CONTROLLABLE FABRICATION OF ZINC OXIDE FUNCTIONAL NANO-/MICRO-STRUCTURE IN AQUEOUS SOLUTION

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ABSTRACT

Nanostructures of ZnO show intriguing chemical, electrical, and physical properties and are promising for a broad range of applications in catalysis, electronics and photonics. Cost-effective techniques that can be used to prepare structures with controllable compositional, structural, and functional properties are fundamental to the utilization of ZnO in small scale devices with enhanced performance. Although many methods have been developed to fabricate ZnO nanostructures, systematic research on functional materials development based on ZnO is still needed as this fascinating material probably has the richest family of low-dimensional nanostructures.

The research reported in this thesis aims to develop ZnO-based nanostructural materials using a facile and low-temperature aqueous solution growth approach, to analyze their compositional, mechanical, structural, and functional properties using advanced characterization techniques, to get a better understanding of the mechanisms behind nanostructure growth, and to explore their potentials in catalytic, optical, and electronic applications.

In the first part of this thesis, low-dimensional ZnO nano-/micro-rods with tailored structural property (growth direction, aspect ratio, and surface distribution density) were grown on glass substrates in aqueous solutions containing zinc salt and hexamethylenetetramine at temperatures generally lower than 95^{o}C. The substrates were pre-deposited with a thin layer of ZnO seeds using a magnetron sputter. The potential influences of growth conditions, typically including concentration, pH, type of zinc salt, solution temperature, reaction duration, and inorganic or organic additive, have been subjected to systematic investigation. This led to an improved understanding of the chemical reactions and nucleation/growth processes involved in the morphological evolution of ZnO-based hierarchical nanostructures.

The second part of the thesis, ZnO nano-/micro-rod arrays with controllable distribution density have been successfully synthesized by adjusting the initial pH of the weak acidic growth solution. ZnO arrays with a large inter-rod space provide a good opportunity for

characterizing the property of an individual rod. In this research, mechanical property tests have been successfully peformed directly on a single rod without the need of any complicated sample preparation. The electronic properties of these aligned ZnO nanorod arrays have also been explored by studying the *I-V* characteristics of both heterojuction and homojuction *p-n* devices.

In next two chapters, complex ZnO structures, including nanotubes and three-dimensional ball-shaped clusters have been presented and disscussed, respectively. The morphology and microstructure of these structures were characterized by scanning electron microscopy, transmission electron microscopy, and *in-situ* cathodoluminescence. The corresponding growth mechanisms were proposed based on the analysis of the characterization results.

Chapter 7 describes that aligned ZnO nano-rod arrays were further used as templates to prepare a novel composite nanostructure. By coating these ZnO nanorods with TiO_2 nanowires using magnetron sputtering technique, a ZnO/TiO_2 core-brush structure has been successfully achieved. Their morphology and microstructure have been investigated using scanning electron microscopy, transmission electron microscopy, powder X-ray diffractometer, energy-dispersive X-ray spectroscopy and X-ray Photoelectron Spectroscopy. This composite nanostructure shows a significantly enhanced photocatalytic activity in decomposition of a typical organic dye under UV and sunlight irradiation. This new structure has many other interesting properties and may have great potential in other optoelectronic applications.

In the last part of this thesis, conclutions and future works are addressed according to the synthesis, characterization and application results.

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