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MoS_2-CuBTC Hybrid Nanostructure: A Promising Material for High-Performance Hydrogen Sensing

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ABSTRACT

Hydrogen (H_2) gas is widely recognized as a pivotal clean energy carrier in the transition toward a carbon-neutral society. However, the safety infrastructure for hydrogen energy deployment remains underdeveloped compared to the well-established frameworks for natural gas and gasoline. A critical aspect of this challenge is the deployment of H_2 gas detection systems, which must function reliably across diverse structural surfaces and environmental conditions. Conventional H_2 gas sensors often characterized by bulkiness and susceptibility to environmental variations, present significant limitations in terms of flexibility and seamless integration with key infrastructure components such as pipelines and valves. In this work, we present the successful synthesis of a Copper(II) benzene-1,3,5-tricarboxylate (CuBTC) MOF with functionalized conductive 2H phase of MoS_2, yielding a heterostructured hybrid material (CuBTC-MoS_2) with enhanced performance for H_2 sensing detection. The synthesized hybrid material shows rapid response and recover with high response toward H_2 gas at room temperature (20 ℃) due to the synergistic effects of MoS_2 and CuBTC. The uniform decoration of MoS_2 on the edge of CuBTC was confirmed by Transmission electron microscopy (TEM) and emission scanning electron microscopy (FESEM). In addition, high-angle-annular dark-field (HAADF) and color mapping images also proved well distribution of MoS_2 flakes on CuBTC. The 2H-MoS_2 was confirmed by the Raman spectroscopy. The X-ray diffraction (XRD) analysis presents sharp and intense peaks of both MoS_2 and CuBTC confirmed the successful formation of the MOS_2-CuBTC hybrid material. To assess the H_2 sensing suitability of the MoS_2-CuBTC hybrid, different performance metrics has been employed including response/recovery time, sensitivity, detection limit, stability, and selectivity. The MoS_2-CuBTC material shows a rapid response (9 s) and recovery (7 s) towards 1% H_2 gas with high response at room temperature. In contrast, the bare MoS_2 shows almost no measurable response. The MoS_2-CuBTC hybrid also shows higher selectivity over other interference gases and wide range of detection capability (1-0.1%). This multifunctional material presents a promising pathway for the scalable production of high-performance chemical-sensitive electronics, offering a transformative solution for real-time hydrogen safety management.

KEY WORDS

Functionalized MoS_2, MOF electronics, on-demand devices, hydrogen detection

BIOGRAPHY

Md Abdul Jalil is a PhD student at the University of Adelaide's School of Chemical Engineering working on developing 2D materials, and their composites, for sensing applications. He earned his M. Sc in Physics from BUET, Bangladesh. He then studied at CUET, Bangladesh, obtaining his M. Phil. Prior to beginning his PhD, he was a Lecturer in the Department of Physics at CUET. He has expertise in advanced materials synthesis and characterization techniques. His research aims to develop scalable, cost and energy effective sensors for safety monitoring in hydrogen energy sector.

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