InGaN/GaN MQW Nanorods LED Fabricated by ICP-RIE and PEC Oxidation Processes

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Abstract: The InGaN/GaN nanorods LED was successfully fabricated by ICP-RIE and PEC processes. Compared with as-grown sample, the PL and EL peak-wavelengths of the nanorods with PEC show 8.6 and 10.5 nm blue-shift, respectively.

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1. Introduction

Direct wide-bandgap gallium nitride (GaN) and other III-nitrides based light emitting diodes (LEDs) have attracted much attention for various potential applications [1]. Fabricating nano-structures on the LEDs can enhance the performance effectively due to the quantum confinement and strain releasing effect. In this paper, we introduce a novel method combining inductively coupled plasma reactive ion etching (ICP-RIE) and photoelectrochemical (PEC) oxidation process [2] with self-assembly Ni metal islands [2]. After the PEC oxidation process, the Ga2O3 oxide layer were formed on the surface of the nanorods sidewall and etched layer by ICP-RIE which electrically isolates individual nanorods.

2. Experiment and Discussions

The process flowchart for the nanorods LED with PEC oxidation process was shown in Fig. 1. First, a 100 Å Ni layer was then deposited on top of the LED and then subsequently rapid temperature annealing (RTA) to form self-assembled Ni metal clusters. Then, the LED samples were etched down to the n-type GaN layer by ICP-RIE system to form nanorods. The Ni nano-mask was removed and following the PEC oxidation process. An 800 W Hg lamp was used as the illumination source in this PEC oxidation process. The Ga2O3 layer was formed at the nanorods sidewall and the ICP etched n-type GaN layer. Finally, a Ni/Au layer was deposited to form the p-type ohmic contacts of each individual nanorods and a Cr/Au layer was deposited onto the p and n bonding layer electrode. Figure 2 shows the SEM images of each step during fabrication processes.

The normalized photoluminance (PL) spectrum of the as-grown LED sample, nanorods LED samples with and without PEC process are shown in Fig. 3, all measured at room temperature. The PL emission peaks of the InGaN/GaN MQW active layer were observed at 449 nm (2.76 eV) for as-grown sample, 445.2nm (2.78 eV) for nanorods sample without PEC oxidation process and 440.4 nm (2.81 eV) for the nanorods sample with PEC oxidation process. The PL-peak intensities of InGaN/GaN MQW active layer are enhanced by a factor of approximately 6 and 5 compared with as-grown LED samples in both the samples with and without PEC oxidation process, respectively. The blue-shift phenomena were observed both at the nanorods LED samples with and without PEC oxidation process. The blue-shift of nanorods LED samples with and without PEC are 3.8 nm (20 meV) and 8.6 nm (50 meV), respectively. The blue-shift maybe caused by the partial reduction of the piezoelectric field which resulted from the strain release of the nanorods structures. In addition, the PL intensity is enhanced by a factor of 5 of the nanorods without PEC and of 6 of the nanorods with PEC oxidation process. That is because of the band structure of the InGaN/GaN MQW active layer of the nanorods samples became flatter and increasing the wave-function overlap of the electron and the hole. The nanorods LED with PEC oxidation process have larger blue-shift than without PEC process implying larger piezoelectric reduction. This might be due to the smaller diameters of nanorods by PEC oxidation process. It shows that the PEC oxidation process not only formed an oxidation layer to isolate individual nanorods electrically but also reduce the diameter of the nanorods for relaxing the strain effectively.

The Fig. 4 shows the normalized EL spectrum of the as-grown LED and nanorods LED samples with PEC process at an injection current of 1mA. The EL emission peaks of the InGaN/GaN MQW active layer were observed at 467.9nm (2.65 eV) for as-grown sample, 457.4nm (2.71 eV) for nanorods samples with PEC oxidation process and 450.4 nm (2.78 eV) for the nanorods sample with PEC oxidation process. The blue-shift of nanorods LED samples with PEC are 10.5nm (60 meV) and shifting is 10.5nm (60 meV). The results of the EL spectra are similar to the PL spectra which suggest that the PEC oxidation effectively reduces the strain of the nanorods LED.

3. Summary

We successfully fabricated the InGaN/GaN MQW nanorods LED by using Ni nano-masks, ICP-RIE etching and PEC process. The PEC oxidation process produces a Ga2O3 oxidation layer surrounding the nanorod to isolate
individual nanorod and brings p-type electrode deposited on p-type GaN nanorods. An enhancement by a factor of 6 and 5 times in photoluminescence intensities of nanorods with and without PEC process, respectively, compared to that of as-grown structure were observed in this work.

4. Reference

Fig. 1 schematic illustration of InGaN/GaN MQW nanorods LED process flowchart.

Fig. 2 the SEM images of
(a) Ni nano-masks on p-GaN top surface after RTA process.
(b) InGaN/GaN MQW nanorods LED after ICP-RIE etching.
(c) InGaN/GaN MQW nanorods LED after PEC process.
(d) InGaN/GaN MQW nanorods LED after deposited contact metal.

Fig. 3 normalized PL intensity spectra for as-grown LED and nanorods LED with/without PEC at room temperature.

Fig. 4 normalized EL intensity spectra for as-grown LED and nanorods LED with PEC at room temperature.