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Background of the invention

This invention relates to light emitting diodes (LEDs) and, more particularly, to LEDs for use in lightwave systems.

In lightwave communication systems the light source is typically a diode laser or an LED which is coupled to an optical fiber. Information to be transmitted over the fibre is digitally encoded and used to pulse modulate the light intensity of the source. Depending upon the particular application, the bit rate of the system typically ranges from a few megabits per second to a few gigabits per second. In addition, the unrepeated transmission path length of the system often dictates whether a laser or an LED is used. Lasers are usually found on long haul systems (e.g., hundreds of kilometers long) which require repeaters to regenerate and amplify the digital signal, whereas LEDs are common in short haul systems (e.g., a few tens of kilometers long or less) which [illegible] not require repeaters. One version of such [illegible]ort haul systems is known as an optical data link (ODL).

The design of lasers and LEDs for lightwave systems generally takes the form of a double heterostructure; e.g., an active, narrow bandgap layer sandwiched between and lattice-matched to a pair of opposite-conductivity-type, wider bandgap cladding layers. Under forward bias minority carriers are injected in the active region where they undergo radiative recombination to generate a light output at a wavelength related to the bandgap of the active layer. The direction of the light output depends on the device design. In lasers and edge-emitting LEDs light is extracted in a direction parallel to the active layer, and the output emerges from an end face (e.g., a cleaved facet) orthogonal thereto. On the other hand, in surface-emitting LEDs light is extracted in a direction perpendicular to the active region, and the output emerges from one of the cladding layers [illegible]d/or from the substrate (if the latter is trans[illegible]ent at the wavelength of the generated light).

In order to couple light out of a surface-emitting LED, one major surface, say the bottom of the substrate, is typically provided with an annular electrical contact, and the opposite major surface is provided with a dot-shaped electrical contact in registration with the annulus. The dot contact restricts light emission to a correspondingly small area of the active region under the annulus, thereby enhancing the coupling efficiency, for example, to an optical fiber.

In common surface-emitting LEDs the dot contact is positioned in the center of the chip, which is typically a square parallelepiped. Illustratively, the major surfaces of the chip are about 0.56 mm (22 mils) square (0.31 mm^2 (480 square mils)) and about 1700 chips are obtained from a 25 mm (one inch) square wafer. Of course, the bigger the chip size, the fewer the chips which can be obtained fromi given semiconductor wafer. Consequently, the unit cost of the chips is commensurately higher. It might appear that the straightforward solution to the problem is simply to scale down all of the dimensions of the device. This approach, however, is impractical because the annular contact also serves as a bonding pad for a wire bond. Reducing the chip size thus reduces the area of the bonding pad, making the wire bond operation a difficult and low yield process. Also, reducing the dot contact diameter increases the current density and hence degrades the reliability of the device.

A LED with an integral lens and a metal contact surrounding the light emitting region is disclosed in EP—A—0 103 443.

A. C. Carter in the Radio and Electronic Engineer, vol. 51, no. 7/8, pages 341—348 (July/August 1981) discloses a very small LED having the features of the first part of Claim 1 which uses a rectangular chip (0.2×0.3 mm). The light emitting portion is offset towards one end of the chip, leaving room for a thermocompression gold wire bond to the chip to provide electrical contact.

Summary of the invention

With the invention as set out in the claims the light emitting portion is in one quadrant and an L-shaped contact is in the remaining three quadrants. We have found that such a contact spreads the current effectively whilst the arrangement permits a substantial reduction in size relative to LEDs with annular contacts. Thus, a considerable size reduction is obtained without foregoing the effective spreading of the current.

For LEDs with essentially identical design criteria, our design illustratively achieves a reduction in chip area by a factor of more than two (e.g. 0.13 mm^2 (200 square mils) compared to 0.31 mm^2 (480 square mils)) and a corresponding decrease in unit cost.

Brief description of the drawing

Figure 1 is a partially cut away, isometric view of a surface-emitting LED in accordance with one-embodiment of our invention; and

Figure 2 is a magnified, cross-sectional view of the dot contact, heterostructure and lens of Figure 1.

Detailed description

With reference now to the figures, a surface emitting LED chip 10 has the general form of a parallelepiped having, typically, square, parallel major surfaces 12 and 14. Surface 12 is herein called the output surface because the light beam output λ emerges from it. In accordance with our invention, means are provided for causing the light beam λ to emerge from a spot which is asymmetrically positioned on the surface; i.e. toward one corner. More specifically, a dot-shaped electrical contact 16 is formed on the opposite major surface 14, and an optional, approximately hemispheric, integral lens 18 is formed in output surface 12. The dot contact 16 and the lens 18 are essentially in registration with one another and are asymmetrically positioned

›ward one corner of chip 10. A broader area contact 19, in the general shape of an L, is formed on output surface 12 so that the beam λ emerges from between the legs of the L. Viewed in another way, the dot contact 16 is positioned in one quadrant of surface 14, and L-shaped contact 19 is positioned in the remaining three quadrants of surface 12. The L-shaped contact spreads the applied current over surface 12 and allows the light beam to emerge.

