第 22 卷第 2 期 半 导 体 学 报 Vol. 22, No. 2
2001 年 2 月 CHINESE JOURNAL OF SEMICONDUCTORS Feb., 2001

GSMBE-Grown InGaAs/InGaAsP Strained Quantum Well Lasers at 1.84 Micron Wavelength*

BAI Jin-song, FANG Zu-jie, ZHANG Yun-mei and CHEN Gao-ting

(*Information Optoelectronic Technology Division, Laboratory of Information Optics, Shanghai Institute of Optics and Fine Mechanics, The Chinese Academy of Sciences, Shanghai 201800, China*)

LI Ai-zhen and CHEN Jian-xin

(*State Key Laboratory of Functional Materials of Informatics, Shanghai Institute of Metallurgy, The Chinese Academy of Sciences, Shanghai 200050, China*)

Abstract: GSMBE-grown 1.84 micron wavelength InGaAs/InGaAsP/InP strained quantum well lasers are reported. Lasers with 800 micron-long cavity and 40 micron-wide planar electrical stripe have been operated under the pulsed regime at room temperature. At 20℃, the threshold current density is 3.8kA/cm^2 and the external different quantum efficiency is 9.3%.

Key words: GSMBE; midinfrared band; strained quantum well laser

PACC: 4255P; 6855; 8115G **EEACC**: 4320J; 0510D; 4250

CLC number: TN248.4; TN405.984 **Document code**: A **Article ID**: 0253-4177(2001)02-0126-04

1 Introduction

The MOVPE (Metal Organic Vapour Phase Epitaxy)-grown 1.8μm[1] and 2.07μm[2] wavelength InGaAs/InGaAsP/InP strained quantum well lasers were reported by Forouhar *et al*. in 1992 for the first time. The performance of the lasers, whose wafers are all grown by MOVPE with the longest emission wavelength being 2.07μm[1—8], has been improved rapidly in recent years[3—8]. To extend the emission wavelength beyond 2.07μm, indium-rich high strains and thick layers in the quantum wells are both required[2,8]. The well thickness is limited due to the critical thickness, which decreases with the increase of the strains[2], so the emission wavelength is limited to 2.07μm. A low growth temperature is considered to be advantageous to both the growth of indium-rich highly strained quantum wells, which is because of the indium segregation[8], and the increase of the critical thickness[9,10]. For 1.3μm wavelength InAsP/InGaAsP/InP highly strained quantum well lasers, it is reported[9] that at the growth temperature of 520℃, the critical thickness 70nm of MOMBE (Metal Organic Molecular Beam Epitaxy) is about twice as much as that of MOVPE at the growth temperature of 620℃, as shows that the extension of the emission wavelength of InGaAs/InGaAsP/InP strained quantum well lasers beyond 2.07μm may be determined by MOMBE or GSMBE (Gas-Source Molecular Beam Epitaxy), whose growth temperatures are about 100℃ lower than that of MOVPE.

* Project Supported by 95 Basic Research Plan of The Chinese Academy of Sciences Under Contract No. KJ951-81-706-06.

BAI Jin-song male, born in 1967, Ph.D, his research interests include semiconductor lasers, other photonics devices and optical communication technology.

Received 22 July 2000, revised manuscript received 20 October 2000

GSMBE is used to grow the InGaAs/InGaAsP/InP strained quantum well materials at 500℃ or so[11,12]. As for the laser devices, the GSMBE-grown InGaAs/InGaAsP/InP strained quantum well lasers with 2.0μm wavelength at the lasing temperature of 77K has been reported[13].

In this letter, room temperature pulsed operation of the GSMBE-grown 1.84μm-wavelength InGaAs/InGaAsP/InP strained quantum well lasers are presented. The lasers with 800μm-long cavity and 40μm-wide planar electrical stripe are operated under the pulsed regime at room temperature. At 20℃, the threshold current density is obtained to be 3.8kA/cm^2 and the external different quantum efficiency is 9.3%.

2 Material Growth and Device Fabrication

The laser wafers were grown on the (100) oriented Si-doped n-InP substrate by GSMBE according to our design. The conduct band profile is schematically shown in Fig. 1. Outgassing of the substrate having been finished, the following layers were grown orderly: 1μm-thick Si-doped InP

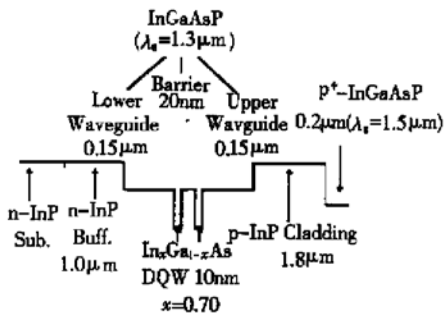

FIG. 1 Conduction Band Profile of $In_xGa_{1-x}As$/InGaAsP (x = 0.70) Strained Quantum Well Lasers InGaAs/InGaAsP

buffer layer; 0.15μm-thick Si-doped InGaAsP(L_g=1.3μm) lower waveguide layer; undoped InGaAs/InGaAsP strained double quantum-well active layer that consisted of two 10nm-thick $In_{0.70}Ga_{0.30}As$ wells and a 20nm-thick InGaAsP(L_g= 1.3μm) barrier, with 1.2% compressive strain and a 1.8μm emission wavelength; 0.15μm-thick Be-doped InGaAsP (L_g = 1.3μm) upper waveguide layer; 1.8μm-thick Be-doped InP confining layer and 0.2μm-thick Be-heavily-doped InGaAsP (L_g = 1.5μm) ohmic contact layer. The growth temperature was about 500℃.

