

Description

Technical Field

This invention pertains to buried heterostructure lasers with MOCVD growth over patterned substrates.

Background of the Invention

Semiconductor lasers fabricated from strained layer quantum well material have attracted considerable interest as pump lasers for erbium doped glass fiber amplifiers. However, ridge waveguide lasers with planar multi-quantum well (MQW) $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}/\text{GaAs}$ heterostructures grown by molecular beam epitaxy (MBE) and metal organic chemical vapor deposition (MOCVD) growth techniques are weakly index-guided, and their mode stability is not expected to be as good as that for a strongly index-guided buried heterostructure lasers. For example, see N. K. Dutta et al. "Temperature Dependence of Threshold of Strained Quantum Well Lasers", *Appl. Phys. Lett.* 58 (11), 18 March 1991, pages 1125-1127. The latter include several types of $\text{InGaAs}/\text{GaAs}$ buried heterostructure lasers fabricated using multistep growths. An improvement in the lateral optical confinement in quantum well stripes resulted in lasers with $\text{GaAs}/\text{AlGaAs}$ heterostructures fabricated using a single step growth on nonplanar GaAs substrates. One example of such a single growth structure is disclosed in an article by D. E. Ackley and G. Horn entitled "Twin-Channel Substrate-Mesa Guide Injection Lasers Fabricated by Organometallic Vapor Phase Epitaxy", *Applied Physics Letters*, Vol. 42, No. 8, April 1983, pages 653-655. Ackley and Horn disclose a high-power index-guided laser fabricated by a one-step organometallic vapor phase epitaxy on photolithographically patterned and etched substrates. A narrow mesa is defined by a twin-channel v-groove structure. The twin channel structure provides for an improved control over the width of the lateral waveguide relative to a single groove configuration, which allows well-controlled zero order mode operation. However, the growth of the active layer is continuous over the side walls of the v-grooves of the twin-channel defined mesa structure. This would lead to the spreading of carriers across the whole of the width of the active layer, not just across its portion on the mesa. Lateral electrical confinement was achieved by ion implantation after the growth of the semiconductor structure. Since ion-implantation requires subsequent heating of the device, this adds to the complexity of the process, negating the advantages of the single-step growth processing. Therefore, it is desirable to produce a buried heterostructure laser in a more simplified manner.

A laser as set out in the preamble of claim 1 is dis-

closed in Patent Abstracts of Japan vol. 12, no. 304 (E-646) [3151], 18th August 1988 (JP-A-63 073 691).

Summary of the Invention

According to the invention there is provided a laser and a fabrication method as set out in the independent claims hereof.

Each of said bottom and top confining layers may be of $\text{Al}_x\text{Ga}_{1-x}\text{As}$, with x being from 0.1 to 0.4, and said active layer may be GaAs . Each of the confining layers may comprise $\text{Al}_{0.4}\text{Ga}_{0.6}\text{As}$, and may further comprise a thin $\text{Al}_{0.15}\text{Ga}_{0.85}\text{As}$ layer positioned between the active layer and the $\text{Al}_{0.4}\text{Ga}_{0.6}\text{As}$ layer.

The active layer may comprise $\text{In}_y\text{Ga}_{1-y}\text{As}$ wells and GaAs barriers with y being within a range of from 0.05 to 0.25, and preferably three $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}$ wells and four GaAs barriers.

The top electrode may comprise AuBe , and the overlay electrode may comprise TiAu .

Preferably, said grooves are etched with a mixture of $\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ in ratio of 1:1:1.

The dielectric layer may comprise SiO_2 .

Each of the layers of the semiconductor structure may be deposited by MOCVD.

In this process a single-step metal organic chemical vapor deposition (MOCVD) growth has been used to fabricate a buried heterostructure $\text{InGaAs}/\text{GaAs}$ multi-quantum well laser over a patterned GaAs substrate. The pattern is a reentrant mesa defined by two dovetailed grooves formed by wet chemical etching oriented along $[011]$ direction. Growth over the mesa results in isolated buried heterostructures. The 250 μm long lasers emitted near 1 μm . The external differential quantum efficiency in the current range of from 30 mA to about 50 mA is almost independent of temperature in the temperature range of 10°C to 90°C which suggests a minimal temperature dependent leakage current. Lasers with coated facets have threshold currents of 20 mA and emit $> 100 \text{ mW/facet}$ at room temperature.

