Extended Abstracts of the 20th (1988 International) Conference on Solid State Devices and Materials, Tokyo, 1988, pp. 343-346

D-5-4

CW Operation and Extremly Low Capacitance of TJ-BH Laser Diodes Having MQW Active Layers Fabricated by Entire MOVPE

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Transverse junction buried heterostructure (TJ-BH) laser diodes using MQW (un-GaAs 110Å, un-$Al_{0.3}Ga_{0.7}As$ 190Å, 5wells) as active layers have been successfully fabricated by an entire MOVPE process. The TJ-BH MQW laser diodes exhibited not only CW operations at room temperature (average threshold current I_{th}=9.5mA) and high uniformity of laser characteristics but also extremely low capacitance less than 0.05pF at zero bias voltage. TJ-BH MQW laser diodes are likely to prove very suitable for high speed response OEIC's.

1. Introduction

Recently, various papers on laser diodes of transverse junction type have demonstrated very attractive possibilities for these devices in the field of Optoelectronic integrated circuits (OEIC's). [1)-3)] In particular, the TJ-BH laser diode [2)] has shown promise for the above applications, as buried heterostructures are eminently useful in obtaining a low threshold current.[4)] Furthermore, it has been also demonstrated that multiquantum well (MQW) laser diodes have superior properties such as not only lower threshold current densities [5)] but less dependence on temperature [6)].

We have already reported on the fabrications of TJ-BH laser diodes by an complete LPE method[2)], an MOVPE/LPE hybrid process and an entire MOVPE method[7)]. In this paper, we demonstrate that a new type of TJ-BH laser diodes in which an MQW was applied to the active layer, was produced by an entire MOVPE method.

2. Fabrication of TJ-BH MQW laser diode

An MQW structure grown on a semi-insulating GaAs : Cr wafer by the LP-MOVPE method was used to fabricate TJ-BH MQW laser diodes. A schematic cross-section and a schematic energy band diagram of the MQW active layer in the TJ-BH MQW laser diode are illustrated in Fig. 1.

The procedure for TJ-BH MQW laser diodes by this entire MOVPE method is shown in Fig. 2. First, a SiNx film was deposited on an MQW epitaxial wafer to a thickness of 200nm by a plasma-enhanced CVD (P-CVD). Next, an unmasked stripe region of 100μm width every 300μm was formed along the (110) direction and etched to about 2.0μm depth. The etching front went into an $Al_{0.42}Ga_{0.58}As$ cladding layer below the active layer to oxidize the surface in contact with the etchant. Therefore, surface oxides were removed by an in-situ etching using HCl in vapor phase [7),8)]. After a 2-minute pause from the end of vapor phase etching, an $Al_{0.35}Ga_{0.65}As$ layer for n-type carrier injection and a GaAs layer for n-type Ohmic contact were selectively regrown on the lower $Al_{0.42}Ga_{0.58}As$ cladding layer by LP-MOVPE. In the same way, an $Al_{0.35}Ga_{0.65}As$ layer for p-type carrier injection was embedded close to the edge of the n-type carrier injection layer. Finally, n- and p- Ohmic contacts, using AuGe/Ni/Au and AuZn/Ni/Au metals, respectively, were formed on each GaAs contact layer.

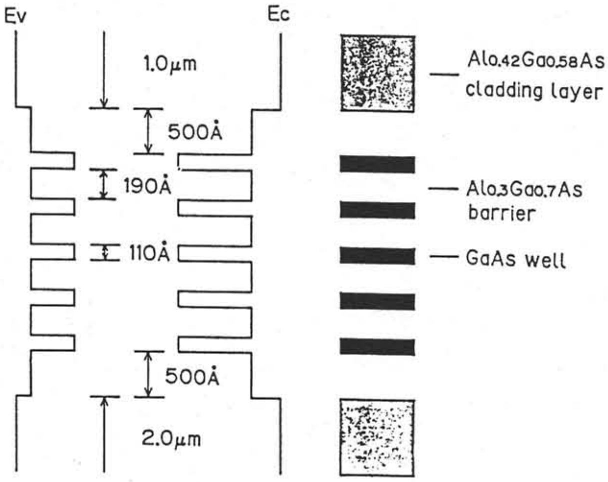

Fig.1 Schematic energy band diagram and structure of MQW.

