Supporting Information

Fully Inkjet-printed Mesoporous SnO_2 Based Ultra-sensitive Gas Sensors for Trace Amount NO_2 Detection

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A. Schematic diagram of the home-built gas sensing set up

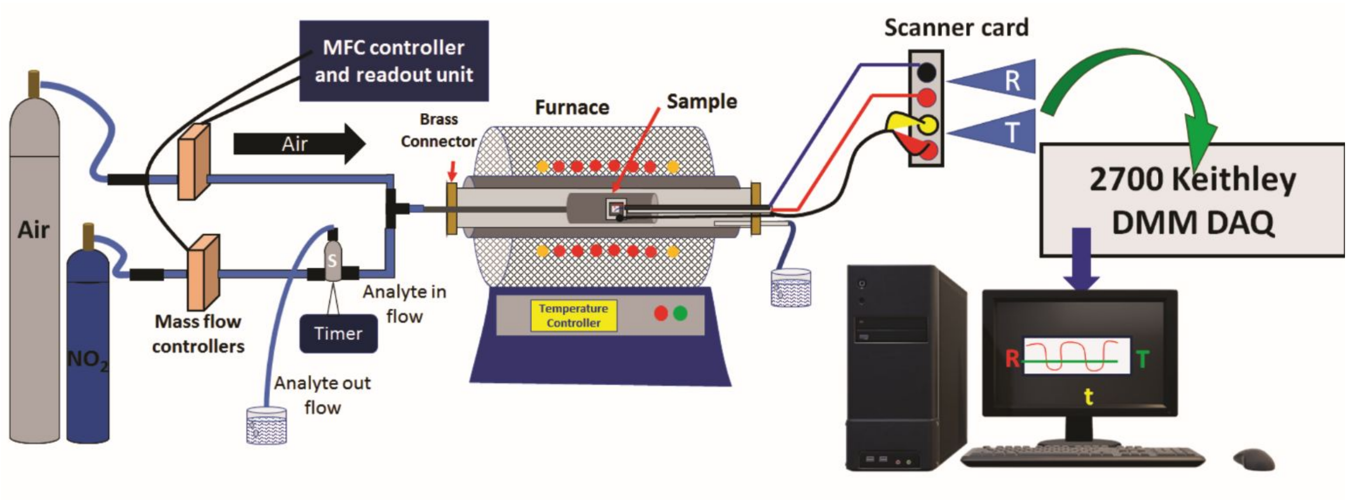

Figure S1. A schematic diagram of the assembled gas sensing set up used in the present study.[S1]

B. Characterization of the inkjet printable mesoporous SnO_2 precursor ink

The as-prepared co-continuous mesoporous SnO_2 ink has been characterized for its suitability in inkjet printing. A dimensionless parameter, Ohnesorge number (Oh) can be defined as:

$$Oh = \frac{\eta}{\sqrt{\rho \sigma l}}$$

where η, ρ, σ and l are the dynamic viscosity, fluid density, surface tension and the characteristic length scale (droplet diameter) respectively.

Here, the measured parameters turn out be 4.46 mPa.s (Figure S2), 875 kgm^{-3}, 21 mNm^{-1} (Video S1), and 15 µm, respectively.

This results in the value of the Ohnesorge number to be 0.2686. An inverse of Ohnesorge number Z (Oh^{-1}) is considered as the measure of suitability of an ink for inkjet printing and should be within a range of 1- 10 to ensure ease of printing.

In the present case, the inverse Ohnesorge number

$Z = Oh^{-1} = \frac{\sqrt{\rho \sigma l}}{\eta}$ can be calculated as 3.72, which fits well within the preferred window prescribed for inkjet printing.

