

Description

This invention relates to lightwave communication apparatus and, more particularly, to methods for making packages for optoelectronic devices, such as light-emitting diodes (LEDs).

Optical or lightwave communications systems are presently being intensively explored because of their promise for delivering greater quantities of information over a transmission medium than is possible with conventional electrical communications systems. Fundamental to any lightwave system is a lightwave source, such as a laser or an LED; a transmission medium, such as an optical fiber; and a detector, such as a semiconductor photodetector. Optical couplers are commonly used between the source and the detector for operating on the transmitted information (e.g., monitoring, amplifying). Devices such as lasers, LEDs and photodetectors that operate both electronically and optically are known as optoelectronic devices.

Various techniques are known for packaging subassemblies for optoelectronic devices that appropriately align an optoelectronic device with various lenses, reflectors, and optical fiber transmission media. The supports for various optoelectronic devices and the reflecting surfaces may, for example, be defined in monocrystalline silicon by taking advantage of known anisotropic etching properties of silicon. Because silicon etches preferentially along predictable crystallographic planes, various grooves, cavities and alignment detents can be quickly and easily made with great precision by masking and etching various surfaces of monocrystalline silicon support structures.

Semiconductor lasers differ from semiconductor LEDs in that they emit light from a junction periphery in a direction parallel to the junction; whereas, LEDs emit light in a direction transverse to the junction through the "top" of the device. LEDs are commonly used in conjunction with multi-mode optical fibers for providing data communications (e.g., communication between computers); whereas, lasers are commonly used in conjunction with single-mode optical fibers to provide voice and voice-related communications.

Because LEDs emit light in the vertical direction, LED packages are somewhat difficult to make because, for structural reasons, it is preferred that the optical fiber extend from the package in a horizontal direction. Bending the fiber 90° is poor practice for both structural and optical reasons. Thus, it is preferred that the LED package contain a reflector for changing the direction of the emitted light prior to transmission by the optical fiber (see e.g. DE-A-3 543 558, which discloses a package method and apparatus according to the preamble of present claims 1 and 10, respectively.)

According to the present invention, there is provided a method as defined in claim 1, or a package as defined in claim 10.

In accordance with the invention, efficient coupling between an optoelectronic device and an optical fiber is obtained by using different monocrystalline elements of different crystallographic orientation for mounting, respectively, the fiber and the optoelectronic device. For example, the crystallographic orientation of an upper monocrystalline element is chosen such that a horizontal groove for supporting the optical fiber and a reflecting surface for directing light into the fiber may both be made by anisotropic etching. The crystallographic orientation of a lower monocrystalline silicon element is chosen such that appropriate etching will yield a mounting surface for an optoelectronic device which is suitable for directing light from the reflecting surface into the optical fiber with maximum efficiency.

In one illustrative embodiment, the upper monocrystalline element is {100} silicon, and the second monocrystalline element is {112} silicon. As will be explained more fully later, this permits anisotropic etching so as to form a V-groove that supports a horizontally-extending optic fiber, a reflecting surface that extends at 54.74°, and a support surface for the optoelectronic device that extends at 19.48° with respect to the horizontal. These relative angles provide for optimum optical coupling between the optoelectronic device and the optical fiber, while providing horizontal surfaces for supporting both electronic circuitry and the optical fiber, as is desired for secure packaging and integration of the package apparatus into a lightwave communications system.

These and other objects, features, advantages and embodiments of the invention will be better understood from a consideration of the following detailed description taken in conjunction with the accompanying drawing.

FIG. 1 is a sectional schematic view of an optoelectronic device package made in accordance with an illustrative embodiment of the invention;

FIG. 2 is a view taken along lines 2-2 of FIG. 1, except that the optoelectronic device and lens are eliminated for the sake of clarity;

FIG. 3 is a view taken along lines 3-3 of FIG. 1, except that the optoelectronic device and lens have been eliminated for the sake of clarity;

FIG. 4 is a view taken along lines 4-4 of FIG. 1;

FIG. 5 is a schematic view illustrating the relevant geometry of the apparatus of FIG. 1.

FIG. 6 is a schematic illustration of another embodiment of the invention;

FIG. 7 is a view taken along lines 7-7 of FIG. 6.

