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Electronic Supplementary Information

A Mechanical Actuated SnO_2 Nanowire for Small Molecules Sensing

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Experimental

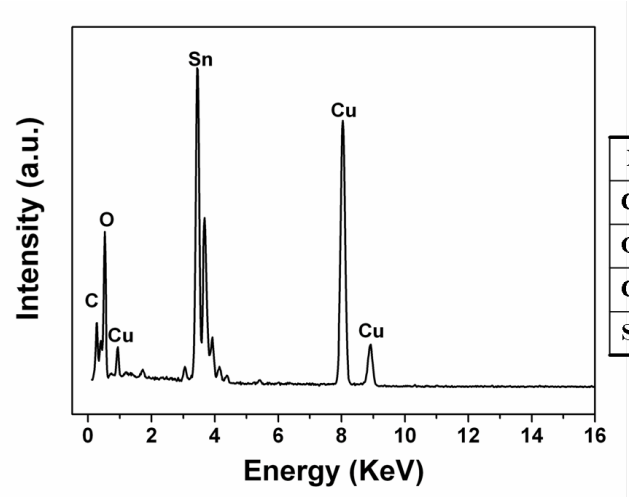
Preparation of the SnO_2 nanowires: SnO_2 nanowires were grown by the vapor–liquid–solid (VLS) process consists of a horizontal quartz reaction chamber, silicon substrate, a DC controller, a gas supply and control system, and a rotary pump system. The source material, high-purity (99.99%) powders of Sn, was first loaded in an alumina boat. Growth substrate of Si (100) was covered with a 10-nm-thick Au film, and then was placed on 2/3 height of the boat. The alumina boat was positioned at the center of a quartz reaction chamber that was inserted into a horizontal tube furnace. The furnace was heated from room temperature to 850 °C at a rate of 20 °C min^{-1} under a flow of N_2 (160 sccm) with a trace amount of oxygen. The growth time was 1 h at 850 °C. The furnace was then cooled to room temperature at a rate of 5 °C min^{-1}.

Structure and optical analysis of SnO_2 nanowires: After nanowire growth, morphological investigations were performed by field-emission SEM (JSM 7401F). For further structural studies, the nanowires were removed from the Si growth substrate by sonication in isopropyl alcohol and then deposited on carbon-coated copper grids for TEM (JEM-1200EX) characterization. The Renishaw RM2000 microscopic confocal Raman spectrometer (Gloucestershire, United Kingdom) was used for Raman measurements with 514.5 nm excitation wavelengths at 25% energy and a laser spot size of 2.0 μm.

The calculation of the SnO2 nanowire: The resonance frequency of the fork with the SnO_2 FW is about 1700 Hz higher (Figure S2a, b). This increase in the resonance frequency is related to Young's modulus of the SnO_2 FW, which is given by

$$E = \frac{4\pi^2 \left(f^2 - f_0^2\right) m_{eff} l}{A} \qquad (1)$$

where l and A are the length and cross-sectional area of the SnO_2 FW, respectively, f and f_0 are the resonance frequencies of the tuning fork with a SnO_2 FW and with the FW severed, respectively, m_{eff} is the effective mass for the oscillation beam of the tuning fork.[20] The Young's moduli of a single SnO_2 a nanowire was calculated as 178.2 *GPa*. This demonstrates a simple method of determining the mechanical properties of a semiconductor nanowire.



Element	Weight (%)	Atomic (%)
C (K)	5.93	21.71
O (K)	13.14	36.11
Cu (K)	38.02	26.31
Sn (K)	41.14	15.24

Figure S1. EDS analysis taken from the body of SnO_2 nanowire. C and Cu signals in the spectra come from copper TEM grid coated with carbon film.