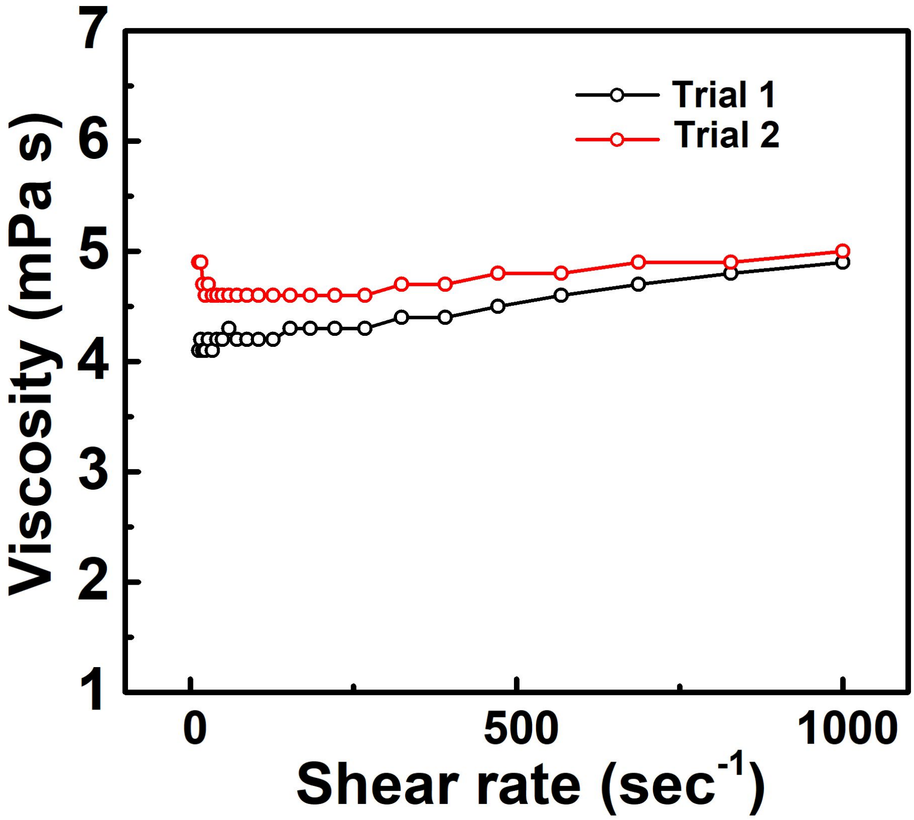

Figure S2: Viscosity measurement of the mesoporous SnO_2 ink.

C. **Cross-section SEM micrographs of printed mesoporous SnO_2 films demonstrating correlation between the film thickness and the number of printing passes**

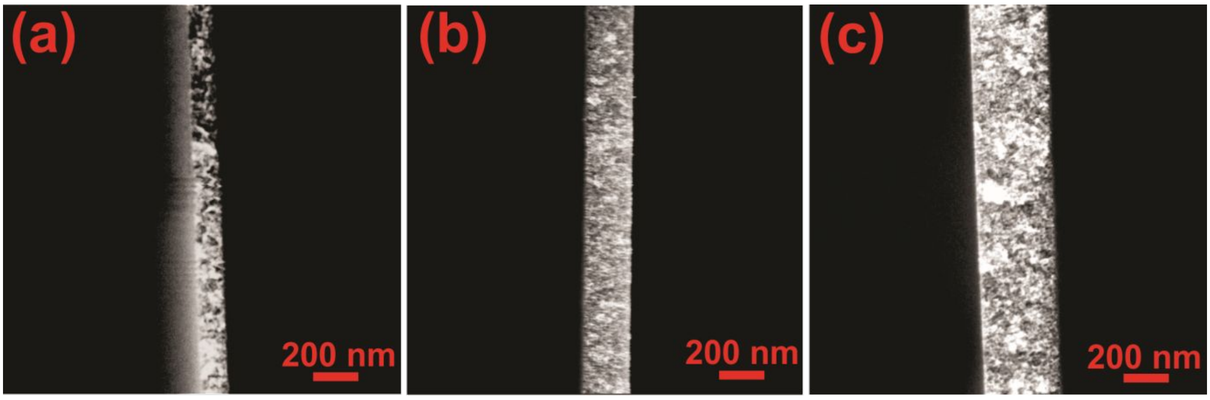

Figure S3: (a-c) Cross-section SEM micrographs of printed and annealed 1-, 2- and 3-layer mesoporous SnO_2 films, respectively. An increasing printing passes has found to increase the film thickness, with the thickness value ranging from 101 nm, 204 nm and 322 nm for 1-, 2- and 3-layer mesoporous SnO_2 films, respectively.