Referring now to FIG. 1, there is shown a schematic view of an LED assembly or package 11 made in accordance with one embodiment of the invention. The purpose of the package is to provide a secure mounting for an LED 13 and an associated lens 14 such that output of the light generated by the LED is directed into an optical fiber 15. Once proper mounting surfaces have been defined, these elements may be secured within the package by epoxy or some other bonding material, as is known in the art. In accordance with this embodiment of the invention, the package 11 comprises an upper monocrystalline silicon element 17 and a lower monocrystalline silicon element 18, which have relative crystallographic orientations chosen to provide optimum mounting surfaces. A reflecting surface 19 is formed in the upper crystalline silicon element which is metallized, as is known in the art, so as to reflect light from the LED 13 into the fiber 15. As shown more clearly in FIG. 4, the fiber 15 is contained within upper silicon element 17 by a V-groove 20 having side walls 21 that extend at 54.74° angles with the horizontal as shown.

In accordance with the invention, the upper silicon element 17 is {100} oriented monocrystalline silicon while the lower element is {112} monocrystalline silicon. As is known in the art, the V-groove shown in FIG. 4 can easily be made by photolithographic masking and etching of the {100} element. That is, with all of element 17 masked, except for an opening in the upper surface 22 corresponding to the desired location of the groove as can be appreciated from FIG. 4, an etchant will preferentially etch along the {111} crystallographic planes so as to leave side walls 21 that correspond to such planes and are at 54.74° with respect to the horizontal. Referring to FIG. 3, the element 17 is likewise masked with a rectangular opening in the lower surface of the mask. When the etchant etches, a polyhedron or pyramid of four surfaces is formed, with surface 19 having a slope at 54.74° with respect to the horizontal as a necessary consequence of the elements' crystallographic orientation. Surface 19 corresponds to the {111} plane.

Likewise, the {112} oriented silicon element 18 is masked except for an opening at its upper surface and etched so as to form a surface 23 which is parallel with the {111} crystallographic plane. It can be shown that one of the {111} planes in {112} oriented silicon is at an angle with respect to the horizontal of 19.48°. After surface 23 has been formed, it is metallized, and LED 13 is mounted on it. With reflecting surface 19 extending at 54.74 degrees, the light projected normally with respect to surface 23 will be reflected from surface 19 in a direction parallel to the V-groove in element 17, and thus parallel to the central axis of optical

fiber 15 as required for maximum coupling efficiency.

The condition for relating the angle α that surface 19 bears to the horizontal to the angle β of surface 23, such as to obtain reflected light that is parallel to the optical fiber axis, can be appreciated from FIG. 5, which illustrates the relevant geometry. First, consider line 19' to extend at the same angle α with respect to the horizontal as does the reflecting surface 19 of FIG. 1. We wish the light directed into the fiber 15 to be directed along a line 24 which is parallel with the horizontal and therefore forms an angle α with respect to line 19'. The exercise is to determine the angle β which accomplishes this desired result. First, construct a perpendicular 25 through the line 19' at the point of incidence. Since the angle of incidence must equal the angle of reflection,

$$\gamma_1 = \gamma_2 \quad (1)$$

Since the angle between line 24 and 19' is equal to α , γ_1 may be expressed as

$$\gamma_1 = 90^\circ - \alpha \quad (2)$$

from geometry and from Equation (1),

$$2\gamma_1 = 90^\circ - \beta. \quad (3)$$

Then from equations 2 and 3,

$$\beta = 2\alpha - 90^\circ. \quad (4)$$

This shows that an angle β of 19.48°, together with an angle α of 54.74°, will reflect light that is parallel to the horizontally-extending optical fiber axis.

A detailed discussion of different ways for forming desired crystal orientations in silicon, and etching to desired crystallographic planes, are described in some detail in the paper "Silicon as a Mechanical Material," Proceedings of the IEEE, Volume 70, No. 5, May 1982, pp. 420-457. In one experimental embodiment of the invention, masking and etching of element 18 was accomplished by first thermally growing a 0.5 micrometer thick layer of silicon dioxide a wafer from which the element 18 is to be defined on and covering this with a photolithographic mask which was patterned in a known manner. The holes in the oxide were then formed by etching in buffered hydrofluoric acid which dissolved only the unmasked silicon dioxide. The recesses in the silicon were then formed by using the patterned SiO_2 as a mask and etching the exposed silicon in an ethylene diamine pyrocatechol solution which produced the recess in which surface 23 is defined.