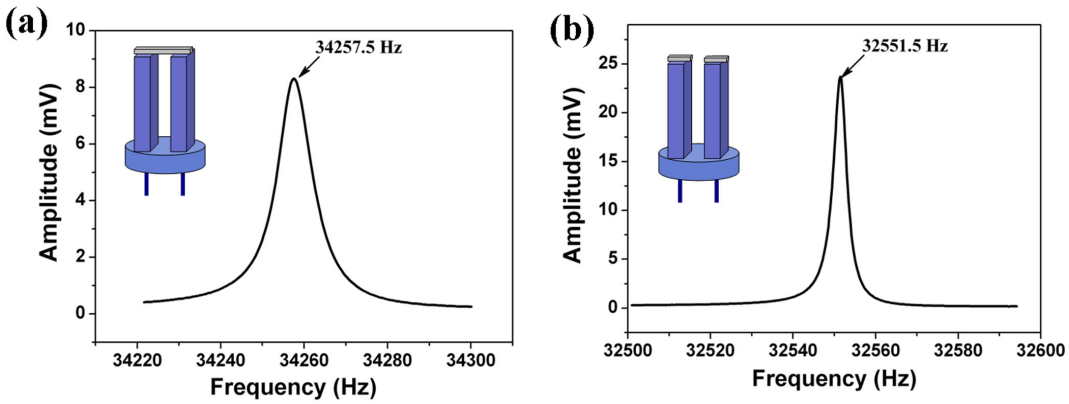


Figure S2. Frequency dependence of the oscillation amplitude of a microfabricated tuning fork with a single SnO_2 nanowire (a), and of the same device after cutting the SnO_2 wire (b). The corresponding resonance frequencies are f and f_0 respectively.

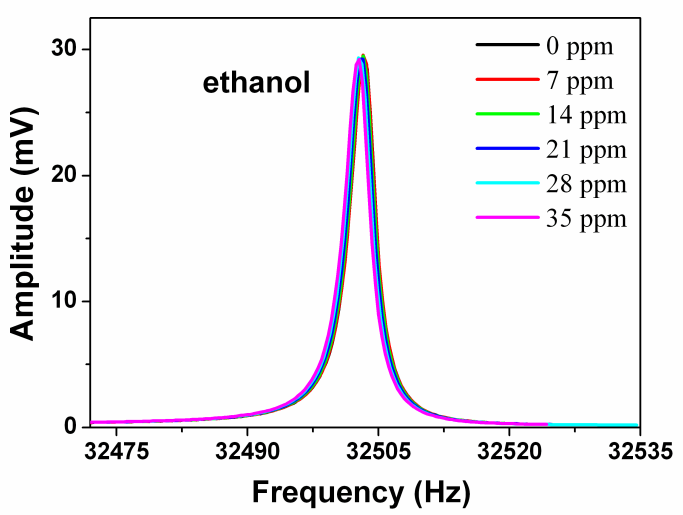


Figure S3. The resonance response of the sensor device with a broken SnO_2 wire upon exposure to ethanol vapors in different concentrations.

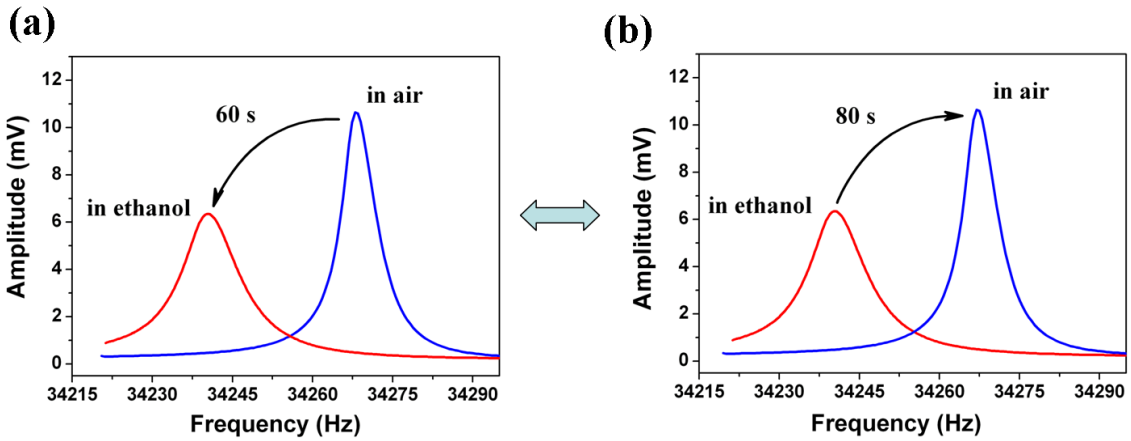


Figure S4. The shifts in resonance responses of the SnO_2 FW-based sensor between air and the 35 ppm ethanol vapor at 25 °C, showing the response time (a) and recovery time (b), respectively.

