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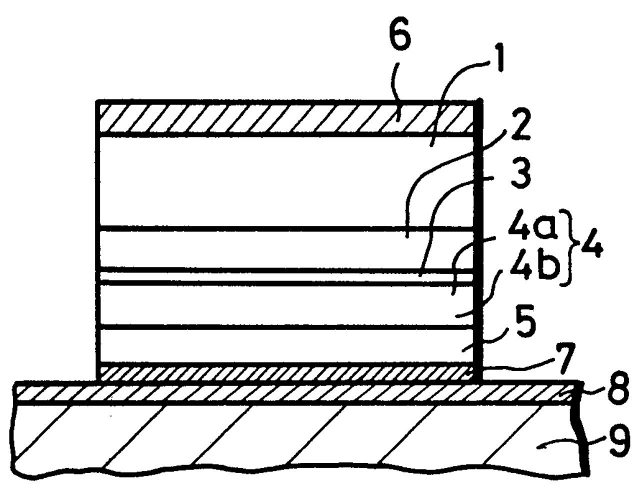
(54) Semiconductor laser devices

(57) A semiconductor laser device has at least one cladding layer (4) formed of a thin AlGaInP layer (4a) having a larger energy band gap than that of an active layer (3) adjacent thereto, and an AlGaAs layer (4b) having a higher thermal conductivity than that of the AlGaInP layer (4a) and a larger energy band gap than that of the active layer (3). The AlGaAs layer (4b) is located between the AlGaInP layer (4a) and a heat sink (9), whereby heat generated in the active layer (3) is effectively radiated to the heat sink (9), so that the semiconductor laser is capable of continuously emitting laser light of a short wavelength at room temperature.

FIG. 2



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The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

FIG. 1

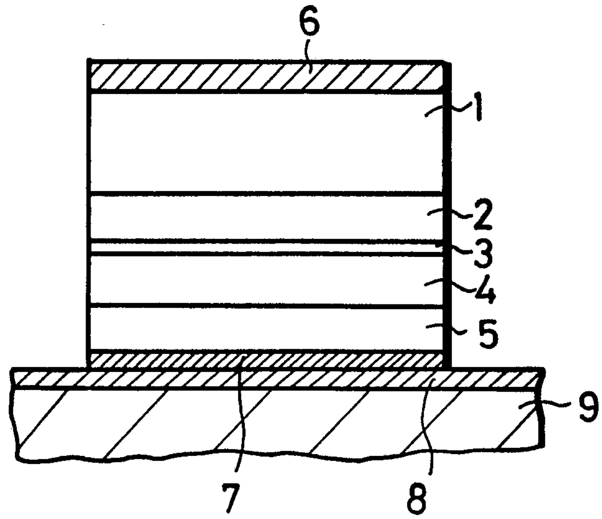
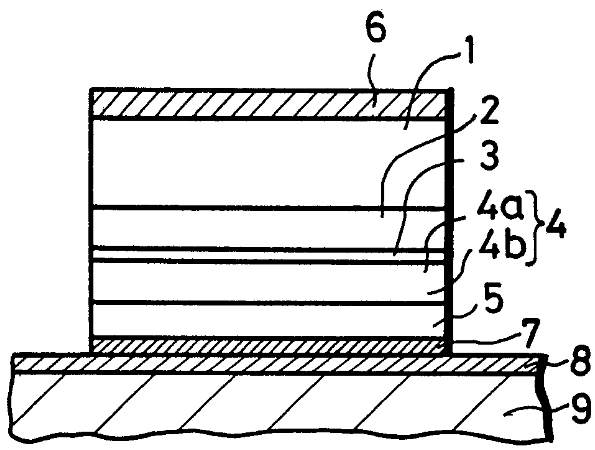


FIG. 2



SPECIFICATION

Semiconductor laser devices

This invention relates to semiconductor laser devices.

Recently, there has been an increased demand for a semiconductor laser device which can continuously emit laser light of a short wavelength band at room tempserature. For example, if an optical disc apparatus such as a so-called compact disc (CD) apparatus, a video disc apparatus or the like employs a light source that produces laser light of short wavelength, high density recording becomes possible and it also becomes possible to use a lens system having a small numerical aperture (NA) so that the optical system thereof can be produced at low cost. Further, since the light from a short wavelength light source is visible, it becomes easy and safe to handle a semiconductor laser. Furthermore, photosensitive material employed in a laser printer and the like has high sensitivity in the range of the visible spectrum, so that it becomes advantageous to use a short wavelength semiconductor laser as a light source for exposure. For this reason, there is a need for short wavelength semiconductor lasers which can continuously emit light at room temperature to be produced for industrial use.

