Performance improvement of dye-sensitized solar cells by reducing the formation of Zn^{2+}/dye complex

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Abstract

In the past few decades, various semiconducting materials including metal oxides have been explored as alternative materials for Si based devices. Especially, ZnO which has been the most attractive for photonic devices due to its high conductivity and natural abundance. In order for dye-sensitized solar cells (DSSCs) to achieve higher efficiency researchers have investigated ZnO as a photo electrode material. However, since ZnO is unstable in acidic solutions, ZnO-based DSSCs show lower performance. In this study, we investigated the effect of the formation of Zn^{2+}/dye complex on the performance of devices fabricated with ZnO nanowires (ZnO NWs).

Introduction

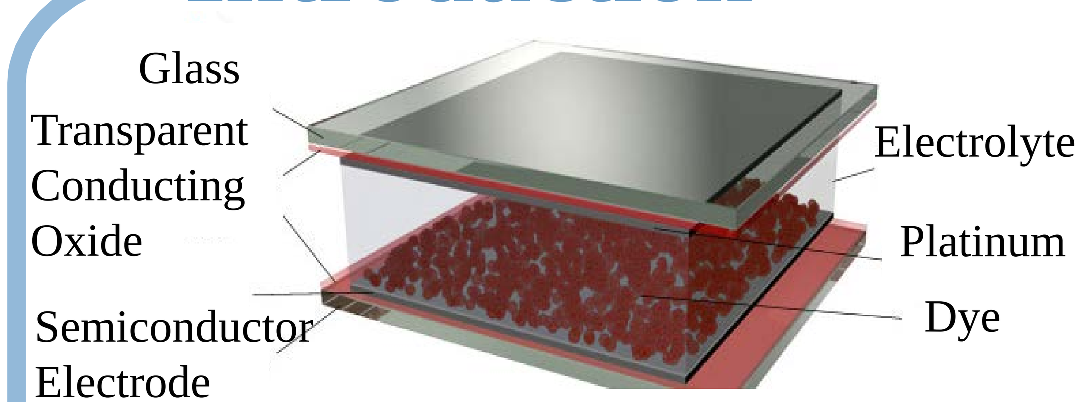

Fig. 1 Schematic of DSSC based on semiconductor electrode. [1]

❑ ZnO

ZnO has a large band gap energy (3.4eV). Its electron mobility (1000 $cm^2 V^{-1} s^{-1}$) is higher than that of TiO_2, and the electron effective mass (0.26) is lower than that of TiO_2. Also, ZnO synthesis is relatively easy compare to other metal oxide materials. Therefore, ZnO is highly attractive as a photonic device material.

❑ DSSC

Ruthenium-based N-719 dyes absorb visible light, the absorbed photon energy excites electrons. Separated electrons and holes move into charge collecting electrodes, generating a current flow.

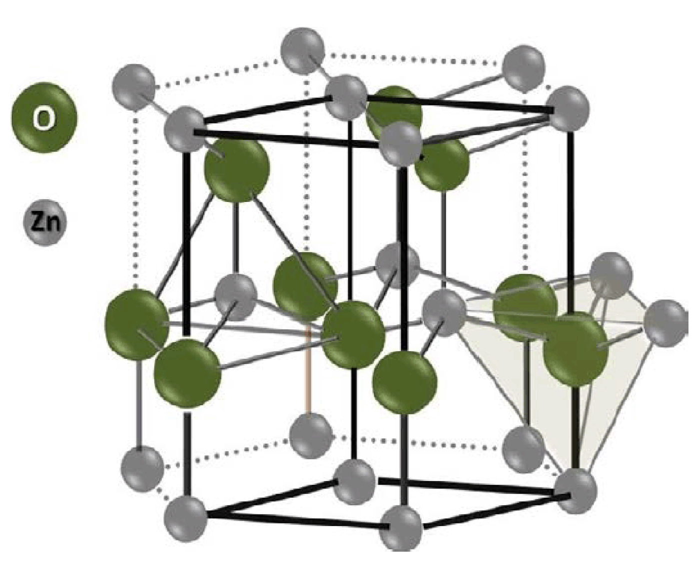

Fig. 2 Crystal structure of wurtzite ZnO. [2]

