

LASER DIODE

The present invention relates to a laser diode.

There is known in the art a laser diode which has a double heterogeneous construction such as is shown in Fig.1 of the accompanying drawings. This laser diode comprises, as shown in Fig.1, a GaAs active layer 2, which is disposed for laser oscillation in a semiconductor substrate 1, and an electrode 3 which is disposed on the substrate surface and to which an Au wire 4 is bonded.

It is customary that the aforementioned active layer 2 is formed in a band shape at a depth of about 2 μm and is enclosed in the centre of the substrate 1 by a GaAlAs buried layer 5 on the substrate surface, as is shown in Fig.1. Here, in order to facilitate the wire bonding process, according to the prior art, the bonding of the Au wire 4 is effected at the central portion of the substrate surface, as is shown in Fig.1. However, since a portion of the active layer 2 is positioned just below the bonding area, there arises the problem that mechanical damage is caused by the bonding stress in the GaAs active layer 2 or in $\text{Ga}_{1-x}\text{Al}_x\text{As}$ layers 6 (wherein x stands for a mole fraction) just below the bonding area or at the interface in between. This deteriorates the life time of the laser diode.

As one method for preventing the aforementioned mechanical damage, there has been proposed a construction, in which the laser diode is secured to a submount 7 such that the surface closer to the GaAs active layer 2 faces downward, as shown in Fig.2, and in which the Au wire 4 is bonded to the back of the substrate remote (at a distance of about 98 μm) from the GaAs active layer 2. According to

the method thus proposed, however, although the deterioration in the life time of the laser diode is slightly reduced by improving the thermal resistance to some extent, the Au wire 4 is still bonded to the active layer 2 so that deterioration in the life time resulting from mechanical damage applied to the active layer 2 cannot be avoided.

According to the present invention there is provided a laser diode having an active layer for laser oscillation formed in a portion of a semiconductor substrate and a bonding wire bonded to an electrode formed on the substrate, the position at which the bonding wire is bonded is laterally removed from the active layer, with the lateral width of the wire at the wire bonding position being greater than the lateral width of the active layer.

The active layer may be positioned away from the centre of the substrate and the wire bonding position is located to one side of the active layer, preferably at the central portion of the substrate or in the vicinity thereof.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figs. 1 and 2 are sectional views showing examples of a laser diode according to the prior art and have already been discussed;

Fig.3A is a sectional view showing the construction of the laser diode according to a first embodiment of the present invention;

Fig.3B is a top plan view showing the same laser diode;

Fig.4A is a sectional view showing how the laser diode is sealed up;

Fig.4B is a top plan view of the same;

Fig.5 is a sectional view showing the construction of the laser diode according to a second embodiment of the present invention;

Figs. 6A to 6C are views showing portions of a wafer at different steps in the process of fabricating a laser diode according to the present invention;

Fig. 7 is a characteristic diagram illustrating the change in the photo output power of the laser diode during a life test; and

Fig. 8 is a sectional view showing another embodiment of the present invention.

Fig. 3A is a schematic sectional view showing a first embodiment of laser diode according to the present invention, in which the wire bonding position to a surface electrode 20 is shifted from the position of an active layer 13 disposed at the substrate central position. In Fig. 3A, reference numerals 10, 11 and 12 indicate an n-type GaAs substrate forming a main portion of the chip, an n-type GaAlAs buried layer, and a p-type GaAlAs buried layer, respectively. A central region, which is separated from other regions by the buried layers 11 and 12, has formed therein the GaAs active layer 13 having a width 2 to 3 μm and arranged for laser oscillation, a p-type GaAlAs layer 14 acting as an optical guide layer, an n-type GaAlAs layer 15, an n-type GaAlAs layer 16 and a Zn diffused layer 17. Numerals 18, 19 and 20 indicate a back electrode made of a complex film of Au group metal, an insulating film and the surface electrode made of a complex film of Au group metal. Moreover, the laser diode chip 21 having the construction thus far described is secured to a submount 23 by means of solder 22 with the back electrode 18 facing downward. On the other hand, an Au wire 26 having a diameter of 25 μm is thermo-compression bonded to the surface electrode 20 while avoiding the active layer 13 running in a band shape through the central portion of the chip. Since the bonding portion has a width W_3 of about 90 μm whereas the chip 21 and the active layer 13 have widths W_1 and W_2 of 400 μm and 2 to 3 μm , respectively, the bonding

process can be sufficiently effected while being kept away from the active layer 13 at the chip central portion. Fig. 3B is a top plan view showing the construction thus far described.

