

Description

Background of the Invention

This invention relates to optical fiber connectors.

Due to the increasing need for higher capacity data and voice transmission, use of optical fiber arrays is becoming necessary in many applications. Alignment of such fiber arrays either with other arrays or with optical components is troublesome, especially for the case of single mode fibers which have an extremely small core diameter (typically approximately 8 μm).

A typical connector for fiber arrays comprises two plugs of silicon with grooves formed therein for accommodating the fibers. Each plug is formed from two mated grooved members which are bonded together to encase the fibers. The grooves are formed prior to bonding by anisotropically etching a major surface of each member in an array corresponding to the fibers so that when the members are bonded, each fiber lies in a channel which is precisely aligned with all other fibers in the array.

While the fibers within a plug may be fairly closely aligned with each other, a problem exists in aligning these fibers with another fiber array or with an array of optical components. One technique employs a precise thickness of each plug and a precise lapping of the edges of each plug for alignment of different plugs, aided by four springs, each contacting one of the major surfaces of the aligned plugs (see, e.g., U.S. Patent No. 4,725,120 issued to Parzygnat). While effective in aligning the plugs, such precise machining of the plug surfaces is expensive. Another approach employs etching of deep grooves in the top and bottom surfaces of each plug and then aligning the two plugs by means of a chip extending between the two plugs and having ridges which fit within the deep grooves. (See, e.g., U.S. Patent No. 3,864,018 issued to Miller). Again, precise machining of the plug surfaces is expensive. A still further approach employs grooves which are machined on the edges of the plugs and utilizes alignment pins pressed into the grooves by spring clips to bridge the gap between plugs (see, C. M. Miller, "Optical Fiber Splices and Connectors", Chapter 7 pp.336-338) Marcel Dekker Inc.1986. Again, the alignment grooves have to be precisely machined with respect to the fiber grooves and this adds considerable expense to the connector.

An alternative approach is to form deeper alignment grooves in the same surfaces of the silicon members and at the same time as the fiber grooves. Guiding rods are pressed into the alignment grooves by spring plates and span the gap between plugs to provide the alignment (see, e.g., U.S. Patent No. 4,279,468 issued to Turley).

A still further approach is to form beveled surface portions at the edges of the silicon members which

have the same slope as the fiber grooves. The alignment pins can then be provided in the recesses formed by said beveled surfaces. (See Patent Abstracts of Japan, Vol 4, No. 82 (P-15)(564) June 13, 1980, and JP-A-55-45051 (Nippon Denshin) 29-03-1980). A problem with this approach is that the pins may not be in alignment with the fibers in the event of overetching or underetching of the silicon members.

It is, therefore, an object of the invention to provide a connector for optical fibers which will produce close alignment of the fibers with other fibers or optical components.

According to the present invention there is provided a connector as defined in claim 1.

The invention consists therefore in an optical fiber connector which includes first and second blocks of material with edge and major surfaces. Each block includes at least one groove formed with sloping sidewalls in a major surface. Each block further includes a beveled portion extending from the major surface on each edge surface such that the slope of each beveled portion is the same as the sidewalls of the groove. The two blocks have their major surfaces in contact so that the two grooves form a housing for an optical fiber. A spline is disposed in contact with the beveled portions of both blocks at one edge, extending beyond said blocks, and adapted for engagement with the beveled portions of similar blocks for alignment therewith. The spline is held in contact with the beveled portions by a spring force applied to the spline which is essentially parallel with the major surfaces of the blocks such that the central axes of the fiber and spline are rectilinear.

Brief Description of the Drawing

These and other features of the invention are delineated in detail in the following description. In the drawing:

FIG. 1 is an exploded perspective view of a connector in accordance with one embodiment of the invention;

FIG. 2 is an end view of a portion of the connector of FIG. 1;

FIG. 3 is a cross-sectional view of a portion of the connector during a stage of fabrication in accordance with an embodiment of the invention; and FIG. 4 is an exploded perspective view of a connector in accordance with a further embodiment of the invention.

It will be appreciated that for purposes of illustration, these figures are not necessarily drawn to scale.

