

Supporting Information

High sensing properties of 3 wt% Pd doped $\text{SmFe}_{1-x}\text{Mg}_x\text{O}_3$ nanocrystalline powders to acetone vapor with ultralow concentrations under light illumination

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EXPERIMENTAL SECTION

Preparation of Pd:SmFe_{0.9}Mg_{0.1}O₃

Pd:SmFe_{0.9}Mg_{0.1}O₃ nanocrystalline powders were prepared by a sol-gel method. First, a stoichiometric ratio of samarium oxide, magnesium nitrate, ferric nitrate, polyethylene glycol (PEG, molecular weight 20,000) and nitric acid (all analytically pure) was weighed and mixed in deionized water. Then, HNO₃ was added to adjust the pH to 1.5~2. The mixture was heated in a water bath at 80°C for two days with continuous stirring to obtain a highly viscous sol that became a gel in the next few hours. The gel was dried in a baking box at 100°C for 24 h to obtain a dry powder, which was ground into fine powders. The powders were annealed in an oven at 750°C for 6 h after preheating at 400°C for 2 h. After a period of grinding, we obtained SmFe_{1-x}Mg_xO₃. Then, the obtained powders were mixed with an appropriate amount of PdCl₂ and ground for half an hour. The obtained mixture was annealed in an oven at 750°C before obtaining SmFe_{1-x}Mg_xO₃ doped with 3 wt% Pd.

Fabrication of the sensor

Pd:SmFe_{1-x}Mg_xO₃ was blended with an appropriate amount of deionized water to form a paste. The sensors were fabricated by coating the paste onto a ceramic tube with an approximately 2 mm external diameter, 8 mm length and 1.6 mm internal diameter with two electrodes. Figure S1a (Supporting Information) shows the structure schematic of sensor. It can be seen that a pair of gold electrodes connected with Pt wire were installed at each end of the ceramic tube, between the two gold electrodes was the area which used for coating nanoparticles. A Ni-Cr heating wire used as a heat supply source was inserted into the ceramic tube to control the operation temperature of the gas sensor. To improve the stability and repeatability, the ready-made sensors were annealed at 240°C for 24 h on aging equipment in air.

Gas-Sensing Test

The schematic diagram of entire arrangement of the experiment is shown in Figure S1b (Supporting Information). A characterization system WS-30A (Wei Sheng Electronic technology Co., Ltd., Zhengzhou, China) was used to measure the gas-sensing performance of the sensors. The characterization system (WS-30A) we used has been Upgraded and modified according to our experimental needs. Adding the irradiation function, filter function, etc. The static test-gas chamber was a 20 L covered glass container, and the temperature of the sensor was controlled by a computer. For the measuring concentration of acetone vapor, a calculated amount of liquid acetone using the ideal gas equation, which was calculated by the following formula

$$C = 8.314 \times \frac{\varphi \times T}{PMV} \times V_L \times 10^6$$

Where φ the required liquid quality score; T the environment temperature; P (pa) the atmospheric pressure; M (g/mol) the molar mass; V (L) the volume of the chamber; V_L (uL) the volume of the liquid. During the entire measurement process, two fans were always turned on to volatile the acetone in the test-gas chamber.⁵⁸ Cold LED lights with a power consumption of 50 mW were the light source. The distance from the LED to the sensor was approximately 15 cm. Light filters (10 cm length, 10 cm width and 0.3 cm thick) for different wavelengths were used for the LEDs and sensors to filter the light. The light from the LED was passed through a filter to obtain light with a special wavelength to irradiate the sensor.

