Study on Synthesis and Gas Sensitivity of SnO_2 Nanobelts *

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(Received 10 November 2005)

Tin dioxide (SnO_2) nanobelts have been successfully synthesized in bulk quantity by the CVD process based on the thermal evaporation of tin powders. The x-ray diffraction analysis indicates that the nanobelts are the tetragonal rutile structure of SnO_2. Scanning electron microscopy and transmission electron microscopy observations reveal that the nanobelts are uniform. The selected-area electron diffraction analysis demonstrates that the nanobelts are single crystals. The energy dispersive x-ray analysis of the nanobelt shows that the nanobelts are composed of Sn and O. Gas-sensing components have been manufactured with prepared SnO_2 nanobelts. Their performance indicates that SnO_2 nanobelts have high sensitivity and selectivity to liquefied petroleum gas with fairly good response-recovery characteristic and stability at 220° C.

PACS: 81. 07. Bc, 85. 35. Be, 85. 35. −p

The development of nanotechnology provides excellent sensitive materials for sensors. Compared with the traditional sensors, nano-sensor has smaller size, higher precision, and its performance is greatly improved. Furthermore, the use of nanotechnology to fabricate sensor is standing on the scale of atom, thus it greatly enriches the theories of sensors, promotes the standard of making sensors, and expands the fields of sensor applications. The nano-sensors have been widely developed in the field of biology, chemistry, machinery, navigation, military, etc.[1,2]

Pan *et al.*[3] reported that they have synthesized oxide nanobelts for the first time in 2001. Because of the good geometry symmetry, nice crystal, configuration singleness, and lack of lacuna in prodigious scale, nanobelts have many applications in constructing nanoscale electronic and optoelectronic devices. Therefore, nanobelts are an ideal system for studying the basic electrics, calorifics, optics and electron transportation process of quasi-one-dimensional nanomaterials in experiment and theoretically. Nanobelts have potential applications in constructing nanoscale functional devices.[4,5]

The preparation methods and configuration of the SnO_2 nanomaterials are focused on in this thesis. The gas sensitivity of the component made by SnO_2 nanobelts is also studied.

The synthesis process of the SnO_2 nanobelts is briefly described as follows: an alumina boat loaded with pure Sn powders (2 g, 200 mesh, 99.9%) was placed in the middle of a quartz tube ($30 \times 1200\,mm^2$) and inserted into a horizontal tube furnace. The reaction chamber was heated to 1000°C rapidly (about 30 min) from room temperature under a flowing Ar (60 sccm) atmosphere. Subsequently, the furnace was kept at 1000°C for 3 h, and then cooled down to room temperature. After reaction, it would be observed that white wool-like products have been formed in high yield on the walls of the alumina boat.

The as-synthesized products were characterized by using x-ray powder diffraction (XRD) (Philips PW 1710 with Cu K_α radiation), scanning electron microscopy (SEM, JEOL JSM-6300), transmission electron microscopy (TEM, JEM 200CX) and energy-dispersed x-ray spectroscopy (EDX). For the SEM observation, the as-synthesized products were directly mounted on copper stubs. For the TEM observation, the products were scratched off the alumina boat and ultrasonically dispersed in ethanol for 15 min, and then a drop of the solution was placed on a holey carbon copper grid. The gas sensitivity measurement was taken by the gas sensitivity testing system (HW-30A).

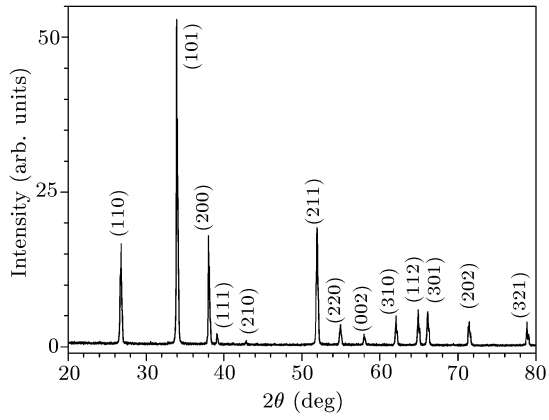


Fig. 1. The XRD pattern recorded from the synthesized SnO_2 nanobelts.

The XRD pattern (Fig. 1) from the as-synthesized

* Supported by the National Natural Science Foundation of China under Grant No 19974055.

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bulk samples reveals the crystal structure and phase purity of the products. All the diffraction peaks can be indexed to the tetragonal rutile structure of SnO_2, with lattice constants of $a = 0.4734$ nm and $c = 0.3185$ nm, which are consistent with the standard values for bulk SnO_2. No impurities, such as unreacted Sn or other tin oxides, were detected.

