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Facile fabrication of bismuth oxide anchored graphene oxide for the effective electrochemical sensing of diuron

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Highlights

- γ-Bi_2O_3 interconnected with GO as a modified electrode for the electrochemical detection of DU.
- γ-Bi_2O_3/GO/GCE elucidates an extensive detection range with a lower detection limit.
- γ-Bi_2O_3/GO/GCE achieves stupendous selectivity, durability, and recovery of DU in the real samples.

Abstract

Background

Diuron (DU), a weed controller widely used in the agricultural industry, prolonged conception of this agrochemical residue contaminated with environmental water bodies and soil sources could cause an acute impact on the human health system. This work utilized the electrochemical determination technique due to their rapid detection, outstanding sensitivity, and economical purpose.

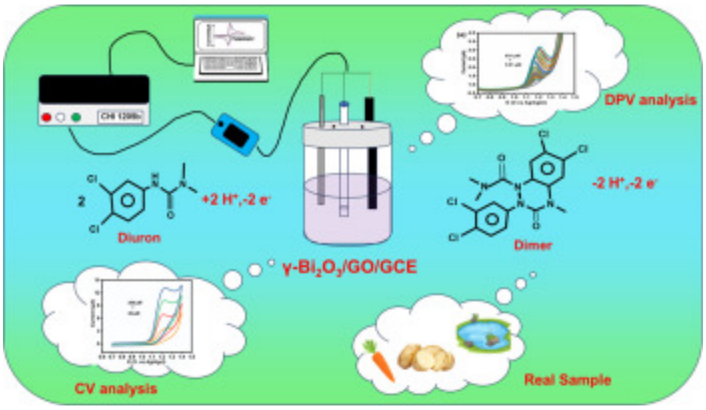
Methods

The electrochemical behavior of DU at the γ-Bi_2O_3 microplates interconnected with sheet-like graphene oxide (GO) as a surface-modified electrode was scrutinized by cyclic voltammetry (CV) and differential pulse voltammetry (DPV). The surface-modified γ-Bi_2O_3/GO/GCE elucidates superior electrocatalytic performance towards the irreversible oxidation response of diuron than the other surface-modified electrode in the phosphate buffer solution of 0.1 M.

Significant findings

The γ-Bi_2O_3/GO/GCE electrode displayed an extensive detection range of 0.1–631 μM with a 0.751 μM lower detection limit furthermore, noticeable 0.0280 $\mu A\ \mu M^{-1}\ cm^{-2}$ sensitivity for diuron determination. In addition, the DPV experiment exposed that the γ-Bi_2O_3/GO/GCE electrode achieves stupendous selectivity, durability, and acceptable feasibility of the real-time samples.

Graphical abstract



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Introduction

Diuron (DU) is a herbicide used in the prevention of weeds in the agriculture industry to enhance the quality and quantity of agricultural production by effectively controlling and eradicating insects and pests, thereby enhancing global food supplies in the "Green Revolution" agriculture system [1]. As well as, DU is also treated in the transport industry as an antifouling paint agent in ships, and boats and also a weed controller in the railroad and airport runways [2,3]. Inappropriate usage of this kind of agrochemical residue contaminated with environmental sources for instance soil and water because the half-life of DU residue substances is >300 days in the soil and 14 days in the aqueous sources [4,5]. Therefore, roots can absorb it and impact the entire plant via photosynthesis. Furthermore, high dosages of DU linger in vegetables, fruits, and environmental water sources therefore prolonged conception of DU can lead to cancer and gene damage diseases, additionally produce methemoglobin in the blood, damage in the liver, and endocrine disorders in the spleen in the human body [6]. Considering this acute health impact on humans, the European Commission announced DU as a harmful and hazardous substance [7]. To determine this toxic substance from the environment certain analytical techniques occur for example gas chromatography (GC) [[8], [9], [10]]. High-performance liquid chromatography (HPLC) [[11], [12], [13]]. capillary electrophoresis (CE) [14,15] and electrochemical sensors [9, [16], [17], [18], [19]] comparing this analytical technique electrochemical sensor analytical performance was much superior to those of the other analytical techniques because it is easy to feasible, has a rapid analytical response, has high sensitivity, is technically diminished, and is economical, so prudent fascinates the researchers [20,21].

Bismuth-based materials are applicable in an extensive range of applications, for instance, energy devices, bio-sensors, photocatalysts, electrochemical detection, and so on because of their superior active surface area, outstanding conductivity, band gap energy, and also non-toxicity [22,23]. Bi_2O_3 is one of the most important p-type semiconductor metal oxides notably Bi_2O_3 demonstrates five different phases, for instance, monoclinic (α), tetragonal (β), body-entered cubic (γ), face-centered cubic (δ), and triclinic (ε) phases [24,25]. Furthermore, γ-Bi_2O_3 has superior physical and chemical properties compared with other different phases of Bi_2O_3 because of their extensive band gap energy for example (~2.8–3.96 eV), enhanced higher active surface area, and remarkable durability and also γ-Bi2O3 nanoparticles as an electrode modifier has garnered significant interest in the past decade due to its exceptional electron mobility [26,27]. Consequently, considering these stupendous factors of γ-Bi_2O_3 applicable in various applications, for example, electrochemical detection, photocatalyst, and energy-based applications. Conversely, the electrocatalytic activity of γ-Bi_2O_3 is relatively low because of their electron-hole pair recombination [28].

