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Novel Window-Structure AlGaInP Visible-Light Laser Diodes with Non-Absorbing Facets Fabricated by Utilizing GaInP Natural Superlattice Disordering

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Window-structure AlGaInP visible-light (λ_L=680 nm) laser diodes (LDs) have been fabricated, for the first time, by utilizing GaInP natural superlattice (NSL) disordering with selective Zn diffusion. The bandgap energy for the active layer near the mirror facets is increased by 70 meV by the NSL disordering. An 80 mW output power in a fundamental transverse-mode has been achieved for the uncoated window LDs under 1 μsec long pulsed operations. The maximum output power density for the window LDs is estimated to be 10 MW/cm^2, which is five times higher than that for conventional LDs.

KEYWORDS: window-structure, natural superlattice, disordering, high power, AlGaInP, visible-light laser, MOVPE, bandgap energy, Zn diffusion

High power AlGaInP visible-light laser diodes (LDs) have been desired for use in optical-disk memory systems and many other applications. Many efforts have been made to achieve high power operations[1-3] since the success in room temperature cw lasing in 1985.[4-6] However, the output powers for commercially available AlGaInP LDs have been less than several milliwatts. The main reason is that the catastrophic optical damage (COD) due to thermal runaway induced by light absorption at the facets occurs at a relatively low output power density of 1–2 MW/cm^2.[2] Window-structures with non-absorbing facets have been reported for AlGaAs LDs to be effective for increasing maximum output power limited by COD.[7,8] This paper, for the first time, reports the fabrication of novel window-structure AlGaInP LDs by utilizing GaInP natural superlattice (NSL) disordering[9,10] and demonstrates marked improvement in the maximum output power.*

Figure 1 shows the window AlGaInP LD structure. The LDs were grown by three step low pressure

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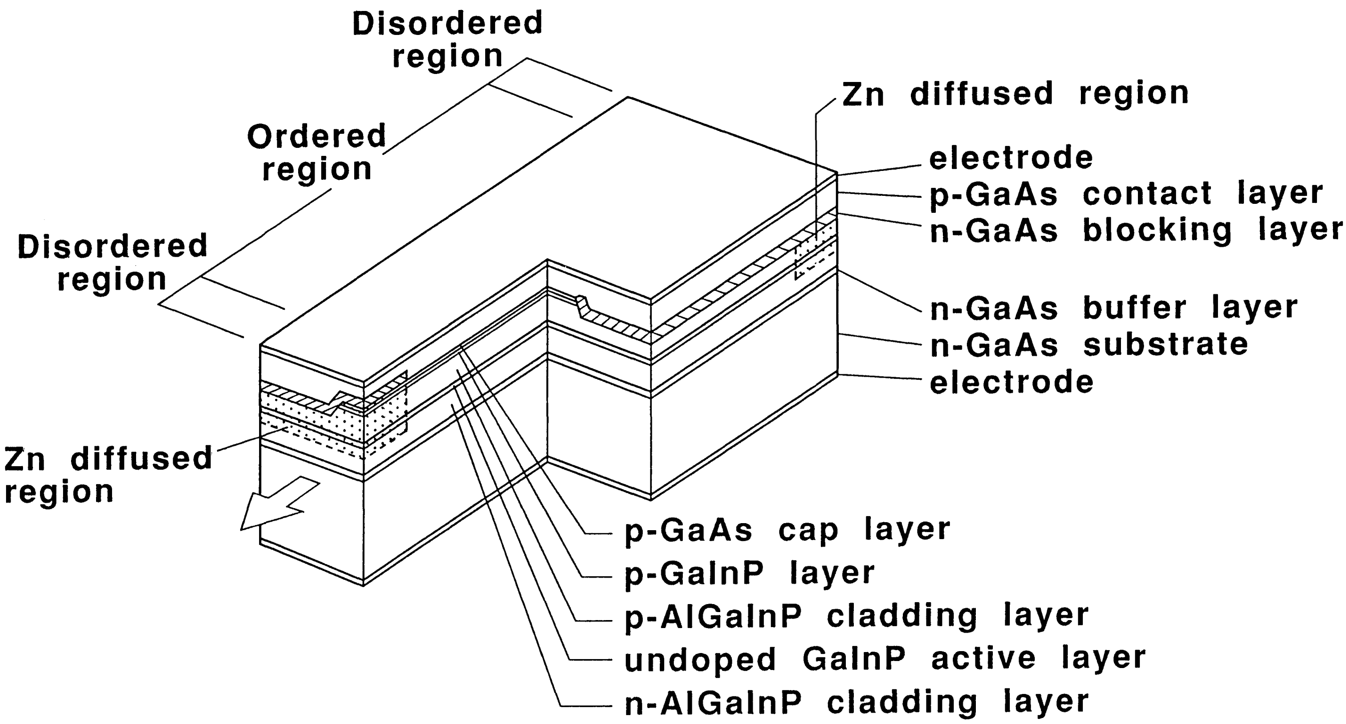

