Abstract

In this thesis, a comprehensive research has been made on the theoretical modeling, realization and characterizations of a newly proposed compositionally graded AlGaN/GaN heterostructure for electronic applications. The improvement has been introduced in theoretical modeling of different kind of existing AlGaN/GaN heterostructures for depletion mode HEMT device applications and the model has been validated through the existing reports. The improvement in device performances in terms of 2DEG carrier concentration, output current and transfer characteristics has been analytically explained and the importance of compositional grading in the heterostructures has been presented. Three different AlGaN/GaN quantum well heterostructures have been grown by PAMBE technique for comparative analysis.

The crystalline quality of the samples has been primarily examined through FESEM and HRTEM measurements. An optimization technique has been performed on the HRXRD scan results of the samples executed in 002 symmetric and 104, 105 asymmetric planes. This technique has allowed accurately determining the Al molar fractions and lattice relaxations of individual AlGaN thin films in the compositionally graded AlGaN epitaxial layers. The measured parameters have been used along with the Mathews-Blakeslee critical thickness model in an alternative way to determine the thicknesses of individual AlGaN thin films. Alternative ways of measuring the coupling coefficient in asymmetric planes and mosaic tilts in AlGaN epitaxial layers have been presented with HRXRD measurements. It has been found that the graded AlGaN/AlN/GaN sample consists of 3.4 nm of $Al_{0.41}Ga_{0.59}N$, 12.6 nm of $Al_{0.33}Ga_{0.67}N$ and 8 nm of $Al_{0.19}Ga_{0.81}N$ epitaxial layers successively from surface to the channel.

Ohmic contact formations on the samples were performed with different metallization schemes. The transport measurements with Hall experiments have confirmed the confined 2DEG carrier concentration of 2.3×10^{13} cm^{-2} with a room temperature carrier mobility of 960 $cm^2v^{-1}s^{-1}$ in the graded AlGaN/AlN/GaN sample.

The proposed theoretical model has been applied using the measured structural and electrical data of the sample and the saturation drain current of the anticipated HEMT device with standard process variables has been predicted to be 1.2 A/mm. The maximum transcoductance was predicted as 180 mS/mm at 8 V drain voltage and a moderately flat transfer characteristic (20% fall upto − 4 V gate bias) was predicted as well. These may suggest that the proposed compositionally graded AlGaN/AlN/GaN quantum well heterostructures have potential application in high power and high linear HEMT device applications.