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Surface-grooved ZnO Nanowires and Tetrapods by Physical Vapor Deposition

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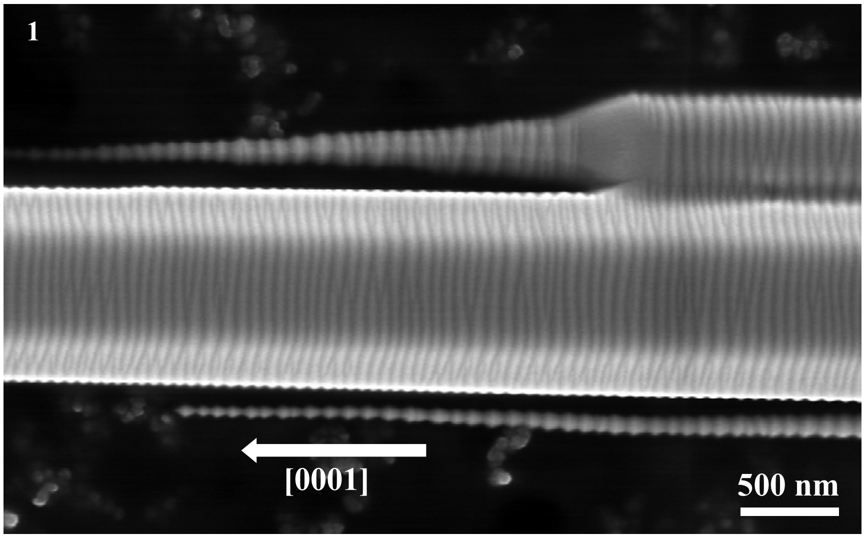
Zinc oxide nanostructures, being biocompatible, biodegradable and less toxic, have attracted significant interests because of its potential applications in diagnostics, treatment and prevention of diseases. One-dimensional (1D) ZnO nanostructures can be functionalized by chemical or biological molecules. To make it easier to functionalize nanowires (e.g., attachment of biomolecular recognition elements or other types of molecules or nanoparticles onto the surfaces of nanowires) it is desirable to fabricate nanowires with rough or corrugated surfaces. Previously, we reported the synthesis of nano-pyramid decorated ZnO microwires/nanowires [2]. We report here the synthesis of ZnO nanowires and tetrapods with grooved surfaces.

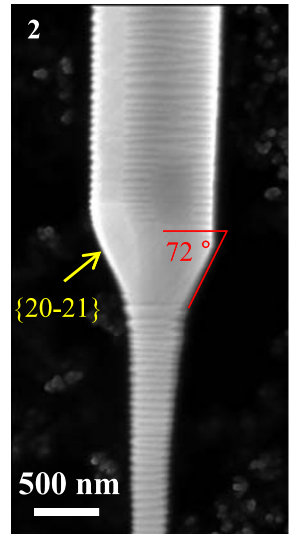
The ZnO nanostructures were synthesized in a high temperature tube furnace by a standard thermal evaporation-condensation process. The experimental setup was similar to those reported in literature [3]. The morphology of the synthesized ZnO nanostructures was characterized by a high-resolution field emission SEM (JEOL JSM-6320F).

