CuO Nanowires by Oxidation Reaction

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ABSTRACT

CuO nanowires were prepared by an oxidation reaction. For oxidation reaction, a copper plate was heated in a furnace tube under a normal atmosphere. The heating temperature was varied from 400, 500 and 600°C. The nanowires were then characterized by Field Emission Scanning Electron Microscope (FE-SEM), Energy Dispersive Spectroscopy (EDS) and Transmission Electron Microscope (TEM) for morphology, chemical composition and crystal structure, respectively. After heating, the color of the copper plate turned black. It was found that the black products were the copper CuO which exhibited nanostructure with a diameter ranging from 100–300 nm. The diameters of CuO nanowires was about 100 nm at the heating temperature of 400°C and about 200–300 nm at 500–600°C. Moreover, from cross-section of FE-SEM image, it suggested that the growth process began with the formation of thin layer of Cu_2O, then thick layer of CuO and finally, CuO nanowires.

Key words: CuO nanowires, Oxidation reaction

INTRODUCTION

CuO is a p-type metal-oxide semiconductor with a narrow band gap of 1.2 eV and a monoclinic crystal structure. It has received much attention due to a wide range of potential applications such as photoconductive, photothermal, catalysis and gas sensor (Hu et al., 2003). Also, CuO is an important building block of most high-temperature superconductors.

Recently, research community has a great interest on the nanostructures. The nanostructures would open new potential applications due to the distinctive and novel properties from conventional bulk materials. For example, the band gap of CuO nanoparticles (E_g= 2.43 eV) is much larger than that in bulk CuO (Huang et al., 2004).

CuO nanostructures can be synthesized by various techniques such as thermal evaporation (Huang et al., 2004), thermal decomposition (Xu et al., 2002) and oxidation (Xu et al., 2004(b)). The oxidation technique is a simple, cheap and most commonly used for the synthesis of CuO nanostructures.

Huang and co-workers (Huang et al., 2004) synthesized CuO nanowires by thermal evaporation of copper foil in O_2 ambient at the temperature from 300°C to 900°C. The diameter of nanowires was about 40–150 nm. Xu and co-workers (Xu et al., 2002) synthesized CuO nanorods by thermal decomposition of CuC2O4. The results showed that the nanorods were composed of CuO with diameter of 30–100 nm, and length ranging from 1 to 3 μm. XU and co-workers (Xu et al., 2004(a)) prepared CuO nanowires from copper foils, oxidized in wet air at temperatures between 300 and 800°C. The nanowire diameter was between 50 and 400 nm.

Here, we report on the preparation of CuO nanowires by oxidation reaction via heating of a copper plate.

MATERIALS AND METHODS

The commercial copper plate (commercial grade), about 2 cm x 4 cm, was cleaned by acetone and heated to temperature of 400°C, 500°C and 600°C in air at atmospheric pressure for 6 hr. After oxidation reaction via heating, the copper plate was immediately taken from the furnace and cooled down in air. The obtained CuO nanowires were characterized by Field Emission Scanning Electron Microscope (FE-SEM), Energy Dispersive Spectroscopy (EDS) and Transmission Electron Microscope (TEM) for morphology, chemical composition and crystal structure, respectively.

RESULTS AND DISCUSSION

After heating, the color of the copper plate turned black. The black products were investigated by FE-SEM and the images of the black products heated at 400, 500 and 600°C as shown in Figure 1. Clearly, the black products exhibited nanostructure with diameter ranging from 100–300 nm. The diameter of nanowires was about 100 nm at heating temperature of 400°C and about 200–300 nm at 500–600°C. Higher heating temperature led to larger diameter of nanowires because higher temperature means higher energy given which results in more oxidation.

Figure 2 (a) and (b) shows FE-SEM cross-section images of CuO nanowires, heated at 600°C, at x1,000 magnification and x5,000 magnification, respectively. Typically, three zones can be observed on copper plate. The first layer is a red and thick layer. The second layer is black with the thickness of 6 μm. The topmost layer is the zone of black nanowires black layer. EDS was performed on each zone and the measured EDS spectra are shown in Figure 3 (a) and (b) for the topmost layer and first layer, respectively. EDS spectrum on the second layer is similar to the EDS spectrum of nanowires. The atomic ratio of copper and oxygen obtained from the EDS spectrum is 42:58 for the topmost layer and 55:45 for the second layer which can be approximately assigned to CuO and Cu_2O layer, respectively. Therefore, the thick Cu_2O layer should firstly be formed on copper plate, followed by the formation of CuO layer and then CuO nanowires was finally formed on CuO layer. However, the growth mechanism of CuO nanowires remains to be investigated.