Characterization

The structure of the resultant powders was characterized by the X-ray diffraction patterns (XRD, Bruker D8 ADVANCE, Germany) using $\text{CuK}\alpha$ radiation to determine the phase composition at room temperature. The Pd element distribution in the material was analyzed by energy-dispersive X-ray spectroscopy (EDAX, Horiba EX250, Japan) and X-ray photoelectron

spectroscopy (XPS, Thermo Fisher Scientific Thermo escalab 250XI, USA). The microstructure of 3 wt% Pd-doped $\text{SmFe}_{1-x}\text{Mg}_x\text{O}_3$ was observed by field emission scanning electron microscopy (FE-SEM, Hitachi SU8020, Japan). The gas-sensing response, S , was defined as R_g/R_a , where R_a is the resistance of the sensor in air, and R_g is the resistance in the tested gas. The response time was defined as the time taken to reach 90% of the maximum response, and the recovery time was defined as the time taken to reach 10% of the maximum response. Both are important parameters for a practical sensor. The resistance of the sensor was measured in air. In this work, the gas-sensing properties were measured in the temperature range of $80^\circ\text{C} - 340^\circ\text{C}$.

Figure legends

Figure S1. Schematic structure of the gas sensor (a); Schematic diagram of entire arrangement of the experiment (b).

Figure S2. The XRD patterns of $\text{Pd:SmFe}_{1-x}\text{Mg}_x\text{O}_3$ ($x=0, 0.1, 0.2, 0.3$) annealed at $750\text{ }^\circ\text{C}$.

Figure S3. The EDS (a) and EDAX (b) mapping result on Pd element for $\text{Pd:SmFe}_{0.9}\text{Mg}_{0.1}\text{O}_3$ annealed at $750\text{ }^\circ\text{C}$. The red dots represent Pd element.

Figure S4. XPS spectra of $\text{Pd:SmFe}_{1-x}\text{Mg}_x\text{O}_3$.

Figure S5. SEM micrographs of $\text{Pd:SmFe}_{1-x}\text{Mg}_x\text{O}_3$ annealed at $750\text{ }^\circ\text{C}$. (a) $x=0$; (b) $x=0.1$; (c) $x=0.2$; (d) $x=0.3$.

Figure S6. SEM micrographs of $\text{Pd:SmFe}_{0.9}\text{Mg}_{0.1}\text{O}_3$ annealed at $750\text{ }^\circ\text{C}$ with different magnification: (a) -200nm ; (b) -500nm ; (c) $-1\mu\text{m}$; (d) $-10\mu\text{m}$.

Figure S7. The UV–visible diffuse reflectance spectra (a) and the energy band gap (b) of the as-prepared $\text{Pd:SmFe}_{0.9}\text{Mg}_{0.1}\text{O}_3$ samples.

Table legends

Table S1. The gas sensing properties of acetone gas for several sensors. The T_o ($^\circ\text{C}$) means the optimal operating temperature of the sensor and the C (ppm) means the concentration of acetone gas, and the S means the response of sensor to acetone gas.

Figure S1.

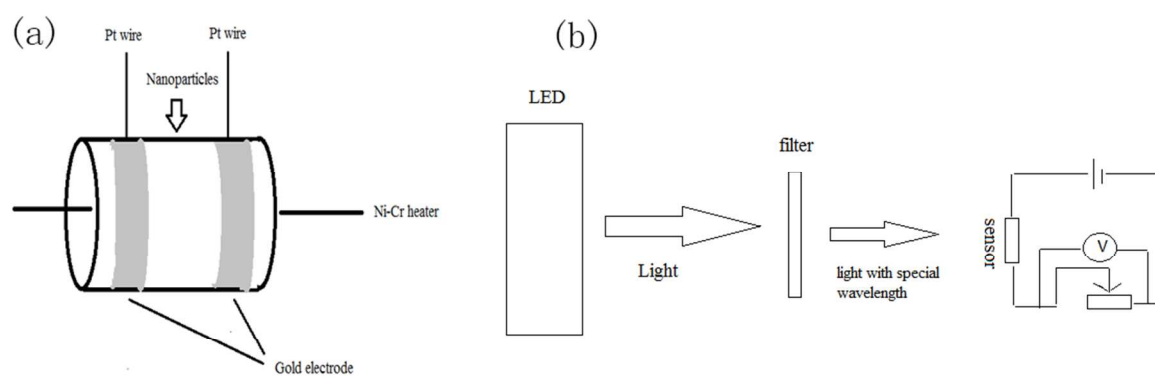


Figure S2.

