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Improvement of III-V dilute nitride thin films for solar cell application: Effect of antimony doping

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Highly mismatched alloys such as GaNAs demonstrate exotic electronic properties such as the splitting of the conduction bands (CB) into E_- and E_+ sub-bands, and make them promising for novel application. However, the incorporation of nitrogen atoms in the host GaAs severely degrades the electro-optical properties of this alloy with added challenges of the precise control of the compositions. Here we focus on the effect of Sb doping on the compositional and electro-optical properties of GaNAs thin films grown by molecular beam epitaxy. Sb has enhanced the nitrogen incorporation rate significantly, and the precise control of the group-V atoms (N,As,Sb) is performed using a simple equation based on surface reaction model. While there were no distinguishable effect of Sb addition on the electro-optical properties of the E_+ bands in GaNAs strained layers studied by laser-modulated photo-reflectance (PR) spectroscopy, marked improvement was observed when Sb was added to lattice-matched GaInNAs thin films. It is revealed that the N incorporation rate in both the GaInNAs and GaNAs system is affected by the Sb adatoms in the same manner. PR spectroscopy also revealed that the impact of Sb addition was significant on the epitaxial quality of the overgrown thin films that accompanied increased abruptness around the GaNAs/GaAs hetero-interfaces. While deep localized states dominated the photo-luminescence (PL), and Sb showed only marginal impact on the defect distribution and the PL quality, Sb impact was prominent in improving the transport property of the electron mobility that was ascribed to the reduced potential fluctuation of the E_- band. The rate of potential fluctuation reduction was calculated even faster for the E_+ sub-bands.

Keywords : Dilute nitride semiconductors, highly mismatched alloys, molecular beam epitaxy, carrier localization, phtoreflectance spectroscopy.