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GaInAs/InP Strained Quantum-Well Lasers with Narrow Active Region Fabricated by EBX Direct Writing and 2-Step OMVPE Growth

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By employing an EBX direct writing method followed by a wet chemichal etching and OMVPE regrowth, GaInAs/InP compressively and tensile-strained quantum-well lasers with quasi-quantum-wire active region were realized for the first time. A CW threshold current as low as $16mA$ (J_{th}=$816A/cm^2$, L=$980\mu m$) was obtained with $Ga_{0.66}In_{0.34}As$/InP tensile-strained single-quantum-well BH laser consisting of 30-40nm wide and 70nm periodic active region.

1. Introduction

Several fabrication methods have been studied to realize quantum-wire and quantum-box structures aiming at high performance photonic devices, such as lasers[1],[2], amplifiers[3], and switches/modulators[4]. As a first step to achieve these devices, we have investigated the fabrication method by employing 2-step OMVPE growth and wet-chemical etching[5],[6], because the etching of an ultra-fine pattern and the regrowth on it are essentially required and GaInAs(P)/InP material has less problem of surface oxidization during the process interval.

Recent studies of strained quantum-well lasers revealed excellent performances, and the introduction of strained quantum-well systems into quantum-wire and quantum-box structures seems to be very attractive[7].

In this report we would like to present our latest results on the fabrication process of GaInAs/InP strained quantum-well lasers with quasi-quantum-wire active region and their fundamental lasing properties.

2. Fabrication Process

Prior to fabricate quantum-wire size structures, we made lasers with large size wire structures in order to investigate the regrowth interface. Figure 1 shows the threshold current density J_{th} dependence on the cavity length of lattice-matched MQW lasers with the active region width of around 100nm. Data for 1-step grown quantum-well lasers are also shown for reference. It was found that J_{th} was fairly reduced by using p-InP substrate due to an elimination of a potential barrier for holes at the regrowth interface[8],[9].

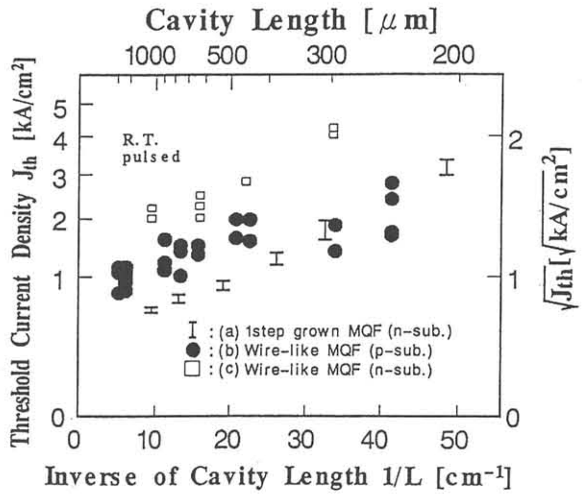

Fig. 1 Threshold current density of three different groups of lasers as a function of the cavity length[8].

Then an EBX direct writing was employed to reduce the wire width (L_x) and the period (Λ) of the active region. A thin (20-30nm) SiO_2 film for the etching mask was deposited by CVD. The dose condition of 1.3-1.6nC/cm was used to transfer periodic line pattern on PMMA resist. After etching the SiO_2 mask by BHF solution, the wafer was etched by diluted Br-methanol.