5 Now, when the bonding position is shifted from the chip centre, it is necessary to use a relatively hard solder such as a PbSn solder as the solder 22 for connecting the back electrode 18 of the substrate and the submount 23. This is necessary to prevent possible imbalance in the
10 positional precision and the thermal resistance of the chip 21, which might result if the chip 21 becomes inclined by applying pressure irregularly during the bonding operation. Thus, it is possible to provide a laser diode which is highly precise and efficient.

15 Figs. 4A and 4B are respectively a schematic sectional view and a top plan view showing the sealed state of a laser diode device. In these Figures: reference numeral 21 indicates the laser diode chip; numeral 23 the submount supporting the laser chip; numeral 26 the Au wire; numeral
20 25 a cylindrical frame made of an insulator; numeral 27 a lead acting as an anode; numeral 29 a monitor fiber; numeral 24 a conductive case acting as a cathode; and numeral 28 a glass window coated with a reflection preventing film. In order to bias the laser diode in the forward direction,
25 moreover, a negative voltage is impressed through the submount 23 and the solder 22 upon the back electrode 18 of chip 21 while using the conductive case 24 as the cathode. On the other hand, the conductive anode terminal (i.e. the lead) 27 is fixed to the case 24 through the insulator 25
30 while being electrically insulated from the case 24, and a positive voltage is impressed upon the surface electrode 20 of the chip 21 from that anode 27 through the wire 26.

 Since the bonded position of the Au wire 26 is kept away from the active layer 13, i.e. since there is no active
35 layer 13 just below the ball of the wire 26, the stress

during the bonding process is not applied directly to the active layer 13. As a result, the active layer 13, the optical guide layers 14 and 15, and their interfaces can be prevented from being mechanically damaged by stress during the bonding process so that the deterioration in the life time can be markedly reduced.

Moreover, since a relatively hard solder is used as the solder 22, it is possible to prevent the positional precision and the thermal resistance from becoming inadequate as a result of the chip 21 becoming inclined by the unbalance in the pressure application, which is caused by the fact that the bonding position is not located at the central portion of the chip 21.

Next, a second embodiment of laser diode device according to the present invention will be described with reference to Figs.5 to 6C. In this embodiment, the sealed state is omitted from description because it is the same as that of the first embodiment shown in Figs.4A and 4B.

Fig.5 is a schematic sectional view showing the laser diode and corresponds to Fig.3 showing the first embodiment. In Fig.5, the same parts as those of Fig.3 are indicated by the same reference numerals, and their explanations are omitted.

This second embodiment is characterised by the facts that the active layer 13 is disposed at a position spaced from the central portion of the chip 21 and that the bonding position of the Au wire 26 is kept away from the aforementioned active layer 13, e.g. at the central portion of the chip 21. According to this embodiment, the stress during the wire bonding operation is applied to the central portion of the chip 21. As a result, since the active layer 13 is at a position spaced from the central portion, the aforementioned mechanical damage caused by the aforementioned stress does not take place so that the deterioration in the life time of the laser diode can be remarkably

reduced. According to the present embodiment, since the bonding position is located at the centre, the chip 21 is prevented from being inclined even if a relatively soft solder such as indium is used as the solder 22.

5 Incidentally, the chip size has a width W_1 of 400 μm , a thickness of 300 μm and a height of 100 μm whereas the active layer 13 has a width W_2 of about 2 μm at the most so that the characteristics of the laser diode are not changed even if the position of the active layer 13 is shifted up to
10 about 100 μm from the central portion of the chip, to which the Au wire 26 is to be bonded.

Figs.6A to 6C show a portion of the process of fabricating the laser diode according to the second embodiment.

15 First of all, without changing the process of fabricating the laser diode of the buried heterogeneous construction according to the first embodiment of the present invention, for example, as shown in Fig.5: (1) the four epitaxial layers 16,15,13 and 14 are consecutively
20 formed on the n-type GaAs substrate (or the wafer); (2) the regions to be formed with the buried layers 11 and 12 are selectively removed by a chemical etching treatment; (3) the buried layers 11 and 12 are formed by epitaxial growth; (4) a Zn ampoule is diffused; and (5) the surface and back
25 electrodes are then formed, thus completing the laser diode. The hatched portions 31 appearing in Fig.6A indicate the positions of the active layers 13. In this state, a wafer 33 is adhered to a soft sheet 32 and is cleaved from the wafer side to form cleaved facets 34 which intersect the
30 running direction of the active layers at a right angle. Fig.6A shows the state at which the wafer formed with the aforementioned laser diodes is cleaved.

