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Research Article

FABRICATION OF A MULTILAYER GA-AS LASER DIODE WITH MONO CHROME OUTPUT

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ABSTRACT
This paper aimed to investigate the method of fabricating five layers Ga-As Laser Diode and the optical properties of its Output spectrum. Using the LPE, the diode laser consisted of five epitaxial layers. The thickness of the active layer was 0.05 micrometers. The impurity density was measured using SIMS device. The threshold current intensity of laser was obtained about 41.2 mA. It was shown that mono chrome output could be achieved by adjusting the current density.

Keywords: *Laser Threshold Current, Output Spectrum, the Length of Laser Cavity, Semiconductor Laser*
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INTRODUCTION
In 1962, the first semiconductor laser consisting of pulsed arsenide gallium crystal at liquid nitrogen temperature was constructed by several groups (Kooehncv; Csle, 2004). The threshold current density and the divergence of this laser's output light were so high that it was practically useless. Therefore, there were endeavors to reduce the intensity of laser's current and improved the output spectrum of laser. Discovering the compound semiconductor Al_xGa_{1-xAs} which had crystal lattice constant similar to Ga_{As}, the major steps were taken to improve the output light from semiconductor lasers (Kooehncv; Csle, 2004).

The important point about $AlGa_{AS}$ is that it has a lower refractive index than Ga_{As} and its gap energy is greater than that of gallium – arsenide. Thus, if a semiconductor layer of gallium arsenide is placed between two layers of $AlGa_{AS}$, the optical and electrical confinement is simultaneously obtained (Kooehncv; Csle, 2004; Naser).

Figure (1) shows the structure of dissimilar double semiconductor laser which is formed of five layers. The laser active layer which is the combination place of electron and hole is formed of semiconductor Ga_{As} .The two layers including Al_xGa_{1-xAs} - and Al_xGa_{1-xAs} are at its two sides. Since the refractive index of Ga_{As} is more than $AlGa_{AS}$, the produced light is trapped between the two layers. This phenomenon will lead to the convergence of output light of the laser. The n-Ga_{As} layer, known as shield, is added to this structure for improving the epitaxial growth of next layers. The fifth layers of Ga_{As-p} is considered to prevent oxidation of fourth layers, i.e. $AlGa_{AS-p}$. The main structure of laser consists of two layers of Al_xGa_{1-xAs} and one pure Ga_{As} layer. The electrons direct bias and holes are injected from p region and n region to the diode, respectively. They are combined together at the central active region (Ga_{As} layer). The semiconductor energy gap of Ga_{As} equals to

$ev = 1.42E_s$ .the radiated wavelength is equal to:

m) $=\frac{hc}{Eg} = \frac{1/24ev.\mu m}{1/42} = 0/87(1)\lambda$ (µ

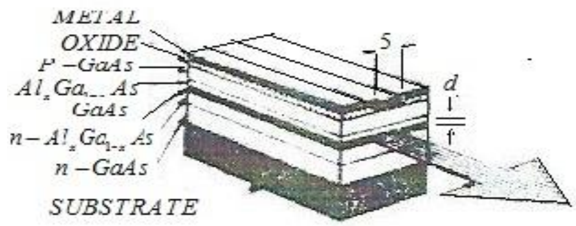

Figure 1: The structure of tape dissimilar double semiconductor laser which is consisted of 5 layers

Method of Construction

The preparation of single-crystal substrate n-Ga_{As} was performed with directed (100) through mechanical abrasion with Al_2O_3, Sic powders in dimensions of 0:05 ... 3,5,10 microns. By mechanical abrasion and chemical milling, the substrate thickness was declined to reach from 600 microns to 380 microns. The sample surface was perfectly flat and like a mirror. Using LPE apparatus and cold cloud method, the epitaxial growth began from temperature 838°C. First, a gallium was placed within each of the five houses in graphite plant. The10.6 tour vacuum was heated at 900 ° C for 10 hours. After chemical milling and degreasing process, then, the solid Ge, Sn, Te, Al, Ga_{As} materials were added to each of the houses in graphite plant. It was again placed inside the reactor and heated to 900°C for one hour. In the next step, the heating with oxygen gas continued with 9.999% purity for 4 hours and the reactor temperature was reduced to 838°C. The molten solution was kept at this temperature for at least 2 hours to reach steady state temperature. By moving the movable part of the graphite plant, the molten solution of first house was placed over the substrate. The reactor temperature dropped after about 10 minutes and the first epitaxial layer formed over the substrate. By reduction of 0.3° C temperature per minute for the reactor set at 833° C, the molten solution of second house was placed over the substrate to prepare the second epitaxial layer. Similarly, the molten solution of the third to fifth houses was transferred over the substrate at different temperatures in order to grow other layers. The contact time of molten solution with the substrate controls the thickness of layer. The molten solution should remain for approximately 20 minutes on the substrate to form an epitaxial layer thickness of about 4 microns. This time is reduced to a few seconds to form thin layers with a thickness of less than a tenth of a micron. The SIMS apparatus was used to study the elements of each layer and measure the density of impurity. For this purpose, the cesium ion beam was collided with constant energy to the surface of sample. Thus, the constituent atoms of surface were separated by the collisions of energetic cesium ions and counted by using a mass spectrometer. Using LPE apparatus and cold cloud method, the epitaxial growth of five layers Ga_{As} / $AlGa_{As}$ was performed with thickness of 0.1 to 5 microns. For this purpose, the AFM and SIMS apparatus are used.