After forming the surface 23, the lower silicon element 18 was stripped of its silicon dioxide, and a new oxide layer 0.1 micrometers thick was regrown. The sample was then coated by sputtering with a 0.03 micrometer thick layer of chromium, followed by a 0.2 micrometer thick layer of gold. Careful coating with photoresist and multiple exposures and development allowed a conductor pattern to be formed which preserved the metallization over the lip of the recess. After etching away the exposed gold and chromium, the sample was replated with gold to a 5 micrometer thickness. This extra thickness was provided to insure sufficient current-carrying capacity for the performance of the LED without overheating the conductors and to provide a good bonding pad for the LED. Individual elements were cut from the wafer and LEDs were epoxy bonded into the etched recesses and wire bonded. A simple jig was designed and fabricated to hold the surface 23 at a horizontal angle so that the LED could be positioned, epoxied, and wire bonded with standard equipment. Spherical lenses were epoxied onto the LEDs, and the submounts were attached to a header. The headers made convenient test vehicles for holding devices and making electrical connections.

The upper monocrystalline element 17 is identical to a corresponding element described in U.S.-A-4,897,711 and so its construction will not be reviewed in detail. The masking and etching may proceed as generally described with respect to the lower element 18; that is, the same SiO_2 masking and etch and silicon etch may be used as described above. After the fiber has been epoxied in the groove and the upper element 17 has been epoxied to lower element 18, a lid may be included on the top surface 22 as generally described in U.S.-A-4,897,711. Various other mounting structures and electrical contacts may be made as generally described in the Blonder et al. patent application and elsewhere in the literature.

From the foregoing, it can be appreciated that the package of FIG. 1 provides for optimum optical coupling between the LED device 23 and the optical fiber 15, in a manner that is consistent with the use of a horizontally-extending V-groove for supporting the fiber and conventional metallization for making electrical contact to the LED 23. The final result is a package in which it is not necessary to bend the optical fiber to make it extend in a horizontal direction. This would not be true, for example, if the LED were made to be supported on a flat horizontal surface and the optical fiber extended axially in a vertical direction. The resulting 90° bend that would be required to bring the fiber to a horizontal position would be a source of mechanical stress, as well as optical transmission losses. Other designs could be configured in which the

optical fiber extends at other angles from the package, but such configurations would normally be inferior to the ones shown in which the fiber extends in a horizontal direction.

FIGs. 6 and 7 illustrate an alternative embodiment of the invention comprising an upper monocrystalline silicon element 27 and a lower monocrystalline silicon element 28. The lower silicon element has a {112} crystallographic orientation which is essentially the same as the lower element 18 of FIG. 1, except that it has been rotated 180° with respect to the orientation shown in FIG. 1. Therefore, the effective angle β of mount surface 23' with respect to the horizontal is -19.48° rather than 19.48°. The upper silicon element 27 has a {110} orientation. With this orientation, etching from the bottom surface of element 27 will yield opposite sloping walls and opposite vertical walls. The reflector wall 29 will have an angle with respect to the horizontal of 35.26° which corresponds to a {111} crystallographic plane. It can therefore be seen that this combination of angles for surfaces 23' and 29 complies with Equation (4). The fiber groove is made by etching silicon element 27 from the top surface which, with the {110} orientation of element 27, yields the U-shaped groove 30 having a horizontal axis as shown in FIG. 6. With the U-shaped groove, of course, the fiber 31 will again extend in a horizontal direction. The vertical sidewalls of groove 30 correspond to the {111} planes. The LED 32 is mounted such as to project light that is reflected from reflecting surface 29 in a horizontal direction for optimum coupling into the optical fiber 31.

While the invention was stimulated by a need to provide optimum coupling between an LED and an optical fiber, it can be seen that it may be used in any optoelectronic device in which optimum coupling with a fiber is desired. For example, the LEDs of FIGs. 4 and 5 could be photodetectors which are optimally positioned by the package to receive light from the optical fiber. If lasers were made so as to emit light from the side opposite the side that is mounted on a support plane, then the invention would be applicable to such lasers. Silicon was chosen as the monocrystalline substance that seems to be the most practical for implementing the invention, but clearly other crystalline substances, such as germanium, could alternatively be used. While the relative angles obtained through etching are extremely precise, the absolute angles are dependent on the precision with which the monocrystalline elements were initially cut, as is known in the art.