Brief Description of the Drawings

FIG. 1 is a schematic representation of a buried heterostructure $\text{InGaAs}/\text{GaAs}$ MQW laser;

FIG. 2 is a schematic representation of the compound semiconductor substrate with a reentrant mesa bordered by two dovetailed grooves used in the fabrication of the laser of FIG. 1;

FIG. 3 is a plot of power in mW versus current in mA for continuous wave operation of the laser of FIG. 1 at room temperature and wavelength of approximately 0.98 μm ;

Fig. 4 is a plot of light versus current curves for a buried heterostructure laser operated at temperatures ranging from 10°C to 90°C ;

Fig. 5 is a plot of threshold current versus temper-

ature for a buried heterostructure laser.

Detailed Description

This invention embodies the fabrication of a buried heterostructure laser using a single-step growth by MOCVD over a reentrant mesa patterned semiconductor substrate. The growth over the reentrant mesa produces a discontinuity in the growth of a bottom confining layer and of an active layer, while the overgrowth of the top confining layer results in a buried heterostructure laser structure. The laser is a structure comprising group III-V or II-VI compound semiconductors, such as GaAs, AlAs, AlGaAs, InP, GaInP, AlInP, GaInAs, GaInPAs, AlGaInAs, and other lattice compatible compound semiconductors based on group III-V or II-VI semiconductors.

FIG. 1 is a schematic cross-sectional representation of a laser, 10, according to the invention. Laser 10 includes in an ascending order, a bottom electrode, 11, a patterned substrate, 12, of one conductivity type provided with dovetailed grooves, 13, forming a reentrant mesa, 14, a discontinuous buffer layer, 15, having sections 15-1, 15-2 and 15-3 of said one conductivity type, a discontinuous bottom confining layer, 16, having sections 16-1, 16-2 and 16-3 of said one conductivity type, a discontinuous active layer, 17, having sections 17-1, 17-2 and 17-3, a top confining layer, 18, of another conductivity type opposite to said one conductivity type, a contact layer, 19, of said another conductivity type, a dielectric layer, 20, having a window, 21, a top stripe electrode, 22, within the window, and an overlay electrode, 23.

Construction of laser 10 is described below. For clarity reasons, various elements of the laser are not drawn to scale. The invention is described with reference to an $\text{Al}_x\text{Ga}_{1-x}\text{As}/\text{GaAs}/\text{In}_y\text{Ga}_{1-y}\text{As}$ system in which x is from 0 to 0.4 and y is from 0 to 0.25.

Substrate 12 is a heavily doped n^+ type GaAs having two dovetailed grooves 13 which form reentrant mesa 14. (FIG. 2). Typically the thickness of the substrate ranges from 100 to 500 μm and the doping concentration of the substrate ranges from 1×10^{17} to $1 \times 10^{19} \text{cm}^{-3}$. In some applications the substrate may be first grown on a master substrate of silicon which is common to a number of devices on the master substrate. Buffer layer 15 is also n -type GaAs deposited in a thickness typically ranging from 0.1 μm to 5 μm , and with a doping concentration of from 1×10^{17} to $1 \times 10^{19} \text{cm}^{-3}$. The buffer layer serves the purpose of stopping possible propagation of defects from the substrate. The buffer layer is in the form of independent sections 15-1, 15-2 and 15-3. Sections 15-1 overlay the bottom of each dovetailed groove 13; section 15-2 overlays the top surface of mesa 14; and sections 15-3 overlay each of the remaining portions of the top surface of the substrate.

The bottom and the top confining layers 16 and

18 are provided to confine carriers and, thus, the radiation of active layer 17 within the narrow thickness of the active layer. The confining layers are typically deposited in a thickness of up to 3 μm , and with a doping concentration of from 1×10^{17} to $1 \times 10^{19} \text{cm}^{-3}$. In this embodiment, the confining layers are of $\text{Al}_x\text{Ga}_{1-x}\text{As}$ with x ranging from 0.1 to 0.4. The bottom confining layer is an n -type $\text{Al}_x\text{Ga}_{1-x}\text{As}$ and is in the form of independent sections 16-1, 16-2 and 16-3 which overlay sections 15-1, 15-2 and 15-3, respectively, of the buffer layer.

Active layer 17 is in the form of independent sections 17-1, 17-2 and 17-3 which overlay sections 16-1, 16-2 and 16-3, respectively, of the bottom confining layer. The active layer includes at least one quantum well (QW) comprising $\text{In}_y\text{Ga}_{1-y}\text{As}$ well and GaAs barriers, with y being from 0.05 to 0.25.

