Application of Zinc Selenide and its Graphitic Carbon Nitride Composite Materials in Photocatalytic Degradation of Crystal Violet and Electrocatalytic Reduction of CO_2

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Abstract

A combination of graphitic carbon nitride and zinc selenide was used to synthesize composite materials through hydrothermal reactions. Various proportions of the two materials were used to create different composites, which were then characterized using multiple instruments including XRD, FE-TEM, FT-IR, SEM-EDS, UV–Vis DRS, PL, EPR, HR-XPS, and BET. To test the photocatalytic efficiency of the synthesized composites, degradation experiments were conducted using crystal violet. Among the zinc selenide composite materials, ZnSe/g-C_3N_4-5wt% demonstrated the highest degradation efficiency. Electrochemical experiments were conducted to investigate the electrocatalytic reduction of carbon dioxide by suspending the zinc selenide composite materials coating them onto the surface of a graphite rod serving as the working electrode. Cyclic voltammetry tests were carried out to identify the optimal catalyst and reduction potential. The superior composite material identified was ZnSe/g-C_3N_4-5wt%. Under constant potential conditions at -0.5 V, -0.7 V, and -0.9 V, the reduction of carbon dioxide in an alkaline solution was conducted for 1 hour. The resulting products were analyzed using GC-FID. Preliminary findings suggest that the ZnSe/g-C_3N_4-5wt% composite demonstrates outstanding electrocatalytic performance. Electrocatalytic reduction of carbon dioxide at lower voltages predominantly yields acetone, and further confirmation through GC/MS is under investigation.

Result and Discussion

XRD

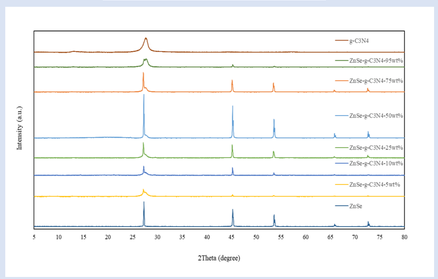
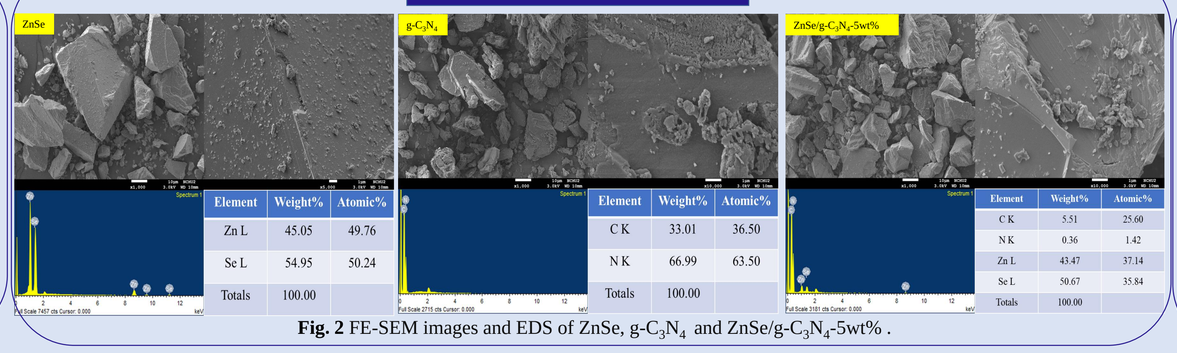


Fig. 1 XRD patterns of ZnSe composites using different content of g-C_3N_4.

FE-SEM-EDS



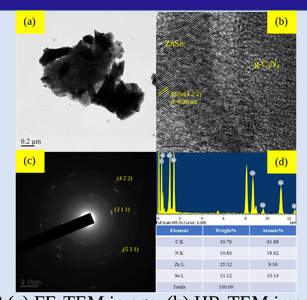
Element	Weight%	Atomic%
Zn L	45.05	49.76
Se L	54.95	50.24
Totals	100.00	

Element	Weight%	Atomic%
C K	33.01	36.50
N K	66.99	63.50
Totals	100.00	

Element	Weight%	Atomic%
C K	5.51	25.60
N K	0.36	1.42
Zn L	43.47	37.14
Se L	50.67	35.84
Totals	100.00	

Fig. 2 FE-SEM images and EDS of ZnSe, g-C_3N_4 and ZnSe/g-C_3N_4-5wt% .

