"Photo Current" in The Dark from Ti/CdSe Schottky Diode

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Abstract. CdSe was electrochemically deposited on pure Ti from $SeSO_3^{2-}$ source forming Ti/CdSe Schottky diode with deposition time 113s, 225s and 450s. SEM and current-voltage were employed to study the photo-electronic properties of the Schottky diode. The results show interesting, unexpected phenomena. The current density and the open-circuit voltage of 113s in the dark Ti/CdSe are higher than its analogous devices. Then an interpretation was probably given.

1. Introduction

With the progress of science and technology and the development of humans, energy and environmental problems has been widely concerned. Solar energy [1] application was found as a new energy resource. Quantum dots sensitized solar cell (QDSCs) is a research hotspot in recent year [2]. QDSCs are contained with three main parts, namely, the photo anode adsorbed with quantum dots (composite materials), the counter electrode and electrolyte. This study describes the prepared, symptom and synthesis method of the photo anode material.

Due to its intrinsic structure, CdSe quantum dots [3] has different features, such as quantum localization effect [4], surface effect, quantum size effect [5] and so on, at the same time, a CdSe quantum dot can absorb a high energy to produce multiple electron-holes, which called multiple exciton-effects [6]. CdSe has different characteristics when its Nano-crystals was in different particle size. CdSe Semiconductor is narrow band gap [7], so that the energy which inspired the exciton can mostly come from the solar spectrum.

Ti/CdSe Schottky [8-10] combined metal to the n-type semiconductor forming barrier. As a whole, Metal - Semiconductor has the same Fermi level in thermal equilibrium. Compared to the Schottky barrier, the biggest difference is that the PN junction has a lower junction voltage, and the metal has a relatively thin side (almost non-existent) the width of the depletion region. From the semiconductor to the metal, electronics needed to overcome the barrier; by metal to semiconductor, electronics blocked by the barrier. When adding forward bias the barrier on one side neighbors the semiconductor decline; conversely, in reverse bias, semiconductor side barrier.

Heat and light are most common and widespread in nature, so Solar thermal utilization project has been the forefront in modern technology. Ti/CdSe from electrochemical method had been tested and was found a good photon to current conversion efficiency properties.

2 Experiment

2.1 Cleaning Ti slice

The Ti (purity 99.99%) was soaked in 0.1M H_2SO_4 solution for 12h, and then was rinsed with acetone , distilled water, ethanol, distilled water in ultrasonic devices to remove surface dirt.

2.2 Electrochemical deposition of CdSe [11]

5mM Na_2SeSO_3solution was prepared by mixing 0.1M $Na_2SO_3$and weighed powdered 5 mM Se in 1M NH_3/NH_4^+ buffer in a 70 ºC aqueous bath until Se was completely dissolved. All solutions were prepared with triply distilled water and reagent grade of Na_2SO_3, NH_4OH, NH_4Cl, $CdSO_4$ and ethylene diamine tetraacetic acid (EDTA) with a concentration of 0.1, 1, 1, 0.2 and 0.2M, respectively. The pH value was measured to be about 10. All CdSe thin films were electrodeposited on Ti. Standard CdSe deposition on Ti was carried out at -1.33V. A standard three electrode configuration was used with Ti/CdSe as the working electrode on a SCE set a saturated calomel as the reference electrode and Pt as the counter electrode. A new solution was made for each deposition. But for Ti/CdSe, the process was in different time of 113s, 225s, 450s.

Photoelectrochemical measurements were carried out on a electrochemical workstation (CHI660D, Shanghai Chenhua Instrument Co. Ltd. Shanghai, China). A 150 W Xe lamp(CHF-XM-500W ,Beijing Changtuo Co. Ltd., Beijing,China) equipped with an AM 1.5G filter was used as the light source. The intensity of the incident light was measured with solar power meter TES 1333 (TES Co. Taiwan China) and fixed at 100 mW cm^{-2} under air mass 1.5 global (AM 1.5 G, using 1.5AM filter, Beijing Changtuo Co. Ltd. Beijing, China).

