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Combustion synthesis of g-C_3N_4/Fe_2O_3 nanocomposite for superior photoelectrochemical catalytic performance

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ABSTRACT

The g-C_3N_4/Fe_2O_3 nanocomposite was produced by the solution combustion synthesis (SCS) of iron-nitrate/g-C_3N_4 mixtures of varying concentration ratios and using urea as a fuel. The following methods did characterization of the products: X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), field-emission scanning electron microscopy (FE-SEM), transmission electron microscopy (TEM), Fourier-transform infrared spectroscopy (FTIR), Brunauer-Emmett-Teller investigation (BET), ultraviolet–visible light analysis (UV–vis) and photoluminescence measurement (PL). Effect of iron nitrate on stability and photocurrent density under simulated visible-light irradiation was determined. The photocurrent density obtained (4.25 μA/Cm^2) was twelve times the pure g-C_3N_4, and higher than those reported for g-C_3N_4 having Fe_2O_3. The following mechanisms contributed to the higher photocurrent density achievement: reduction of the bandgap, escalation of the specific area, diminution of the electron-hole recombination, and enhancement of the visible-light harvest—the synthesized nanocomposite decolorized methylene blue three times stronger than pure g-C_3N_4. The produced g-C_3N_4/Fe_2O_3 nanocomposite is, therefore, a potential material for photoelectrochemical cells and pollutant removal applications.

1. Introduction

Photocatalytic technology has attracted much attention as a fresh approach to solving the recent environmental problems [1]. Photoelectrochemical (PEC) water splitting can result in hydrogen production, which is a clean alternative to widely used fossil fuels [2,3].

The graphitic carbon nitride is a hopeful photocatalyst material with various applications such as water splitting and pollutant removal [4]. Other properties of this material include high electrical conductivity, non-toxicity, and high chemical stability [5]. However, a small specific area, rapid electron-hole recombination, and low active sites may restrict the applications of g-C_3N_4 [1,6,7]. An excellent strategy can be the coupling of g-C_3N_4 with another semiconductor [5,8].

Iron oxides are abundant, inexpensive, environmentally benign, and with useful applications. Fe_2O_3 can decompose water into H_2 and O_2 in a photoelectrochemical process. However, the Photoelectrochemical activity of Fe_2O_3 has been restricted because of various factors; charge conductivity is often weak, and the recombination rate of electron-hole pairs is rapid [9,10].

The incorporation of Fe_2O_3 in g-C_3N_4 resulted in a remarkable improvement in the photocatalytic activity. This improvement is assigned to the enhanced visible light absorbance, improved charge carriers separation, and transferability. So the g-C_3N_4/Fe_2O_3 nanocomposites could act as high-performance photocatalysts for use in photoelectrochemical cells [11–14]. Since there are only a few studies on the synthesis of g-C_3N_4/Fe_2O_3 composites for use in photoelectrochemical cells, introducing new methods for the fabrication of this composite can improve the properties of the final composite, but also can develop its practical applications.

The preparation of nanocrystalline oxides is achievable by the solution combustion technique. In this method, an oxidizer (usually in the form of nitrate) and fuel (usually urea and glycine citrate) are dissolved in water. The solution is then heated to dry. Upon the mixture reaches a critical temperature, the oxidizer is decomposed, and the fuel is ignited. The advantages of SCS are: saving energy as low external heating is required, precursor mixing at the molecular level, convenient processing, simple experimental setup, significant time saving, high purity products and product with the high specific surface area due to the large volume of the gases liberated during the combustion reaction [15,16]. The higher surface area of the oxides derived from SCS is reflected in much higher photoactivity of the SCS oxides [17]. So SCS can be an excellent candidate for the synthesis of g-C_3N_4/Fe_2O_3, and it is expected that the final product has a high potential for use in photoelectrochemical cells.

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