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Synergetic combination of nano hexagons SnS_2/Sulfur substituted graphitic carbon nitride: Evaluation of electrochemical sensor for the agricultural pollutant in environmental samples

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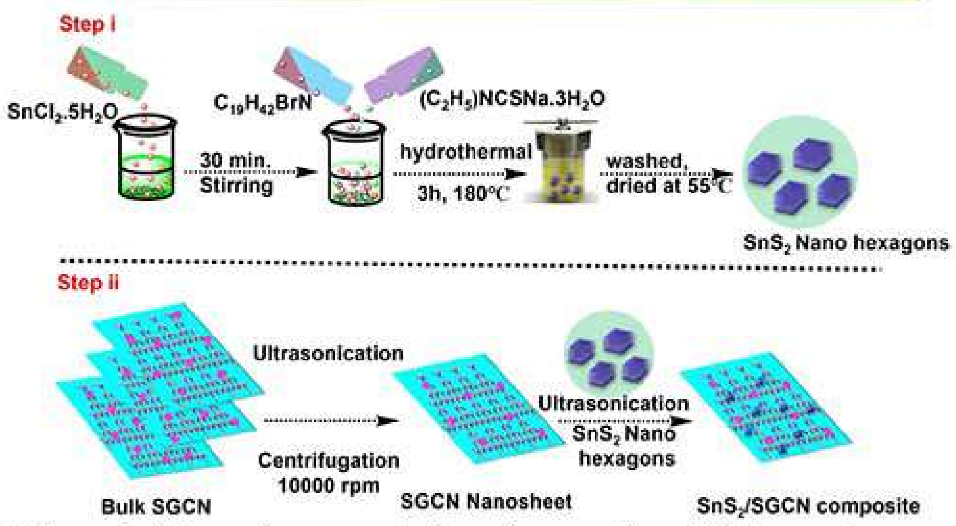
Abstract

In the modern era, the pesticide is highly formulated for huge harvest yield in agriculture. Nevertheless, improper disposal of pesticide residues from industries has severely impacted living beings and posed a serious threat. Thus, researchers are keen to evaluate carbendazim's complex chemical constituents in food samples through sensitive and selective detection. This study discusses nano hexagon-shaped tin sulfide (SnS_2) incorporated on the high defective sites of sulfur-doped graphitic carbon nitride (SGCN), a nanocomposite network prepared *via* ultrasonic dispersion. It displays low electron transfer resistance, high effective surface area, and excellent film electrode stability. A modified screen-printed carbon electrode (SPCE) was implemented to sense the carbendazim(CBZ) residues in environmental samples. Under the optimized conditions, the sensor presents a differential pulse voltammetry current response for CBZ concentration from 0.002 to 416 µmol. L^{-1} with a nanomolar detection (3×10^{-8} mol. L^{-1}). It also exemplifies high sensitivity (0.1366 µA μM^{-1} cm^{-2}), selectivity, reproducibility, and long-term storage stability. Further, the proposed sensor was implemented to determine CBZ in apple, orange, cucumber, and carrot samples. Good recovery was found using the standard addition method that substantiates the excellent analytical performance of the proposed electrochemical sensor.

Synthesis



Scheme 1. Schematic representation of preparation of SnS_2 nano hexagons and SnS_2/SGCN composite.

