Growth of ZnO nanowires by evaporation of mechanically milled powder

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ZnO nanowires have been synthesized from a mechanically milled ZnO powder by evaporation and vapor deposition. The general morphology of nanowires is similar to that obtained from unmilled commercial ZnO powder but a higher yield is achieved. Nanowires grown from the milled sample have a preferential [001] growth direction.

1. Introduction

Zinc oxide (ZnO) is an important semiconductor with a wide band gap of 3.37 eV at room temperature. Owing to the asymmetric wurtzite structure, ZnO is a unique material for optoelectronics, lasing and piezoelectricity.

One dimensional ZnO nanowires [1] represent a new class of ZnO morphologies with novel exciting applications. Nanowires grow in most cases along [001] direction (c-axis) which is observed to be the fastest growing direction for zinc oxide. Due to internal crystal structure features, such nanowires usually have hexagonal cross section. Nanobelts are considered as a special class of nanowires having rectangular cross section. They have three types of typical growth directions and external facets.

ZnO nanowires and nanobelts are considered to be used as active elements and interconnections in nanoelectronics. Prototypes of nanowire based transistors and light-emitting diodes are demonstrated and simple nanowire based circuitry is created [2]. In addition, ZnO nanowires are shown to be efficient nanoscale lasers [3] and can be used as light sources, waveguides and optical switches in nanoscale optics.

The problem of an efficient large-scale nanowire preparation is still challenging. Mechanical milling has been widely tried in some recent works dealing with one-dimensional nanostructures growth [4-6]. This paper describes the preparation of ZnO nanowires by evaporation of a mechanically milled ZnO powder. The product obtained is compared with that grown from unmilled powder

2. Preparation of nanowires

Commercially available ZnO powder was milled using a rotating steel mill with a magnet (Uni ball mill). 3 g of ZnO powder and 4 steel balls (with a diameter of 24 mm) were put into a vial and the latter was filled with nitrogen. The milling had been conducted for 100 hours. Fig. 1 shows SEM images and XRD patterns of milled and unmilled samples. Broad ZnO peaks can be observed in the XRD pattern of the milled sample suggesting a small crystallite size and possibly high level of structural defects in ZnO structure. In contrast with unmilled commercial ZnO powder, it can be clearly seen from SEM images that particles of the milled sample have irregular shapes.

The evaporation of starting powders was performed at 1300^0C for 1 h in a tube furnace. Ar was used as a carrier gas. Si substrates for the collection of nanostructures were located downstream in a tube furnace at the temperature zone of 250-350^0C. Milled and unmilled ZnO powders were used for vapor generation as comparative samples in different experiments.

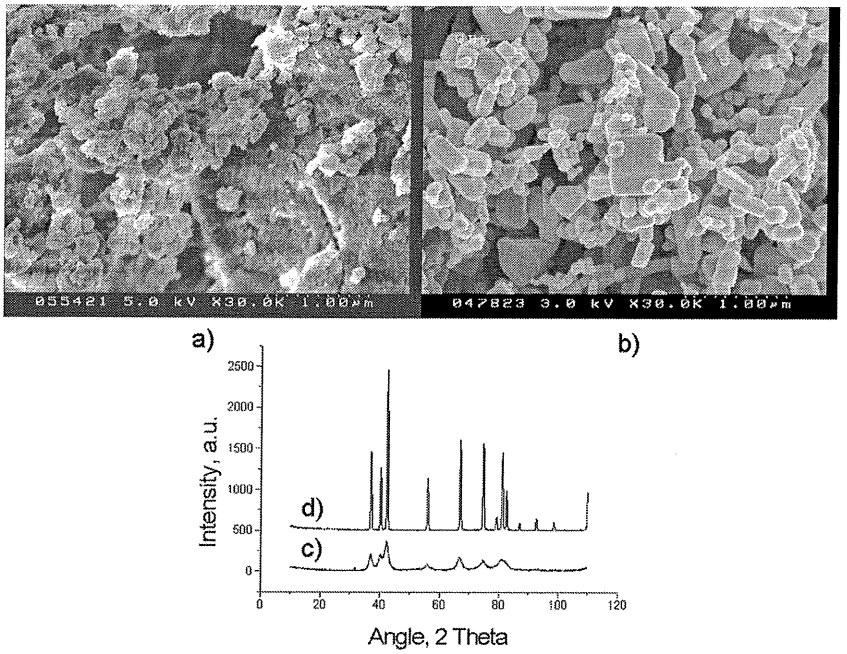

Fig.1. SEM images and XRD patterns of ZnO powders.
a, c) ZnO powder milled in nitrogen
b, d) unmilled ZnO powder

3. Results

Long (up to tens of μm) ZnO nanowires (fig.2) were obtained from the unmilled sample. Typical diameter of nanowires is 20-60 nm. The surface of nanowires is rough. No particles are found at the tips. XRD pattern shows a series of ZnO peaks with intensities reasonably resembling those from standard intensities of PDF cards. No dominating peaks are found.

