Interface engineering for green indium gallium nitride laser diodes

Thermal treatment results in low threshold current density of 1.85kA/cm² under continuous-wave operation at room temperature.

University of Chinese Academy of Sciences has developed an interface engineering thermal treatment of indium gallium nitride (InGaN) quantum well active regions in green laser diode (LD) structures [Aiqin Tian et al, Optics Express, vol25, p415, 2017]. The resulting laser diodes had a low threshold current density of $1.85kA/cm^2$ under continuous-wave operation at room temperature.

Green laser diodes should lead to more compact projectors and other display technologies based on laser light. At present, green light for such applications tends to use non-linear optics to frequency shift light produced at other wavelengths, increasing device sizes and reducing power efficiency.

The green laser diode structures were grown by metal-organic chemical vapor deposition (MOCVD) — see Figure 1. The material quality of the wells was improved by thermal ramping from 700°C to 850°C over 240 seconds and holding for 30 seconds before

Contact	p^+-GaN
Cladding	p-AlGaN/GaN superlattice
Electron blocking	p-AlGaN
Waveguide	InGaN
Quantum wells	2x(InGaN/GaN)
Waveguide	InGaN
Cladding	n-AlGaN
Contact	n-GaN
Substrate	GaN/sapphire or freestanding GaN

Figure 1. Epitaxial structure.

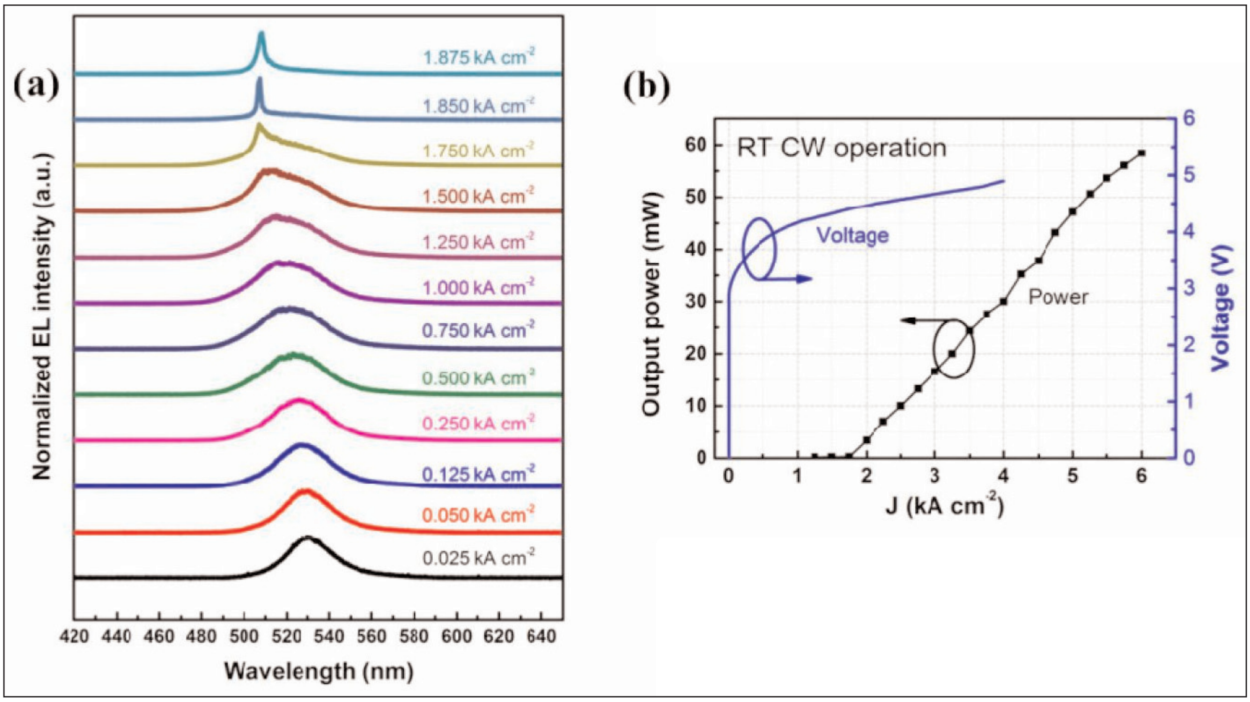

Figure 3. (a) Emission spectra at different current density. (b) Power-current-voltage curve of typical green laser diode under continuous-wave operation at room temperature.

