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(54) PACKAGE FOR HOUSING AT LEAST AN ELECTRO-OPTIC ACTIVE ELEMENT, ELECTRO-OPTIC AND ASSEMBLING METHOD

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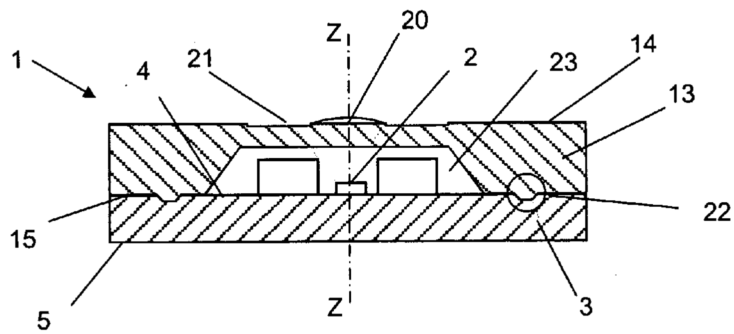
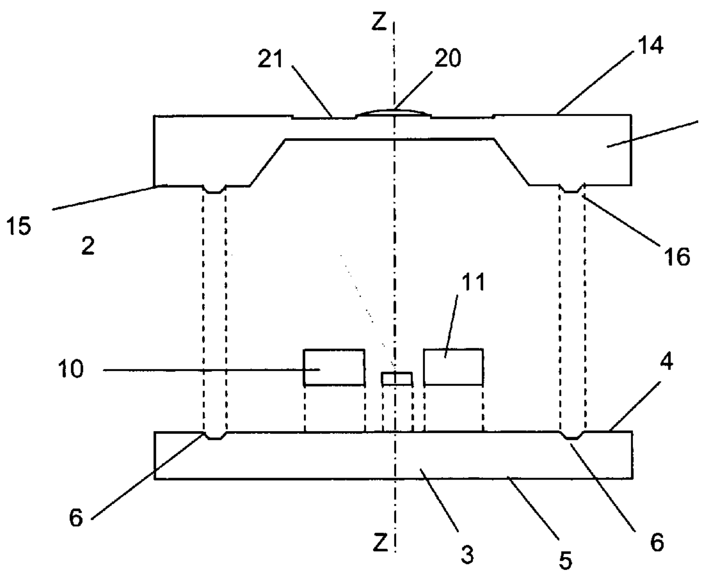
(57) ABSTRACT

A package houses at least one electro-optic active element for transmission using an optical fiber. The package has a bearing element for the at least one electro-optic active element. Advantageously, the package has a sandwich-like structure and includes a closing element associated with the bearing element using a suitable aligning and coupling device to define a hermetically closed housing seat. Moreover, the closing element houses a lens in axial alignment with the electro-optic active element. An electro-optic module includes the package associated with a casing having a receptacle housing an optical fiber.