Detailed Description

One form of the connector is illustrated in the exploded perspective view of FIG. 1 and the end view

of FIG. 2. Each half connector (plug), e.g., 1, includes two blocks 10 and 11, of a material with facing major surfaces 12 and 13, respectively. The plugs are desirably made from a crystal material such as silicon, for reasons which will become clearer. Each major surface has an array of grooves, e.g., 14 and 15, etched therein. The grooves are of a size and shape so that when the two blocks are bonded together, corresponding grooves in each surface will accommodate an optical fiber, e.g., 16, from an array of fibers to be connected (see FIG. 2). Each fiber will make contact with the sloped surfaces of the two corresponding grooves from the blocks as shown.

Use of a crystal for the block material permits taking advantage of certain crystal planes to precisely form the groove surfaces. For example, a silicon block with a major surface in the (100) crystallographic plane will be etched anisotropically to form grooves with surfaces lying in the (111) planes. Therefore, the angle of the two sloping walls of a groove will always be precisely determined by the orientation of the crystal planes (in this example, approximately 55°) with respect to the major surface regardless of the time of etching the major surface. The size of the opening will therefore primarily be determined by the size of the openings in the etch mask. Even if some over-etching or underetching of the grooves should occur, the angles of the groove walls will remain the same and the position of each fiber will shift with respect to the major surface of the block by the same amount. Thus, the fibers will always be coplanar.

It will be appreciated that while the grooves are shown with a "V" configuration, it is also possible to achieve grooves with a flat bottom by stopping the etching short of a complete etching of the crystal planes. However, sloping sidewalls with the same orientation will still be produced.

While the fibers in each plug are closely coplanar with each other, mating such a plug with the other plug of the connector of the same construction (30 of FIG. 1) to make the connection to another fiber array (within fiber ribbon 21) presents a serious problem. This is due to the fact that the grooves of the blocks making up the other plug, 30, may not have been etched to precisely the same extent as those of the plug 1. Hence, the two fiber arrays may be shifted with respect to their respective block surfaces and therefore misaligned. This problem is especially acute when the fibers are single mode fibers since they have an extremely small core diameter (typically 8 μm).

In accordance with a main feature of the invention, alignment between the fiber arrays is provided by forming beveled portions (17, 18, 19 and 20) on each edge surface of each block 10 and 11 (the beveled surfaces are similarly formed on the blocks of plug 30). The beveled portions extend from the major surfaces (12 and 13) of each block and have the same slope as the groove surfaces.

Such beveled portions can be formed as illustrated in FIG. 3. Each block, such as 10, is formed from a larger silicon wafer 40. A standard mask material, 41, such as thermally grown SiO_2 is deposited over the major surface of the wafer which is the (100) crystallographic plane. The mask openings are formed by standard photolithographic techniques to expose the areas of silicon where the fiber grooves will be etched. Wider mask openings are also formed over the silicon areas adjacent to the fiber grooves (one on each side of the array). Typically, the openings for etching the fiber grooves are approximately 140 μm wide, while the openings for etching the larger grooves are approximately 1000 μm wide. A standard anisotropic etchant is then applied to the structure to form the fiber grooves (e.g., 14) and deeper grooves 21 and 22 adjacent thereto. The deeper grooves include side walls, e.g., 18 and 20, which have the same slope as the fiber grooves since they are formed by the same anisotropic etch along the same crystal planes (the (111) plane). The fiber grooves would be typically approximately 98 μm deep while the adjacent grooves (21 and 22) would be approximately 500 μm deep.

With certain etchants, such as ethylene diamine pyrocatechol (EDP), it is possible to etch both sets of grooves in a single step, since no significant undercutting of the mask is produced for the fiber grooves while the deeper grooves are being etched. An etchant which tends to undercut the mask, such as KOH, can still be used in a single step if the mask openings over the fiber groove area are made sufficiently narrow to take this undercutting into account. Alternatively, the two sets of grooves can be formed in two etching steps. For the first step, mask openings would be formed only over the area of the deeper grooves and those areas would be etched to a predetermined depth short of the desired depth for those grooves. Openings in the mask would be made over the area comprising the fiber grooves, and these fiber grooves would then be etched to their desired depth while the etching of the deeper grooves would be completed.