Top confining layer 18 is of a p -type $\text{Al}_x\text{Ga}_{1-x}\text{As}$ with x ranging from 0.1 to 0.4. Layer 18 overlays sections 17-1, 17-2 and 17-3 of the active layer and those portions of sections 15-2 and 15-3 and of sections 16-2 and 16-3 which are laterally exposed, such that section 17-2 of the active layer on the mesa is buried and is separated from sections 17-1 and 17-3 by the top confining layer.

Thin contact layer 19 of highly doped p^+ type GaAs completes the compound semiconductor structure. Typically, the doping concentration of the contact layer ranges from 1×10^{19} to $1 \times 10^{20} \text{cm}^{-3}$. Contact layer 19 is provided in a thickness ranging from 0.01 to 0.1 μm to facilitate establishing an ohmic contact between top confining layer 18 and top electrode 22.

Dielectric insulating layer 20, having window 21 which is centered over mesa 14, overlays the upper surface of contact layer 19 except for that portion of the surface of contact layer 19 which is exposed in the window, that is for an area immediately overlaying the area of mesa 14 and, thus, of section 17-2 of the discontinuous active layer 17. The dielectric layer insulates the top surface of contact layer 19 and protects it from environmental influences. The dielectric layer may be of a material selected from such insulating materials as SiO_2 , SiN_x and borosilicate glass (Vycor®). The first two are deposited by plasma CVD, while the latter is deposited by e-beam deposition. Top electrode 22 overlays that portion of the surface of contact layer 19 which is exposed in window 21. Since window 21 is of approximately the same length and width as the mesa, top electrode 22 is also centered over the mesa and over section 17-2 of the active layer which is upon the mesa. Top electrode 22 is of a metal or metal alloy selected from metals or alloys which are inert to or complement the conductivity type of the top confining and contact layers.

Overlay electrode 23 is deposited over the insulating layer 19 and in electrical contact with top electrode 22. Overlay electrode 23 covers the whole of the upper surface of dielectric layer 18 and of top

electrode 22. Overlay electrode 23, deposited in a thickness of from 0.05 to 1.0 μm , acts as a protective cover, as a surface for establishing an electrical contact to top electrode 22, and as a broad electrical connection area.

Bottom electrode 11 is formed on the bottom surface of substrate 12 by depositing a suitable metal or alloy compatible with the conductivity type of the substrate, and alloying the electrode to the substrate. Optionally a layer of gold may be deposited on top of either one or both of overlay electrode 23 and bottom electrode 11. Finally, the bottom side of the laser may be mounted on a copper slab which serves as a heat sink.

The preparation of the device begins with forming in the substrate a pattern shown in FIG. 2. Wafer substrates were etched to form "dovetail" grooves on either side of a reentrant mesa. Layers 15-19 forming the laser structure are then grown upon the patterned substrate in succession preferably by such known methods as metal organic vapor phase epitaxy (MOVPE), also known as metal organic chemical vapor deposition (MOCVD). These layers may also be deposited by such other known method as molecular beam epitaxy (MBE) or hydride vapor phase epitaxy (VPE). An important requirement is the deposition of layers 15-17 such that section 17-2 on the mesa is grown apart from other sections, e.g., 17-1 and 17-3 of layer 17. Due to the dovetailed shape of the grooves and of the reentrant shape of the mesas, the MOCVD growth of layers 15, 16 and 17 over the mesas is not continuous with the growth in the grooves and in the field. This results in an isolated layered structure including the MQW active layer 17-2 above the mesas. The top confining layer 18 fills in regions in the grooves, along the side and above the mesas. It is important that the substrate should be so oriented and the etching is so conducted that when the buffer, bottom confining and active layers are deposited, they form discontinuous layers and especially that at least section 17-2 of active layer 17 on the mesa does not have any continuity with sections 17-1 in the grooves. Hence this growth process results in MQW active regions (17-2) on top of the mesa which are buried in higher band gap and lower index layer 18. This assures that the current applied between top electrode 22 and bottom electrode 11 will pass through active layer section 17-2 but carriers will not spread along the whole of the active layer, including sections 17-1.

