One-step, solid-state reaction to the synthesis of copper oxide nanorods in the presence of a suitable surfactant

Wenzhong Wang[ab] Yongjie Zhan[a] and Guanghou Wang*[ab]

[a] *National Laboratory of Solid State Microstructures & Department of Physics, Nanjing University, Nanjing 210093, P. R. China. E-mail: wangqun@netra.nju.edu.cn*
[b] *Structure Research Laboratory, University of Science and Technology of China, Hefei, Anhui 230026, P. R. China*

Received (in Cambridge, UK) 11th October 2000, Accepted 8th March 2001
First published as an Advance Article on the web 29th March 2001

A novel and simple one-step, solid-state reaction in the presence of a suitable surfactant has been developed to synthesize uniform copper oxide nanorods with average diameters of *ca.* 8 nm and lengths of up to 400 nm.

One-dimensional nanostructural materials are currently the focus of considerable interest. Many methods have been used for the preparation of nanorods or nanowires.[1–6] However, to our knowledge, complex process control, high reaction temperatures or long synthesis time may be required for these approaches. Here we report a novel and simple one-step, solid-state reaction in the presence of a suitable surfactant, polyethylene glycol (PEG) 400, for preparation of copper oxide nanorods. This method requires no complex apparatus and techniques. The process is carried out in air at room temperature and the synthetic time is very short.

Transition metal oxide-containing glasses are of interest due to their possible technological application in electrical and optical switching devices. Copper oxide is a p-type semiconductor and it is useful for the preparation of organic catalysts. Great attention has been devoted to metal–organic chemical vapor deposition (MOCVD) processes for the fabrication of copper oxides. Interest has been spurred on by the applications of these materials for the vapor phase deposition of high-T_c superconducting films.[7–10] Applications of copper oxides have recently been extended to gas sensors.[11–13]

The procedure employed by us for preparing copper oxide nanorods is as follows. In a typical synthesis, 5.045 g of $CuCl_2 \cdot 2H_2O$ and 3 g of NaOH were ground for 5 min each before mixing together, 6 ml of polyethylene glycol (PEG) 400 was then added to the mixture. After 30 min of grinding, the mixture was washed in an ultrasonic bath three times with distilled water and then with EtOH to remove the PEG. Finally, the product was dried in air at 60 °C for 3 h.

X-Ray powder diffraction (XRD) was carried out on a Rigaku D_{max} γ_A X-ray diffractometer with Cu-Kα radiation (λ = 0.154178 nm). Transmission electron microscopy (TEM) micrographs were taken using a JEM-200CX transmission electron microscope, with an accelerating voltage of 200 kV.

Fig. 1 shows the XRD pattern of a sample of the copper oxide nanorods prepared by the one-step, solid-state reaction in the presence of a suitable surfactant, PEG 400. Powder XRD peaks of the copper oxide are consistent with the data of the JCPDS file.[14] The peaks at 2θ values of 32.530, 35.408, 38.728, 45.200, 48.856, 53.525, 58.627, 60.266, 67.976, 74.940 and 81.273° correspond to the crystal planes of 110, 002, 111, 112, 202, 020, 202, 113, 220(312), 004, 313 of crystalline copper oxide, respectively.

The TEM image of the copper oxide sample of Fig. 1 is shown in Fig. 2, which reveals that the copper oxide powders consist of uniform nanorods. It can be seen that the nanorods have average diameters of *ca.* 8 nm and lengths of up to 400 nm. The formation of a rod shape of copper oxide is speculated to be due to the surfactant assemblage because PEG in water can form a chain structure.[15]

In summary, a novel and facile method has been developed to synthesize copper oxide nanorods. This relatively fast reaction gives nanorods or nanometric powders with potentially broad applications in the synthesis and in the shape control of nanometric powders.

