Optical properties of nonpolar GaN/(AlGa)N multiple quantum wells

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We present a detailed study of the optical properties of non-polar $(11\bar{2}0)$ *a*-plane GaN/(Al,Ga)N multi- quantum well structures (MQWs). Our structures were grown by metal organic chemical vapor deposition (MOCVD) along a nonpolar crystallographic direction. Nonpolar growth is a promising means of circumventing the strong polarization-induced electric fields in wurtzite nitride semiconductors. The total polarization of a III-N film consists of spontaneous and piezoelectric polarizations. Both contributions are quite strong for the conventional growth along the crystallographic single polar [0001] axis of the wurtzite crystal. Polarization discontinuities along this growth direction create fixed sheet charges at surfaces and interfaces. The resulting internal electrical fields spatially separate electrons and hole wavefunctions, thus reducing the oscillator strength for their recombination and lowering their recombination energy. These effects due to the quantum confined Stark effect (QCSE) have been thoroughly analyzed for GaN/(AlGa)N and GaN/InGaN quantum wells [1,2]. Conversely, polarization-induced electric fields should not affect nitride semiconductors grown along nonpolar directions (i.e., perpendicular to [0001] axis) due to the absence of polarization discontinuities along these crystallographic directions [3].

We studied Non-polar $(11\bar{2}0)$ *a*-plane GaN thin films with planar growth surfaces, grown on $(1\bar{1}02)$ oriented, r-plane sapphire substrates. These non-polar films serve as template layers for subsequent growth of AlGaN/GaN structures [4]. The structures contained 10-periods of GaN/($Al_{0.2}Ga_{0.8}$)N MQWs of high quality and sharp interfaces as evidenced by their distinct satellite peaks in high resolution X ray diffraction (HRXRD) measurements. Four different samples were grown with various GaN quantum well widths (nominally from 4 nm to 9 nm) and fixed AlGaN barrier thickness (10 nm) and composition (x=0.2). We used Dynamic diffraction simulations to the HRXRD measurements in order to accurately determine the MQWs dimensions and Al content in the barriers. We investigated the optical properties of these MQWs structures using low temperature photoluminescence (PL), PL excitation (PLE) and time resolve PL (TRPL) measurements. Our measurements were compared with measurements of similar structures grown along the [1000] polar crystallographic direction. We show that the energy of the PL emission from the nonpolar samples gets lower for wider QW widths due to the quantum size effect only, where in polar samples there is also a pronounced effect due to the QCSE [2].

The low temperature PLE spectra of the nonpolar samples show also nearly zero Stoke shifts which are independent of the QW widths, in marked contrast to that observed from the polar samples. This clearly demonstrates the absence of polarization field in the non-polar MQWs samples. The measured PL decay times, in the range of 200-300 ps, are quite similar for all the non-polar MQW samples and that of bulk GaN. This is strikingly different than the PL decay times of polar GaN/AlGaN [1] and InGaN/GaN [2] MQWs, where the PL decay times strongly depend on the MQW width and they reach few nanoseconds.

We view these differences as strong manifestations for the absence of electrostatic fields in the non-polar MQWs. Our interband PL, PLE and TRPL measurements are favorably compared with an eight-band K•P model [2], which takes into account the growth direction, the resulting lattice mismatch strain tensor and two-dimensional quantum confinement.

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