

Synthesis and Characterization of CuO Nanowires and Nanobelts

William C. Lowes and Jingyue (Jimmy) Liu

Center for Nanoscience and Department of Physics and Astronomy, University of Missouri-St. Louis, One University Boulevard, St. Louis, Missouri 63121, USA (Email: liuj@umsl.edu)

With a narrow band gap of 1.2eV the p-type semiconductor CuO possesses interesting physicochemical properties; it is a Mott insulator, has unique magnetic properties and has potential applications in micro-devices, field emission, heterogeneous catalysis, energy storage and sensing. Although CuO nanostructures can be synthesized via chemical routes [1] nanowires of CuO have been produced by simply oxidizing Cu in air or oxygen environment [2-3]. The proposed oxidation process consists of two steps: first Cu is oxidized to Cu₂O and then the Cu₂O is further oxidized to CuO [2]. The detailed growth processes of CuO nanowires by direct oxidation of Cu, however, are not completely understood. Two growth mechanisms have been proposed: vapor-solid growth process [2] and stress-induced growth process [3]. In this paper, we report study of the growth processes of CuO nanowires, their dependence on the experimental parameters and the unusual growth of large CuO nanobelts by direct thermal oxidation of various Cu substrates.

Copper turnings, coupons or films were used as Cu substrates to grow CuO nanowires. Simply, various Cu substrates were put inside a tube furnace reactor (filled with air or oxygen) and the furnace was heated to the desired temperatures for a certain period of time. We have tested many experimental parameters such as oxidation temperature, types of substrates with various surface treatments and the residence time for oxidation. After thermal oxidation inside the tube furnace all the Cu substrates turned black in color and the outside black film can be easily flaked off. A field emission SEM equipped with an energy dispersive X-ray spectrometer and a Robinson backscattered electron detector was used to characterize the morphology, composition and size distribution of the fabricated CuO nanostructures.

Figure 1a shows a SEM image of Cu turnings after heating in air at 450°C for two hours. Many CuO nanowires were uniformly grown out of the Cu substrate. The diameters of the CuO nanowires range from 40 nm to 150 nm with a average diameter of about 100 nm and their lengths range from 0.5 μm to 6 μm with a average length of about 2.5 μm. SEM Cross-sectional examination and EDS analysis revealed the presence of a thick layer of CuO/Cu₂O right below the CuO nanowires. It is not clear why certain regions (labeled by A) of the polycrystalline Cu substrates grew less CuO nanowires than other regions did (labeled by B). Figure 1a also shows the presence of large CuO nanobelts which are clearly shown in the plan-view image of figure 1b. The lengths and widths of these nanobelts are much longer and wider than those of the nanowires; their thicknesses, however, can be as thin as 10 nm or less. Figure 2a shows a SEM image of the same type of Cu turnings after heating in air at 450°C for 10 hours. The average diameter and the length of the CuO nanowires grew to about 150 nm and 6 μm, respectively. Some of the nanowires grew as long as 15 microns; their diameters, however, did not increase much. Figure 2b reveals the presence of large CuO nanobelts after 10 hours of oxidation at 450°C; the SEM image shows that the CuO nanobelts did not grow much after 8 more hours of oxidation. After about 20 hours of oxidation at 450°C, some of the very thin CuO nanowires grew as long as about 100 μm as clearly shown in the SEM image of figure 3. The growth processes of the CuO nanowires and nanobelts and their dependence of the experimental parameters will be discussed [4].

References

- [1] X. Song, H. Yu and S. Sun, *J. Colloid and Interface Science* 289 (2005) 588.
- [2] X. Jiang, T. Herricks and Y. Xia, *Nano Lett.* 2 (2002) 12.
- [3] A. Kumar, et. Al, *J. Phys.: Condens. Matter.* 16 (2004) 8531.
- [4] The authors acknowledge the funding of this research by the University of Missouri-St. Louis.

