第26卷 第9期
2005年9月

半 导 体 学 报
CHINESE JOURNAL OF SEMICONDUCTORS

Vol.26 No.9
Sep.,2005

Compressively Strained InGaAs/InGaAsP Quantum Well Distributed Feedback Laser at 1.74μm*

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Abstract: The compressively strained InGaAs/InGaAsP quantum well distributed feedback laser with ridge-waveguide is fabricated at 1.74μm. It is grown by low-pressure metal organic chemical vapor deposition (MOCVD). A strain buffer layer is used to avoid indium segregation. The threshold current of the device uncoated with length of 300μm is 11.5mA. The maximum output power is 14mW at 100mA. A side mode suppression ratio of 35.5dB is obtained.

Key words: DFB laser; compressive strain; quantum well
EEACC: 2520D; 2530C; 4320J
CLC number: TN248.4 **Document code:** A **Article ID:** 0253-4177(2005)09-1688-04

1 Introduction

High strained InGaAs/InGaAsP quantum well distributed feedback lasers at wavelength range from 1.6 to 2.0μm can be used in remote sensing, pollutant detection, and molecular spectroscopy[1]. However, the high strain quantum wells make it difficult to obtain high performance laser diodes. With the increase of the wavelength from 1.6 to 2.0μm, the indium concentration in the quantum well should be increased. However, high indium concentration will lead indium segregation during the quantum well growth. At long wavelength range the laser characteristics deteriorate because of large optical loss, such as Auger recombination and intervalence band absorption. Much effort has been spent on the research of long wavelength lasers, most of which were prepared by MBE such as a 2.05μm DFB MQWs laser successfully fabricated by metalorganic molecular beam epitaxy (MOMBE) under low temperature[2~4]. A high performance InGaAs/InGaAlAs QW 1.83μm laser was realized by solid-source molecular-beam epitaxy (MBE)[5].

Hydrogen chloride (HCl) gas monitoring is important, such as in the semiconductor processes, because it is widely used for etching or cleaning in LSI manufacturing and silicon epitaxial process. HCl has a strong absorption line at 1.744μm. In this paper we report on the low threshold InGaAs/InGaAsP QWs diode lasers with wavelength of 1.74μm grown by MOCVD. During the MOCVD growth, a strain buffer layer is used to avoid indium segregation. Mechanisms of indium segregation are related to the growth conditions and the surface quality of the interface. Growth conditions are well understood, such as low growth temperature, high

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* Project supported by the National Natural Science Foundation of China (No.60176023)

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Received 1 March 2005, revised manuscript received 9 May 2005

V/Ⅲ, and growth rate are widely used in high strained materials growth. Based on the knowledge that strained layers can be used to remove threading dislocation, we insert a strain buffer layer to improve the quality of the interface on which the strained quantum wells are grown. The thickness of the strain buffer layer is below the critical thickness.

2 Experiment

The wafer used in this work was grown by metalorganic vapor phase epitaxy (MOVPE) with a horizontal reactor under low pressure of 2.2kPa and at 655 ℃. TMG, TEGa, and TMI were Ⅲ group metalorganic sources, PH_3 and AsH_3 were Ⅴ group sources. SiH_4 and DEZn were employed as n- and p-type dopants. Ⅴ to Ⅲ ratio are 70 in the InGaAs well layer and 250 in the InGaAsP barrier layer as well as confinement layer. A 40nm thick InGaAs layer (with strain of 1.9%) was grown first as shown in Fig. 1. A strain InGaAs layer (with strain of 0.9%) was grown before the high strained InGaAs layer as strain buffer layer to improve the quality of the interface between InP and high strained InGaAs. The band diagram of the laser structure is shown in Fig. 2. The buffer layer of 1μm-thick with graded n-type doping InP (Si-doped, $n = 1\times10^{18} \sim 5\times10^{17}\,\mathrm{cm}^{-3}$) was grown on the n-InP substrate. The four-pair quantum-well structures sandwiched between 100nm-thick InGaAsP (λ = 1.3μm) SCH layers were grown successfully. The same strain buffer layer as described above was grown in the lower InGaAsP SCH layer. The wells were compressively strained (+1.6%) $In_{0.77}Ga_{0.23}As$ with a thickness of 7nm and the barriers were tensile strained (-0.3%) InGaAsP (λ = 1.2μm) with a thickness of 10nm. The E_g increased from SCH layer (λ = 1.3μm) to the barrier layer (λ = 1.2μm) continuously. Relatively high barrier heights also act as carrier blocking layers[6,7]. Bragg corrugation with a pitch of 271nm was formed on the upper confinement layer using holographic lithography. After definition the grating was dry-etched and chemically wet-etched to transfer the pattern from the resist into the semiconductor. Following removal of the resist, the grating was then overgrown with InP and highly doped InGaAs layer to make a good Ohmic contact. At last, a ridge wave-guide laser with an active region width of 3μm was fabricated. The uncoated laser samples were mounted on a copper heat sink with p-side up.