Next, scribing operations are conducted along lines parallel to the active layers 31, as indicated by single-
35 dotted lines 35 in Fig.6B. At this time, it will be seen

that the active layers 31 are located at positions away from the centres between the scribed lines 35. Fig.6C is a schematic sectional view showing a section taken along line A-A of Fig.6B.

5 After that, the chips 33 are peeled from the sheet 32 and separated from one another, and the aforementioned cleaved facets of the chips 33 are subjected to passivation with SiO_2 or the like by a sputtering process, thus completing the laser diode elements.

10 Thus, according to the present invention, it is possible to provide the laser diode chip as shown in Fig.5 merely by shifting the positions of the scribing operations without any change in the processes of fabricating the laser diode of the prior art.

15 According to the embodiment described above, the deterioration in the life time of the laser diode can be remarkably reduced.

Fig.7 illustrates the life test results of the laser diode device according to the present embodiment. If the screening tests (e.g. tests of continuous operation at a high temperature for 20 hours) of the respective laser diode devices are conducted after the bonding processes, 2 or 3% of the devices of the prior art have their photo output powers abruptly deteriorated by mechanical damage, as indicated by a curve B in Fig.7. On the contrary, most of the laser diode devices according to the present invention exhibit the photo output powers, as indicated by a curve A in Fig.7, and few of them are abruptly deteriorated. This is because it is possible by shifting the position of the active layer and the wire bonding position to prevent the

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active layer or the line from being mechanically damaged by the bonding stress.

Moreover, since the bonding position is located at the chip centre during the bonding operation, the force is

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applied on an average to the whole construction of the chip. As a result, chip 21 can be prevented from being inclined thereby to eliminate any deterioration in the thermal resistance and the positional precision. Incidentally, similar effects can be attained even if In, Au, Sn and so on are used as the solder in the present embodiment.

Moreover, since there arises neither mechanical damage nor chip inclination, the load during the bonding operation can be enlarged. As a result, a good connection of the Au wire can be ensured, improving the reliability. On the other hand, the time period for the bonding operation can be shortened to improve the ease of manufacture.

The present invention should not be limited to the embodiments thus far described but can be modified in various manners.

Fig.8 shows a modification of the laser diode of the buried heterogeneous construction, in which the second embodiment is modified such that the laser diode chip is secured upside down to the submount. In this modification, too, the position of the active layer 13 is shifted from the central portion of the chip 21 within such a range as is allowed by the characteristics, and the Au wire 26 is bonded to the central portion of the chip 21. Thus, this modification can also enjoy the same effects as those of the foregoing second embodiment.



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CLAIMS:

1. A laser diode having an active layer for laser oscillation formed in a portion of a semiconductor substrate and a bonding wire bonded to an electrode formed on the substrate, the position at which the bonding wire is bonded is laterally removed from the active layer, with the lateral width of the wire at the wire bonding position being greater than the lateral width of the active layer.
2. A laser diode as set forth in claim 1, wherein said active layer is positioned away from the centre of said substrate, and wherein said wire bonding position is located to one side of the active layer.
3. A laser diode as set forth in claim 2, wherein said wire bonding position is located at the central position of said substrate or in the vicinity thereof.
4. A laser diode as set forth in claim 1, wherein said wire bonding position is removed from the centre of the substrate and the substrate is secured to a submount by PbSn solder.
5. A laser diode as set forth in any one of the preceding claims, wherein said wire bonding process is effected by a thermo-compression bonding method.
6. A laser diode as set forth in any one of the preceding claims wherein said electrode to which the wire is bonded is formed over a top surface of the substrate, on an insulating film.
7. A laser diode as set forth in any one of claims 1 to 5 wherein said electrode to which the wire is bonded is on the



- 10 -

back surface of the substrate.

8. A laser diode substantially as any herein described with reference to Figs. 3 and 4, or Figs. 5 and 6, or Fig. 8 of the accompanying drawings.
