abstract

The energy band gap of a semiconductor material critically influences the operating wavelength in an optoelectronic device. Realization of any desired band gap, or even spatially graded band gaps, is important for applications such as lasers, light-emitting diodes (LEDs), solar cells, and detectors. New band gaps can be achieved by alloying between two compound semiconductors. Compared to traditional thin films, nanowires offer greater flexibility for achieving a variety of alloy compositions. Furthermore, the nanowire geometry permits simultaneous incorporation of a wide range of compositions on a single substrate. Such controllable alloy composition variation can be realized either within an individual nanowire or between distinct nanowires across a substrate.

This dissertation explored the control of spatial composition variation in ternary chalcogenide alloy nanowires. Nanowires were grown by the vapor-liquid-solid (VLS) mechanism using chemical vapor deposition (CVD). Additional deposition from vapor-solid (VS) growth influenced the nanostructure morphology. The relative contributions of VLS and VS growth were evaluated in terms of gas-phase supersaturation. Growth parameters were extensively investigated and optimized. Composition and structure were characterized by scanning electron microscopy (SEM), transmission electron microscopy (TEM), energy-dispersive x-ray spectroscopy (EDS), and x-ray diffraction (XRD). Optical properties were investigated through photoluminescence (PL) measurements.

The chalcogenides selected for study in this dissertation were lead sulfide (PbS), cadmium sulfide (CdS), and cadmium selenide (CdSe). First, the growth modes of PbS were unified, and the resulting wires were capable of lasing with wavelengths over 4000 nm, representing the longest known wavelength from a sub-wavelength wire. Then, CdS was integrated into the growth of PbS to form Cd\textsubscript{x}Pb\textsubscript{1-x}S alloy nanowires. It was established that the cooling process significantly affects the alloy composition and structure. Quenching was critical to retain metastable alloys with x up to 0.29, a new composition for nanowires. Alternatively, gradual cooling permitted phase segregation, which generated heterostructure configurations with light emission in both the visible and mid-infrared (IR) regimes. The CdS-CdSe alloy system was explored both for composition grading across a substrate, which led to the fabrication of a variable-wavelength photodetector, and as individual axial heterostructure nanowires, which have future applications in color-tunable LEDs.