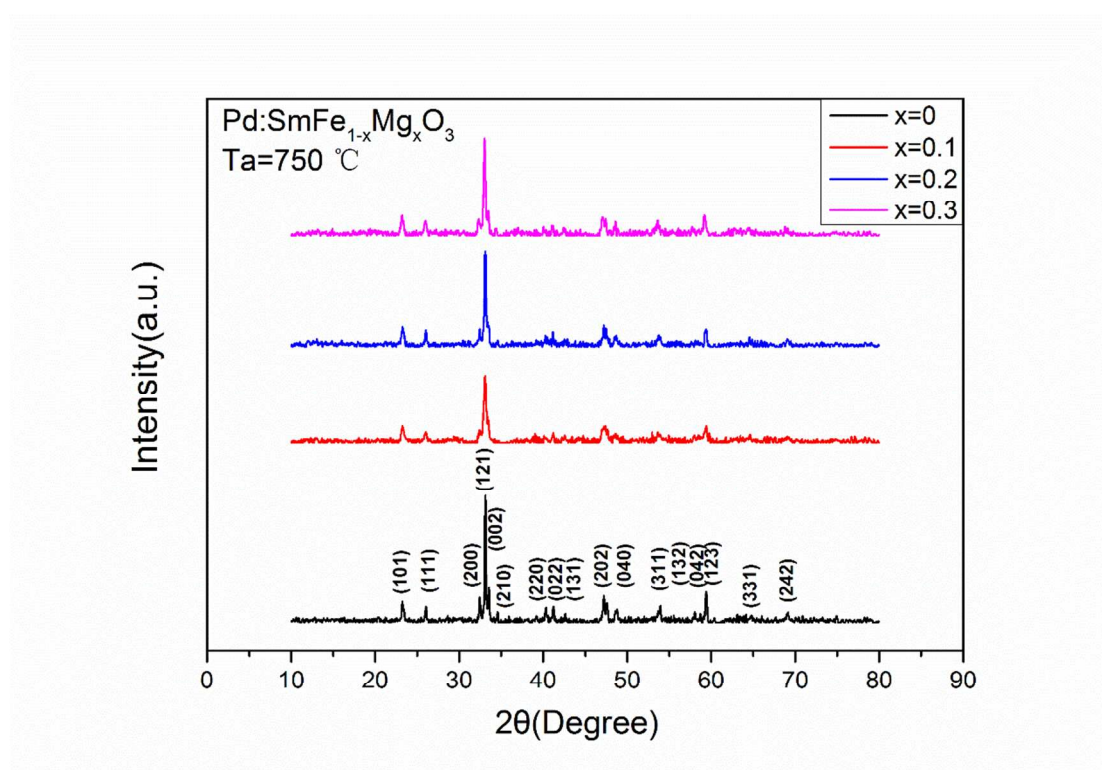


Figure S3.

