Electronic Supplementary Information (ESI)

Tuning gas-sensing properties of reduced graphene oxide using tin oxide nanocrystals

Shun Mao, Shumao Cui, Ganhua Lu, Kehan Yu, Zhenhai Wen and Junhong Chen*

Department of Mechanical Engineering, University of Wisconsin-Milwaukee, 3200 N Cramer Street, Milwaukee, WI 53211, USA.

Experimental methods

Preparation of RGO: GO suspension was prepared by a modified Hummers method. To reduce the prepared GO, $H_3NO{\cdot}HCl$ was added into the GO suspension and the mixture was stored at 80 °C for 30 hours with continuous stirring. The product was then isolated by filtration and washed with distilled water and acetone to yield pure RGO powder. To prepare the RGO suspension, RGO powder was added in DMF and sonicated for 2 hours, resulting in a transparent, black, and stable RGO suspension.

Preparation of SnO_2 nanocrystal (NC): A mini arc was driven by a commercial tungsten inert gas (TIG) arc welder (Miller Maxstar 150 STH) and SnO (99.9%, Alfa Aesar) was used as the precursor material. After the SnO power was vaporized, pure O_2 was introduced and mixed with the vapor in downstream. The mixed aerosol went through a tube furnace which helped completely oxidize the vapor and form crystalline SnO_2 NCs. The synthesized NCs were then cooled and deposited onto RGO sheets through an electrostatic force directed assembly (ESFDA) process.

Sensor fabrication: To prepare RGO gas sensor, gold interdigitated electrodes with both finger-width and inter-finger spacing of about 1 μm and thickness of 50 nm were fabricated using an e-beam lithography process (Raith 150 lithography tool, 30 kV) on a silicon wafer with a top layer of thermally-formed SiO_2 (thickness of 200 nm). To place RGO sheets between Au electrodes, one droplet (2 μL) RGO suspension (1 mg RGO/25 mL DMF) was pipetted onto the electrodes to form a discrete network of RGO sheets after the solvent evaporation.

RGO NC-SnO_2 characterization: A Hitachi S-4800 Scanning electron microscope was used for SEM characterization at an acceleration voltage of 10 kV. A Hitachi H 9000 NAR Transmission electron microscope was used for TEM and selected area diffraction analyses. X-ray photoelectron spectroscopy (XPS) was conducted using an HP 5950A with an MgK_α source. The dc measurement was performed by recording the drain current when ramping the drain-source voltage V_d from -2 to +2 V (with a step of 0.1 V); while the FET measurement was performed by recording the drain current when ramping the gate voltage V_g from -40 to +40 V (with a step of 0.1 V).

Gas sensing test: An air-tight test chamber with an electrical feedthrough was used for the gas-sensing characterization. Variations in the device resistance were monitored by simultaneously applying a constant dc voltage and recording the change in current passing through RGO channel. A typical sensing test cycle consists of three consecutive steps that include exposure of the device to clean air flow to record a base value of the sensor resistance, to target gas to register a sensing signal, and to clean air flow for sensor recovery.

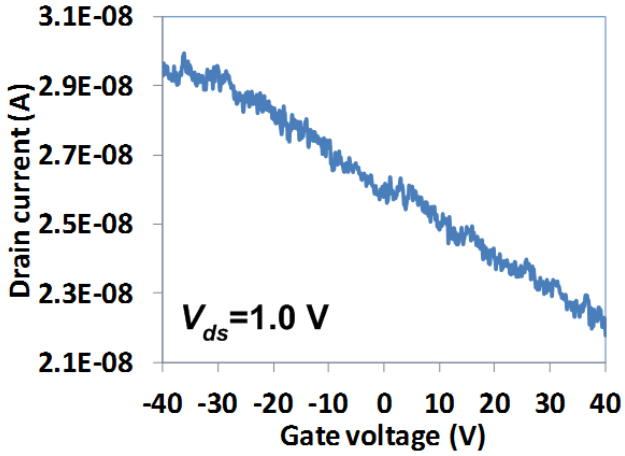

Fig. S1 FET measurement result (V_{ds} = 1.0 V) of the RGO sensor. The bare RGO sensor shows a p-type semiconducting behaviour in ambient environment.

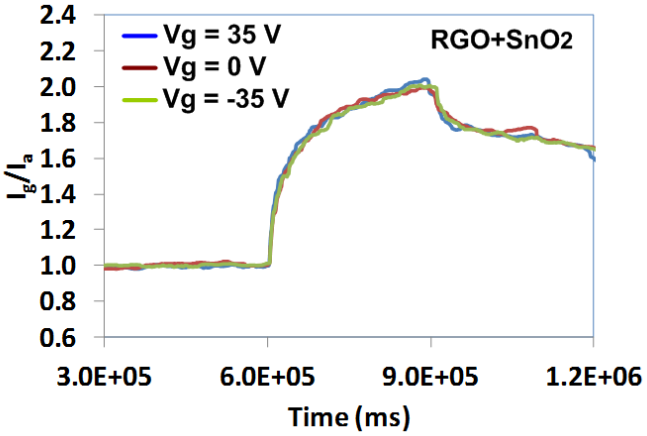

Fig. S2 NO_2 sensing results of the SnO_2 NC-RGO sensor under different V_g. The sensor sensing signals are similar under positive, neutral, and negative gate voltages.

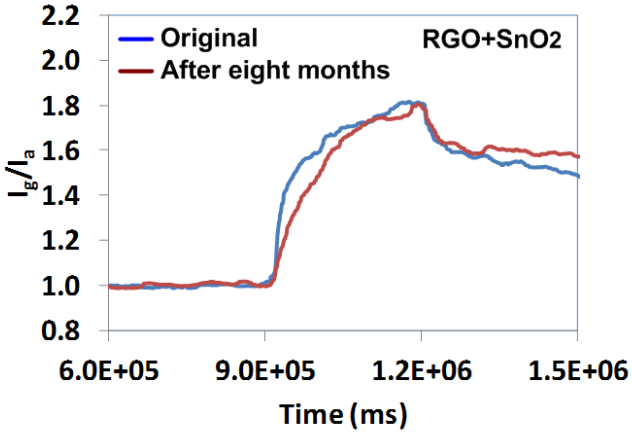

Fig. S3 NO_2 sensing results of the SnO_2 NC-RGO sensor after storage in ambient environment for eight months. The sensor response to NO_2 is on the same level as it was tested eight months ago.