Chemical Physics Letters 808 (2022) 140097

Contents lists available at ScienceDirect

Chemical Physics Letters

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

Influence of hydrothermal temperature on the structural, morphological, optical and photocatalytic properties of ternary Cu_2SnS_3 nanoparticles

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ARTICLE INFO

Keywords:
Agglomeration
Cu_2SnS_3
Dye degradation
Photocatalysis
Photoinduced carrier
Rhodamine B

ABSTRACT

Controllably synthesis of ternary Cu_2SnS_3 (CTS) nanoparticles using a simple and green hydrothermal method is presented in this study. The effect of synthesis temperature on the formation of CTS nanoparticles and its utilization as a catalyst for the degradation of Rhodamine B (Rh-B) dye was studied. The CTS nanoparticles were characterized by X-ray powder diffraction, Raman spectroscopy, FTIR spectroscopy, scanning electron microscopy and UV–Visible spectroscopy. The results showed that synthesized CTS nanoparticles have agglomerated morphology, with the energy band gap of 1.74 eV. Due to the lower band gap of CTS, the light absorption into the visible region extends and an even photoinduced carrier separates well so that it presented higher photocatalytic activity. With the exposure of visible light, the maximum degradation of Rh-B has been achieved.

1. Introduction

In the progressing world, fast development in the field of textile, agriculture and pharmaceutical industries provoked water pollution. The effluents released from such industries contain various pollutants which are hazardous to human health as well as the environment [1]. Dyes are the organic compounds that are most commonly used in the industries like food, paper, paints, plastics, pulp, pharmaceutical, leather and textile [2–6]. Rh-B is one of the major pollutants. It is a synthetic chemical compound of aromatic structure and cationic type of organic xanthene dye [7]. It has a more rigid structure than other dyes and since it is a cationic dye it can be used to dye anionic fabrics like polyester fabrics which contain negative charges [7]. Nevertheless, it is also toxic and carcinogenic for living species. It causes irritation to skin, eyes and also affectsthe respiratory system [8–10]. The Rh-B contaminated drinking water has been proven hazardous to humans and animals which leads to subcutaneous tissue-borne sarcoma [7]. The aquatic life especially the plants get affected by the dye as it hinders light penetration and hence reduces photocatalysis and natural purification [11]. So it is necessary to remove the dye before it is discharged into the fresh water bodies. For environmental concern, many conventional methods like physical, chemical and biological have been used for the treatment of wastewater [12]. Among these photocatalysis has gained great attention of researchers as it is a unique, simple, effective and green technology offering biodegradable and non-toxic end products [7].

CTS is a ternary chalcogenide p-type semiconductor material having ~1.3–1.6 eV band gap with high absorption coefficient ($>10^4 cm^{-1}$) [13–15]. Since the constituent elements of CTS are earth-abundant and nontoxic, can be well applied for the photodegradation of dyes which is eco-friendly and economical as well. Apart from photocatalysis, due to the outstanding optical-thermal–mechanical properties, CTS possesses a wide range of applications in solar cells, super-capacitors, lithium batteries, gas sensing, etc. [16–18]. In the present work, we have employed the simple, economical and eco-friendly hydrothermal method. As this method gives us a wide temperature range to control the morphology as well as the particle size with the phase pure material without any high temperature annealing process [4]. Also this method produces porous nanocrystals which is a favourable condition for photocatalytic application [19]. We have varied the synthesis temperature to tune the morphology and size of nanoparticles and applied well for the degradation of Rhodamine B (Rh-B) dye under visible light irradiation.

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https://doi.org/10.1016/j.cplett.2022.140097
Received 25 January 2022; Received in revised form 26 September 2022; Accepted 29 September 2022
Available online 13 October 2022