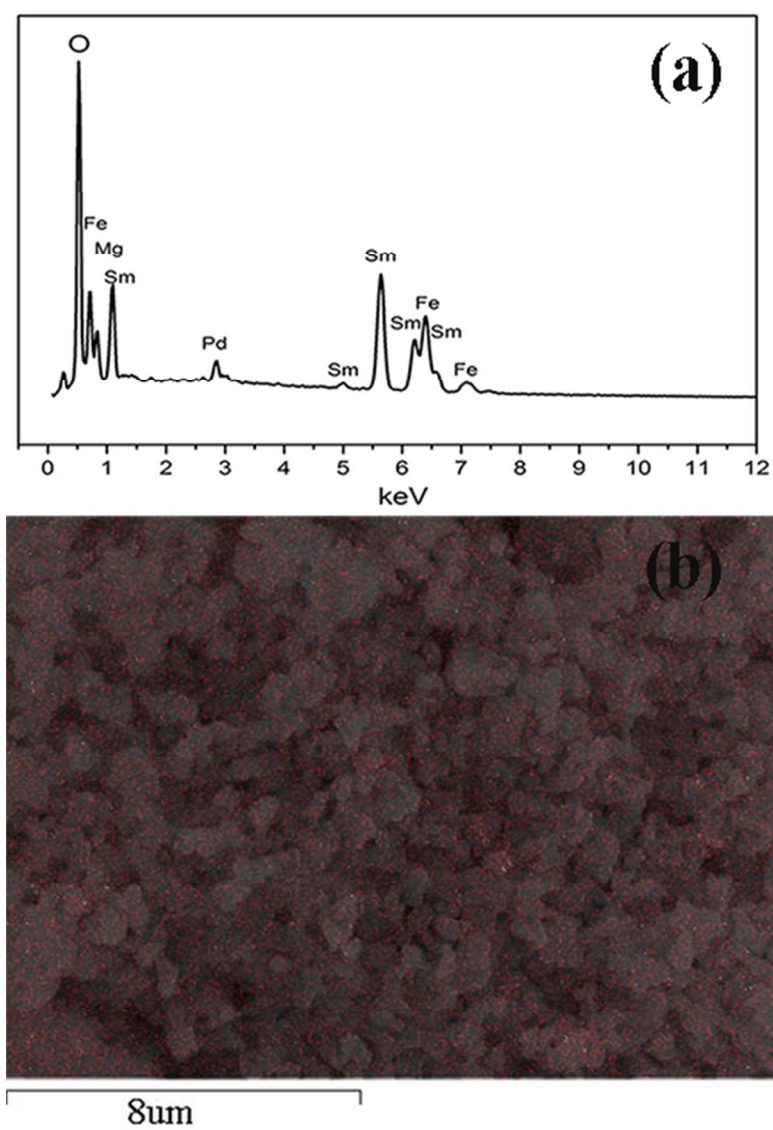


Figure S4.