After the etching of the grooves, the mask is stripped off. The wafer is then cut into individual blocks by sawing through the etched surfaces of the deeper grooves 21 and 22 along lines illustrated as 42 and 43. The saw lines extend substantially the entire length of the deeper grooves (into the plane illustrated in FIG. 3) and substantially parallel to the longitudinal dimension of the fiber grooves. When the sawing is complete, a plurality of blocks such as 10 of FIGs 1 and 2 are produced with beveled surfaces (e.g., 18 and 20) formed from one wall of the deep grooves on either side of the fiber grooves. The plugs also include ledge portions, 23 and 24, of FIG. 2 formed from part of the bottom surface of the deep grooves. These ledge portions can remain as shown or can be removed if desired.

Returning to FIGs. 1 and 2, the blocks are assem-

bled by placing each fiber of the array within its corresponding groove and mating the two blocks 10 and 11 to form the appropriate housing for each fiber (FIG. 2). The two major surfaces are bonded together by standard means such as epoxy.

In order to align and couple the plug 1 of FIGs. 1 and 2 with a similarly formed plug 30, elastically loaded splines in the form of guiding rods 25 and 26 are utilized. Each rod is held in contact with the beveled portions 17, 18, 19 and 20 of a corresponding edge surface of the plug 1. The rods also extend beyond the front surface of the plugs so that each rod can be slid into contact with the beveled portions of the edge surfaces of the other plug 30. The splines as shown are in the form of rods which are cylindrical in shape but can be tapered at one end for easy insertion. However, the splines can be any member bridging the longitudinal gap between plugs which can be held in contact with and align the beveled portions.

The rods, 25 and 26, are spring loaded to maintain intimate contact with the beveled portions. In this example, the spring force is provided by means including a clip portion 27 extending around the two plugs (except for a narrow gap). Extending from the clip are a pair of prongs 28 and 29, each adjacent to a corresponding edge surface of the assembled plug but maintaining a slight gap therewith which is smaller than the diameter of the rods. The rods are inserted in this gap and held against the beveled portions of the edge surfaces by the spring force created by the prongs 28 and 29. This force tends to pull the blocks apart but for the presence of the clip portion. Since the rods are in a fixed position against the beveled portions and the beveled portions are etched at the same time and along the same crystallographic planes as the fiber grooves, the center axes (32 and 33 of FIG. 2) of the rods will be coplanar with all the center axes (e.g., 34) of the fibers. That is, the rods and fibers are coplanar. This will be the case regardless of any overetching or underetching of the two blocks 10 and 11 during the formation of the grooves since any shift in the position of the fibers relative to the major surfaces of the blocks will be experienced to the same extent by the guiding rods.

The guiding rods are inserted within the gaps formed between the prongs 35 and 36 and the beveled portions (not shown) of the edge surfaces of the blocks of the other plug 30 until the front faces of the plugs are in physical contact. (The spring means of the two plugs are typically identical.) The rods 25 and 26 are, therefore, pressed into intimate contact with the beveled surfaces of both plugs 1 and 30. Since the rods are coplanar with the fibers of the plug 1 as discussed previously, and the beveled portions of the other plug 30 are also formed at the same slope as the fiber grooves of that plug, it follows that when rods 25 and 26 are pressed against the beveled portions of plug 30 they will also be coplanar with the fibers of

that plug and that the two fiber arrays will be in complete alignment. This will be the case regardless of the amount of overetch or underetch of the silicon blocks forming either plug. It will be appreciated that, although two guiding rods, 25 and 26, are shown as attached to one plug (1), if desired, one rod could be attached to one of the edge surfaces of each plug 1 and 30, prior to mating.

While the invention has been described with regard to connecting two fiber arrays, it should be appreciated that the principles are applicable to connecting single fibers together or connecting one or more fibers to one or more optical components. For example, as shown in FIG. 4, the plug 1, can be formed as before but with one of the silicon blocks 10 being extended so that a semiconductor laser 50 can be formed on the major surface along with contacts 51 and 52 and a waveguide 53. Of course, other types of components, such as receivers, can be formed on the surface. The other plug, 30, can be formed as before, but this time enclosing a single fiber 32, and retaining the rods 25 and 26. When the two plugs are mated as before, the fiber, 32, will meet a fiber, 16, preinserted within the groove formed by the two silicon blocks 10 and 11 of plug 1 which latter fiber is in contact with the waveguide 53 formed up to the edge of the groove. The rods will be held against the beveled portions of plugs 1 and 30 by the prongs 35 and 36 of plug 30 (i.e., no spring is needed around blocks 10 and 11. Thus, connection between the fiber 32 and laser 50 is established with a close alignment. Of course, a plurality of fibers within each plug may also be connected with this type of arrangement.