Fig. 1. Window AlGaInP LD structure. The window structure is formed by selective Zn diffusion into the GaInP active layer near the facets and the resultant natural superlattice disordering. A refractive-index waveguide for fundamental transverse-mode control is formed through the cavity.

metalorganic vapor phase epitaxy. In the first step growth, a Si-doped n-GaAs buffer layer, a 1 μm thick Si-doped n-$(Al_{0.6}Ga_{0.4})_{0.5}In_{0.5}P$ cladding layer ($1-2\times10^{17}$ cm^{-3}), an 800 Å thick undoped $Ga_{0.5}In_{0.5}P$ active layer, a 1 μm thick Zn-doped p-$(Al_{0.6}Ga_{0.4})_{0.5}In_{0.5}P$ cladding layer ($3-5\times10^{17}$ cm^{-3}), a 50 Å thick Zn-doped p-$Ga_{0.5}In_{0.5}P$ layer and a 0.25 μm thick Zn-doped p-GaAs cap layer were grown successively on a (001) oriented Si-doped n-GaAs substrate. The source materials were trimethylaluminum (TMA), triethylgallium (TEG), trimethylindium (TMI), phosphine (PH_3), dimethylzinc (DMZ) and disilane (Si_2H_6).[11] The growth conditions for the undoped GaInP active layer were 660°C growth temperature, 150 V/III ratio and 70 Torr growth pressure. The undoped GaInP active layer, grown under these growth conditions, contains NSL.[9] After the first step growth, the window-structure was formed by selective Zn diffusion into the GaInP active layer near the mirror facets. The Zn diffusion disordered the GaInP NSL and increased the active layer bandgap energy. Figure 2 shows photoluminescence (PL) spectra for the active layer. The PL peak wavelength for the disordered region was 645 nm and that for the ordered region was 672 nm. The active layer bandgap energy was increased by 70 meV by the NSL disordering. Then, a 5 μm wide ridge stripe waveguide was formed by chemical etching in both the ordered and the disordered regions for stable fundamental transverse-mode operations. In the second step growth, the n-GaAs blocking layer was selectively grown, both on the outside of the ridge stripe and on the ridge stripe in the disordered region for current confinement. The active layer in the disordered region is not current-injected. In the third step growth, the epitaxial layer surface was covered by a p-GaAs contact layer. The mirror facets were formed by cleaving the wafer at the disordered region. The laser cavity was 500–540 μm long. The ordered region was 400 μm long and the disordered region on each facet was 50–70 μm long. The mirror facets were uncoated.

Pulsed light output power versus current characteristics at room temperature for a typical window LD are shown in Fig. 3, together with those for a conventional LD cleaved from the same wafer. Pulsed current with 1 μs pulse width, which is sufficiently long to optically destroy the conventional LDs' facets, was used. The repetition rate was 1 kHz. The conventional LDs failed at 15 mW due to COD. The maximum output power density was estimated to be 1.7 MW/cm^2. In contrast, an output power of more than 80 mW was achieved for the window LDs. The maximum output power density for window LDs was estimated to be 10 MW/cm^2 by using the radiation angles in the perpendicular direction (34°) and in the parallel direction (8°) measured at 80 mW. The estimated maximum output power density for the window LDs was five times higher than that for conventional LDs. The threshold current was 100 mA, which was as low as that for conventional LDs, and the wavelength was 680 nm for the window LDs.

Preliminary life tests for uncoated window LDs have been started under 10 mW cw constant output power operations at 50°C. The LDs have shown quite stable operations over 400 hours, as shown in Fig. 4.