Hence, Carbon-based nanomaterials like reduced graphene oxide (rGO), graphitic carbon nitride, graphene oxide (GO), and porous carbons are widely used in the electrochemical detection methods [29,30], for the detection of hazardous pesticides, and biological materials and so on due to their electrical conductivity and superior active surface area and fast electron transfer efficiency [15,[31], [32], [33], [34]]. An atomic-layer-thick and two-dimensional structure with numerous oxygen-containing functional groups, therefore, enhances the excellent mechanical strength, chemical stability, and stupendous electrical conductivity of graphene oxide (GO) [[35], [36], [37], [38]] which improves the electrochemical properties of metal, metal oxide is used as an electrode material in electrochemical analysis [39,40]. So, γ-Bi_2O_3 combined with GO increased the durability, active surface area, and accelerated electron transfer in electrochemical reactions due to the synergistic effect between γ-Bi_2O_3 and GO.

Herein, the hydrothermally synthesized γ-Bi_2O_3 is ultrasonically interconnected with GO. The physical characterization of the γ-Bi_2O_3/GO/GCE is investigated by X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FT-IR), Raman Spectra, Field-Emission Scanning Electron Microscopy (FE-SEM), and High-Resolution Scanning Electron Microscopy (HR-TEM). The electrocatalytic performance of the γ-Bi_2O_3/GO/GCE was scrutinized by electrochemical impedance spectroscopy (EIS), cyclic voltammetry (CV), and differential pulse voltammetry (DPV) techniques to determine the extraordinary conductivity lower detection limit with sensitivity, and extensive detection range. Additionally, the electrochemical performance of DU was probed in the real-time sample to determine the remarkable recovery range.

Section snippets

Materials and instrumentation

All the materials and instrumentation techniques shown in the supplementary information

Synthesis of bismuth oxide

Bismuth oxide is synthesized employing the method. Primarily, 1.5 g of Bismuth nitrate (Bi $(NO_3)_3$). $5H_2O$ is dissolved in 50 ml of distilled (DI) water under stirred at room temperature for 15 min, after that 0.5 g of Hydroxylamine hydrochloride (NH_2OH. HCl) were dissolved in 10 ml of DI water and this solution is sonicated in a sonication bath with the frequency about 100 Hz for one hour until it is fully

Physical characterization

The XRD patterns of γ-Bi_2O_3/GO were depicted in Fig. 1**a.** Characteristic diffraction peaks of γ-Bi_2O_3 were located at 12.03°, 24.30°, 26°, 32.74°, 33.61°, 36.80°, 41.14°, 46.88°, 49.95°, 54.33°, 55.35°, 60.84°, 68.34°, 75.20°, 77.91°, and 86.99° could originate to the (110), (220), (013), (123), (400), (330), (332), (431), (521), (600), (611), (622), (127), (800), (028), and (840) planes of Cubic γ-Bi_2O_3 (01–074–1375) [41], respectively, while the GO characteristic peaks appeared at 10.6° and

Electrocatalytic performance of γ-Bi_2O_3/GO/GCE

Electrochemical impedance spectroscopy (EIS) elucidates electron transfer capability and electrocatalytic conductivity behavior of unmodified and modified electrodes. In Fig. 4**a.** the Nyquist plots of bare GCE, γ-Bi_2O_3/GCE, GO/GCE, and γ-Bi_2O_3/GO/GCE were examined by 0.1 M PBS pH 2. The Randle's circuit was assisted in fitting the equivalent circuit of unmodified and modified electrodes for Electrochemical impedance spectroscopy analysis. The high ionic concentration of the PBS facilitates

Conclusion

In summary, hydrothermally synthesized γ-Bi_2O_3 was ultrasonically interconnected with GO as the modified electrode γ-Bi_2O_3/GO/GCE for the electrochemical determination of DU. The stupendous electrocatalytic performance and remarkable conductivity of γ-Bi_2O_3/GO/GCE due to the synergistic effect between the γ-Bi_2O_3 and GO, diffusion-controlled layers play a vital role in the determination of DU compared to those of other surface-modified electrodes because γ-Bi_2O_3/GO/GCE shows 0.751 µM lower

CRediT authorship contribution statement

Nandhini Munusamy: Writing – original draft, Software, Methodology, Investigation,

Conceptualization. **Francis Packiaraj Don Disouza:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Shen-Ming Chen:** Supervision, Resources, Project administration, Funding acquisition. **Kumar Krishnan:** Software, Formal analysis, Data curation. **Mukesh Kumar Dharmalingam Jothinathan:**

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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