Supplementary Materials: A Single Nanobelt Transistor for Gas Identification: Using a Gas-Dielectric Strategy

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1. Strategies and models for the reported MOS based E-noses.
2. SEM images of SnO2 nanowires/nanobelts.
3. Schematic diagrams of the device fabrication process.
4. Multiple measurement results of gas-dielectric devices.
6. Response to three analytes (NO2, NO and H2S) in solid-dielectric device.
### 1. Table S1. Strategies and models for the reported metal oxide semiconductor (MOS) based E-noses.

<table>
<thead>
<tr>
<th>Material</th>
<th>Type</th>
<th>Operating Temperature (°C)</th>
<th>Surface Modification</th>
<th>Target Species</th>
<th>Data Evaluation Modeling</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SnO₂ nanowire array</td>
<td>Resistor</td>
<td>240–285</td>
<td>Pristine Ag Pd</td>
<td>H₂, CO, C₂H₄</td>
<td>LDA a</td>
<td>[1]</td>
</tr>
<tr>
<td>SnO₂ nanowire</td>
<td>Resistor</td>
<td>350</td>
<td>–</td>
<td>H₂, CO</td>
<td>Radial plots of the response signals</td>
<td>[3]</td>
</tr>
<tr>
<td>SnO₂ nanowire array with changed density</td>
<td>Resistor</td>
<td>247–327</td>
<td>–</td>
<td>2–Propanol (0.5–50 ppm), Ethanol (0.5–50 ppm), CO (0.5–10 ppm)</td>
<td>LDA</td>
<td>[4]</td>
</tr>
<tr>
<td>CNT-SnO₂ film</td>
<td>Resistor</td>
<td>250–300</td>
<td>–</td>
<td>Ethanol (100–1000 ppm), Methanol (100–1000 ppm)</td>
<td>–</td>
<td>[6]</td>
</tr>
<tr>
<td>In₂O₃ nanowire</td>
<td>Resistor</td>
<td>25</td>
<td>–</td>
<td>H₂ (500–2000 ppm), Ethanol (50–200 ppm), NO₂ (0.1–1 ppm)</td>
<td>PCA c</td>
<td>[7]</td>
</tr>
<tr>
<td>In₂O₃: Mg nanowire</td>
<td>FET</td>
<td>RT</td>
<td>Pristine Au Ag Pt</td>
<td>CO (0.5–100 ppm), Ethanol (100 ppm), H₂ (100 ppm)</td>
<td>–</td>
<td>[8]</td>
</tr>
<tr>
<td>Single SnO₂ nanowire</td>
<td>FET</td>
<td>RT</td>
<td>–</td>
<td>NO (10–100 ppb), NO (50–300 ppb), H₂S (50–300 ppb)</td>
<td>LDA</td>
<td>Our work</td>
</tr>
</tbody>
</table>

* LDA: Linear Discriminant Analysis; b MEK: Methylethylketone; c PCA: Principal Component Analysis.
2. SEM Images of SnO$_2$ Nanowires/Nanobelts

Single-crystal nanowires/nanobelts of SnO$_2$ were synthesized by vapor transport as previously reported [9]. The nanowires/nanobelts have the regular shape and the smooth surface with diameters of 100–800 nm and lengths of tens of micrometers.

3. Fabrication Process of SnO$_2$ Nanobelt FET with Gas Dielectric

The device fabrication process is shown in Figure S2. (a) The patterned Ti/Au gate electrodes were deposited on the insulated glass substrate by ultraviolet lithography. The polymethyl methacrylate (PMMA) layer was spin-coated onto the substrate as dielectric. The thickness of the PMMA layer is 500 nm; (b) Electron Beam Lithography was used to remove part of the PMMA and to create a groove with the width ranged from a few micrometers to tens of micrometers; (c) A single-crystal nanobelt of SnO$_2$ was suspended on the groove of the PMMA layer by nanomechanical manipulation; (d) The gold films were placed by a “stamping gold layer” technique [10], which serves as the mask for source-drain electrode deposition; (e) The Ni/Au (40 nm/40 nm) electrodes were deposited by thermal evaporation; (f) The adhered gold films were removed by mechanical probe.
4. Multiple Measurement Results of Gas-Dielectric Devices

The comparative results in Figure S3 show that both SnO$_2$ and CuPc nanowire FETs with gas dielectric present the excellently reproducible electrical characteristics. For the same semiconductor material, both low and high-mobility devices present the good repeatable electrical characteristics.

![Figure S3](image)

Figure S3. The multimeasured transfer curves of the gas-dielectric nanowire FETs with different mobilities and semiconductor materials: (a) SnO$_2$ with mobility at 91.4 cm$^2$V$^{-1}$s$^{-1}$; (b) SnO$_2$ with mobility at 163.7 cm$^2$V$^{-1}$s$^{-1}$; (c) CuPc with mobility at 0.007 cm$^2$V$^{-1}$s$^{-1}$; (d) CuPc with mobility at 0.22 cm$^2$V$^{-1}$s$^{-1}$.

As shown in Figures S4, the electrical characteristic of the SnO$_2$ nanobelt FET with gas dielectric was measured in dry air, and then in N$_2$. The measurements in N$_2$ were carried out after the N$_2$ stream was introduced into the chamber for 1 h and 3 h, respectively. These measured results show that the device performance is highly repeatable both in dry air and N$_2$.

![Figure S4](image)

Figure S4. Transfer curves of the gas-dielectric SnO$_2$ nanobelt based FET tested in dry air and N$_2$.
5. Testing Process for Gas Sensing

Figure S5 shows a schematic representation of the experimental setup for gas detection. The device was placed into the stainless testing chamber and its leading wires were connected to a Keithley 4200-SCS station, for electrical characterization. The testing gas was introduced to the chamber through the stainless pipes. Prior to the testing, pure dry N₂ was introduced into the chamber for 2 h, so as to purge the testing chamber of undesired residual gases. The electrical characteristics of the FET nanosensor were first measured in the N₂ for 2 h to confirm the stability of devices. Subsequently, the testing gas was introduced to the chamber and diluted by N₂. The stream of N₂ and the testing gas was introduced under the controlled flow rate, by Mass Flow Controllers (MFC CS200A). The total gas flow rate was kept at 500 sccm. At the end of the testing cycle, the testing gas was collected by an alkaline solution.

![Figure S5. Schematic images of the experimental setup used for gas sensing.](image)

6. Response to Three Analytes (NO₂, NO and H₂S) in a Solid-Dielectric Device

(a) Schematic image of a solid-dielectric nanobelt device; (b) Transfer curves of the solid-dielectric device to various concentrations of H₂S. The well overlapped curves show that the solid-dielectric device does not respond to H₂S; (c, d) Parameter percentage variation at different NO₂ and NO concentrations in solid-dielectric device. All electrical measurements were carried out at room temperature.

![Figure S6.](image)
References


