Supporting Information

Controllable synthesis of an intercalated SnS_2/aEG structure for enhanced NO_2 gas sensing performance at room temperature

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Abstract: Supporting information provide: (i) XRD diffraction patterns of aEG, (ii) FT-IR spectra of SnS_2/aEG-IV and PVP, (iii) Raman spectra of aEG and SnS_2/aEG-IV, (iv) TEM image of flower like SnS_2, (v) EDS elemental mapping of the SnS_2/aEG-III, (vi) SEM images of SnS_2/aEG-IV, (vii) HRTEM images of SnS_2/aEG-III, (viii) Fitted impedance parameters all of the samples, (ix) The gas sensing properties of SnS_2/aEG-III compared with the references based on SnS_2, (x) XPS spectra of the pristine SnS_2, aEG, SnS_2/aEG-III and of the used SnS_2/aEG-III NC, (xi) Dynamical response transient of the pristine aEG, SnS_2, SnS_2/aEG-I, SnS_2/aEG-II and SnS_2/aEG-IV NCs, (xii) Table of the comparative response and response/recovery time of all the samples, (xiii) The calibration curve and the reproducibility of SnS_2/aEG-III, (xiv) FT-IR informations of vibration of PVP, (xv) Humidity test on SnS_2/aEG-III, (xv) A diagram of the delivery system for the gas sensing and humidity test.

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Table S1 Comparison of NO_2 Sensing Performance of the SnS_2-based Sensor developed in this work with the previous ones.

Sample	Working temperature/°C	NO_2 concentration /ppm	Sensitivity	Response /Recovery time	Refs.
SnS_2	120	10	~36	—	[22]
SnO_2/SnS_2	100	1	51.1	299s/143s	[23]
SnS_2	120	0.1	5.7	—	[24]
SnS_2	250	10	~15	6s/40s	[25]
SnO_2/SnS_2	80	8	5.3	159s/297s	[26]
SnS_2-reduced graphene oxide	80	0.6	~1	>5min	[27]
SnS_2 Nanograins on Porous SiO_2 Nanorods	RT	10	~7	—	[28]
SnS_2/aEG-III	RT	100	21.19	0.53s/ 51.73s	Our work

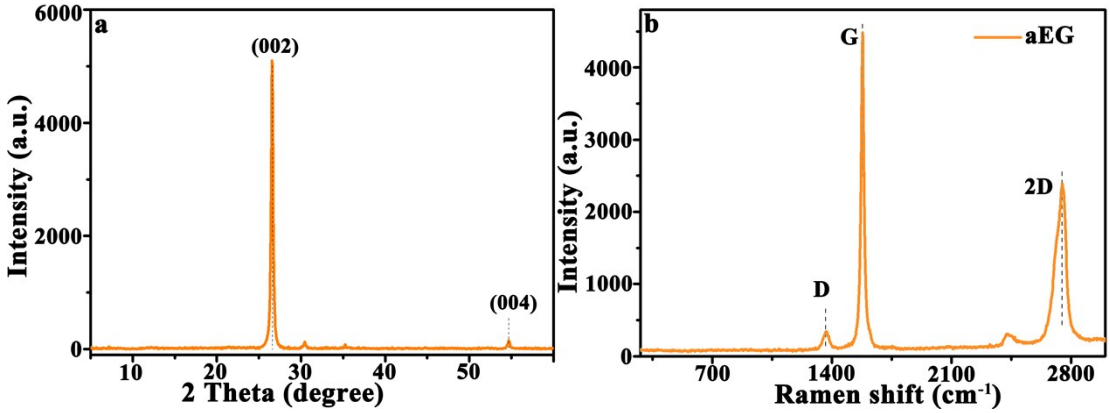

Fig. S1 XRD diffraction pattern (a) and Raman spectrum (b) of aEG.