D. Scanning electron micrograph of the flat and solid SnO_2 thin film printed without the polymer templating agent.

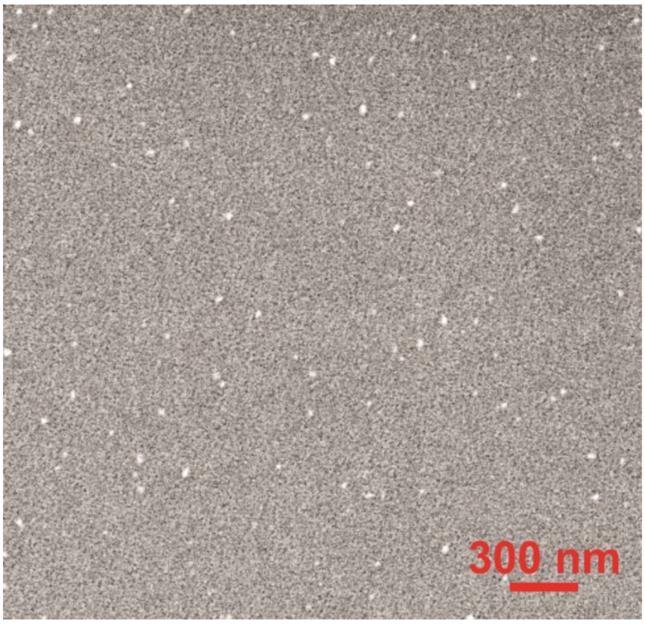

Figure S4. Scanning electron micrograph of non-porous, flat and solid SnO_2 thin film.

E. Comparison of response at 5 ppm NO_2 concentration for the printed 1-layer SnO_2 sensor as a function of measurement temperature

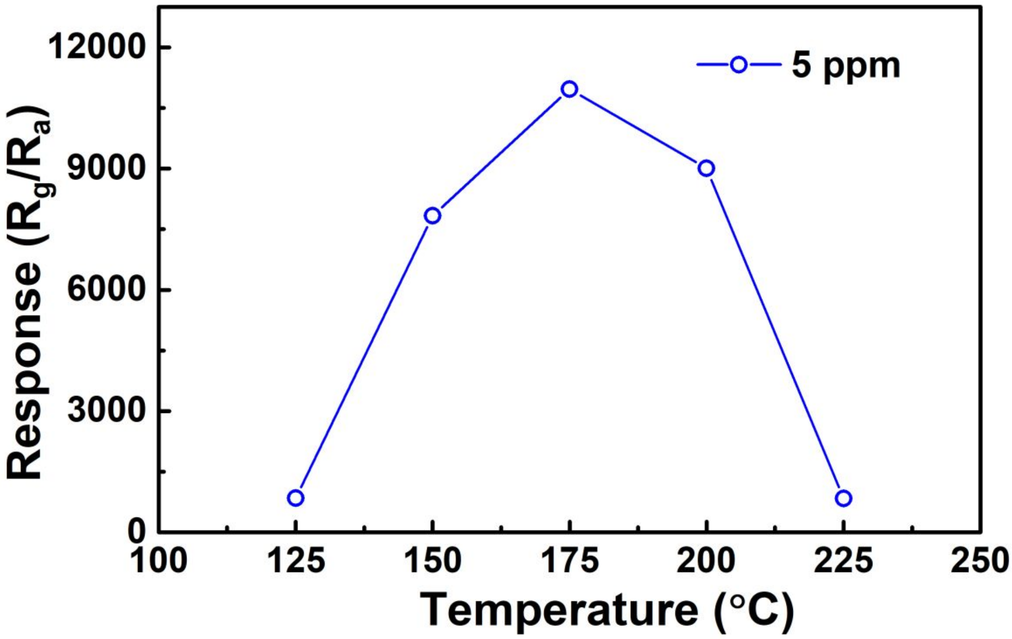

Figure S5. Sensor response at 5 ppm NO_2 concentration for 1-layer printed mesoporous SnO_2 sensor, measured at different temperatures.