This chip design results in a reduction in chip area by more than a factor of two (2.4 has been realized) and corresponding decrease in LED unit cost. As compared with a conventional LED chip having an area of 0.31 mm^2 (480 square mils), one embodiment of our chip is only 0.13 mm^2 (200 sq. mils), which means that about 3900 chips can be obtained from a 25 mm (one inch) square wafer instead of only about 1700 chips. This calculation assumes a kerf loss of about 50 µm (2 mils) on each side of a chip.

The LED also includes a semiconductor body which illustratively comprises a semiconductor substrate 20, a double heterostructure 22, and a contact-facilitating layer 24. The heterostructure 22 includes a relatively narrow bandgap active layer 26 sandwiched between a pair of opposite-conductivity-type, wider bandgap cladding layers 28 and 30. Contact-facilitating layer 24 is formed on cladding layer 30. A dot contact 16 is formed on layer 24, and the remainder of layer 24 is covered with a dielectric layer 32 before being bonded to heat sink 34.

All of the semiconductor layers may be epitaxially grown by a variety of well-known techniques such as, for example, liquid phase epitaxy (LPE) or metallo-organic chemical vapor deposition (MOCVD).

The conductivity-type of the active layer 26 is not critical, although a p-type layer may be desirable for high speed applications (e.g. above about 100 Mb/s) because it has a lower minority carrier lifetime than an n-type layer.

The composition of the active layer 26 depends upon the desired wavelength of operation. For long wavelength systems (e.g. 1.1—1.6 µm), the active layer 26 is InGaAsP and the cladding layers 28 and 30 are InP. The contact-facilitating layer 24 has the same conductivity type as cladding layer 30 and illustratively comprises highly doped InGaAs or InGaAsP. The substrate 20 is InP which is transparent to the light generated in the InGaAsP active layer. Hence, the substrate remains a part of the end product. Indeed, the lens 18 is etched or otherwise formed in the substrate.

On the other hand, for shorter wavelength systems (e.g. 0.8—0.9 µm), the active layer 26 is $Al_xGa_{1-x}As$ with $0 \leq x \leq 0.1$ typically, and the cladding layers 28 and 30 are $Al_yGa_{1-y}As$ and $Al_zGa_{1-z}As$ with $y, z > x$ and typically $0.20 \leq y, z \leq 0.40$. In this case, both the contact-facilitating layer and the substrate are GaAs. However, because a GaAs substrate would absorb light generated by the $Al_xGa_{1-x}As$ active layer, the substrate is removed and no integral lens need be employed.

Example

This example describes a long wavelength InP/InGaAsP (λ=1.3 µm) LED fabricated in accordance with our invention. Materials, compositions, dimensions and other parameters are provided by way of illustration only and, unless otherwise stated, are not intended to limit the scope of the invention.

Using LPE the following epitaxial layers were grown on a (100)-oriented InP substrate 20 thinned to about 100 µm and doped n-type with S to about 5×10^{18} cm^{-3}; a 5 µm thick, InP cladding layer 28 doped n-type with Sn to about 1×10^{18} cm^{-3}; a 1.5 µm thick, InGaAsP active layer 26 doped n-type with Sn to about 1×10^{17} cm^{-3}; a 2 µm thick, InP cladding layer 30 doped p-type with Zn or Cd to about 5×10^{18} cm^{-3}; and a 0.5 µm thick. InGaAsP contact-facilitating layer 24 doped p-type with Zn to about 1×10^{19} cm^{-3}.

Electrical contacts were formed on the wafer as follows. The contact facilitating layer 24 and the substrate 20 were covered with suitable masks with openings corresponding to dot contacts 16 and L-shaped contacts 19, respectively. Au-Be dot contacts 16 (25 µm in diameter) were evaporated and alloyed on to the layer 24, and Au-Sn-Cr-Au L-shaped contacts (280 µm (11 mil) legs each about 130 µm (5 mils) wide) were evaporated and alloyed onto substrate 20.

The substrate 20 was masked and photoelectrochemical (PEC) etching was used to form the approximately hemispherical, integral lens 18 in a cylindrical cavity 21 of the substrate. PEC is well known and its use in making such lenses is described, for example, in U.S. Patent 4,415,414. Then, a SiO_2 dielectric layer 32 was plasma deposited over the remainder of layer 24. Openings were etched into layer 32 in registration with dot contacts 16. A Ti-Pd-Au adhesion layer (not shown) was evaporated over both the dielectric layer 32 and the dot contacts 16 before electroplating a 10—15 µm thick Au heat sink 34. Then, the wafer was diced by sawing into individual chips which measured about 360 µm (14 mils) square. About 3900 chips were obtained from a 25 mm (one inch) square wafer. Finally, a 25 µm (1 mil) diameter Au wire 36 was bonded to the L-shaped contact 19 on each chip.