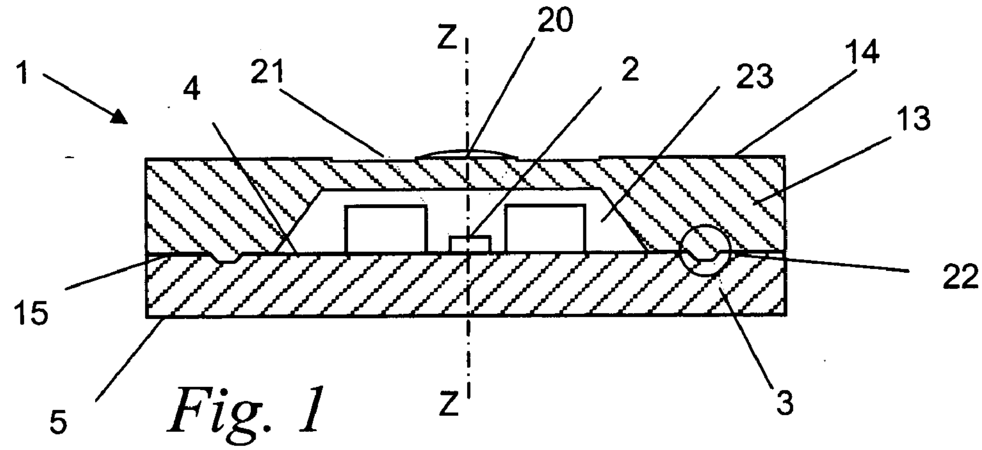


Fig. 1

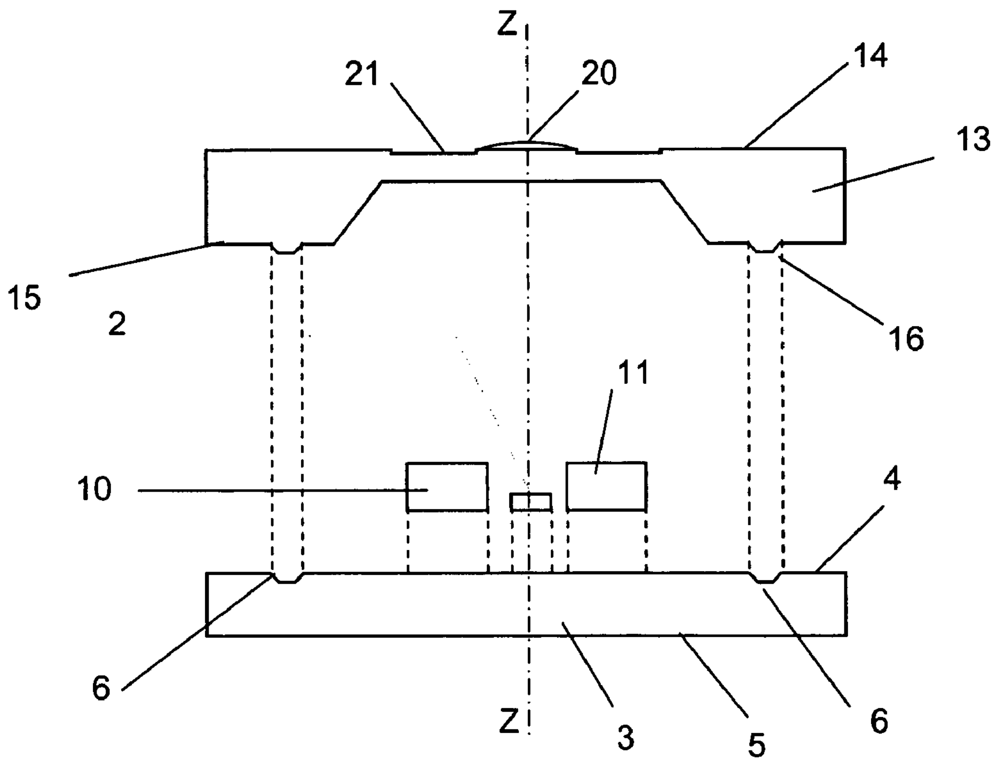


Fig. 2

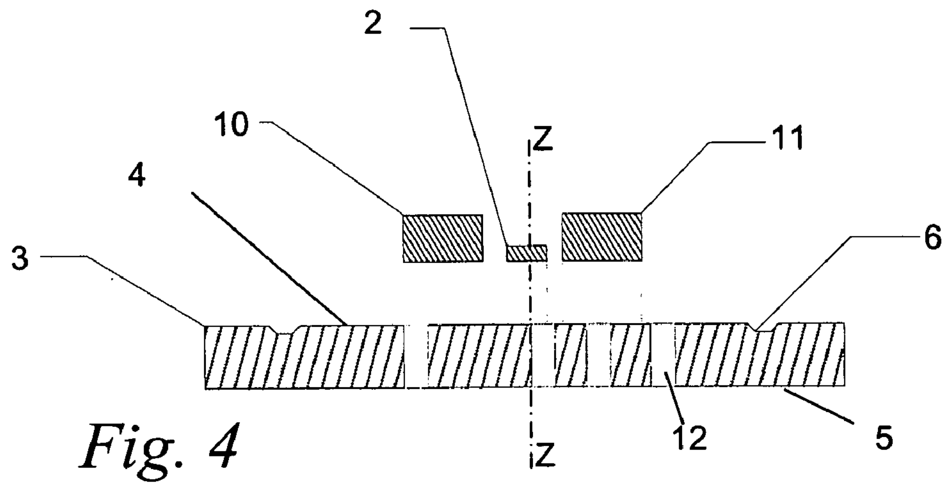


Fig. 4

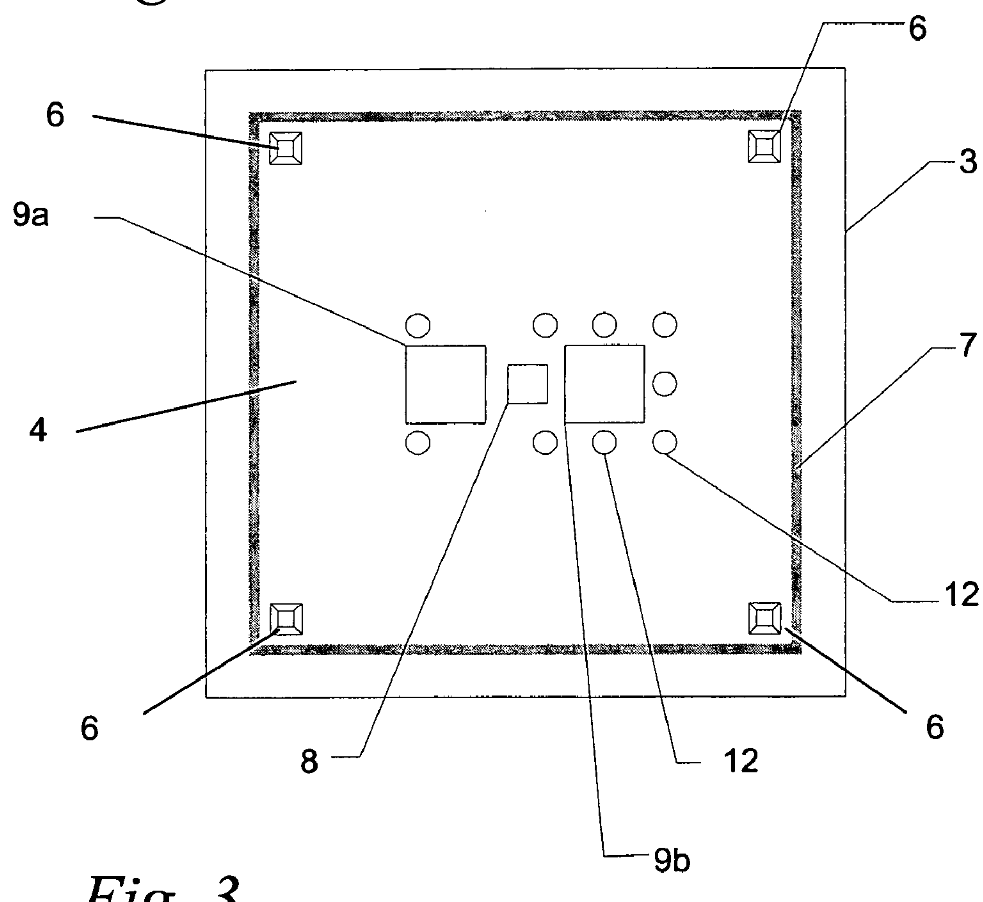


Fig. 3

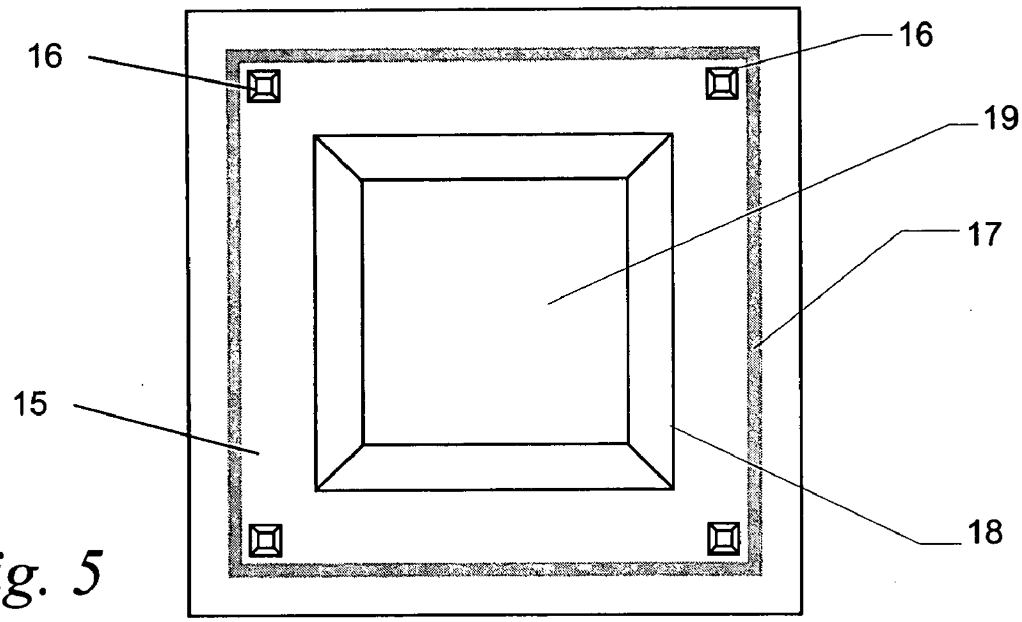


Fig. 5

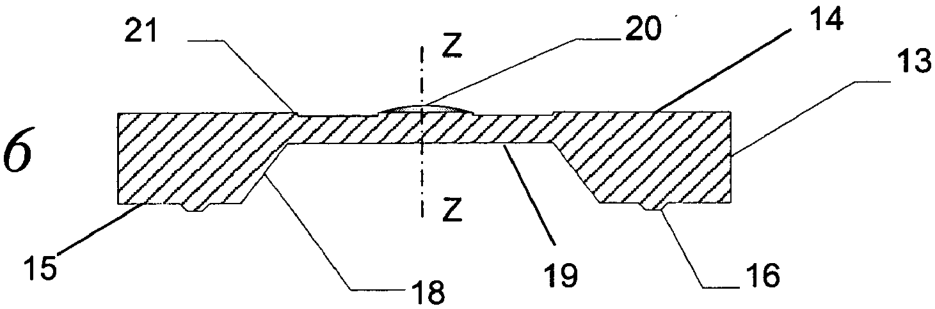


Fig. 6

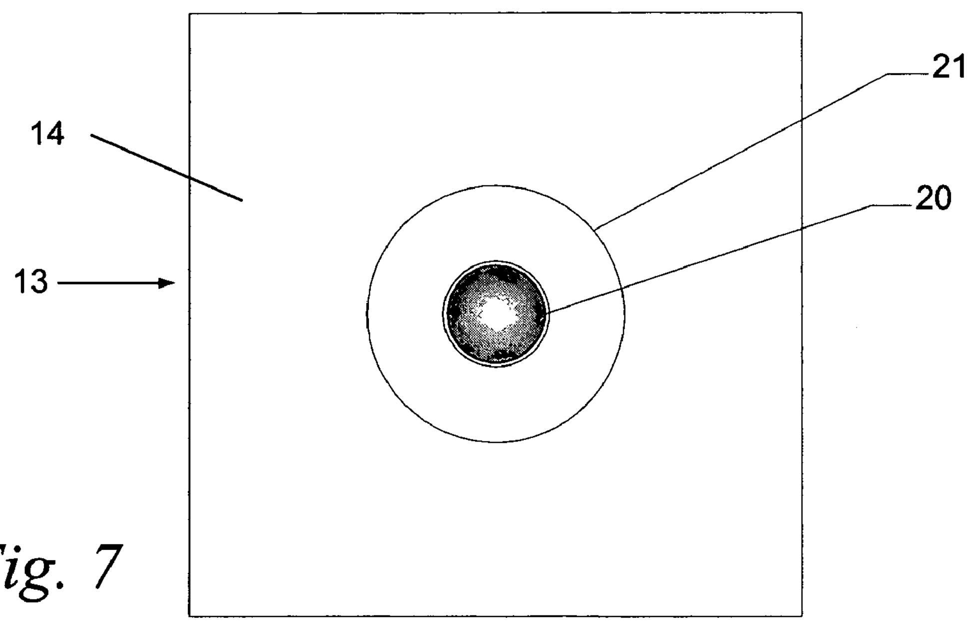