3. Lasing Properties

We obtained room temperature CW operations of three different quantum-well lasers with quasi-quantum-wire active region, namely lattice-matched 3-quantum-well lasers[9], compressive-strained (CS) 5-quantum-

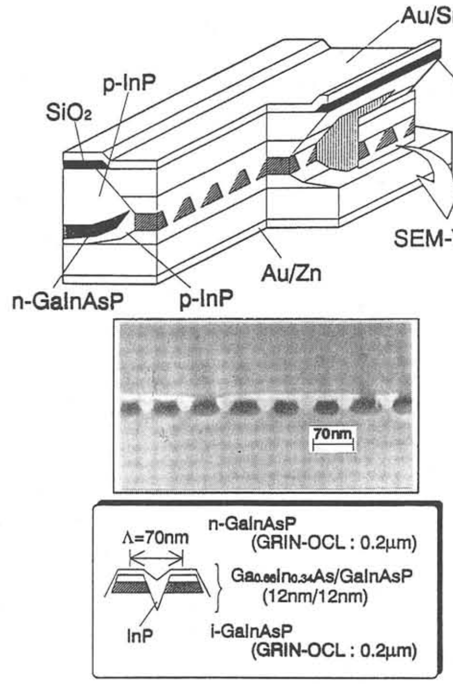

Fig. 2 Schematic structure and cross sectional SEM photograph of $Ga_{0.66}In_{0.34}As$/InP TS-SQW laser (L_x=30-40nm, Λ =70nm)[11].

well lasers[10], and tensile-strained (TS) single-quantum-well (SQW) lasers[11]. These samples were completed in a BH structure with 2μm wide stripes in the 3rd growth by LPE. For an example, the schematic structure and cross sectional SEM photograph of $Ga_{0.66}In_{0.34}As$ /InP TS-SQW laser (L_x=30-40nm, Λ=70nm) are shown in Fig.2.

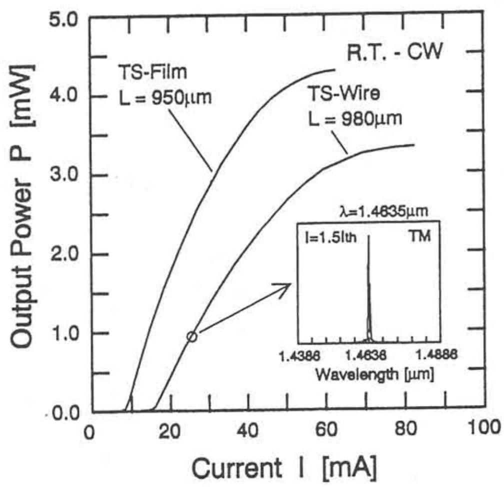

Fig. 3 I-L characteristics of $Ga_{0.66}In_{0.34}As$/InP TS-SQW laser (L_x=30-40nm, Λ=70nm)[11].

As can be seen in Fig.3, a minimum J_{th} of 816A/cm^2 was obtained with the TS-SQW laser with wire active region (L=980μm), while that of a quantum-film laser fabricated on the same wafer was 421A/cm^2 (L=950μm) which is comparable to the best value ever reported for lasers with a similar cavity structure[11]. This fact implies that this OMVPE regrowth does not induce serious increase of the threshold and further improvement in J_{th} of the quasi-quantum-wire laser can be attained by increasing the optical confinement factor ξ of the active region.