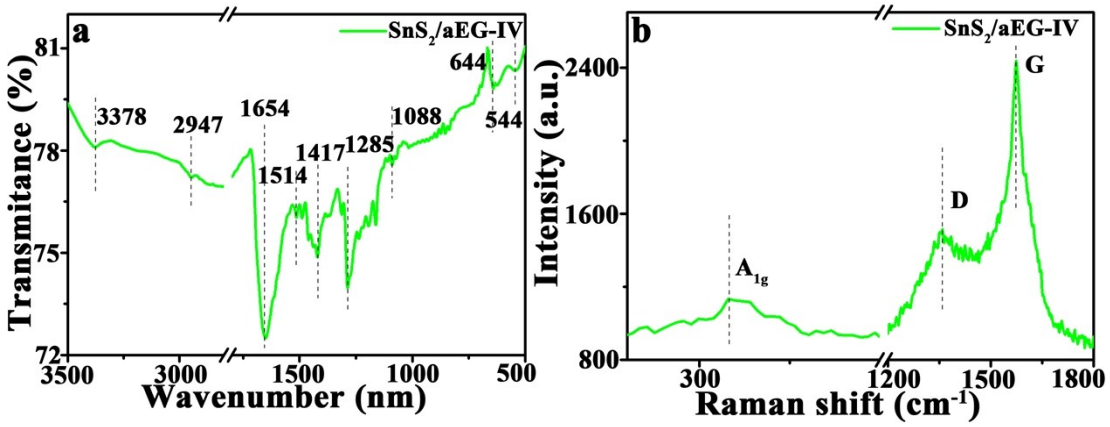

Fig. S2 (a) FT-IR spectrum and (b) Raman spectrum of SnS_2/aEG-IV.

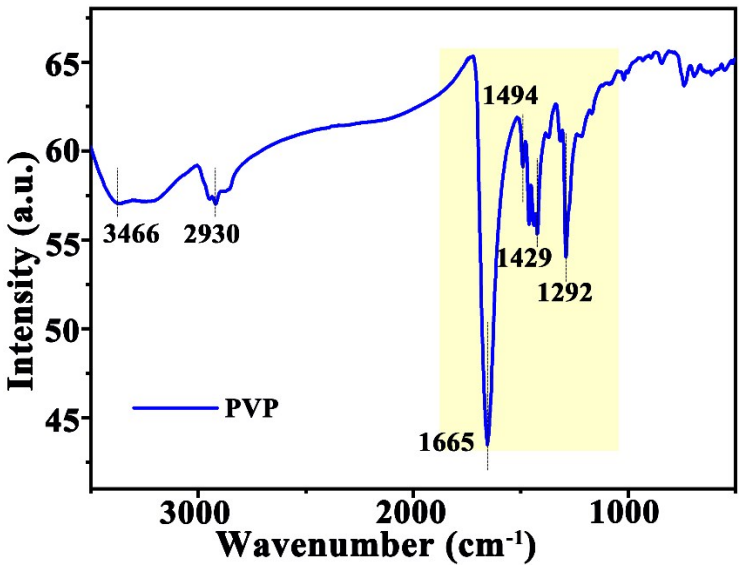

Fig. S3 Spectra of FT-IR of PVP.

Table S2 FT-IR Wavenumber, assignment, and mode of vibration of PVP.

Wavenumber / cm^{-1}	Assignment	Vibration mode
~3466	H_2O combined	Stretching O-H
~2930	CH_2	Bending C-H
~1665	C=O	Stretching C-O
~1494	CH_2	Bending CH_2
~1429	CH_2	Bending CH_2
~1292	C-N	Stretching C-N

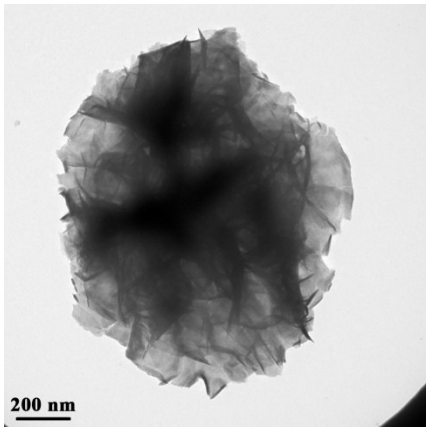

Fig. S4 TEM image of the flower like SnS_2.

