A simplified patterning process for the selective 1D ZnO nanorods growth

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In the last decade, one-dimensional (1D) Zinc Oxide (ZnO) nanorods have drawn much attention due to their remarkable performance in piezoelectric, optoelectronic, and electrochemical applications[1-3]. The ZnO nanorods have been synthesized on various substrates by low temperature seeded hydrothermal growth[4]. Most recently, the integration of ZnO nanorods on two-dimensional (2D) materials have been achieved to develop a novel system with unique properties[5]. However, the patterning and assembling steps of the 1D nanorods to a specific region of 2D materials are relatively complicated, which includes extra etching[6] or the lift-off processes[7] of the patterning ZnO nanorods.

In our work, we introduce a novel patterning method for ZnO nanorods growth, which can avoid any etching steps and longtime lift-off processes. Figure 1 shows the microfabrication steps, ZnO nanorods of the diameter of 50 nm to 200 nm have been grown by the hydrothermal method on an e-beam evaporated ZnO thin film seed layer. The patterning of ZnO seed layer has been achieved both on conventional mask-based and direct-write mask-less photolithography. Normally, before the evaporation of the seed layer, several minutes' oxygen plasma ashing is performed and a Titanium thin film is first deposited to increase the adhesion between photoresist and as-evaporated layer. After hydrothermal growth, nanorods grown on the resists will be lifted off in the solvent for a relatively long time[7]. However, in our simplified processes, the oxygen plasma ashing and the deposition of Titanium are omitted, and the photoresist is treated with an extra hard-bake before the evaporation of seed layer. These processes may attribute to the reduced adhesion between photoresist and ZnO seed layer. As a result, the seed layer may be absent on the photoresist, the ZnO nanorods have been found to grow only on the regions without photoresist. Moreover, the photoresist remains on the substrate after the hydrothermal growth, which can protect areas from the polluted solution and unwanted nanowires. Finally, the photoresist can be removed easily by the solvent without any unwanted damaging of nanorods. Figure 2 shows the comparison between the growth of nanorods on the samples patterned with the normal process (Figure 2.a) and the simplified process with treated resists (Figure 2.b-c). Energy-dispersive X-ray spectroscopy (EDX) has been used to determine the elements of the sample with treated resists after nanorods growth (Figure 3). Additionally, details of the growth processes of ZnO nanorods and devices fabricated based on this method will be presented.

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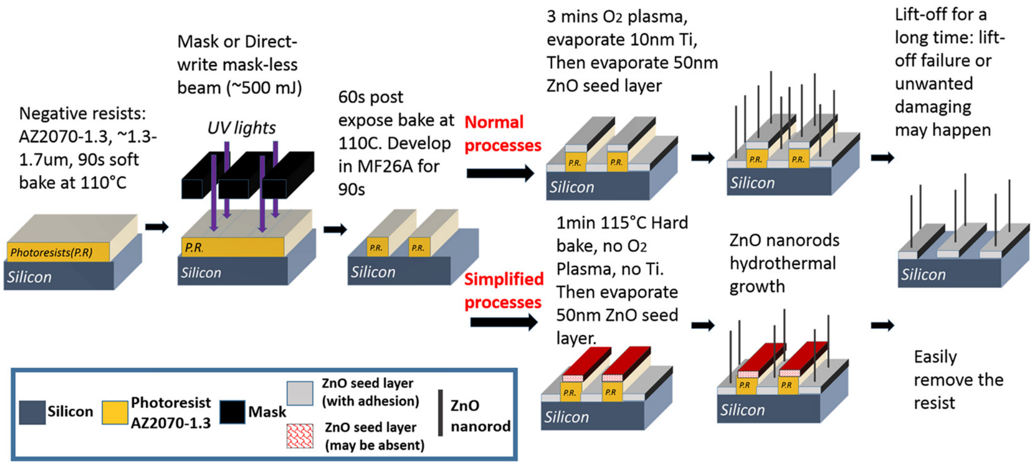

Figure 1. Schematic of microfabrication processes.

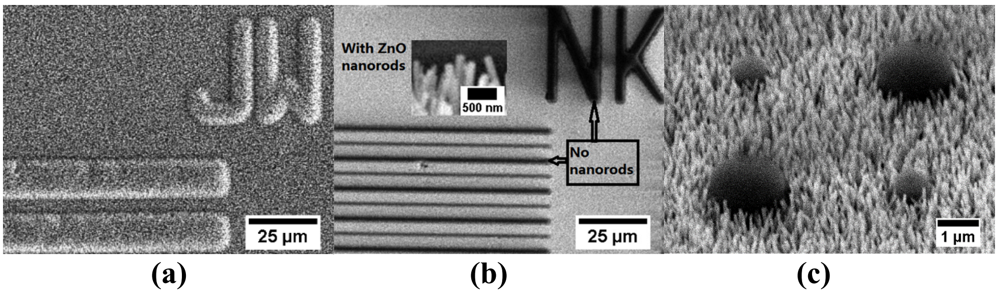

Figure 2. The patterned feature achieved: (a) ZnO nanorods grown everywhere with normal processes; (b-c) ZnO nanorods will not grow on the treated photoresist with different feature sizes.

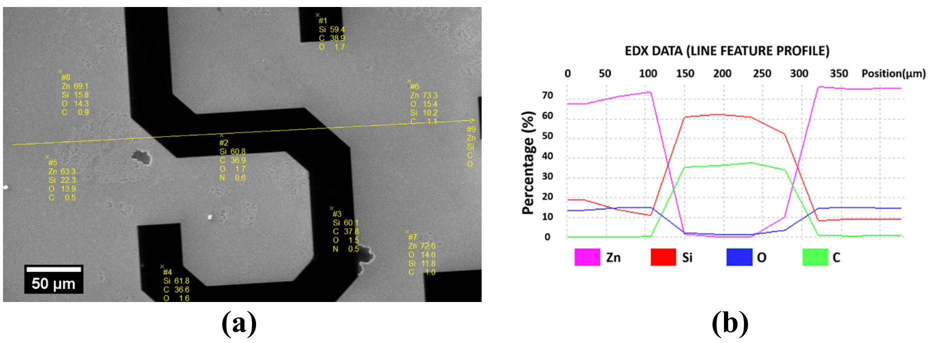

Figure 3. The EDX data for the sample with the treated resist after hydrothermal growth (a) SEM image for the features; (b) Elemental data collected by line scanning shown in SEM image.