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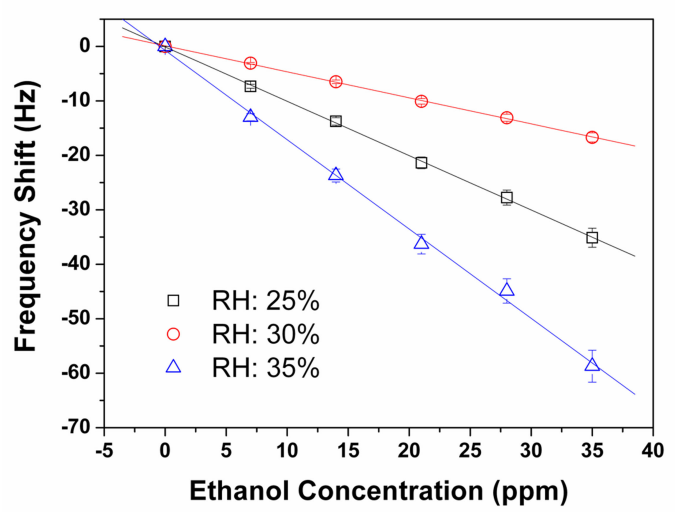

Figure S5. Resonance frequency shift as a function of ethanol concentration at 25, 30, and 35% RH on SnO_2 nanowire device.

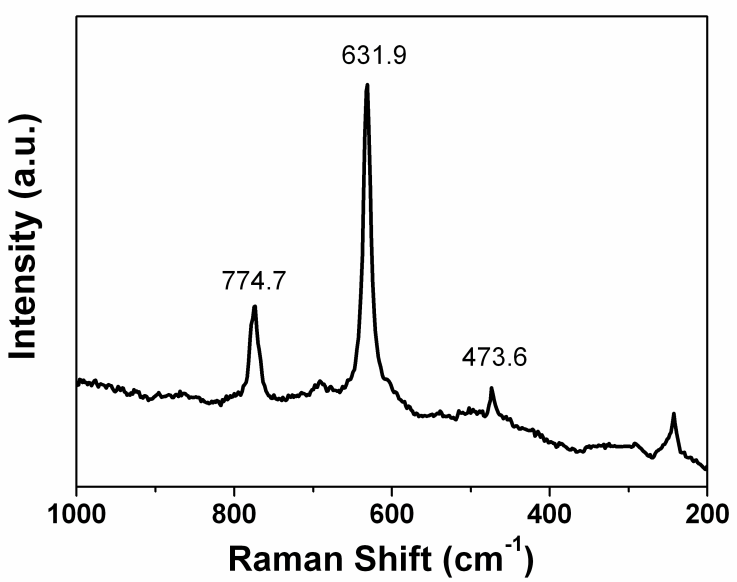

Figure S6. Raman spectrum of the SnO_2 nanowires.

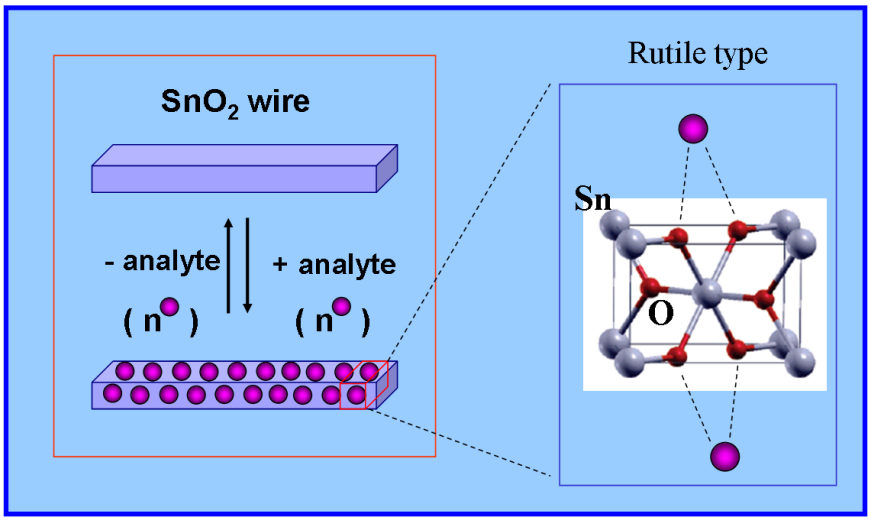

Figure S7. The mechanism of the gas adsorption on the SnO_2 wire.