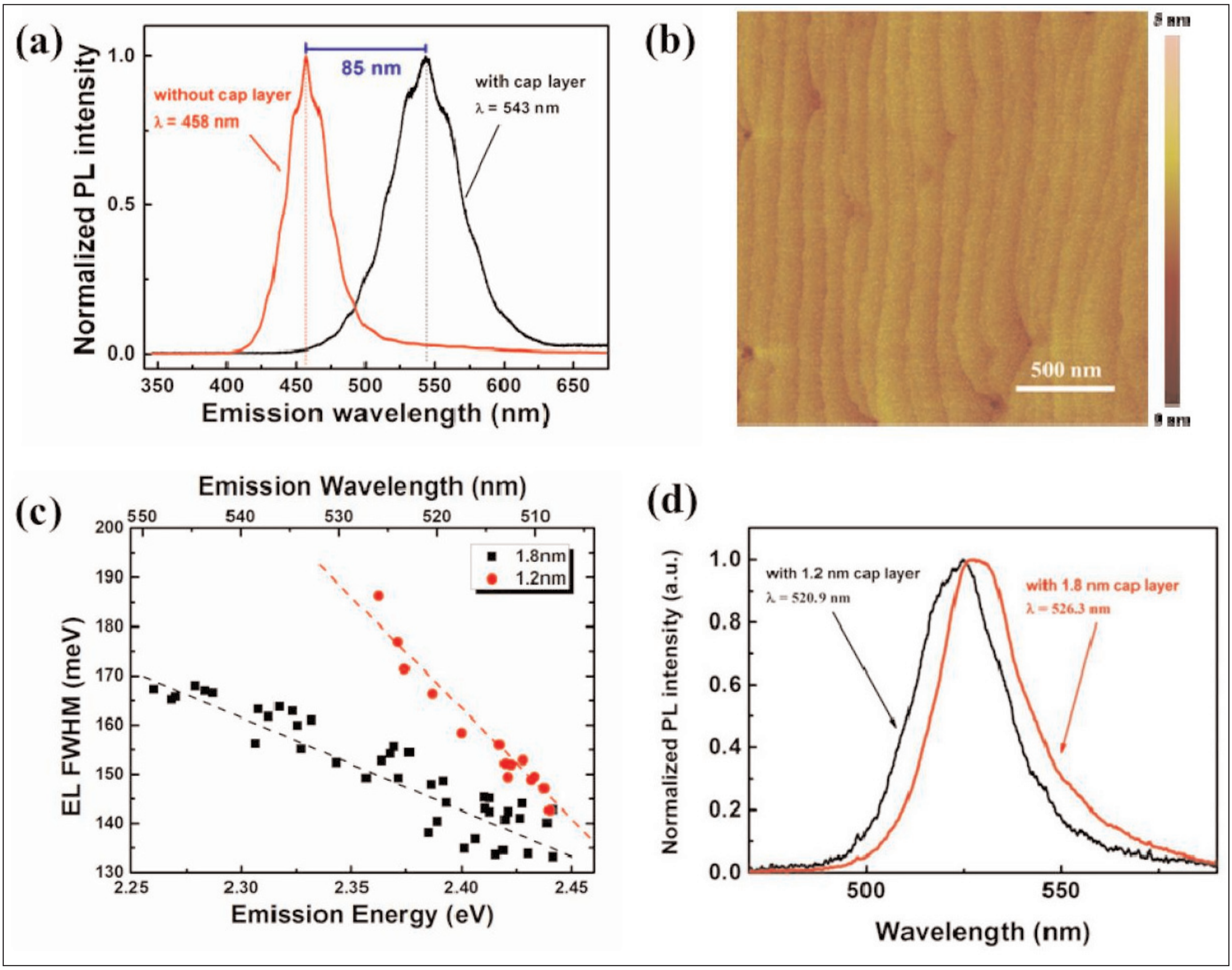

Figure 2. (a) Photoluminescence (PL) spectra of green InGaN/GaN QWs with and without GaN cap layer, (b) atomic force microscope (AFM) images of 15nm quantum barrier layers on GaN/sapphire template, (c) electroluminescence full-width at half maximum (FWHM) dependent on emission energy of laser diode groups with 1.2nm and 1.8nm GaN cap layer, (d) PL spectra of green InGaN/GaN QW with 1.2nm and 1.8nm GaN cap layer.

growing the 15nm GaN barrier at 850°C. The indium layer was protected from loss of indium during the thermal treatment by a 1.8nm GaN cap layer grown at 700°C.

The thermal treatment suppressed trench defects and removed indium clusters that arise from severe segregation effects usually seen in the high-indium-content InGaN needed for green light emission (Figure 2).

Thermal treatment suppressed trench defects and removed indium clusters that arise from severe segregation effects usually seen in the high-In-content InGaN needed. The treatment process was developed using material grown on GaN/sapphire templates and free-standing GaN

The treatment process was developed using material grown on GaN/sapphire templates and free-standing GaN. Electroluminescence and cathodoluminescence studies showed that the indium clusters were formed both at and away from dislocations.

The laser diodes used material deposited on free-standing GaN. Laser diodes with 10μm ridge-waveguide width and 800μm cavity length had a threshold current density of 1.85kA/cm^2 under continuous-wave operation at room temperature (Figure 3). A low voltage of 4V at threshold is attributed to suppressed carbon impurity in magnesium-doped AlGaN cladding layer. At 6kA/cm^2 injection the output power was 58mW. The green laser wavelength was around 508nm. ■

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