In operation, when such a chip is forward biased and driven by a current of about 150 mA, it generates about 3 mW of optical power at a wavelength of 1.3 µm and is capable of operating digitally at data rates up to about 90 Mb/s. For substantially higher bit rates the minogity carrier lifetime in the active layer should be reduced by substituting, for example, a thinner (e.g. 0.5 µm), heavily doped, p-type InGaAsP layer for the n-type layer.

Claims

1. A light emitting diode comprising

ward one corner of chip 10. A broader area contact 19, in the general shape of an L, is formed on output surface 12 so that the beam λ emerges from between the legs of the L. Viewed in another way, the dot contact 16 is positioned in one quadrant of surface 14, and L-shaped contact 19 is positioned in the remaining three quadrants of surface 12. The L-shaped contact spreads the applied current over surface 12 and allows the light beam to emerge.

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Claims

1. A light emitting diode comprising

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a semiconductor body (20, 22) having substantially the shape of a parallelepiped having first (12) and second (14) opposing major surfaces, said body including an active layer (26) for generating optical radiation in response to the flow of electrical current therethrough,

an electrical contact (19) on the first major surface (12), and means including a dot-shaped electrical contact (16) on the second major surface (14) for causing the radiation to emerge from said active layer (26) and through said first major surface (12) as a beam in a direction essentially orthogonal to said active layer (26), characterised in that

the dot-shaped electrical contact (16) is positioned in one quadrant of the second major surface (14), and

the electrical contact (19) on the first major surface (12) is L-shaped, being positioned in the remaining three quadrants so that said beam emerges between the legs of the L.

A diode as claimed in Claim 1 wherein said causing means includes a lens (18) on said first major surface (12), positioned substantially in registration with said dot-shaped contact (16).

Patentansprüche

1. Lichtemittierende Diode mit

einem Halbleiterkörper (20, 22), der im wesentlichen die Form eines Parallelepiped mit sich gegenüberliegender erster und zweiter größerer Fläche hat und eine aktive Schicht (26) zur Erzeugung optischer Strahlung abhängig von einem durch die Schicht fließenden, elektrischen Strom aufweist,

einem elektrischen Kontact (19) auf der ersten größeren Fläche (12) und

einem punkförmigen elektrischen Kontact (16) auf der zweiten größeren Fläche (14), um ein Austreten der Strahlung aus der aktiven Schicht (26) und durch die erste größere Fläche (12) als Strahl im wesentlichen orthogonal zu der aktiven Schicht (26) zu veranlassen, dadurch gekennzeichnet,

daß der punktförmige elektrische Kontact (16) in einem Quadranten der zweiten größeren Fläche (14) angeordnet ist und

daß der elektrische Kontakt (19) auf der zweiten größeren Fläche L-förmig und in den restlichen dre Quadranten angeordnet ist, so daß der Strahl zwischen den Schenkeln des L austritt.

2. Diode nach Anspruch 1, bei der die Einrichtung, die das Austreten der Strahlung veranlaßt, eine Linse (18) auf der ersten größeren Fläche (12) aufweist, die im wesentlichen fluchtend mit dem punktförmigen Kontakt (16) angeordnet ist.

Revendications

1. Une diode électroluminescente comprenant

un bloc de semiconducteur (20, 22) ayant pratiquement la forme d'un parallélépipède comportant des première (12) et seconde (14) surfaces principales opposées, ce bloc contennt une couche active (26) qui est destinée à générer un rayonnement optique sous l'effet du passage d'un courant électrique à travers elle

un contact électrique (19) sur la première surface principale (12), et des moyens comprenant un contact électrique en forme de pastille (16) sur la seconde surface principale (14), pour provoquer l'émergence du rayonnement à partir de la couche active (26) et à travers la première surface principale (12), sous la forme d'un faisceau orienté dans une direction pratiquement orthogonale à la couche active (26), caractérisée en ce que

le contact électrique en forme de pastille (16) est positionnée dans un quadrant de la seconde surface principale (14), et

le contact électrique (19) sur la première surface principale (12) a une forme en L, et il est positionné dans les trois quadrants restants, de façon que le faisceau émerge entre les branches du L.

2. Une diode selon la revendication 1, dans laquelle les moyens qui provoquent l'émergence du rayonnement comprennent une lentille (18) sur la première surface principale (12), positionnée pratiquement en coïncidence avec le contact en forme de pastille (16).

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