

Micro-structural Investigation of InGaAsN Lattice-matched Films Grown on Off-angle Ge (001) Substrates by MOVPE

Thursday 21 May 2015 13:00 (3h 30m)

In this work, the InGaAsN lattice-matched films were grown on off-angle Ge (001) substrates with inclined surfaces of 4° and 6° towards the $[1\ 1\ 0]$ direction. All the samples were grown by metalorganic vapor phase epitaxy (MOVPE) using low temperature (550°C) GaAs buffer layer. To compare the InGaAsN film on on-axis Ge (001) substrate, micro-structural properties of the films on off-angle Ge (001) substrates were investigated by high-resolution X-ray diffraction (HRXRD), Raman scattering, atomic force microscopy (AFM) and transmission electron microscopy (TEM). Since, InGaAsN with about 1-eV bandgap and lattice-matching to Ge is a candidate component material for the InGaP(N)/InGaAs/ InGaAsN/Ge four-junction-structure solar cells. HRXRD $2\theta/\omega$ (004) results showed the Pendellösung fringes which clearly indicate a flat interface and a smooth surface for the InGaAsN films on off-angle Ge substrates. Furthermore, the smooth surface with low RMS roughness was obviously observed by AFM. Cross-sectional dark-field TEM images showed the GaAs buffer layer with a few anti-phase domains (APDs) at the GaAs/Ge interface. And then, APDs-free InGaAsN layer was observed on the off-angle Ge substrates. On the other hand, both the InGaAsN films and the GaAs buffer layers on on-axis Ge substrates demonstrated a high density of anti-phase boundaries. Our results indicate that high structural quality InGaAsN lattice-matched films were successfully grown on the off-angle Ge (001) substrates.

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Session Classification: Poster-3

Track Classification: Material Physics, Nanoscale Physics and Nanotechnology