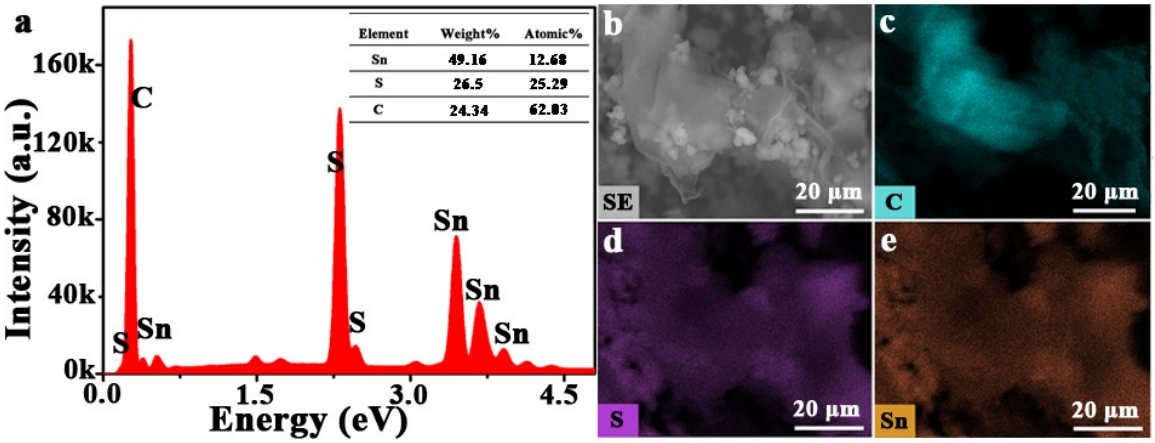

Fig. S5 (a) EDS image of SnS_2/aEG-III; EDS elemental mapping of the SnS_2/aEG-III (b) for C (c) S (d) and Sn (e) elements.

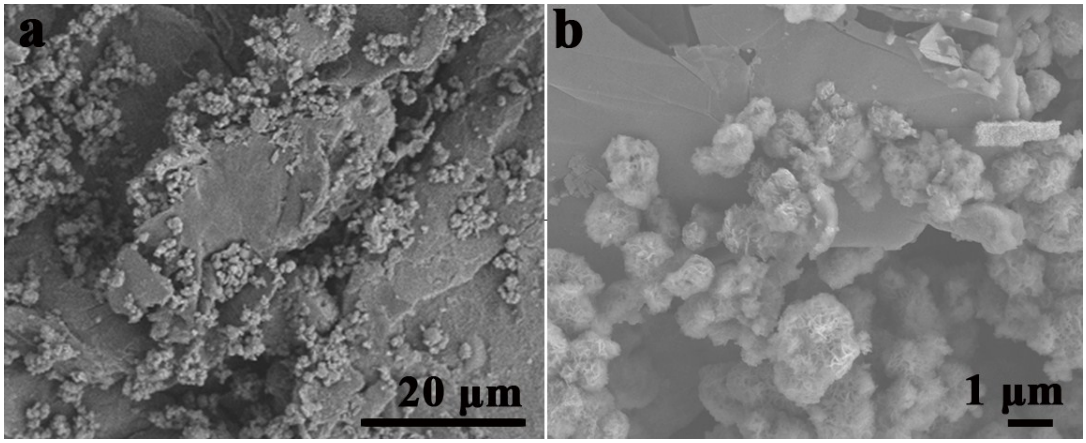

Fig. S6 SEM images of SnS_2/aEG-IV.