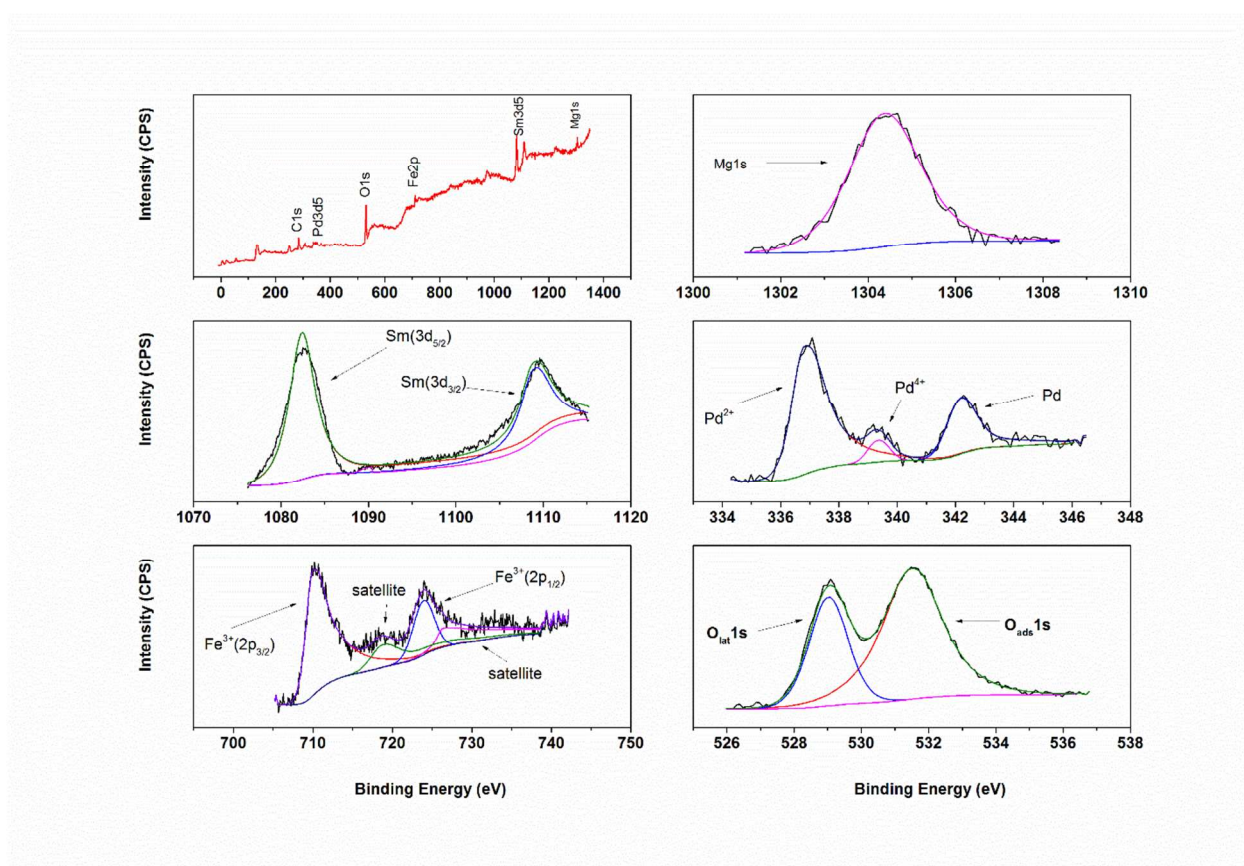


Figure S5.