The current density versuspotential (J-V) curve of the working electrode was measured by a linear sweep voltammogram with a potentiostat CHI660D. In all J-V measurements, a two-electrode configuration similar to that typically used for solar cells test was used. Similar configuration of cells was: work electrode, photo anode Ti/CdSe, the counter electrode is a coil of Pt, reference electrode is HgO filled with1M KOH. Then the computer recorded the data.

3 Results and discussions

Electrochemical workstation was used to test prepared materials. CdSe spectral response is visible light[7]. The experiments comparing the performance of Ti/CdSe from duration of deposition time, measurement and characterize their dark curvea, exploring their intrinsic properties preliminary.

3.1 Analysis SEM images

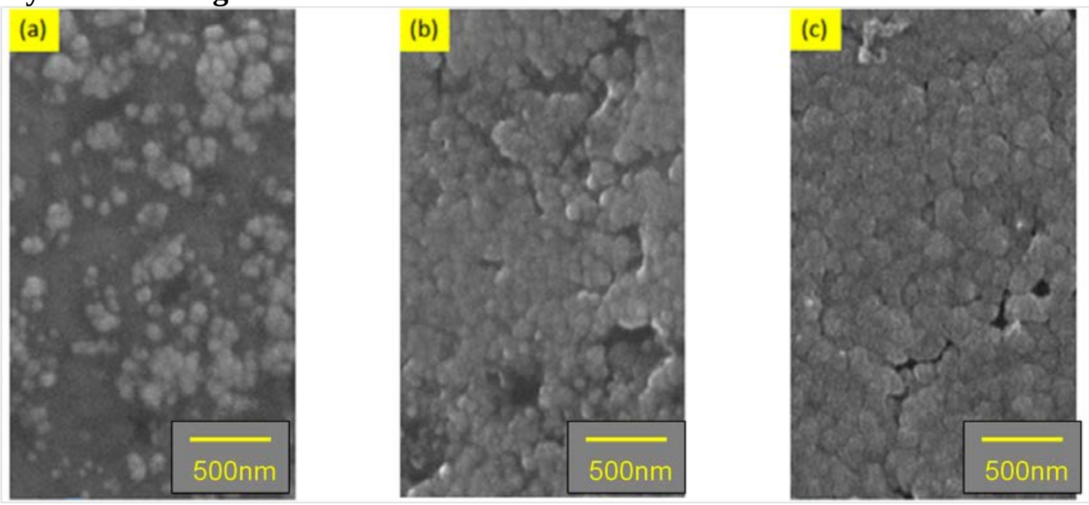

Fig. 1 Ti/CdSe with deposition time of 113s(a)225s(b)450s(c)

Fig. 1 shows CdSe was deposited 113s, 225s, 450s, on Ti. 113s CdSe particles are sparsely distributed, particles agglomeration occurs less. 225sTi/CdSe are reunited of single particles. It forms large agglomerates of particles after 450s. As a continuation of the deposition time, the agglomeration phenomenon is more obvious.

