Journal of Colloid and Interface Science 471 (2016) 76–80

Contents lists available at ScienceDirect

Journal of Colloid and Interface Science

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

Synthesis of Cu_2O nanoparticle films at room temperature for solar water splitting

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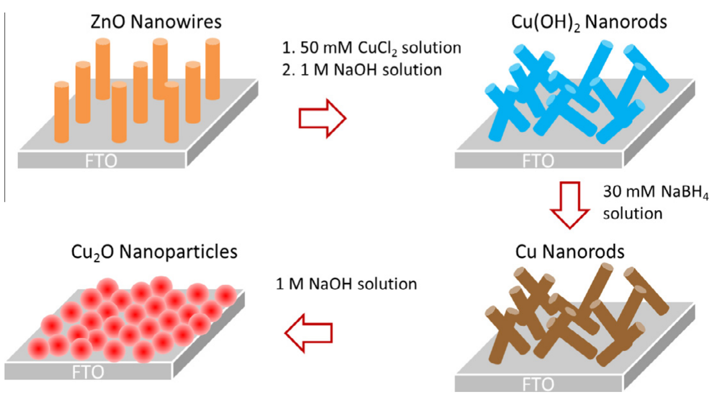
GRAPHICAL ABSTRACT

We demonstrate a simple fabrication at room-temperature of Cu_2O nanoparticle films by transformation of ZnO nanorods as sacrificial scaffolds for photoelectrochemical water-splitting applications with no energy requirement.



ARTICLE INFO

Article history:
Received 7 January 2016
Revised 4 March 2016
Accepted 4 March 2016
Available online 8 March 2016

Keywords:
Zinc oxide
Copper(I) oxide
Nanoparticles
Photoelectrochemical

ABSTRACT

A Cu_2O nanoparticle film using ZnO nanorods as a sacrificial scaffold was fabricated near 23 °C, for applications in photoelectrochemical (PEC) water splitting. Three chemical solutions were utilized to convert ZnO nanorods to a Cu_2O nanoparticle film – solutions of $CuCl_2$ and NaOH, $NaBH_4$ and NaOH, respectively. The structural evolution from ZnO through $Cu(OH)_2$ and metallic Cu to Cu_2O phase was analyzed at each stage with X-ray diffraction and X-ray absorption spectra. The energy bandgap was deduced from IPCE; the concentration of carriers and flat-band of a Cu_2O nanoparticle film were obtained from a Mott-Schottky plot. Significantly, the Cu_2O nanoparticle film exhibited a useful PEC response to water oxidation. This nanostructure synthesized with no energy requirement can not only illustrate a great prospect for solar generation of hydrogen but also offer a blueprint for the future design of photocatalysts.

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http://dx.doi.org/10.1016/j.jcis.2016.03.010

1. Introduction

Semiconductor nanostructures have attracted considerable attention as efficient energy-conversion devices owing to their unique physical and chemical properties [1–3]. Among them, copper(I) oxide (Cu_2O), as a non-stoichiometic *p*-type semiconductor, is highly attractive because of its prospective application in antibacterial activity, photocatalysis, solar-driven water splitting, conversion of solar energy, gas sensor, oxidation of carbon monoxide, a negative electrode material for a lithium-ion battery, and a metal-insulator-metal resistive switching memory and chemical template [4–6]. The progress in nanomaterial science and nanotechnology has greatly accelerated the development of the synthesis and applications of Cu_2O nanostructures. So far, several Cu_2O architectures with varied morphologies have been synthesized through reactive sputtering, chemical deposition, electrochemical deposition, thermal oxidation, etc., but most reported syntheses require complicated processes and high temperature, consuming much energy [7–16].

In this work, we demonstrate a simple fabrication, near 23 °C, of a Cu_2O nanoparticle film by transformation of ZnO nanorods as sacrificial scaffolds for a photoelectrochemical (PEC) water-splitting application *with no energy requirement*. The synthesis near 23 °C to form a Cu_2O nanoparticle film and its PEC properties are systematically analyzed. These novel Cu_2O nanoparticle films not only function as a photocathode for PEC hydrogen generation but also offer a new opportunity to develop electronic and photoelectronic devices based on 3D hierarchical nanomaterials.