In the preferred embodiment, the laser is an $\text{Al}_x\text{Ga}_{1-x}\text{As}/\text{GaAs}/\text{In}_y\text{Ga}_{1-y}\text{As}$ structure comprising, in an ascending sequence, a 0.1 to 0.5 μm thick AuGe electrode 11, about 100 μm thick (100) oriented heavily doped ($2 \times 10^{18}\text{cm}^{-3}$) n^+ -GaAs substrate 12, a 0.2 to 0.3 μm thick n-type GaAs buffer layer 15 ($3 \times 10^{18}\text{cm}^{-3}$), having sections 15-1, 15-2 and 15-3, a 1.5 μm thick n- $\text{Al}_{0.4}\text{Ga}_{0.6}\text{As}$ bottom confining layer 16 (2

$\times 10^{18}\text{cm}^{-3}$), having sections 16-1, 16-2 and 16-3, an MQW active layer 17 having sections 17-1, 17-2 and 17-3 consisting of three $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}$ wells 80 $\text{\AA}$ thick each and four GaAs barrier layers 200 $\text{\AA}$ thick each, 1.5 μm thick, p- $\text{Al}_{0.4}\text{Ga}_{0.6}\text{As}$ top confining layer 18 ($2 \times 10^{18}\text{cm}^{-3}$), and a 200 $\text{\AA}$ thick heavily doped ($1 \times 10^{19}\text{cm}^{-3}$) p^+ -GaAs contact layer 19. Alternatively, each of the confining layers may be deposited as a composite of 1.5 μm thick $\text{Al}_{0.4}\text{Ga}_{0.6}\text{As}$ and a 400 $\text{\AA}$ thick $\text{Al}_{0.15}\text{Ga}_{0.85}\text{As}$ layers, with the latter being in contact with the active layer. The $\text{Al}_{0.15}\text{Ga}_{0.85}\text{As}$ layers are deposited optionally to narrow the far field of the device. The structure further includes an about 3000 Angstrom thick SiO_2 layer 20 having 2 to 4 μm wide window 21, a 0.08 μm thick AuBe top electrode 22 co-extensive of window 21 and an 0.1 μm thick TiAu overlay electrode 23.

The laser semiconductor structure shown in FIG. 1 was grown on one lateral surface of a n^+ -GaAs (100) substrate wafer which was patterned with grooves to leave mesas parallel to the $[011]$ direction. Standard photolithographic and wet chemical techniques were used to obtain mesas of $\sim 4 \mu\text{m}$ wide. Wet chemical etching of n^+ -GaAs wafers with a mixture of $\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ in a ratio of 1:1:1 is used to produce in the substrate wafer two dovetailed grooves 13 and the reentrant mesa 14 per device. The etching is conducted at room temperature for a period of from 5 to 15, preferably 10 seconds. The dovetail grooves are from 5 to 3, preferably 4 μm wide and from 3 to 1, preferably 2 μm deep and are spaced each from another a distance of from 4.5 to 3.5 μm defining the reentrant mesa. The following layers were then grown over the etched wafer using the MOCVD growth technique: 0.5 μm thick n^+ -GaAs buffer layer, followed by a 1.5 μm thick n- $\text{Al}_{0.4}\text{Ga}_{0.6}\text{As}$ confining layer, the MQW active region consisting of 3 wells of 80 $\text{\AA}$ thick $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}$ and four 200 $\text{\AA}$ thick GaAs barrier layers, 1.5 μm thick p- $\text{Al}_{0.4}\text{Ga}_{0.6}\text{As}$ confining layer and a 200 $\text{\AA}$ thick p^+ -GaAs contacting layer. The dopants used were Zn and Si for the p-type and n-type layers, respectively.

After semiconductor layers 15-19 are deposited on the patterned substrate wafer, the fabrication process of the lasers (FIG. 1) is continued by formation of a SiO_2 layer and of AuBe (p-contact) top electrode, wafer thinning, formation of an AuGe (n-contact) bottom electrode, and formation of TiAu metal overlayer on the top of the SiO_2 and AuBe layers. The p-side of the wafer (surface of contact layer 19) is processed by depositing 3000 $\text{\AA}$ SiO_2 and opening 2.5 - 4.5 μm wide windows over the mesas and active regions on the mesas, using photolithography and buffered oxide etchant to pattern the SiO_2 . AuBe alloy (p-contact metal) was deposited in a thickness of 0.08 μm using standard photolithographic and lift-off methods resulting in AuBe contacts to contact layer 19 exposed in window 21 in the SiO_2 layer. The AuBe p-contact was then alloyed in a forming gas environ-

ment at 420°C for 30 sec. After this the bottom side of the wafer was thinned to 100 μm by chemo-mechanically polishing the substrate side using a 3 percent Bromine-Methanol solution. The bottom electrode 11 (n-contact) was prepared by depositing an AuGe alloy over the bottom surface of the substrate, and rapid thermally alloying at 350°C for 30 sec in forming gas. Deposition of thin layers of Ti and Au in a total thickness of from 0.05 to 1.0 μm by an e-beam evaporation process on top of the SiO_2 layer and of top electrode 22 completed the p-side processing. The wafer was then cleaved to produce chips of 250 μm cavity length.