Experimental Details

❑ ZnO NWs Synthesis

- ►Chemical vapor deposition
- ►Fluorine-doped tin oxide (SnO_2:F) on glass
- ►Zn powder (Sigma Aldrich Co.)
- ►Mixture of O_2 and N_2 (1:20 v/v)

❑ Fabrication of DSSC

- ►Dye: 0.5mM N719 in Ethanol
- ►Electrolyte solution based on I_2
- ►Pt layer: Spincoating method using 0.1M $H_2PtCl_6 \cdot 6H_2O$ in Ethanol

❑ TiO_2 Layer

- ►Commercially purchased TiO_2 paste (DSL18NR-T)
- ►Doctors blading method
- ►Sintering process at 450^oC for 30min.

❑ Characterization

- ►Scanning electron microscope
- ►Solar simulator
- ►Semiconductor analyzer

Results & Discussion

Sample No.	Electrode	Soaking Time (hr)	V_{oc} (mV)	J_{sc} (mA/cm^2)	V_{max} (mV)	J_{max} (mA/cm^2)	FF (%)	η (%)
1	TiO_2	48	635	4.63	480	4.08	66.6	1.96
2	ZnO NWs	0.5	580	1.32	440	1	57.5	0.44
3	ZnO NWs	48	275	0.12	130	0.06	23.6	0.008

Table 1 Summary of values including the type of electrodes, soaking time into the dye (N719) solution, open-circuit voltage, short-circuit current, and overall light conversion efficiency for ZnO NWs and TiO_2 electrodes.

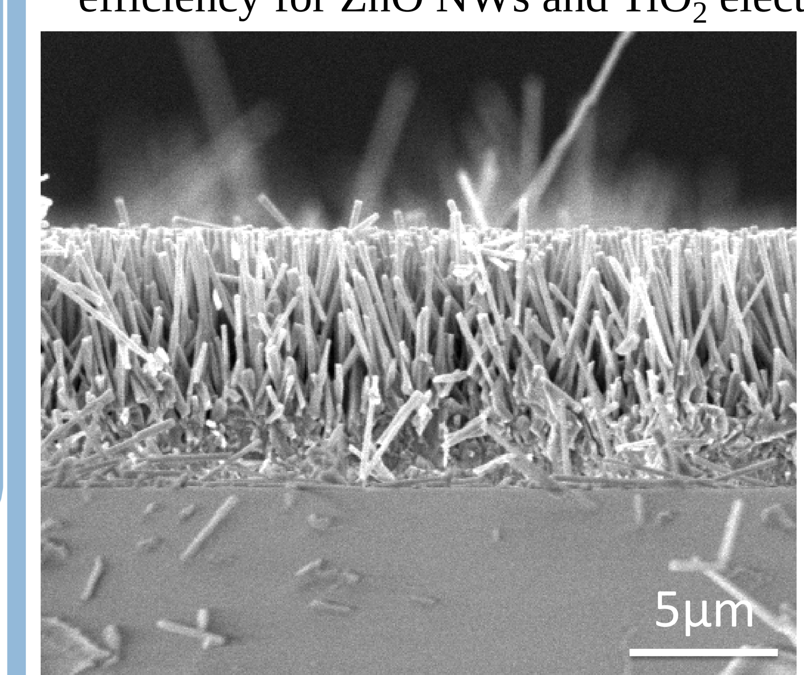

Fig. 3 Cross section SEM image of ZnO nanowires.

Figure 3 shows that well-aligned hexagonal wurtzite ZnO NWs were synthesized by chemical vapor deposition. Average diameter and height of ZnO NWs are 200nm and 9μm, respectively.

Figure 4 shows that the ZnO NW-based DSSC device soaked into the dye solution for 30min. shows the general I-V characteristics of solar devices, whereas the ZnO NW-based device soaked for 48hr. shows poor characteristics.