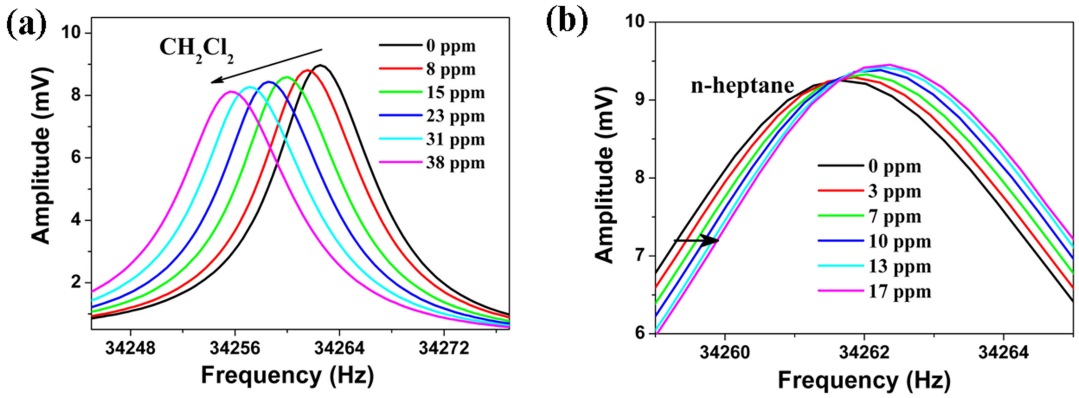

Figure S8. Oscillation amplitude vs. frequency plots showing different resonance peaks of the MTF with a SnO_2 wire between air and different vapor concentrations of ethanol, CH_2Cl_2 (a), and heptane (b).

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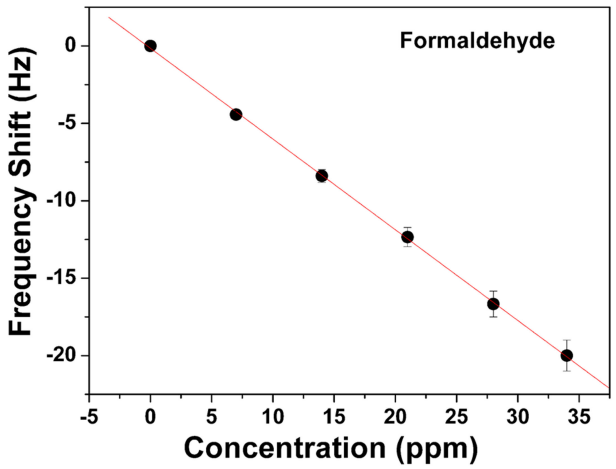

Figure S9. The resonance frequency shift of the SnO_2 nanowire QTF was made as a function of formaldehyde concentration.

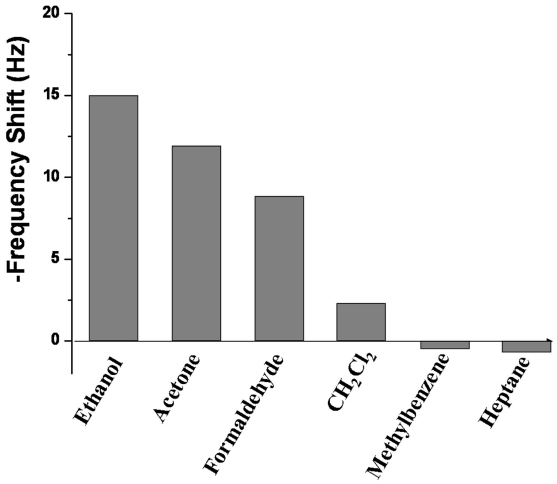

Figure S10. The frequency shift of the same SnO_2 nanowire device exposed to several different organic vapors at 15 ppm.