The 250 μm long lasers emitted near 1 μm . Lasers with coated facets were found to have threshold currents of ~ 20 mA and were capable of emitting >100 mW per facet at room temperature continuous wave (CW) operation. See FIG. 3. For an example of coating mirror facets on a laser device see U.S. Patent 4,749,255 issued June 7, 1988, to Utpal K. Chakrabarti et al. Light intensities for lasers with uncoated facets in mW versus current characteristics of the laser in mA at different temperatures are shown in FIG. 4. The external differential quantum efficiency is found to be nearly independent of temperature in the range of 10°C to 90°C suggesting a low temperature dependence of leakage current. The lasing threshold was found to increase from 30 mA at room temperature to ~ 50 mA at 90°C operation. The nearly parallel slopes of the L-I curves show a small variation of the external quantum efficiency with temperature which suggests a low temperature dependent leakage current. The threshold current plotted as a function of temperature is shown in FIG. 5. The dependence of the threshold current on temperature is represented by the expression:

$$I_{th} = I_0 \exp(T/T_0) \quad (1)$$

where I_{th} is the threshold current and T is the temperature while I_0 and T_0 are constants. For the temperature range of 10°C to 90°C, the value of the characteristic temperature, T_0 , is determined to be 120K.

Claims

1. A buried heterostructure laser, which comprises: a compound semiconductor structure and a top (22,23) and a bottom (11) electrode to the said structure, said structure including GaAs and AlGaAs and comprising in an ascending order a substrate (12) of one conductivity type, a buffer layer (15) of said one conductivity type, a bottom confining layer (16) of said one conductivity type, an active layer (17) and a top confining layer (18) of the conductivity type opposite to said one conductivity type, said substrate having two parallel grooves (13) each having a dovetailed cross-

section, forming a reentrant mesa (14) between them, said buffer layer, said bottom confining layer and said active layer each having sections arranged in columns on the mesa and in the grooves, each of said sections in one column being laterally discontinuous with respect to the related sections in adjacent columns,

CHARACTERIZED IN THAT

said structure also includes InGaAs, being an AlGaAs/GaAs/InGaAs system

said substrate is of (100) orientation, and said grooves are etched with [011] orientation,

said active layer is a multiquantum well system of InGaAs wells and GaAs barriers,

said top confining layer overlies sections of the active layer on top of each column and sloped walls of sections of the buffer layer, bottom confining layer and active layer so as to bury the section of the active layer of the column above the mesa and separate this section from the columns in the grooves,

a contact layer (19) of said opposite conductivity type is on top of the top confining layer,

a dielectric layer (20) having a window (21) coextensive with the mesa is on top of the contact layer, and

said top electrode includes a stripe electrode (22) and an overlay electrode (23), said stripe electrode being in contact with an area of the contact layer exposed in said window, said stripe electrode being in the form of a narrow metal stripe and being coextensive with and in superimposed relation with the mesa and the section of the active layer above the mesa, and said overlay electrode is on the whole of the upper surface of the said stripe electrode and of said dielectric layer.

2. The laser of claim 1, in which said active layer comprises $\text{In}_y\text{Ga}_{1-y}\text{As}$ wells and GaAs barriers, y being in the range 0.05 to 0.25.
3. The laser of claim 2, in which the active layer includes three $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}$ wells and four GaAs barriers.
4. The laser of any of the preceding claims, in which each of said bottom and top confining layers is of $\text{Al}_x\text{Ga}_{1-x}\text{As}$, x being in the range 0.1 to 0.4.
5. The laser of claim 4, in which each of said confining layers comprises $\text{Al}_{0.4}\text{Ga}_{0.6}\text{As}$.
6. The laser of claim 5, in which each of said confining layers further comprises a thin $\text{Al}_{0.15}\text{Ga}_{0.85}\text{As}$ layer positioned between the active layer and the $\text{Al}_{0.4}\text{Ga}_{0.6}\text{As}$ layer.



ment at 420°C for 30 sec. After this the bottom side of the wafer was thinned to 100 μm by chemo-mechanically polishing the substrate side using a 3 percent Bromine-Methanol solution. The bottom electrode 11 (n-contact) was prepared by depositing an AuGe alloy over the bottom surface of the substrate, and rapid thermally alloying at 350°C for 30 sec in forming gas. Deposition of thin layers of Ti and Au in a total thickness of from 0.05 to 1.0 μm by an e-beam evaporation process on top of the SiO₂ layer and of top electrode 22 completed the p-side processing. The wafer was then cleaved to produce chips of 250 μm cavity length.