Claims

1. An optical fiber connector comprising:

a first block of material (10) having two major and two longitudinal edge surfaces, said block including at least one longitudinal groove (14) formed with sloping sidewalls in one of said major surfaces, parallel to said longitudinal edge surfaces, said block also including a beveled surface portion (18 and 20) on each longitudinal edge surface, which extends outwardly from said one major surface such that the slope of each beveled surface portion is the same as one of the sidewalls of the groove;

a second block of material (11) having two major and two longitudinal edge surfaces, said block including at least one longitudinal groove (15) formed with sloping sidewalls in one of said major surfaces, parallel to said longitudinal edge surfaces, said block also including a beveled surface portion (17 and 19) on each longitudinal edge surface, which extends outwardly from said one major surface such that the slope of each

bled by placing each fiber of the array within its corresponding groove and mating the two blocks 10 and 11 to form the appropriate housing for each fiber (FIG. 2). The two major surfaces are bonded together by standard means such as epoxy.

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The rods, 25 and 26, are spring loaded to maintain intimate contact with the beveled portions. In this example, the spring force is provided by means including a clip portion 27 extending around the two plugs (except for a narrow gap). Extending from the clip are a pair of prongs 28 and 29, each adjacent to a corresponding edge surface of the assembled plug but maintaining a slight gap therewith which is smaller than the diameter of the rods. The rods are inserted in this gap and held against the beveled portions of the edge surfaces by the spring force created by the prongs 28 and 29. This force tends to pull the blocks apart but for the presence of the clip portion. Since the rods are in a fixed position against the beveled portions and the beveled portions are etched at the same time and along the same crystallographic planes as the fiber grooves, the center axes (32 and 33 of FIG. 2) of the rods will be coplanar with all the center axes (e.g., 34) of the fibers. That is, the rods and fibers are coplanar. This will be the case regardless of any overetching or underetching of the two blocks 10 and 11 during the formation of the grooves since any shift in the position of the fibers relative to the major surfaces of the blocks will be experienced to the same extent by the guiding rods.

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that plug and that the two fiber arrays will be in complete alignment. This will be the case regardless of the amount of overetch or underetch of the silicon blocks forming either plug. It will be appreciated that, although two guiding rods, 25 and 26, are shown as attached to one plug (1), if desired, one rod could be attached to one of the edge surfaces of each plug 1 and 30, prior to mating.

While the invention has been described with regard to connecting two fiber arrays, it should be appreciated that the principles are applicable to connecting single fibers together or connecting one or more fibers to one or more optical components. For example, as shown in FIG. 4, the plug 1, can be formed as before but with one of the silicon blocks 10 being extended so that a semiconductor laser 50 can be formed on the major surface along with contacts 51 and 52 and a waveguide 53. Of course, other types of components, such as receivers, can be formed on the surface. The other plug, 30, can be formed as before, but this time enclosing a single fiber 32, and retaining the rods 25 and 26. When the two plugs are mated as before, the fiber, 32, will meet a fiber, 16, preinserted within the groove formed by the two silicon blocks 10 and 11 of plug 1 which latter fiber is in contact with the waveguide 53 formed up to the edge of the groove. The rods will be held against the beveled portions of plugs 1 and 30 by the prongs 35 and 36 of plug 30 (i.e., no spring is needed around blocks 10 and 11. Thus, connection between the fiber 32 and laser 50 is established with a close alignment. Of course, a plurality of fibers within each plug may also be connected with this type of arrangement.