F. Sensor performance of printed flat and solid SnO_2 thin film based gas sensor with respect to NO_2 gas concentration

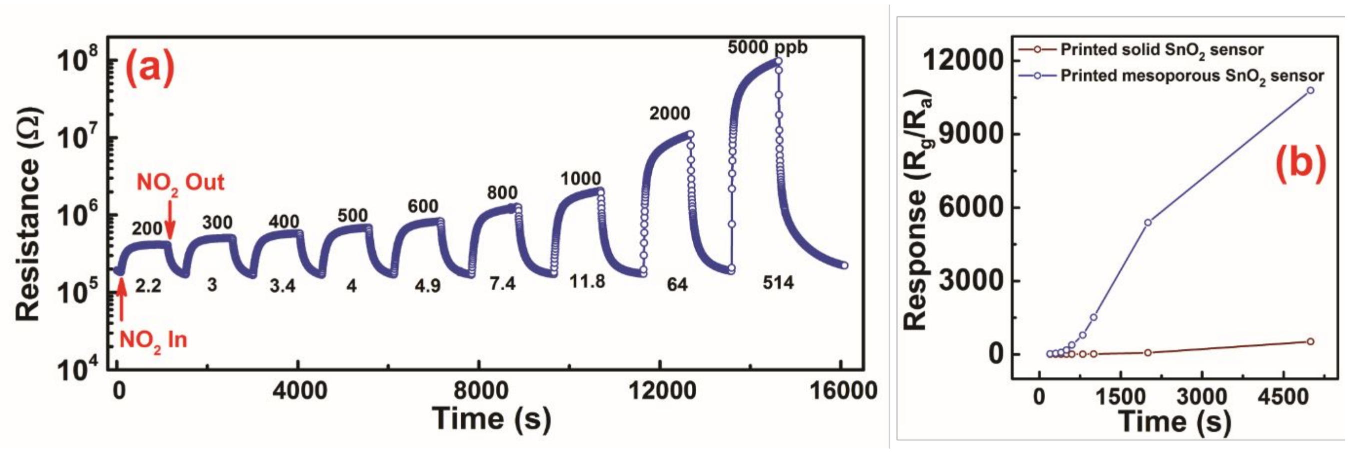

Figure S6: (a) Printed solid and flat SnO_2 thin film based sensor performance as a function of NO_2 concentration. (b) Comparison plot of mesoporous and non-porous (solid) tin oxide sensor performance at different concentration of NO_2.