Claims

1. A method for making an optoelectronic device package (11) comprising the steps of mounting an optical fiber (15) such that it axially extends in a first direction; forming a flat reflective surface (19) by masking a first monocrystalline element (17) and etching it to a first crystallographic plane; positioning the first monocrystalline element relatively to the optical fiber so that the reflective surface (19) extends at a first angle α with respect to the first direction, said first angle α not being 45° ; mounting an optoelectronic device (13) such that an optical path is described between the optoelectronic device and the optical fiber axis by way of the reflecting surface, characterized by:
 - forming a flat mounting surface (23) for the optoelectronic device by masking a second monocrystalline element (18) and etching it to a second crystallographic plane; the second monocrystalline element (18) having a crystal orientation different from that of the first monocrystalline element (17);
 - fixing the second monocrystalline element to the first monocrystalline element such that the mounting surface extends at a second angle β with respect to the first direction;
 - mounting the optical fiber to one of the monocrystalline elements to reference the first direction to the crystallographic directions of the first and second monocrystalline elements;
 - and mounting the optoelectronic device on the mounting surface so as to orient the optoelectronic device at the second angle β , the crystal orientation of the second monocrystalline element being selected relatively to that of the first monocrystalline element so that the second angle β of the mounting surface is appropriate relatively to the first angle α of the reflective surface for giving optical transmission over the optical path between the optoelectronic device and the optical fiber.
2. The method of Claim 1 further characterized in that:
 - the second angle β is equal to approximately $2\alpha - 90^\circ$, where α is the first angle.
3. The method of Claim 2 further characterized in that:
 - the step of mounting the optical fiber comprises the step of masking and etching the first monocrystalline element so as to make a groove (20) defined by crystallographic planes, and then bonding the optical fiber in the groove.
4. The method of Claim 3 further characterized in that:
 - the first monocrystalline element is {100} silicon; the second monocrystalline element is {112} silicon; the first crystallographic plane is a {111} plane, and the second crystallographic plane is a {111} crystallographic plane.
5. The method of Claim 4 further characterized in that:
 - the optical fiber is mounted in a V-groove defined by {111} planes in the first monocrystalline silicon element.
6. The method of Claim 5 further characterized in that:
 - the first angle α is substantially 54.74° , and the second angle β is substantially 19.48° .
7. The method of Claim 3 further characterized in that:
 - the first monocrystalline element is {110} silicon; the second monocrystalline element is {112} silicon; the first crystallographic plane is a {111} plane; and the second crystallographic plane is a {111} plane.
8. The method of Claim 7 further characterized in that:
 - the optical fiber is mounted in a groove defined by {111} crystallographic planes in the first monocrystalline element.
9. The method of Claim 8 further characterized in that:
 - the first angle α is substantially 35.26° , and the second angle β is substantially -19.48° .
10. An optoelectronic device package (11) comprising an optical fiber (15) that extends in a first direction; a flat reflective surface (19) defined by a first crystallographic plane of a first monocrystalline element (17), positioned relatively to the optical fiber so that the reflective surface extends at a first angle α with respect to the first direction, said first angle α not being 45° ; and an optoelectronic device (13) included in an optical path that includes the axis of the optical fiber and the reflective surface, characterized in that:
 - the optoelectronic device is mounted on a flat mounting surface (23) defined by a second crystallographic plane of a second monocrystalline element (18) having a crystal orientation different from that of the first monocrystalline element;



the second monocrystalline element is fixed to the first monocrystalline element such that the mounting surface extends at a second angle β with respect to the first direction; and

the optical fiber is mounted onto one of the monocrystalline elements whilst extending in said first direction, the crystal orientation of the second monocrystalline element being selected relatively to that of the first monocrystalline element so that the second angle β of the mounting surface is appropriate relatively to the first angle α of the reflective surface for giving optical transmission over the optical path between the optoelectronic device and the optical fiber.

