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Zinc Oxide Combs

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Zinc oxide has been actively pursed because of its great potential for broad device applications [1]. In recent years, the discovery of ZnO nanobelt morphology [2] and the demonstration of room-temperature UV lasing action [3] from ZnO nanowires strongly stimulated the research in one-dimensional (1D) ZnO nanostructures. As a result, a variety of 1D ZnO nanostructures, such as belt-like [2], wire-like [3], tetrapod-like [4], and comb-like [5], were obtained. In this abstract we report the controlled growth of comblike ZnO nanowire assemblies that consist of a periodic array of very uniform, perfectly aligned and evenly spaced ZnO nanowires or nanobelts.

The ZnO combs were synthesized in a tube furnace system [2] by thermal evaporation of commercial ZnO powder at 1350−1450 °C in flowing Ar at a flow rate of 50−200 sccm and a pressure of 50−150 Torr for 0.5−3 h. Systematic growth experiments show that the yield and dimension of the ZnO combs are sensitive to the growth parameters (such as growth time), making it possible to controlled growth of ZnO combs.

Figure 1A shows a typical scanning electron microscopy (SEM) image of the ZnO combs formed by evaporating ZnO powder at 1400 °C for 30 min. Microscale comblike ZnO structures with dense nanowire array growing from the thinner edge of a thick ZnO ribbon were grown in a high yield. The widths and heights of the nanowire arrays can be up to 100 μm and 20 μm, respectively. High-magnification SEM images (Fig. 1B) show that each array usually contains several tens to several hundreds of very straight, perfectly aligned and evenly spaced nanowires with almost constant diameter and spacing. The diameters of the nanowires generally range from 100 to 150 nm and the spacings are 100–250 nm. By simply increasing the growth time, we were able to control the dimensions of the combs and even the shape of the associated nanowires. Figures 1C and 1D show SEM images of the ZnO combs formed after 2-h growth. Distinct from the 30-minute-combs shown in Figs. 1A and 1B, the 2-hour-combs are mainly made of periodic arrays of straight ZnO nanobelts [2] that have a rectangular cross section (insets in Figs. 1C and 1D). Each nanobelt has a uniform width and thickness, and the typical widths and thicknesses are in the range of 200−500 nm and 50−150 nm, respectively. The spacing between the nanobelts for all combs varies in a wide range from 0.2 to 1.5 μm; however, for an individual comb the nanobelts on it are evenly spaced and such uniformity can extend to up to 100 μm wide. The lengths of the belts range from 10 to 50 μm.

Figure 2A is a transmission electron microscope (TEM) image of part of a ZnO comb, displaying parallel, straight, uniform nanobelts growing perpendicularly from one edge of the comb ribbon. The

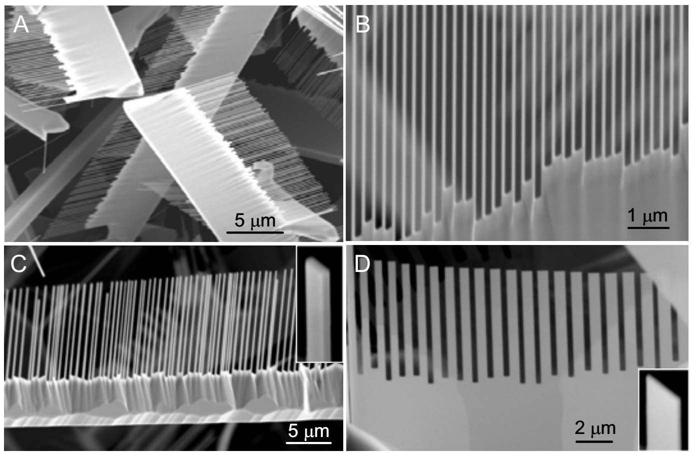

Fig. 1. SEM images of ZnO combs. A. Low-magnification SEM images of ZnO combs formed by evaporating ZnO powder at 1400 °C for 30 min. B. High-magnification image of a ZnO comb having nanowires 100 nm in diameter at a spacing of 150 nm. C and D. ZnO combs formed after 2 h growth, consisting of a periodic array of rectangular ZnO nanobelts. The insets display the rectangular cross section of the nanobelts.

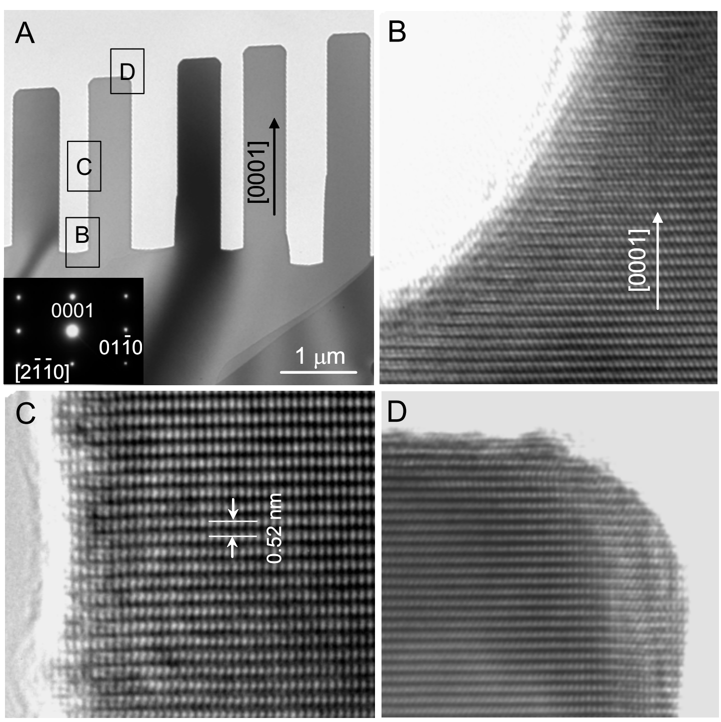

Fig. 2. TEM and high-resolution TEM images of ZnO combs consisted of a ZnO nanobelt array. A. TEM image of a ZnO comb. The inset is an electron diffraction pattern of the entire comb. B to D. High-resolution TEM images recorded in different regions of the comb structure in A.

electron diffraction pattern (inset in Fig. 2A) recorded on the entire comb structure shows that the entire comb is a single crystal with nanobelts growing along [0001]. Figure 2B–D shows high-resolution TEM images taken in different regions on this comb (see Fig. 2A). Such images clearly show the (0001) atomic planes (separation, 0.52 nm) perpendicular to the nanobelt axis, confirming <0001> to be the preferred growth directions for the wurtzite ZnO nanobelts, as well as the single crystalline nature of the entire comb structure. The surfaces of the nanobelt are clean, atomically sharp, and without any amorphous sheathed phase.

The unique ZnO combs might have implications in applications such as diffraction gratings, ultraviolet laser arrays [5], cantilever arrays, and sensor arrays.

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