Supporting Information

Synergistic Improvement of Sensing Performance in Ferroelectric-Based Gas Sensors Using Remnant Polarization

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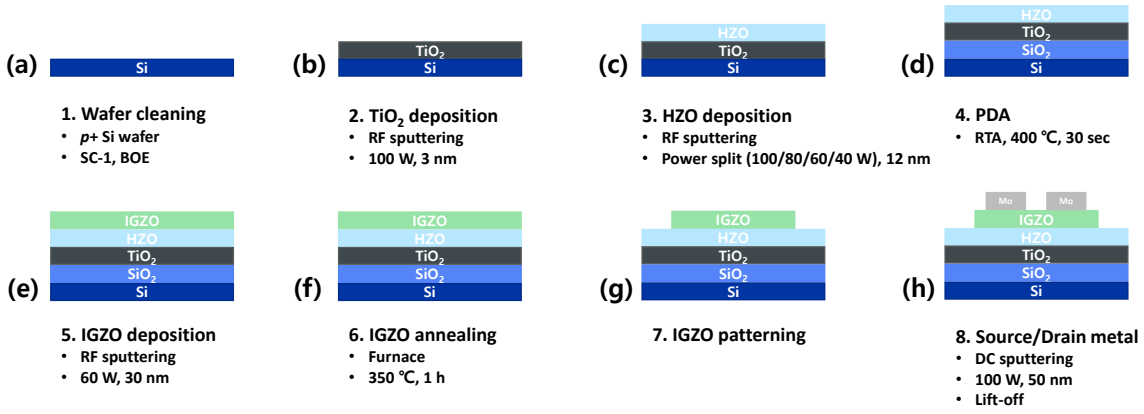

Figure S1. Fabrication process flow of the IGOZ FeTFT gas sensors. (a) Wafer cleaning. (b) TiO_2 deposition. (c) HZO depostion. (d) Post-deposition annealing (PDA). (e) IGZO deposition. (f) IGZO annealing. (g) IGZO patterning. (h) Source/drain metal formation.

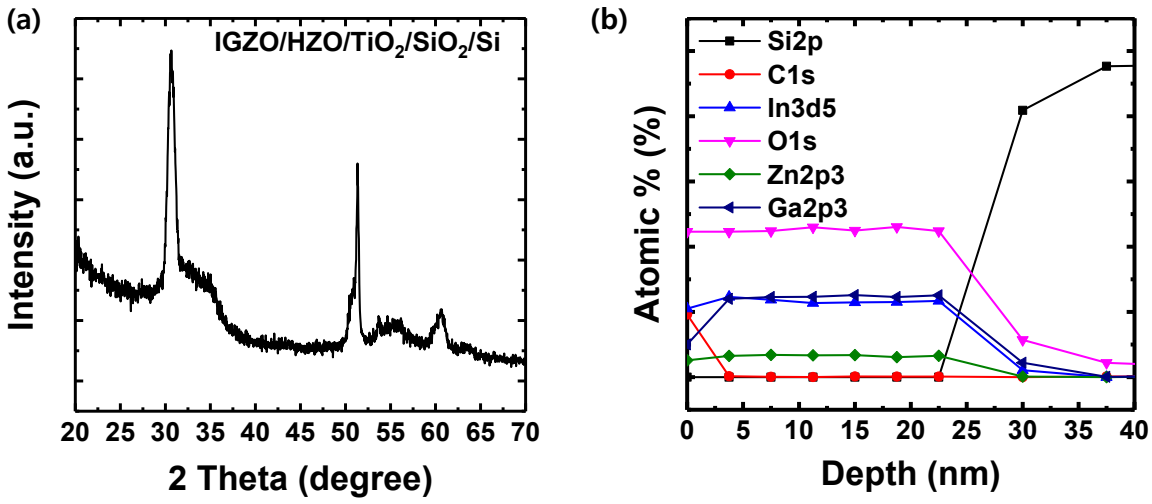

Figure S2. (a) X-ray diffractograms and (b) EDS line scan of the IGZO film.

