

CORRECTION

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Correction: Bimetal-decorated resistive gas sensors: a review

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The authors sincerely regret that in the published article, in eqn (3) the “+” symbol was omitted on the left side, and a previous version of Fig. 5 was inadvertently used; in addition, the final two paragraphs from section 3, “Bimetal-decorated resistive gas sensors”, Tables 2 and 3, and the Author contributions section, were omitted from the final published article. These details correspond to the revised manuscript that was approved for publication during the peer review process.

The correct form of eqn (3) is as follows:



The correct version of Fig. 5 is as follows:

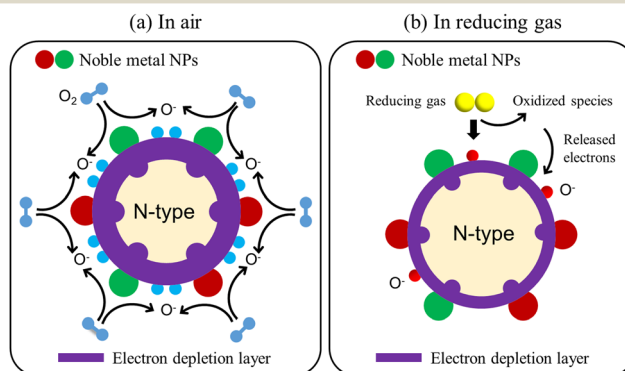


Fig. 5 (a) and (b) Catalytic effect of noble metals for enhanced gas response of resistive gas sensors.

The omitted paragraphs, and Tables 2 and 3, should appear immediately before the heading “Conclusions and outlook”, and should read as follows:

Table 2 summarizes the gas sensing performance of various bimetal-decorated resistive gas sensors. Overall, bimetal-decorated gas sensors have been successfully used for the detection of various gases such as H₂, NO₂, C₃H₆O, H₂S, CH₄, and CO gases. The optimal sensing temperature varies between RT to 400 °C depending on gas type, type of sensing material and type of bimetallic system. Response and recovery times also mainly depend on the sensing temperature; however, they are often short. Bimetal-decorated gas sensors generally have good long-term stability and show good stability at least up to 30 days after fabrication.

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Table 2 Summary of gas sensing performance of various bimetal-decorated resistive gas sensors

