2008 TAIWAN INTERNATIONAL SCIENCE FAIR

CATEGORY : Engineering

PROJECT : Titania Nanotubes for Solar Energy and Catalysis

AWARDS : Engineering First Award

SCHOOL : Raffles Junior College

FINALISTS : Yin Jianyang David

COUNTRY : Singapore

Abstract

Titania Nanotubes for Solar Energy and Catalysis

2008 Taiwan Tnternational Science Fair

Introduction

The discovery of titania (TiO_2) nanotubes suggests vast improvements over extant titania properties. Titania nanotubes are aligned in highly-ordered arrays with a large geometric surface area, making them the ideal material for many applications. However, the mechanism responsible for the growth rates of highly-ordered nanotubes with optimal adhesive properties is not fully explained or understood.

Purpose of Research

The aims of this project were threefold: to explore the effects of different anodizing parameters on the fabrication of titania nanotubes; to study the photocatalytic activity of the nanotubes; and to deposit gold nanoparticles into the nanotubes.

Methodology

Nanotube Fabrication:
Titanium foil was subjected to potentiostatic anodization with the use of various fluorine-based electrolytes, anodization voltage and duration to compare the effects of different parameters. Scanning electron microscopy (SEM) was used to characterize the nanotube diameter and length of the anodized samples.

Photo-electrochemica1 Water-splitting:
A PEC cell was assembled using the nanotubes as the photoanode and the samples were anodically polarized in a 1M KOH electrolyte. A potentiostat was employed to control the applied bias and to measure the photocurrent response under light irradiation. Overall photoconversion efficiency (ηc) of the samples was then calculated.

Catalyst Support:
A gold precursor solution was prepared with $HAuC1_4 \cdot 3H_2O$. Using a novel deposition-precipitation (DP) protocol, gold nanoparticles were deposited on the nanotubes. SEM was used to scan for traces of gold and their locations. Energy-Dispersive X-ray (EDX) spectroscopy was used to confirm the identity of the gold nanoparticles.

Data and Discussion

Nanotube Fabrication:
Preliminary studies found the glycerol/water and glycerol/formamide combinations to be the most promising. In glycerol/water-based electrolytes, higher water content corresponded to a decrease in nanotube length while higher anodization voltage resulted in a significant increase in tube diameter and length. In glycerol/formamide-based electrolytes, higher water content corresponded to a decrease in nanotube diameter while

higher fluorine concentration resulted in an increase in inter-tubular spacing. The effects of various fabrication parameters were better understood, contributing to greater control over array dimensions.

Photo-electrochemical Water-splitting:
A higher anodizaion voltage resulted in a significant improvement in photoconversion efficiency. However, this trend was reversed in chlorine-doped samples, where a longer anodization duration corresponded with better photoconversion efficiency. Doping was found to enhance the photoresponse of the samples, with 6.32 % photoconversion efficiency obtained, suggesting new strategies for light harvesting and a step closer towards commercially-viable solar energy.

Catalyst Support:
Gold nanoparticles (5-10 nm) were successfully deposited onto the titania nanotube samples. Based on current literature, this was the first successful attempt at depositing gold nanoparticles into titania nanotubes. An EDX spectrum confirmed the identity of the gold nanoparticles. Compared to current catalytic converters, the gold/titania nanotube structure offered a larger catalytic surface area for reactants and the ability to function at low temperatures.

Conclusion

By understanding the effects of various parameters on titania nanotube fabrication, the anodization process can be optimized to enable more precise control over array dimensions. High photocatalytic efficiency has also been achieved. In addition, doping is found to improve the photoresponse of titania nanotubes. Gold nanoparticles have been deposited, to our knowledge for the first time, onto the surface and inner walls of titania nanotubes.

Word Count: 500 (excluding headings)

評語

本作品創新性很好，亦得到很好的結果，表達清晰，在學術及應用上深具潛力，是件優秀作品。