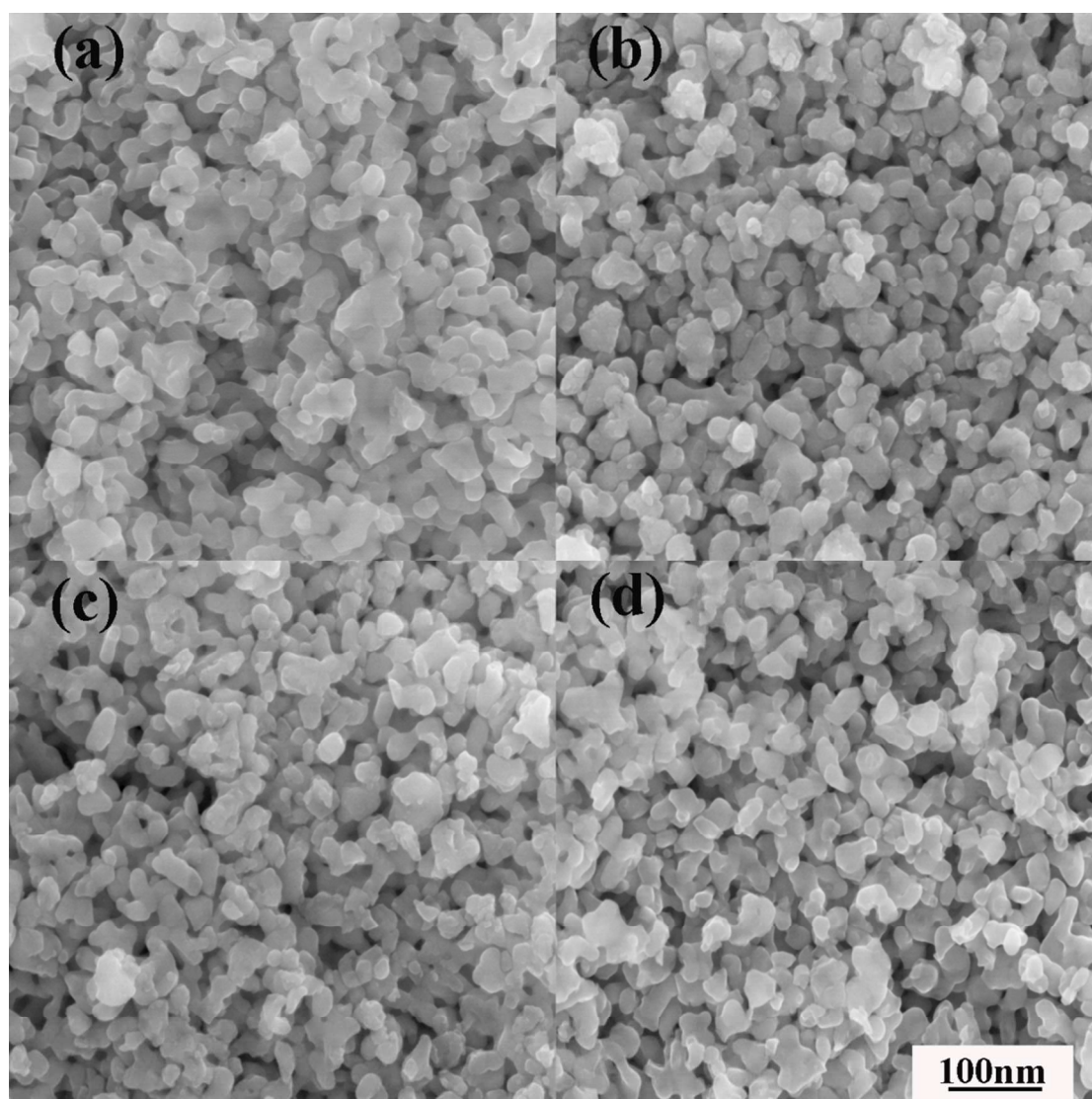


Figure S6.

