Electronic Supplementary Material (ESI) for RSC Advances.

Supplementary information

Diethylamine gas sensor using V_2O_5-decorated α-Fe_2O_3 nanorods as sensing material

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1. Experimental section

1.1 Synthesis Process.

All chemicals were of reagent grade and used without further purification. Ferric chloride hexahydrate ($FeCl_3 \cdot 6H_2O$), ammonium metavanadate (NH_4VO_3), ethanol, *N,N*-Dimethylformamide (DMF), and polyvinyl pyrrolidone (PVP) were purchased from Sinopharm.

1.2 Preparation of α-Fe_2O_3 nanorods.

α-Fe_2O_3 nanofibers were synthesized by simple electrospinning technique. In a typical procedure, 2 ml DMF solutions of 1 mmol of $FeCl_3 \cdot 6H_2O$ and 4 ml ethyl alcohol solutions of PVP (8 wt %) were prepared with mechanical stirring for at least 2 h to obtain homogeneous dispersions, respectively. Then two kinds of solution were mixed together with mechanical stirring for at least 2 h. The precursor solution was transferred into a 5 ml springe with a stainless steel needle (the inner diameter is 0.6 mm). The flow rate of the precursor solution is about 0.4 ml/ h. The distance of an aluminum collector and needle was 12.5 cm. The high voltage DC power connected the needle, the voltage between the collector and needle was about 12 kV. After this, the pre-oxidized nanofibers were obtained by annealing the as-spun fibers at 450 °C for 2 h with a heating rate of 1 °C/ min in air.

1.3 Preparation of V_2O_5-decorated α-Fe_2O_3 composite nanorods .

V_2O_5-decorated α-Fe_2O_3 composite nanorods were synthesized by environment-friendly soak-calcination strategy. Briefly, α-Fe_2O_3 nanorods was dissolved in 0.5 mol/L aqueous NH_4VO_3 solution under continuously stirring for 24 h at room temperature. Then the resultant V_2O_5-decorated α-Fe_2O_3 precursor was collected by centrifugation, washed with distilled water and absolute ethanol for several times, and dried by vacuum. Subsequently, the as-synthesized precursor was calcined at

350 °C for 2 h with a heating rate of 1 °C/ min in air.

1.4 Characterization of sample

The morphologies and sizes of the samples were determined by a field emission gun scanning Electron microscopy (Hitachi S-4800 equipped with an EDS) at an accelerating voltage of 5 kV. The crystalline phases of the synthesized samples were carried out by X-ray diffraction (XRD) on a Rigaku D/MAX-2500 with Cu Kα radiation at. 50 kV. The structures of the samples were also studied using Transmission electron microscopy (TEM, JEOL JEM-2100F microscope). The specific surface area was calculated from the Brunauer–Emmett–Teller (BET) plot of the nitrogen adsorption isotherm and the pore size distribution of the sample was calculated from desorption branch isotherms.

1.5 Fabrication and measurement of gas sensor

The fabrication and testing principles of the gas sensor are similar to that described in our previous reports. Firstly, the V_2O_5-decorated α-Fe_2O_3 nanorods, α-Fe_2O_3 nanorods and commercial V_2O_5 powders were mixed with terpineol to form a paste and then coated onto the outside surface of an alumina tube (5 mm in length, 1 mm in external diameter, and 0.8 mm in internal diameter, attached with a pair of gold electrodes). A platinum coil through the tube was employed as a heater to control the operating temperature. To improve their stability and repeatability, the gas sensors were aged at 300 °C for 10 days in air. The test gases and volatile organic compounds (VOCs) were injected into a closed 10 litres of glass bottle by a microinjector.

Gas sensors based on metal oxide nanostructures generally consist of three parts, i.e., sensing film, electrodes and heater. Metal oxide nanostructures react in the form of a film which will change in resistance upon exposure to target gases. Currently, metal oxide nanostructures sensors have been characterized in three ways: conductometric, field effect transistor (FET) and impedometric ones. The conductometric type is the most common gas sensor which is suitable for most nanomaterials. And most of the current nanostructure-based gas sensors are indirectly heated type structures which can be divided into two types, i.e., cylindrical

(alumina tube) and planar layouts (ceramic wafer substrate). In our works, the nanopowders were mixed with terpineol to form a paste and then coated onto the alumina tube. And the sensing properties of the sensors were measured by a NS-4003 series gas sensing measurement system which was made by Zhong-Ke Micro-nano IOT. The gas response behavior of sensor was investigated under laboratory conditions (50 RH%, 25 °C). The response and recovery times were defined as the time required for a change of the resistance to reach 90% of the equilibrium value after injecting and that for removing the detected gas, respectively. When air and ppm-level target gas were flowed through the sensor element, the corresponding steady-state resistances of the sensor in air (R_{air}) and in the air-gas mixture (R_{gas}) were recorded, respectively. The sensor response (S) for oxidizing gas (NO or NO_2) is defined as the ratio of R_{gas}/R_{air}, while the response for reducing gas (H_2S, H_2, CO or CH_4) is defined as the ratio of R_{air}/R_{gas}.