The Optical Characteristics and Laser Output Spectrum

The figures 2, 3, 4 and 5 show the output spectrums (λ-P) in four different electric currents. According to figure 2, there is no mode at I=39.93^{MA}, because the current through the laser diode is lower than laser threshold current. With the gradual increase of the current density, it can be seen that diode begins to produce laser at I=$41/2^{mA}$. This intensity is called the laser threshold current. The laser modes are created at the spectra shown in Figures 3, 4 and 5 which are related to the currents above the threshold intensity. With the gradual increase of current through the diode, it can be seen that the number of appeared modes decreases gradually and only are one of the modes strongly enhanced. Given the size of the made chips, the threshold current density may be calculated at area unit:

$$I = \frac{41/2 \times 10^{-3} A}{200 \times 300 \times 10^{-8} cm^2} \cong 70 \frac{A}{cm^2} \qquad (2)$$

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This is the minimum threshold intensity that has been reported by LPE.
The following equation can be used to calculate the laser's resonant cavity length (L) with having the wavelength of each mode (λ) and wavelength difference between sequential modes (Δλ):

$$\Delta\lambda = \frac{\lambda^2}{2Ln_G}\Delta q \qquad (3)$$

Where, qΔ for two sequential modes is 1. The laser's active layer GaAsnG has a value of 4.3 and is put in the equation. The following table shows the different values of λ, Δ, L obtained in several spectra of built laser.

Table 1: Experimental results of wavelength - cavity length

m)λ(μ	**Nm)Δλ(**	**L=(μm)**
0/8797	0/40	225
0/8814	0/50	180/67
0/8813	0/46	196/23
0/8818	0/40	226

If all values of λ, Δλ are placed in the equation 3, the cavity length for each mode is obtained. The average of numbers can be calculated to obtain an approximate value of the cavity length in which the value of $L_{av}\cong$ 207 m μ is roughly obtained. This value is consistent with the experimental value measured by optical microscope (almost 200 mμ).