Fig. 7

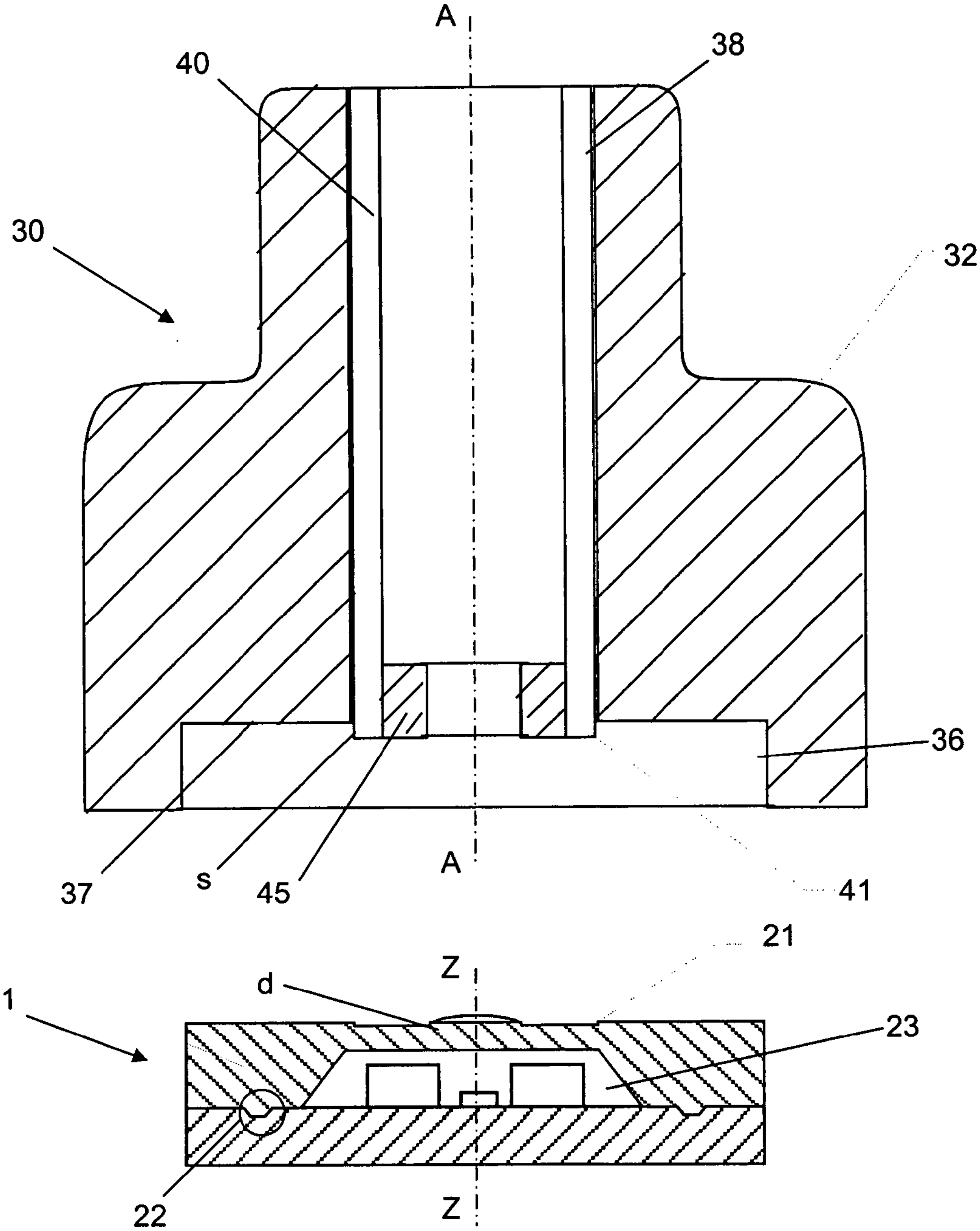


Fig. 8

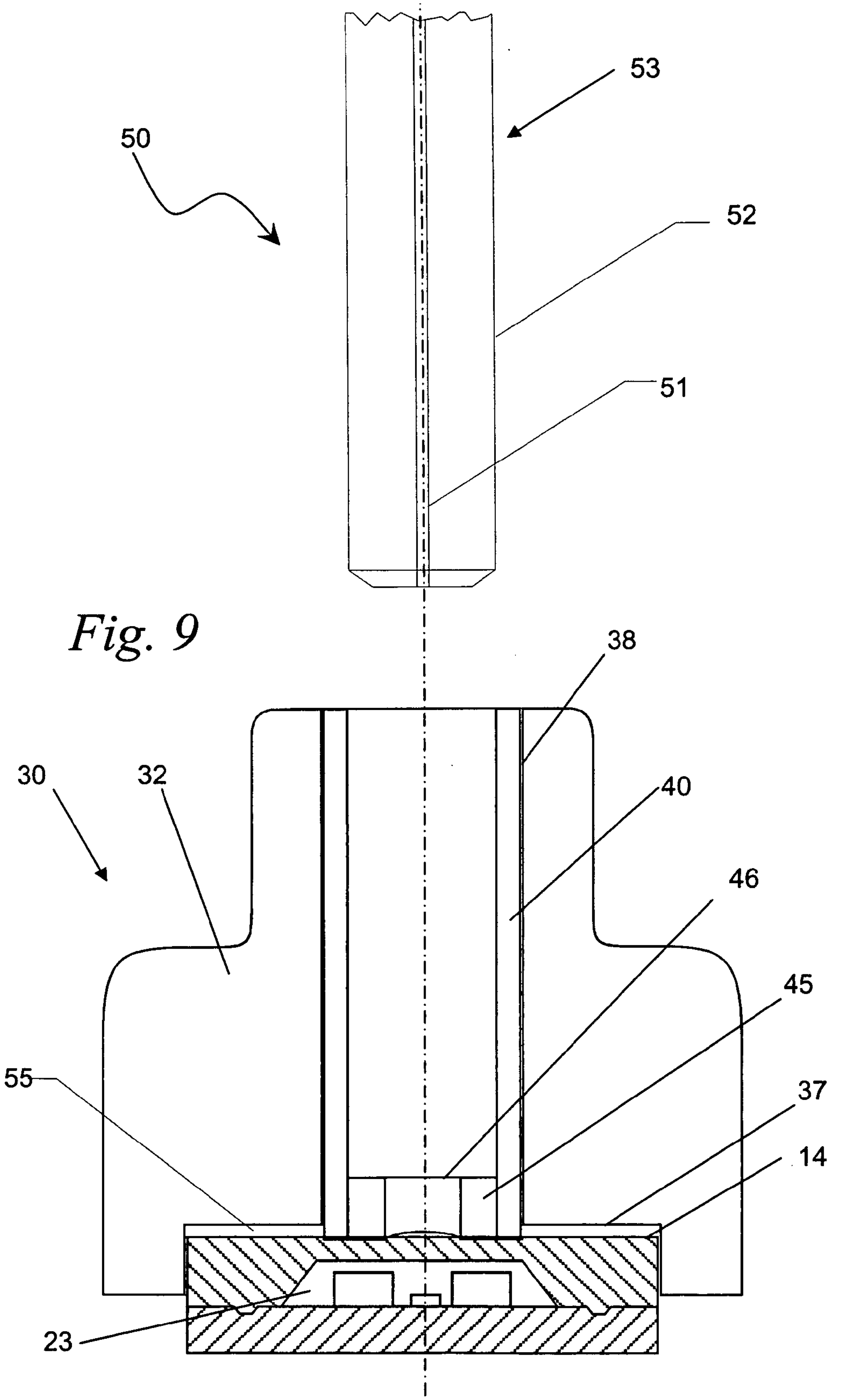


Fig. 9

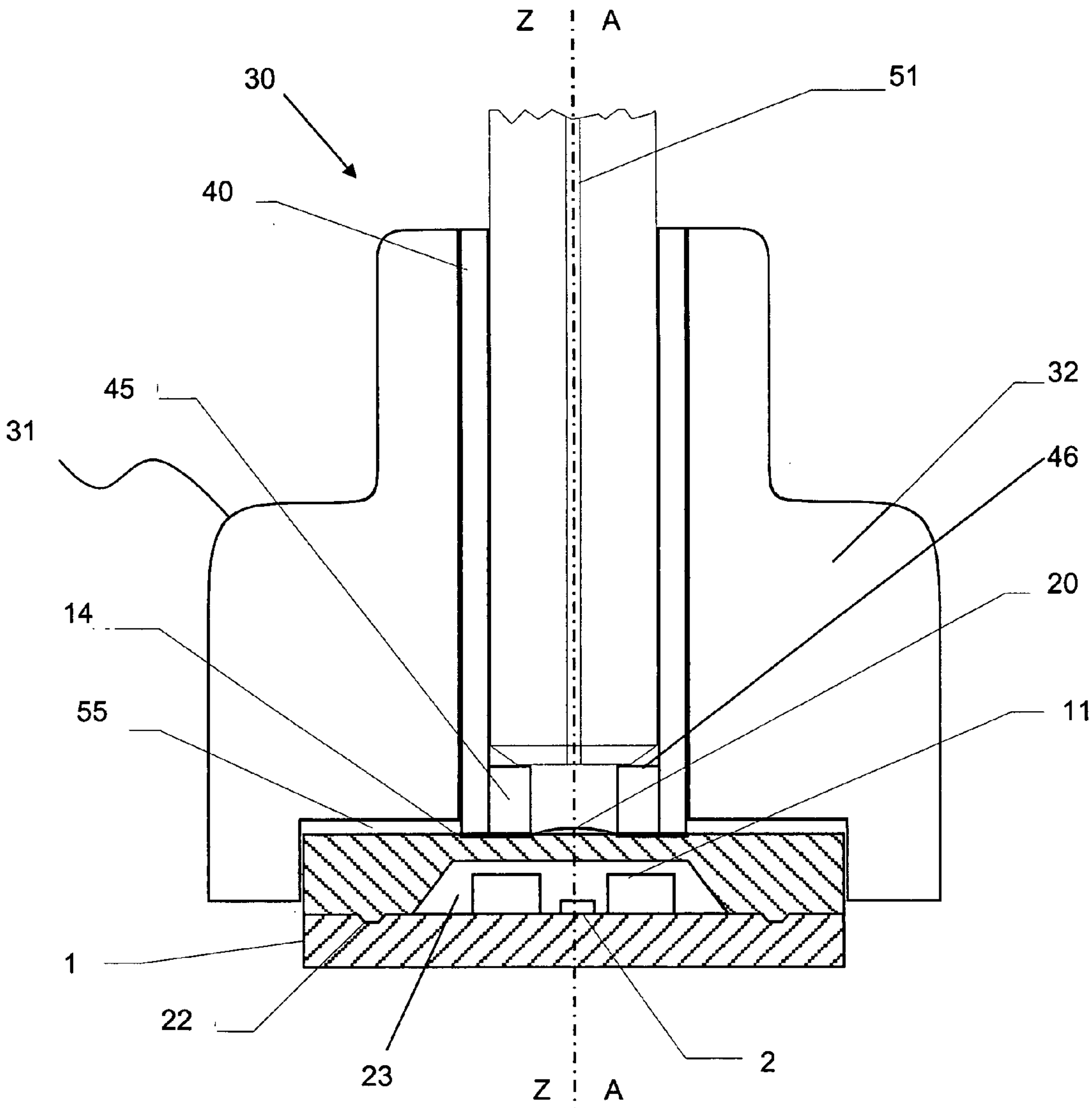


Fig. 10

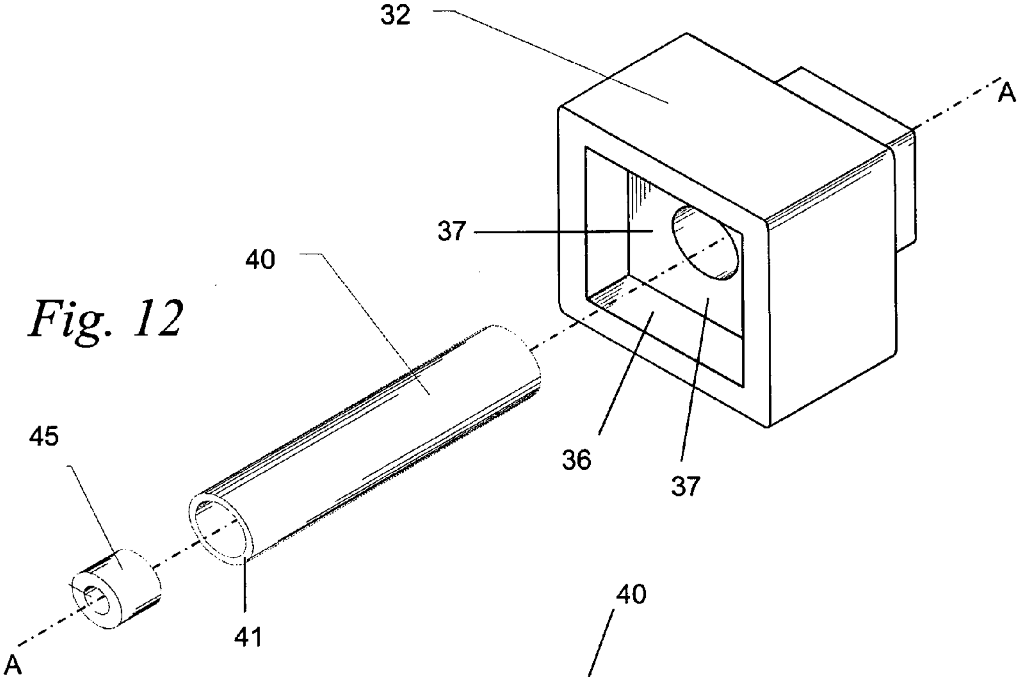


Fig. 12

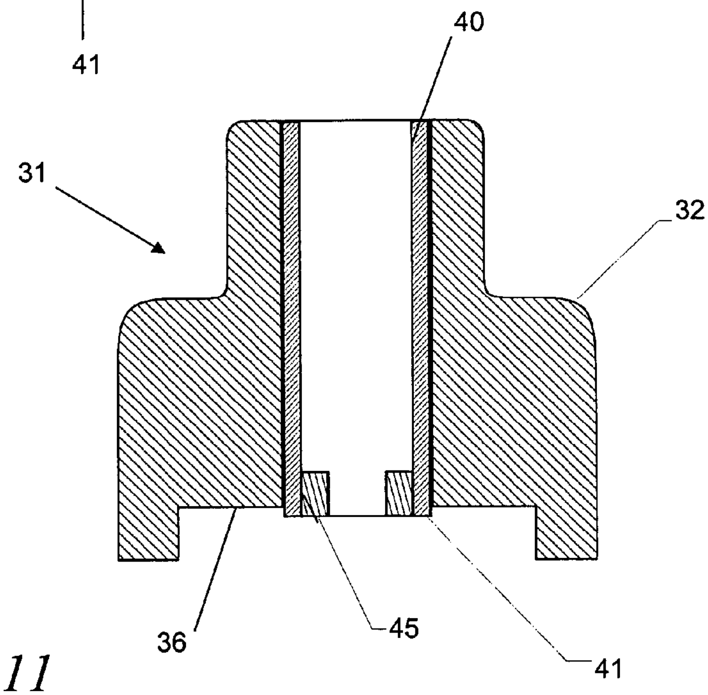


Fig. 11

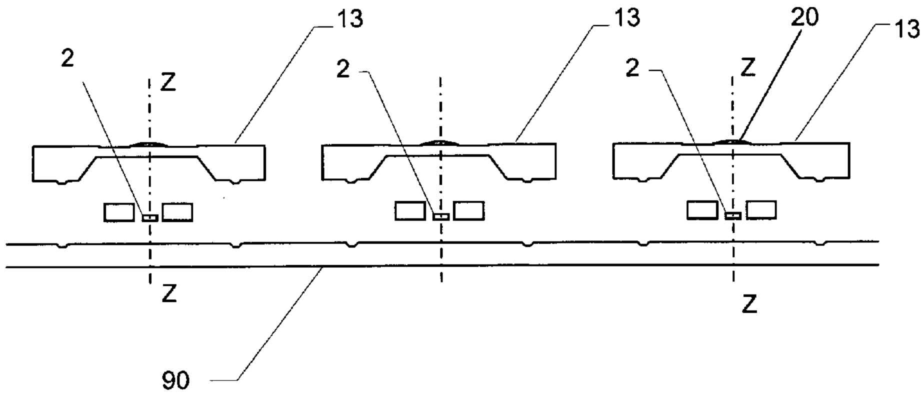
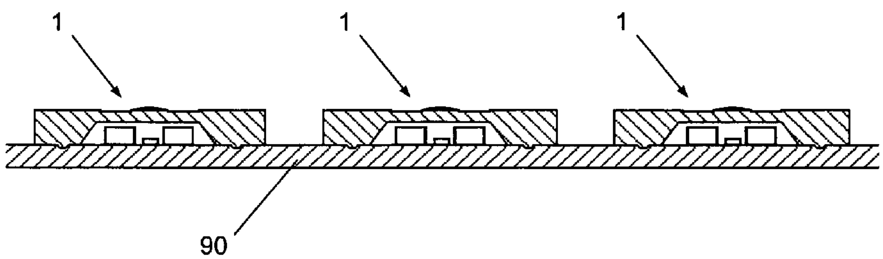