Claims

1. An optical fiber connector comprising:

a first block of material (10) having two major and two longitudinal edge surfaces, said block including at least one longitudinal groove (14) formed with sloping sidewalls in one of said major surfaces, parallel to said longitudinal edge surfaces, said block also including a beveled surface portion (18 and 20) on each longitudinal edge surface, which extends outwardly from said one major surface such that the slope of each beveled surface portion is the same as one of the sidewalls of the groove;

a second block of material (11) having two major and two longitudinal edge surfaces, said block including at least one longitudinal groove (15) formed with sloping sidewalls in one of said major surfaces, parallel to said longitudinal edge surfaces, said block also including a beveled surface portion (17 and 19) on each longitudinal edge surface, which extends outwardly from said one major surface such that the slope of each



beveled surface portion is the same as one of the sidewalls of the groove;

said one major surface of said second block being in contact with said one major surface of the first block so that the two grooves form a housing for an optical fiber (16) therein and the beveled surface portions of both blocks at each longitudinal edge form a recess for receiving an alignment spline therein;

an alignment spline (25 or 26) disposed inside one of said recesses, extending beyond the front of said blocks, and adapted for being received by a corresponding recess formed in two similar contacting blocks for alignment therewith; and

means (27, 28 and 29) for maintaining said alignment spline inside said one recess;

CHARACTERIZED IN THAT

said means (27, 28 and 29) for maintaining said alignment spline inside said one recess are adapted for holding the spline in intimate contact with each of the two beveled surface portions forming the recess, by applying a spring force to the spline which is essentially parallel with the major surfaces of the blocks, such that the central axes of the fiber and the spline are coplanar.

2. The connector according to claim 1 wherein said one major surface of each block includes a plurality of grooves adapted to receive an array of optical fibers.
3. The connector according to claim 1 wherein the blocks comprise silicon and the groove sidewalls and beveled surface portions are obtainable by etching along the (111) crystallographic planes of the blocks.
4. The connector according to claim 3 wherein the beveled surface portions of the blocks and the grooves are able to be formed at the same time by anisotropically etching the major surface.

Patentansprüche

1. Lichtwellenleitersteckverbinder, der umfaßt:
einen ersten Materialblock (10) mit zwei größeren und zwei länglichen Kantenflächen, wobei besagter Block mindestens eine Längsnut (14) einschließt, die mit geneigten Seitenwänden in einer der besagten größeren Flächen gebildet ist und parallel zu besagten länglichen Kantenflächen verläuft, wobei besagter Block auch einen abgeschrägten Flächenabschnitt (18 und 20) auf jeder länglichen Kantenfläche einschließt, die sich von der einen besagten größeren Fläche derart nach außen erstreckt, daß die Neigung
2. Steckverbindung nach Anspruch 1, wobei die einen besagte größere Fläche von jedem Block eine Mehrzahl von Nuten einschließt, die für die Aufnahme einer Gruppe von Lichtwellenleitern geeignet sind.
3. Steckverbinder nach Anspruch 1, wobei die Blöcke aus Silizium bestehen und die Seitenwände der Nuten und die abgeschrägten Flächenabschnitte durch Ätzen entlang der (111) Kristallebenen der Blöcke gewonnen werden können.

von jedem abgeschrägten Flächenabschnitt einem der Seitenwände der Nut entspricht;

einen zweiten Materialblock (11) mit zwei größeren und zwei länglichen Kantenflächen, wobei besagter Block mindestens eine Längsnut (15) einschließt, die mit geneigten Seitenwänden in einer der besagten größeren Flächen gebildet ist und parallel zu besagten länglichen Kantenflächen verläuft, wobei besagter Block auch einen abgeschrägten Flächenabschnitt (17 und 19) auf jeder länglichen Kantenfläche einschließt, die sich von der einen besagten größeren Fläche derart nach außen erstreckt, daß die Neigung von jedem abgeschrägten Flächenabschnitt einem der Seitenwände der Nut entspricht;

wobei die besagte eine größere Oberfläche des besagten zweiten Blocks mit der einen besagten größeren Fläche des ersten Blocks derart in Kontakt steht, daß die zwei Nuten darin ein Gehäuse für einen Lichtwellenleiter (16) bilden und die abgeschrägten Flächenabschnitte beider Blöcke an jeder länglichen Kante eine Ausnehmung zur Aufnahme eines Ausrichtstifts darin bilden;

einen Ausrichtstift (25 oder 26), der innerhalb einer der besagten Ausnehmungen angeordnet ist, sich über die Vorderseite besagter Blöcke hinaus erstreckt und zur Aufnahme in einer in zwei ähnlichen kontaktierenden Blöcken zur Ausrichtung dazu gebildeten entsprechenden Ausnehmung geeignet ist; und