Results

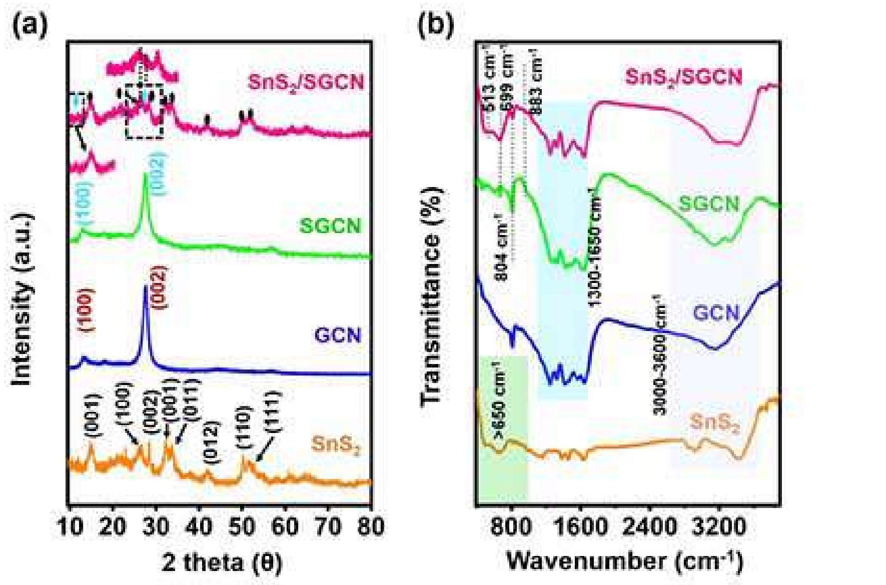


Figure 1. (a) XRD patterns, and (b) FTIR spectrum of SnS_2, GCN, SGCN, and SnS_2/SGCN.

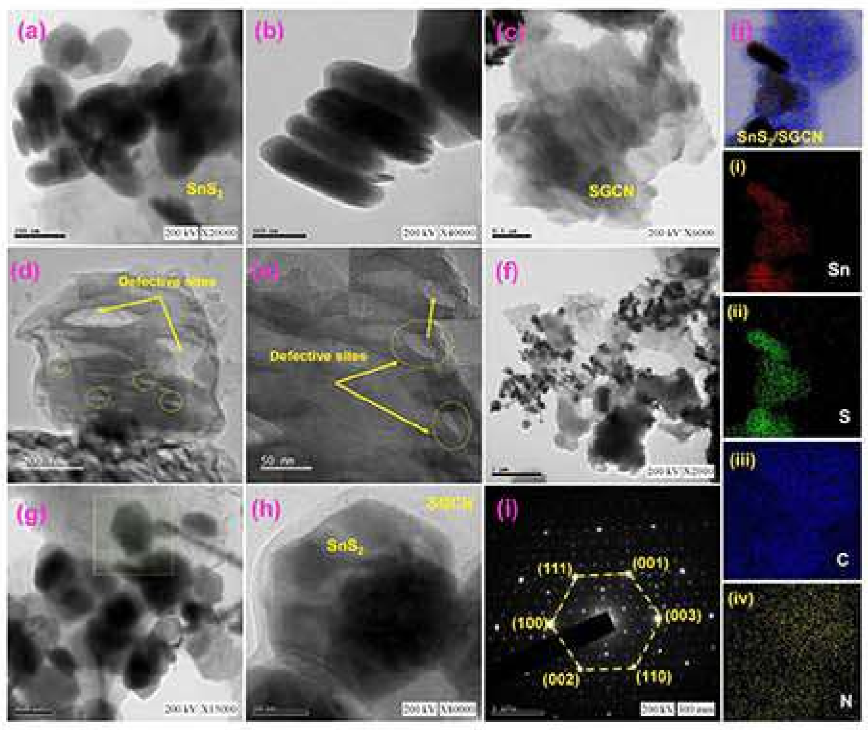


Figure 2. (a - b) HR-TEM images of SnS_2, (c - e) SGCN, (f - h) SnS_2/SGCN, and (i) SEAD pattern, and j (i-iv) Elemental mapping for the prepared SnS_2/SGCN composite.