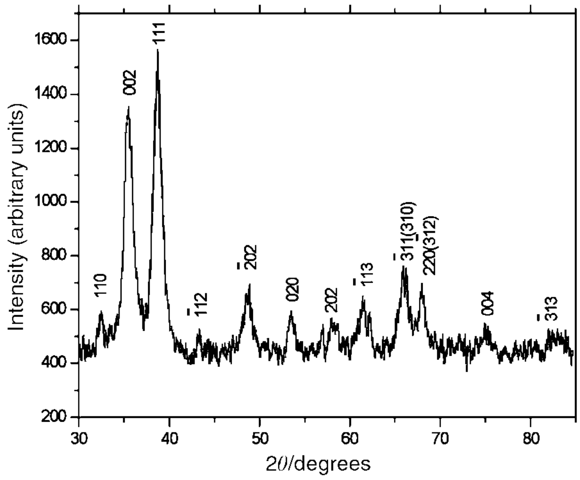

Fig. 1 XRD pattern of a copper oxide nanorod sample produced by a one-step, solid-state reaction in the presence of a suitable surfactant at room temperature.

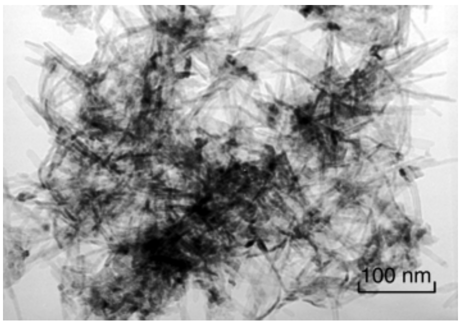

Fig. 2 TEM image of the copper oxide nanorod sample shown in Fig. 1.

This work was supported by the National Natural Science Foundation of P. R. China (No. 29890210, 10023001, 10074024).

Notes and references

1 H.-P. Lin and C.-Y. Mou, *Science*, 1996, **273**, 765.
2 H.-P. Lin, S. Cheng and C.-Y. Mou, *Chem. Mater.*, 1998, **10**, 581.
3 S. A. Davis, S. L. Burkkett, N. H. Mendeison and S. Mann, *Nature*, 1997, **385**, 420.
4 M. Zhang, Y. Bando, K. Wada and K. Kurashima, *J. Mater. Sci. Lett.*, 1999, **18**, 1911.
5 B. Cheng, W. Q. Jiang, Y. R. Zhu and Z. Y. Chen, *J. Mater. Sci. Lett.*, 2000, **19**, 503.
6 S. A. Sapp, B. B. Larshmi and C. R. Mortiu, *Adv. Mater.*, 1999, **11**, 402.

7 J. G. Bednorz and K. A. Muller, *Z. Phys., B*, 1986, **64**, 189.
8 A. D. Berry, K. D. Gaskill, R. T. Holm, E. J. Cukauskas, R. Kaplan and R. L. Henry, *Appl. Phys. Lett.*, 1988, **52**, 1743.
9 G. Malandrino, G. G. Condorelli, G. Lanza and I. L. Fragala, *J. Alloys Compd.*, 1997, **251**, 314.
10 G. Malandrino, G. G. Condorelli, G. Lanza, I. L. Fragala, U. Scottidi Uccio and M. Valentino, *J. Alloys Compd.*, 1997, **251**, 332.
11 T. Ishihara, M. Higuchi, T. Takagi, M. Ito, H. Nishiguchi and T. Takita, *J. Mater. Chem.*, 1998, **8**, 2037.
12 T. Ishihara, K. Kometani, M. Hashida and Y. Takita, *J. Electrochem. Soc.*, 1991, **138**, 173.
13 J. Tamaki, K. Shimanoe, Y. Yamada, Y. Yamamoto, N. Miura and N. Yamazoe, *Sens. Actuators B*, 1998, **49**, 121.
14 Joint Committee on Powder Diffraction Standards, *Diffraction Data File, No.5-661, JCPDS International Center for Diffraction Data*, Peensylvania, 1991.
15 J.-H. Sun, Y-J. Gong, W.-H. Fan, D. Wu and Y.-H. Sun, *Chem. J. Chin. Univ.*, 2000, **21**, 95.