Interface structure and anisotropic strain relaxation of nonpolar a-GaN on r-sapphire

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Abstract : The growth of the high-quality GaN epilayers is of significant technological importance because of their commercializedoptoelectronic applications as high-brightness light-emitting diodes (LEDs) and laser diodes (LDs) in the visible and ultraviolet spectral range. The GaN-based heterostructural epilayers have the polar *c*-axis of the hexagonal structure perpendicular to the interfaces of the active layers. The Ga and N atoms in the *c*-GaN are alternatively stacked along the polar [0001] crystallographic direction, which leads to spontaneous polarization. In addition, in the InGaN/GaN MQWs, the stress applied along the same axis contributes topiezoelectric polarization, and thus the total polarization is determined as the sum of spontaneous and piezoelectric polarizations. The total polarization in the *c*-GaN heterolayers, which can generate internal fields and spatial separation of the electron and hole wave functions and consequently a decrease of efficiency and peak shift. One of the possible solutions to eliminate these undesirable effects is to grow GaN-based epilayers in nonpolar orientations. The polarization effects in the GaN are eliminated by growing the films along the nonpolar $[11\bar{2}0]$ (*a*-GaN) or $[1\bar{1}00]$ (*m*-GaN) orientation. Although the use of the nonpolar epilayers in wurtzite structure clearly removes the polarization matters, however, it induces another problem related to the formation of a high density of planar defects. The large lattice mismatch between sapphiresubstrates and GaN layers leads to a high density of defects (dislocations and stacking faults). The dominant defects observed in the GaN epilayers with wurtzite structure are one-dimensional (1D) dislocations and two-dimensional (2D) stacking faults. In particular, the 1D threading dislocations in the *c*-GaN are generated from the film/substrate interface due to their large lattice and thermal coefficient mismatch. However, because the *c*-GaN epilayers were grown along the normal direction to the basal slip planes, the generation of basal stacking faults (BSFs) is localized on the *c*-plane and the generated BSFs did not propagate into the surface during the growth. Thus, the primary defects in the *c*-GaN epilayers are 1D threading dislocations. Occasionally, the particular planar defects such as prismatic stacking faults (PSFs) and inversion domain boundaries are observed. However, since the basal slip planes in the *a*-GaN are parallel to the growth direction unlike *c*-GaN, the BSFs with lower formation energy can be easily formed along the growth direction, where the BSFs propagate straightly into the surface. Consequently, the lattice mismatch between film and substrate in *a*-GaN epilayers is mainly relaxed through the formation of BSFs. These 2D planar defects are placed along only one direction in the cross-sectional view. Thus, the nonpolar *a*-GaN films have different atomic arrangements along the two orthogonal directions ($[0001]_{GaN}$ and $[\bar{1}100]_{GaN}$ axes) on the *a*-plane, which are expected to induce anisotropic biaxial strain. In this study, the anisotropic strain relaxation behaviors in the nonpolar *a*-GaN epilayers grown on $(1\bar{1}02)$ *r*-plane sapphire substrates by metalorganic chemical vapor deposition (MOCVD) were investigated,and the formation mechanism of the abnormal zigzag shape PSFs was discussed using high-resolution transmission electron microscope (HRTEM).

Key Words : nonpolar *a*-GaN, MOCVD, TEM, strain relaxation

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