In order to construct a short wavelength semiconductor laser, it is necessary to increase the band gap width of an active layer thereof. In this case, when the material of the active layer is selected, there are various kinds of restrictions. For example, it is necessary to consider a cladding layer for confining carriers and light in the active layer, and also to consider, from a crystal property standpoint, a lattice constant of a crystal substrate on which layers making up the laser are epitaxially grown.

With respect to short wavelength semiconductor lasers of this kind, an AlGaInP/GaAs-system semiconductor laser, in which a semiconductor layer of AlGaInP-system is epitaxially grown on an GaAs substrate so as thereby to construct a semiconductor laser, attracts attention as a semiconductor laser with a so-called wavelength band of 600nm which lies in a range of from 580nm to 680nm.

Such an AlGaInP/GaAs semiconductor laser may for example be constructed as shown in Fig. 1 of the accompanying drawings. The laser shown in Fig. 1 comprises a GaAs substrate 1. A first cladding layer 2, an active layer 3, a second cladding layer 4 and a capping layer 5 are grown epitaxially, in sequence and in the foregoing order, on one major surface of the substrate 1. An electrode 6 is deposited on and in ohmic contact with another major surface of the GaAs substrate 1 and an electrode 7 is deposited on and in ohmic contact with the capping layer 5. The electrode 7 itself is arranged to function as a heat sink. Alternatively, the electrode 7 is soldered via a solder layer 8 to a heat sink, that is, a radiator 9.

The layers 2 to 4 are made of material having a composition given by the general formula:

$$(Al_xGa_{1-x})_yIn_{1-y}P \qquad (1).$$

The active layer 3 is made of $Ga_{0.52}In_{0.48}P$ having a thickness of, for example, 0.1 to 0.2 micrometres. The first and second cladding layers 2 and 4 are each made of an AlGaInP-system semiconductor layer having a band gap width (forbidden band width) larger than that of the active layer 3 by about 0.3eV. Specifically, the cladding layers 2 and 4 are each made of, for example, $Al_{0.26}Ga_{0.26}In_{0.48}P$ of which the Al content (the value of x in Formula 1) is greater than 0.3, more preferably greater than 0.5. The thickness of each of the layers 2 and 4 is selected to be more than 0.8 micrometres, which is thick enough to confine carriers and light within the active layer 3, which has a thickness of, for example, 1 micrometre. Further, the capping layer 5 is, for example, a GaAs layer.

The AlGaInP/GaAs-system semiconductor laser of the above construction emits laser light of a short wavelength (653nm). In this case, the semiconductor laser can continuously emit laser light at a temperature of 228 K, but cannot do so at room temperature.

The reason why this semiconductor laser cannot continuously emit laser light at room temperature may be that heat generated in the active layer 3 in operation is not conducted effectively to the heat sink 9.

A semiconductor laser based on the InGaAsP/GaAs-system and formed to have a mesa-type structure so as thereby to be capable of continuously emitting laser light at room temperature is disclosed, for example, in (i) Nikkei Electronics, 1985, May 20, pages 151 to 153, (ii) Nikkei Micro Device, 1985, Summer edition, pages 21 to 23, and (iii) Electronics Letters, 1985, January 17, Vol. 21, No. 2, pages 54 to 56. According to this mesa-type semiconductor laser, grooves are formed to enter a cladding layer on which a metal electrode, which becomes a heat sink, is deposited. The metal electrode is deposited on the upper surface of the mesa-type semiconductor laser opposite to the GaAs substrate, so as to cover the inside of the grooves, whereby the metal electrode, functioning as a heat sink, approaches the active layer as closely as possible. Thus, the heat generated from the active layer can be radiated effectively so as thereby to enable the semiconductor laser to continuously emit laser light at room temperature.

However, the fact that the electrode is disposed very near to the active layer, as described above, gives rise to a leakage current problem. Further, from a technical standpoint, it is difficult to form such grooves so as to be spaced apart from the active layer by a proper distance and with a proper depth to approach the active layer sufficiently without leakage current occurring. There is therefore a problem if semiconductor lasers having uniform characteristics are to be mass-produced.

According to one aspect of the invention there is provided a semiconductor laser device comprising:

a substrate;

a first cladding layer formed on one surface of the substrate;

an active layer formed on the first cladding layer;

a second cladding layer formed on the active layer;

a capping layer formed on the second cladding layer;

a first electrode deposited on another surface of the substrate; and

a second electrode deposited on the capping layer;

wherein the second cladding layer has an energy band gap width which is larger than that of the active layer and is formed of a first layer adjacent the active layer and a second layer having a thermal conductivity which is higher than that of said first layer.