Sensing material	Gas and conc./ppm	T ($^{\circ}\text{C}$)	Response (R_a/R_g) or (R_g/R_a)	Response time (s)/ recovery time (s)	Long-term stability (days)	Detection limit	Ref.
AuPd/SnO ₂ nanoparticles	H ₂ 100 ppm	150	72.8	Not reported	30	Not reported	58
AuPd/SnO ₂ nanorods	H ₂ 100 ppm	175	46.4	19/302	35	Not reported	59
AuPd/ZnO NWs	NO ₂ 1 ppm	100	94.2	35/30	Not reported	Not reported	60
AuPd/In ₂ O ₃ porous spheres	C ₃ H ₉ N 100 ppm	175	367.0	2/300	Stable for 30 days	300 ppb	61
AuPd/WO ₃ hierarchical bundles	C ₄ H ₁₀ O 50 ppm	200	91.0	8/12	20	1 ppm	62
AuPd/WO ₃ nanorods	C ₃ H ₆ O 2 ppm	300	12.0	5/3	56	100 ppb	64
AuPd/SnO ₂ nanosheets	C ₃ H ₆ O 2 ppm	250	6.6	4/6 (to 20 ppm acetone)	40	45 ppb	65
	HCHO 2 ppm	110	4.1	Not reported	40	30 ppb	
AuPd/WO ₃ nanospheres	C ₄ H ₈ O ₂ 10 ppm	250	400.0	8/4	30	100 ppb	69
PdAu/W ₁₈ O ₄₉ nanowires	H ₂ S 50 ppm	100	55.5	10/9	56	Not reported	72
	CH ₄ 1000 ppm	320	7.8	25/15	56	Not reported	
PdRu/SnO ₂ nanoclusters	C ₃ H ₉ N 100 ppm	230	78.3	10/81	15	1 ppm	74
AuPt/ZnO nanorods	H ₂ 250 ppm	130	157.4	115/not reported (RT)	Not reported	Not reported	75
AuPt/ZnO nanowires	H ₂ S 20 ppm	300	17.7	17/151	30	Not reported	76
AuPt/ZnO nanoflowers	C ₇ H ₈ 50 ppm	175	69.7	22/137	30	500 ppb	77
AuPt/In ₂ O ₃ nanofibers	O ₃ 110 ppb	90	10.3	Not reported	30	20 ppb	78
	C ₃ H ₆ O 50 ppm	240	7.1	Not reported	30	500 ppb	
PtCu/WO ₃ /H ₂ O nanoplates	C ₃ H ₆ O 50 ppm	280	204.9	3/8	Not reported	10 ppb	79
PtNi ₃ /WO ₃ nanoplates	HCOOH 100 ppm	220	591.0	3/not reported	60	500 ppb	80
AuPt/Carbon nanofibers	H ₂ 4 vol%	RT	48%	7/18	210	Not reported	81
Ni-Pt/CNF	H ₂ 100 ppm	RT	13%	32/72	Not reported	10 ppb	82
PtPd-WO ₃ NFs	C ₃ H ₆ O 1 ppm	300	97.5	4.2/204	Not reported	1.07 ppb	83
PtRh-WO ₃ NFs	C ₃ H ₆ O 1 ppm	350	104.0	4/176	Not reported	0.3 ppb	
PtPd/In ₂ O ₃ nanoparticles	H ₂ 100 ppm	RT	29.8	58/200	30	Not reported	84
PdPt/ZnO nanorod clusters	H ₂ 1%	50	70%	5/76	Not reported	0.2 ppm	86
PdPt/SnO ₂ NWs	NO ₂ 0.1 ppm	300	880.0	13/9	Not reported	Not reported	89
PtPd/Ru-implanted	C ₃ H ₆ O 50 ppm	20	4.2	77/48	Not reported	1 ppb	92
WS ₂ nanosheets							
PdPt NOS-SnO ₂	H ₂ 1000 ppm	50	75680	1/8	30	10 ppm	93
PtPd/SnO ₂ multishell hollow microspheres	HCHO 1 ppm	190	867%	5/7	42	50 ppb	94
PtPd/SnO ₂ nanosheets	CO 1 ppm	100	6.5	5/4	60	Not reported	95
	CH ₄ 500 ppm	320	3.1	5/4	60	Not reported	
PtRu/Flower-like WO ₃	C ₈ H ₁₀ 100 ppm	170	261.0	2/329	14	1.97 ppm	97
Ag ₆ Au ₁ /In ₂ O ₃ nanoclusters	HCHO 5 ppm	170	277.0	147/186	15	26 ppb	98
AgPd/ZnO nanoplates	H ₂ 500 ppm	400	78.0	2/13	28	800 ppb	99
AuAg/MWCNTs/WO ₃	NO ₂ 1000 ppb	RT	1.995 ($\Delta R/R_a$) (%)	267/very slow recovery	95	45 ppb	100

Table 3 Summary of key properties of bimetallic systems used for enhancement of sensing performance of resistive gas sensors