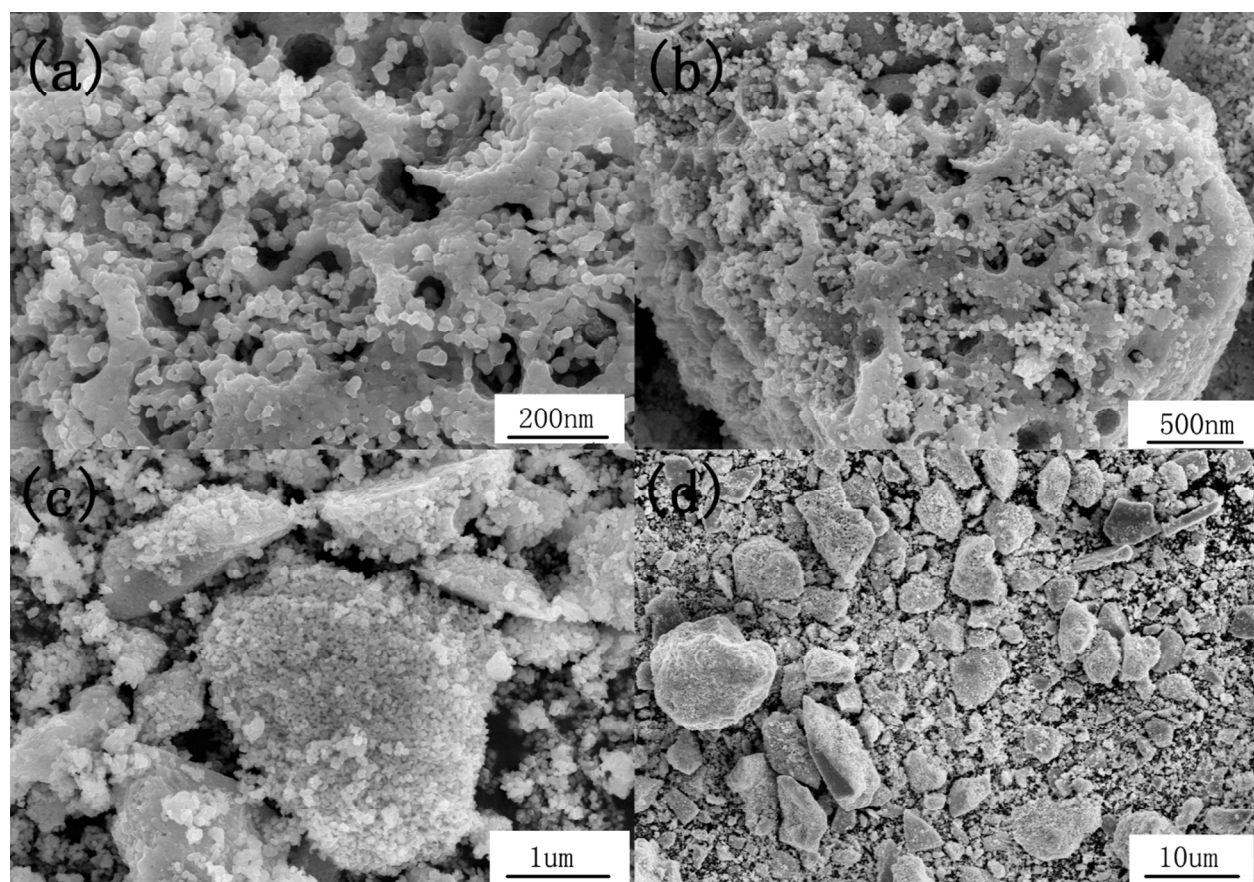


Figure S7.

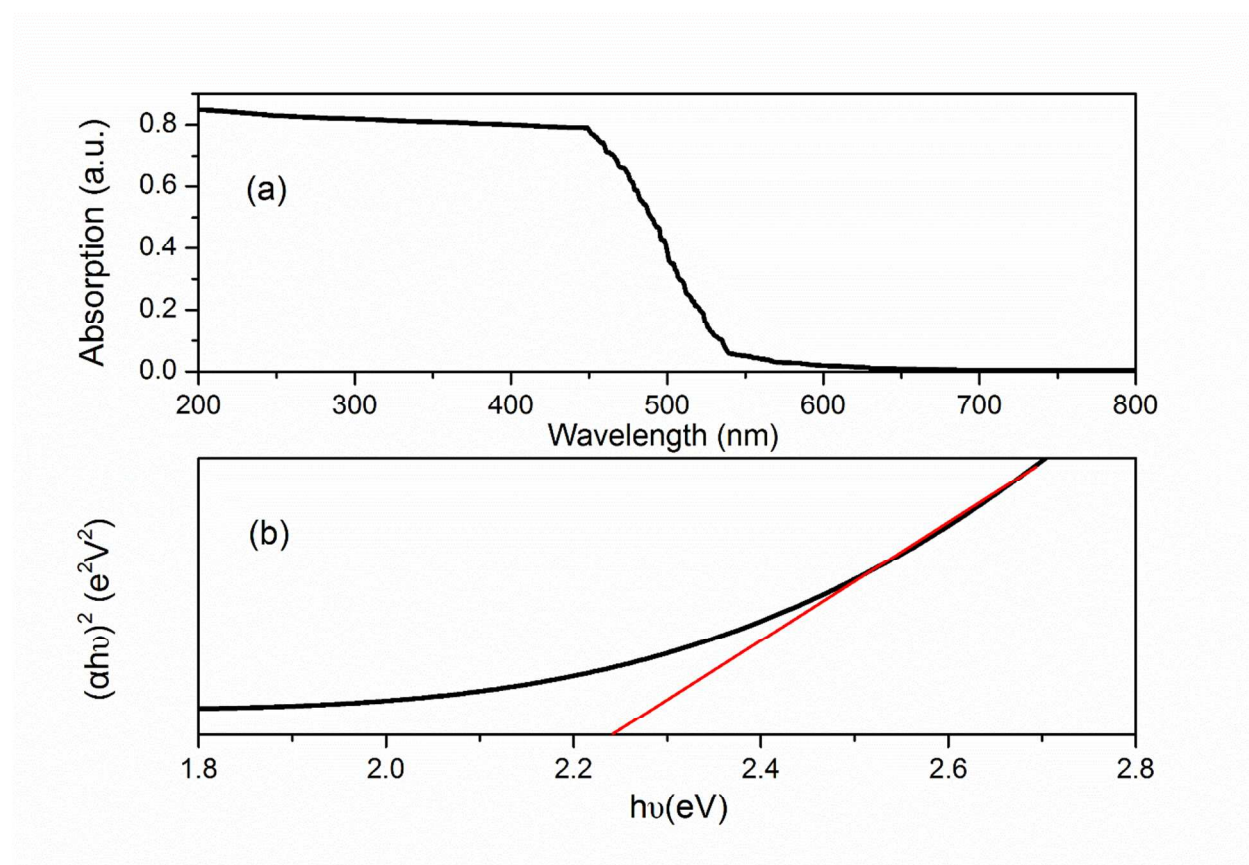


Table S1.

