Solar Energy Materials & Solar Cells 133 (2015) 32–38

Contents lists available at ScienceDirect

Solar Energy Materials & Solar Cells

journal homepage: www.elsevier.com/locate/solmat

WO_3/TiO_2 core–shell nanostructure for high performance energy-saving smart windows

Bohr-Ran Huang*, Tzu-Ching Lin, Ying-Ming Liu

Graduate Institute of Electro-Optical Engineering, Department of Electronic Engineering, National Taiwan University of Science and Technology, 43, Sec. 4, Taipei 106, Taiwan, ROC

ARTICLE INFO

Article history:
Received 16 June 2014
Received in revised form
2 November 2014
Accepted 3 November 2014

Keywords:
WO_3/TiO_2
Core–shell
Photodegradation
Electrochromic
Photoinduced hydrophilicity

ABSTRACT

The electrochromic, photodegradation, and photoinduced hydrophilicity properties of the WO_3/TiO_2 core–shell nanostructure as a smart building material for energy-saving are investigated. The core–shell nanostructure exhibits a highly reduced ion intercalation capacity with good reversible electrochemical cycling of intercalation–deintercalation, and shows a higher coloration efficiency (110.8 $cm^2\ C^{-1}$), faster switching speed (0.7 s and 2.9 s) and better cycling performance than as-deposited WO_3 nanowires (NWs). The TiO_2 shell layer greatly enhanced the photocatalytic oxidation activity of WO_3 NWs, increasing the photoinduced hydrophilic conversion. The enhanced photocatalytic reaction by the core–shell structure was attributed to the multi-electron reduction in the interlayer, caused by the electrons injected from the conduction band of the WO_3 NWs. These results suggest that the WO_3/TiO_2 core–shell nanostructure enhances the electrochromic, photodegradation, and photoinduced hydrophilicity properties due to the increased density of charge separated electron–hole pairs aided by the TiO_2 and WO_3 interlayer. The WO_3/TiO_2 core–shell structure was found to possess superior properties giving it good potential for use in energy-saving smart windows.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Smart building materials have attracted considerable research and development interest due to potential applications such as smart building glazing, self-cleaning exterior tiles, and anti-fogging mirrors [1–4]. Among transition metal oxides, tungsten trioxide (WO_3) and titanium dioxide (TiO_2) exhibit excellent electrochromic properties, environmental purification, and self-cleaning properties [2,5,6]. TiO_2 is an effective photocatalyst under ultraviolet (UV) irradiation for decomposing volatile organic compounds. It is also super-hydrophilic and potentially useful in smart windows. However, TiO_2 has three disadvantages that restrict itself from being widely adopted in practical applications: (1) the rapid recombination of photogengerated electron–hole (E–H) pairs that significantly reduces photocatalytic efficiency [7], (2) long coloration time and low electrochromic efficiency [8], and (3) its light response region is located in the UV wavelength, which accounts for only ~5% of the energy of sunlight. When TiO_2 is combined with WO_3, the spectral of absorption increases due to the band gap of WO_3 (2.8 eV, $\lambda = 443$ nm) being smaller than that of TiO_2 (3.2 eV, $\lambda = 388$ nm). This allows light with $\lambda \leq 443$ nm to be absorbed by the heterogeneous structure, and the photocatalytic activity can be extended to a large spectral range [9,10]. The WO_3 can act as an electron scavenger and can pull the photo generated conduction band electrons of TiO_2 to its own conduction band, thus keeping the E–H pairs apart longer to improve overall photocatalytic performance [11]. In addition, the WO_3 has been intensively studied because of its superior electrochromic properties such as stability, low power consumption, good coloration effect, and high contrast [12,13].

The present work develops a WO_3/TiO_2 core–shell nanowire (NW) structure for smart building materials such as electrchromic windows, and surfaces which feature photodegradation and photoinduced hydrophilicity. The TiO_2 shell layer uniformly covers the WO_3 NWs. By combining TiO_2 and WO_3 through this fabrication method, we are able to enhance the coloration efficiency, reduce the photodegradation time, and increase the photoinduced hydrophilicity stability of the core–shell structure through the extension of the absorption range, the charge separation, and an optimized interfacial area between the materials. The effect of different TiO_2 shell layer thicknesses on WO_3 NWs for smart building material properties is discussed.

2. Experimental

Indium tin oxide (ITO) glass substrates were cleaned in an acetone bath for 15 min with ultrasonic agitation then rinsed in DI water for 15 min and finally etched by air plasma for 20 min. The

---

* Corresponding author. Tel.: +88 62 2730 3273; fax: +88 62 2737 6424.
E-mail addresses: huangbr@mail.ntust.edu.tw (B.-R. Huang), D9702308@mail.ntust.edu.tw (T.-C. Lin), M10019020@mail.ntust.edu.tw (Y.-M. Liu).

http://dx.doi.org/10.1016/j.solmat.2014.11.007
0927-0248/© 2014 Elsevier B.V. All rights reserved.

tungsten (W) films were first deposited on an ITO glass substrate by reactive DC magnetron sputtering system. The deposition was carried out under an argon flow rate of 20 sccm, under DC power of 15 W for 15 min. The thickness of the deposited W film was about 80 nm. The samples were subsequently subjected to thermal annealing in a quartz tube furnace at 550 °C in nitrogen ambient (99.5% purity) for 60 min under 50 Torr. The core structure tungsten oxide NWs formed on the ITO glass. Different thicknesses (40, 50, 60, 70, and 80 nm) of titanium films were separately deposited on the as-deposited samples. The WO_3/TiO_2 core–shell nanostructure was finally synthesized by annealing Ti/WO_3 films at 550 °C in nitrogen and oxygen atmosphere with 100 sccm of each for 1 h under 50 Torr.