Bimetallic system	Sensing material	Selectivity to gas	Long-term stability (days)	Ref.
AuPd	SnO ₂ nanoparticles	H ₂	30	58
	SnO ₂ nanorods	H ₂	35	59
	ZnO nanowires	NO ₂	Not reported	60
	In ₂ O ₃ porous spheres	C ₃ H ₉ N	30	61
	WO ₃ hierarchical bundles	C ₄ H ₁₀ O	20	62
	WO ₃ nanorods	C ₃ H ₆ O	35	64
	SnO ₂ nanosheets	C ₃ H ₆ O, HCHO	40	65
	WO ₃ nanospheres	C ₄ H ₈ O ₂	30	69
	W ₁₈ O ₄₉ nanowires	H ₂ S, CH ₄	56	72
PdRu	SnO ₂ nanoclusters	C ₃ H ₉ N	15	74
AuPt	ZnO nanorods	H ₂	Not reported	75
	ZnO nanowires	H ₂ S	30	76
	ZnO nanoflowers	C ₇ H ₈	30	77
	In ₂ O ₃ nanofibers	O ₃ , C ₃ H ₆ O	30	78
	Carbon nanofibers	H ₂	180	81
PtCu	WO ₃ /H ₂ O hollow sphere	C ₃ H ₆ O	Not reported	79
PtNi	WO ₃ nanoplates	HCOOH	60	80
	Carbon nanofibers	H ₂	Not reported	82
PtRh	WO ₃ NFs	C ₃ H ₆ O	Not reported	83
PtPd	WO ₃ NFs	C ₃ H ₆ O	Not reported	83
	In ₂ O ₃ nanoparticles	H ₂	30	84
	ZnO nanorod	H ₂	Not reported	86
	SnO ₂ NWs	NO ₂	Not reported	89
	Ru-implanted WS ₂ nanosheets	C ₃ H ₆ O	Not reported	92



Table 3 (continued)

Bimetallic system	Sensing material	Selectivity to gas	Long-term stability (days)	Ref.
PtRu AuAg	SnO ₂	H ₂	30	93
	SnO ₂ multishell hollow microspheres	HCHO	42	94
	SnO ₂ nanosheets	CO, CH ₄	60	95
	Flower-like WO ₃	C ₈ H ₁₀	2	97
	In ₂ O ₃ nanocluster	HCHO	15	98
AgPd	MWCNTs/WO ₃	NO ₂	95	100
	ZnO nanoplates	H ₂	4	99

Finally, detection limits down to ppb levels have been reported for bimetal-decorated gas sensors, showing their potential for the development of highly sensitive and reliable gas sensors.

Table 3 summarizes the selectivity and long-term stability of various bimetal-decorated gas sensors. The selectivity ratio of Au₆₅Pd₃₅ bimetallic decoration for the SnO₂ gas sensor is 7.18, which is seven times higher than that of the pristine SnO₂ sensor at 150 °C.⁵⁸ While the optimal sensing temperature of the pristine ZnO sensor was 150 °C with a selectivity ratio of 3.15, AuPd bimetallic decoration decreased the sensing temperature to 100 °C and simultaneously increased the selectivity ratio to 14.95.⁶⁰ For the pristine In₂O₃ sensor, which operated optimally at temperatures above 250 °C, AuPd bimetallic decoration reduced the sensing temperature to 175 °C, achieving a high selectivity ratio of 10.00.⁶¹ In addition, while the selectivity ratio of the pristine ZnO sensor was 1.00, PtAu bimetallic decoration increased the selectivity ratio to 14.70 at 130 °C.⁷⁵ Similarly, for the pristine ZnO sensor with an optimal sensing temperature of 200 °C, AuPt bimetallic decoration reduced the sensing temperature to 175 °C, resulting in a high selectivity ratio of 10.00.⁷⁷ Additionally, for a pristine WO₃ sensor with an optimal sensing temperature of 300 °C, PtNi₃ bimetallic decoration lowered the sensing temperature to 220 °C, achieving a selectivity ratio of 10.32.⁸⁰ In particular, for the NOS PdPt/SnO₂ sensor, the selectivity ratio was 1.87, while NOS Pd₂Pt/SnO₂ led to a dramatic increase in the selectivity ratio to 929.53 at 25 °C, achieved through an optimal Pd:Pt atomic loading ratio. These results underscore the effectiveness of bimetallic catalysts in improving both the selectivity and operating temperature of resistive gas sensors, highlighting their potential for high-performance applications.

The author contributions section should read as follows:

Author contributions

Ka Yoon Shin: conceptualization, writing – original draft; Yujin Kim: investigation, visualization; Ali Mirzaei: conceptualization, writing – original draft; Hyoun Woo Kim: supervision, validation; Sang Sub Kim: supervision, project administration, writing – review & editing.

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