The 250 μm long lasers emitted near 1 μm. Lasers with coated facets were found to have threshold currents of ~20 mA and were capable of emitting >100 mW per facet at room temperature continuous wave (CW) operation. See FIG. 3. For an example of coating mirror facets on a laser device see U.S. Patent 4,749,255 issued June 7, 1988, to Utpal K. Chakrabarti et al. Light intensities for lasers with uncoated facets in mW versus current characteristics of the laser in mA at different temperatures are shown in FIG. 4. The external differential quantum efficiency is found to be nearly independent of temperature in the range of 10°C to 90°C suggesting a low temperature dependence of leakage current. The lasing threshold was found to increase from 30 mA at room temperature to ~50 mA at 90°C operation. The nearly parallel slopes of the L-I curves show a small variation of the external quantum efficiency with temperature which suggests a low temperature dependent leakage current. The threshold current plotted as a function of temperature is shown in FIG. 5. The dependence of the threshold current on temperature is represented by the expression:

$$I_{th} = I_0 \exp(T/T_0) \quad (1)$$

where I_{th} is the threshold current and T is the temperature while I_0 and T_0 are constants. For the temperature range of 10°C to 90°C, the value of the characteristic temperature, T_0 , is determined to be 120K.

Claims

1. A buried heterostructure laser, which comprises:
 - a compound semiconductor structure and a top (22,23) and a bottom (11) electrode to the said structure,
 - said structure including GaAs and AlGaAs and comprising in an ascending order a substrate (12) of one conductivity type, a buffer layer (15) of said one conductivity type, a bottom confining layer (16) of said one conductivity type, an active layer (17) and a top confining layer (18) of the conductivity type opposite to said one conductivity type, said substrate having two parallel grooves (13) each having a dovetailed cross-

section, forming a reentrant mesa (14) between them, said buffer layer, said bottom confining layer and said active layer each having sections arranged in columns on the mesa and in the grooves, each of said sections in one column being laterally discontinuous with respect to the related sections in adjacent columns,

CHARACTERIZED IN THAT

said structure also includes InGaAs, being an AlGaAs/GaAs/InGaAs system

said substrate is of (100) orientation, and said grooves are etched with [011] orientation,

said active layer is a multiquantum well system of InGaAs wells and GaAs barriers,

said top confining layer overlies sections of the active layer on top of each column and sloped walls of sections of the buffer layer, bottom confining layer and active layer so as to bury the section of the active layer of the column above the mesa and separate this section from the columns in the grooves,

a contact layer (19) of said opposite conductivity type is on top of the top confining layer, a dielectric layer (20) having a window (21) coextensive with the mesa is on top of the contact layer, and

said top electrode includes a stripe electrode (22) and an overlay electrode (23), said stripe electrode being in contact with an area of the contact layer exposed in said window, said stripe electrode being in the form of a narrow metal stripe and being coextensive with and in superimposed relation with the mesa and the section of the active layer above the mesa, and said overlay electrode is on the whole of the upper surface of the said stripe electrode and of said dielectric layer.

2. The laser of claim 1, in which said active layer comprises In_yGa_{1-y}As wells and GaAs barriers, y being in the range 0.05 to 0.25.
3. The laser of claim 2, in which the active layer includes three In_{0.2}Ga_{0.8}As wells and four GaAs barriers.
4. The laser of any of the preceding claims, in which each of said bottom and top confining layers is of Al_xGa_{1-x}As, x being in the range 0.1 to 0.4.
5. The laser of claim 4, in which each of said confining layers comprises Al_{0.4}Ga_{0.6}As.
6. The laser of claim 5, in which each of said confining layers further comprises a thin Al_{0.15}Ga_{0.85}As layer positioned between the active layer and the Al_{0.4}Ga_{0.6}As layer.



7. The laser of any of the preceding claims, in which said stripe electrode comprises AuBe.
8. The laser of any of the preceding claims, in which said overlay electrode comprises TiAu.
9. A method of making a buried heterostructure laser as claimed in any of the preceding claims, wherein
said buffer layer, bottom confining layer,
active layer, top confining layer and contact layer
are deposited by MOCVD.
10. The method of claim 10, in which said grooves
are etched with a mixture of $\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ in
the ratio of 1:1:1.