Mitteln (27, 28 und 29) zum Festhalten des besagten Ausrichtstifts innerhalb der einen besagten Ausnehmung;

dadurch gekennzeichnet, daß

besagte zum Festhalten besagter Ausrichtungsstifte innerhalb der einen besagten Ausnehmung bestimmte Mittel (27, 28 und 29) dazu geeignet sind, daß sie auf den Stift eine im wesentlichen parallel zu den größeren Flächen des Blocks wirkende Federkraft derartig ausüben, daß die Mittelachsen der Faser und des Stifts koplanar sind, um damit den Stift in engem Kontakt mit jeder der abgeschrägten Flächenabschnitte, die die Ausnehmung bilden, zu halten.



4. Steckverbinder nach Anspruch 3, wobei die abgeschrägten Flächenabschnitte der Blöcke und die Nuten gleichzeitig durch anisotropes Ätzen der größeren Fläche geformt werden können.

Revendications

1. Connecteur pour fibres optiques comprenant :
 un premier bloc de matériau (10) ayant deux surfaces principales et deux surfaces de bord longitudinales, ledit bloc comportant au moins une rainure longitudinale (14) formée avec des parois latérales inclinées dans l'une desdites surfaces principales, parallèle auxdites surfaces de bord longitudinales, ledit bloc comportant aussi une portion de surface en biseau (18 et 20) sur chaque surface de bord longitudinale, qui s'étend vers l'extérieur depuis ladite surface principale de sorte que la pente de chaque portion de surface en biseau soit la même que celle des parois latérales de la rainure;
 un second bloc de matériau (11) ayant deux surfaces principales et deux surfaces de bord longitudinales, ledit bloc comportant au moins une rainure longitudinale (15) formée avec des parois latérales inclinées dans l'une desdites surfaces principales, parallèle auxdites surfaces de bord longitudinales, ledit bloc comportant aussi une portion de surface en biseau (17 et 19) sur chaque surface de bord longitudinale, qui s'étend vers l'extérieur depuis ladite surface principale de sorte que la pente de chaque portion de surface en biseau soit la même que celle des parois latérales de la rainure;
 ladite surface principale dudit second bloc étant en contact avec ladite surface principale du premier bloc de sorte que les deux rainures forment un logement pour une fibre optique (16) dans celles-ci, et de sorte que les portions de surface en biseau des deux blocs à chaque bord longitudinal forment un retrait pour recevoir dans celui-ci une cannelure d'alignement;
 une cannelure d'alignement (25 ou 26) disposée à l'intérieur de l'un desdits retraits, s'étendant au-delà de la partie frontale desdits blocs, et prévue pour être reçue par un retrait correspondant formé dans deux blocs similaires en contact pour s'aligner avec celui-ci; et
 des moyens (27, 28 et 29) pour maintenir ladite cannelure d'alignement à l'intérieur dudit retrait;
 caractérisé en ce que
 lesdits moyens (27, 28 et 29) pour maintenir ladite cannelure d'alignement à l'intérieur dudit retrait sont prévus pour retenir la cannelure en contact intime avec chacune des deux portions de surface en biseau formant le retrait, en appli-

quant une force de ressort à la cannelure qui est essentiellement parallèle aux surfaces principales des blocs, de sorte que les axes centraux de la fibre et de la cannelure soient coplanaires.

2. Connecteur selon la revendication 1, dans lequel ladite surface principale de chaque bloc comporte une pluralité de rainures prévues pour recevoir un ensemble de fibres optiques.
3. Connecteur selon la revendication 1, dans lequel les blocs comprennent du silicium et les parois latérales des rainures et les portions de surface en biseau peuvent être obtenues par gravure le long des plans cristallographiques (111) des blocs.
4. Connecteur selon la revendication 3, dans lequel les portions de surface en biseau des blocs et les rainures peuvent être formées en même temps par gravure anisotrope de la surface principale.