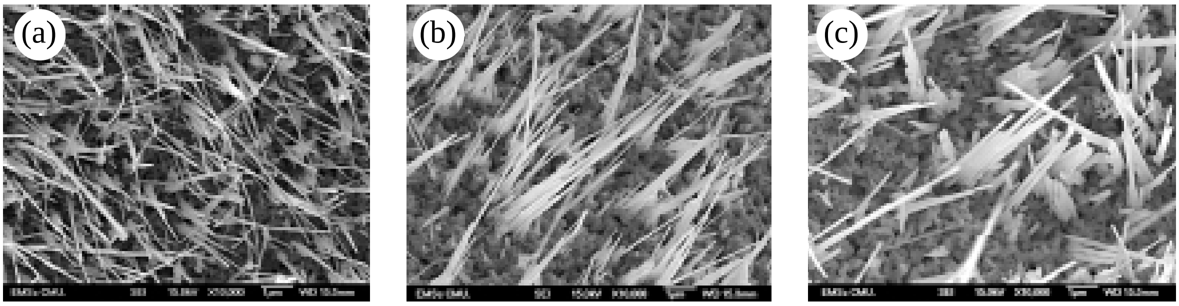

Figure 1. FE-SEM images of CuO nanowires oxidation at temperature (a) 400°C, (b) 500°C and (c) 600°C.

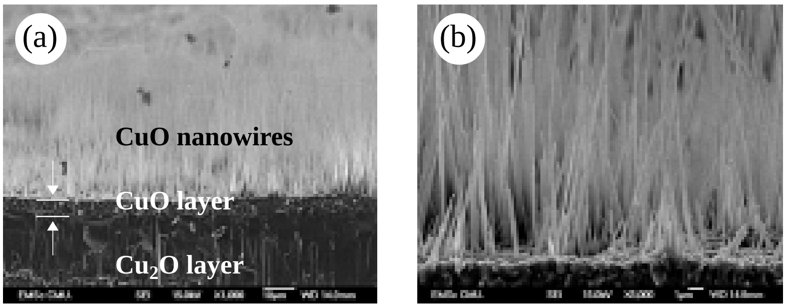

Figure 2. FE-SEM cross section images of CuO nanowires heated at 600°C (a) at low magnification (x1,000) and (b) at higher magnification (x5,000).