Fig. 13

Fig. 14



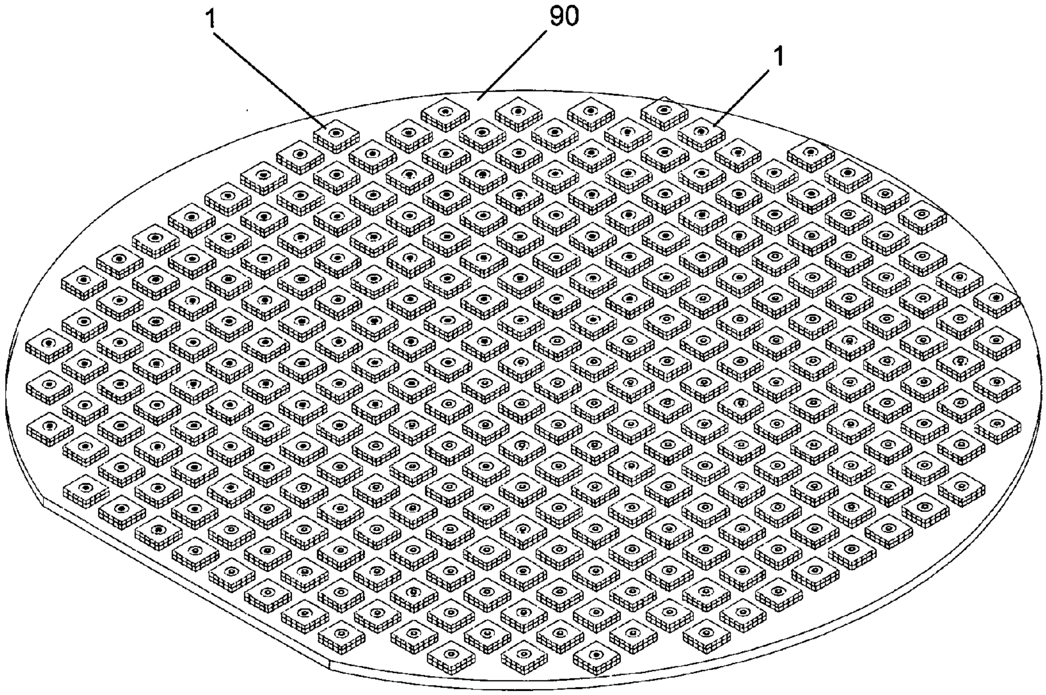


Fig. 15

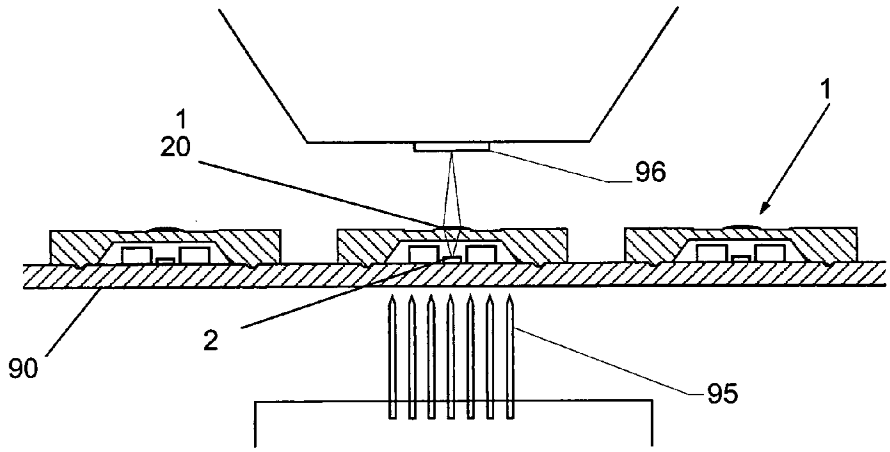


Fig. 16

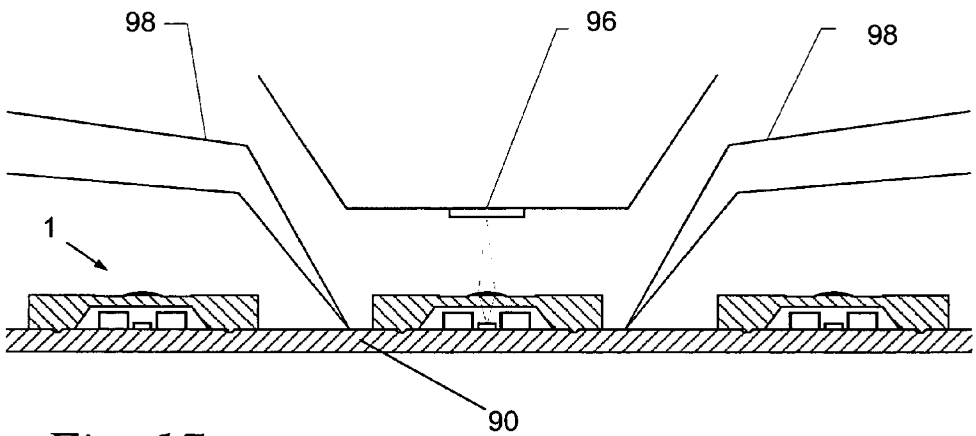


Fig. 17

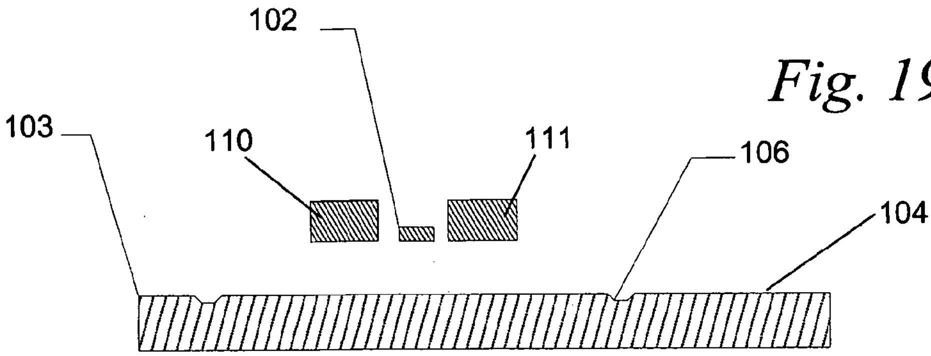

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Fig. 19

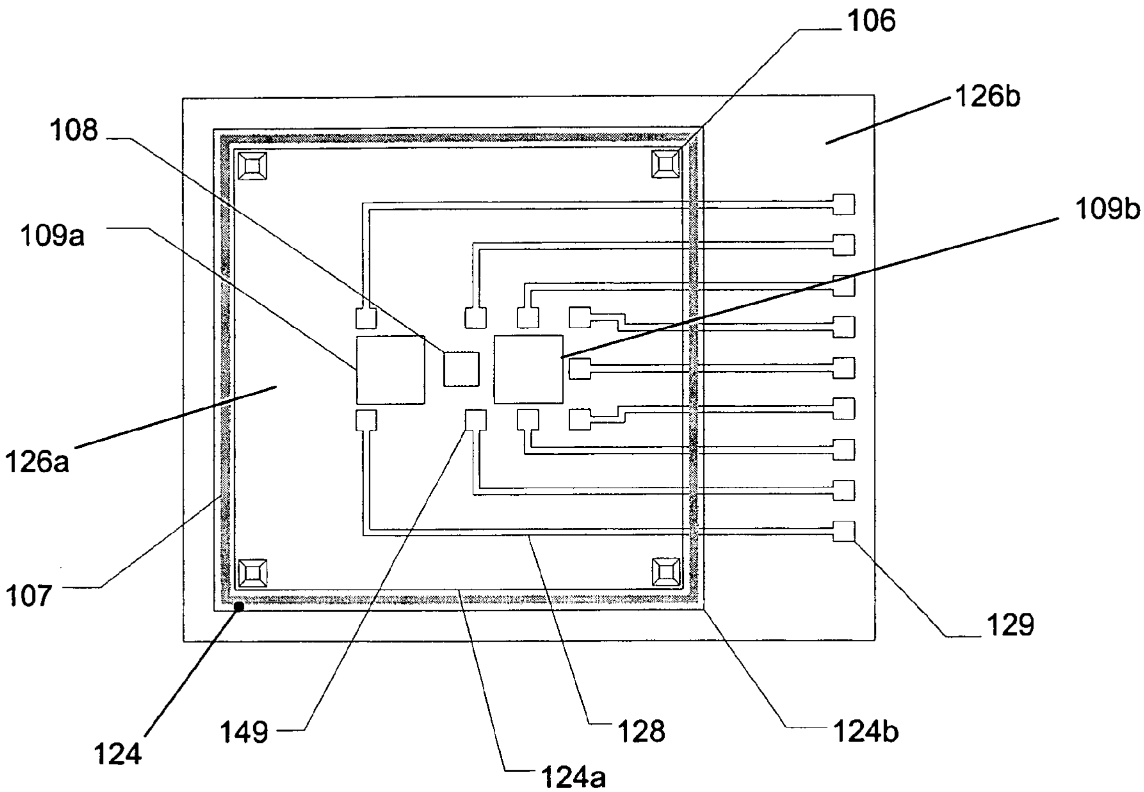
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Fig. 18

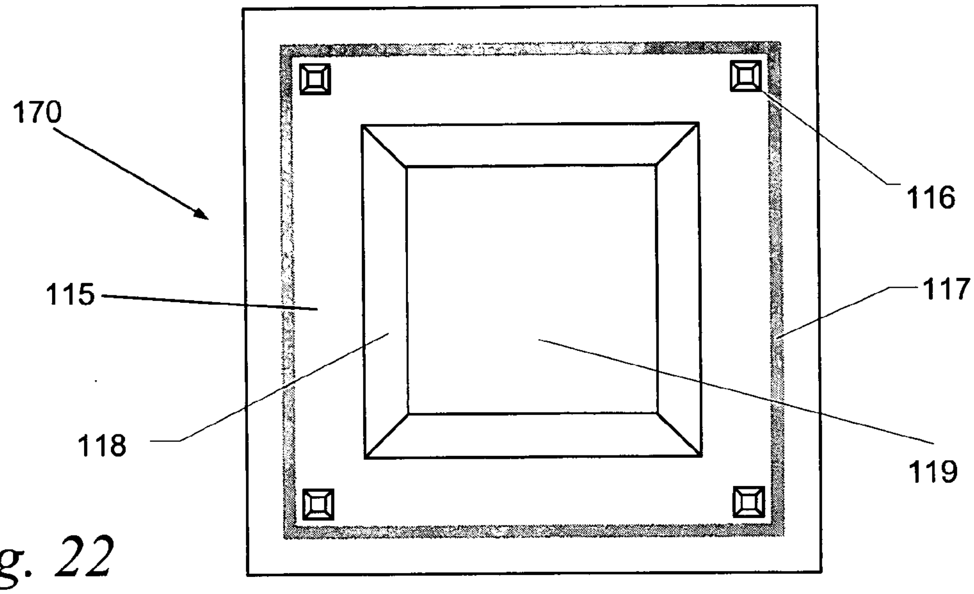


Fig. 22

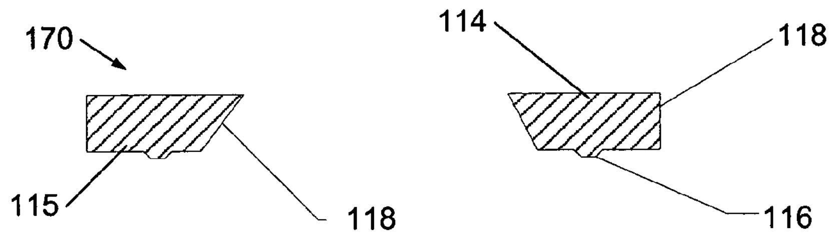


Fig. 21

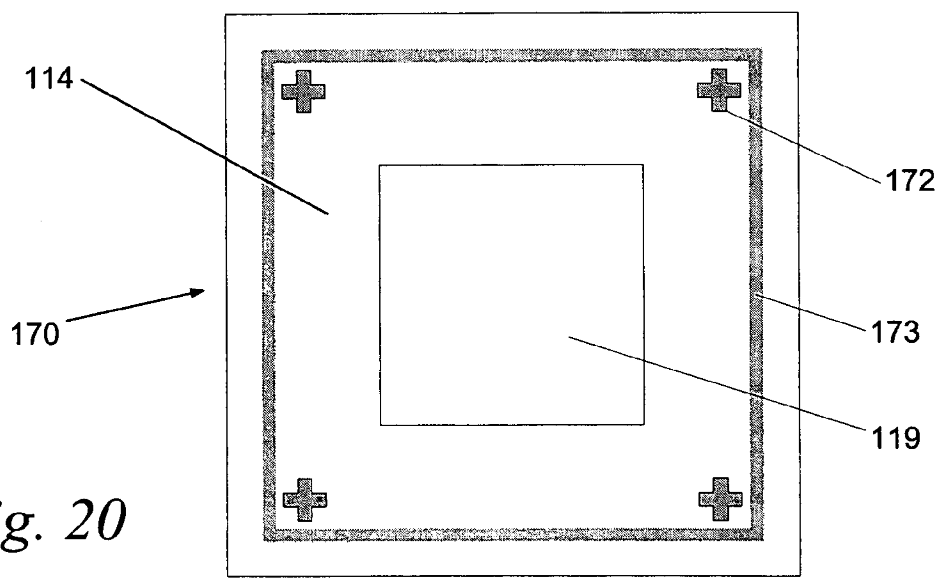


Fig. 20

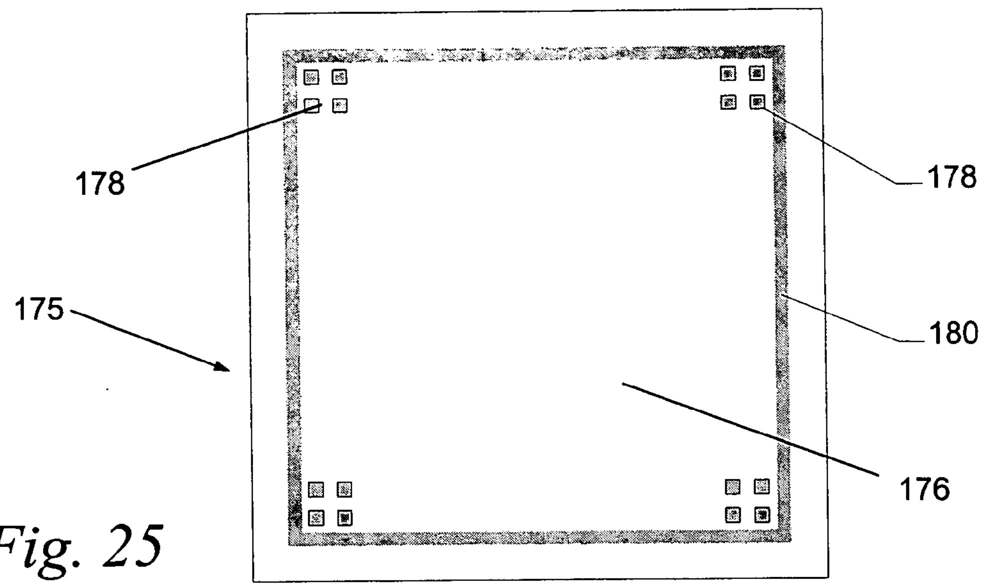
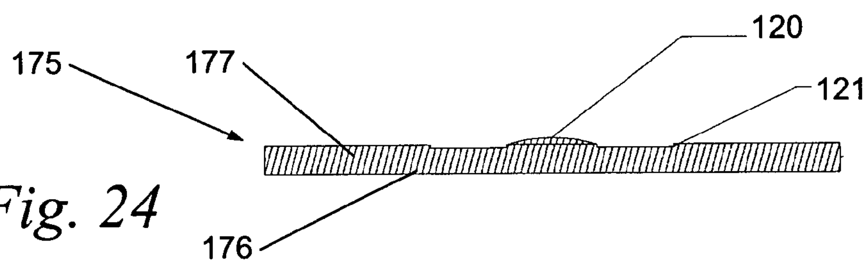


Fig. 25



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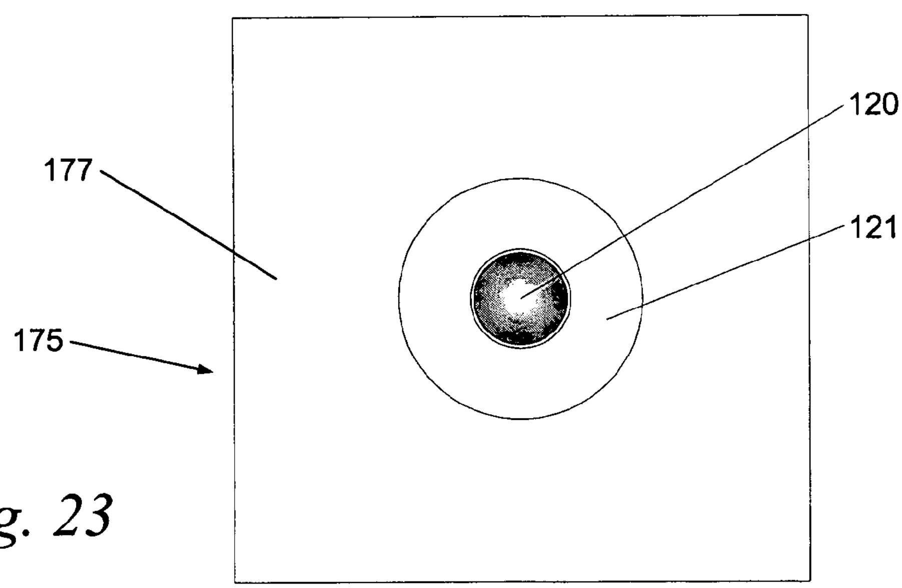

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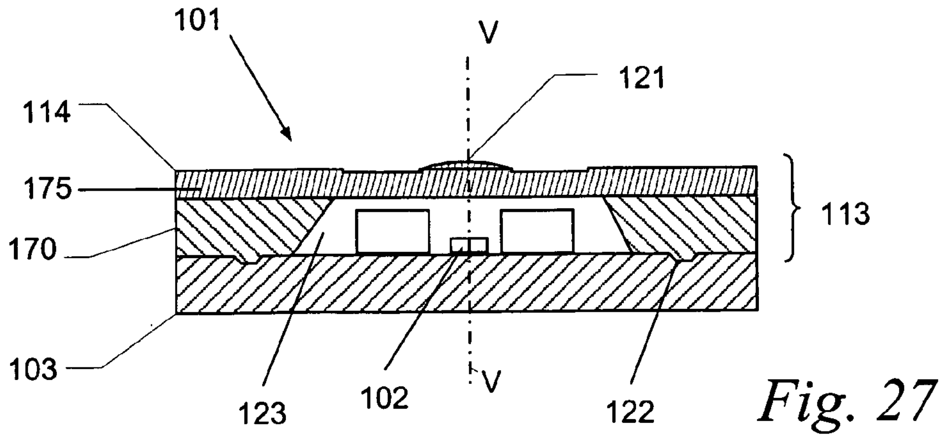
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Fig. 27

