ABSTRACT

III-V multijunction solar cells have demonstrated record efficiencies with the best device currently at 46% under concentration. Dilute nitride materials such as GaInNAsSb have been identified as a prime choice for the development of high-efficiency, monolithic, lattice-matched multijunction solar cells as they can be lattice-matched to both GaAs and Ge substrates and offer bandgaps in the 1-eV range. Multijunction cells using dilute nitrides have demonstrated efficiencies of 44% for terrestrial concentrators, and with their upright configuration they are a direct drop-in product for today’s space and concentrator solar panels. The work presented in this dissertation focuses on the development of dilute nitride antimonide (GaNAsSb) materials and solar cells – distinct from the more usual GaInNAs compositions – grown using plasma-assisted molecular beam epitaxy, coupled with modeling and characterization of single- and multijunction solar cells.

N-free ternary compounds such as GaInAs and GaAsSb were investigated first in order to understand their structural and optical properties prior to introducing nitrogen. The formation of extended defects and the resulting strain relaxation in these lattice-mismatched materials is investigated through extensive structural characterization. Temperature- and power-dependent photoluminescence revealed inhomogeneous distribution of Sb in GaAsSb films leading to carrier localization effects at low temperatures. Tuning of the growth parameters was shown to suppress these Sb-induced localized states.

Nitrogen was then introduced and the growth process was optimized to obtain high quality GaNAsSb films lattice-matched to GaAs. Near 1-eV single-junction GaNAsSb solar cells were produced. The best devices used a p-n heterojunction configuration and demonstrated a current density of 20.8 mA/cm², a fill factor of 64 % and an open-circuit voltage of 0.39 V,
corresponding to a bandgap-voltage offset of 0.57 V, comparable with the state-of-the-art for this type of solar cell. Post-growth annealing was found to be essential to improve $V_{oc}$ but was also found to degrade the material quality of the top layers. Alternatives are discussed to improve this process. Unintentional high background doping was identified as the main factor limiting the device performance. Bi-surfactant mediated growth is proposed for the first time in this material system to reduce this background doping and preliminary results are presented.