A typical low-magnification SEM image (Fig. 2(a)) reveals the as-synthesized products which consist of a large quantity of 1-D nanostructures with lengths from several tens to several hundreds of micrometres; some of them even have lengths of several millimetres. A representative high magnification SEM image (Fig. 2(b)) of a curved SnO_2 1-D nanostructures reveals that their geometrical shape is belt-like, which is distinct from those of previously reported nanowires and nanotubes, and their thickness is about 30 nm.

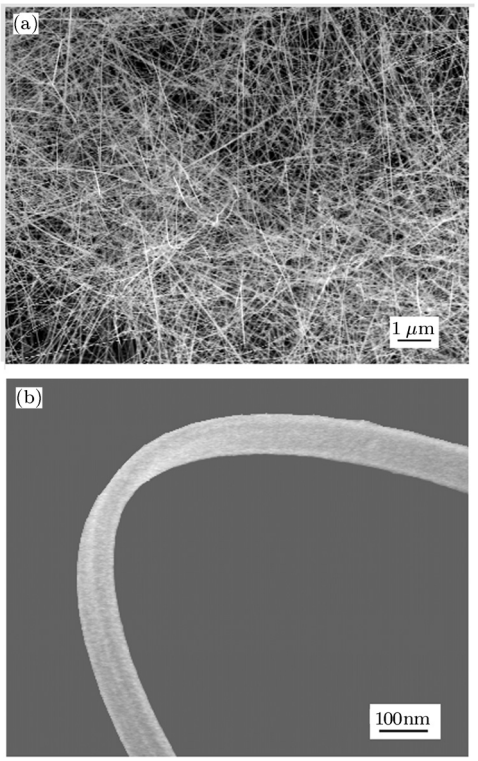


Fig. 2. The SEM morphologies of the synthesized SnO_2 nanobelts.

TEM and SAED studies of the as-synthesized products provide further insight into the belt-like SnO_2 nanostructures. Straight SnO_2 nanobelts can be observed in Fig. 3(a). The nanobelts are uniform in width. The ripple-like contrast can also be seen in SnO_2 nanobelts, indicating the presence of strain.[6–8] The SAED pattern (Fig. 3(b)) taken from the straight section of the nanobelt demonstrates that this particular nanobelt is single crystal. The EDX analysis of the nanobelt (Fig. 4) shows that the nanobelts are composed of Sn and O, the peaks of Cu are generated from the Cu grids.

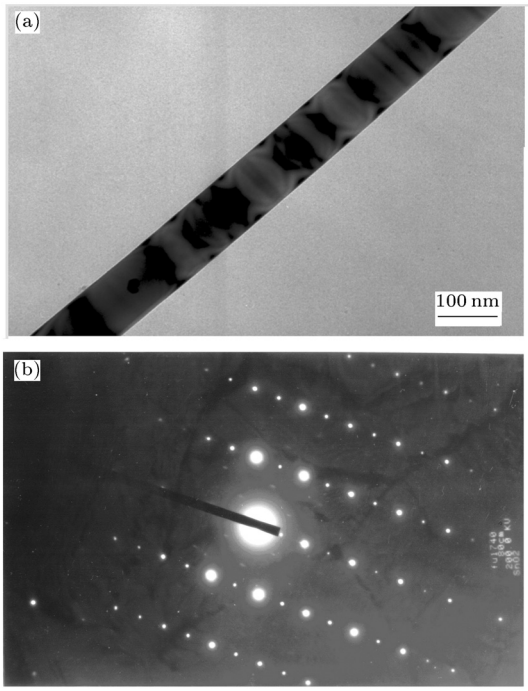


Fig. 3. TEM images of SnO_2 nanobelts and the SAED pattern from this belts.

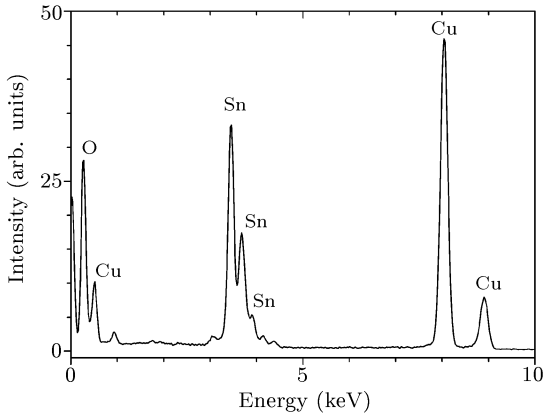


Fig. 4. The EDX pattern recorded from the synthesized SnO_2 nanobelts.