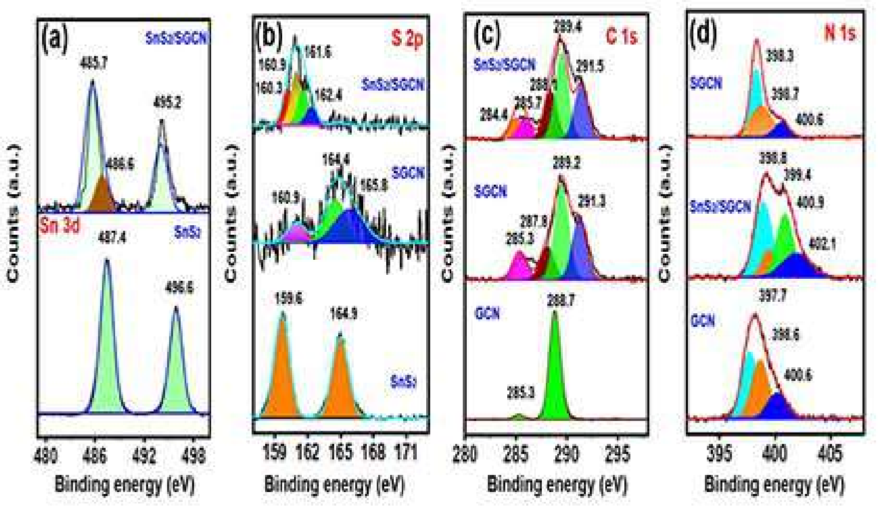
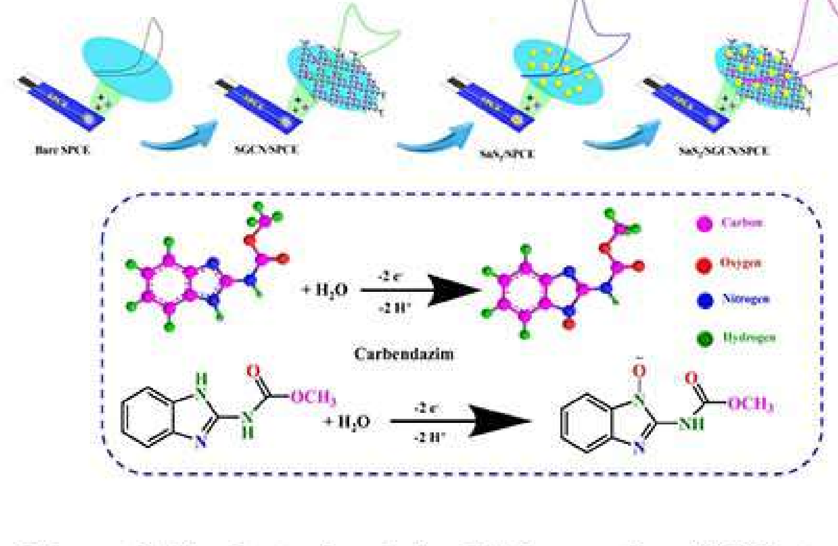


Figure 3. Individual deconvolution high-resolution XPS spectrum of SnS_2, SGCN, SnS_2/SGCN (a) Sn 3d, (b) S 2p, (c) C 1 s, and (d) N 1 s.



Scheme 2. The electrochemical oxidation reaction of CBZ at different electrodes and reaction mechanism

