

Hybrid nanostructure of ZnO NWs and TiO₂ NPs and its application for DSSCs

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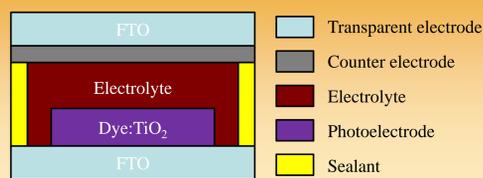
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Introduction

Among the different renewable and sustainable forms of energy, solar energy is one of the most promising solutions because it is safe, clean and its energy source is unlimited. Dye-sensitized solar cell is one of the most promising next-generation solar cell which has shown photovoltaic characteristics up to 11% while maintain a low cost production. ZnO-TiO₂ hybrid nanostructure is proposed as the photoelectrode material for DSSCs. Through a continuous CVD process, a hybrid composed of two different materials, ZnO and TiO₂, can be synthesized by a single synthesis route. Furthermore, the ratio of anatase and rutile TiO₂ can be controlled by adjusting the CVD parameters during deposition. Additionally, to solve the potential possibility of electrolyte leakage, a polymer gel-based electrolyte is studied to improve the long term stability of DSSCs.

□ Dye-Sensitized Solar Cell (DSSC)

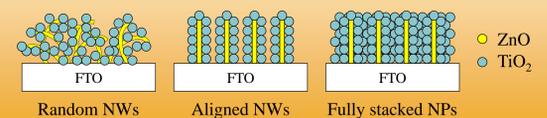


- 1) **Photoelectrode:** TiO₂ is the most widely used material for photoelectrode. TiO₂ nanoparticles receive an electron from dye and deliver the electron to the transparent conducting oxide layer.
- 2) **Dye:** Diverse ruthenium complex dyes can be used to DSSCs because they absorb long wavelength visible light by metal to ligand charge transfer.
- 3) **Electrolyte:** Iodide/triiodide redox couple transfer the electron from counter electrode to hole of dye molecule.
- 4) **Counter electrode:** Platinum can be used for counter electrode because it can be a reduction catalyst of triiodide.

Objectives

- 1) To synthesize high-quality ZnO-TiO₂ hybrid nanostructures, as an effective photoelectrode material for dye-sensitized solar cells through a continuous process by **chemical vapor deposition (CVD)**.
- 2) To optimize the **ratio of anatase and rutile TiO₂** crystals for dye-sensitized solar cells by controlling CVD deposition parameters.
- 3) To investigate the **relationship between photocatalytic activity and photovoltaic properties** of as-synthesized photoelectrode for application in dye-sensitized solar cells.
- 4) To fabricate dye-sensitized solar cells using as synthesized ZnO-TiO₂ hybrid nanostructure (i.e. core-shell), as an effective photoelectrode to **improve photovoltaic properties** and device performance.

□ Designed structure



Procedure

□ Procedure overview

○ Method: Chemical vapor deposition (CVD)

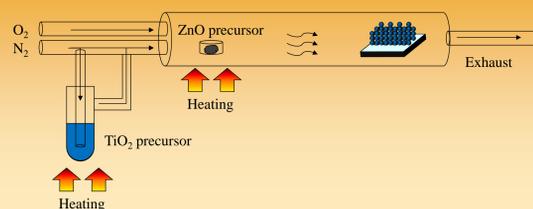
○ Materials

- Mixture of ZnO and graphite or Zn powder
- Ti{OCH(CH₃)₂}₄ or TiCl₄
- N₂ and O₂ gas
- Fluorine-doped tin oxide (FTO)
- Other materials for treatments

○ Controllable parameters

- Temperature of precursor and substrate
- Composition and flow rate of gases
- Ramping rate and reaction time
- Pressure
- Pre-surface treatment

□ Schematic illustration

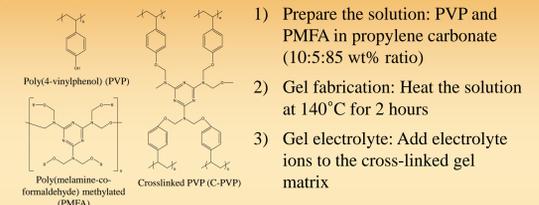


□ Procedure

- 1) Carrier gas, 100 SCCM of N₂, flows through the tube.
- 2) Substrate and ZnO precursor are heated to 300°C and 900°C, respectively.
- 3) The temperatures are kept during reaction process.
- 4) After growth of the ZnO NWs, ZnO precursor is cooled down and bubbler containing TiO₂ precursor is connected.
- 5) The bubbler is heated and TiO₂ NPs will be grown on the ZnO NWs

□ Polymer gel electrolyte preparation

To improve long-term stability, polymer gel electrolyte instead of generic liquid electrolyte will be applied.

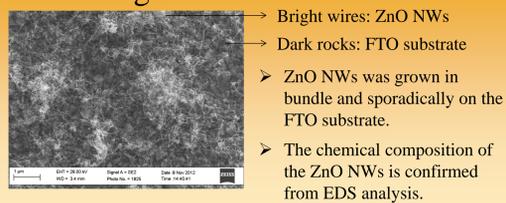


□ DSSC assembly

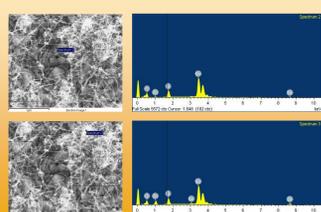
- 1) **Dye absorption:** The photoelectrode synthesized in previous section is immersed into N719 dye in EtOH solution for 24 hours.
- 2) **Counter electrode:** 0.05M H₂PtCl₆ in IPA solution is spin coated on another cleaned FTO substrate.
- 3) **Assemble and Electrolyte:** Put the polymer gel electrolyte in the gap between two electrodes and seal the electrodes.

Results

□ SEM image



□ EDS analysis



Future plan

1. ZnO NWs: Experimental parameters of CVD such as temperature, gas flow rate, starting material, and pressure will be adjusted to optimize density and length of NWs. Additionally, vertically aligned NWs will be fabricated through pre-treatment or vapor trapping method.
2. TiO₂ NPs: On the ZnO NWs, TiO₂ NPs will be grown by same method. Experimental parameters will be adjusted to obtain large quantity NPs with desired diameter, 25nm.
3. DSSC assembly: Hybrid nanostructure of ZnO-TiO₂ will be used as a photoelectrode for DSSCs. In order to improve long-term stability, polymer gel electrolyte will be applied.

Summary

In this research, a hybrid nanostructure made of ZnO-TiO₂ is proposed as the photoelectrode for DSSCs. The proposed photoelectrode due to its hybrid nanostructure nature is expected to show higher photovoltaic characteristics due to the shorter electron pathway and lower interfacial impedances. The selected method for synthesizing the hybrid photoelectrode is CVD because it provides 1) good step coverage, 2) synthesis of high quality materials, 3) it is overall a cost-effective process, and 4) flexible conditioning. By carrying out the proposed work, we will investigate the relationship between the photocatalytic activity and the photovoltaic properties of the proposed photoelectrode. Therefore, we are optimistic that DSSCs with better performing characteristics could be achieved through a cost-effective process based on the proposed work.