Dye-sensitized solar cell based on ZnO nanorod arrays

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**Problems**

Seeking for new alternative energy sources owning to:
- Limited resource of petroleum-based fuel
- Increasing in crude oil price
- Environment concerns

**Alternative energy must be:**
- Technically acceptable
- Economically competitive
- Environmentally acceptable
- Easily available

Renewable Energy is the most promising

SOLAR POWER
Solar Cells

Solar cells convert sunlight directly into electricity.

- When sunlight is absorbed, the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity.

PROBLEM

- Low efficiency
- Required a large area
- Expensive
- Economically incompatible

Research & Development are urgently needed

http://www.eere.energy.gov/
http://encyclobeamia.solarbotics.net/articles/solar_cell.html

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Introduction

- ZnO has a wide band gap of 3.37 eV and a large excitation binding energy of 60 meV.

A collection of nanostructures of ZnO*

Synthesis method:
- Vapor-liquid-solid growth
- Chemical vapor deposition
- Electrochemical vapor deposition

A challenge to develop a simple size-controllable fabrication method

A Simple Solution-Based Fabricating Method

Experimental Procedure*

FTO → Seeding → Hydrothermal Growth → ZnO nanorod arrays

Spin Coating + Annealing

Immersing in Precursor solution

\[ \text{Zn}^{2+} + \text{OH}^- \rightarrow \text{Zn(OH)}_4^{2-} \]

\[ \text{Zn(OH)}_4^{2-} \rightarrow \text{ZnO}_2^{2-} + 2\text{H}_2\text{O} \]

\[ \text{ZnO}_2^{2-} + \text{H}_2\text{O} \rightarrow \text{ZnO} \text{(S)} + 2\text{OH}^- \]

Chemical Reaction

* Reuters, Isao, Tsuchizu, Takahiro, Kikura, Akihito. 52nd Annual Meeting of the Japan Society of Applied Physics, Saitama University, 2005.3.29

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Morphology

A well-aligned array of ZnO nanorods grew vertically on the substrate.

Cross-section view
A high density ZnO nanorods grew uniformly in large area.
Crystallinity

ZnO nanorods were strongly oriented to the substrate.

(002)

In situ X-ray diffraction of ZnO nanorods on FTO substrate

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Variable-aspect ratio Synthesis of ZnO nanorod Arrays

Size of ZnO nanorod could be freely modified by controlling the solution condition:

- Temperature
- Precursor Concentration
- Reaction Time
- Multi-Step Growth
Nanorod Arrays vs. Nanoparticles

K. S. Kim et al. reported that the nanorods array electrode showed stable photovoltaic properties and exhibited much higher energy conversion efficiency compared with nano-particulate electrode. (K.S. Kim et al., Bull. Korean Chem. Soc., 27 (2006) 295.)

- **Grain Boundaries**
  Particles >>>>> Rods

- **Electron Pathway**
  Nanorod offers a great potential for improved electron transport.

Nanorod arrays are the promising structure for the next generation solar cell.
Dye-sensitized Solar Cell Measurement

- FTO Substrate
- Seeding
- Electrolyte
- ZnO Nanorod Arrays

Solar cell tester (CEP-2000)

DSC Fabrication

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The longer nanorod length, the higher cell conversion efficiency.

<table>
<thead>
<tr>
<th>No.</th>
<th>Rod Length (nm)</th>
<th>Efficiency (%)</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>2.59</td>
<td>0.94</td>
</tr>
<tr>
<td>B</td>
<td>3.94</td>
<td>1.27</td>
</tr>
<tr>
<td>C</td>
<td>5.10</td>
<td>1.42</td>
</tr>
<tr>
<td>D</td>
<td>10.79</td>
<td>1.69</td>
</tr>
</tbody>
</table>

The longer nanorod length, the higher cell conversion efficiency.
A higher amount of the adsorbed dye on longer nanorods, resulting in improving conversion efficiency.
Conclusions

• High-density well-aligned ZnO nanorods arrays have been successfully synthesized on FTO substrate by simple solution method.

• Size of ZnO nanorods is easily controlled by adjusting solution condition (reaction temperature, precursor concentration, and reaction time)

• The short circuit density and cell performance significantly increase as the nanorods length increases.
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