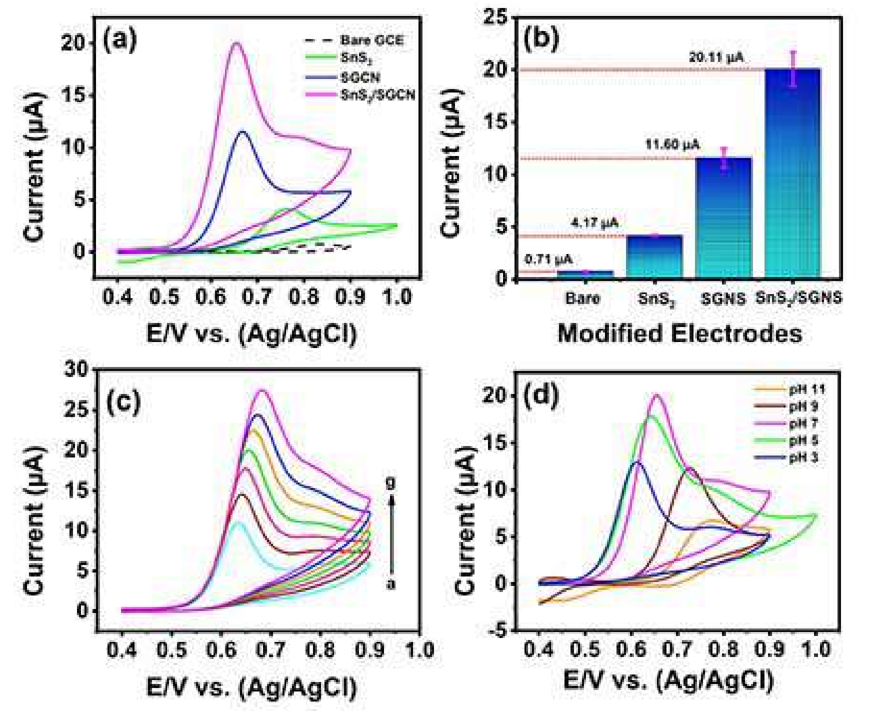


Figure 4. (a) CV oxidation response for Bare SPCE, SGCN, SnS_2, and SnS_2/SGCN modified SPCE in the existence of 200 µM of CBZ, (b) Bar diagram for modified electrodes, (c) CV response at different quantities of CBZ (50 – 350 µM), (d) effect of pH at SnS_2/SGCN/SPCE with the presence of CBZ (200 µM) in different pH.

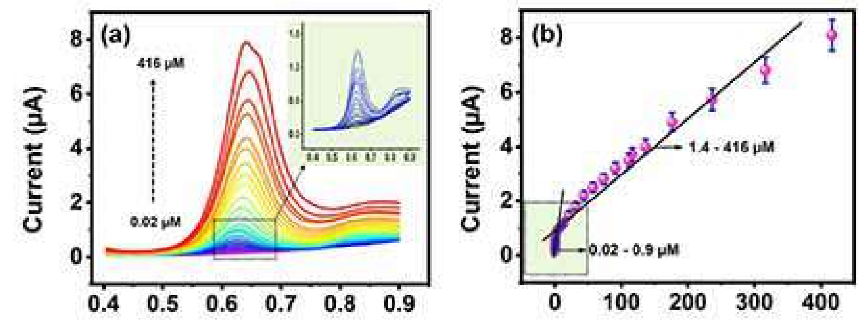


Figure 5. (a) DPV response of SnS_2/SGCN/SPCE for the addition of CBZ (20 nM to 416 µM) in N_2 saturated PBS (pH 7.0). (b) Corresponding linear plot for the concentration of CBZ (µM) *vs.* oxidation peak current.

Conclusion

Herein, we reported a cost-effective approach to preparing S-doped GCN incorporated with nano hexagons SnS_2 *via* ultrasonic dispersion method. Thus, the SnS_2/S-GCN/SPCE sensor delivers an excellent linear range and provides a predominant nanomolar level limit of detection, high selectivity, and sensitivity towards CBZ. Finally, the practical feasibility was also analyzed with apple, orange, carrot, and cucumber with an appreciable recovery result. Further, the proposed sensor can be an excellent candidate in miniaturized devices for the electrochemical sensing of agricultural pollutants.

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Publications

Ragurethinam Shanmugam, Jaysiva Ganesamurthi, Tse-Wei Chen, Shen-Ming Chen, Krishnapandi Alagumalai, Jawaher Alkhantani, Mona S Alwahibi, M Ajmal Ali. "*Synergetic combination of Nano hexagons SnS_2/Sulfur substituted graphitic carbon nitride: Evaluation of electrochemical sensor for the agricultural pollutant in environmental samples.*" Chemical Engineering Journal (2022).

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