G. Printed 2-layer SnO_2 sensor characteristics with respect to temperature and NO_2 gas concentration

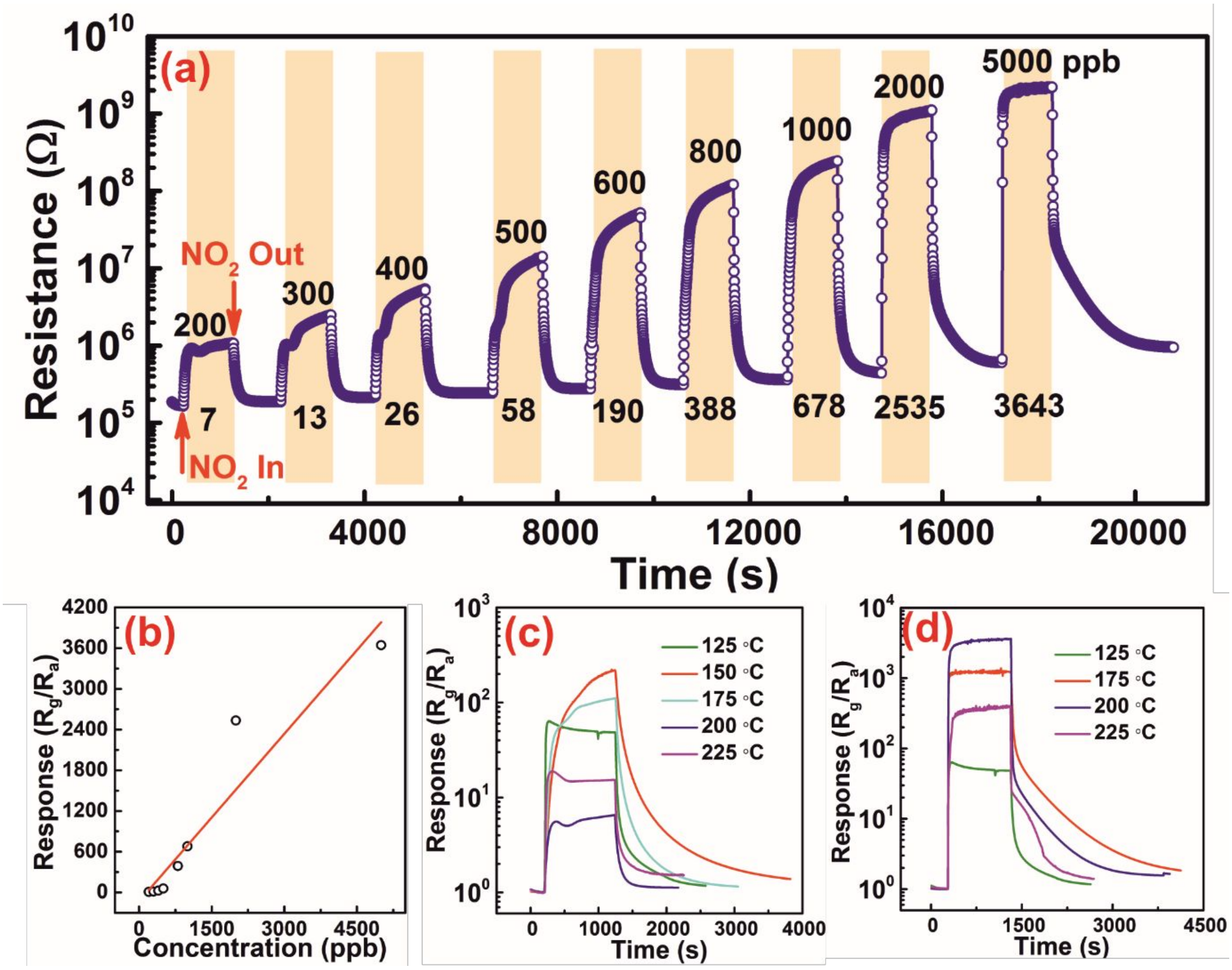

Figure S7. (a) Response curves of the 2-layer printed and annealed mesoporous SnO_2 based sensor measured with respect to varying analyte gas concentration. (b) Response-concentration relationship curve for the 2-layer printed sample showing a linear correlation. (c-d) Comparison of response curves for NO_2 concentration between 200 ppb to 5000 ppb measured at different temperatures.

H. Printed 3-layer SnO_2 sensor characteristics with respect to temperature and NO_2 gas concentration

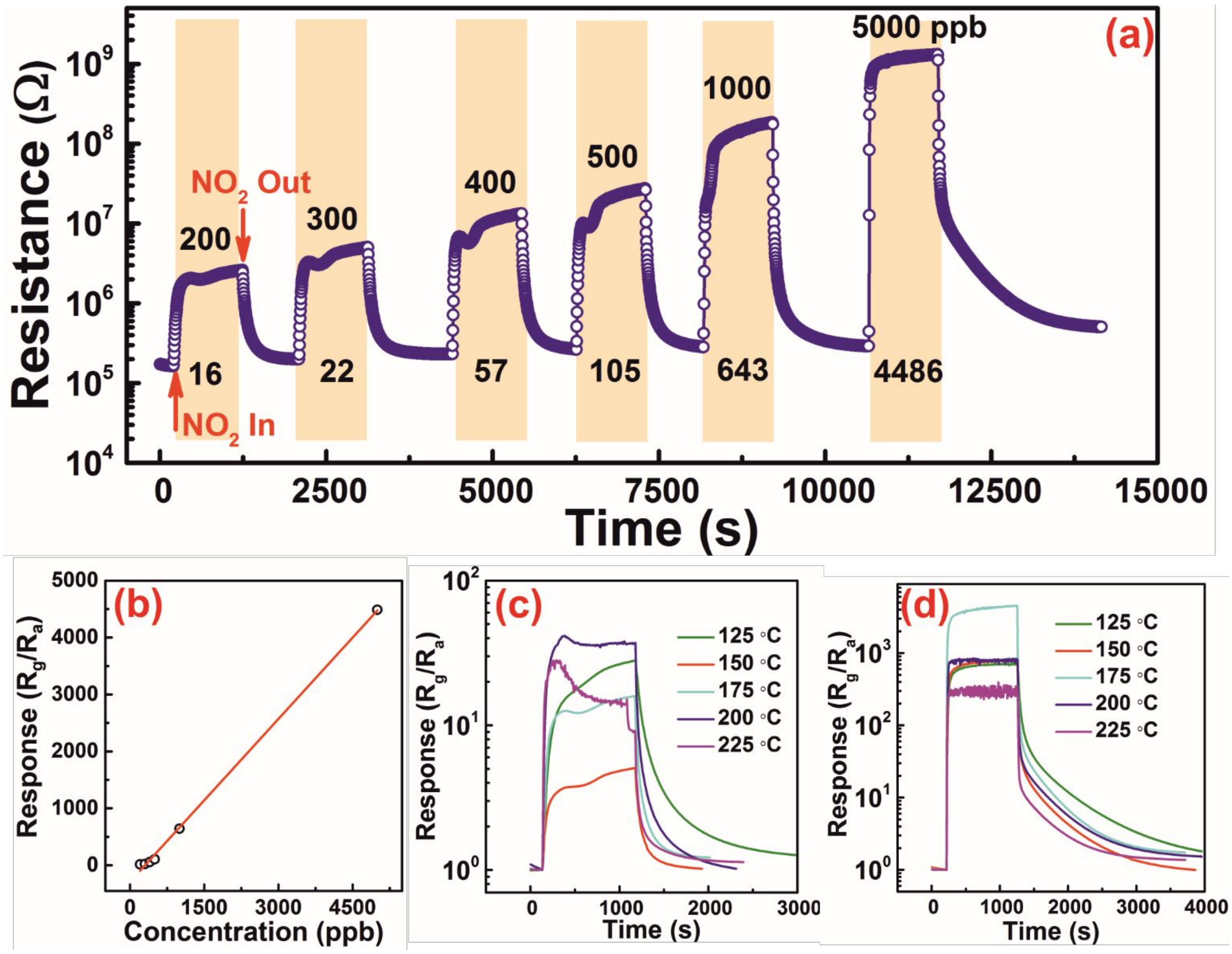

Figure S8. (a) Response curves of the 3-layer printed and annealed mesoporous SnO_2 based sensor measured with respect to varying analyte gas concentration. (b) Response-concentration relationship curve for the 3-layer printed sample showing a linear correlation. (c-d) Comparison of response curves for NO_2 concentration between 200 ppb to 5000 ppb measured at different temperatures.

