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Vertically-Aligned ZnO Nanowire Arrays and Their Application as UV Sensors

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As a direct wide band-gap (3.37eV) semiconductor with a large exciton binding energy (60meV), ZnO is one of the most important semiconductor materials for applications in optoelectronics, sensors, and actuators. For the known one-dimensional (1D) nanomaterials, ZnO nanowires and nanobelts are among the most promising and most extensively studied 1D nanostructures due to their interesting properties. Recently, growth of vertical aligned nanowire arrays have received considerable attention not only for fabricating array of vertical field effect transistors, but more importantly due to their applications in nanogenerators and nanopiezotronics for converting mechanical energy into electrical energy and fabricating piezoelectric-semiconducting coupled devices.

In this work, growth of vertically aligned ZnO nanowire arrays has been systematically attempted on a variety of important semiconductor substrates by vapor-liquid-solid process and excellent results were achieved on SiC and GaN substrates. ZnO (0001) plane has small lattice mismatch (<6%) with SiC (0001) and GaN (0001) planes. The small lattice mismatch between the nanowires and substrates is believed to play a key role in hetero-epitaxial growth of vertically aligned arrays. For nanowires, which have a significant surface to volume ratio, the surface energy dominates nanowires' growth process, especially at their nucleation and initial growth stage. The bigger lattice mismatch results in higher strain energy. Higher strain energy state becomes unstable and other lower strain energy states associated with other ZnO planes can occur, effectively reducing the total energy of the system. However, at our synthesis condition, ZnO nanowires prefer [0001] direction as the fastest growth direction. Thus, if the (0001) plane of ZnO is not the boundary with the lowest energy, ZnO nanowires would have higher possibility to lose the coherence with the substrates, and the fastest (0001) growth direction could point to any random direction. Therefore, vertical aligned ZnO nanowire array is much easier to achieve when there is a small lattice mismatch between ZnO nanowires and substrates.

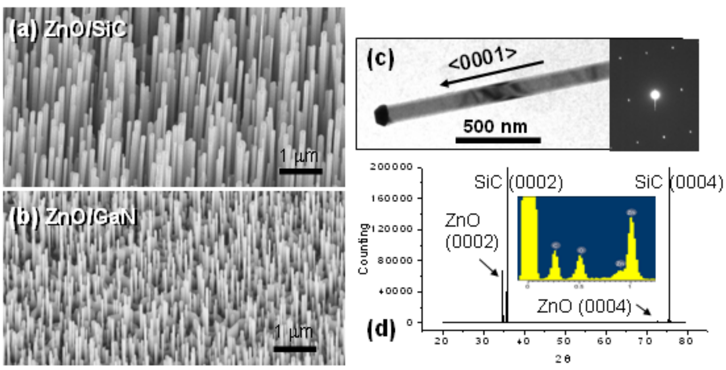

Figure 1: Characterization of ZnO nanowire arrays.

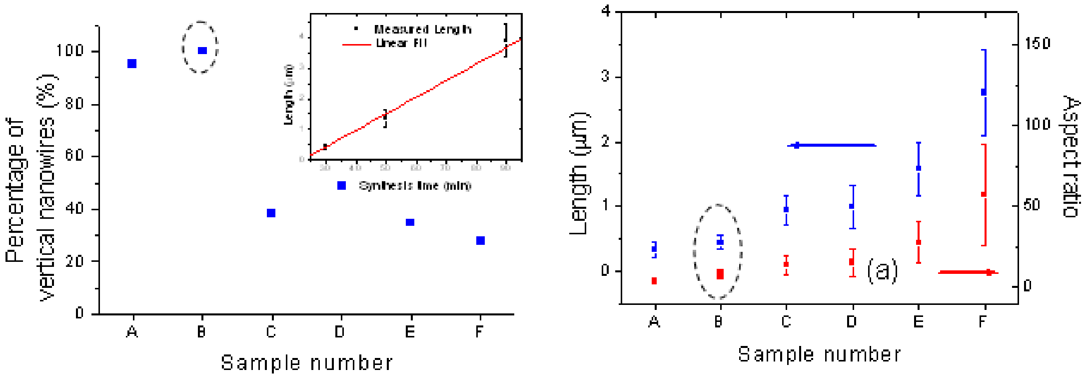

Figure 2: Statistical analysis on synthesis results.

Statistical techniques were employed to investigate some growth related issues, which are essentially important for reliable nanodevice fabrication. In addition, the growth of nanowalls connecting individual aligned nanowires was discussed and growth mechanism was proposed. These conductive and interconnected nanowalls are indispensable for nanodevices fabricated on nonconductive substrates for serving as a common electrode. Finally, these arrays have been integrated as ultra violet detectors and good results were obtained, suggesting a board application of vertically aligned ZnO nanowire arrays.

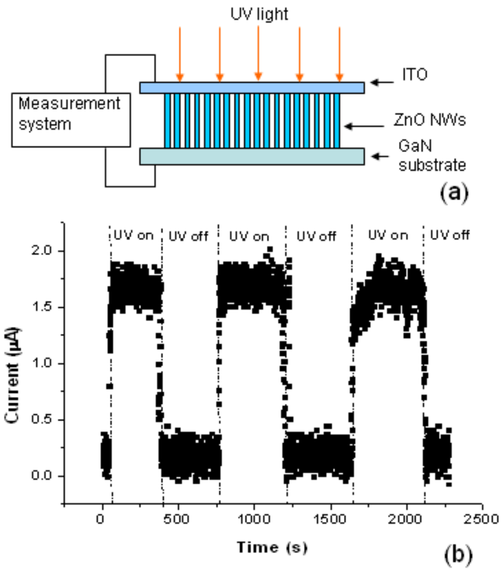

Figure 3: Schematic diagram of an array-based UV sensor and its UV sensing performance.