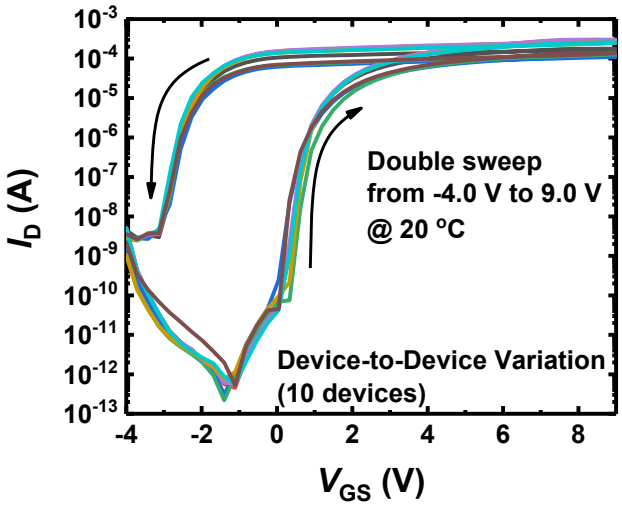

Figure S3. Devic-to-device variation of the fabricated FeTFT gas sensors. Transfer characteristics (I_D-V_{BG}) are measured at 10 independent samples of the FeTFT gas sensors. The V_{GS} is double-swept from -4.0 V to 9.0 V with a drain voltage of 1.0 V.

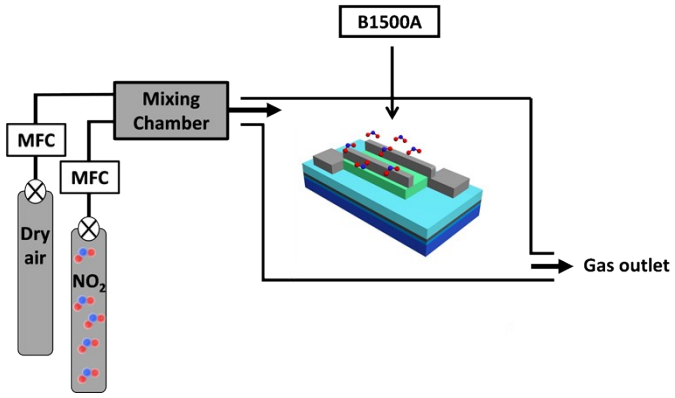

Figure S4. Schematic diagrams of gas sensing measurement system. Gas sensing characteristics of the sensors are analyzed by using a semiconductor parameter analyzer (B1500A) and the probe station that contains a test chamber, chuck, gas inlet, and outlet. NO_2 gas is used as a target gas and gas flow is controlled by a mass flow controller (MFC). The operating temperature of the sensing material in the sensor is set to 150 °C by an external heater. The target gas is mixed with dry air with a relative humidity of 4% for controlling the gas concentration and then the gas is injected into the test chamber.

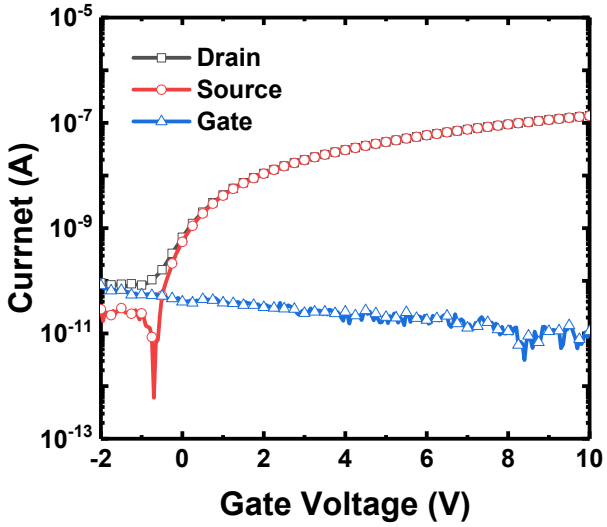

Figure S5. Drain, source, and gate currents versus V_{BG} of the reference TFT gas sensor measured at 20 °C.

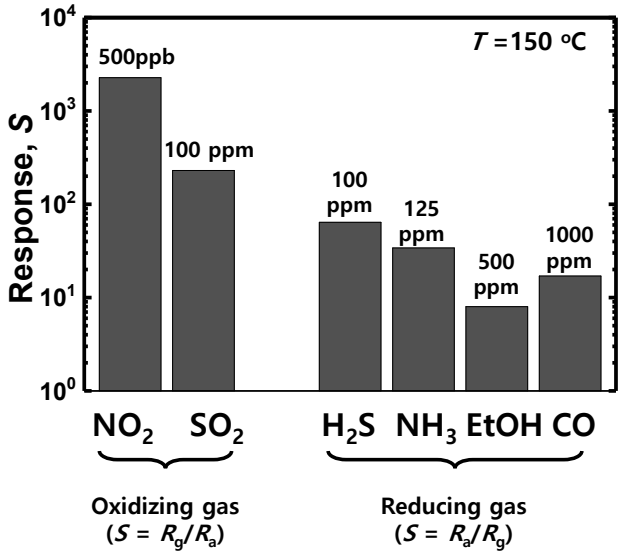

Figure S6. Response of the FeTFT gas sensor to NO_2, SO_2, H_2S, NH_3, EtOH, and CO gases (NO_2 500 ppb, H_2S 100 ppm, H_2S 100 ppm, NH_3 125 ppm, EtOH 500 ppm, and CO 1000 ppm).

