Materials Science and Engineering Doctoral Defense

Evaluation of Compound Semiconductors for Infrared Photo-detection Applications

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abstract

In this dissertation research, conventional and aberration-corrected (AC) transmission electron microscopy (TEM) techniques were used to evaluate the structural and compositional properties of thin-film semiconductor compounds/alloys grown by molecular beam epitaxy for infrared photo-detection. Imaging, diffraction and spectroscopy techniques were applied to TEM specimens in cross-section geometry to extract information about extended structural defects, chemical homogeneity and interface abruptness. The materials investigated included InAs1-xBix alloys grown on GaSb (001) substrates, InAs/InAs1-xSbx type-II superlattices grown on GaSb (001) substrates, and CdTe-based thin-film structures grown on InSb (001) substrates.

The InAsBi dilute-bismide epitaxial films were grown on GaSb (001) substrates at relatively low growth temperatures. The films were mostly free of extended defects, as observed in diffraction-contrast images, but the incorporation of bismuth was not homogeneous, as manifested by the lateral Bi-composition modulation and Bi-rich surface droplets. Successful Bi incorporation into the InAs matrix was confirmed using lattice expansion measurements obtained from misfit strain analysis of high-resolution TEM (HREM) images.

Analysis of averaged intensity line profiles in HREM and scanning TEM (STEM) images of the Ga-free InAs/InAs1-xSbx type-II strained superlattices indicated slight variations in layer thickness across the superlattice stack. The interface abruptness was evaluated using misfit strain analysis of AC-STEM images, electron energy-loss spectroscopy and 002 dark-field imaging. The compositional profiles of antimony across the superlattices were fitted to a segregation model and revealed a strong antimony segregation probability.

The CdTe/MgxCd1-xTe double-heterostructures were grown with Cd overflux in a dual-chamber molecular beam epitaxy with an ultra-high vacuum transfer loadlock. Diffraction-contrast images showed that the growth temperature had a strong impact on the structural quality of the epilayers. Very abrupt CdTe/InSb interfaces were obtained for epilayers grown at the optimum temperature of 265 °C, and high-resolution imaging using AC-STEM revealed an interfacial transition region with a width of a few monolayers and smaller lattice spacing than either CdTe or InSb

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