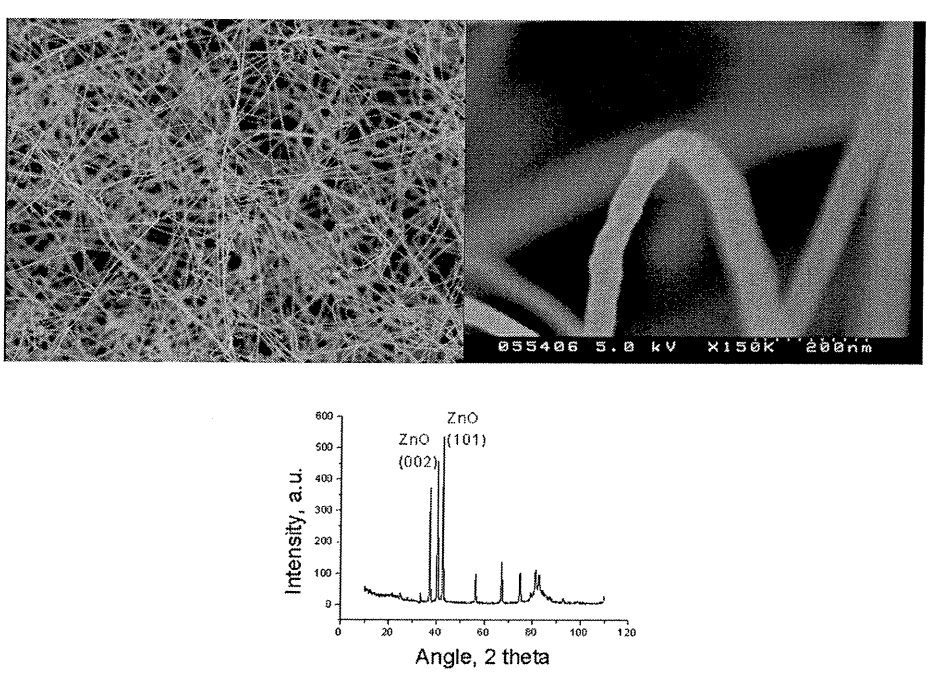

Fig.2. SEM images and XRD pattern of ZnO nanowires produced from the unmilled sample

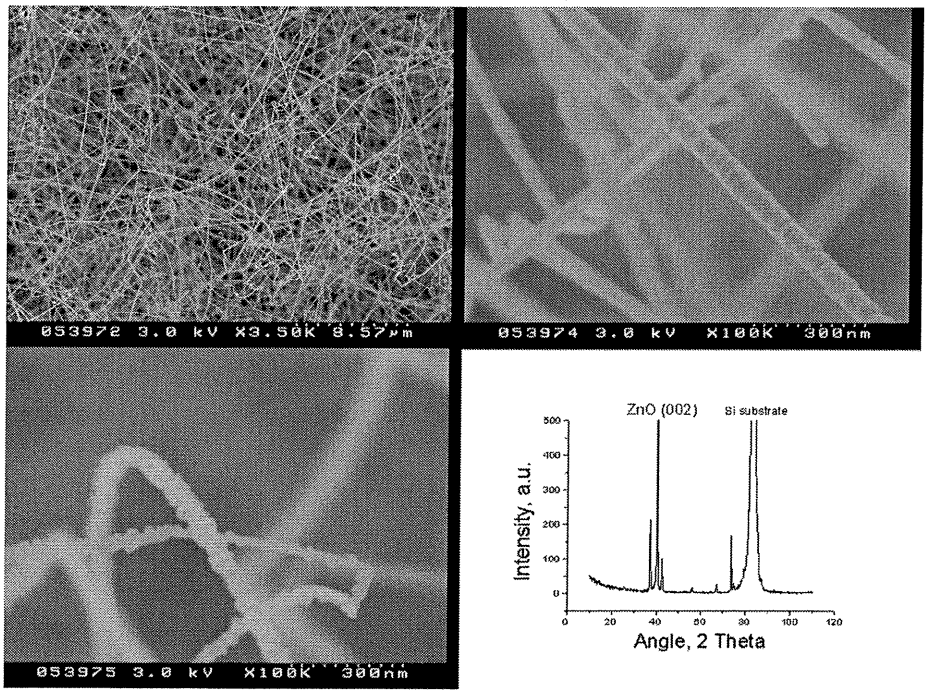

Fig.3. SEM images and XRD pattern of ZnO nanowires produced from the milled sample

The morphology of ZnO nanowires produced from the milled sample (fig.3) is very similar to that obtained from the unmilled ZnO powder. However, XRD pattern is quite different and the (002) diffraction peak is much stronger than any other peak suggesting a preferential growth of the (002) planes. Weight loss measurements of starting powders showed that the weight loss of source material was about 3 times higher (15.7 wt. %) for the milled sample.

In summary, mechanical milling at room temperature modifies vaporization behavior of ZnO powder. The morphology of ZnO nanowires obtained from milled and unmilled samples is similar but a higher yield is achieved from the milled sample. Nanowires grown from the milled powder have a preferential [001] growth direction.

Acknowledgments

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References

[1] G.-C. Yi, C. Wang and W. Park, *Semicond. Sci. Technol.* **20**, S22 (2005)
[2] R.S. Friedman, M.C. McAlpine, D.S. Ricketts, D. Ham, C.M. Lieber, *Nature*, **434**, 1085 (2005)
[3] M.H. Huang, S. Mao, H. Feick, H.Q. Yan, Y.Wu, H. Kind, E. Weber, R. Russo, P.D. Yang, *Science* **292**, 1897 (2001)
[4] Y. Chen, M. Conway, J.S. Williams, J. Zou, *J. Mater. Res.*, **17**,1896 (2002)
[5] L.W. Yin, Y. Bando, M.S. Li, Y.X. Liu, Y.X. Qi, *Adv. Mater.*, **15**, 1840 (2003)
[6] J.S. Lee, K.S. Park, M.I. Kang, I.W. Park, S.W. Kim, W. K. Cho, H.S. Han, S. Kim: *J. Cryst. Growth*, **254**, 423 (2003)