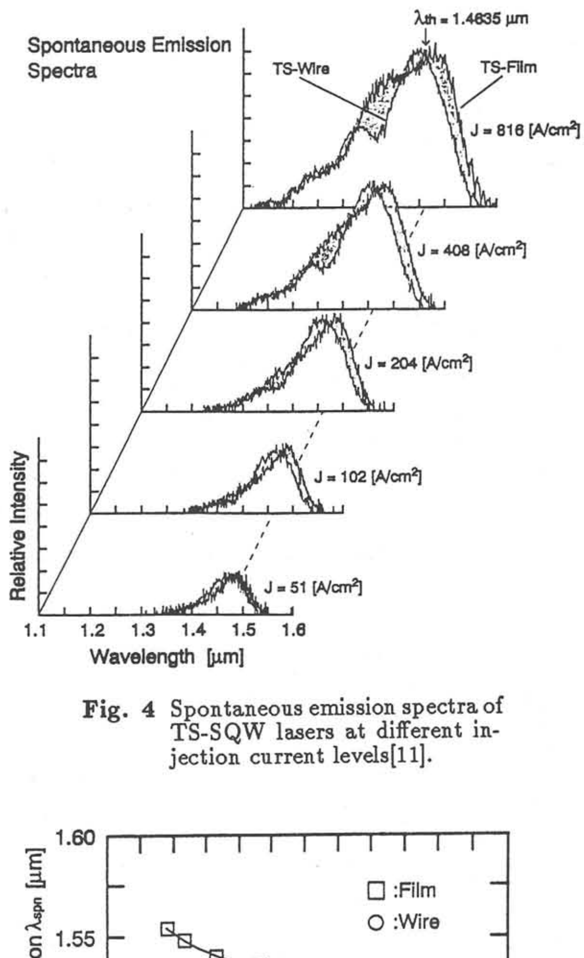

Fig. 4 Spontaneous emission spectra of TS-SQW lasers at different injection current levels[11].

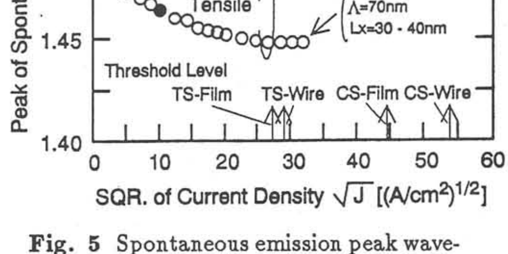

Fig. 5 Spontaneous emission peak wavelength of TS-SQW lasers and CS-MQW lasers as a function of square root of injection current density[10],[11].

Figure 4 shows the spontaneous emission spectra of TS-SQW lasers (wire- and film-laser) at several injection currents between 1 and $16mA$[11]. As can be seen, there were two peaks observed for both types of lasers. The longer wavelength peak is assigned to the light hole (LB)-conduction band (CB) recombinations, and the shorter wavelength peak to the heavy hole (HB)-CB recombinations. Focusing on the longer side spontaneous emission peak wavelength, that of the TS-SQW wire laser always arose at the shorter side of that of the TS-SQW film laser. This peak wavelength dependence on the square-root of the injection current density is depicted in Fig.5. The measured data for CS-MQW lasers of ref.[10] is also plotted. By comparing the peak wavelength of the film laser and that of the wire laser, the peak shift due to the lateral quantum confinement effect was found to be around $10meV$ for the TS-SQW laser and to be $20meV$ for the CS-MQW laser, this result indicates that an effective mass of holes in the lateral direction of the CS-MQW is smaller than that of the TS-SQW[7].

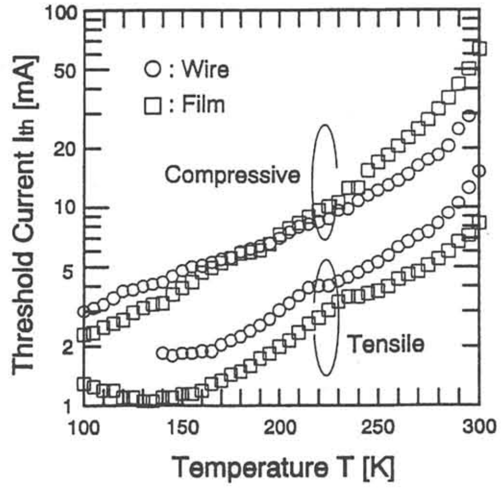

Fig. 6 Temperature dependence of threshold current of TS-SQW lasers and CS-MQW lasers[10],[11].

Temperature dependences of the threshold current of these CS-MQW and TS-SQW lasers are compared in Fig.6. A slight improvement of the characteristic temperature was found in the CS-MQW quasi-quantum-wire laser, but in the TS-SQW quasi-quantum-wire laser.

4. CONCLUSION: Room temperature CW operation of GaInAs/InP quasi-quantum-wire laser was achieved by employing 2-step OMVPE growth and wet-chemical etching. Further improvements can be expected by reducing the active wire width and its size fluctuation.

5. REFERENCES

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