The SiO_2 film being the mask was evaporated onto the wafers by thermo-decomposition method. The 40μm-wide planar electrical stripe structure was fabricated by standard optical processing. The ohmic contact AuZn/CrAu was as the p-side by lift-off technology, while AuGeNi was used as the n-side after the n-substrate was lapped to 100μm thickness. The wafer was metalized at 300℃ for 30s. Chips 800μm long were obtained by cleaving the wafer and then soldering the p-side onto a Cu heatsink with In.

3 Device Performance

At the constant temperature of 20℃, the lasers were characterized under the pulsed regime, using the pulse 5 meters width at 1kHz repetition rate.

The peak optical power of the devices was measured by a calibrated HgCdTe detector. In Fig. 2, it is the typical curve of peak optical power versus current amplitude. The threshold current

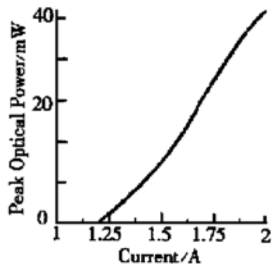

FIG. 2 Pulsed Peak Optical Power Versus Current Amplitude at 20℃

was 1.20A and the peak optical power was 50mW/facet when the current amplitude was 2.0A. The threshold current density and the different quantum efficiency were 3.8kA/cm^2 and 9.3%, respectively, which is comparable with 2.5kA/cm^2 and 5% of the first MOCVD-grown 1.80μm wavelength device[1].

The pulsed lasing spectrum at the current amplitude of 2.0A and 20℃ is shown in Fig. 3, with a multiple-longitudinal-mode structure. The center wavelength was about 1.840μm.

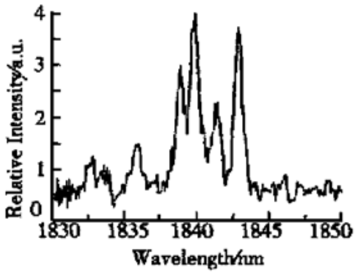

FIG. 3 Pulsed Lasing Spectrum at 20℃ and 2.0A Current Amplitude The pulsed current is with 5ms-width and 1kHz repetition rate.

The lasers could not operate until the heatsink temperature was increased to 56℃. The characteristic temperature of the threshold current density T_0 was 25K between 5 and 56℃.

The typical current-voltage characteristics of the device at 20℃ are shown in Fig. 4. The turn-on voltage is 0.4V. The leakage current is 500mA versus the negative voltage of 1.0V, which was greater by one order than 10—20mA reported by Forouhar[1,2], as indicates that the quality of the grown epilayers should be improved.

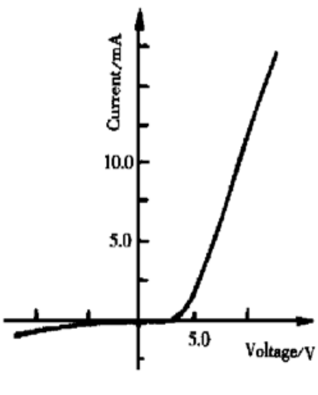

FIG. 4 Typical Current-Voltage Characteristics of Devices at 20℃

So, we can predict that GSMBE is also suitable for the 1.8—2.0μm InGaAs/InGaAsP strained quantum well lasers. The improvement in both material growth and optimal design of the device is necessary for the fabrication of lasers with longer emission wavelength and higher performance.

4 Conclusion

In conclusion, the GSMBE-grown 1.84μm wavelength InGaAs/InGaAsP/InP strained quantum well lasers have been fabricated. The lasers with 800μm-long cavity and 40μm-wide planar electrical stripe have been operated under the pulsed regime at room temperature. At 20℃, the threshold current density and the external different quantum efficiency are 3.8kA/cm^2 and 9.3%, respectively.

References

[1] S. Forouhar, A. Larsson, A. Ksendzov, R. J. Lang, N. Tothill and M. D. Scott, Room-Temperature Operation of MOCVD-Grown GaInAs/InP Strained-Layer Multiquantum Well Lasers in 1.8μm Range, Electron. Lett., 1992, **28** (10): 945—947.

[2] S. Forouhar, A. Ksendzov, A. Larsson and H. Temkin, InGaAs/InGaAsP/InP Strained-Layer Quantum Well Lasers at ~2μm, Electron. Lett., 1992, **28**(15): 1431—1432.

