Synthesis of Characterization and Sensing properties of Metal-Oxide Nanostructures

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1. Introduction

One-dimensional (1D) metal-oxide semiconductor nanostructures have attracted significant attention over the past decade due to their unique electronic, optical, and magnetic properties. Metal-oxide nanostructures represent building blocks for functional device architectures [1-3].One of the examples is provided by the extensive studies of indium oxide (In_2O_3). In_2O_3 is an important wide band gap (3.6 eV) and transparent semiconductor material with attractive optoelectronic properties. There is growing attention in the synthesis of In_2O_3 nanostructures due to their diverse morphologies, interesting properties and important potential applications in nanodevices. Here we report an efficient route for the temperature dependent synthesis of single-crystalline 1D In_2O_3 nanostructures on Au-coated silicon substrate by chemical vapor deposition. The gas sensing properties toward hydrogen gas have been tested over a wide range of concentrations and operating temperatures. Also thermal oxidation of Ni and Ti into their native oxide nanostructures reported.

2. Experimental details

The synthesis of In_2O_3 nanostructures was performed in a simple chemical vapor deposition (CVD) system. The quartz tube has a length of 80 cm and a diameter of 5 cm. Two removable rubber corks were fixed to both ends of the quartz tube with an inlet and outlet respectively. Argon gas was introduced into the quartz tube from one end and flowed out from the other end. In this experiment 0.3 g of high-purity indium grains (purity:99.99%) was placed on an alumina boat. A silicon wafer coated with an Au film with a thickness of 10 nm was placed above the In grains, with its surface directed towards the In grains. The tube chamber was purged for 30 min. with Ar gas (purity: 99.99%) at a rate of 100 mL/min^{-1} and then the furnace was heated to 800°C at a rate of 25°C/min and kept at this temperature for 1 h. After cooling to room temperature, a uniform layer of yellow color product with high purity was deposited on the silicon wafer. In order to study extensively the effect of temperature on the morphology of In_2O_3 nanostructures, the synthesis was also carried out at 700 and 900°C.

Thermal oxidation of Ni and Ti metal foils in presence of oxygen atmosphere was carried out in horizontal tube furnace. The hydrogen sensing behavior of In_2O_3 nanowires and nanoneedles were investigated at different operating temperatures.

Results and discussion:

In_2O_3 nanostructures formed under different reaction temperature. It was found that reaction temperature had a profound effect on the morphology of In_2O_3 nanostructures. When the reaction was carried out at 700°C In2O3 nanorods with variable diameters were formed. When the reaction temperature was increased to 800°C In_2O_3 nanowires were formed. In_2O_3 nanoneedles were formed at 900°C.

Detailed structural analysis was carried out for In_2O_3 nanostructures. On the basis of growth temperature a possible growth mechanism is proposed. Hydrogen gas sensors of In_2O_3 nanowires and nanoneedles are fabricated. Our results illustrates that the sensor response of In_2O_3 nanowires increases with the hydrogen concentration and operating temperature. Considering the nanosized effect In_2O_3 nanowires showed better gas sensor response compared with the In_2O_3 nanoneedles and could be more promising in real device application. In addition to In_2O_3 nanostrutcures Ni and Ti metal foils were annealed at different reaction condition in horizontal tube furnace to fabricate their native oxides. A variety of NiO, and TiO_2 nanostructures were formed by by changing the experimental conditions. TiO_2 nanorods and nanowires were formed by selecting appropriate reaction conditions.

In conclusion variety of In_2O_3, NiO and TiO_2 nanostructures were formed in horizontal tube furnace by varying the experimental conditions. Detailed structural analysis was carried out to know the crystal structure and growth mechanism. In order to compare hydrogen gas sensors performance In_2O_3 nanowires and nanoneedles were investigated in details.

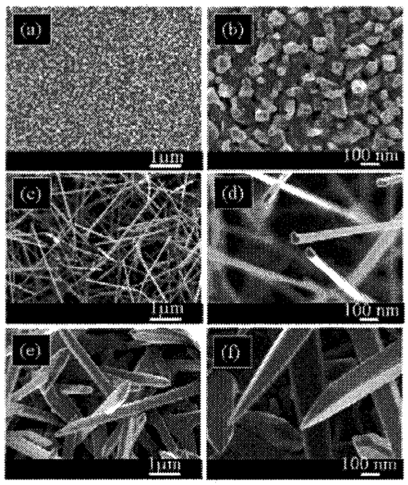

Figure 1. Low and high magnification FESEM images of In_2O_3 nanorods (a) and (b); nanowires (c) and (d); and nanoneedles (e) and (f).

References:

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