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Cu_2O Nanocubes for Efficient Photocatalytic Hydrogen Evolution

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ABSTRACT

Cu_2O nanoparticles (NPs) were directly synthesized via a one-pot in-situ reduction method. The physical and photophysical properties of this photocatalyst were characterized to investigate the effects of Cu_2O nanocubic on the photocatalytic hydrogen production activity. The experimental data revealed that Cu_2O is an ideal candidate for hydrogen production (under visible light) with an average rate of 2.1 mmol min^{-1} g^{-1}.

Keywords: Cu_2O Nanocubes, hydrogen production, photocatalysts, semiconductors.

1. Introduction

In recent years, the global energy demand has increased continuously due to the increase in population and industrial development, so it is interesting to develop an alternative strategy for generating clean energy. Hydrogen is regarded as a promising fuel to solve energy and environmental problems all around the world. As one of the efficient technologies, photocatalytic hydrogen evolution from water has attracted substantial attention to produce hydrogen [1,2]. Photocatalytic water-splitting using semiconductor-based transition metal oxides for hydrogen production offers a promising way to realize clean, low-cost, and environmentally friendly production of hydrogen by use of visible light. Copper oxide Cu_2O has attracted considerable attention as a photo/electrocatalyst and has a range of desirable properties such as being nontoxic and readily accessible from earth-abundant precursors [3,4]. In the present study, we successfully prepared a Cu_2O photocatalyst via a one-pot in-situ reduction method. The effects of Cu_2O NPs on the visible optical absorption and charge carrier separation, and hence the photocatalytic activities were discussed in detail.

2. Experimental

Synthesis of Cu2O Nanocube. Cu_2O nanocube was fabricated by dissolving an appropriate amount of $CuSO_4 \cdot 5H_2O$ and sodium citrate tribasic dihydrate into 80 mL of deionized water. And then, the solution was stirred for 15 min. After that, 1.25 M of NaOH was added into the solution and further stirred for 15 min. Subsequently, the ascorbic acid aqueous solution was dripped into the above solution. The solution was continuously stirred for 5 min and aged for 1 h. The Cu2O nanocubes were obtained by centrifugation. The deionized water and ethanol were used to wash the Cu2O nanocubes for three times.

Photocatalytic Performance Test. All photocatalytic measurements were carried out in in a double walled Pyrex reactor, connected to a thermostated bath, allowing temperature control; the latter was fixed at an optimal value of 50 ± 0.5 C; above the water evaporation predominates. three LED lamps as the visible light source were used for photocatalytic hydrogen production. 100 mg of catalyst was added into a mixture of deionized water and (Na_2SO_4, 0.1 M) with stirring. Then, the system was degassed with N_2 for 30 min. The reaction system is irradiated by a light source with different wavelengths.

3. Results and Discussion

Physico-chemical characterization.

The photocatalysts prepared by reduction method was subjected to physico – chemical characterization. To investigate the structure of copper oxide, the XRD analysis was carried out and the XRD patterns was presented in Figure 1 Powder X-ray diffraction (XRD) pattern demonstrates that the Cu_2O has the characteristic peaks located at ~30°, ~36°, ~43°, ~62°, and ~74°, ascribed to the (101), (111), (200), (220), and (311) facets, respectively [5,6]. No peaks of starting oxides or secondaryphases were detected suggesting the pure phase of Cu_2O.

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Figure.2 displays the reflectance spectra of the Cu_2O material. the as-prepared Cu_2O showed an enhanced absorption in the long wavelength region ranging from 200 to 900 nm, which might be due to the strong absorption of the Cu_2O layer in this region.

Scanning electron microscopy (SEM) image (Fig.3) show that the Cu_2O present a uniform nano-cube morphology with a size of ~200 nm. Energy-dispersive X-ray spectroscopy (EDS) studies were further performed to examine the elemental composition of the copper oxide (figure.3). The stoichiometric ratio of Cu and O elements for Cu_2O was found to be ~ 2:1 confirming the successful formation of Cu_2O phase.

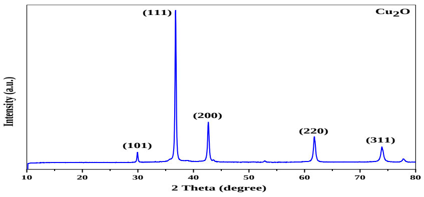


Figure 1:. X-ray diffraction patterns of Cu_2O.

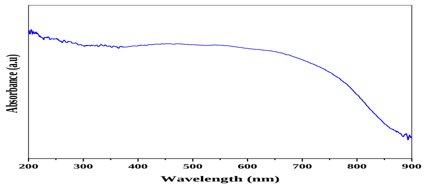
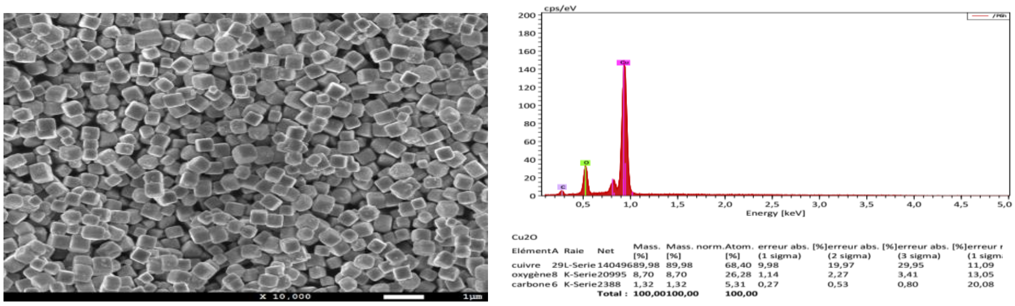


Figure 2 : UV–vis diffuse reflectance spectra of Cu_2O Nanocubes



Figuer 3: SEM and EDX of Cu_2O Nanocubes.

Photocatalytic performance for hydrogen production.

The photocatalytic H_2 evolution reaction activities of Cu_2O photocatalysts under visible-light irradiation were investigated using Na_2SO_4 as a sacrificial agent. The investigated Cu_2O nanocube, exhibits a high photocatalytic H_2 production rate of 2.1 mmol h^{-1} g^{-1}. This result is due to efficient charge separation induced by the Cu_2O semi-conductor and its ability to visible light absorption.

4. Conclusions

In summary, we report a synthetic strategy to construct Cu_2O nanocubes via a simple reduction method. The Cu_2O material was successfully used as a photocatalyst for visible light-assisted hydrogen production. An evolution rate of 2.1 mmol h^{-1} g^{-1} was obtained under optimal conditions. It was believed that the Cu2O nanocubes could significantly facilitate the separation of photogenerated electron-hole pairs and promote electron transfer in the system, greatly improving the photocatalytic H_2 production activity.

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