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Investigation of Oxide Mode in 1.3 μm InGaAsN Vertical Cavity Surface Emitting Lasers

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***Abstract* --** In this report, 1.3 μm oxide confined InGaAsN/GaAs VCSELs grown by MOVPE were fabricated. The lasing spectra with blue-shift oxide mode were observed. The related DC characteristics of the fabricated VCSELs are also reported.

1.Introduction:

This report will demonstrate the oxide mode of InGaAsN vertical cavity surface emitting laser (VCSEL) in 1.3 μm range. The wavelength blue shift amount could be up to 40 nm, which is larger than previous reported results observed in highly strained InGaAs quantum well VCSELs [1]. This blue shift oxide mode can be attributed to the large detuning between the gain peak and cavity resonance. And the effective optical thickness shrinkage of the oxide layer will also result in a new cavity resonance, which is so called oxide mode [2].

2. Experiment

Samples used in this study were all prepared by metalorganic vapor phase epitaxy (MOVPE), and grown on 2-inch n^+-GaAs substrates. The VCSEL structure consists of a InGaAsN/GaAs double quantum well (DQW) active region sandwiched by a Si-doped n-distributed Bragg reflector (DBR) mirror and a C-doped p-DBR mirror. The DQW active region consists of two 7 nm-thick InGaAsN well layers and 10.5 nm-thick GaAs barrier layers. The indium composition in the well layers was around 0.35 and N composition was 0.01. Both the n- and p-DBR were composed of interlaced 1/4 λ-thick GaAs and $Al_{0.89}Ga_{0.11}As$ layers with a 20 nm-thick interface grading to reduce the series resistance. There were 40.5 and 26 AlGaAs/GaAs pairs used as the n- and p-DBR mirrors, respectively. A 20 nm-thick AlAs layer was inserted at the interface of the first p-DBR pair and the active region to define the oxide aperture after selective wet oxidation. The detail processing procedure and parameters were well described in previous work [3].

3. Results and Discussion

Figure 1 shows the continuous-wave (CW) light output-current-voltage (L-I-V) characteristics of the fabricated VSCELs under room temperature (RT).

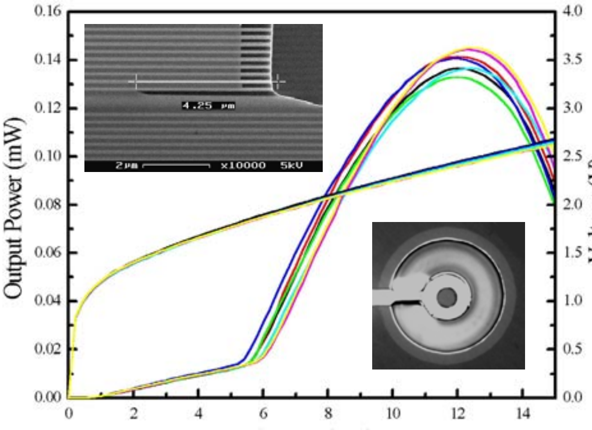

Fig.1 LIV characteristics of the fabricated devices. The inset in the lower right corner shows the top view microphotograph of the device, and the inset in the upper left corner is the cross-section SEM photograph of the oxide-confined VCSELs, the tapered oxide layer can be easily observed.

It is worth noting that the threshold currents of these devices are about 1mA instead of 5mA. The devices had already lased in oxide-mode wavelength when driving current exceed 1mA, though the output power seemed small, and until driving current higher than 5mA the main mode began to lase and output power increased rapidly. This phenomenon had been manifested in our previous works [1].

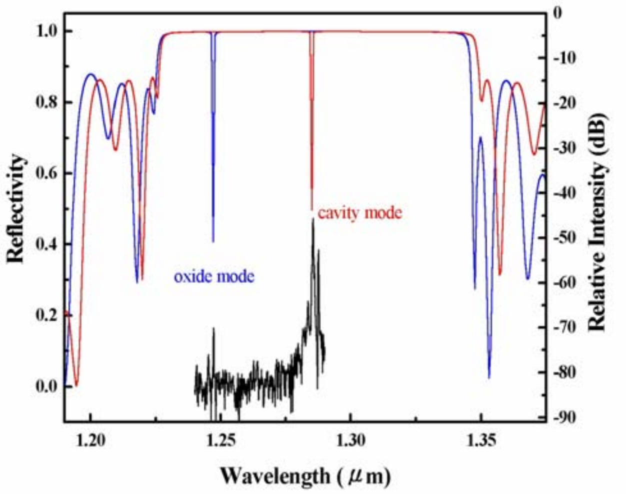

Fig.2 Simulated reflectance spectra before (blue curve) and after (red curve) oxidation. The cavity resonance wavelength of two different mode correspond to the observed lasing spectrum.

From the SEM picture, it was found that the thickness of the tapered oxide layer front was around 107 nm. According to the SEM measurement result, we simulated the reflectance spectrum of the VCSELs sample with a 107 nm-thick AlO_x layer as a replacement of the unoxidized semiconductor layer. The simulated reflect-ance spectra before and after oxidation were represented in Fig.2, and the lower part also shown the corresponded lasing spectrum, whose main peak wavelength was 1.285 μm and oxide-mode was 1.247 μm. Such an observation can be attributed to the large detuning between the gain peak and cavity resonance. And the effective optical thickness shrinkage of the oxide layer will result in a new cavity resonance, which is so called oxide mode [2]. The blue shift oxide modes were resulted from these two factors combination. After oxidation, the reflective index of AlAs was changed from 2.91 to 1.55 when it was converted into AlO_x. Thus, the effective optical thickness will also decrease. When the driving current was small, carriers tended to distribute along the perimeter of the oxide aperture. Since the refractive index difference between the oxide layer and unoxidized GaAs is larger than that of the $Al_{0.89}Ga_{0.11}As$/GaAs DBR pair adjacent to the cavity, the reflectivity of the area beneath the oxide layer is thus larger than that inside the aperture. Hence, photons underneath the oxide layer require less threshold gain to reach stimulated emission. As a result, the emission wavelength blue shifted from the designed cavity resonance [2]. Besides that, the gain spectrum was closer to the shorter wavelength initially. As a result, the emission wavelength blue shifted from the designed cavity resonance under lower injection current. Once the drive current increased, both of the cavity resonance and gain spectrum red shifted and the designed cavity resonance began to lase. This phenomenon also influenced the light output power versus current (L-I) characteristics obviously.

4. Conclusion

In this report we demonstrated the fabrication and optical property of InGaAsN oxide confined VCSELs emitting in 1.3 μm region, and describe the oxide mode phenomenon. The simulated reflectance spectra shown well agreement with the measured lasing spectra.

Reference

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