In summary, the fabrication and characteristics of novel window-structure AlGaInP LDs have been presented for the first time. The window-structure was fabricated by utilizing GaInP NSL disordering. An output power of more than 80 mW has been achieved under pulsed operations. A marked window effect has been

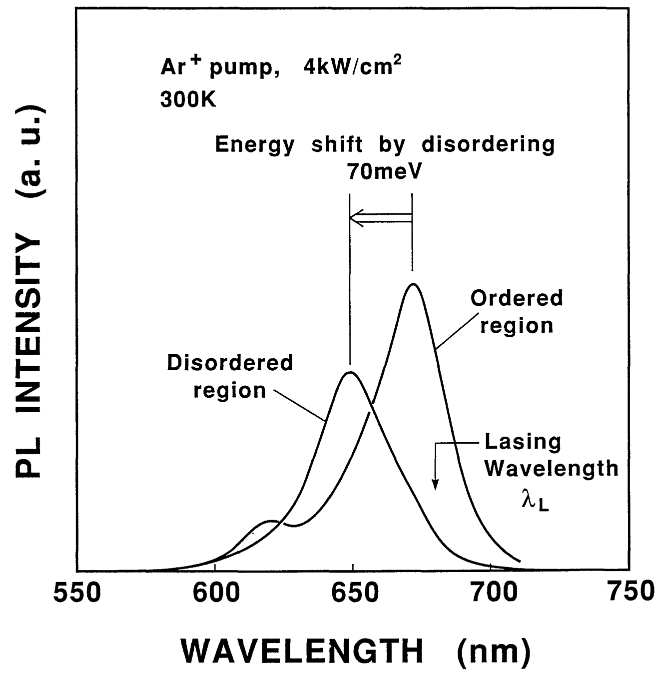

Fig. 2. Photoluminescence spectra at 300 K for disordered and ordered regions in the GaInP active layer. The PL peak wavelength for the disordered region is 645 nm and that for the ordered region is 672 nm. The active layer bandgap energy is increased by 70 meV by the NSL disordering.

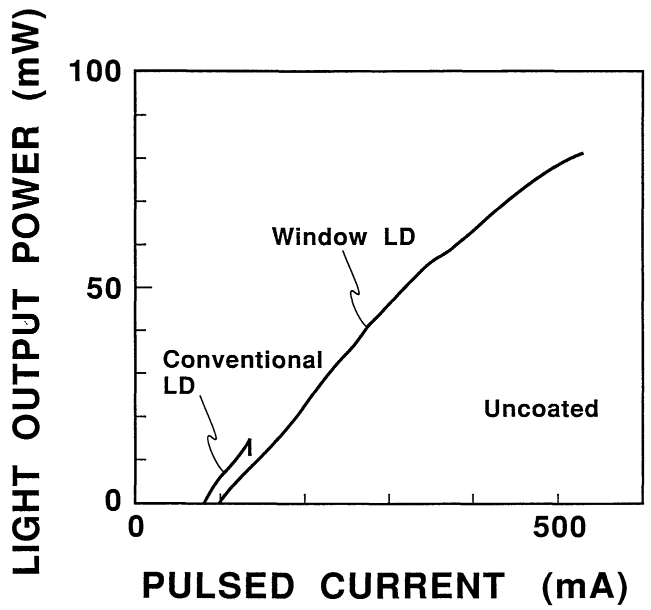

Fig. 3. Pulsed light output power versus current characteristics for an uncoated window AlGaInP LD and a conventional one cleaved from the same wafer. The pulse width is 1 μs. The maximum output power for the window LD is more than 80 mW, which is five times higher than that for the conventional LD.

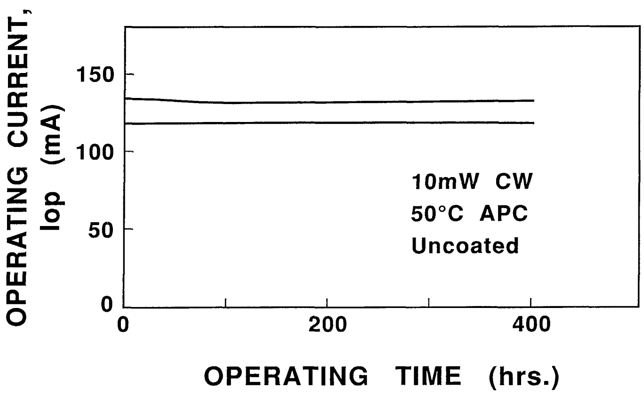

Fig. 4. Aging test results for uncoated window LDs under 10 mW cw constant output power operations at 50°C. Two LDs have been under stable operations for over 400 hours.

demonstrated by the significantly increased 10 MW/cm^2 maximum output power density for the window LDs. Stable operations under 10 mW cw at 50°C have been shown. These results indicate that this window structure is quite promising for obtaining high power visible-light LDs.

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