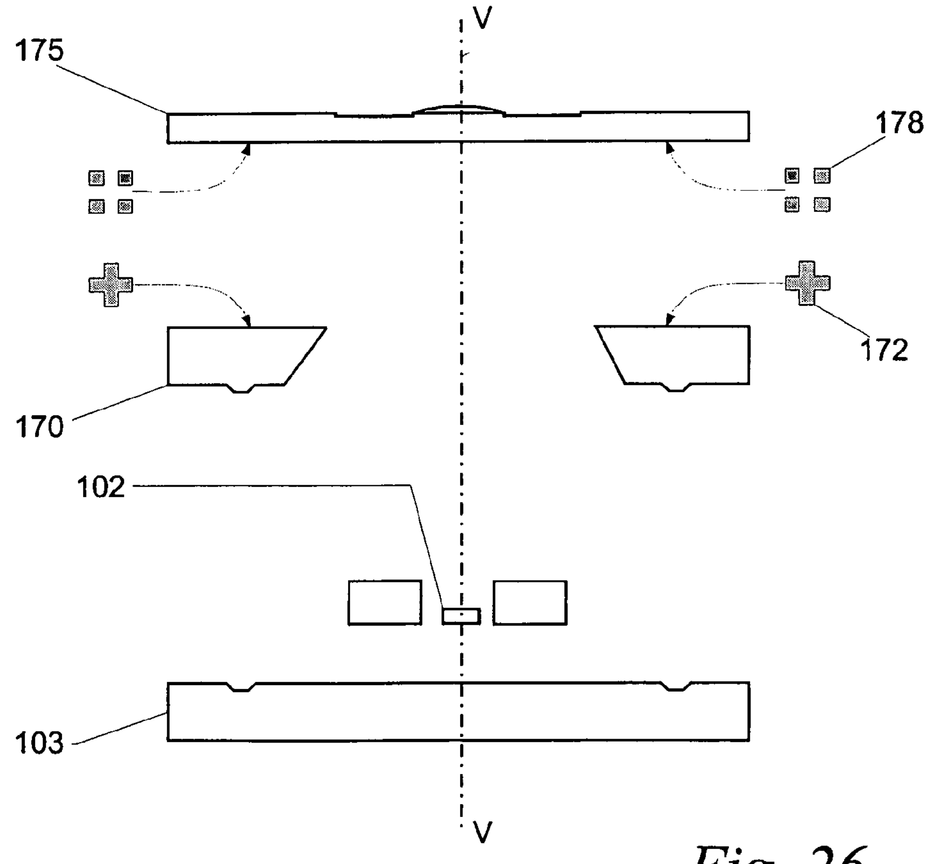
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Fig. 26

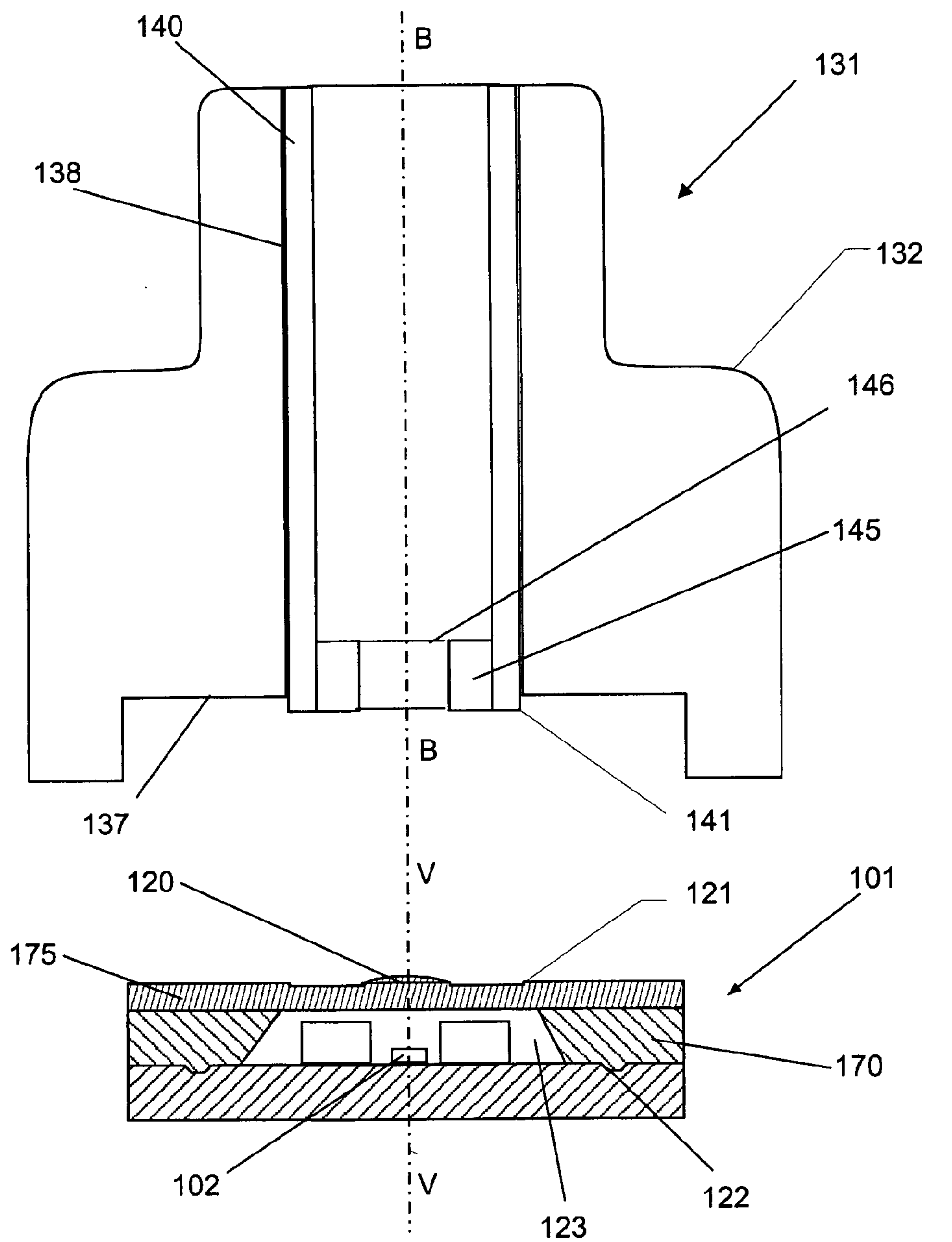

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Fig. 28

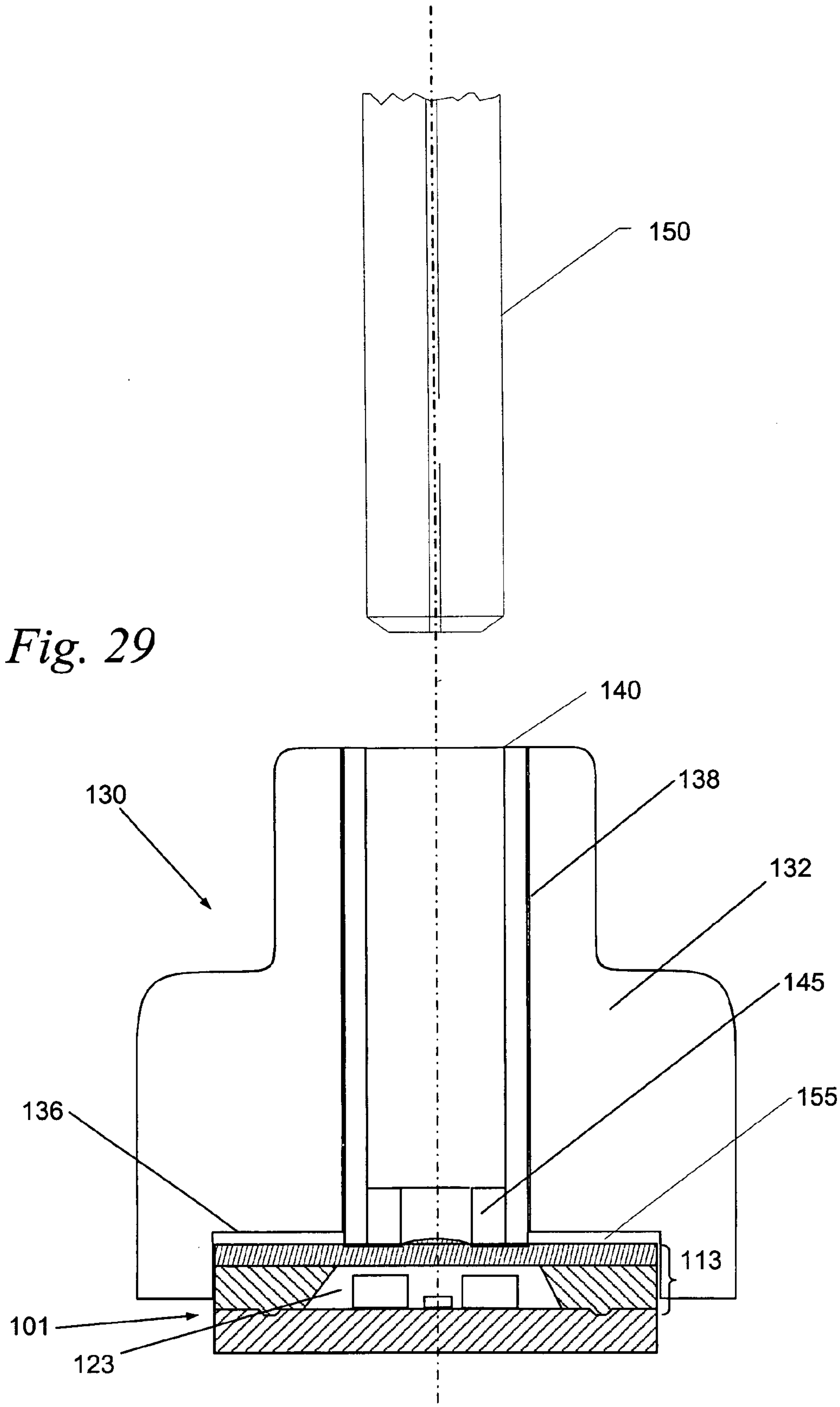
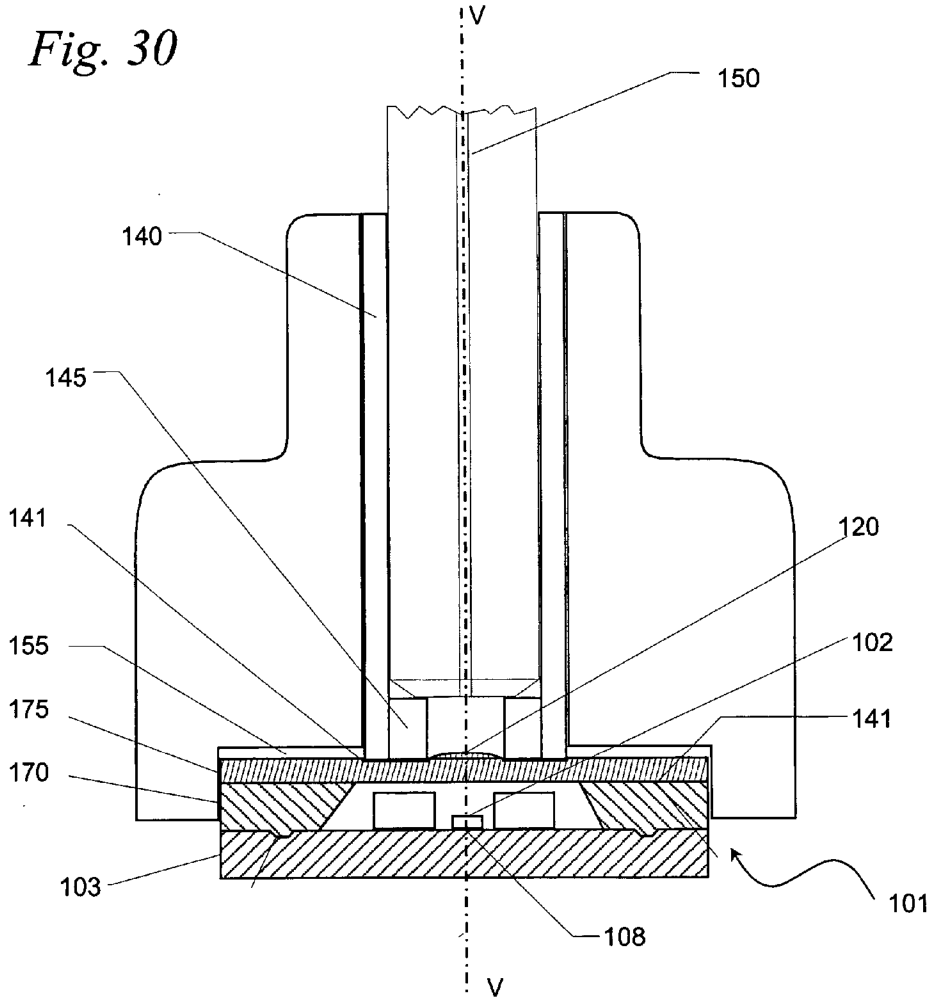


Fig. 29

Fig. 30



PACKAGE FOR HOUSING AT LEAST AN ELECTRO-OPTIC ACTIVE ELEMENT, ELECTRO-OPTIC AND ASSEMBLING METHOD

PRIORITY CLAIM

[0001] The present application claims priority from European Patent Application No. 04425400.1 filed May 31, 2004, the disclosure of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Technical Field of the Invention

[0003] The present invention relates to a package for housing at least one electro-optic active element, an electro-optic module, be it either a transmitter or a receiver, of the type used in the field of telecommunications by optical fiber transmission, and relative assembling method.