I. Comparison of 2- and 3-layer printed mesoporous SnO_2 based gas sensor performance with respect to temperature and analyte gas concentration.

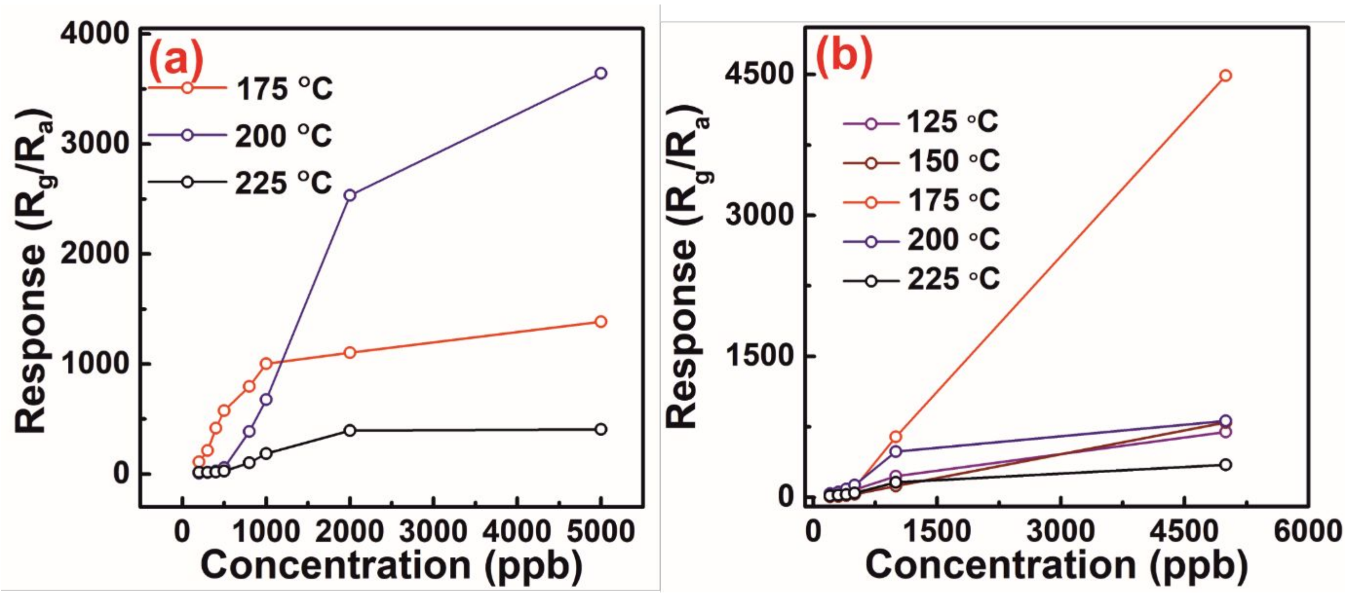

Figure S9. (a-b) 2-and 3-layer printed SnO_2 sensor performance comparison plot showing responses as a function of temperature and concentration, varied between 200 ppb to 5000 ppb.

J. Exemplary reproducibility test of 1-layer co-continuous mesoporous SnO_2 based NO_2 sensor and 175 °C along with average response versus NO_2 gas concentration data

