High-optical-confinement LDs using AlInN/GaN lattice-matched heterostructures

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Among III-nitride semiconductors, AlInN is the only ternary alloy that can be grown lattice-matched to GaN at an In composition of 17% [1]. Lattice-matched AlInN/GaN heterostructure should be free from cracks, strain-driven composition inhomogeneities, and strain-related defects, which are limiting the performance of UV/visible light-emitting devices such as LEDs and LDs when using conventional lattice-mismatched AlGaN/GaN or InGaN/GaN heterostructures. In addition, an AlInN/GaN structure has a large bandgap discontinuity ($ΔE_g \sim 1$ eV) and a large refractive index contrast ($Δn/n \sim 7\%$ in the visible region) even at the lattice-matched condition [1], which improves carrier and optical confinements [2]. Thus, AlInN/GaN structures are expected not only to improve device properties but also to increase the design flexibility for novel III-nitride devices. Here we report p-type and n-type doping control in AlInN and demonstrate lasing actions from GaN-based LDs using AlInN lattice-matched cladding layers.

The GaN-based LD structures were grown on free-standing GaN (0001) substrates by MOVPE. The LD structure consists of an n-type GaN buffer layer, an n-type AlInN/GaN superlattice (SL) cladding layer, an n-type GaN waveguide layer, InGaN/GaN multiple quantum wells, a p-type GaN waveguide layer, a p-type AlInN/GaN SL cladding layer, a p-type GaN contact layer. Si and Mg were used as the n-type and p-type dopants, respectively. In Mg-doped AlInN, we found that one of the compensating defects for Mg acceptors is related to the presence of surface pits. P-type AlInN was therefore successfully obtained by decreasing the surface pit density [3]. Following the growth, index guided LD structures with a cavity length of 1 mm and a stripe width of 2 μm were fabricated. No high reflection coatings were deposited on the cavity facets. The device characterization was carried out on wafer.

Lasing action at a wavelength of 418 nm was achieved under pulsed current injection (pulse width of 1 μs and duty cycle of 1%) at room temperature. The threshold current density was 4 kA/cm². The optical power was measured from a single facet and the slope efficiency was 0.4 W/A. The LDs showed a uniform far field pattern thanks to the strong optical confinement ensured by the AlInN cladding layers. These results show that the lattice-matched AlInN/GaN combination is a promising approach to UV/visible LDs.