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Synthesis and Characterization of GaN/ZnS Nanomaterials

氮化镓和硫化锌纳米材料的制备和性能

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Abstract

Low-dimensional semiconductor compound nanomaterials, such as III-V group GaN and II-VI group ZnS, have attained much interest over the last decade because of their novel properties and expected diverse applications particularly in nanotechnology and optoelectronics. Therefore it is not surprising that nanoscience and nanotechnology are hot topics. Studying nanomaterials is essential for understanding the behavior of these low-dimensional nanomaterials and utilizing their outstanding properties.

This work presents the approaches in synthesis of intrinsic GaN nanowires, GaN nanowires doped with silicon, GaN nanoflakes, ZnS nanoribbons and nanowires. This work is also dedicated to the study of these structures and their properties on nano and atomic levels, and discussion of the relevant growth mechanisms.

Hot-filament chemical vapor deposition (HFCVD) was used to grow III-V group GaN nanowires. Different morphologies of the GaN nanostructures were obtained by synthesis at various temperatures. The GaN nanowires grew optimally on graphite substrates at temperature of 900 °C. Bulk quantities of GaN nanowires doped with silicon grew on Au-coated Si (100) wafers using similar procedure as applied to GaN nanowires prepared on graphite substrates. The GaN nanowires doped with silicon were systematically characterized by scanning electron microscopy, transmission electron microscopy, x-ray diffraction, Raman spectroscopy, and photoluminescence (PL). The analysis shows diameters of nanowires mostly smaller than 10 nm and lengths up to several hundreds micrometers. Since the wire diameters is smaller than the Bohr exciton radius of GaN in most of cases, the quantum confinement effect is evident in the optical and Raman properties of the GaN nanowires. EDX and EELS integrated in a TEM

instrument reveal that the doping level of silicon is 3% and it is uniformly distributed over the whole bulk of GaN nanowires. The GaN nanowires doped with silicon exhibit intense emission peak at 344 nm, which is blue shifted from the peak corresponding to the GaN bulk emission. The blue shift designates the quantum confinement effect. The detailed TEM analysis discloses that the GaN nanowires grow along the [001] crystallographic directions. For this particular case, a possible growth model based on the oxide-assisted metal-catalyst VLS (vapor-liquid-solid) growth of the nanowires is proposed. GaN nanoflakes were fabricated too. Their field emission properties were comparable with the field emission performance of materials traditionally used for electron field emission.

The second scope of this work is synthesis and characterization of ZnS (II-VI semiconductor compound) nanoribbons and nanowires. The ZnS nanoribbons were synthesized in bulk quantities using hydrogen-assisted thermal evaporation at 1100°C. The prepared ZnS nanoribbons are single crystals with uniform and flat morphology. The width and length of the nanoribbons are sensitive to the duration of the deposition process and deposition temperature. Most ZnS nanoribbons are wurtzite structures and have a [120] growth direction. The strong green emission of the nanoribbons, centered at 534.5 nm implies possible exploitation of these nanostructures in nanoscale optoelectronic devices.

This work also claims the first synthesis of ultrafine zinc sulfide (ZnS) nanowires with a sphalerite structure. The ZnS nanowires were synthesized over large areas on Au-coated silicon substrates with high density. The ZnS nanowires prepared at 1050 °C have diameters of 10-20 nm and lengths of several micrometers. These nanowires with a sphalerite structure grow in the [111] direction. Their growth is explained by the VLS

(vapor-liquid-solid) model, in which the deposition temperature is a very important factor for controlling the nanostructures of final products.

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