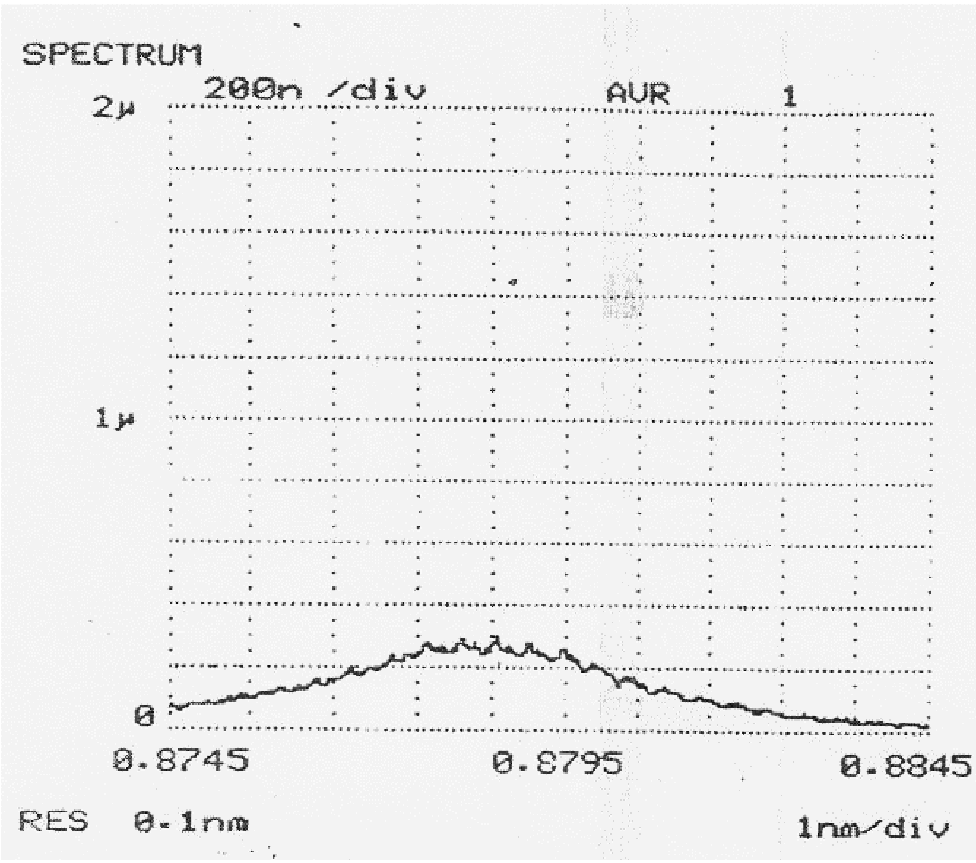

Figure 2: The p-λ spectrum for sample made at current I=39/93mA

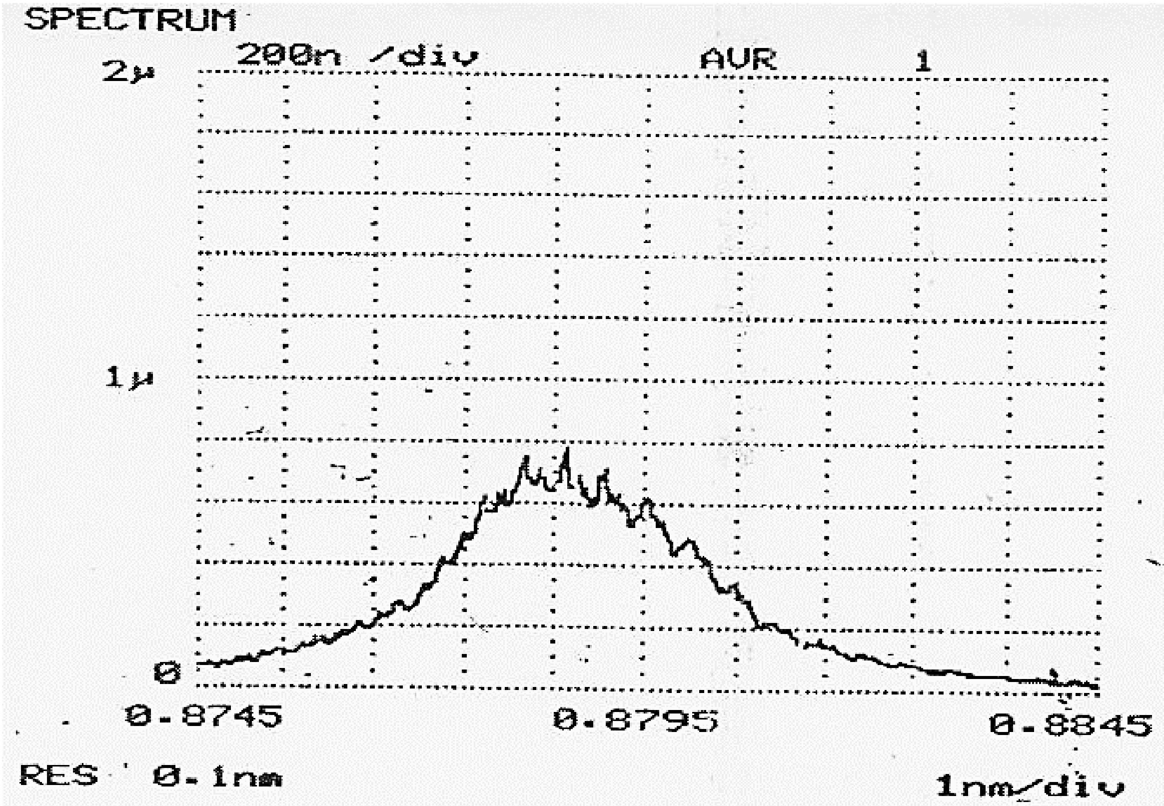

Figure 3: The p-λ spectrum for sample made at current I=41/20mA

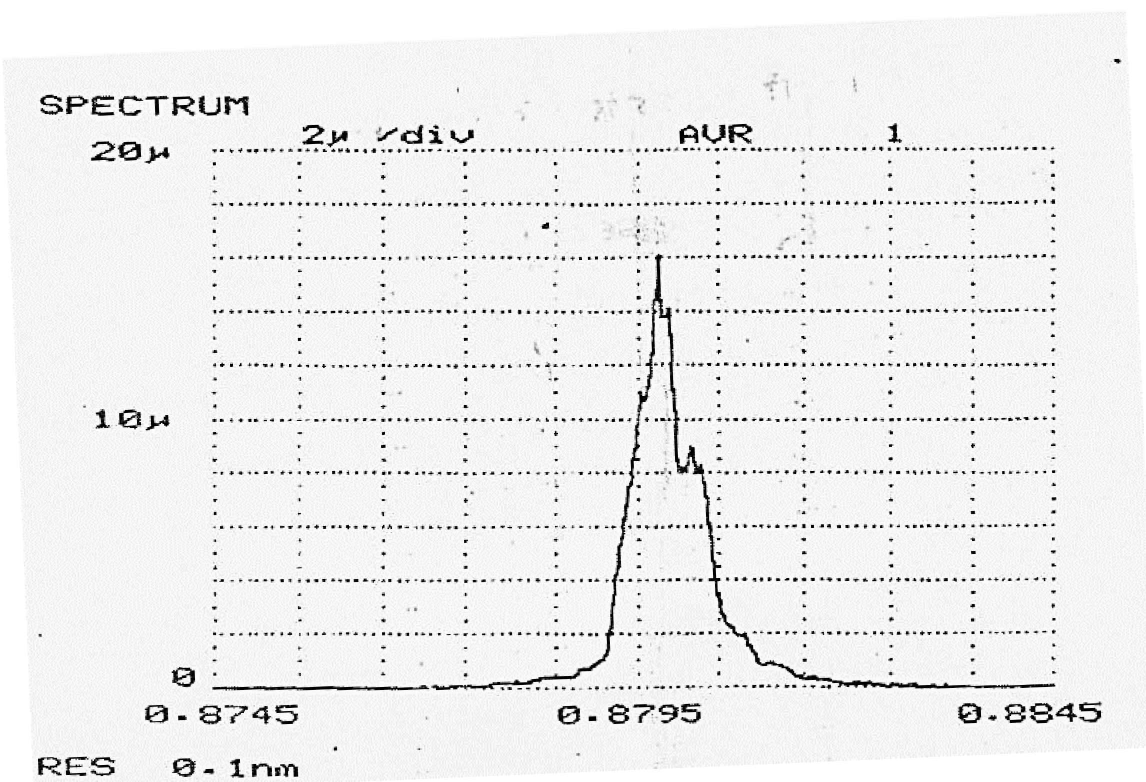

Figure 4: The p-λ spectrum for sample made at current I=57/88mA

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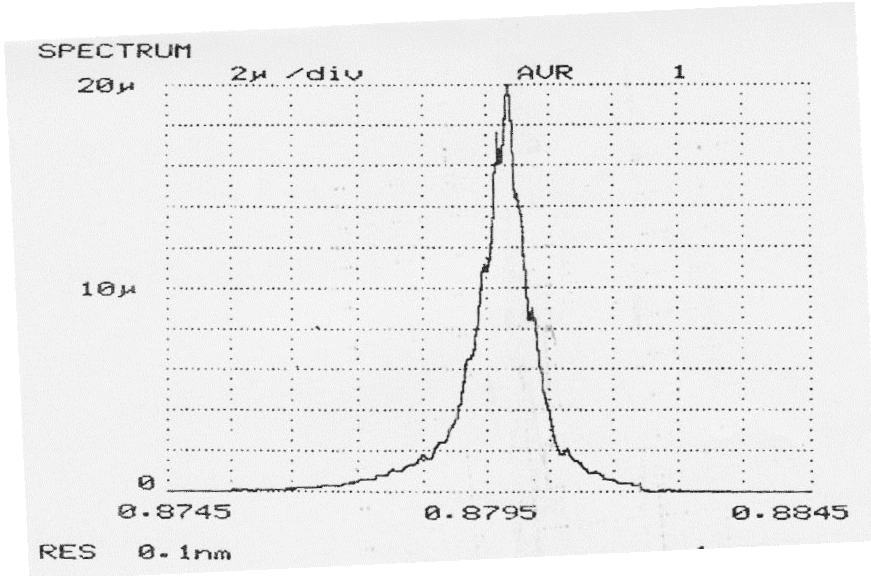

Figure 5: The p-λ spectrum for sample made at current I=60/55mA

Conclusion

This paper explained the method of constructing a gallium-arsenide semiconductor laser diode with 5 epitaxial layers. In the investigation of laser output spectrum, it can be observed that with increasing intensity of the current passing through the sample, all generated modes are removed and only one enhanced mode remains. The observed length of the laser cavity is in good agreement with theoretical calculations.

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