Template-Assisted Self-Assembly and Alignment of ZnO Nanowires with Post-Deposition Growth

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As a direct and wide bandgap semiconducting material, ZnO draws a lot of interests as the candidate for electronic and optoelectronic applications. The large field of applications has led to the demand for building ZnO nanostructures through low-cost bottom-up process to reduce the consumption of raw materials and production energy. Various techniques have been studied to align one-dimensional metal or semiconducting materials, such as electric-field assisted assembly, [1] fluid flow directed assembly, [2] Langmuir-Blodgett technique,[3] pattern transfer process,[4] and optical lithography assisted assembly.[5] In this work, a nanoimprint-assisted self-assembly method is demonstrated for large-scale alignment of ZnO nanowires at predetermined locations.

A thin layer of poly(methyl methacrylate) (PMMA) was spin-coated onto the flexible poly(ethylene terephthalate) (PET) substrate. After performing nanoimprint lithography with a 700 nm period and 350 nm depth mold, reactive-ion etching was applied to remove the residue layer. The PET substrate with PMMA patterns was then immersed into the well-dispersed ZnO nanowires suspension. Commercialized ZnO nanowires with a nominal diameter of 40 nm and a length of 300 nm were purchased from HARP Engineering. The deposition container was placed in an ultrasonic agitator in order to improve the diffusion of ZnO nanowires into the trenches between PMMA protrusions (Figure 1a). After rinsing with de-ionized water, the substrate was blown dry by nitrogen gas and placed in acetone to remove the PMMA template patterns (Figure 1b). Partially aligned ZnO stripe patterns are achieved. For many applications that require high stripe conductivity, further processing is needed to improve the connectivity among the ZnO nanowires within the stripes. To achieve this, ZnO nanowires in the stripes were then used as seeds for post-deposition hydrothermal growth[6], which enlarges each individual ZnO nanowire to improve inter-wire connectivity. As shown in Figure 1c, ZnO nanowires become much larger than their original sizes and were aligned in parallel. Electrical characterization will be performed to evaluate the impact of post-deposition nanowire growth on stripe conductivity. This template-assisted self-assembly of nanowires demonstrates the feasibility to pattern and precisely direct the horizontal growth of inorganic nanocrystals from solution at predetermined locations with post-deposition adjustment, and can be employed into various patterns and dimensions for potential solution-processed electronic and optoelectronic applications.

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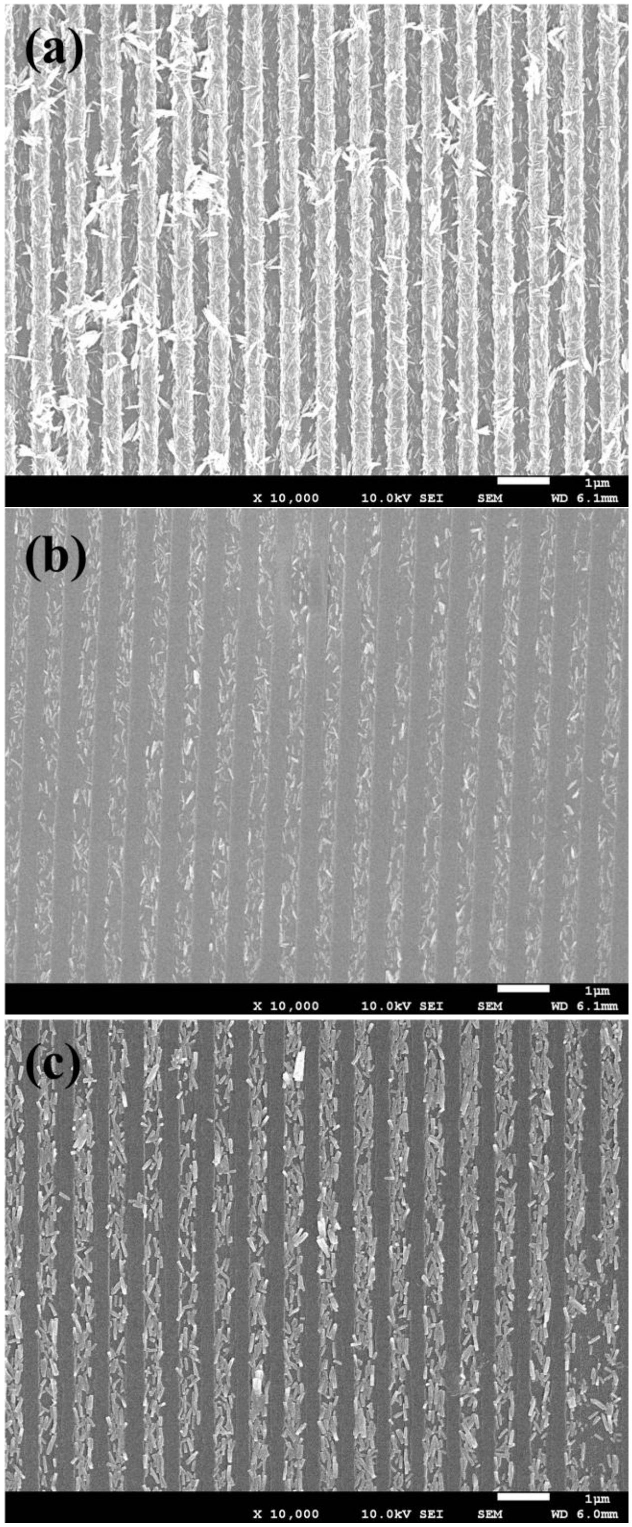

Figure 1. Scanning electron microscopy (SEM) images of template-assisted self-assembly of ZnO nanowires: (a) after ZnO nanowire deposition; (b) after PMMA template removal; (c) after ZnO nanowire post-deposition growth. Scale bars is in 1 μm.