[3] J. S. Major, Jr., D. W. Nam, J. S. Osinsk and D. F. Welch, High-Power Single-Mode 2μm InGaAsP Lasers Diodes, IEEE Photonics Technol. Lett., 1993, **5**(7): 733—734.

[4] R. U. Martinelli, R. J. Menna, A. Triano, M. G. Harvey and G. H. Olsen, Temperature Dependence of 2μm Quantum-Well InGaAs/InGaAsP/InP Diode Lasers, Electron. Lett., 1994, **30**(4): 324—326.

[5] M. Ochiai, H. Temkin, S. Forouhar and R. A. Logan, InGaAs-InGaAsP Buried Heterostructure Lasers Operating at 2.0μm, IEEE Photonics Technol. Lett., 1995, **7**(8): 825—827.

[6] Ramon U. Martinelli, R. J. Menna, G. H. Olsen and J. S. Vermaak. 1.95um Strained InGaAs-InGaAsP-InP Distributed-Feedback Quantum-Well Lasers, IEEE Photonics Technol. Lett., 1994, **6**(12): 1415—1417.

[7] X. He, D. Xu, A. Ovtchinnikov, F. Malarayap, R. Supe, S. Wilson and R. Patel, Highpower Efficient GaInAsP/InP (1.9μm) Laser Diodes Arrays, Electron. Lett., 1999, **35** (5): 397—398.

[8] Jie Dong, Akinori Ubukata and Koh Matsumoto, 1.95μm Wavelength InGaAs/InGaAsP Laser with Compressively

Strained Quantum Well Active Layer, Jpn. J. Appl. Phys., 1997, **36** (Part I, 9A): 5468—5471.

[9] Hideo Sugiura, Manabu Mitsuhara, Hiromi Oohashi, Takuo Hirono and Kiichi Nakashima, Metalorganic Molecular Beam Epitaxy of Strained InAsP/InGaAsP Multi-Quantum-Well for 1.3μm Wavelength Laser Diodes, J. Cryst. Growth, 1995, **147**: 1—7.

[10] G. L. Price, Critical-Thickness and Growth-Mode Transitions in Highly Strained $In_xGa_{1-x}As$ Films, Phys. Rev. Lett., 1991, **66**(4): 469—472.

[11] H. Temkin, D. G. Gershoni, S. N. G. Chu, J. M. Vandenberg, R. A. Hamm and M. B. Panish, Critical Layer Thickness in Strained $Ga_{1-x}In_xAs$ /InP Quantum Wells, Appl. Phys. Lett., 1989, **55**(16): 1668—1670.

[12] SUN Dianzhao, WANG Xiaoliang, LI Xiaobing *et al*., Study on GSMBE Growth of InGaAs/InP Superlattice Materials, Chinese Journal of Semiconductors, 1995, **16**(10): 725—729 (in Chinese) [孙殿照, 王晓亮, 李晓兵, 等, InGaAs/InP 超晶格材料的 GSMBE 生长研究, 半导体学报, 1995, **16**(10): 725—729].

[13] BAI Jinsong, FANG Zujie, ZHANG Yunmei, CHEN Gaoting, LI Aizhen and CHEN Jianxin, MBE-Grown Ridge-Waveguide InGaAs/InGaAsP Strained Quantum Well Lasers at 2μm Wavelength, Chinese Journal of Laser, 2000, **B9** (2): 111—115 (in English) [柏劲松, 方祖捷, 张云妹, 陈高庭, 李爱珍, 陈建新, MBE 生长 2μm 波长脊波导结构 InGaAs/InGaAsP 应变量子阱激光器, 中国激光, 2000, **B9**(2): 111—115].

GSMBE 生长 1.84 m 波长 InGaAs/InGaAsP 应变量子阱激光器*

柏劲松　方祖捷　张云妹　陈高庭

(中国科学院上海光学精密机械研究所 信息光学实验室信息光电子技术研究室, 上海　201800)

李爱珍　陈建新

(中国科学院上海冶金研究所 信息功能材料国家重点实验室, 上海　200050)

摘要: 报道了 GSMBE 方法生长波长 1.84μm 的 InGaAs/InGaAsP/InP 应变量子阱激光器. 40μm 条宽、800μm 腔长的平面电极条形结构器件, 室温下以脉冲方式激射, 20℃下阈值电流密度为 3.8kA/cm^2, 外微分量子效率为 9.3%.

关键词: GSMBE; 中红外波段; 应变量子阱激光器

PACC: 4255P; 6855; 8115G　　**EEACC**: 4320J; 0510D; 4250

中图分类号: TN248.4; TN405.984　　**文献标识码**: A　　**文章编号**: 0253-4177(2001)02-0126-04

* 中国科学院九五基础研究资助项目(KJ951-81-706-06).

柏劲松　男, 1967 年出生, 博士, 目前研究兴趣是半导体激光器、光学器件的光通讯技术.

2000-07-22 收到, 2000-10-20 定稿