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Different crystalline properties of undoped-GaN depending on the facet of patterns fabricated on a sapphire substrate

Kwang Jae Lee[1,2], Hyun June Kim[1,2], Dong Woo Park[1], Byounggu Jo[1], Jaesu kim[1], Jin Soo Kim[1], Jin Hong LEE[2], Young Min Noh[2]

[1]Division of Advanced Materials Engineering, Research Center of Advanced Materials Development (RCAMD) Chonbuk National University, Jeonju 561-756, Chonbuk, Korea
[2]Korea Photonics Technology Institute, Gwangju 500-779 Chonnam, Korea

Recently, a patterned sapphire substrate (PSS) has been intensively used as one of the effective ways to reduce the dislocation density for the III-nitride epitaxial layers aiming for the application of high-performance, especially high-brightness, light-emitting diodes (LEDs). In this paper, we analyze the growth kinetics of the atoms and crystalline quality for the undopped-GaN depending on the facets of the pattern fabricated on a sapphire substrate. The effects of the PSS on the device characteristics of InGaN/GaN LEDs were also investigated. Several GaN samples were grown on the PSS under the different growth conditions. And the undoped-GaN layer was grown on a planar sapphire substrate as a reference. For the (002) plane of the undoped-GaN layer, as an example, the line-width broadening of the x-ray diffraction (XRD) spectrum on a planar sapphire substrate is 216.0 arcsec which is significantly narrower than that of 277.2 arcsec for the PSS. However, the line-width broadening for the (102) plane on the planar sapphire substrate (363.6 arcsec) is larger than that for the PSS (309.6 arcsec). Even though the growth parameters such as growth temperature, growth time, and pressure were systematically changed, this kind of trend in the line-width broadening of XRD spectrum was similar. The emission wavelength of the undoped-GaN layer on the PSS was red-shifted by 5.7 nm from that of the conventional LEDs (364.1 nm) under the same growth conditions. In addition, the intensity for the GaN layer on the PSS was three times larger than that of the planar case. The spatial variation in the emission wavelength of the undoped-GaN layer on the PSS was statistically ±0.5 nm obtained from the photoluminescence mapping results throughout the whole wafer. These results will be discussed in terms of the mixed dislocation depending on the facets and the period of the patterns.