[0004] 2. Description of Related Art

[0005] As it is well known, the recent years have seen the development of data transmission on optical fibers, in the technical field of telecommunications .

[0006] Optical fibers are used for transmitting information through light pulses, in the infrared field, by means of a very thin glass or plastic fiber cable. The pulses are transmitted from the centre of the fiber, called nucleus or "core", which is surrounded by a "cladding" or shell coating, preferably made of silicon oxide, which entraps the signals in the core. Optical fibers may be further coated by external protective layers called "jackets".

[0007] Optical fibers can be of the singlemode or multimode type, i.e. fibers capable of transmitting respectively a single signal, or light pulse, or more signals on the same core, such core having varying sizes, depending on the case..

[0008] The signals, or light pulses, are introduced into one end of the optical fiber by means of transmitters and, through subsequent reflections, they reach the opposite end where they are collected by suitable receivers.

[0009] Electro-optic modules are thus used for transmission, as they allow to couple transmitters and receivers, made of electro-optic active elements, to the optical fiber.

[0010] In particular, in the case of receivers, the electro-optic active element detects the optical radiations transmitted across the optical fiber connected therewith and it may comprise a photo-detector PIN diode or an APD (Avalanche Photo Detector).

[0011] Instead, in the case of a transmitter or optical source, the active element emits optical radiations onto the optical fiber connected therewith and it may comprise a Vertical Cavity Surface Emitting Laser (VCSEL) or a LED (Light Emitting Diode).

[0012] In both cases, the electro-optic module must provide a package for housing the electro-optic active element and to place it in optical connection with the optical fiber associated with the module itself.

[0013] The optical fiber may be permanently fixed onto the package by means of the common flexible metallic couplings, or it may be loosely associated to it by means of an optical connector and a suitable receptacle.

[0014] For a better communication and thus a better coupling between the electro-optic element and the optical fiber, a lens fixed on the package is interposed between them, which allows to suitably guide the light pulses coming from and/or addressed to the optical fiber.

[0015] Several solutions for the realization of optical modules for telecommunications are known. For example, U.S. Pat. No. 5,337,398 describes an electro-optic module comprising a package and a connector for an optical fiber. In particular, such package comprises a silicon substrate whereon a plurality of electro-optic elements connected to electric devices by means of suitable metallizations are placed. Alignment markers or fiducials are realized on the substrate in correspondence with the electro-optic elements for connecting a lens support and an optical fiber connector.

[0016] Another known solution, variously developed, is described in U.S. Pat. No. 6,542,672B2 wherein an optical module comprises a package or first wafer which is associated below with a discrete electro-optic element, such element being in communication with an optical fiber, which is associated above with the package itself. The optical fiber is inserted in a suitable alignment recess realized on top of the first wafer or, alternatively, in a second wafer suitably connected with the first. The optical coupling is aided by a lens interposed between the electro-optic element and the optical fiber.

[0017] Moreover, European Patent No. 0 413 489 A2 describes an optical module solution wherein the package comprises a bearing element having a first and a second surface and made of a material which allows the transmission of radiations. The bearing element has, starting from the first surface, a recess, which develops between the same two surfaces without, however, putting them in communication with one another. On the second surface an electro-optic active element is suitably associated and axially arranged with respect to the recess. A connector for the optical fiber is also provided comprising an element equipped with a receptacle apt to contain the optical fiber, which is secured by adhesive sealing means. During the assembly the first surface of the bearing element faces the connector, the recess being axially arranged in correspondence with the slot and with the electro-optic element.

[0018] Although advantageous under several aspects, the known solutions exhibit various drawbacks hereafter described.

[0019] First of all, these known solutions require complex optical module designs and/or complex assembly steps to ensure the alignment between the optical fiber and the optical module, or, more in particular, the electro-optic active element contained in such module. Moreover, several solutions require suitable metallizations to be carried out thus introducing additional processing steps and, thus, processing costs.

[0020] All of this limits the possibility of obtaining sealed environments, thus reducing the reliability of the optical module. Moreover, the modules made available by the prior art documents exhibit a components rigidity which forces and limits the typology of the elements which can be used in the module itself, which are thus rarely interchangeable with others on sale.

[0021] A further drawback of the prior art is given by the complexity of the assembly steps required to realize reliable optical modules. Such complexity is due to the need to carry out active alignments during the assembly step, i.e. to carry out suitable tests for verifying the alignment between the electro-optic active element and the optical fiber. Obviously, such complexity results in an increase in the realization times and of the manufacturing costs of the module itself.

[**0022**] The technical problem underlying the present invention is that of devising a package which allows to obtain a sealed housing for an electro-optic active element and an electro-optic module capable of ensuring an efficient coupling between the electro-optic active element and the optical fiber as well as a simple and fast assembly method for realizing an electro-optic module with a reliable alignment between the electro-optic active element and the optical fiber that overcomes the drawbacks mentioned with reference to the prior art.

SUMMARY OF THE INVENTION

[**0023**] The idea of solution underlying the present invention is that of providing a package for housing an electro-optic active element for optical fiber transmission having a region, apt to house said active element, hermetically sealed, as well as interacting means apt to ensure correct alignment between the active element of the electro-optic module and the optical fiber associated therewith.

[**0024**] The idea of solution also provides the devising of an assembly method which can be implemented using commercial mass produced machinery capable of ensuring reliable alignment between the electro-optic active element and the optical fiber for optical modules manufactured on a large scale.

[**0025**] In accordance with an embodiment of the invention, a package for housing an electro-optic active element comprises a base having a surface to which the electro-optic active element is mounted, and a first peripheral metallization loop formed on the base surface around electro-optic active element. A cover has a cavity and a peripheral rim surface with a second peripheral metallization loop formed on the cover peripheral rim surface and having a shape matching the first peripheral metallization loop. Alignment means associated with the base surface and the cover peripheral rim surface function to align the first and second peripheral metallization loops with each other when the cover is placed on the base to enclose the electro-optic active element.

[**0026**] The characteristics and advantages of the package, of the electro-optic module and of the assembly method according to the invention will become apparent from the following description of embodiments thereof given by way of indicative and non-limiting examples with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[**0027**] A more complete understanding of the method and apparatus of .the present invention may be acquired by reference to the following Detailed Description when taken in conjunction with the accompanying Drawings wherein:

[**0028**] **FIGS. 1 and 2** respectively show section and exploded views of a package realized according to the present invention;

[**0029**] **FIGS. 3 and 4** respectively show top and section views of a bearing element according to the present invention;

[**0030**] **FIGS. 5, 6** and **7** respectively show bottom, section and top views of a closing element;

[**0031**] **FIG. 8** shows an exploded view of an electro-optic module realized according to the present invention;

[**0032**] **FIGS. 9 and 10** show section views of the electro-optic module of **FIG. 8** with an optical fiber, respectively in external and inserted position;

[**0033**] **FIGS. 11 and 12** show section and exploded views of a receptacle realized according to the present invention;

[**0034**] **FIGS. 13, 14** and **15** show the package of **FIG. 2** in different assembly steps of the method according to the present invention;

[**0035**] **FIGS. 16 and 17** show a wafer comprising a plurality of packages realized according to the invention during an alignment test;

[**0036**] **FIGS. 18 and 19** respectively show top and section views of a further embodiment of the bearing element of **FIG. 3**;

[**0037**] FIGS. **20** to **25** show respective views of a further embodiment of the closing element of **FIG. 5**;

[**0038**] **FIGS. 26 and 27** show respective exploded and perspective views of the package of **FIG. 13**;

[**0039**] **FIGS. 28, 29** and **30** show respective views of a first embodiment of the electro-optic module according to the present invention.

DETAILED DESCRIPTION

[**0040**] With reference to such figures, and in particular to the embodiment of **FIG. 1**, reference **1** globally and schematically indicates a package for housing at least one electro-optic element **2**.

[**0041**] The package **1** has a substantially flat sandwich-like structure and has a vertical axis Z-Z. The word vertical is intended with reference to the orientation of the package **1** in the annexed figures.

[**0042**] The electro-optic element **2** can be a VCSEL, a PIN or a photo-detector, an APD or a LED depending on the functionality of the electro-optic module wherein such element is inserted.

[**0043**] The package **1** comprises a bearing element **3** preferably made of a silicon die, with an upper surface **4** and a lower surface **5**. In a preferred embodiment, the silicon die is substantially flat and square-shaped.

[**0044**] As it can be seen from **FIG. 3**, the upper surface **4** has a metallic pad **8** (substantially square-shaped in the figure embodiment) apt to enable the positioning and the fixing, by welding, of the electro-optic active element **2**.

[**0045**] In the shown embodiment, the electro-optic active element **2** is preferably a VCSEL and another two electro-optic active elements, a PIN **10** or second electro-optic active element and a supplying driver **11** or third electro-optic active element, are present. For the sake of clarity, the electro-optic active element, the second and the third electro-optic active elements will be hereafter called active elements **2**, **10** and **11**.

[0046] The upper surface **4** has, in such case, a further pair of pads **9***a* and **9***b* (substantially square-shaped in the figure embodiment) each arranged symmetrically with respect to the pad **8**, and apt to enable the positioning and the fixing of the active elements **10** and **11**.

[0047] Preferably, the pad **8** and the pair of pads **9***a* and **9***b* are realized by photolithographic technique.

[0048] The bearing element **3** has, peripherally to the pad **8** and to the pair of pads **9***a* and **9***b*, a plurality of conduits or vias **12** passing between the upper surface **4** and the lower surface **5**. The vias **12** enable the realization of electric connections. The number and shape of the vias **12** can vary according to the type of package to be realized and to the operation thereof.

[0049] In particular the vias **12** are shaped and suitably filled with dielectric material so as to create a structure having a section similar to that of a coaxial cable and substantially conductive for transmitting a modulated electric signal even at high frequency.

[0050] Advantageously, according to the present embodiment, the electric contacts are placed on the lower surface **5** of the bearing element **3**, opposed with respect to the surface **4** whereon the active elements **2**, **10** and **11** are mounted. In this way, the assembly step of the package on the board is remarkably simplified.

[0051] Advantageously, according to the invention, the upper surface **4** has a first metallization loop **7**, square-shaped in the embodiment, arranged near a peripheral edge of the bearing element **3**.

[0052] As can be seen from **FIGS. 3 and 4**, the upper surface **4** has four alignment seats **6** arranged symmetrically with respect to the axis Z-Z and internally to the first metallization loop **7**, near the four corners thereof.

[0053] The number and conformation of the alignment seats **6** depend both on the technique used for realizing them, and on the type of package to be obtained. Among the techniques used for this purpose there are the anisotropic wet etch and the plasma dry etch of the bearing element **3**.

[0054] According to a preferred conformation, the seats **6** are realized by means of a wet etch which creates seats with pyramidal profiles following the crystalline planes of the silicon substrate used for realizing the bearing element **3**.

[0055] The four alignment seats **6** have, according to a preferred embodiment, a square-based frustum of pyramid shape originating from bearing element **3**.

[0056] The package **1** comprises, advantageously according to the invention, a closing element **13** juxtaposed to the bearing element **3** and preferably realized on a silicon substrate different to the substrate of bearing element **3**.

[0057] In this way, the closing element **13** and the bearing element **3** define a closed housing seat **23** for the active elements **2**, **10** and **11**.

[0058] In particular, the closing element **13** has an upper surface **14** and a lower surface **15**. The lower surface **15** is preferably square-shaped and comprises, in correspondence with the four corners thereof, four projections **16** of a shape conjugated to the alignment seats **6** of the bearing element **3**, as shown in the **FIGS. 5 and 6**.

[0059] Such projections **16** are symmetrically arranged with respect to the axis Z-Z.

[0060] In this way the interaction between the four projections **16** and the alignment seats **6** ensures, in a simple and lasting manner, the reciprocal positioning between the bearing element **3** and the closing element **13**.

[0061] The lower surface **15** has, moreover, a cavity **18** axially made with respect to the axis Z-Z, with square based frustum of pyramid shape. Preferably the cavity **18** has a depth p greater than a maximum height h between the active elements **2**, **10** and **11**.

[0062] According to the present embodiment the cavity **18** forms the housing seat **23**, as shown in **FIG. 8**.

[0063] The four projections **16** and the cavity **18** are preferably realized by means of anisotropic wet etches.

[0064] The cavity **18** has an inner surface **19** preferably coated, by deposition, of a non-reflective material.

[0065] The lower surface **15** of the closing element **13** also has a second metallization loop **17**, which is juxtaposed to the first loop **7** of the bearing element **3** when the closing element **13** is placed above the bearing element **3**.

[0066] In such way, the coupling between the first loop **7** and the second sealing loop **17**, possibly by interposing welding paste, ensures the hermetic closure between the bearing element **3** and the closing element **13** themselves, and thus the hermetic sealing of the housing seat **23** they define.

