Journal of Environmental Chemical Engineering 13 (2025) 115854

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

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

Plant extract aided synthesis of iron sulphide/nickel sulphide type-II heterostructure for photochemical CO_2 reduction and simultaneous degradation of dyes

G.S. Poornima [a], M.K. Prashanth [b], H. Shanavaz [c], Shwetha Rajappa [d], Fahd Alharethy [e], K. Yogesh Kumar [c,*], Krishna Kumar Yadav [f], Byong-Hun Jeon [g,*], M.S. Raghu [a,*]

[a] Department of Chemistry, New Horizon College of Engineering, Outer Ring Road, Bangalore 560103, India
[b] Department of Chemistry, BNM Institute of Technology, Banashankari, Bangalore 560070, India
[c] Department of Chemistry, Faculty of Engineering and Technology, Jain University, Bangalore 562112, India
[d] Department of Sciences and Humanities, School of Engineering and Technology, CHRIST University, Mysore Road, Bangalore, Karnataka 560074, India
[e] Department of Chemistry, College of Science, King Saud University, Riyadh 11451, Saudi Arabia
[f] Faculty of Science and technology, Madhyanchal Professional University, Ratibad, Bhopal, MP 462044, India
[g] Department of Earth Resources and Environmental Engineering, Hanyang University, 222, Wangsimni-ro, Seongdong-gu, Seoul 04763, Republic of Korea

ARTICLE INFO

Keywords:
FeS/NiS heterostructure
Type –II
Green synthesis
Waste to wealth
Photocatalysis
CO_2 reduction
Dyes

ABSTRACT

The green synthetic route, solving issues in the energy sector and the removal of wastes for a clean environment are the major concerns across the globe for a sustainable future. The current work involves the synthesis of iron sulphide (FeS), nickel sulphide (NiS) and FeS/NiS heterostructure using a *Calotropis procera* leaf and flower extract as a reducing agent without any additional sulphur source. Structural optical, photo/electrochemical and morphological characterizations suggest the formation of a heterostructure between FeS and NiS of type II with tuned edge potentials. Due to which FeS/NiS showed enhanced activity in evolving CO and CH_4 through photoctalytic CO_2 reduction reaction (CRR) and was found to be 2.5 and 2 times higher than FeS and NiS, respectively. Further, all three materials were studied for photocatalytic degradation of two cationic dyes (methylene blue: MB and safranin O: SO) under different light sources. The % degradation of dyes MB and SO was found to be 98 and 96 %, respectively, in the presence of FeS/NiS heterostructure under sunlight. The factors affecting the dye degradation (pH, initial concentration, catalyst dosage) were optimized to achieve maximum efficiency. The degradation study using FeS/NiS was additionally examined in industrial effluent and the simultaneous degradation of MB and SO and the results are satisfactory. Photocatalytic mechanism was predicted based on the degradation results using liquid chromatography mass spectrophotometry (LCMS). The decreased charge transfer resistance, superior photocurrent response, bandgap tuning, shift in edge potentials, and formation of heterostructure and effective charge separation could be attributed to the appreciable efficiency of FeS/NiS. This work may lead to further research on the formation of metal sulfide-based heterostructures using a green approach and their application towards waste reduction and converting them to wealth towards energy and environmental remediation.

1. Introduction

Carbon dioxide (CO_2) accumulation in the atmosphere is a significant environmental challenge in the 21st century. CO_2, a key greenhouse gas, plays a crucial role in global warming and climate change, impacting ecosystems, weather patterns, and human societies [1,2]. Anthropogenic emissions, mostly from fossil fuel combustion, deforestation, and industrial activity, have skyrocketed since the industrial revolution, upsetting the natural carbon cycle [3–5]. Reducing CO_2 emissions is crucial to keep global temperature rise within 1.5–2 °C [6,7]. CO_2 reduction seeks to address climate action, clean energy, and sustainable industrial practices. Reduction of CO_2 into value-added

* Corresponding authors.
E-mail addresses: yogeshkk3@gmail.com (K.Y. Kumar), bhjeon@hanyang.ac.kr (B.-H. Jeon), raghuhassan2009@gmail.com, dr.msraghu@newhorizonindia.edu (M.S. Raghu).

https://doi.org/10.1016/j.jece.2025.115854
Received 10 January 2025; Received in revised form 7 February 2025; Accepted 16 February 2025
Available online 18 February 2025