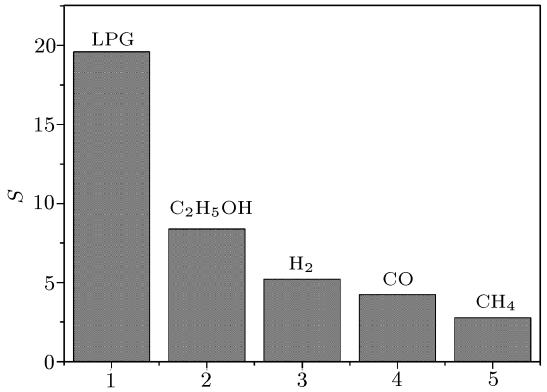


Fig. 5. The sensitivity to different gases.

Gas-sensing components have been manufactured with prepared SnO_2 nanobelts,[9,10] and their performance indicates that SnO_2 nanobelts have high sensitivity and selectivity to LPG at 220°C, compared with C_2H_5OH, H_2, CO, and CH_4 (Fig. 5).

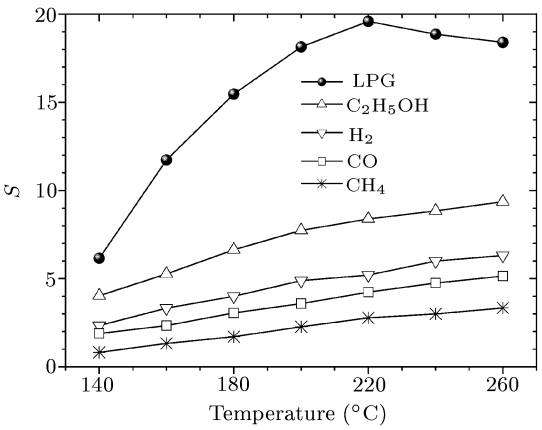


Fig. 6. The relationship between sensitivity and temperature.

Figure 6 shows the relation between sensitivity and working temperature of the components to different gases. The gas concentration is 1.0×10^{-3}. From 140°C to 260°C, the value of gas sensitivity increases gradually, but different gas has different range. The component is more sensitive to LPG, and the max appears at 220°C.

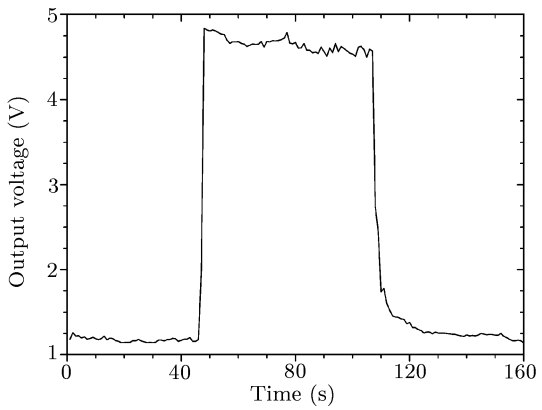


Fig. 7. The response-recovery characteristics.

The response-recovery characteristic and long-term stability of the component are measured. Figure 7 shows that the component has a fairly good response-recovery characteristic. The response time is about 2 s, and the recovery time is about 5 s. The stability of the component is observed during 90 days. Figure 8 shows that the component also has fairly good long-term stability, compared with the component made by SnO_2 micro-powder.[11] This to some extent solves the poor long-term stability of the SnO_2 sensor.

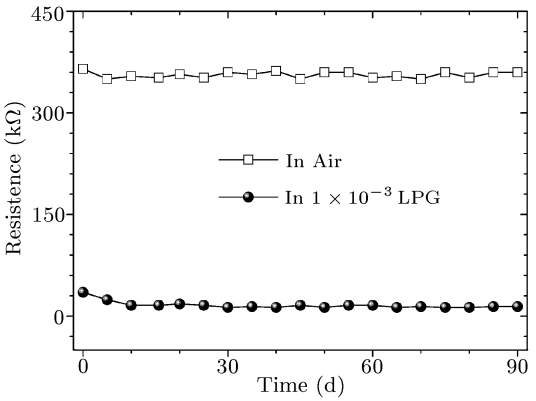


Fig. 8. Stability of the sensor.

Tin dioxide (SnO_2) nanobelts have been successfully synthesized in bulk quantity by CVD process based on the thermal evaporation of tin powders. Gas-sensing components have been manufactured with prepared SnO_2 nanobelts. Their performances indicates that it has high sensitivity and selectivity to LPG with fairly good response-recovery characteristic and long-term stability.

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