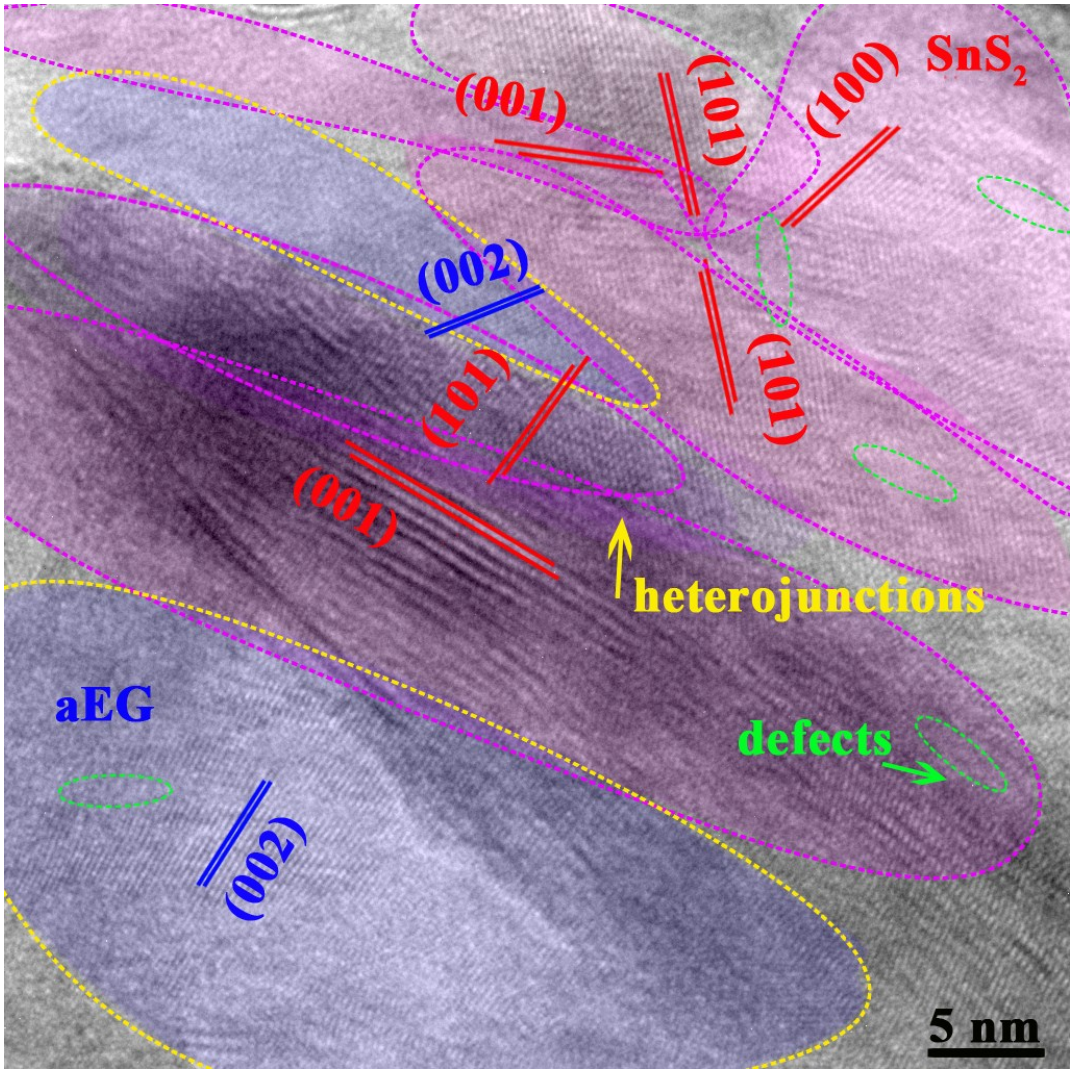

Fig. S7 Enlarged view of 4h and 4i in text.

Table S3 The comparative XPS peak positions of the pure SnS_2, aEG, fresh SnS_2/aEG-III and of the used SnS_2/aEG-III NCs

	Binding energy (eV)		
	Sn ($3d_{5/2}$/$3d_{3/2}$)	**S ($2p_{3/2}$/$2p_{1/2}$)**	**C 2s**
SnS_2	487.16/495.60	163.39/162.21	—
aEG	—	—	284.65
SnS_2/aEG-III (fresh)	487.23/495.65	163.45/162.35	284.60
SnS_2/aEG-III (used)	487.30/495.69	163.40/162.25	284.66

Table S4 Fitted impedance parameters of the samples

Samples	**SnS_2**	**aEG**	**SnS_2/aEG-III**
R_Ω (Ω)	34	26	18
R_{ct} (Ω)	1483	380	153