11. The optoelectronic device package of Claim 10 further characterized in that:

the second angle β is equal to $2\alpha - 90^\circ$, where α is the first angle.

12. The optoelectronic device package of Claim 11 further characterized in that:

the optical fiber is mounted in a groove (20) defined by crystallographic planes in the first monocrystalline element.

13. The optoelectronic device package of Claim 12 further characterized in that:

the first monocrystalline element is {100} silicon, the second monocrystalline element is {112} silicon; the first crystallographic plane is a {111} plane and the second crystallographic plane is a {111} plane.

14. The optoelectronic device package of Claim 13 further characterized in that:

the optical fiber is contained in a V-groove defined by {111} planes in the first monocrystalline silicon element.

15. The optoelectronic device package of Claim 14 further characterized in that:

the first angle α is substantially 54.74° and the second angle β is substantially 19.48° .

16. The optoelectronic device package of Claim 12 further characterized in that:

the first monocrystalline element is {110} silicon, the second monocrystalline element is {112} silicon; the first crystallographic plane is a {111} plane; and the second crystallographic plane is a {111} plane.

17. The optoelectronic device package of Claim 16 further characterized in that:

the optical fiber is mounted in a groove

defined by {111} crystallographic planes in the first monocrystalline element.

18. The optoelectronic device package of Claim 17 further characterized in that:

the first angle α is substantially 35.26° , and the second angle β is substantially -19.48° .

Patentansprüche

- Verfahren zur Herstellung einer optoelektronischen Bauteilbaugruppe (11) umfassend die Schritte des Befestigens einer optischen Faser derart, daß sich diese in einer ersten Richtung axial erstreckt, Ausbilden einer ebenen reflektierenden Oberfläche (19) durch maskieren eines ersten monokristallinen Elementes (17) und dessen Ätzen zu einer ersten kristallographischen Ebene, Positionieren des ersten monokristallinen Elementes relativ zur optischen Faser so, daß sich die reflektierende Oberfläche (19) unter einem ersten Winkel α in Bezug auf die erste Richtung erstreckt, wobei der erste Winkel α ungleich 45° ist, Befestigen einer optoelektronischen Einrichtung 13 derart, daß ein optischer Weg zwischen der optoelektronischen Einrichtung und der optischen Faserachse durch die reflektierende Oberfläche beschrieben wird, gekennzeichnet durch Ausbilden einer flachen Befestigungsfläche (23) für die optoelektronische Einrichtung durch Maskieren eines zweiten monokristallinen Elementes (18) und dessen Ätzen zu einer zweiten kristallographischen Ebene, wobei das zweite monokristalline Element (18) eine Kristallorientierung aufweist, die von derjenigen des ersten monokristallinen Elementes (17) verschieden ist, Befestigen des zweiten monokristallinen Elementes an dem ersten monokristallinen Element derart, daß die Befestigungsoberfläche sich unter einem zweiten Winkel β in Bezug auf die erste Richtung erstreckt, Befestigen der optischen Faser an einem der monokristallinen Elemente, um die erste Richtung zu den kristallographischen Richtungen des ersten und zweiten monokristallinen Elementes in Bezug zu setzen, und Befestigen der optoelektronischen Einrichtung an der Befestigungsoberfläche, um so die optoelektronische Einrichtung unter dem zweiten Winkel β zu orientieren, wobei die Kristallorientierung des zweiten monokristallinen Elementes in bezug auf diejenige des ersten monokristallinen Elementes so gewählt ist, daß der zweite Winkel β der Befestigungsoberfläche relativ zum ersten Winkel α der reflektierenden Oberfläche geeignet ist, um optische Übertragung entlang



des optischen Weges zwischen der optoelektronischen Einrichtung und der optischen Faser bereitzustellen.