[0067] The closing element **13** also has, on the upper surface **14**, a lens **20** and, peripherally thereto, a recess **21**, for example shaped as a circular crown, both axially arranged with respect to axis Z-Z, as shown in **FIG. 7**.

[0068] Suitably, the recess **21** has a depth d of an appropriate and defined value.

[0069] The lens **20** maybe refractive or diffractive depending on the typology of package **1** to be realized and it is obtained by means of known techniques: plasma etch by means of grey-scale mask, direct writing, holography, controlled density and temperature photoresist for generating a lenticular surface then used as hard mask of variable thickness.

[0070] The recess **21** maybe realized simultaneously with the lens **20**, or in a previous or subsequent step.

[0071] For the package **1**, the cavity **18** forms the housing seat **23** for the active elements **2**, **10** and **11**; the four projections **16** and the four seats **6** realize coupling and alignment means **22**, moreover, the first **7** and the second metallization loop **17**, possibly by interposing welding paste, ensure the hermetic sealing thereof.

[0072] In particular, the interaction between the seats **6** and the projections **16** ensures a mechanical alignment with such precision as to allow a passive optical alignment, i.e. without light transmission, through the involved optical elements. The first and second juxtaposed metallization loops **7** and **17** allow such a welding as to make the housing of the active components inside the housing seat **23** hermetic, which thus results in a hermetical seal.

[**0073**] The thus obtained package **1** ensures the alignment between the lens **20** and the electro-optic active element **2** with tolerances of the photolithographic type. In fact, the electro-optic active element **2** is placed by a pick-and-place machine which ensures a maximum error lower than 1 μm, whereas the optical coupling and alignment means **22** ensure maximum misalignments of the photolithographic type, thus constituting the maximum global alignment tolerance of the package **1**.

[**0074**] The invention also relates to an electro-optic module **30**, shown in **FIGS. 9 and 10**, and used for housing and associating an optical fiber **50** with package **1**, the latter being realized according to the above indicated description.

[**0075**] Hereafter, for what concerns the package **1**, the same numeric references as above will be used for indicating corresponding parts.

[**0076**] The cylinder-shaped optical fiber, of the standard type, comprises a core, apt to transmit light pulses, surrounded by a coat or shell, which allows to protect these pulses from possible distortions. In particular, **FIG. 9** shows an end part **53** of any optical connector associated with an optical fiber **51** inserted in a fibula **52** and hereafter, for convenience, globally indicated as optical fiber **50**.

[**0077**] The electro-optic module **30**, as shown in **FIGS. 11 and 12**, has a casing **31** which comprises a mechanical bearing body **32**, the shape, size and composition of which depend on the application wherein the optical fiber **50** is used.

[**0078**] The bearing body **32** also has a parallelepiped-shaped box-like seat **36**, apt to fittingly house, at least partially, the package **1**.

[**0079**] The casing **31** also has an axial alignment sleeve **40** for the optical fiber **50** which can be precisely inserted in a receptacle **38**, the correct alignment being ensured by the axial alignment sleeve **40**, advantageously available for purchase at low cost.

[**0080**] As shown in **FIG. 8**, the sleeve **40** is slightly longer than the receptacle **38** and thus a lower end **41** projects from the inner surface **37** by an appropriate previously calculated value s. Suitably, the value s is greater than the depth d of the recess **21** realized on the closing element **3** of the package **1**.

[**0081**] Advantageously, moreover, the casing **31** has a cylindrical spacer **45** fittingly inserted from the lower end **41** of the sleeve **40** and aligned below it. The spacer **45** has an axial hole **46** of the same size as the diameter of the lens **20** of the package **1** and of height equal to the axial distance of the position of an image plane of the lens **20** itself.

[**0082**] In this way, the spacer **45** forms, internally to the sleeve **40**, an abutting plane **46** for the end of the optical fiber **50** inserted into the sleeve **40**.

[**0083**] According to a preferred embodiment, the package **1** is precisely and axially inserted in the box-like seat **16** of the bearing body **32** with its upper surface **14** facing the inner surface **37** of the body **32**. In this way, the axis Z-Z and the axis A-A are aligned. The lower end **41** of the sleeve **40** and the spacer **45** are inserted in the precision recess **21** and an air space **55** is obtained between the upper surface **14** and the inner surface **37**. Suitably, the height of the air space **55** is equal to the difference between the projection of the sleeve **40**, value "s", and the depth of recess **21**, "d".

[**0084**] It should be noted that the box-like seat **36** allows, if present, an approximate pre-alignment between the package **1** and the body **32**, such box-like seat not being strictly necessary for the realization of the module **30**. The correct alignment of the optical elements is in fact ensured by the mechanical alignment of the sleeve **40** inside the recess **21**, as shown in **FIG. 8**. This alignment is possible and sufficient as the recess **21** is obtained photolithographically and it is aligned to the lens **20**, whereas the sleeve **40** is normally manufactured, by now, at an industrial level on large scale and at low cost with very good tolerances of the sizes thereof (external diameter, internal diameter, thickness, concentricity).

[**0085**] The bearing body **32** may also be fixed to the package **1** by means of welding paste or resin, not indicated in the figure, and placed in correspondence with the air space **55**.

[**0086**] In the thus realized electro-optic module **30**, the lower end **41** of the sleeve **40** and the spacer **45** in interaction with the recess **21** as well as the box-like seat **36** realize coupling and reciprocal alignment means **59** and they allow to hermetically associate the casing **31** with the package **1**.

[**0087**] It is also possible to envisage further embodiments of the package and of the electro-optic module according to the present invention, as shown in FIGS. **18** to **30**. In the following description, numbers from **100** will be used and, preferably, a **1** will be placed in front of the numbers used above to indicate corresponding parts.

[**0088**] According to such embodiments the package **101** has advantageously a substantially flat sandwich-like structure, and it comprises a bearing element **103** with an overlying closing element **3**, preferably realized on different silicon layers. The integral bearing element **103**, has, in plan, a substantially square-shaped first portion **126*a*** next to a second portion **126*b***, which allows the housing of first electric connection terminals **129**.

[**0089**] Advantageously, the first portion **126*a*** has a vertical axis V-V. The term vertical is used with reference to the orientation of the package **101** in the annexed figures.

[**0090**] The bearing element **103** has an upper surface **104** which, in the first portion **126*a***, comprises a metallic pad **108**, centrally arranged with respect to the axis V-V and a pair of pads **109*a*** and **109*b***, each arranged symmetrically with respect to the pad **108**, all pads being made square-shaped in the figure embodiment and apt to enable the positioning and fixing, by welding, of electro-optic active elements **102**, **110** and **111**. Preferably, the pad **108** and the pair of pads **109*a*** and **109*b*** are realized by means of photolithography.

[**0091**] Advantageously, on the upper surface **104** of the bearing element **103** a plurality of metallic tracks **128** is realized, each apt to connect first terminals **129**, realized on the second portion **126*b***, with second terminals **149** realized in the proximity of the pad **108** and of the pair of pads **109*a*** and **109*b***.

[0092] The metallic tracks **128**, suitably realized by means of a metallization step, carry high frequency signals, and thus they must be suitably shaped.

[0093] Advantageously, the upper surface **104** of the bearing element **103** has a crown **124** having an inner edge **124***a* and an outer edge **124***b*, square-shaped in the figure embodiment, realized near a peripheral edge of the first portion **126***a* of the bearing element **103**, preferably realized by deposition of a dielectric material layer.

[0094] Advantageously, the upper surface **104** has a first metallization loop **107** that is square-shaped and placed on top of the crown **124**.

[0095] In this way, the crown **124** is interposed between the plurality of metallic tracks **128** and the first metallization loop **107**, thus preventing electric interferences during the operative step of the package **101**.

[0096] According to the present embodiment, the plurality of metallic tracks **128** is placed on the same upper surface **104** whereon active components **102**, **110** and **111** are installed.

[0097] As it can be seen from **FIG. 18**, the upper surface **104** has four alignment seats **106** made internally to the first loop **107**, in proximity of its four corners and preferably obtained by anisotropic wet etch.

[0098] Advantageously, the package **101** comprises the closing element **113** which, according to a preferred embodiment, comprises a first component **170** and a second component **175**, juxtaposed. The first component **170**, realized on a silicon substrate, is flat and has dimensions such that it can overlie exactly over the first portion **126***a* of the bearing element **103** along the axis V-V.

[0099] In particular, the first component **170**, as it can be seen in **FIGS. 20, 21** and **22**, has an upper surface **114** and a lower surface **115**.

[0100] The lower surface **115** has four projections **116** of a shape conjugated to the alignment seats **106**, a second metallization loop **117** juxtaposed to the first loop **107**, thus ensuring, in a simple and lasting manner, the reciprocal and hermetic positioning along the axis V-V between the first component **170** and the bearing element **103**.

[0101] The first component **170** also has a cavity **118** passing between the lower surface **115** and the upper surface **114**, centrally arranged along the axis V-V and frustum of pyramid shaped originating from the lower surface **115**.

[0102] Advantageously, the upper surface **114** has four first alignment markers **172** each placed near each one of the four corners of the first component **170**. In the indicated embodiment, the four first markers **172** have a cross-like shape, each of them defining four quadrants of equal size.

[0103] The upper surface **114** also comprises a third metallization loop **173** placed between the peripheral edge and the first four markers **172**.

[0104] Advantageously, the first component **170** has a thickness s greater than a maximum height h between the active elements **102**, **110** and **111**.

[0105] The second component **175** of the closing element **113** is substantially flat, as it can be seen in **FIGS. 23, 24** and **25**, and preferably made of transparent material, in the spectral region wherein silicon is opaque, preferably glass or quartz.

[0106] The second component **175** has a lower surface **176** and an upper surface **177**.

[0107] The lower surface **176** comprises four second markers **178**, each comprising four quadrants equal and complementary to each of the four markers **172** and such that they realize, when overlain, a continuous quadrant. In such way, during the assembly step, the first markers **172** and the second markers **178** ensure, in a simple and lasting manner, the reciprocal positioning between the first component **170** and the second component **175**.

[0108] It should be noted that the shape of the markers **178** depends only on the alignment machines used and that it is absolutely arbitrary.

[0109] Moreover, the lower surface **176** comprises a fourth metallization loop **180** placed between a peripheral edge and the four second markers **178**, such fourth loop **180** being superimposable onto the third loop **173** of the first component **170** and thus ensuring a hermetic closure.

[0110] In such way, the closing element **113** and the bearing element **103** define a closed housing seat **123** for the active elements **102**, **110** and **111**.

[0111] Moreover, the coupling between the first metallization loop **107** and the second metallization loop **117** ensures the hermetic closure between the bearing element **103** and the closing element **113** and thus the hermetic sealing of the housing seat **123** they define.

[0112] The second component **175** has an upper surface **177**, a centrally placed lens **120** and a recess **121**, preferably circular, arranged in axial alignment and peripherally with respect to the lens **120** itself.

[0113] The lens **120** can be refractive or diffractive depending on the typology of package **101** to be realized and it is obtained by means of known techniques.

[0114] The recess **121** can be realized simultaneously with the lens **120** or in a subsequent step provided that it is arranged axially with respect to the lens **120** and to the second markers **178**.

[0115] In such way, the alignment of the bearing element **103** with the first component **170**, realized by means of the four projections **116** inserted in the four seats **106**, and the alignment of the first component **170** with the second component **175**, realized by means of the second markers **178** complementary to the first markers **172**, ensure the optical coupling between the electro-optic active element **102** arranged in the hermetic housing seat **123** and the lens **120** the along axis V-V. In other words, the package **101** thus realized ensures an alignment between the electro-optic active element **102** and the lens **120** with tolerances of the photolithographic type.

[0116] The package **101** is associated with an optical fiber, globally indicated with **150**, by means of a casing **131** completely similar to the one described above in order to realize an electro-optic module **130** as shown in **FIGS. 28, 29** and **30**. The casing **131** preferably has a symmetry axis B-B.

[0117] In the case of the casing **131** the same numbers used in the previous description, with a 1 placed in front, will be used. The package **101** is axially inserted, along the axis B-B in a box-like seat **136** of a bearing body **132** with the upper surface **177** of the second component **175** of the closing element **113** facing an inner surface **137** of the bearing body **132**. In such way, the axis B-B coincides with the axis V-V.

[0118] The casing **131** has a sleeve **140** which can be axially inserted in a suitable receptacle **138** realized along the axis B-B, which puts the inner surface **137** in communication with the opposite end of the body **132**. The sleeve **140**, apt to allow the insertion of an optical fiber **150**, is longer than the receptacle **138** and projects, below, by a prefixed amount "s".

[0119] The casing **131** also has a spacer **145** fittingly inserted from the lower end of the sleeve **140**. The spacer **145** has a central hole the diameter of which is equal to the diameter of the lens **120** of the package **101** and a height equal to the axial distance of the position of an image plane of the lens **120**.

[0120] The package **101** is partially and axially inserted in the box-like seat **136** and, in such way, the sleeve **140** and the spacer **145** are partially housed in the recess **121**. The box-like seat **136**, the sleeve **140** and the spacer **145** form reciprocal optical coupling and aligning means **122** between the package **101** and the casing **131**.

[0121] An air space **155** is defined between the upper surface **177** of the package **101** and the inner surface **137** of the body **132**.

