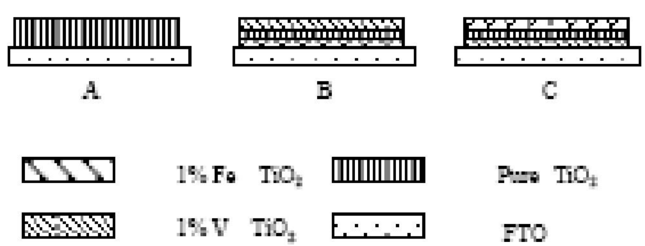

Figure 1: Schematic diagram of the TiO_2 electrode

These three kinds of nanocrystalline TiO_2 film total thickness is the same. The film was deposited on only the FTO-coated side of the glass.

The nanocrystalline TiO_2 film dried at room temperature, heats up to 450°C maintains 30 minutes[5]. A 10μm-thick film of TiO_2 was then printed on the treated conducting glass.

RESULTS AND DISCUSSION

XRD analysis of electrode

The X-ray diffraction spectrum of the nanocrystalline TiO_2 film is shown in Figure 2. It shows peaks characteristic of anatase and the few rutiles. The results suggest that significant crystal growth occurs in the TiO_2 films during heat treatment, but there no obvious characteristics of vanadium or iron peak. The possible reason is that the doping quantity is too few[6]. The Fe^{3+} ionic radius is 0.064 nm and the V^{5+} 0.059nm all similar with the Ti^{4+} (0.075 nm). Under high temperature, $Fe^{3+}$and V^{5+} are highly uniform distribution into the TiO_2 lattice, they replaced the lattice position of Ti^{4+}.

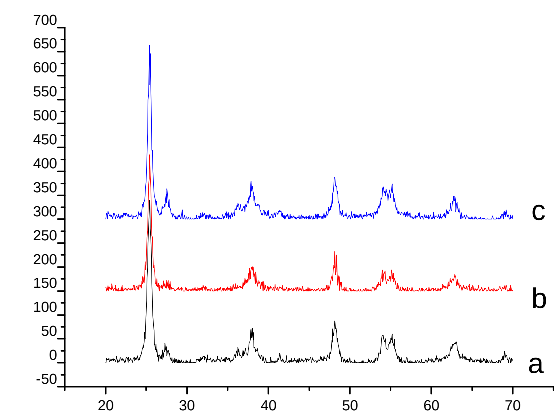

Figure 2: XRD pattern of the samples a pure TiO_2 b 1% V c 1% Fe

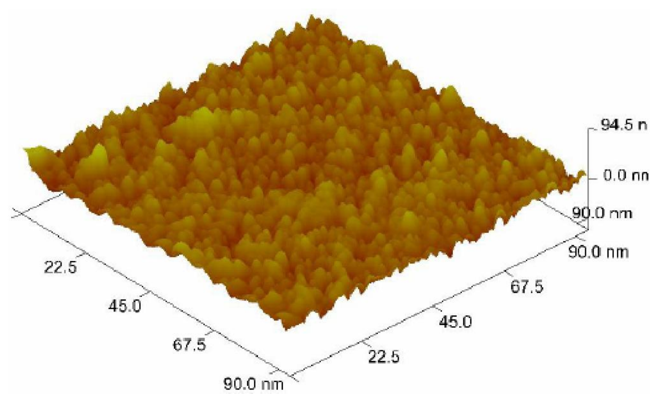

Figure 3: AFM surface images of TiO_2 films

Figure 2 is the TiO_2 thin film electrode's atomic force microscope chart, it shows that the electrode surface is the spherical pellet and the particle size is 3-6nm.