Patentansprüche

1. Laser mit vergrabener Heterostruktur umfassend: eine Verbindungshalbleiterstruktur und eine obere Elektrode (22, 23) und eine Bodenelektrode (11) zu der Struktur,
wobei die Struktur GaAs und AlGaAs umfaßt und in aufsteigender Folge ein Substrat (12) mit einem Leitfähigkeitstyp, eine Pufferschicht (15) mit dem einen Leitfähigkeitstyp, eine Bodeneinschlußschicht (16) mit dem einen Leitfähigkeitstyp, eine aktive Schicht (17) und eine obere Einschlußschicht (18) des dem einen Leitfähigkeitstyps entgegengesetzten Leitfähigkeitstyps hat, wobei das Substrat zwei parallele Furchen (13) hat, die jede einen schwalbenschwanzartigen Querschnitt haben, der eine zurücktretende Mesa (14) zwischen diesen ausbildet, wobei die Pufferschicht, die Bodeneinschlußschicht und die aktive Schicht jede Abschnitte haben, die in Säulen an der Mesa und in den Furchen angeordnet sind, wobei jeder Querschnitt in einer Säule in Bezug auf die zugehörigen Abschnitte in benachbarten Säulen seitlich nicht zusammenhängend ist, dadurch gekennzeichnet, daß
die Struktur ebenfalls InGaAs umfaßt, dieses ein AlGaAs/GaAs/InGaAs-System ist,
das Substrat (100) Orientierung hat und die Furchen mit $[01\bar{1}]$ Orientierung geätzt sind,
wobei die aktive Schicht ein Mehrfachquantenmuldensystem von InGaAs-Mulden und GaAs-Barrieren ist,
wobei die obere Einschlußschicht über Abschnitten der aktiven Schicht oben auf jeder Säule und geneigten Wänden der Abschnitte der Pufferschicht, der Bodeneinschlußschicht und der aktiven Schicht jeweils so liegt, daß der Abschnitt der aktiven Schicht der Säule oberhalb der Mesa vergraben ist und dieser Abschnitt von den Säulen in den Furchen getrennt ist,

wobei eine Kontaktschicht (19) des entgegengesetzten Leitfähigkeitstyps oben auf der oberen Einschlußschicht ist,

wobei eine dielektrische Schicht (20), die ein Fenster (21) hat, das sich mit der Mesa gleicherstreckt, oben auf der Kontaktschicht ist, und

die obere Elektrode eine Streifenelektrode (22) und eine Überlagerungselektrode (23) umfaßt, wobei die Streifenelektrode in Kontakt mit einem Bereich der in dem Fenster freigelegten Kontaktschicht ist, wobei die Streifenelektrode von der Form eines schmalen Metallstreifens ist und sich mit der Mesa und mit dem Abschnitt der aktiven Schicht über der Mesa in überlagerndem Verhältnis gleicherstreckt und die Überlagerungselektrode auf der gesamten oberen Oberfläche der Streifenelektrode und der dielektrischen Schicht ist.

2. Laser nach Anspruch 1, bei welchem die aktive Schicht $\text{In}_y\text{Ga}_{1-y}\text{As}$ -Mulden und GaAs-Barrieren umfaßt, wobei y im Bereich von 0,05 bis 0,25 ist.
3. Laser nach Anspruch 2, bei welchem die aktive Schicht $\text{In}_{0,2}\text{Ga}_{0,8}\text{As}$ -Mulden und vier GaAs-Barrieren umfaßt.
4. Laser nach einem der vorstehenden Ansprüche, bei welchem jede Boden- und obere Einschlußschicht aus $\text{Al}_x\text{Ga}_{1-x}\text{As}$ ist, wobei x im Bereich von 0,1 bis 0,4 ist.
5. Laser nach Anspruch 4, bei welchem jede Einschlußschicht $\text{Al}_{0,4}\text{Ga}_{0,6}\text{As}$ umfaßt.
6. Laser nach Anspruch 5, bei welchem jede Einschlußschicht ferner eine dünne $\text{Al}_{0,15}\text{Ga}_{0,85}\text{As}$ -Schicht zwischen der aktiven Schicht und der $\text{Al}_{0,4}\text{Ga}_{0,6}\text{As}$ -Schicht angeordnet umfaßt.
7. Laser nach einem der vorstehenden Ansprüche, in welchem die Streifenelektrode AuBe umfaßt.
8. Laser nach einem der vorstehenden Ansprüche, in welchem jede Überlagerungselektrode TiAu umfaßt.
9. Verfahren zur Herstellung eines Lasers mit vergrabener Heterostruktur nach einem der vorstehenden Ansprüche,
bei welchem die Pufferschicht, die Bodeneinschlußschicht, die aktive Schicht, die obere Einschlußschicht und die Kontaktschicht durch MOCVD abgeschieden sind.
10. Verfahren nach Anspruch 9, bei welchem die Furchen mit einer Mischung von $\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ im



Verhältnis von 1:1:1 geätzt sind.