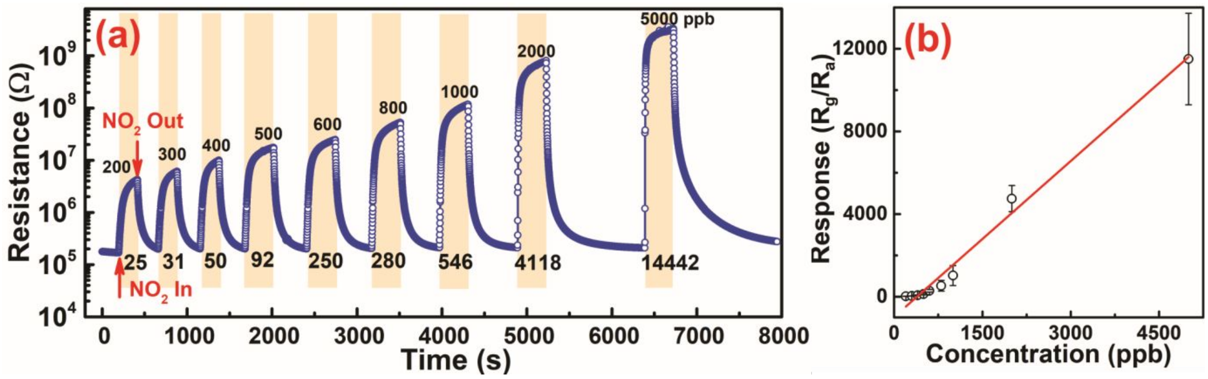

Figure S10: (a) An exemplary reproducibility test measurement with 1-layer co-continuous mesoporous SnO_2 based NO_2 sensor, carried out at 175 °C. (b) An average response (with standard deviation) versus NO_2 concentration plot, computed from three individual measurement data sets obtained from different mesoporous SnO_2 sensors, all measured at 175 °C.

K. Mesoporous SnO_2 (1-layer, printed) based sensor performance at 200 ppb NO_2 concentration measured at different temperatures

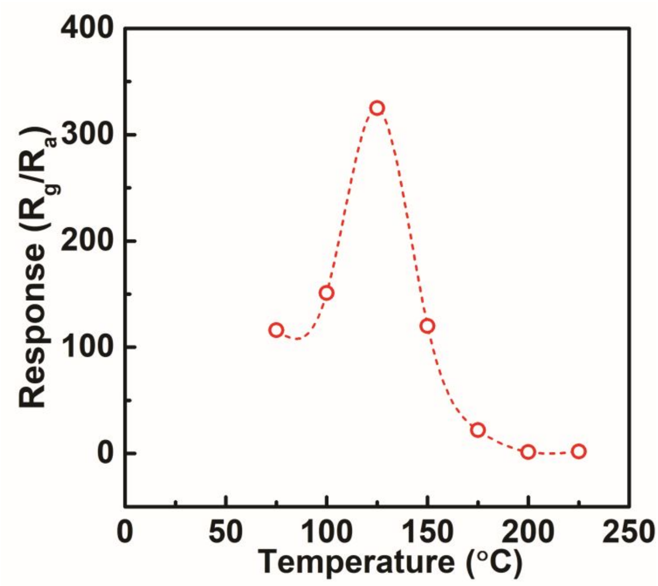

Figure S11 Mesoporous SnO_2 (1-layer, printed) based sensor response at 200 ppb NO_2 concentration compared for different measurement temperatures from 75 °C to 225 °C.

N. Comparison of NO_2 sensing ability of the printed (1-layer) mesoporous SnO_2 film with dry air and humid (RH 40 %) and as the carrier gas

