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Influences of direction for hexagonal-structure arrays of lens patterns on structural, optical, and electrical properties of InGaN/GaN MQW LEDs

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Recently, to develop GaN-based light-emitting diodes (LEDs) with better performances, various approaches have been suggested by many research groups. In particular, using the patterned sapphire substrate technique has shown the improvement in both internal quantum efficiency and light extraction properties of GaN-based LEDs.

In this paper, we discuss the influences of the direction of the hexagonal-structure arrays of lens-shaped patterns (HSAPs) formed on sapphire substrates on the crystal, optical, and electrical properties of InGaN/GaN multi-quantum-well (MQW) LEDs. The basic direction of the HSAPs is normal (HSAPN) with respect to the primary flat zone of a c-plane sapphire substrate. Another HSAP tilted by 30o (HSAP30) from the HSAPN structure was used to investigate the effects of the pattern direction. The full width at half maximums (FWHMs) of the double-crystal x-ray diffraction (DCXRD) spectrum for the (0002) and (1-102) planes of the HSAPN are 320.4 and 381.6 arcsecs., respectively, which are relatively narrower compared to those of the HSP30. The photoluminescence intensity for the HSAPN structure was ~1.2 times stronger than that for the HSAP30. From the electroluminescence (EL) measurements, the intensity for both structures are almost similar. In addition, the effects of the area of the individual lens pattern consisting of the hexagonal-structure arrays are discussed using the concept of the planar area fraction (PAF) defined as the following equation;

PAF = [1-(patterns area/total unit areas)]

For the relatively small PAF region up to 0.494, the influences of the HSAP direction on the LED characteristics were significant. However, the direction effects of the HSAP became small with increasing the PAF.