The morphology of the films was characterized by a field emission scanning electron microscope (FESEM, JEOL JSM-6500F) and a high resolution transmission electron microscope (HRTEM, Philips Tecnai F20 G2). X-ray diffraction (XRD) measurements were conducted using CuK_α radiation (Bruker D8 phaser). Cyclic voltammetry (CV) and chronoamperometry (CA) measurements were performed in 1 M lithium perchlorate ($LiClO_4$) using a propylene carbonate (PC)–water mixture as the electrolytes, a platinum plate as the counter electrode, tungsten oxide as the working electrode and a saturated calomel electrode (SCE) as the reference electrode. Optical transmittance spectra were recorded on a JASCO V-560 ultraviolet–visible (UV–vis) spectrophotometer. Contact angle measurement was conducted on three points for each sample and the experimental error for each point was within $\pm 2^\circ$. The UV-lamp used in the experiment had a wavelength of 369 nm using a 4 W black light bulb with an intensity of 0.1 mW/cm^2. The chemical binding of oleic acid on the samples was investigated by Fourier-transform infrared (FTIR) spectrometry (BomemDA8.3).

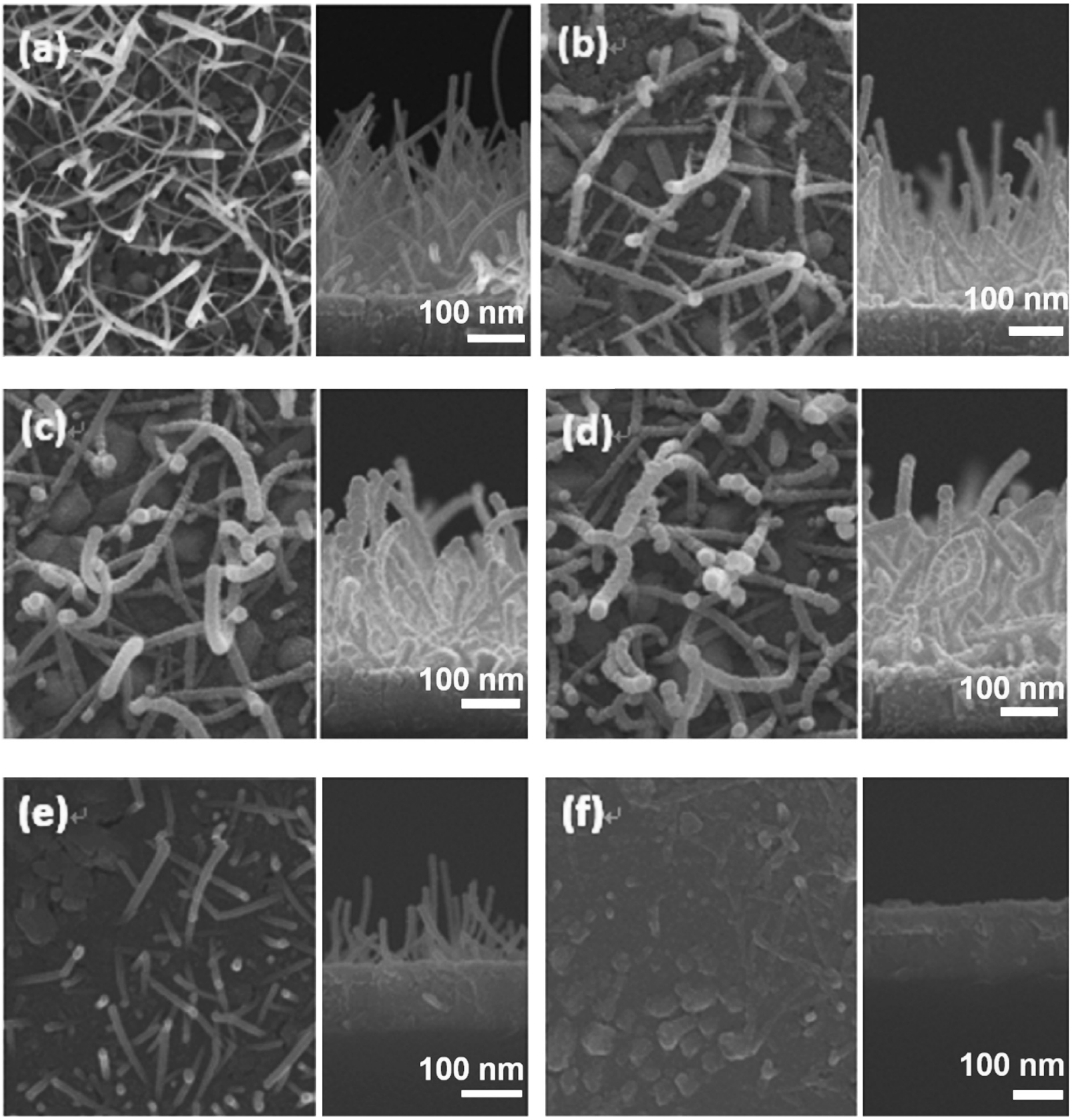

Fig. 1. SEM images of the cross-section and plain-view of the (a) as-deposited WO_3 NWs (W1) and WO_3/TiO_2 core–shell structure with the different Ti thicknesses of (b) WT1, (c) WT2, (d) WT3, (e) WT4, and (f) WT5.

Download English Version:

https://daneshyari.com/en/article/6535272

Download Persian Version:

https://daneshyari.com/article/6535272

Daneshyari.com