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Metalorganic Chemical Vapor Deposition Overgrowth on the Bragg Grating for Gallium Nitride Based Distributed Feedback Laser

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Abstract : Laser diodes fabricated from the III-nitride material system are emerging solutions for the next generation telecommunication systems and optical clocks based on Ca at 397nm, Rb at 420.2nm and Yb at 398.9nm combined 556 nm. Most of the applications require single longitudinal optical mode lasers, with very narrow linewidth and compact size, such as communication systems and laser cooling. In this case, the GaN based distributed feedback (DFB) laser diode is one of the most effective candidates with gratings are known to operate with narrow spectra as well as high power and efficiency. Given the wavelength range, the period of the first-order diffraction grating is under 100 nm, and the realization of such gratings is technically difficult due to the narrow line width and the high quality nitride overgrowth based on the Bragg grating. Some groups have reported GaN DFB lasers with high order distributed feedback surface gratings, which avoids the overgrowth. However, generally the strength of coupling is lower than that with Bragg grating embedded into the waveguide within the GaN laser structure by two-step-epitaxy. Therefore, the overgrowth on the grating technology need to be studied and optimized. Here we propose to fabricate the fine step shape structure of first-order grating by the nanoimprint combined inductively coupled plasma (ICP) dry etching, then carry out overgrowth high quality AlGaN film by metalorganic chemical vapor deposition (MOCVD). Then a series of gratings with different period, depths and duty ratios are designed and fabricated to study the influence of grating structure to the nano-heteroepitaxy. Moreover, we observe the nucleation and growth process by step-by-step growth to study the growth mode for nitride overgrowth on grating, under the condition that the grating period is larger than the mental migration length on the surface. The AFM images demonstrate that a smooth surface of AlGaN film is achieved with an average roughness of 0.20 nm over 3 × 3 μm2. The full width at half maximums (FWHMs) of the (002) reflections in the XRD rocking curves are 278 arcsec for the AlGaN film, and the component of the Al within the film is 8% according to the XRD mapping measurement, which is in accordance with design values. By observing the samples with growth time changing from 200s, 400s to 600s, the growth model is summarized as the follow steps: initially, the nucleation is evenly distributed on the grating structure, as the migration length of Al atoms is low; then, AlGaN growth alone with the grating top surface; finally, the AlGaN film formed by lateral growth. This work contributed to carrying out GaN DFB laser by fabricating grating and overgrowth on the nano-grating patterned substrate by wafer scale, moreover, growth dynamics had been analyzed as well.

Keywords : DFB laser, MOCVD, nanoepitaxy, III-niitride
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