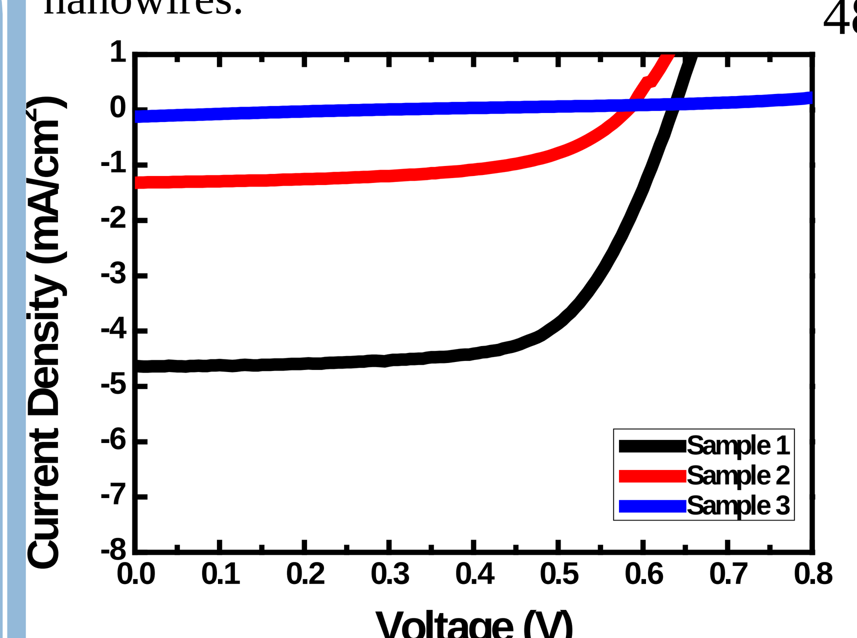

Fig. 4 I-V curve comparing the photovoltaic behavior of samples.

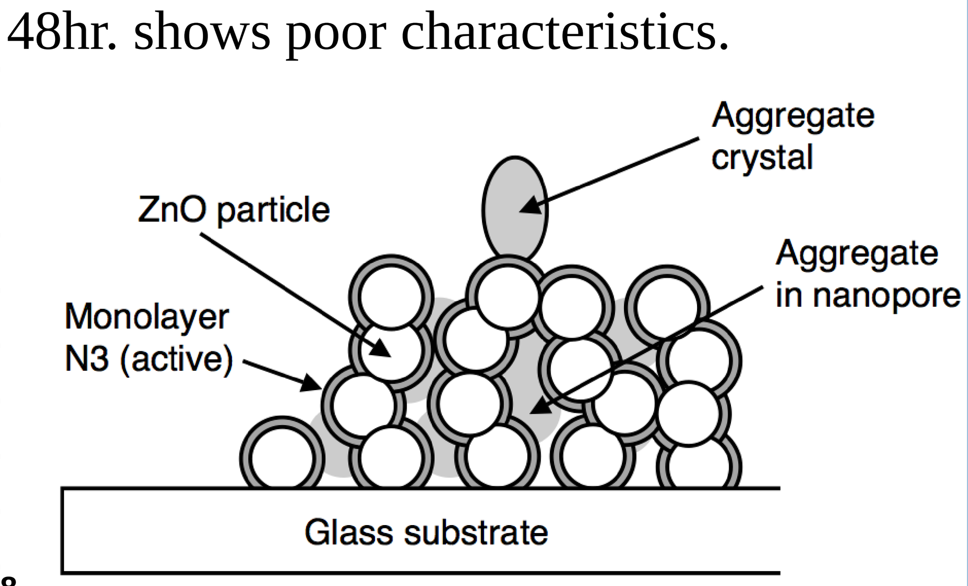

Fig. 5 Proposed structure of a N3-dye-sensitized ZnO film with Zn^{2+}/dye complex. [3]

Figure 5 shows Zn^{2+}/dye complex formation between ZnO nanoparticle and dye (N3). The Zn^{2+}/dye complex impedes the transportation of electrons from dye to ZnO nanostructures.

Conclusion

In this research, the performance of DSSC devices using TiO_2 and ZnO NWs have been compared by using a solar simulator. As a result, the efficiency of DSSC using ZnO NWs is lower than that of TiO_2, even though ZnO has higher carrier mobility than TiO_2. The low efficiency of solar device using ZnO NWs as a photo electrode is attributed to the dissolution of Zn atoms from surface into the acidic N719-dye solution, forming a Zn^{2+}/dye complex that prevents electron transport from dye to ZnO NWs. The surface treatment and modification of dye solution will be used to reduce the dissolution of Zn atoms and improve efficiency of DSSCs.

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