29p-G21-20

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 ($\Delta Eg \sim 1$ eV) and a large refractive index contrast ($\Delta n/n \sim 7\%$ 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/cm^2. 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.

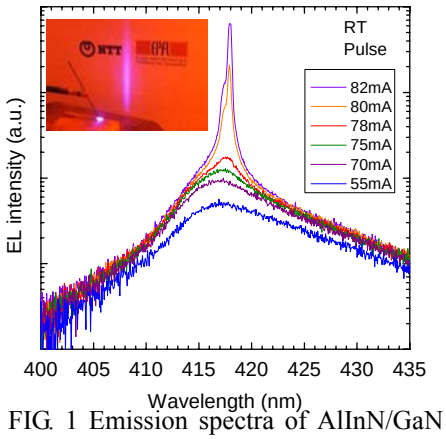

FIG. 1 Emission spectra of AlInN/GaN lattice-matched LD at different currents. Inset: far field pattern of the LD.

[1] J.-F. Carlin and M. Ilegems, Appl. Phys. Lett. **83,** 668 (2003). [2] A. Castiglia *et al.*, Appl. Phys. Lett. **94**, 193506 (2009). [3] Y. Taniyasu *et al.*, Appl. Phys. Lett. **101**, 082113 (2012).