FE-TEM-EDS



Element	Weight%	Atomic%
C K	30.76	61.88
N K	10.80	18.62
Zn L	25.32	9.36
Se L	33.12	10.14
Totals	100.00	

Fig. 3 (a) FE-TEM image, (b) HR-TEM image, (c) SAED and (d) EDS of ZnSe/gC_3N_4-5wt%.

FT-IR

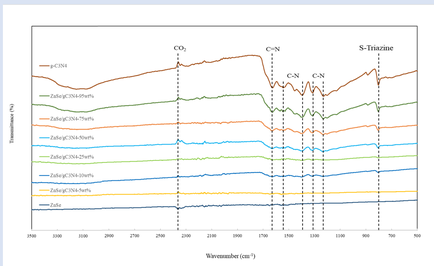


Fig. 4 FT-IR spectra of ZnSe/g-C_3N_4 in different content of g-C_3N_4.

HR-XPS

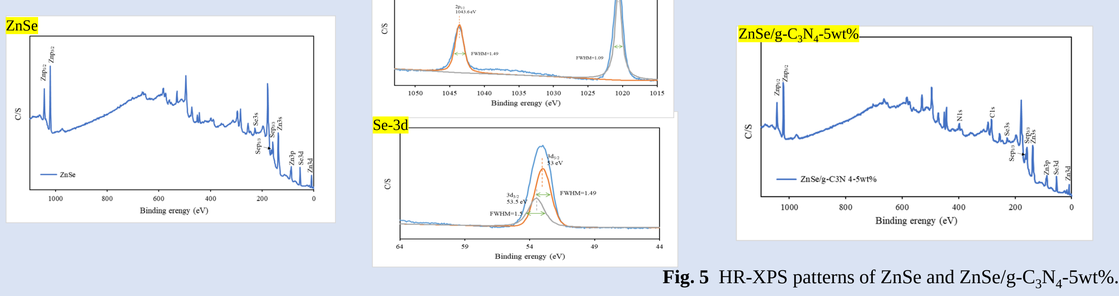


Fig. 5 HR-XPS patterns of ZnSe and ZnSe/g-C_3N_4-5wt%.

DR-UV-Vis

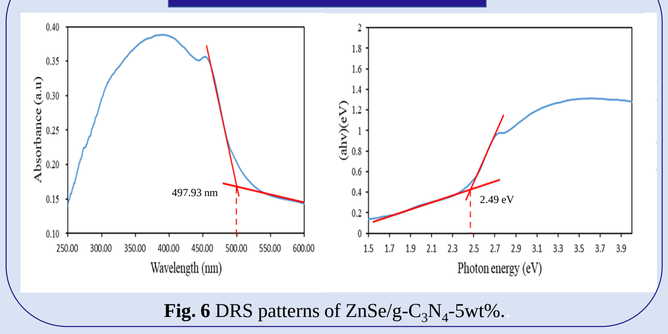


Fig. 6 DRS patterns of ZnSe/g-C_3N_4-5wt%.

Photocatalytic degradation of CV

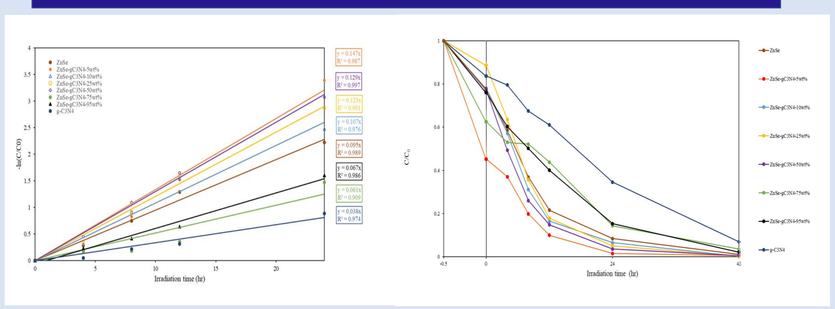


Fig. 7 Photodegradation of CV as a function of irradiation time over different ZnSe/g-C_3N_4.

PL

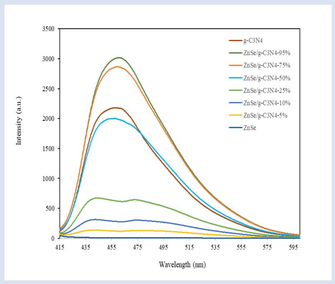


Fig. 8 PL patterns of ZnSe/ g-C_3N_4.