2. Verfahren nach Anspruch 1, ferner dadurch gekennzeichnet, daß der zweite Winkel β ungefähr gleich $2\alpha - 90^\circ$ ist, wobei α der erste Winkel ist. 5
3. Verfahren nach Anspruch 2, ferner dadurch gekennzeichnet, daß:
der Schritt des Befestigens der optischen Faser den Schritt des Maskierens und Ätzens des ersten monokristallinen Elementes umfaßt, um so eine Furche (20), die durch kristallographische Ebenen definiert ist, auszubilden und dann das Befestigen der optischen Faser in der Furche umfaßt. 10 15
4. Verfahren nach Anspruch 3, ferner dadurch gekennzeichnet, daß:
das erste monokristalline Element {100}-Silizium ist, das zweite monokristalline Element {112}-Silizium ist, die erste kristallographische Ebene eine {111}-Ebene ist und die zweite kristallographische Ebene eine kristallographische {111}-Ebene ist. 20 25
5. Verfahren nach Anspruch 4, ferner dadurch gekennzeichnet, daß:
die optische Faser in einer durch {111}-Ebenen in dem ersten monokristallinen Siliziumelement definierten V-Furche befestigt ist. 30
6. Verfahren nach Anspruch 5, ferner dadurch gekennzeichnet, daß der erste Winkel α im wesentlichen $54,74^\circ$ und der zweite Winkel β im wesentlichen $19,48^\circ$ ist. 35
7. Verfahren nach Anspruch 3, ferner dadurch gekennzeichnet, daß:
das erste monokristalline Element {110}-Silizium ist, das zweite monokristalline Element {112}-Silizium ist, die erste kristallographische Ebene eine {111}-Ebene und die zweite kristallographische Ebene eine {111}-Ebene ist. 40 45
8. Verfahren nach Anspruch 7, ferner dadurch gekennzeichnet, daß:
die optische Faser in einer durch kristallographische {111}-Ebenen in dem ersten monokristallinen Element definierten Furche befestigt ist. 50
9. Verfahren nach Anspruch 8, ferner dadurch gekennzeichnet, daß:
der erste Winkel α im wesentlichen $35,26^\circ$ beträgt und der zweite Winkel β im wesentli-

chen $-19,48^\circ$ beträgt.

10. Optoelektronische Bauteilbaugruppe (11), umfassend eine optische Faser (15), die sich in einer ersten Richtung erstreckt, eine flache reflektierende Oberfläche (19), die durch eine erste kristallographische Ebene eines ersten monokristallinen Elementes (17) definiert ist, das relativ zur optischen Faser so angeordnet ist, daß die reflektierende Oberfläche sich unter einem ersten Winkel α in bezug auf die erste Richtung erstreckt, wobei der erste Winkel α nicht 45° ist, und enthaltend eine optoelektronische Einrichtung (13), die in einen optischen Weg einbezogen ist, der die Achse der optischen Faser und die reflektierende Oberfläche umfaßt, dadurch gekennzeichnet, daß:
die optoelektronische Einrichtung an einer ebenen Befestigungsfläche (23) befestigt ist, die durch eine zweite kristallographische Ebene eines zweiten monokristallinen Elementes (18) mit einer Kristallorientierung, die verschieden von derjenigen des ersten monokristallinen Elementes ist, definiert ist, wobei das zweite monokristalline Element an dem ersten monokristallinen Element derart befestigt ist, daß die Befestigungsfläche sich unter einem zweiten Winkel β relativ zur ersten Richtung erstreckt und die optische Faser an einem der monokristallinen Elemente befestigt ist, wobei sich diese in der ersten Richtung erstreckt, wobei die Kristallorientierung des zweiten monokristallinen Elementes relativ zu derjenigen des ersten monokristallinen Elementes so ausgewählt ist, daß der zweite Winkel β der Befestigungsfläche relativ zum ersten Winkel α der reflektierenden Oberfläche geeignet ist, die optische Übertragung entlang des optischen Weges zwischen der optoelektronischen Einrichtung und der optischen Faser bereitzustellen.
11. Optoelektronische Bauteilbaugruppe nach Anspruch 10, ferner dadurch gekennzeichnet, daß:
der zweite Winkel $\beta = 2\alpha - 90^\circ$ ist, wobei α der erste Winkel ist.
12. Optoelektronische Bauteilbaugruppe nach Anspruch 11, ferner dadurch gekennzeichnet, daß:
die optische Faser in einer Furche (20), die durch kristallographische Ebenen in dem ersten monokristallinen Element ausgebildet ist, befestigt ist.
13. Optoelektronische Bauteilbaugruppe nach Anspruch 12, ferner dadurch gekennzeichnet, daß:



das erste monokristalline Element {100}-Silizium ist, das zweite monokristalline Element {112}-Silizium ist, die erste kristallographische Ebene eine {111}-Ebene ist und die zweite kristallographische Ebene eine {111}-Ebene ist.

