Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.110-111

E-2-3

Continuous-Wave Operation of 1.23μm Highly Strained InGaAs Quantum-Well Ridge Waveguide Lasers on GaAs Substrates

Mizunori Ezaki[1,4], Mitsuhiro Kushibe[1,4], Rei Hashimoto[1,4], Gen-ichi Hatakoshi[1,4], Masao Nishioka[1,2] and Yasuhiko. Arakawa[1-3]
[1]Nanoelectronics Collaborative Research Center, [2]IIS and [3]RCAST, University of Tokyo
4-6-1, Komaba, Meguro, Tokyo 153-0041, Japan
Phone: +81-3-5452-6098 ex. 57711
[4]Advanced Electron Devices Laboratory, Corporate R&D Center, Toshiba Corporation
1, Komukai-Toshiba-cho, Saiwai-ku, Kawasaki, 212-8582, Japan
Phone : +81-44-549-2141
Phone : +81-44-549-2141 E-mail: ezaki@ull.rdc.toshiba.co.jp

1. Introduction

Long wavelength quantum-well laser diodes emitting at 1.2-1.3 μm grown on GaAs substrates have gained a great deal of interest during recent years. Compared to conventional InP-based ones, GaAs-based laser diodes offer improved temperature-insensitivity due to larger band-gap discontinuities, availability of larger substrate and potentially lower cost production. In particular, the active materials on GaAs are attractive for their suitability towards long wavelength vertical-cavity surface emitting lasers (VCSELs) since they can be monolithically grown on well-established GaAlAs/GaAs distributed Bragg reflectors. Highly strained InGaAs/GaAs quantum-well (QW) is one of the promising candidates for the active layer in long wavelength laser diodes [1]-[6] and VCSELs [7],[8] on GaAs substrates. The continuous wave (CW) operation of high In-content (=39 %) InGaAs/GaAs QW laser diodes with well-tuned growth conditions using metal-organic chemical vapor deposition (MOCVD), was realized at the emission wavelength of 1.21 μm with a low threshold current density of 300-360 A/cm^2 [5],[6].

In this work, we present MOCVD grown 1.23 μm InGaAs/GaAs ridge-waveguide lasers with excellent characteristics. We achieved room-temperature CW operation with a low threshold current density of 280 A/cm^2.

2. Experimental

Highly strained InGaAs/GaAs single quantum-well (SQWs) laser structure was grown on a (001) oriented GaAs substrate by low-pressure (76 Torr) MOCVD. Source materials were triethylgallium (TEG), trimethylindium (TMI), trimethylaluminum (TMA) and tertiarybutylarsine (TBA). The SQW was grown at a rate of 0.06 nm/s and a temperature of 440 ºC. The composition and width of SQW were obtained from simulating and fitting high-resolution x-ray diffraction (HR-XRD) rocking curves. The active region consists of a 4.6 nm-thick highly strained $In_{0.46}Ga_{0.54}As$/GaAs SQW with a room-temperature (RT) PL peak wavelength of 1230 nm. High quality QWs for highly strained InGaAs/GaAs can be formed by low growth temperature in combination with low growth rate.

The active region of the ridge waveguide (RWG) laser structure is sandwiched between 120 nm-thick GaAs waveguide layers, followed by 2 μm-thick $Ga_{0.47}Al_{0.53}As$ cladding layers, carbon-doped on the p-side and Si-doped on the n-side, respectively. The structure was completed with a 100 nm-thick highly carbon-doped GaAs p-contact layer. RWG lasers with a stripe width of 5 μm were formed by inductively coupled plasma (ICP) etching using a BCl_3/N_2 gas mixture. A 250 nm-thick dielectric (SiO_2) layer was deposited to isolate the p-contact on top of the devices from the rest of the structure. After processing, the lasers were cleaved into various lengths with no coating to the facets. The devices were mounted on copper heat-sinks and measured under CW operation at temperatures in the range of 20 ºC -100 ºC.

3. Results and Discussion

Figure 1 shows the light output power versus current (L-I) curves for a 900 μm-cavity length SWG laser with a stripe width of 5 μm at temperatures ranging from 20 ºC to 100 ºC with temperature steps of 10K. The devices operated CW successfully up to 100 ºC, which was the temperature limit of measurement system. Threshold current and threshold current density at RT were 12 mA and 280 A/cm^2, respectively. The near threshold ($I \sim 1.1\ I_{th}$) peak emission wavelength at RT was 1230 nm, as shown in Fig.1. To our knowledge, this wavelength is the longest ever reported for highly strained InGaAs QW lasers on GaAs substrates under CW operation.

The dependence of the threshold current on the heat-sink temperature was shown in Fig. 2. In the temperature range from 20 ºC to 70 ºC the characteristics temperature T_0 was as high as 120K and dropped to 85 K at high temperatures. This value shows the superior temperature performance of GaAs-based highly strained InGaAs lasers compared with devices made in the conventional InGaAsP/InP material system for which T_0 is typically lower than 80 K [9].