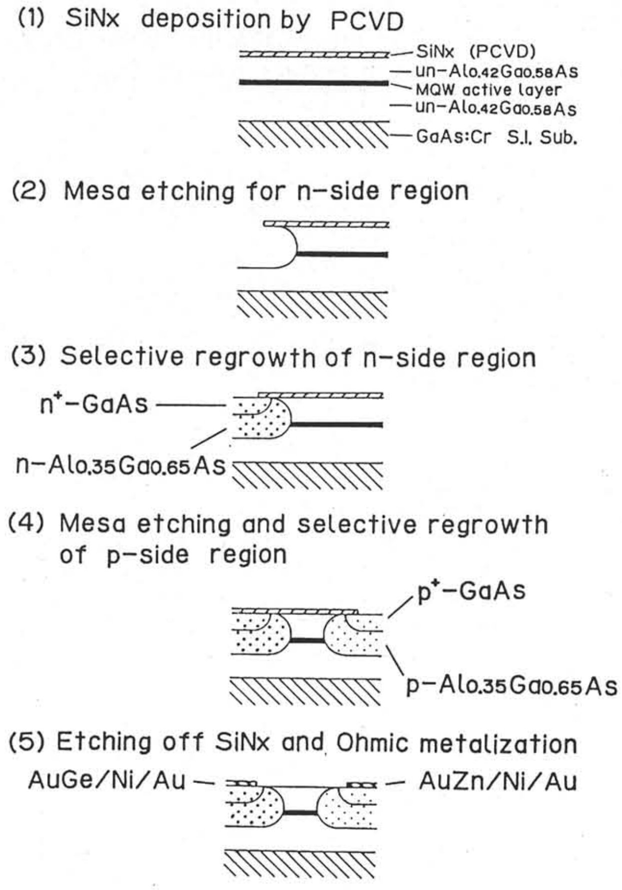

Fig.2 Fabrication process for TJ-BH MQW laser diode by entire MOVPE method.

3. Results and discussion

Figure 3 shows cross-sectional SEM photograph of the TJ-BH MQW laser diode. The excellent embedding of carrier injection layers was achieved, where the active region width was 2.0μm.

From the current-voltage (I-V) characteristics of TJ-BH MQW laser diodes, a differential resistance in the forward bias was estimated at 34 Ω while that in the reverse bias was more than 100kΩ. Further, no hysterisis was observed in the I-V characteristics of the TJ-BH MQW laser diodes.

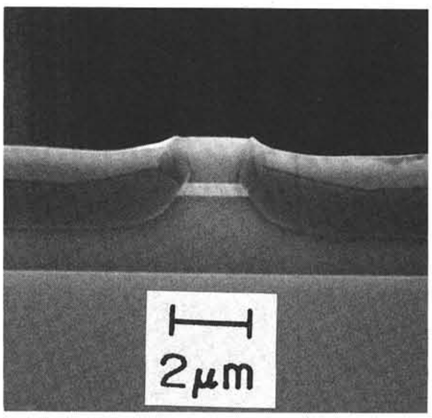

Fig.3 Cross sectional SEM photograph of end facet of TJ-BH MQW laser diode.

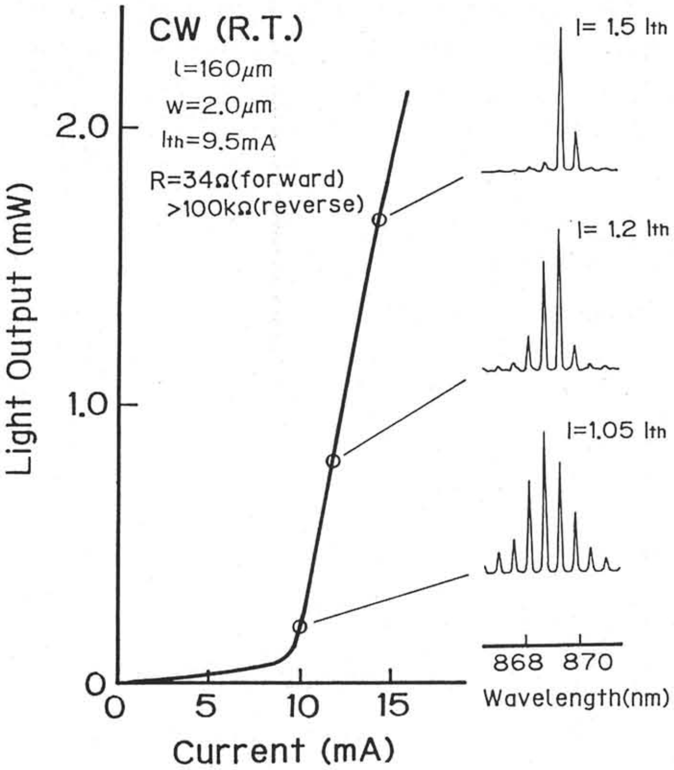

Fig.4 I-L characteristics of TJ-BH MQW laser diode under CW operation at room temperature; cavity length 160μm.

