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Efficient Red-Color Emission of InGaN/GaN Double Hetero-Structure Formed on Nano-Pyramid Structure

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(In, Ga) N-based III-nitride semiconductor materials have been viewed as the most promising materials for the applications of blue and green light emitting devices such as light-emitting diodes (LEDs) and laser diodes. Although the InGaN alloy can have wide range of visible wavelength by changing the In composition, it is very hard to grow high quality epilayers of In-rich InGaN because of the thermal instability as well as the large lattice and thermal mismatches. In order to avoid phase separation of InGaN, various kinds of structures of InGaN have been studied. If high-quality In-rich InGaN/GaN multiple quantum well (MQW) structures are available, it is expected to achieve highly efficient phosphor-free white LEDs. In this study, we proposed a novel InGaN double hetero-structure grown on GaN nano-pyramids to generate broad-band red-color emission with high quantum efficiency. In this work, we systematically studied the optical properties of the InGaN pyramid structures.

The nano-sized hexagonal pyramid structures were grown on the n-type GaN template by metalorganic chemical vapor deposition. SiNx mask was formed on the n-type GaN template with uniformly patterned circle pattern by laser holography. GaN pyramid structures were selectively grown on the opening area of mask by lateral over-growth followed by growth of InGaN/GaN double hetero-structure. The bird's eye-view scanning electron microscope (SEM) image shows that uniform hexagonal pyramid structures are well arranged. We showed that the pyramid structures have high crystal quality and the thickness of InGaN is varied along the height of pyramids via transmission electron microscope. Because the InGaN/GaN double hetero-structure was grown on the nano-pyramid GaN and on the planar GaN, simultaneously, we investigated the comparative study of the optical properties. Photoluminescence (PL) spectra of nano-pyramid sample and planar sample measured at 10 K. Although the growth condition were exactly the same for two samples, the nano-pyramid sample have much lower energy emission centered at 615 nm, compared to 438 nm

for planar sample. Moreover, nano-pyramid sample shows broad-band spectrum, which is originate from structural properties of nano-pyramid structure. To study thermal activation energy and potential fluctuation, we measured PL with changing temperature from 10 K to 300 K. We also measured PL with changing the excitation power from 48 μW to 48 mW. We can discriminate the origin of the broad-band spectra from the defect-related yellow luminescence of GaN by carrying out PL excitation experiments. The nano-pyramid structure provided highly efficient broad-band red-color emission for the future applications of phosphor-free white LEDs.

Keywords: light-emitting diodes, pyramid structure, InGaN, hetero structure