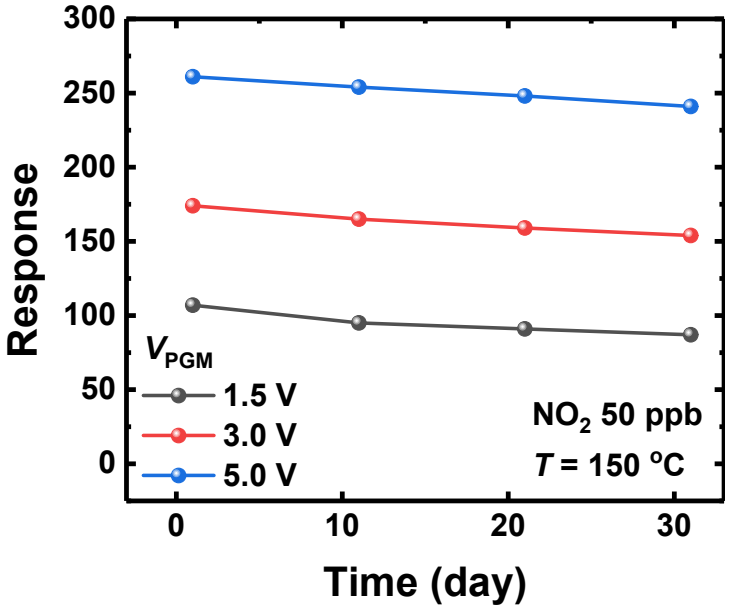

Figure S7. Response of the FeTFT gas sensor to 50 ppb of NO_2 gas over time as a parameter of V_{PGM}. The response is measured under different V_{PGM}s at 150 °C for 30 days. The sensor shows a slight decrease in the response after 30 days. Further research is required to determine the exact mechanism of such degradation.

Table S1. Comparison of this work with previous NO_2 gas sensors.

Sensing material	Sensor platform	Response to NO_2 500 ppb	Operating temperature	Tunability	Ref.
Au-loaded Tellurium	Resistor-type	5.2	180 °C	N/A	[1]
In_2O_3-ZnO	Resistor-type	33	RT (UV irradiation)	N/A	[2]
MoS_2	Resistor-type	5.2	RT	N/A	[3]
MoS_2	Resistor-type	31	RT (Illumination)	N/A	[4]
WO_3	Resistor-type	4.3	150 °C	N/A	[5]
In_2O_3	FET-type	8.2	172 °C	N/A	[6]
WS_2-IGZO	TFT-type	10.2	150 °C	N/A	[7]
IGZO	FET-type	2.14	150 °C	N/A	[8]
IGZO	TFT-type	2272	150 °C	Y (Polarization)	This work (FeTFT)

References

[1] Z. Yuan, Q. Zhao, C. Xie, J. Liang, X. Duan, Z. Duan, H. Tai, *Sens. Actuators B: Chem.* **2022**, 355, 131300.

[2] Y. Liu, J. Zhang, G. Li, J. Liu, Q. Liang, H. Wang, H. Lu, *Sens. Actuators B: Chem.* **2022**, 355, 131322.

[3] Q. He, Z. Zeng, Z. Yin, H. Li, S. Wu, X. Huang, H. Zhang, *Small* **2021**, 8, 2994.

[4] T. Pham, G. Li, E. Bekyarova, M. E. Itkis, A. Mulchandani, *ACS Nano* 2**019**, 13, 3196.

[5] C. Patel, B. Mandal, R. G. Jadhav, T. Ghosh, M. Dubey, A. K. Das, S. Mukherjee, *ACS Appl. Nano Mater.* **2022**.

[6] G. Jung, Y. Hong, S. Hong, D. Jang, Y. Jeong, W. Shin, J. H. Lee, *Sens. Actuators B: Chem*. **2021**, 334, 129642.

[7] H. Tang, Y. Li, R. Sokolovskij, L. Sacco, H. Zheng, H. Ye, G. Zhang, *ACS Appl. Mater. Interfaces*, **2019**, 11, 40850.

[8] W. Shin, G. Jung, S. Hong, Y. Jeong, J. Park, D. Kim, J. H. Lee, *Sensors and Actuators B: Chemical*, **2022**, 357, 131398.