Abstract

In this work, a comprehensive research has been made to comprehend the effect of different grading schemes and material pathways on the structural properties of In(Al,Ga)As metamorphic buffer layers (MBLs) on GaAs (001) substrate. Samples have been grown by molecular beam epitaxy (MBE) equipped with arsenic valve cracker. Reflection high energy electron diffraction (RHEED) has been used to real-time monitor the growth. High resolution x-ray diffraction (HRXRD), field emission scanning electron microscopy (FESEM), room temperature photoluminescence (RTPL) and atomic force microscopy (AFM) has been employed for structural characterization.

Surfaces of these buffers show grid like pattern called cross-hatch (CH). CH pattern, anisotropic dislocation and relaxation, and epitaxial tilt have been investigated on single layer InGaAs/GaAs heteroepitaxial system. Observed anisotropy in surface features and relaxation has been related to the anisotropic dislocation. Smaller oscillations (having period close to the misfit dislocation line spacing) tagged along larger oscillations in CH pattern has been detected which has been attributed to the lower diffusion of adatoms due to higher strain. Compositionally graded metamorphic buffers (MBs) with three different pathways (InGaAs (A10, A11), InAlGaAs (A12) and InAlAs (A13)) have been grown to comprehend the effect of underlying buffer on the top layer. InGaAs containing MB shows the highest relaxation, which has been related to the peierls force, and smoothest surface, which has been related to the group III adatoms kinetics. Results from HRXRD and PL reveal that underlying buffer influence the indium incorporation provided growth temperature is higher than the congruent sublimation temperatures of adatom species. The modulation in indium incorporation has been correlated with the surface roughness. InGaAs MBs with different grading scheme (continuous (A34), step (A32) and logarithmically step grading (A33)) have been grown to compare the grading schemes. The surface of A33 shows irregular CH pattern. The grading scheme has been found to have little impact on lattice relaxation while it affects the lattice tilt significantly. Both α and β dislocations have contributed to the tilt. Growth front roughness has a great impact on the tilt. Tilt magnitude increases with the grading composition while tilt azimuth remains the same. Continuously graded MB (A34) has shown its superiority in terms of moderate tilt, smoothest surface and greater crystalline quality whereas step graded MBs (A32 and A33) have shown greater lattice relaxation. The crystallographic tilt of InGaAs and InAlAs based MB structures on GaAs (001) substrate grown by MBE under varying growth conditions have been investigated, comprehensively. An HRXRD rocking curve based measurement technique to determine the tilt has been developed which is insensitive to the anisotropic relaxation observed in these MBs. Effect of growth temperature, surface topography and grading scheme on tilt behavior of MBs has been investigated. At low temperature and also for continuously graded samples, reduction of tilt has been observed and correlated with the slower relaxation that provide the opportunity for all the slip systems to participate and compete. At high temperature, tilt becomes zero due to the thermal activation of otherwise inactive slip systems. The grading scheme, one that provides the random growth front, results in lower tilt. The present research will enable us to better understand these MBs which in turn will enable us to fully utilize its potential in the field of electronic and optoelectronic devices.