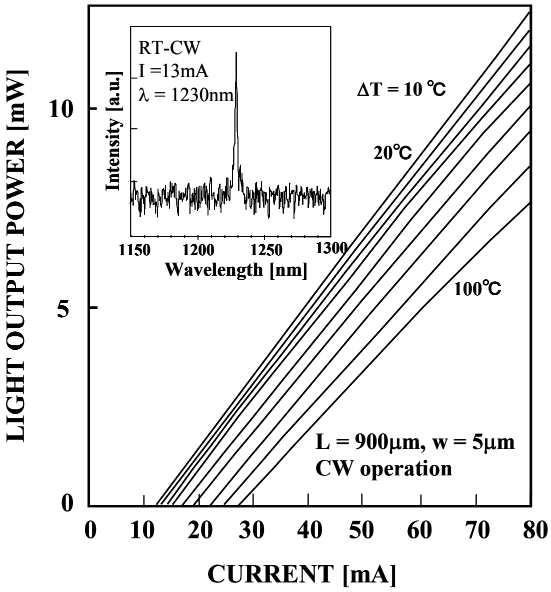

Figure 1. Temperature dependent CW L-I-characteristics for 900 μm-long RWG laser (w = 5μm) with as-cleaved facets. The inset shows the CW lasing spectrum at RT (20ºC).

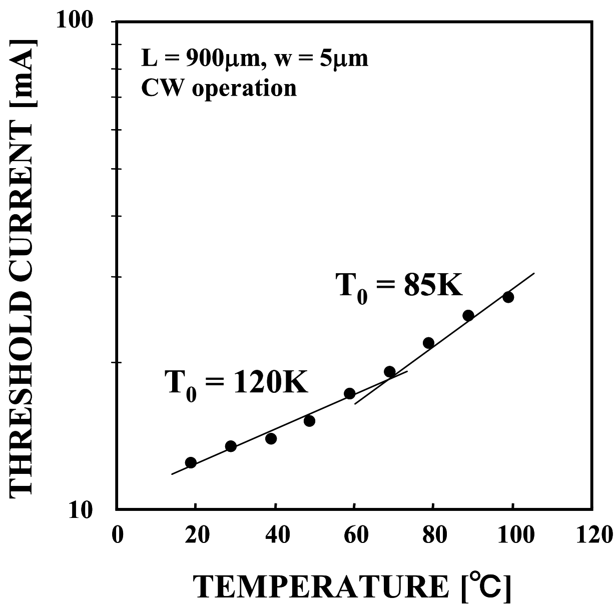

Figure 2. Temperature characteristics of 900 μm-long RWG laser (w = 5 μm) with as-cleaved facets under CW operation at heat-sink temperatures between 20 ºC and 100 ºC.

4. Conclusion

We have demonstrated high-performance highly strained InGaAs/GaAs QW ridge waveguide laser diodes emitting beyond 1.2 μm. Room-temperature CW operation with a low threshold current of 280 A/cm^2 emitting at 1.23 μm was achieved by increasing the In-content to 46 %. Highly strained InGaAs/GaAs SQW was obtained by MOCVD at low growth temperature and rate. The devices showed good temperature characteristics with a high T_0-value of 120 K and a high operating temperature of at least 100 ºC. These results show that high-performance GaAs-based 1.2-1.3 μm lasers can be achieved by highly strained InGaAs(N)/GaAs QWs structures.

Acknowledgement

This work was supported by Focused Research and Development Project for the Realization of the World's Most Advanced IT Nation, IT Program, MEXT. The authors gratefully acknowledge the IT Program (MXIT).

References

[1] D. Schlenker, T. Miyamoto, Z. Chen, F. Koyama and K. Iga, IEEE Photonics Technol. Lett. **11** (1998) 946.

[2] T. Kondo, M. Arai, A. Onomura, T. Miyamoto and F. Koyama, *Proceedings of IEEE LEOS Annual meeting 2002, Glasgow,* WFF5 (2002) 618.

[3] T. Takeuchi, Y.-L. Chang, A. Tandon, D. Bour, S. Corzine, R. Twist, M. Tan and H.-C. Luan, Appl. Phys. Lett. **80** (2002) 2445.

[4] N. Tansu, J.Y. Yeh and L.J. Mawst, IEEE J. Select. Topics Quantum Electron. **9** (2003) 1220.

[5] S. Sato and S. Satoh, Jpn. J. Appl. Phys. **38** (1998) L990.

[6] S. Mogg, N. Chitica, R. Schatz and M. Hammar, Appl. Phys. Lett. **81** (2002) 2334.

[7] N. Nishiyama, M. Arai, S. Shinada, M. Azuchi, T. Miyamoto, F. Koyama and K. Iga, IEEE J. Select. Topics Quantum Electron. **7** (2001) 242.

[8] C. Asplund, P. Sundgren, S. Mogg, M. Hammar, U. Christiansen, V. Oscarsson, C. Runnstrm, F. Odling, and J. Malmquist, Electron. Lett. **38**, (2002) 635.

[9] A.F. Phillips, S.J. Sweeney, A.R. Adams and P.J.A. Thijs, IEEE J. Select. Topics Quantum Electron. **5** (1999) 401.