14. Optoelektronische Bauteilbaugruppe nach Anspruch 13, ferner dadurch gekennzeichnet, daß:

die optische Faser in einer durch {111}-Ebenen in dem ersten monokristallinen Siliziumelement ausgebildeten V-Furche enthalten ist.

15. Optoelektronische Bauteilbaugruppe nach Anspruch 14, ferner dadurch gekennzeichnet, daß:

der erste Winkel α im wesentlichen $54,74^\circ$ und der zweite Winkel β im wesentlichen $19,48^\circ$ beträgt.

16. Optoelektronische Bauteilbaugruppe nach Anspruch 12, ferner dadurch gekennzeichnet, daß:

das erste monokristalline Element {110}-Silizium ist, das zweite monokristalline Element {112}-Silizium ist, wobei die erste kristallographische Ebene eine {111}-Ebene ist und die zweite kristallographische Ebene eine {111}-Ebene ist.

17. Optoelektronische Bauteilbaugruppe nach Anspruch 16, ferner dadurch gekennzeichnet, daß:

die optische Faser in einer durch kristallographische {111}-Ebenen in dem ersten monokristallinen Element ausgebildeten Furche befestigt ist.

18. Optoelektronische Bauteilbaugruppe nach Anspruch 17, ferner dadurch gekennzeichnet, daß:

der erste Winkel α im wesentlichen $35,26^\circ$ beträgt und der zweite Winkel β im wesentlichen $-19,48^\circ$ beträgt.

Revendications

1. Procédé de fabrication d'un dispositif optoélectronique (11), comprenant les étapes qui consistent à monter une fibre optique (15) de manière à ce qu'elle s'étend axialement dans une première direction ; à former une surface réfléchissante plate (19) en masquant un premier élément monocristallin (17) et en le gravant pour obtenir un premier plan cristallographique en plaçant le premier élément monocristallin, relativement à la fibre optique, de

manière à ce que la surface réfléchissante (19) s'étend à un premier angle α par rapport à la première direction, ledit premier angle α ne faisant pas 45° ; à monter un dispositif optoélectronique (13) de manière à ce qu'un trajet optique soit décrit entre le dispositif optoélectronique et l'axe de la fibre optique par l'intermédiaire de la surface réfléchissante, caractérisé en ce que :

on forme une surface de montage plate (23) pour le dispositif optoélectronique en masquant un second élément monocristallin (18) et en le gravant pour obtenir un second plan cristallographique, le second élément monocristallin (18) ayant une orientation cristalline différente de celle du premier élément monocristallin (17) ;

on fixe le second élément monocristallin au premier élément monocristallin de manière à ce que la surface de montage s'étend à un second angle β par rapport à la première direction ;

on monte la fibre optique sur un des éléments monocristallins en prenant comme point de repère de la première direction pour les directions cristallographiques des premier et second éléments monocristallins ;

et on monte le dispositif optoélectronique sur la surface de montage de manière à orienter le dispositif optoélectronique pour qu'il fasse le second angle β , l'orientation cristalline du second élément monocristallin étant choisie relativement à celle du premier élément monocristallin pour que le second angle β de la surface de montage soit approprié, relativement au premier angle α de la surface réfléchissante, pour donner une transmission optique sur le trajet optique entre le dispositif optoélectronique et la fibre optique.

2. Procédé selon la revendication 1, caractérisé de plus en ce que :

le second angle β est égal à environ $2\alpha - 90^\circ$, α étant le premier angle.

3. Procédé selon la revendication 2, caractérisé de plus en ce que :

l'étape de montage de la fibre optique comprend l'étape de masquage et de gravure du premier élément monocristallin de manière à former une rainure (20) définie par des plans cristallographiques, puis de collage de la fibre optique dans la rainure.

4. Procédé selon la revendication 3, caractérisé de plus en ce que :

le premier élément monocristallin est du silicium [100] ; le second élément monocristal-



lin est du silicium [112] ; le premier plan cristallographique est un plan [111] et le second plan cristallographique est un plan cristallographique [111].