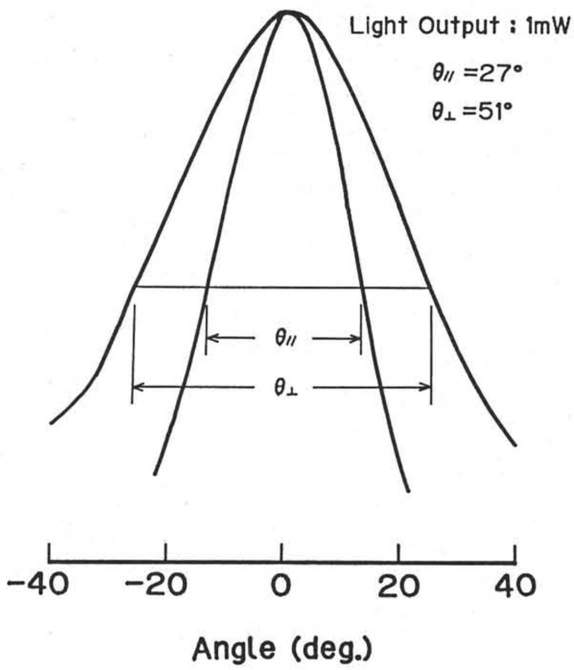

Fig.5 Far-field pattern of TJ-BH MQW laser diode at room temperature.

This indicates that interface oxides between the mesa-etched surface and the carrier injection layer were sufficiently removed.

Figure 4 demonstrates typical characteristics of current-light output (I-L) and lasing spectra of the TJ-BH MQW laser diode operated under CW at room temperature. The lasing wavelength of this sample was 869nm and its threshold current was 9.5mA, where its cavity length was 160μm. The differential quantum efficiency η was about 50%. Every one of 15 randomly chosen laser chips showed CW oscillation at room temperature. The CW average threshold current, which is normalized so that the cavity length was 160μm, was 9.5mA and its uniformity $\pm$5%.

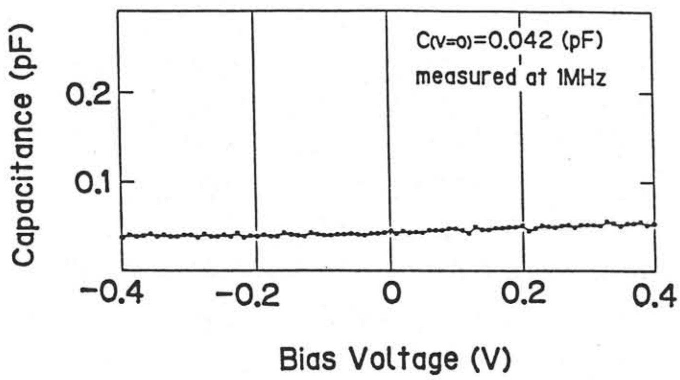

Fig.6 C-V characteristics of TJ-BH MQW laser diode at room temperature.

A far-field pattern for TJ-BH MQW laser diodes is displayed in Fig.5. A stable fundamental transverse mode was obtained. The beam divergence angle, parallel to the MQW layer was 27 degrees, while that perpendicular to it was 51 degrees.

Figure 6 shows typical capacitance-voltage (C-V) characteristics of TJ-BH MQW laser diodes measured at 1MHz. These laser diodes also demonstrated considerably low capacitance of less than 0.05pF at zero bias voltage. This was the first time such an extremely low capacitance was obtained by TJ-BH MQW laser diodes.

Moreover, dependence of the capacitance on bias voltage was much less. Therefore, in combination with the results on the I-V characteristics as mentioned above, it seems that a good p-i-n junction was formed between carrier injection layers through the active layer.

4. Conclusion

TJ-BH MQW laser diodes have successfully fabricated by an entire MOVPE process.

These TJ-BH MQW laser diodes have laser oscillations under CW operation at room temperature as a result of using MQW as an active layer and in-situ HCl etching before selective regrowth for carrier injection layers.

Moreover, These devices show extremely low capacitances less than 0.05pF, the first time such a capacitance has been obtained. Thus, TJ-BH MQW laser diodes are likely to prove eminently suitable for high speed response OEIC's

5. Acknoledgements

The Authors would like to thank J.Saitoh, H.Fujita, T.Yoshitomi, T.Okano, N.Kanoh and K.Yoshida for their useful discussion and continuous encouragement. Thanks are also due to K.Onoda, A.Tohjoh and H.Nakakura for their experimental assistance.

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