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Structural and Carrier Dynamics of GaN and AlGaN-Based Double Heterostructures in the UV Region

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Aluminum gallium nitride-based double heterostructures with two different active layer widths have been grown on GaN templates by metalorganic chemical vapor deposition. Crystalline quality has been investigated using high-resolution x-ray diffraction analysis, and screw, edge, as well as total dislocation densities in the GaN epilayer have been calculated. The dislocation density of GaN has been found to be on the order of 10^8 cm^{-2}. The nominal Al composition and in-plane strain ε_{xx} for the AlGaN layer grown on the GaN layer have been measured by asymmetric reciprocal-space mapping. Surface properties and cross-sectional views of the samples have been analyzed using atomic force microscopy (AFM) and field-emission scanning electron microscopy (FESEM), respectively. Room-temperature time-resolved photoluminescence and photoluminescence measurements have been performed on $Al_{0.18}Ga_{0.82}N/Al_{0.45}Ga_{0.55}N$ double heterostructures and the GaN template. The interface recombination velocity (S) of AlGaN-based double heterostructures has been calculated using carrier decay time measurement, increasing from 8.7×10^3 cm/s to 13.4×10^3 cm/s with varying active layer thickness.

Key words: MOCVD, HRXRD, gallium nitride, aluminum gallium nitride, TRPL

INTRODUCTION

The generation, recombination, and transport of minority carriers play a fundamental role in the operation of semiconductor devices. A clear realization of minority-carrier physics and its relation to process technology is essential to the continuous development of III-nitride bipolar devices. The properties of minority carriers are basic to understanding of the physics of III–V semiconductors. Semiconductor interfaces greatly influence minority-carrier transport. Pioneering work by Bardeen[1] pointed out that the potential barrier at a semiconductor interface is controlled more by charges in interface states than by the contact potential difference of the materials.

The carrier lifetime and the photon decay time of bulk GaN,[2–7] $Al_xGa_{1-x}N$,[8,9] and bulk InGaN[2,10,11] have been measured using time-resolved photoluminescence (TRPL). Decay measurements of InGaN single quantum wells (SQWs),[12,13] AlGaN quantum wells,[14–19] $Al_{0.23}Ga_{0.77}N$/GaN heterostructures,[20] and GaN/AlGaN multiple quantum wells (MQWs)[21] have also been carried out. Most of these studies focused on low-temperature exciton dynamics.[2–6] Only a few investigations at room temperature have been reported.[11,12,21] For these studies at room temperature, the carrier recombination mechanism has been found to be dominated by nonradiative channels. Smith et al.[21] suggested that the major radiative transition at room temperature in GaN/AlGaN MQWs was exciton recombination rather than free carrier recombination. Sun et al.[22] presented a well-width-dependent study of InGaN single quantum wells using the time-resolved

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