5. Procédé selon la revendication 4, caractérisé de plus en ce que :

la fibre optique est montée dans une rainure en V définie par les plans [111] dans le premier élément de silicium monocristallin.

6. Procédé selon la revendication 5, caractérisé de plus en ce que :

le premier angle α est sensiblement égal à $54,74^\circ$ et le second angle β est sensiblement égal à $19,48^\circ$.

7. Procédé selon la revendication 3, caractérisé de plus en ce que :

le premier élément monocristallin est du silicium [110] ; le second élément monocristallin est du silicium [112] ; le premier plan cristallographique est un plan [111] et le second plan cristallographique est un plan [111].

8. Procédé selon la revendication 7, caractérisé de plus en ce que :

la fibre optique est montée dans une rainure définie par les plans cristallographiques [111] dans le premier élément monocristallin.

9. Procédé selon la revendication 8, caractérisé de plus en ce que :

le premier angle α est sensiblement égal à $35,26^\circ$ et le second angle β est sensiblement égal à $-19,48^\circ$.

10. Ensemble de dispositif optoélectronique (11), comprenant une fibre optique (15) qui s'étend dans une première direction ; une surface réfléchissante plate (19) définie par un premier plan cristallographique d'un premier élément monocristallin (17), placé, relativement à la fibre optique, de manière à ce que la surface réfléchissante s'étend à un premier angle α par rapport à la première direction, ledit premier angle α ne faisant pas 45° ; et un dispositif optoélectronique (13) incorporé dans un trajet optique, qui inclut l'axe de la fibre optique et la surface réfléchissante, caractérisé en ce que :

le dispositif optoélectronique est monté sur une surface de montage plate (23) définie par un second plan cristallographique d'un second élément monocristallin (18) ayant une orientation cristalline différente de celle du premier élément monocristallin ;

le second élément monocristallin est fixé

au premier élément monocristallin pour que la surface de montage s'étend à un second angle β par rapport à la première direction ; et

la fibre optique est montée sur un des éléments monocristallins, tout en s'étendant dans ladite première direction, l'orientation cristalline du second élément monocristallin étant choisie relativement à celle du premier élément monocristallin pour que le second angle β de la surface de montage soit approprié, relativement au premier angle α de la surface réfléchissante, pour donner une transmission optique sur le trajet optique entre le dispositif optoélectronique et la fibre optique.

11. Ensemble de dispositif optoélectronique selon la revendication 10, caractérisé de plus en ce que :

le second angle β est égal à $2\alpha - 90^\circ$, α étant le premier angle.

12. Ensemble de dispositif optoélectronique selon la revendication 11, caractérisé de plus en ce que :

la fibre optique est montée dans une rainure (20) définie par des plans cristallographiques dans le premier élément monocristallin.

13. Ensemble de dispositif optoélectronique selon la revendication 12, caractérisé de plus en ce que :

le premier élément monocristallin est du silicium [100] ; le second élément monocristallin est du silicium [112] ; le premier plan cristallographique est un plan [111] et le second plan cristallographique est un plan [111].

14. Ensemble de dispositif optoélectronique selon la revendication 13, caractérisé de plus en ce que :

la fibre optique est contenue dans une rainure en V définie par les plans [111] dans le premier élément de silicium monocristallin.

15. Ensemble de dispositif optoélectronique selon la revendication 14, caractérisé de plus en ce que :

le premier angle α est sensiblement égal à $54,74^\circ$ et le second angle β est sensiblement égal à $19,48^\circ$.

16. Ensemble de dispositif optoélectronique selon la revendication 12, caractérisé de plus en ce que :

le premier élément monocristallin est du silicium [110] ; le second élément monocristallin est du silicium [112] ; le premier plan cristallographique est un plan [111] et le se-



cond plan cristallographique est un plan [111].

17. Ensemble de dispositif optoélectronique selon la revendication 16, caractérisé de plus en ce que :

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la fibre optique est montée dans une rainure définie par les plans cristallographiques [111] dans le premier élément monocristallin.

18. Ensemble de dispositif optoélectronique selon la revendication 17, caractérisé de plus en ce que :

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le premier angle α est sensiblement égal à $35,26^\circ$ et le second angle β est sensiblement égal à $-19,48^\circ$.

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