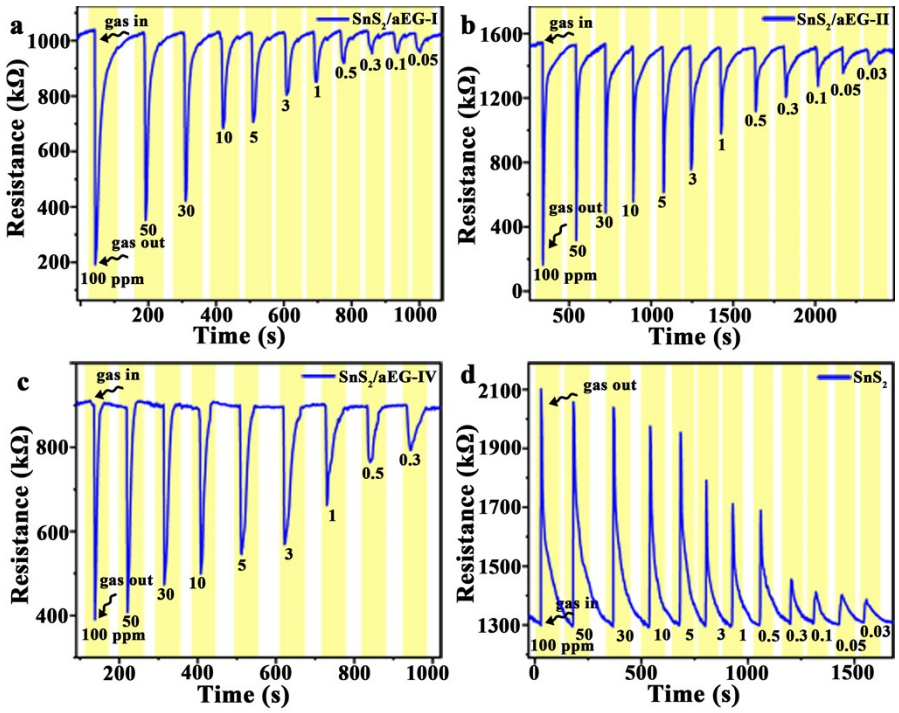

Fig. S8 Dynamical response transient of (a) SnS_2/aEG-I, (b) SnS_2/aEG-II, (c) SnS_2/aEG-IV and (d) SnS_2 to NO_2 gas at room temperature.

Table S5 Response, response time and recovery time of the sensors to NO_2 at room temperature in 30 % humidity.

	SnS_2/aEG-III			SnS_2/aEG-II			SnS_2/aEG-I			SnS_2		
NO_2 (ppm)	R_a/R_g	t_{res}	t_{rec}	R_a/R_g	t_{res}	t_{rec}	R_a/R_g	t_{res}	t_{rec}	R_a/R_g	t_{res}	t_{rec}
100	21.19	0.53	51.73	10.65	1.07	93.33	6.14	1.07	72.53	3.04	1.07	81.60
50	13.39	0.53	58.13	5.17	1.07	93.87	5.79	1.07	74.67	2.70	1.07	78.93
30	9.98	1.07	56.53	3.22	1.60	86.40	5.51	1.07	76.27	2.66	1.60	98.67
10	7.93	1.07	50.67	2.73	3.20	94.93	5.17	1.07	77.33	2.64	1.60	89.07
5	5.94	1.07	44.80	2.42	3.73	85.33	2.93	2.13	60.27	2.20	3.20	72.00
3	5.35	1.60	48.00	2.13	5.33	89.60	2.47	2.13	56.53	2.15	3.73	59.20
1	4.00	2.13	51.20	1.64	5.87	95.47	1.48	2.67	59.20	1.68	3.73	62.40
0.5	2.50	3.20	44.27	1.48	8.00	94.40	1.28	4.27	41.60	1.53	3.73	67.20
0.3	2.40	3.20	42.67	1.39	9.60	82.67	1.21	4.27	37.87	1.47	4.27	73.60
0.1	1.50	3.20	38.40	1.28	10.13	78.93	1.13	5.33	38.93	1.14	4.27	56.00
0.05	1.22	3.73	34.67	1.27	10.13	61.87	1.09	5.87	35.20	1.09	5.87	58.13
0.03	1.09	4.80	30.93	1.23	11.73	62.93				1.07	6.40	51.20
0.01	1.04	8.53	18.13									

t_{res} = Response Time (s), t_{rec} = Recovery Time (s)

