News

24 September 2007

First blue and first cw AlGaN-cladding-free blue-violet nonpolar InGaN/GaN lasers

Last week's 7th International Congress of Nitride Semiconductors (ICNS-7) in Las Vegas, NV, USA saw reports of the latest progress in nonpolar laser diodes from the likes of University of California Santa Barbara and Japan's Rohm Co Ltd.

Conventional gallium nitride lasers are grown on a substrate such as sapphire oriented along the crystallographic c-plane. However, strong polarization fields along the c-plane, together with related piezoelectric effects, segregate electrons and holes in the laser's quantum well active light-emitting region, reducing their efficiency in recombining to produce light. The quantum efficiency is reduced more severely as the lasing emission wavelength shifts from blue-violet (about 400nm) through blue (up to about 490nm)

towards green (beyond 500nm - much sought-after for combination, e.g. in full-color RGB laser displays).

In contrast, using a nonpolar GaN substrate whose crystal is oriented instead along the {1-100} m-plane gives much lower polarization fields and piezoelectric effects in the laser's active layer, so electrons and holes can recombine more efficiently.

Using bulk m-plane GaN substrates from Tokyo-based Mitsubishi Chemical Corp, early this year the first nonpolar m-plane blue-violet nitride laser diodes were reported coincidentally by both Rohm Co Ltd of Kyoto, Japan and the group led by Shuji Nakamura, Steven DenBaars and James Speck at University of California Santa Barbara (Jpn J. Appl. Phys. 46 (2007) issue 9 (23 February): Okamoto et al L187; Schmidt et al L190).

Rohm says its InGaN/GaN multi-quantum-well lasers had threshold current densities comparable to that of conventional c-plane lasers: 3.1kA/cm² for pulsed operation and 4.0kA/cm² for continuous-wave (cw) operation emitting at 401nm (blue-violet).

UCSB's broad-area InGaN/GaN multi-quantum-well devices lased at 405.5nm (blue-violet) with a threshold current density of 7.5kA/cm² in pulsed operation.

Subsequently, UCSB demonstrated the first nonpolar m-plane InGaN/GaN laser without any Al-containing waveguide cladding layers (Daniel F. Feezell et al, Jpn J. Appl. Phys. 46 (2007) issue 13 (23 March) L284). Instead, transverse optical mode confinement is achieved due to the ability to grow thick (>8nm) m-plane InGaN active-region quantum wells (unlike for c-plane material, where thick AlGaN layers can increase the series resistance, operating voltage, operating temperature and threshold current density, as well as leading to cracking due to tensile strain). Pulsed lasing operation was demonstrated with a threshold current density of 3.7kA/cm².

Most recently, at last week's ICNS event, Mathew Schmidt presented UCSB's latest achievement of the first cw operation of a nonpolar m-plane InGaN/GaN laser without any AlGaN waveguide cladding layers (Farrell et al, Jpn J. Appl. Phys. 46 (2007) issue 32 (10 August) L761) . The threshold current density is 6.8kA/cm².

Meanwhile, Rohm's Kuniyoshi Okamoto presented the first nonpolar m-plane InGaN/GaN laser emitting at longer, pure blue wavelengths: 430nm using GaN guiding and 452nm using InGaN guiding (Okamoto et al, Jpn J. Appl. Phys. 46 (2007) issue 35 (7 September) L820) - since extended to 456nm. The threshold current density was 22.3kA/cm² at 452nm. As well as providing optical waveguides for longer lasing wavelengths, the InGaN guiding layers prevent macroscopic cracks developing parallel to the c-plane, which is indispensable for fabricating nonpolar lasers at longer wavelengths beyond the blue region, Okamoto says.

Okamoto reckons the latest results suggest that there is a good possibility of achieving the goal of a green laser diode on m-plane GaN. However, he concedes that indium incorporation is an issue for such longer wavelengths.

*UCSB's Anurag Tyagi also presented the first semi-polar nitride laser diode, using (10-1-1) bulk GaN substrates (Tyagi et al, Jpn J. Appl. Phys. 46 (2007) issue 19 (11 May) L444). Pulsed lasing (at a duty cycle of 0.025%) at 405.9nm has been observed with a threshold current density of 16.5kA/cm². Improvement is planned by using a ridge waveguide structure, says Tyagi.

See related item:

First nonpolar blue-violet laser diodes demonstrated by UCSB

Visit ICNS: www.tms.org/Meetings/specialty/icns7

Visit Rohm: www.rohm.com

Visi UCSB: www.ssldc.ucsb.edu

Semiconductor Today, Juno Publishing and Media Solutions Ltd, Suite no. 133, 20 Winchcombe Street, Cheltenham, GL52 2LY, UK

Web site by No Name No Slogan