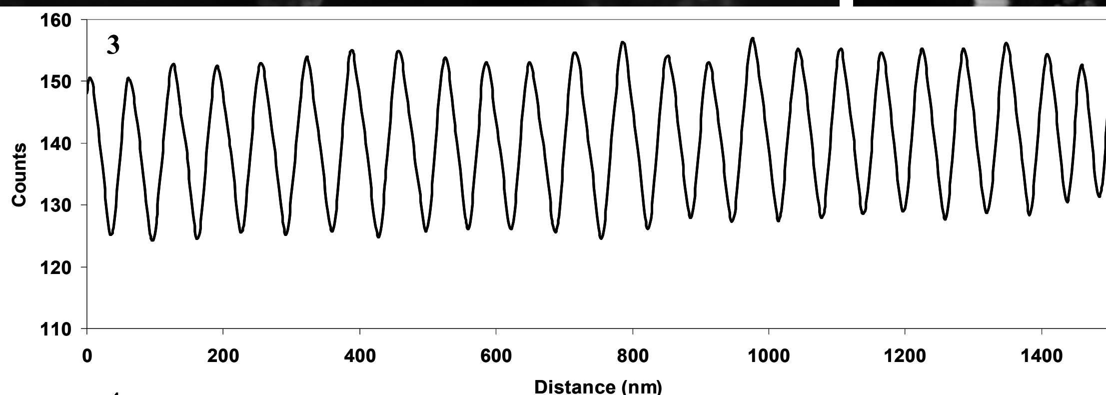
Figure 1 shows a SEM image of the as-synthesized ZnO nanowires, revealing the presence of surface corrugations or grooves on both large and small nanowires. The nanowires grew along the ZnO [0001] direction and the large nanowires usually have a hexagonal cross section. Most of the as-grown nanowires have a pyramid-like transition region between the thicker regions of the nanowire and the thinner regions of the nanowire as clearly shown in Fig. 1 and Fig. 2. The pointed tips of the nanowires shown in Fig. 1 may probably be formed when the furnace temperature was decreased, resulting in less diffusion of the adsorbed molecules, fast nucleation due to drop of temperature, and decrease of molecule flux from the source material. By analysis of many pyramid-like transition regions of grooved nanowires, we estimated that the average basal angle of the pyramidal region (indicated in Fig. 2) is about 72°, which suggests that the pyramidal surface is made up by the ZnO {20-21} planes, in agreement with our previous work [1]. Figure 3 is an intensity profile across the grooves on a nanowire, showing the quasi-periodic nature of the surface grooves with an average pitch distance of about 62 nm. In order to know the pitch distances of the grooves of the whole sample we performed measurements of the pitch distances on many nanowires. Figure 4 shows the histogram of 483 measurements. The mean value of the pitches was measured to be 62 nm and the standard deviation is about 12 nm. The diameter of the nanowires ranges from 0.3 to 2 μm. The tip regions of the nanowires have sizes below about 100 nm in diameter and the average pitch distances are larger, about 74 nm. Such grooved surfaces were also observed on other types of nanostructures such as tetrapods as shown in Fig. 5. The growth mechanism of the grooved surfaces as well as the experimental conditions to synthesize such nanowires will be discussed [3].

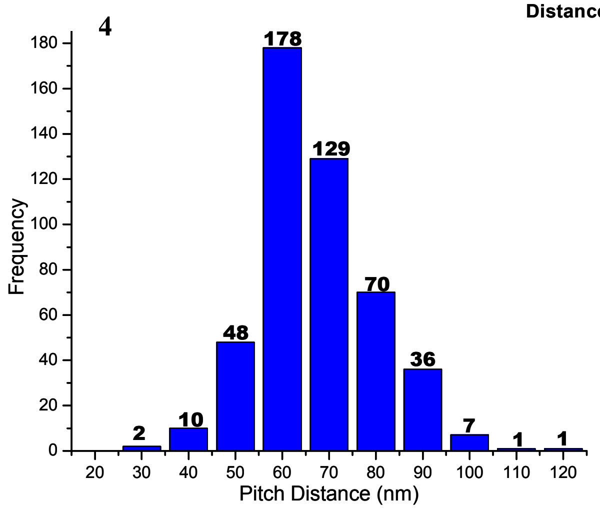
References

[1] D. Tang et al., *Microsc. Microanal.* 15 (Suppl. 2) (2009) 1154.
[2] Z. W. Pan et al., *Science* **291** (2001) 1947.
[3] This research was supported by the University of Missouri-St. Louis.









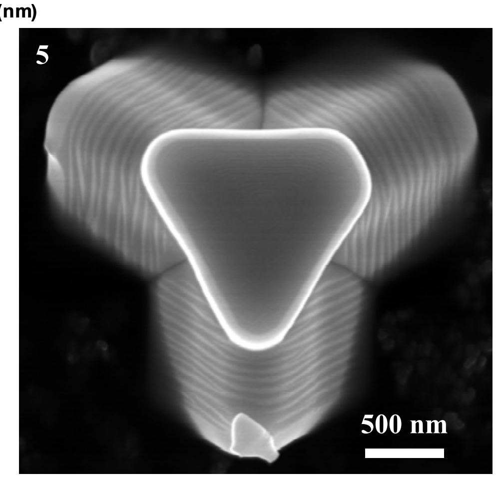


Fig. 1. SEM image shows nanowires with surface grooves.

Fig. 2. SEM image shows the transition region between the two parts of a single crystal nanowire. The inclined transition surfaces are composed of {20-21} planes.

Fig. 3. Intensity line profile across the surface grooves on a nanowire shows the quasi-periodic nature of the grooves with an average pitch distance of 62 nm.

Fig. 4. Histogram of 483 pitch distances measured from many nanowires of various diameters.

Fig. 5. SEM image shows patterned surface grooves on tetrapod surfaces.

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