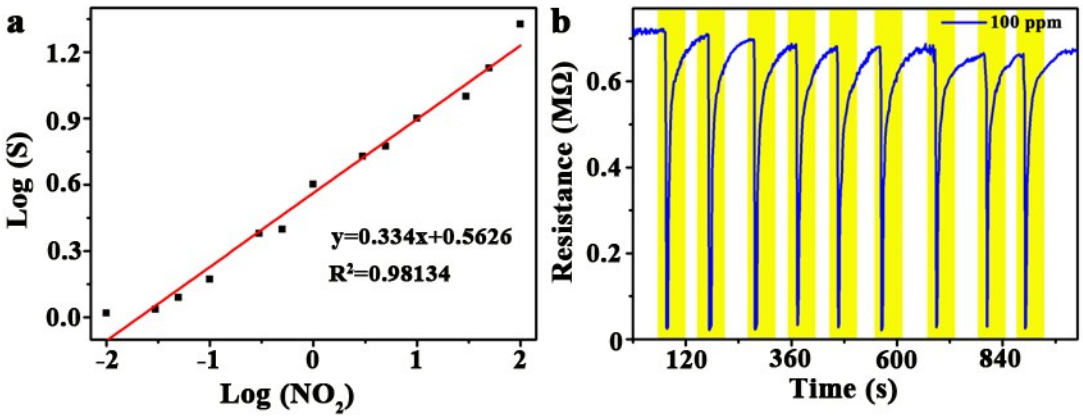

Fig. S9 (a) The calibration curve of SnS_2/aEG-III to 0.01-100 ppm NO_2, (b) The reproducibility of the SnS_2/aEG-III sensor upon successive exposure (9 cycles) to 100 ppm NO_2.

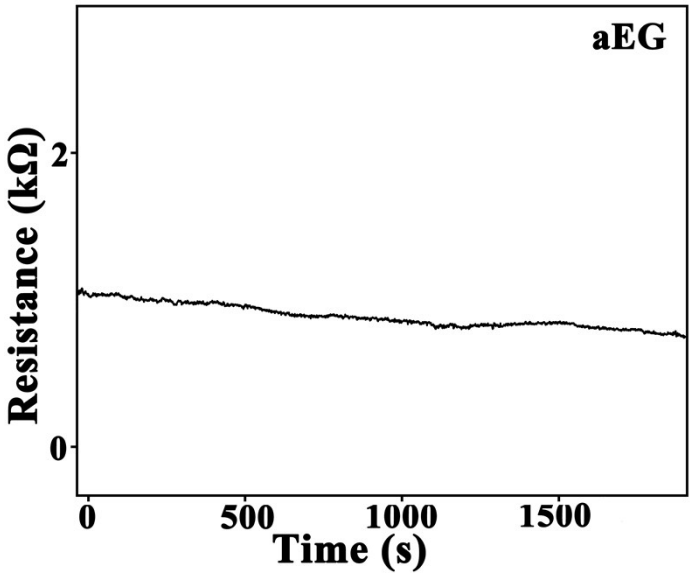

Fig. S10 Dynamical response transient of aEG to NO_2 gas at room temperature.

