Large-Area Fabrication of Oriented TiO$_2$/ZnO Nano Arrays for Dye-Sensitized Solar Cells

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Outline

1. What is a dye-sensitized solar cell (DSSC)?
2. Research on ZnO nanostructures in CAMJ
3. Proposal of ZnO nano-arrays for DSSCs
Dye-Sensitized Solar Cells

- What is a DSSC?
  - 3rd generation solar cells
  - Dye-nanowires harvest solar light

- Why DSSC?
  - Cheap!
  - Efficiency!! 12%
  - Lower illumination
  - Sustainable
  - Environmentally friendly
Hydrothermal processing for high qualified nanowires
Operating principles of dye-sensitized solar cells (DSSCs)

Our design with TiO₂ nanowire arrays
Hydrothermal growth of TiO2 nanowires on Ti Plates

- Ti+10MNaOH
- Ti 5% formamide
- Ti/formic hydrazide/10M NaOH
- Ti+acetone
- Ti/acetone/10M NaOH
- Ti/monoethanolamine/10M NaOH

180oC/20 hours

Wash by deionized water and 0.02M HCl for several times
HRTEM images of TiO$_2$ nanowires

High crystalline TiO$_2$ nanowires sintering at 700$^\circ$C/2hrs, anatase phase
Growth of TiO$_2$ nanowire array on FTO/glass or Ti foils (180°C/4 hours)

TiO$_2$ nanowire array

Needle shape TiO$_2$ nanowires
Growth of TiO$_2$ nanowire membrane (180°C/72 hours)

Gram-level Nanoporous TiO$_2$ membrane
For filters

mm long TiO$_2$ nanowires
For anti-bacteria under UV excitation
Mechanical filtering and photocatalytic degradation of pharmautic pollants by TiO$_2$ nanowire membranes

Mechanical filtering of 250 nm diamond solution

Decomposition of antibiotic trimethoprim (personal care product pollants:
Atrazine, Atenolol, Calfeine, Fluoxetine, Venlafaxin, Monensin, Norfluoxetine, 17α-ethinylestradiol, and triclocarban
**TiO₂ nanoparticle-decorated TiO₂ nanowire array for solar cells**

Irradiation of TiO₂ nanowires by femtosecond laser pulses

TiO₂ nanoparticle-decorated TiO₂ nanowires
Research of ZnO Nanowires in CAMJ

- toward large-area fabrication
- oriented nanowires
- narrow size distribution
- tunable properties

\[
[Zn(nHCONH_2)]^{2+} \xrightarrow{80^\circ C} \text{ZnO}
\]

\[
\text{Zn} + n\text{HCONH}_2 + 2\text{H}_2\text{O} \rightarrow [\text{Zn}(n\text{HCONH}_2)]^{2+} + 2\text{OH}^- + \text{H}_2 \uparrow
\]
ZnO Nanowires, Nanotubes and Nanodisks

- 70-100 µm
- tunable geometries
- tunable diameters
- tunable length
- tunable thickness
ZnO/TiO$_2$ nanowire array on TCO for solar cells

ZnO nanoforest on ITO/glass
Our Proposal for Nano TiO$_2$/ZnO DSSC

- TiO$_2$/ZnO nanowire fabrication
- electrode assembly
- micro-manufacturing of DSSC
- electro-chemical characterization
- device optimization


Flexible solar cell

TiO$_2$ nanoparticles on ZnO nanowires
Our proposals (3D tubular DSSCs)

Fig. 1 The 3D structure compares with the conventional 2D panel

Fig. 5 Schematics of a tubular DSSC
Extensive Applications of ZnO Nanowires

\[ \text{N}_2, \text{NO}_2, \text{NH}_3, \text{CO}, \text{O}_2, \text{acetone, ethanol sensing} \]
Conclusions

- Development of TiO2/ZnO-nanowire based DSSC represents the future of novel solar cells
- TiO2/ZnO nanowire arrays can effectively harvest solar energy as DSSCs
- We have successfully synthesize highly oriented TiO2/ZnO nanowires on ITO/FTO in aquatic solutions
- We have worked on the synthesis, characterization & fabrication of nanotube based electrodes for energy devices
- We are proposing a NSERC grant for nano-structured DSSC
Why ZnO Nanowires?

- a wide band gap semiconductor
- direct path for ion transport
- increased diffusion rate
- low recombination rate
- improved solar cell efficiency