According to another aspect of the present invention there is provided a semiconductor laser comprising:

a substrate;

a first cladding layer formed on one surface of the substrate;

an active layer formed on the first cladding layer;

a second cladding layer formed on the active layer;

a capping layer formed on the second cladding layer;

a first electrode deposited on another surface of the substrate; and

a second electrode deposited on the capping layer;

wherein the second cladding layer is formed of first and second layers, said first layer being located adjacent the active layer, having an energy band gap width larger than that of the active layer and a thickness sufficiently small to present a carrier confinement effect for the active layer, and said second layer being formed on said first layer and having a thermal conductivity higher than that of said first layer, a refractive index smaller than that of the active layer, and a high confinement effect for the active layer.

A preferred embodiment of the invention described hereinbelow provides an improved semiconductor laser which is not formed to have a mesa-type structure and yet which can continuously emit laser light of a so-called short wavelength in the 600nm band, ranging from 580nm to 680nm, at room temperature.

The invention will now be further described, by way of illustrative and non-limiting example, with reference to the accompanying drawing, in which like references designate like elements and parts throughout, and in which:

Figure 1 is a schematic enlarged cross-sectional view of a previously proposed semiconductor laser device; and

Figure 2 is a schematic enlarged cross-sectional view of a semiconductor laser device embodying the present invention.

Fig. 2 is a schematic enlarged cross-sectional view of a semiconductor laser or laser device embodying the invention. In Fig. 2, parts corresponding to like parts in Fig. 1 are designated by the same references and will not be described in detail.

The laser of Fig. 2 comprises the GaAs substrate 1 on which the first cladding layer 2, the active layer 3, the second cladding layer 4 and the capping layer 5 are epitaxially grown. If necessary, a buffer layer (not shown) made of, for example, GaAs, is disposed between the substrate 1 and the first cladding layer 2.

At least the second cladding layer 4 functions as a heat sink. The second cladding layer 4 is formed of an AlGaInP layer 4a adjoining the active layer 3 and an AlGaAs layer 4b which adjoins the AlGaInP layer 4a and whose thermal conductivity is higher than that of the AlGaInP layer 4a. The AlGaInP layer 4a adjacent to the active layer 3 has an energy band gap width which is large as compared with that of the active layer 3, and has a thickness which is sufficiently small to have the effect of confining at least the carriers (but not necessarily light) within the active layer 3. That is, the thickness of the layer 4a is selected to be more than several 100 Angstroms, the thickness lying, for example, in a range of from 0.1 to 0.3 micrometres in the case when it is not desired strongly that the light confinement function (as distinct from the carrier confinement function) be effected fully. On the other hand, it is desirable that the band gap width of the layer 4b be large as compared with that of the active layer 3 and that the refractive index thereof be smaller than that of the active layer 3. However, it is not necessary that the band gap difference between the AlGaAs layer 4b and the active layer 3 be large enough to effect the carrier confinement function. The thickness of the AlGaAs layer 4b is slected to be such that the light can be confined within the active layer 3 at least in cooperation with the AlGaInP layer 4a.

That is, according to the laser device of Fig. 2, in the mixed crystal semiconductor, in accordance with the fact that the more complex the mixed crystal becomes the lower the thermal conductivity becomes, the four element, mixed crystal AlGaInP system layer 4a having a low thermal conductivity exists between the active layer 3 and the heat sink 9 only as a thin part of the cladding layer 4. Accordingly, the heat generated from the active layer 3 is effectively conducted to the heat sink 9 through the layer 4b of high thermal conductivity and the confinement function of the cladding layer 4, particularly the light confinement function which is lowered when the AlGaInP layer 4a is made thin, can be compensated by the cooperation of the AlGaAs layer 4b having the light confinement effect. Thus, the short wavelength semiconductor laser can continuously emit laser light at room temperature.

The embodiment of Fig. 2 will now be described more fully. In the illustrated example, the first cladding layer 2, the active layer 3 and the layer 4a of the second cladding layer 4 are epitaxially grown on one surface of the GaAs substrate 1 as semiconductor layers of AlGaInP. The AlGaAs layer 4b is epitaxially grown on the layer 4a and the capping layer 5, made of GaAs, is epitaxially grown on the layer 4b. The layers 2, 3, 4a, 4b and 5 can be continuously epitaxially grown by a series of processes employing an epitaxy method using, for example, a metal organic compound, that is by a so-called MOCVD (metal organic chemical vapour deposition) method, a so-called MBE (molecular beam epitaxy) method, or the like.

The electrode 6 is deposited on the other surface of the GaAs substrate 1 in ohmic contact therewith and the electrode 7 is deposited on the capping layer 5 in ohmic contact therewith. Then, the face of the electrode 7 is closely coupled through the solder layer 8 to the heat sink 9 so as to be in good thermally conductive contact with the heat sink.

The electrode 7 is, for example, an Au–Zn layer, or is formed as a multilayer structure in which a Ti layer is formed on an Au layer. The electrode 7 is melt-bonded via the solder layer 8, which may be of Sn, Sn–Pb, In or the like, to the heat sink 9.