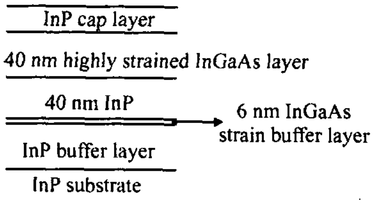

Fig. 1 Schematic of the structure used for investigating the effect of a InGaAs strain buffer layer on surface quality

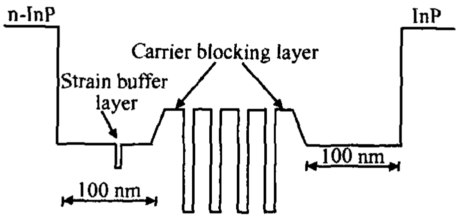

Fig. 2 Band diagram of InGaAs strained QWs laser structure

3 Results and discussion

In Fig. 3 the Pendellösung fringes appear between the InP substrate peak and high strained InGaAs peak, indicating a very high crystalline quality of the high strained InGaAs layer. Without the strain buffer layer there is no Pendellösung fringes and the FWHM of the peak of high strained InGaAs is wider (not shown in this paper). So the strain buffer layer improves the quality of the surface of InP on which the high strained InGaAs is grown. The strain buffer layer was also used in the DFB laser to improve the quality of the quantum wells.

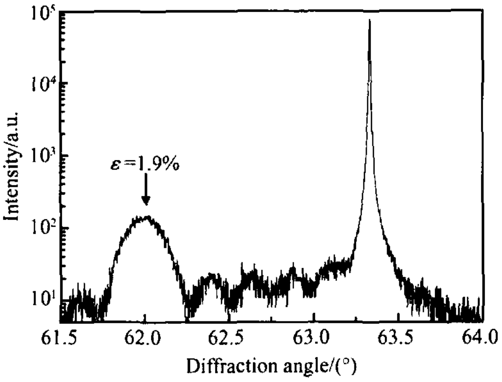

Fig. 3 Rocking curve of sample with large strain $\varepsilon=1.9\%$

Figure 4 shows the CW light-current characteristics of the DFB laser in the temperature range from 10 to 40 ℃. The laser cavity length is 300μm. At 20 ℃, the threshold current is 11.5mA and the slope efficiency ranges from 0.31 to 0.35W/A. There is no saturation of output power up to 14mW. In the temperature ranges from 10 to 40 ℃, the characteristic temperature T_0 is 57K, which is comparable to that of the 1.55μm-wavelength InGaAsP/InP-DFB laser. Both the maximum output power and the slope efficiency are higher than those of the 1.74μm DFB laser reported in Ref. [8] which is the best result until now as far as we know. Figure 5 shows the lasing emission wavelength with the injection current of 50mA (6.7mW). The side mode suppression ratio (SMSR) is 33.5dB. Single-mode operation is observed over relatively wide temperature and injection current range. Figure 6 shows the changes in wavelength with current in temperature range from 10 to 30 ℃. The current-tuning rate of the DFB mode is 0.014nm/mA at 10 ℃, 0.016nm/mA at 20 ℃, and 0.013nm/mA at 30 ℃, which is in the same order as those of the conventional 1.3 and 1.5μm lasers. The total wavelength tuning range is 2.6nm from 10 to 30 ℃. The laser diodes had a screening procedure: 24h under automatic current control (ACC) at 150mA driving current and 100 ℃ (measured at the heat sink). The threshold current and the slope efficiency almost did not change.

