Functional Materials

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Insight into the structural and electrical properties of individual $BaTiO_3$ nanorods

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One-dimensional $BaTiO_3$ nanostructures in the form of nanorods are a potential candidate for energy-harvester systems and sensors. In order to explore possible potential applications of $BaTiO_3$ nanostructures, we report on the template-assisted growth and the structural characterization of $BaTiO_3$ nanorods, the prototyping of functional devices based on them, and the preliminary assessment of their electrical performances [1].

$BaTiO_3$ nanorods were synthesized using sol-gel electrophoretic deposition (EPD) technique [2]. The stoichiometric $BaTiO_3$ sol was deposited into the anodic aluminium oxide (AAO) template while a potential of 30 V was applied between the AAO/Al working electrode and platinum counter electrode. After the deposition samples were annealed at 700 °C for 1 h with subsequent AAO template removal. Resulting $BaTiO_3$ nanorods were characterized by electron microscopy techniques. To study electrical properties, $BaTiO_3$ nanorod devices were fabricated by focused ion beam nanolithography techniques using $[(CH_3)_3CH_3C_5H_4Pt]$ injector to deposit platinum [3].

Obtained $BaTiO_3$ nanorods had diameters ranging from 150 to 200 nm, with an average length of 10-25 µm. The $BaTiO_3$ nanorods were always polycrystalline and composed of well-crystallized nanosized $BaTiO_3$ grains with a pseudo-cubic structure and grain sizes ranging from 20 to 50 nm (Figure 1(a)). A high-temperature hexagonal $BaTiO_3$ polymorph, that was observed as intergrowth of more or less ordered sequences of (111) twins with the perovskite matrix, was present as a minor phase (Figure 1(b)). Its formation was most probably triggered by reduction of Ti^{4+} to Ti^{3+} as a consequence of the local reducing environment, due to the decomposition of the organic precursors during the annealing process.

For the electrical characterization the prototype device was formed by integration of individual $BaTiO_3$ nanorod into simple circuit architecture. Four-probe electrical measurements performed on individual $BaTiO_3$ nanorods revealed the resistivity values between 10 and 100 ohm·cm, which corresponds to typical values for oxygen-deficient $BaTiO_3$. The measurements of electrical resistivity of single nanorods in varying humidity environment showed reproducible response, thus demonstrating that $BaTiO_3$ nanorods can be integrated in more complex circuit architectures with functional capacities of a humidity nano-sensor (Figure 2).

1. K. Zagar, F. Hernandez-Ramirez, J. D. Prades, J. R. Morante, A. Recnik and M. Ceh, Nanotechnology 22 (2011), p. 385501.
2. K. Zagar, A. Recnik, S. Sturm, A. Gajovic M. And Ceh, Mater. Res. Bull. 46 (2011), p. 366.
3. F. Hernandez-Ramirez, J. D. Prades, R. Jimenez-Diaz, T. Fischer, A. Romano-Rodriguez A, S. Mathur and J. R. Morante, Chem. Phys. 11 (2009), p. 7105.
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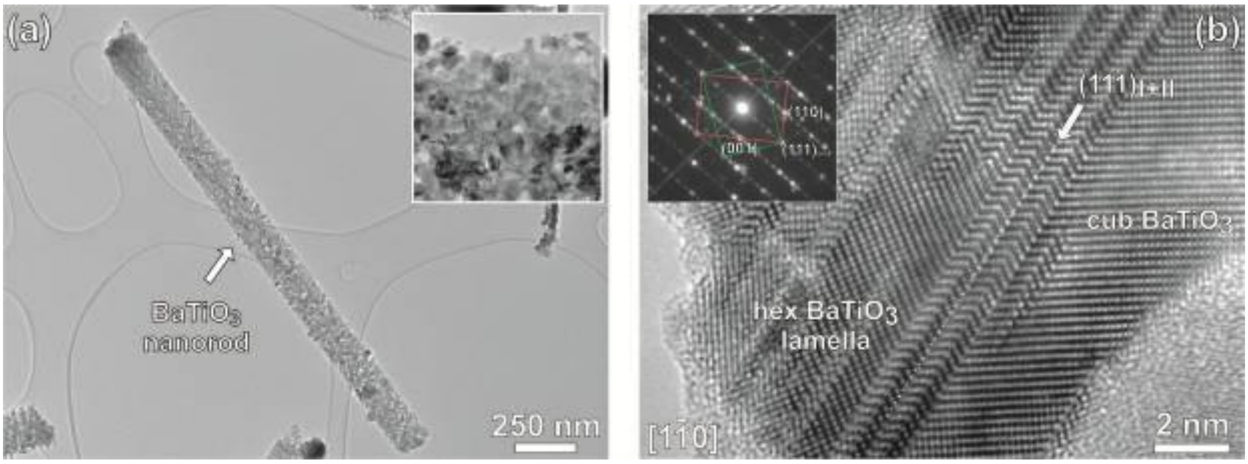

Figure 1. (a) Bright-field image of a uniformly shaped and polycrystalline $BaTiO_3$ nanorod. The inset in the upper right corner shows a higher-magnification bright-field TEM image of polycrystalline $BaTiO_3$ nanorod with grain sizes in the range from 20 to 50 nm. (b) HRTEM image of slabs of hexagonal $BaTiO_3$ polymorph intergrown with cubic $BaTiO_3$ as seen in the $[1\bar{1}0]$ zone axis. The inset presents the SAED corresponding to the hexagonal polymorph.

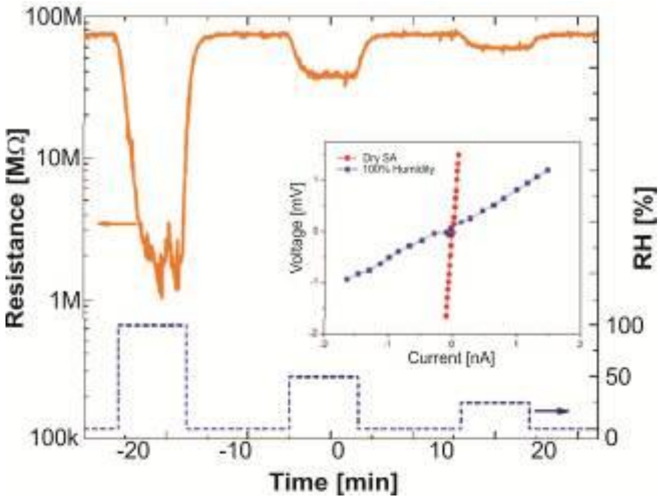

Figure 2. Sensing response of a $BaTiO_3$ nanorod towards pulses of 100, 50 and 25 % of relative humidity (RH) measured at room temperature. Synthetic air was used herein as carrier gas. The inset shows I-V curves obtained in dry and humid (100 % RH) air. A sharp and reversible modulation of the electrical response was observed.