The first cladding layer 2, the active layer 3 and the layer 4a of the second cladding layer 4 have compositions expressed by the above-mentioned Formula (1), in which the value y is selected, for example, to be in a range of from 0.51 to 0.52, the lattice constant thereof is selected to have a value nearly equal to that of the GaAs substrate 1, and the crystal layer is epitaxially grown in match with the GaAs substrate 1.

The active layer 3 can be formed of a semiconductor layer having a thickness of, for example, 0.1 to 0.2 micrometres and in which the band gap of $Ga_{0.52}In_{0.48}P$, where the condition that x=0 is satisfied in the above-mentioned Formula (1), is 1.9eV. In that event, the first cladding layer 2 and the layer 4a of the second cladding layer 4 are formed as AlGaInP semiconductor layers which have large band gaps as compared with that of the active layer 3, the difference therebetween becoming more than 0.3eV, for example of $Al_{0.26}Ga_{0.26}In_{0.48}P$ where the condition that x=0.5 is satisfied in the composition expressed by the above Formula (1). In this case, the thickness of the first cladding layer 2, which is a single layer, is selected to be of such a value, for example one micrometre, as to effect light and carrier confinement. Further, the thickness of the AlGaInP-system layer 4a of the second cladding layer 4 is selected to be such as to carry out the carrier confinement, for example as thin as more than several hundres of angstroms, and preferably in a range of from 0.1 to 0.3 micrometres.

The AlGaAs layer 4b of the second cladding layerd 4 has band gap width larger than the band gap width of the active layer 3, for example a band width of 2.0 to 2.17eV. The AlGaAs layer 4b can be formed of, for example, $Al_{0.8}Ga_{0.2}As$ (the band gap width of which is 2.1eV), according to a composition formula:

$(Al_zGa_{1-z})As$ (2)

where the condition that z is greater than or equal to 0.6 and is less than or equal to unity is satisfied.

The thickness of the AlGaAs layer 4b is selected to be such that the light can be confined within the acrtive layer 3. In practice, the thickness of the layer 4b is selected to be more than 0.8 micrometres and the sum of the thickness of the layer 4b and the thickness of the layer 4a becomes more than one micrometre.

While, in the above-described embodiment, only the second cladding layer 4, namely the cladding layer on the side of the heat sink 9, is composed of the layers 4a and 4b, it is possible for both the cladding layers 2 and 4 to be made up of a thin AlGaInP-system layer which can carry out carrier confinement and an AlGaAs-system layer having a high thermal conductivity and which can be used for carrying out light confinement.

According to the embodiment of the present invention as set forth above, in the cladding layer 4 interposed between the active layer 3 and the heat sink 9, the AlGaInP-system semiconductor layer 4a, which is of low thermal conductivity, is formed to be thin, and the light confinement function is mainly achieved by the AlGaAs layer 4b which is of high thermal conductivity so that the short wavelength semiconductor laser made of AlGaInP-system material can continuously emit laser light at room temperature by virtue of the effective heat radiation action.

Further, since the above-described semiconductor laser embodying the invention is formed as a planar-type structure having no groove, it is possible to achieve many advantages, such as: the semiconductor laser can be manufactured with ease; and a short wavelength semiconductor laser having uniform and stable characteristics can be mass-produced.

CLAIMS

1. A semiconductor laser device comprising:

a substrate;

a first cladding layer formed on one surface of the substrate;

an active layer formed on the first cladding layer;

a second cladding layer formed on the active layer;

a capping layer formed on the second cladding layer;

a first electrode deposited on another surface of the substrate; and a second electrode deposited on the capping layer;

wherein the second cladding layer has an energy band gap width which is larger than that of the active layer and is formed of a first layer adjacent the active layer and a second layer having a thermal conductivity which is higher than that of said first layer.

2. A semiconductor laser device according to claim 1, wherein said first layer is made of a material whose composition is expressed by the formula

$$(Al_xGa_{1-x})_yIn_{1-y}P$$

where y is selected to have a value of 0.51 to 0.52.

3. A semiconductor laser device according to claim 1 or claim 2, wherein said second layer is made of a material whose composition is expressed by the formula

$$(Al_zGa_{1-z})As$$

where the condition that z is greater than or equal to 0.6 and is less than or equal to unity is established.

4. A semiconductor laser device according to claim 1, claim 2 or claim 3, wherein a thickness of said first layer is selected to be in a range of from 0.1 to 0.3 micrometres.

5. A semiconductor laser device according to any one of the preceding claims wherein a thickness of said second layer is selected to be more than 0.8 micrometres.

6. A semiconductor laser device according to claim 4 or claim 5, wherein the sum of the thicknesses of said first and second layers is selected to be more than one micrometre.

7. A semiconductor laser device substantially as herein described with reference to Fig. 2 of the accompanying drawing.

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