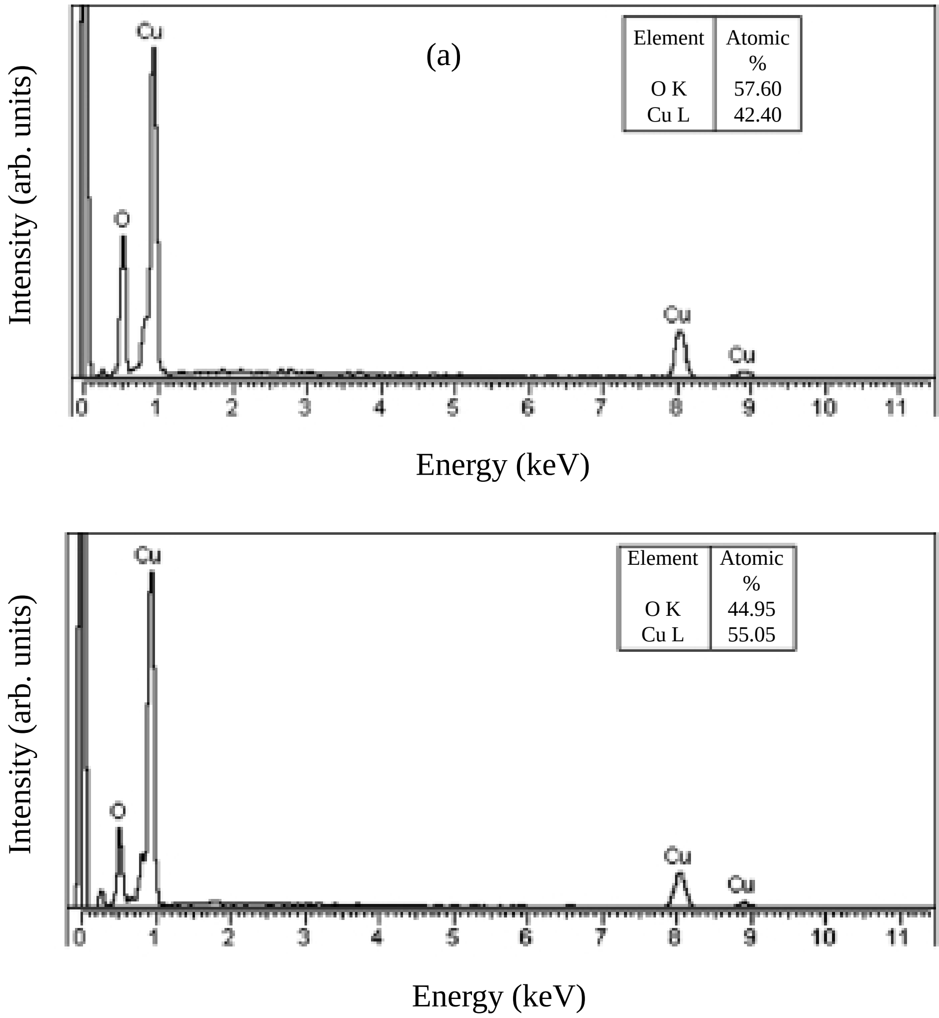

Figure 3. EDS spectra of (a) CuO nanowires and (b) Cu_2O layer.

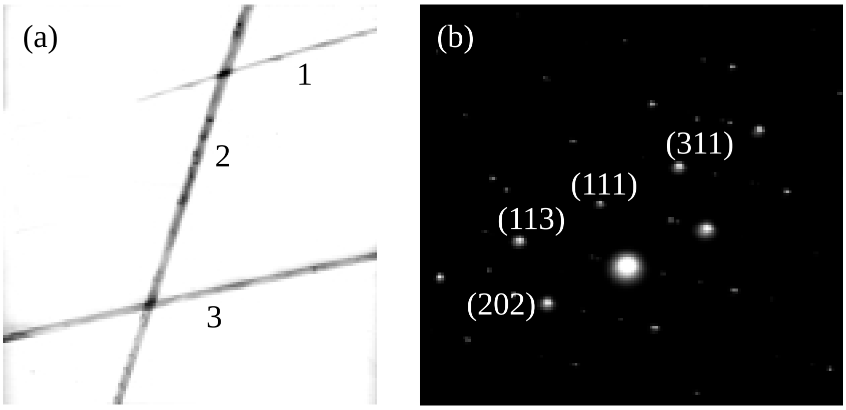

Figure 4. (a) TEM bright field image of CuO nanowires heated at 600°C and (b) the associated SADP of the wire marked 2.

Figure 4 (a) shows TEM bright field image of CuO nanowires heated at 600°C with the associated SADP in Figure 4 (b). The three lines of wire-like structure can be observed from TEM image. The SADP of the wire marked 2 of CuO nanowire shows a spot pattern, indicating a single-crystalline property of the nanowire which corresponds to the monoclinic structure of CuO with the lattice constants, a = 4.7 Å, b = 3.4 Å and c = 5.1 Å, and the spots can be indexed as shown in Figure 4 (b). The SADP also confirms the EDS result that the nanowire is CuO.

CONCLUSION

CuO nanowires were successfully prepared by an oxidation reaction. For oxidation reaction, a copper plate was heated in a furnace tube under normal atmosphere at heating temperature of 400, 500, and 600°C. After heating, the color of the copper plate turned black. It was found that the black products were copper CuO and exhibited nanostructure with diameter ranging from 100–300 nm. The diameter of CuO nanowires was about 100 nm at heating temperature of 400°C and about 200–300 nm at 500–600°C. From cross-section of FE-SEM image, it suggested that the growth process began with the formation of thin layer of Cu_2O, then thick layer of CuO and finally, CuO nanowires. Moreover, from TEM analysis, the CuO nanowires exhibited single-crystalline property with monoclinic structure.

ACKNOWLEDGMENTS

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