Author	Materials	T ₀	C	S	Ref
C. Su et al.	Sm-doped α -Fe ₂ O ₃	240	0.5	2.3	[4]
H. Shan et al.	La-doped α -Fe ₂ O ₃	240	50	26	[5]
S. Wei et al.	ZnO	220	1	7.1	[6]
D. An et al.	ZnO	220	100	6.0	[7]
N. H. Al-Hardan et	Cr-doped ZnO	400	500	90	[8]
C. Peng et al.	ZnO	300	100	18.6	[9]
R.C. Pawar et al.	ZnO	325	2000	84	[10]
A.V. Rajgure et al.	ZnO	350	2000	92	[11]
S. Kim et al.	WO ₃ with both Pd and Au	300	200	152.	[12]
D. Chen et al.	WO ₃	300	2	2	[13]
L. Wang et al.	Au-doped NiO	240	20	7.6	[14]
C. Wang et al.	W-doped NiO	250	100	198.	[15]
Z. Zhang et al.	Co ₃ O ₄	150	10	1.7	[16]
R.K. Mishra et al.	SnO ₂	250	10	42	[17]
W.X. Jin et al.	SnO ₂	260	25	40	[18]
M. Punginsang et	Co-doped SnO ₂	250	20	36.9	[19]
S. Singkammo et	Ni-Doped SnO ₂	350	200	54.2	[20]
S. B. Patil et al.	Co-doped SnO ₂	270	60	32	[21]
M. Epifani et al.	TiO ₂	400	100	1.2	[22]
H. Bian et al.	TiO ₂	500	10	9	[23]
B. Bhowmik et al.	TiO ₂	27	10	1.13	[24]
Z. L. Wu et al.	NdFeO ₃	120	50	300	[25]
X. Liu et al.	SmFe _{0.9} Mg _{0.1} O ₃	260	300	353	[26]
P. Zhang et al.	Ca-doped YbFeO ₃	230	0.1	1.72	[27]
M. Yang et al	LaNi _{0.5} Ti _{0.5} O ₃	350	5	29.	[28]
T. Chen et al.	SmFeO ₃	250	380	2.6	[29]
X. Liu et al.	LaFeO ₃	400	80	204	[30]
P. Song et al	LaFeO ₃	240	200	12.2	[31]
L. Zhang et al.	La _{0.68} Pb _{0.32} FeO ₃	200	50	7	[32]
K. Fan et al	La _{0.75} Ba _{0.25} FeO ₃	240	50	17	[33]
	Pd:SmFe _{0.9} Mg _{0.1} O ₃	220	0.01	1.52	Present work
	Pd:SmFe _{0.9} Mg _{0.1} O ₃	220	0.02	1.66	Present work
	Pd:SmFe _{0.9} Mg _{0.1} O ₃	220	0.05	1.97	Present work
	Pd:SmFe _{0.9} Mg _{0.1} O ₃	220	0.1	2.23	Present work
	Pd:SmFe _{0.9} Mg _{0.1} O ₃	220	0.2	3.37	Present work
	Pd:SmFe _{0.9} Mg _{0.1} O ₃	220	0.5	7.16	Present work
	Pd:SmFe _{0.9} Mg _{0.1} O ₃	220	1	11.9	Present work
	Pd:SmFe _{0.9} Mg _{0.1} O ₃ under 365nm	140	0.5	9.42	Present work
	Pd:SmFe _{0.9} Mg _{0.1} O ₃ under 365nm	140	1	14.1	Present work
	Pd:SmFe _{0.9} Mg _{0.1} O ₃ under 410nm	160	0.5	9.08	Present work
	Pd:SmFe _{0.9} Mg _{0.1} O ₃ under 410nm	160	1	13.2	Present work
	Pd:SmFe _{0.9} Mg _{0.1} O ₃ under 450nm	180	0.5	8.52	Present work
	Pd:SmFe _{0.9} Mg _{0.1} O ₃ under 450nm	180	1	12.4	Present work