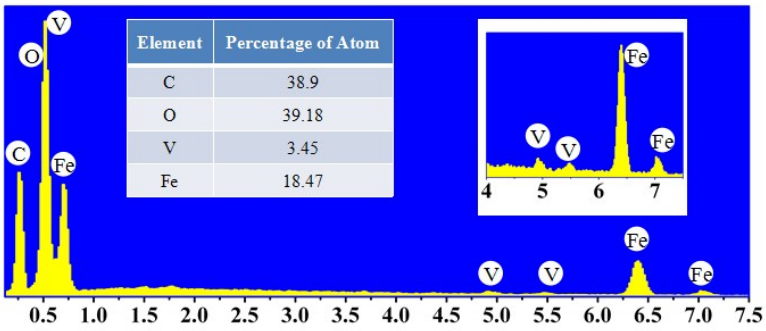

Fig. S1 EDS spectrum of V_2O_5-decorated α-Fe_2O_3 nanorods, showing the presence and proportion of Fe, O and V.

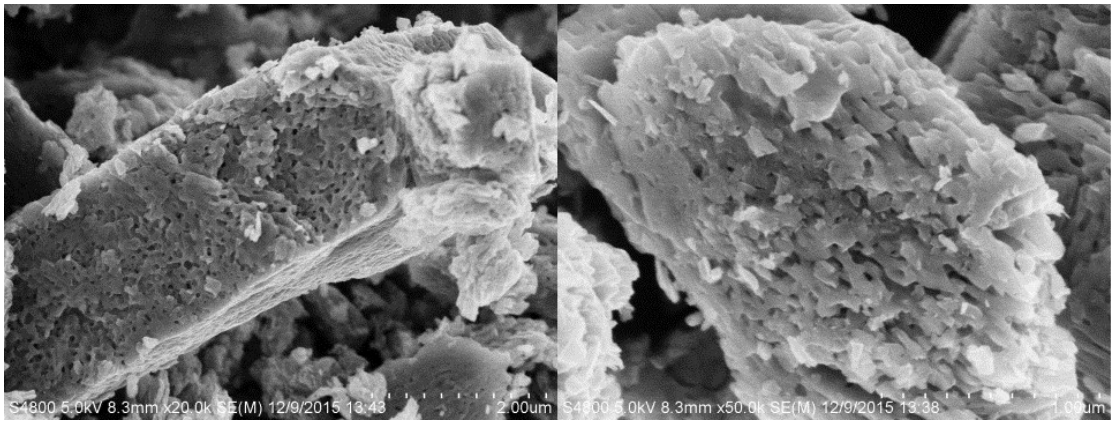

Fig. S2 SEM images of c-V_2O_5.

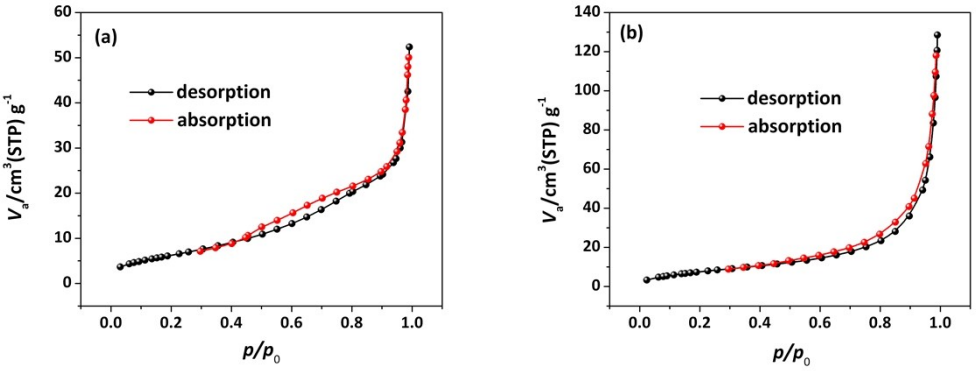

Fig. S3 (a) N_2 adsorption/ desorption isotherms for α-Fe_2O_3 nanorods and (b) N_2 adsorption/ desorption isotherms for V_2O_5-decorated α-Fe_2O_3 composite.

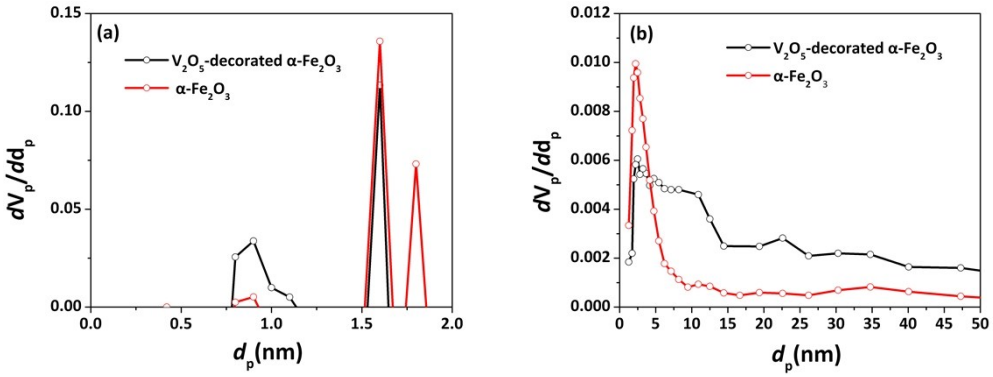

Fig. S4 (a) Micropores distributions for V_2O_5-decorated α-Fe_2O_3 composite and α-Fe_2O_3 nanorods and (b) mesopores distributions for V_2O_5-decorated α-Fe_2O_3 composite and α-Fe_2O_3 nanorods.

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