3.2 Schottky junction

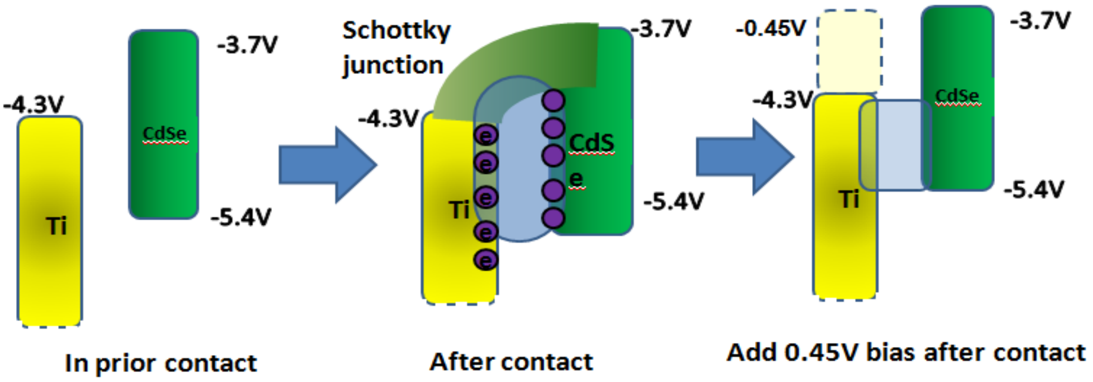

Fig. 2 Ti/CdSe Schottky junction formation

Fig. 2 illustrates Ti/CdSe Schottky junction formed with electrochemical deposition method. In prior of contact the CB (conduct band) and VB (valence band) of CdSe are -3.7V and -5.4V, respond and the work function position of Ti is also denoted. After contact, the density of negative charges neighboring the metal surface of the semiconductor side is increased, while the positive charges density of the semiconductor neighboring the surface of the metal increase. Due to the localization on the freedom charges of the semiconductor CdSe, thus positive charges are distributed in the surface layer. The positive surface layer is relatively thick and called the spatial charge region. When Ti was contacted with CdSe, there is an electronic field in the spatial charge region of CdSe, resulting in band bending inside CdSe.

3.3 The J-V curves

As shown in Fig. 3 the curves of J-V indicate the overall current density is low, this is due to various factors. Pt was used as the counter electrode and the electrolyte was a polysulfide. The catalytic activity of Pt in the polysulfide electrolyte was low and the impedance of the charge transfer between the interface of the counter electrode / electrolyte was high, resulting low efficiency of photoelectric conversion.

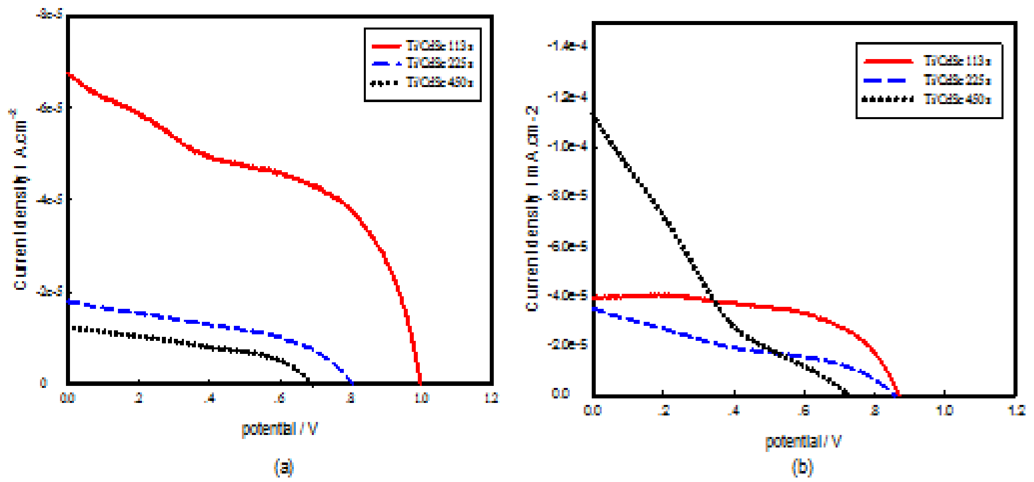

Fig. 3 Current density of Ti/CdSe in the dark (a) and sunshine (b)

Fig. 3 shows the compare of Voc (open circuit voltage) and Jsc [12](short circuit current) in the dark (a) and in one sun illumination (100mw.cm^{-2}) (b). In the dark, 113s-deposited Ti/CdSe is higher than 225s and 450s in the series, especially the difference of Jsc is 3 times. CdSe is a narrow band gap crystal. Thermal vibrations of the lattice can generate exactions. With the shortest deposition time, 113s, smaller size of particles CdSe can more easily tunnel through the boundary barrier toward Ti. So electrons and holes are separated , resulting in a dark current. With longer time for deposition, a lot of particles of CdSe are agglomerated and the barrier becomes too strong, electron-hole pairs cannot be separated easily, thus impacting drawback the Jsc, Voc.