BET

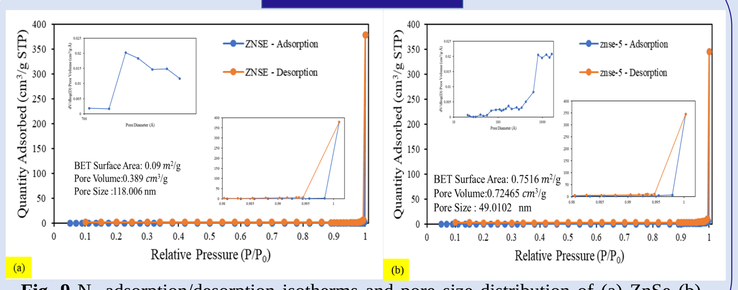


Fig. 9 N_2 adsorption/desorption isotherms and pore size distribution of (a) ZnSe (b) ZnSe /g-C_3N_4-5wt%.

Scavenger effect

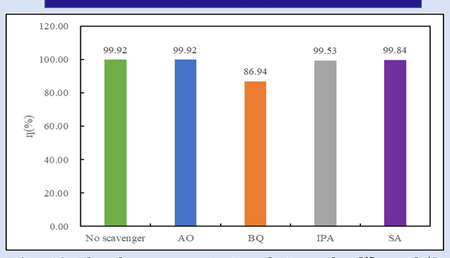


Fig. 10 The dye concentration during photodegradation as a function of irradiation time observed in ZnSe/g-C_3N_4-5wt% photocatalysts.

Electrocatalytic reaction

Fig. 14 Cyclic voltammetry of Na_2CO_3 reduction using bared SPE and SPE coated with ZnSe, g-C_3N_4, and ZnSe/g-C_3N_4.

Fig. 15 GC/FID chromatograms of headspace gas and electrolyte solutions obtained during electrocatalytic ZnSe/g-C_3N_4-5wt% reduction of CO_2 using different potentials -0.5V, -0.7V and -0.9V.

EPR

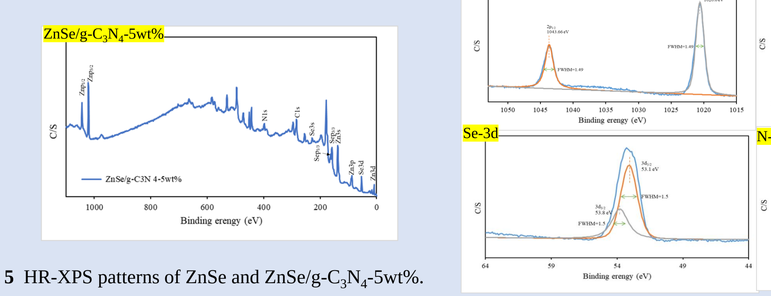


Fig. 11 EPR pattern of ZnSe/g-C_3N_4-5wt%.

Photoreduction of CO_2

Fig. 12 Photocatalytic reduction of CO_2 as a function of irradiation time over ZnSe/ g-C_3N_4-5wt% .

Mechanism

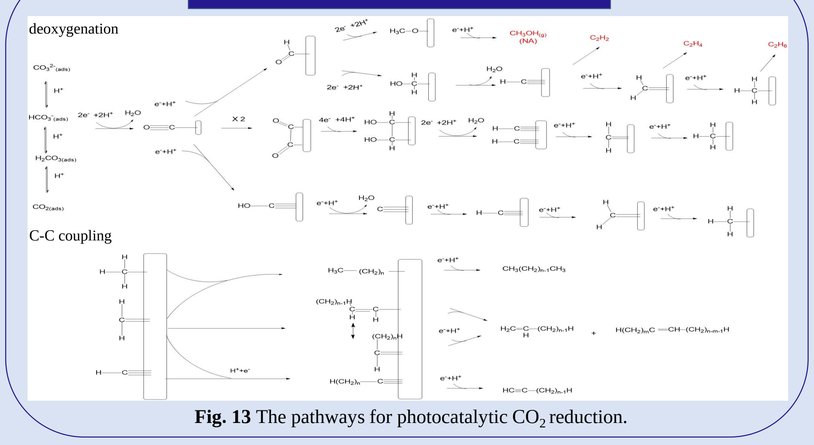


Fig. 13 The pathways for photocatalytic CO_2 reduction.

Summary

The utilization of ZnSe , ZnSe/g-C_3N_4-5wt% for CO_2 reduction and photocatalytic degradation of organic pollutants such as crystal violet (CV) showed remarkable effects, indicating their broad potential in reducing environmental pollution.

Using ZnSe/g-C_3N_4-5wt%, it can be seen that the products that can be obtained under constant potential reduction of CO_2 is acetone.