Revendications

1. Un laser à hétérostructure enterrée, comprenant :

une structure de semiconducteurs composés et une électrode supérieure (22, 23) et une électrode inférieure (11) associées à la structure, cette structure contenant les matériaux GaAs et AlGaAs et comprenant, en ordre ascendant, un substrat (12) d'un premier type de conductivité, une couche tampon (15) du premier type de conductivité, une couche de confinement inférieure (16) du premier type de conductivité, une couche active (17) et une couche de confinement supérieure (18) du type de conductivité opposé au premier type de conductivité, le substrat ayant deux sillons parallèles (13) ayant chacun une section droite en queue d'aronde, formant entre eux une méso à flancs rentrants (14), la couche tampon, la couche de confinement inférieure et la couche active ayant chacune des parties disposées dans des colonnes sur la méso et dans les sillons, chacune de ces parties dans une colonne étant latéralement discontinue vis-à-vis des parties associées dans des colonnes adjacentes,

CARACTERISE EN CE QUE

la structure comprend également le matériau InGaAs et elle consiste en un système AlGaAs/GaAs/InGaAs

le substrat a une orientation (100), et les sillons sont gravés avec l'orientation [011],

la couche active est un système à puits quantiques multiples qui est formé par des puits en InGaAs et par des barrières en GaAs,

la couche de confinement supérieure recouvre des parties de la couche active au sommet de chaque colonne et des parois inclinées de parties de la couche tampon, de la couche de confinement inférieure et de la couche active, de façon à enterrer la partie de la couche active de la colonne qui se trouve au-dessus de la méso et à séparer cette partie vis-à-vis des colonnes se trouvant dans les sillons,

une couche de contact (19) du type de conductivité opposé est formée sur la surface supérieure de la couche de confinement supérieure,

une couche diélectrique (20) ayant une fenêtre (21) qui coïncide avec la méso, est formée sur la surface supérieure de la couche de contact, et

l'électrode supérieure comprend une électrode en ruban (22) et une électrode de recouvrement (23), l'électrode en ruban étant en contact

avec une région de la couche de contact qui est à nu dans la fenêtre, l'électrode en ruban se présentant sous la forme d'un ruban en métal étroit et s'étendant en coïncidence et en superposition avec la méso et la partie de la couche active qui se trouve au-dessus de la méso, et l'électrode de recouvrement est formée sur la totalité de la surface supérieure de l'électrode en ruban et de la couche diélectrique.

2. Le laser de la revendication 1, dans lequel la couche active comprend des puits en $\text{In}_y\text{Ga}_{1-y}\text{As}$ et des barrières en GaAs, y étant dans la plage de 0,05 à et 0,25.
3. Le laser de la revendication 2, dans lequel la couche active comprend trois puits en $\text{In}_{0,2}\text{Ga}_{0,8}\text{As}$ et quatre barrières en GaAs.
4. Le laser de l'une quelconque des revendications précédentes, dans lequel chacune des couches de confinement inférieure et supérieure consiste en $\text{Al}_x\text{Ga}_{1-x}\text{As}$, x étant dans la plage de 0,1 à 0,4.
5. Le laser de la revendication 4, dans lequel chacune des couches de confinement comprend le matériau $\text{Al}_{0,4}\text{Ga}_{0,6}\text{As}$.
6. Le laser de la revendication 5, dans lequel chacune des couches de confinement comprend en outre une couche mince d' $\text{Al}_{0,15}\text{Ga}_{0,85}\text{As}$ placée entre la couche active et la couche d' $\text{Al}_{0,4}\text{Ga}_{0,6}\text{As}$.
7. Le laser de l'une quelconque des revendications précédentes, dans lequel l'électrode en ruban comprend le matériau AuBe.
8. Le laser de l'une quelconque des revendications précédentes, dans lequel l'électrode de recouvrement comprend le matériau TiAu.
9. Un procédé de fabrication d'un laser à hétérostructure enterrée selon l'une quelconque des revendications précédentes, dans lequel la couche tampon, la couche de confinement inférieure, la couche active, la couche de confinement supérieure et la couche de contact sont déposées par dépôt chimique en phase vapeur aux organométalliques (ou MOCVD).
10. Le procédé de la revendication 9, dans lequel les sillons sont gravés avec un mélange de $\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ dans le rapport 1:1:1.