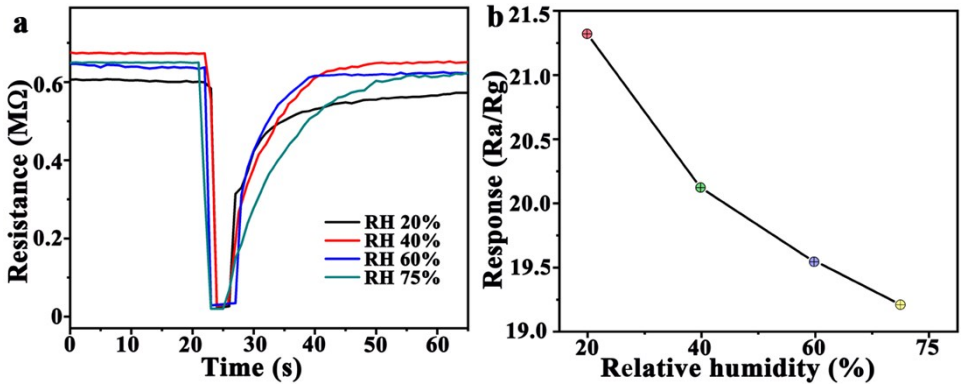

Fig. S11 (a) Response-recovery curves of the SnS_2/aEG-III to 100 ppm NO_2 gas in different relative humidity at RT (27 °C); (b) the gas sensor response corresponding to Figure (a).

Detail description: The first step is to install the modified gold interdigitated electrode in the gas chamber and connect it with the external environment. Then, the chamber was washed with fresh air to remove all impurities. Next, the humidifier system was used to achieve the required humidity (relative humidity (20% - 75%)). The humidity of the system is monitored by a hygrometer. Finally, NO_2 gas (100 ppm) was sent to the chamber. When the resistance is balanced, the oil pump was used to purge the fresh air until the sensor resistance reaches the initial state.

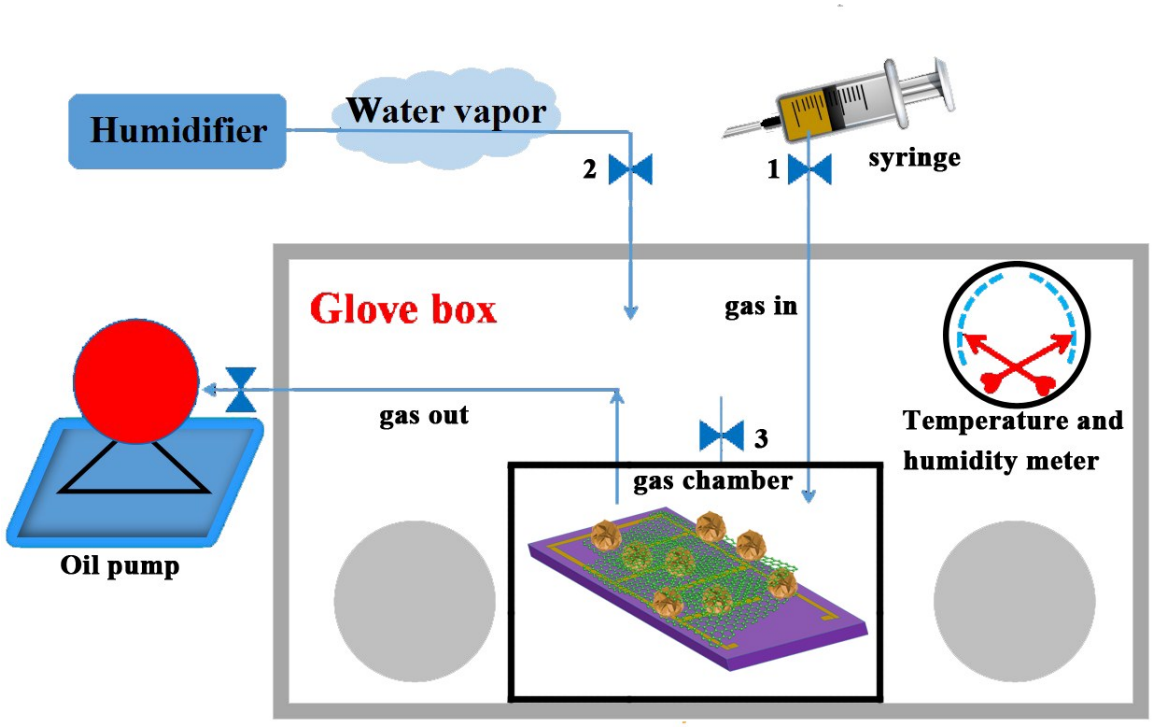

Fig. S12 A diagram of the delivery system for the gas sensing and humidity test.