2. Experimental sections

The Cu_2O nanoparticle films synthesized on FTO glass substrates were fabricated in a simple wet-chemical process, shown in Fig. 1a. The first step is the formation of ZnO nanowires (NWs)

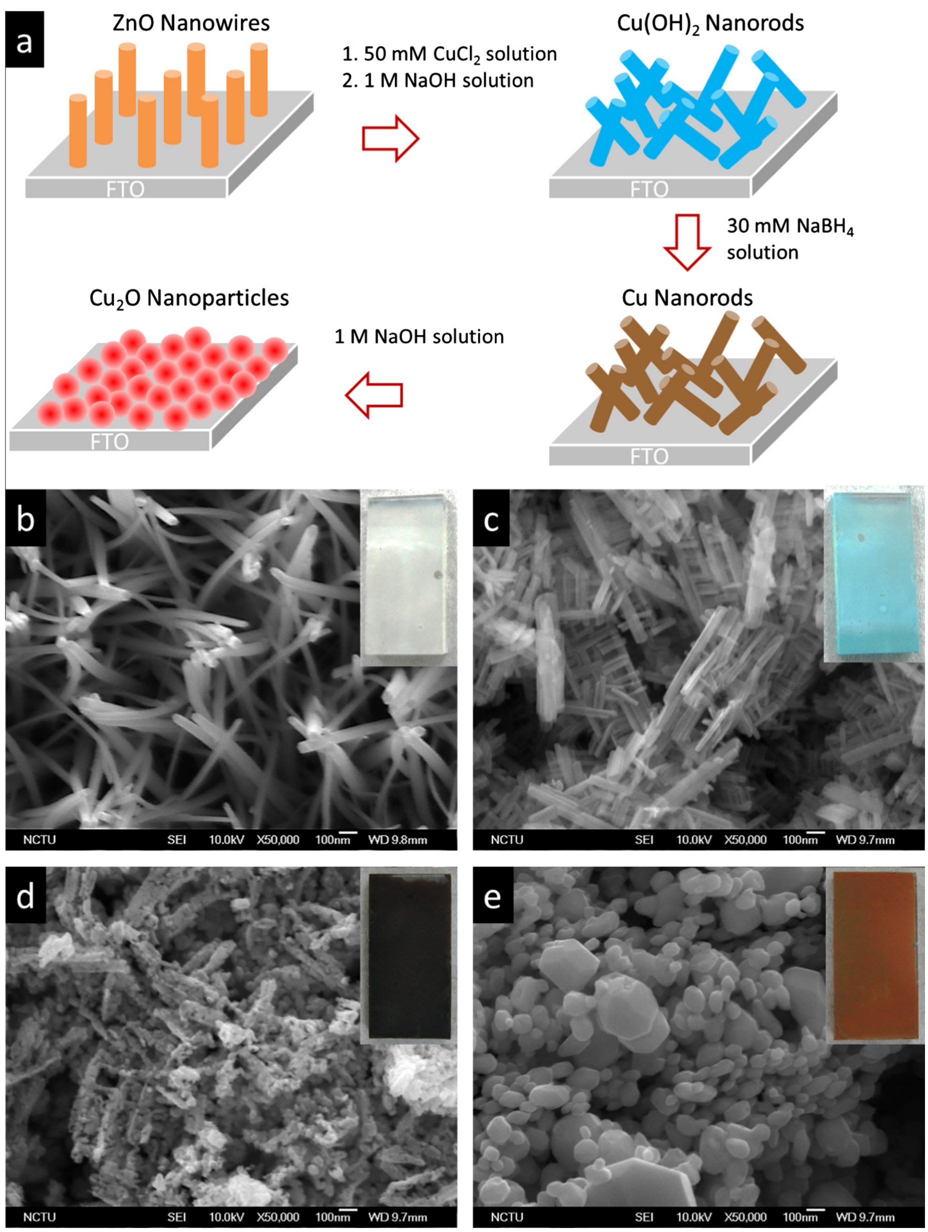

Fig. 1. (a) Schematic diagram of synthesis of a Cu_2O nanoparticle film. FESEM images of (b) ZnO nanorods, (c) $Cu(OH)_2$ nanorods, (d) metallic Cu nanorods, and (e) a Cu_2O nanoparticle film.