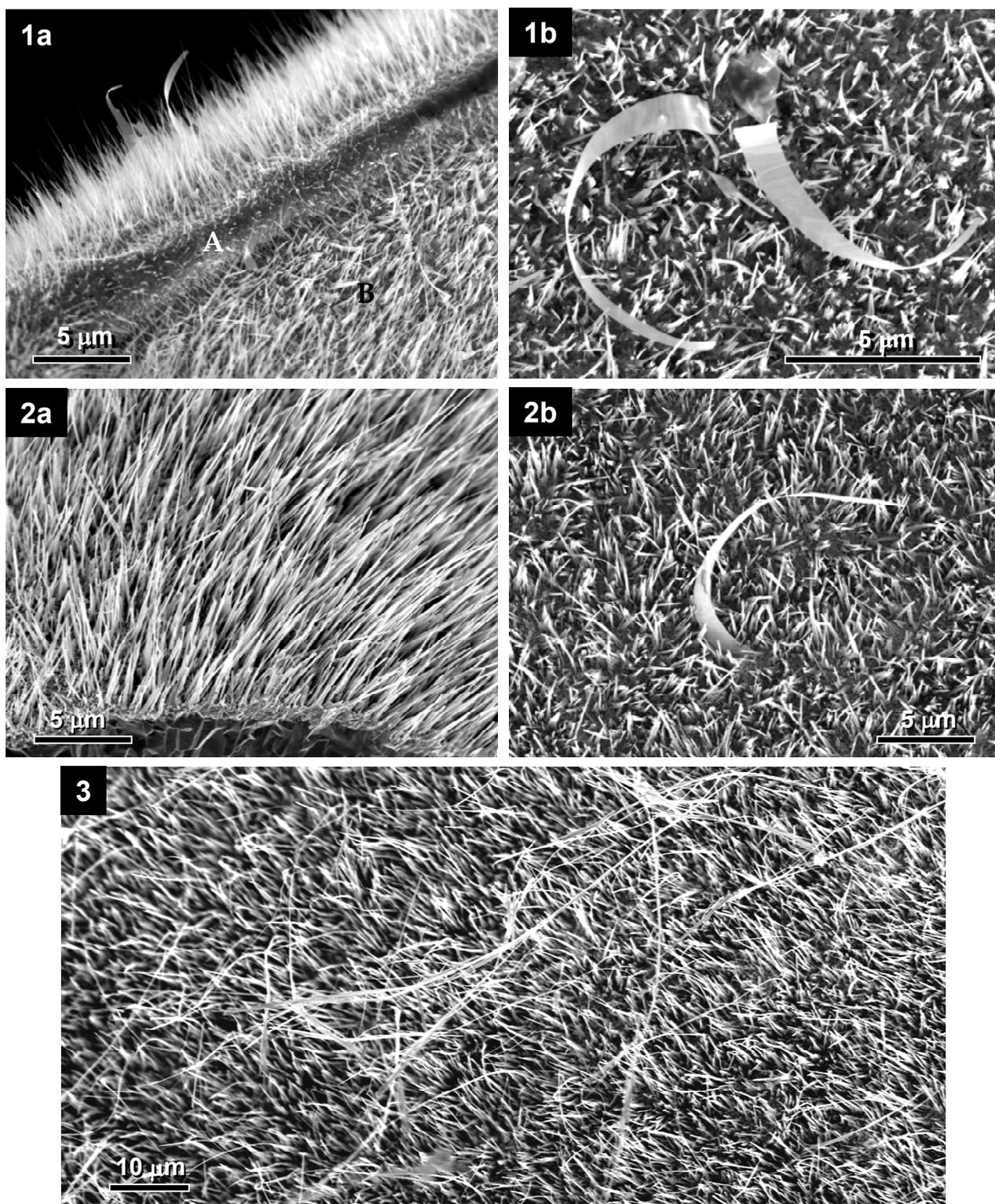


Figure 1. SEM image of CuO nanowires (a) and nanobelts (b) after 2 hours of oxidation at 450°C.
Figure 2. SEM image of CuO nanowires (a) and nanobelts (b) after 10 hours of oxidation at 450°C.
Figure 3. SEM image of CuO nanowires after 20 hours of oxidation at 450°C.