Materials Science and Engineering Doctoral Defense

Characterization of the Structural and Optical Properties of III-V Semiconductor Materials for Solar Cell Applications

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abstract

The work contained in this dissertation is focused on the structural and optical properties of III-V semiconductor structures for solar cell applications. By using transmission electron microscopy, many of their structural properties have been investigated, including morphology, defects, strain relaxation, etc. The optical properties of the semiconductor structures have been studied by photoluminescence and cathodoluminescence.

Part of this work is focused on InAs quantum dots (QDs) embedded in AlGaAs matrices. This QD system is important for the realization of intermediate-band solar cells which has three light absorption paths for high efficiency photovoltaics. The suppression of plastic strain relaxation in the QDs shows a significant improvement of the optoelectronic properties. A partial capping followed by thermal annealing step is used to achieve spool-shaped QDs with a uniform height following the thickness of the capping layer. This step keeps the height of the QDs below a critical value that is required for plastic relaxation. The spool-shaped QDs exhibit two photoluminescence peaks that are attributed to ground and excited state transitions. The luminescence peak width is associated with the QD diameter distribution. An InAs cover layer formed during annealing is found responsible for the loss of the confinement of the excited states in smaller QDs.

The second part of this work is focused on the investigation of the InxGa1-xN thin films having different bandgaps for double-junction solar cells. InxGa1-xN films with $x \leq 0.15$ are grown by metal organic chemical vapor deposition. The defects in films with different indium contents are studied. The effect of the defect on the optical properties of the film are investigated by cathodoluminescence. InxGa1-xN films with indium contents higher than 20% are grown by molecular beam epitaxy. The strain relaxation in the films are measured from the electron diffraction pattern taken in a cross-sectional direction. Moiré fringes in some of the films reveal interfacial strain relaxation that is explained by a critical thickness model.

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