With the sunlight, Jsc of deposition 450s is twice higher than 225s and 113s, but at the expense of Voc. At around 0.45V, J-V curve has a tendency to twist, possible features may be caused by the Schottky barrier. The work function of Ti was in -4.33V, then added 0.45v bias, the band of Ti was at about -3.65V, and CdSe conduction band potential of -3.7 V, both of which were similar, the electronic transmission from CdSe to Ti was not easy.

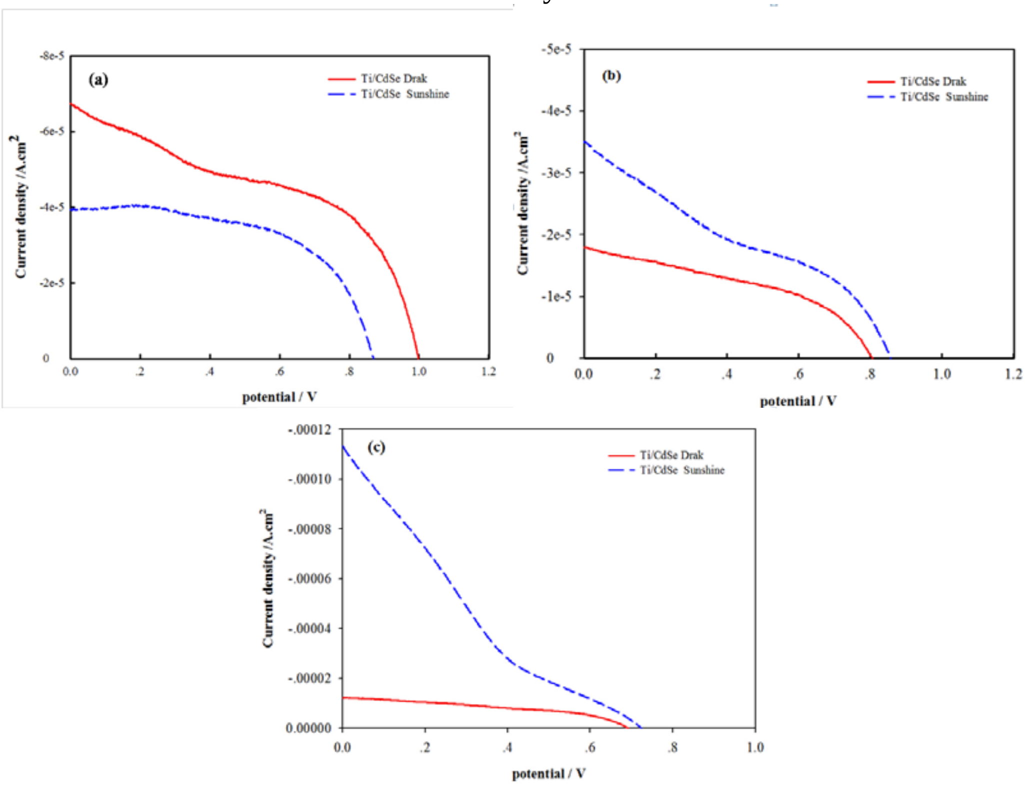

Fig. 4 Ti/CdSe in the dark and under the sunshine in contrast with deposition of 113s (a) 225s (b) 450s (c)

In Fig. 4 (b), (c) with the same deposition time, it always has the same properties: Jsc and Voc under the sunlight are always higher than those in the dark. This is probably due to the narrow band gap of semiconductor CdSe, electron-hole pairs from visible solar spectrum were generated hence the Jsc increased.

4. Summary

Using electrochemical deposition method, with $SeSO_3^{2-}$ as selenium source, CdSe was deposited on pure Ti, forming a Schottky diode. The morphology and properties of the Ti/CdSe surface is different as different deposition time, which has been specifically described in the text. In this paper, SEM, electrochemical workstation etc. was used to analyze the properties of Ti/CdSe. Especially in dark conditions, there are still dark current, which draw our attention.

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