Results

A GY-1 Bromine-tungsten lamp (Tianjin Optics Instrument plant) served as a light source. The luminous intensity is 60mW/cm^2. Figure 4 and 5, respectively, for the measured short-circuit current and open circuit voltage of the current comparison. We can see from the diagram that Fe-Ti-V is the best structure of the electrode compare with others. The open-circuit voltage of it is 83mV, this data is higher than 51% compared to the pure titanium dioxide's result, enhanced 93% compared to the V-Ti-Fe structure's electrode. The short-circuit current is 1.1mA·cm^{-2}, this data is higher than 74% compared to the pure titanium dioxide's result, enhanced 26% compared to the V-Ti-Fe structure's electrode. The possible reason is that Fe-doped TiO_2 is the n-type semiconductor, and V-doped TiO_2 is the P-type semiconductor. In this electrode structure, Fe-doped N-type emiconductor is the cell window layer and direct contact with the conductive glass, after battery absorption appropriate wave band sunlight, stimulates the valence band electron to produce the conduction band electron. V-doped TiO_2 for the P-type semiconductor contacts with transmission electronic media after battery absorption appropriate wave band sun's rays, produces the valence band hole. This is the formation of the following electronic access cycle: The stimulation produces electron after conductive glass spreads to Pt through the outside wire to the electrode In P semiconductor's hole and battery's conductive media contact. This synergy helps to improve battery performance.

In conclusion, the solar cell performance of a nano-crystalline solar cell was much improved by this new method. This work has also proved that enhancing the optical absorption length of TiO_2 film is a feasible strategy to realize a high efficiency DSC with a Doping technology.

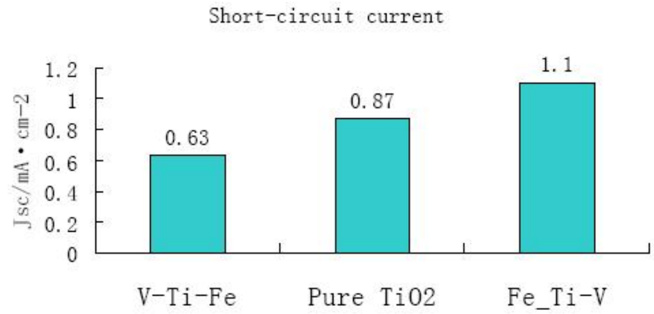

Figure 4: Comparison of short-circuit current

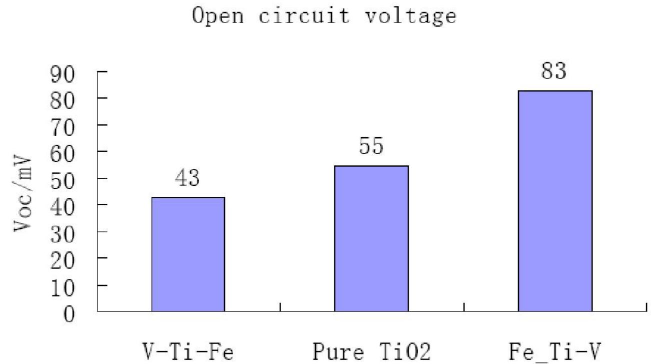

Figure 5: Comparison of open circuit voltage

REFERENCES

[1] Yu-qiao Wang, Yue-ming; Materials Letters., **63**, 1102-1104 **(2009)**.

[2] Haoqin, Sophie Wenger, Ming-Fei Xu, Fei-Fei Gao, Xiao-Yan Jing, Peng Wang, Shaik M.Zakeeruddin, Michael Gratzel; Am.Chem.Soc., **40**, 13364-72 **(2008)**.

[3] Nan Bao, Feng Liu, Feng Zhang, Zhi-Hui Ma, Zhen-Tao Wei; Journal of Functional Materials and Devces, **12**, 462-466 **(2008)**.

[4] Dong-Sheng Huang, Chao-Feng Chen; Chinese Journal of Inorganic Chemistry, **23**, 738-742 **(2007)**.

[5] Li Guo, Song-Yuan Dai, Kong-Jia Wang, Xia-Qin Fang, Shi-Cheng Wu, Pan-Xu; Chemical Journal of Chinese Universities, **10**, 1934-1937 **(2005)**.

[6] Jing-Cheng Wang, Xiao-Yan Sun, Pei Xin; Journal of Meteorology and Environment, **4**, 23-26 **(2008)**.