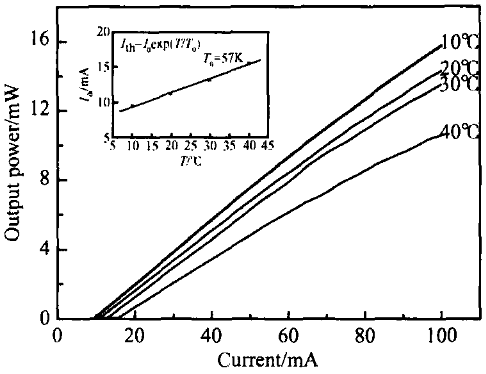

Fig. 4 Light-current characteristics under CW operation Inset shows the current dependence on mount temperature.

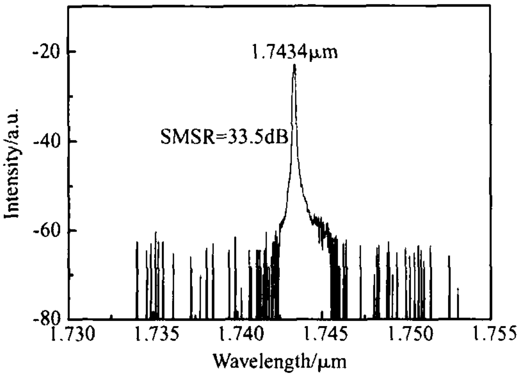

Fig. 5 Wavelength of DFB laser at CW operation with injection current of 50mA

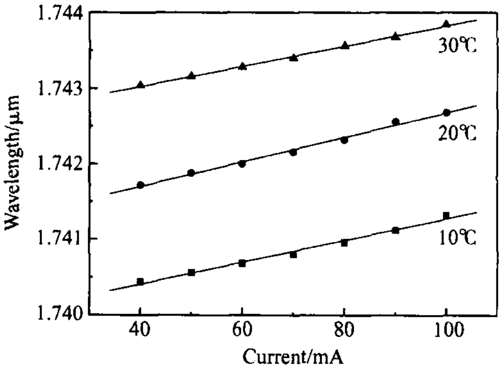

Fig. 6 Wavelength variation with changes in operation temperature and injection current

4 Conclusion

In conclusion, the DFB laser emitting at 1.74μm has been fabricated by introducing a large

compressive strain in the InGaAs/ InGaAsP quantum well. The laser performance is comparable to that of the 1. 55μm-wavelength InGaAsP/ InP-DFB laser, which has the same MOCVD growth condition and fabrication process. Under CW operation the threshold current is 11. 5mA and the maximum output power is more than 12mW. The slope efficiency and the characteristic temperature in a 300μm long laser were 0. 31～0. 35W/ A and 57K, respectively. The wavelength tuning range was 2. 6nm from 10 to 30 ℃ with a tuning rate of about 0. 014nm/ mA. As an optical source, it is suitable for HCl gas monitor system.

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1. 74μm 压应变 InGaAs/ InGaAsP 量子阱分布反馈激光器 *

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摘要: 制备了 1. 74μm 脊波导结构压应变 InGaAs/ InGaAsP 量子阱分布反馈激光器. 采用低压金属有机化合物气相沉积法生长器件材料, 应用应变缓冲层防止 In 的分凝. 未镀膜的腔长为 300μm 的器件阈值电流为 11. 5mA, 100mA 时最大输出功率为 14mW, 边模抑制比为 33. 5dB.

关键词: 分布反馈激光器; 压应变; 量子阱

EEACC: 2520D; 2530C; 4320J

中图分类号: TN248. 4　**文献标识码**: A　**文章编号**: 0253-4177(2005)09-1688-04

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* 国家自然科学基金资助项目(批准号: 60176023)

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2005-03-01 收到, 2005-05-09 定稿