Supplementary Material

Oxygen Vacancy-Engineered Cu_2O@CuS p–p Heterojunction Gas Sensor for Highly Sensitive n-Butanol Detection

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S1. Experimental reagents

The reagents used in this system are shown in Table S1, and all reagents were not processed twice.

Table S1. Reagents used in the experiments.

Reagent name	Molecular Formula	Purity	Manufacturers
Ferric nitrate	$Fe(NO_3)_3 \cdot 9H_2O$	AR	Sinopharm Group Chemical Reagent Co.
Sodium tungstate	$Na_2WO_4 \cdot 2H_2O$	AR	Shanghai Chemical Reagent General Factory
Hydrochloric acid	HCl	38 wt%	Sinopharm Group Chemical Reagent Co.
Ethanol	CH_3CH_2OH	AR	Shanghai Maclean Biochemical Technology Co.
Ammonia	NH_3	25 wt%	Tianjin Zhiyuan Chemical Reagent Co., Ltd.
Formaldehyde	HCHO	37 wt%	Shanghai Maclean Biochemical Technology Co., Ltd.
n-Butanol	$C_4H_{10}O$	AR	Shanghai Maclean Biochemical Technology

			Co., Ltd.
Acetone	C_3H_6O	AR	Shanghai Maclean Biochemical Technology Co., Ltd.
Toluene	C_7H_8	AR	Shanghai Maclean Biochemical Technology Co., Ltd.
Carbon monoxide	CO	99.9%	Guangzhou Yigas Gases Co., Ltd.

S2. Physical schematic diagram of sensor core device



Figure S1. Physical schematic diagram of sensor core device.

S3. EDS analysis of hollow Cu_2O@CuS nano-cube

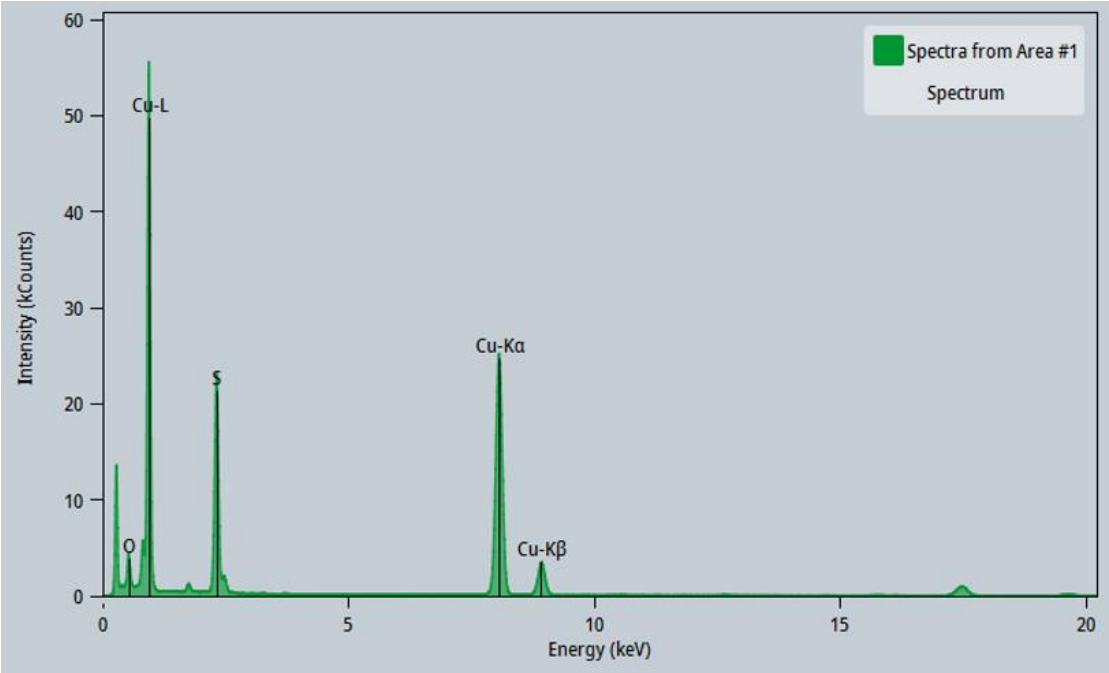


Figure S2. EDS analysis of hollow Cu_2O@CuS nano-cube.

S4. Calculation of the weight ratio of Cu_2O and CuS in Cu_2O@CuS

Table S2. EDS analysis of hollow Cu_2O@CuS nano-cube.

Element	K-factor	Absorption correction	Atomic fraction %	Atomic error %	Mass fraction %	Mass error %	Fit error %
Cu	1.00	1.00	10.38	1.97	3.50	0.40	0.21
O	0.86	1.00	35.29	9.38	23.82	5.19	0.33
S	1.38	1.00	54.33	12.93	72.68	13.28	0.09

The atomic percentages (O: 10.38%, S: 35.29%, Cu: 54.33%) were used to calculate the phase composition. All 35.29 sulfur atoms form CuS while consuming an equivalent number of copper atoms. The remaining 19.04 Cu atoms combine with 9.52 O atoms to form Cu_2O (Cu:O = 2:1). Using molecular weights (Cu_2O: 143.10 g/mol, CuS: 95.62 g/mol) for mass calculation, the weight ratio of Cu_2O to CuS is **1:2.48**, meaning Cu_2O constitutes 28.8% and CuS 71.2% of the composite. A negligible excess of oxygen (0.86 atoms) was disregarded, confirming the material is primarily composed of these two phases. The calculated results align with the measured elemental mass fractions (O: 3.50%, S: 23.82%, Cu: 72.68%).

S5. Comparison of n-butanol gas sensors based on other sensing materials in previous reports

Table S3. Comparison of n-butanol gas sensors based on other sensing materials in previous reports.

Sensor materials	Con. (ppm)	Tem. (℃)	Res. ($S=R_a/R_g$)	t_{res}/t_{rec} (s)	Ref.
Co–$BiVO_4$	100	300	51.8	149/38	[1]
Au/TiO_2	100	240	25	10/51	[2]
Bi-doped $ZnFe_2O_4$	100	175	23.6	16/98	[3]
Bi_2O_3-In_2O_3	100	200	24.15	120/64	[4]
$NiFe_2O_4$	10	130	29.747	16/955	[5]
Sb-doped $ZnFe_2O_4$	100	250	35.5	4/250	[6]
Cu_2O@CuS	100	260	58.944	54/29	This work

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