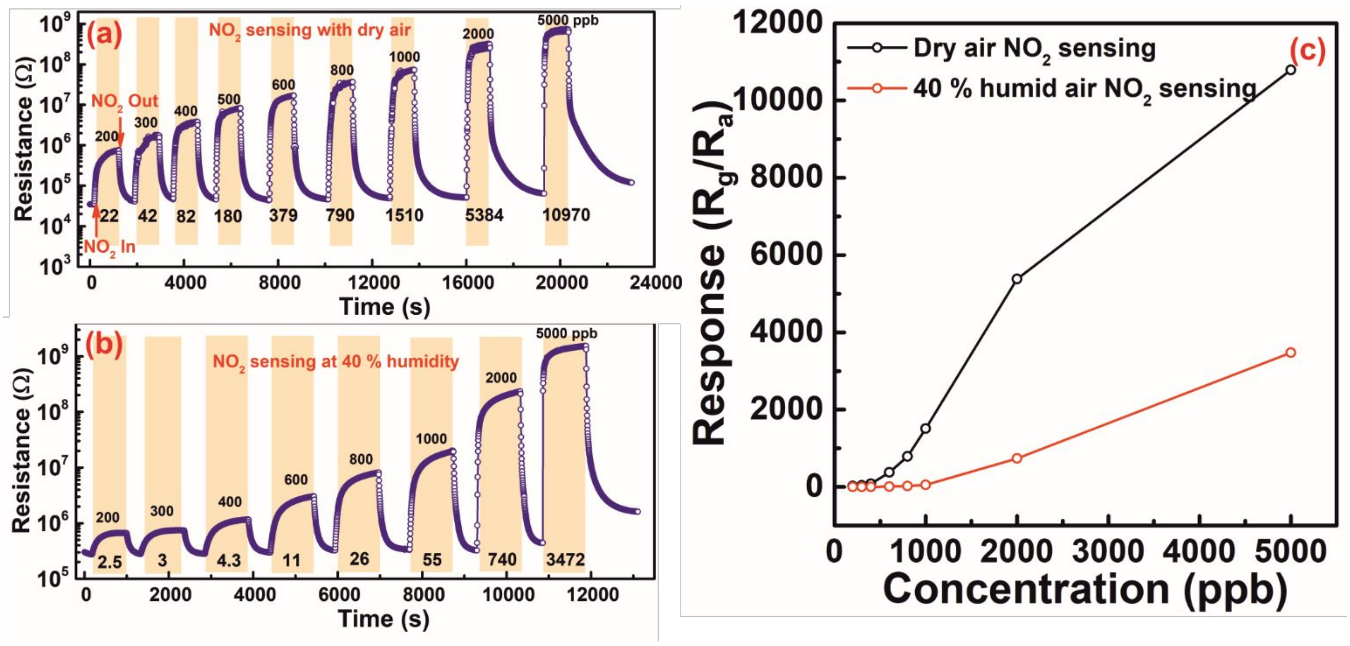

Figure S12: (a-b) NO_2 gas sensing performance measured at 175 °C with respect to dry air and humid air (40% relative humidity at room temperature) as the carrier gas. (c) Comparison of the NO_2 gas sensor performance with dry air and humid air (40 % relative humidity at room temperature) as the carrier gas.

M. Printed (1- layer) mesoporous SnO_2 based gas sensor performance for oxidizing chlorine gas with dry air as the carrier gas

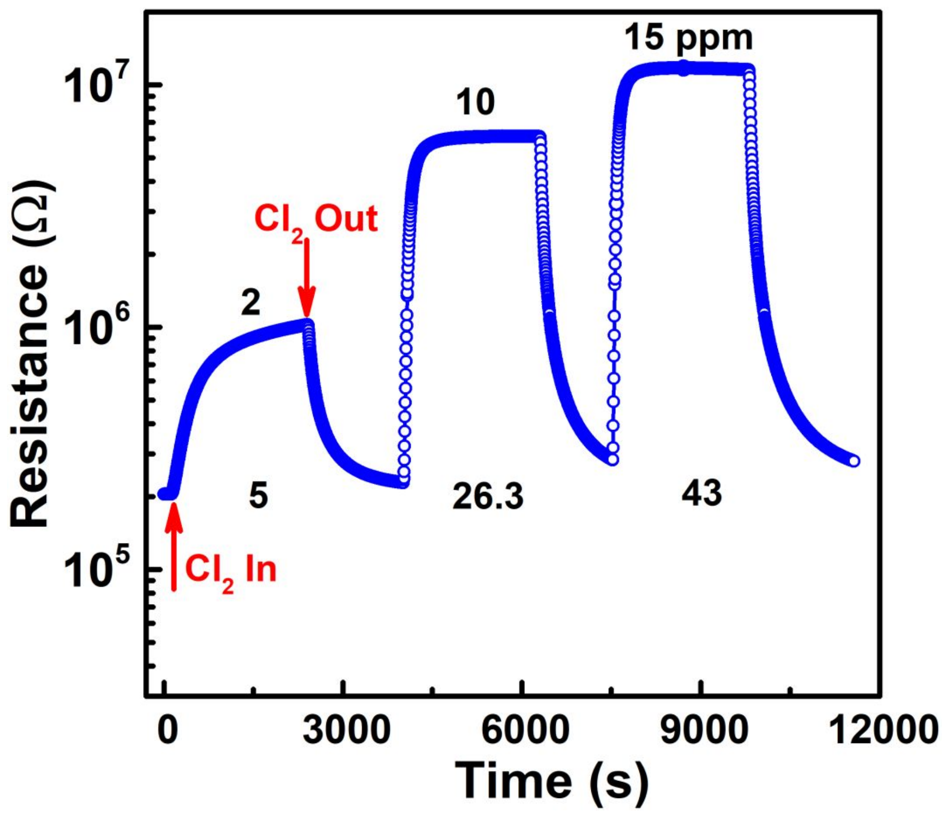

Figure S13: The chlorine gas sensing of the 1-layer printed mesoporous SnO_2 gas sensor measured at 175 °C, showing response against different chlorine gas concentrations

References:

(S1) Tadeo, I. J.; Parasuraman, R.; Krupanidhi, S. B.; Umarji, A. M. Enhanced Humidity Responsive Ultrasonically Nebulised V_2O_5 Thin Films . *Nano Express* **2020**, *1* (1), 010005.