[0122] Thus, the bearing body **132** can be suitably fixed to the package **101** by means of the welding paste or resin, not indicated in the figures and placed in the air space **155**.

[0123] Advantageously, the second component **175** of the closing element **113** made of transparent material is used when the wavelength of the light pulses transmitted along the optical fiber **150** approaches the visible spectrum or in the first window of the optical fibers.

[0124] Finally, the invention relates to a method for assembling a housing package of at least one electro-optic active element shown with reference to FIGS. **1** to **10**.

[0125] The assembled package is the one shown in **FIG. 1** and, hereafter, the same numeric references will be used to indicate corresponding parts.

[0126] In its more general form, the assembly method according to the invention comprises the following steps:

[0127] providing a bearing element **3** for an electro-optic active element **2**;

[0128] placing such electro-optic active element **2** on the bearing element **3** by means of a pick-and-place machine;

[0129] surmounting the bearing element **3**, in axial alignment, with a closing element **13**; and

[0130] sealing the closing element **13** on the bearing element **3** with hermetic closure means to define a hermetically sealed housing seat **23**.

[0131] In particular, making reference to the embodiment shown in FIGS. **1** to **10**, the assembly method according to the invention includes the following steps:

[0132] providing a bearing element **3** realized on a silicon substrate, comprising, on an upper surface **4**, at least one centrally arranged metallic pad **8** and a pair of metallic pads **9***a* and **9***b*, each arranged symmetrically with respect to the pad **8**, all the pads being realized by means of photolithographic techniques.

[0133] In particular, the bearing element **3** has a plurality of vias **12** arranged peripherally to the pad **8** and to the pair of pads **9***a* and **9***b*, passing between the upper surface **4** and the lower surface **5** and suitably filled with dielectric material, a first metallization loop **7** realized near a peripheral edge and four alignment seats **6** made internally to the first loop **7** each near the four corners thereof.

[0134] The method further includes the steps of:

[0135] placing and fixing by welding an electro-optic active element **2** on the first pad **8** and similarly a second **10** and a third **11** electro-optic active element on the pair of pads **9***a* and **9***b*. In particular, the placing and fixing of the active elements **2**, **10** and **11** occurs using of a pick-and-place machine; and

[0136] axially surmounting the bearing element **3** with a closing element **13**, again made of a silicon substrate and comprising, on a lower surface **15**, a centrally arranged cavity **18** apt to define a closed housing seat **23** for the electro-optic active element **2**.

[0137] In the case that the closing element **13** is composed of two or more elements, such as for example in the case of the closing element **113** of the above illustrated second embodiment, the assembly step includes the precautionary assembly of the closing element itself.

[0138] In particular, the closing element **13** comprises four projections **16**, each arranged near the four corners and a second metallization loop **17** realized between the four projections **16** and a peripheral edge of the closing element **13**. Moreover, the closing element **13** has an upper surface **14**, a lens **20**, refractive or diffractive depending on the typology of package **1** to be obtained, and a recess **21** realized peripherally to the lens **20** and arranged axially to the lens **20** itself and to the four projections **16**.

[0139] The assembly method thus includes the step of:

[0140] placing the welding paste in correspondence with the first metallization loop **7** of the bearing element **3**; and

[0141] juxtaposing the closing element **13** to the bearing element **3**, the four projections **16** interacting with the four seats **6** and with the second loop **17** placed on top of the first loop **7**.

[0142] In particular, these steps ensure a hermetic closure for the housing seat **23** and the presence of the projections **6** and of the seats **16** allows to avoid the insertion of the welding paste on the housing seat **23** itself. In fact, the projections **6** and the seats **16** are conjugated parts of the hermetic closing means between the bearing element **3** and the closing element **13**. Moreover, the lens **20**, centrally arranged with respect to the four projections **16**, ensures an axial alignment between the electro-optic active element **2** and the lens itself. The assembly method according to the present invention has the remarkable advantage that it may be realized at the wafer level thus obtaining a considerable reduction in time and costs.

[0143] Moreover, the package alignment test can also be realized at the wafer level, as shown in FIGS. **13** to **17**.

[0144] In particular, as it can be seen from **FIG. 13**, a plurality of bearing elements **3** are realized on a wafer **90**, electro-optic active elements **2**, **10** and **11** being placed and fixed on each of them, by welding, by advantageously using a pick-and-place machine. The electro-optic active element **2** is axially arranged with respect to axis Z-Z. Some welding paste is then placed in correspondence with the first metallization loop **7** and the closing elements **13** are coupled and aligned, by placing the projections **16** in correspondence with the seats **6**. An alignment of the lens **20** on a same axis Z-Z and hermetic closure of the housing seat **23** are thus obtained. The wafer obtained with the hermetic packages according to the invention is shown in **FIG. 15**.

[0145] At this point, it is possible to carry out the alignment test, which varies depending on whether the package is of the type indicated by **1** or the embodiment indicated by **101**.

[0146] **FIG. 16** shows an alignment test in the case of the package **1**, wherein the electric connections are realized by means of the vias **12**. In this case, a plurality of pins **95** or so-called vertical contact probes are placed in correspondence with the lower surface **5** of the bearing element **3**, whereas the insertion or extraction of the light is carried out by means of an optical head **96** placed in correspondence with the upper surface **14** of the closing element **13**. In particular, the optical head **96** essentially comprises a receiver equipped with a suitable optical picking up apparatus in the case wherein the electro-optic element is a laser or a LED, or a transmitter with a suitable optical apparatus, for example an optical fiber, in the case that the electro-optic element is a photo-detector.

[0147] **FIG. 17** shows the alignment test in the case of the package **101** wherein the electrical connections are on the same surface whereon the electro-optic active elements **102**, **110** and **111** are installed.

[0148] In this case, a plurality of pins **98** or so-called cantilever contact probes are used. As previously seen, the light pulses are detected or introduced through the optical head **96**.

[0149] The main advantage of the housing package for at least one electro-optic active element according to the present invention is that of having a sandwich-like structure realized by bearing element **3** being juxtaposed to the closing element **13**, which defines the hermetically closed housing seat **23**.

[0150] Moreover, a further considerable advantage of the package thus realized is that of having coupling and aligning means **22**, comprising conjugated projections **16** and conjugated seats **6** realized by means of photolithographic techniques, which make the alignment between the lens **20** and the electro-optic active element **2** reliable up to photolithographic levels.

[0151] Moreover, the interaction of the first loop **7** and of the second metallization loop **17** makes the closure of the package hermetic and thus the hermetic sealing of the housing seat **23**.

[0152] Advantageously, the coupling and aligning means **22** interposed between the metallization loops and the housing seat **23** further serve as boundary for the expansion of a welding paste or resin deposited therebetween, maintaining the housing seat **23** itself free.

[0153] A main advantage of the electro-optic module realized according to the present invention is that the casing **31** and the package **1** thus realized have reciprocal coupling and aligning means which allow to align, in a reliable way, an optical fiber **50** with an electro-optic element **2** housed in package **1**.

[0154] Another advantage is due to the fact that the coupling and aligning means are realized by means of suitable shapes of the casing and of the package, thus allowing a simple and effective alignment.

[0155] Moreover, the electro-optic module is freely associated to the optical fiber used thanks to the spacer **45** which allows to realize an abutting plane perfectly aligned with the electro-optic element without having to carry out active alignments during the assembly.

[0156] A further advantage is due to the fact that the assembly, both as regards the package and the electro-optic module, can occur by using standard automated machinery which allow to maintain a high reliability of the optical alignment necessary for the optical fiber transmission in the field of telecommunications.

[0157] The assembly method, as well as the alignment tests, is thus simple, reliable and can be realized at low cost.

[0158] Although preferred embodiments of the device of the present invention have been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiments disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

What is claimed is:

1. A package for housing at least one electro-optic active element, comprising:

a bearing element for said at least one electro-optic active element having a sandwich-like structure comprising a closing element associated with said bearing element by means of suitable aligning and coupling means and defining a hermetically closed housing seat, said closing element housing a lens in axial alignment with said electro-optic active element.

2. The package according to claim 1, wherein said aligning and coupling means have at least one alignment seat placed on an upper surface of said bearing element and at least one projection realized on a lower surface of said closing element of a shape conjugated to said housing seat.

3. The package according to claim 2, wherein said aligning and coupling means comprise a first metallization loop realized on said upper surface of said bearing element and a second metallization loop realized on said lower surface of said closing element.

4. The package according to claim 3, wherein said closing element has, on said upper surface, a lens and, peripherally to said lens, a recess axially centered with respect to an alignment axis between said at least one electro-optic active element and said lens.

5. The package according to claim 4, wherein said recess is formed in the shape of a circular crown.

6. The package according to claim 4, wherein said upper surface of said bearing element has a plurality of aligning seats realized symmetrically with respect to said alignment axis and arranged internally to said first metallization loop.

7. The package according to claim 6, wherein said alignment seats have a square-based frustum of pyramid shape originating from said upper surface.

8. The package according to claim 1, wherein said bearing element and said closing element are realized on different silicon substrates.

9. The package according to claim 6, wherein said closing element has, on said lower surface, a plurality of projections realized symmetrically with respect to said alignment axis, in a corresponding position and in a shape conjugated with said alignment seats realized on said upper surface of said bearing element.

10. The package according to claim 1, wherein said closing element has, on a lower surface, a cavity axially centered with respect to an alignment axis between said at least one electro-optic active element and said lens to realize said housing seat for said at least one electro-optic active element.

11. The package according to claim 10, wherein said cavity has a square-based frustum of pyramid shape with a depth p greater than a height h of said at least one electro-optic active element.

12. The package according to claim 11, wherein said cavity has an inner surface coated with a non-reflective material.

13. The package according to claim 1, wherein said bearing element has, on said upper surface, a positioning and fixing metallic pad of said at least one electro-optic active element.

14. The package according to claim 13, wherein said upper surface has a further pair of positioning and fixing pads respectively of a second and of a third electro-optic active element housed in said bearing element.

15. The package according to claim 14, wherein said bearing element has, peripherally to said pad and to said pair of pads a plurality of vias passing between said upper surface and said lower surface to realize electric connections.

16. The package according to claim 14, wherein said bearing element has a substantially squared first portion, next to a second portion, which allows the housing of first electric connection terminals, said first portion housing said metallic pad and said pair of pads and a plurality of metallic tracks to connect said first terminals with second terminals arranged near said pad and said pair of pads.

17. The package according to claim 15, wherein said bearing element has a square-shaped crown realized near a peripheral edge of said first portion and, arranged on top of said crown, said first metallization loop.

18. The package according to claim 14, wherein said closing element comprises a first component and a second component being juxtaposed, said first component being realized with a flat shape and of such size as to be exactly overlapped onto said first portion, said first component having said projections of conjugated shape to said alignment seats, said second metallization loop being juxtaposed to said first loop of said bearing element.

19. The package according to claim 18, wherein said first component has a cavity passing between a lower surface and a centrally arranged upper surface having a frustum of pyramid shape originating from said lower surface.

20. The package according to claim 19, wherein said upper surface has first alignment markers each arranged near each corner of said first component and a third metallization loop arranged between a peripheral edge and said markers, said first component having a thickness s greater than a maximum height h between active elements to be housed in said package.

21. The package according to claim 18, wherein said second component of said closing element is substantially flat and preferably made of transparent material, in the spectral region wherein silicon is opaque, it has a lower surface comprising second markers complementary to said first markers and a fourth metallization loop juxtaposed to said third loop of said first component.

22. The package according to claim 20, wherein said second component is preferably made of glass or quartz.

23. The package according to claim 1, wherein said electro-optic active element is an element selected from the group consisting of a VCSEL, a PIN, a photo-detector, an APD, a LED.

24. An electro-optic module of the type comprising a package housing at least one electro-optic active element associated with a casing comprising a receptacle housing an optical fiber wherein said package and said casing have coupling and aligning means for associating said casing with said package hermetically.

25. The electro-optic module according to claim 24, wherein said casing comprises a bearing body with a longitudinal axis, said bearing body having near a lower end a parallelepiped-shaped box-like seat to fittingly house at least part of said package.

26. The module according to claim 25, wherein said box-like seat defines on said bearing body a flat inner surface, perpendicularly arranged to said longitudinal axis and that said receptacle is axially arranged along said longitudinal axis putting said inner surface in communication with an upper end of said bearing body.

27. The module according to claim 24, wherein said casing has an axial alignment sleeve for said optical fiber, said sleeve being precisely inserted in said receptacle and projecting from said inner surface by a suitable value s.

28. The module according to claim 27, wherein said value s is greater than a depth d of said recess realized on said closing element of said package.

29. The module according to claim 24, wherein said casing comprises a cylindrical spacer fittingly inserted at a lower end of said sleeve and aligned below it, said spacer having an axial hole of the same size as the diameter of a lens of said package and having a height equal to the axial distance of the position of an image plane of said lens.

30. The module according to claim 24, further comprising an air space between an upper surface of said package and an inner surface of said receptacle.

31. The module according to claim 30, wherein said bearing body is fixed to said package by means of a welding paste or resin placed in correspondence with said air space.

32. A method for assembling a package housing at least one electro-optic active element for transmission by means of optical fiber, said method comprising:

providing a bearing element of said package;

placing said electro-optic active element on said bearing element by means of a pick-and-place machine;

surmounting said bearing element with a closing element of said package, said bearing and closing elements being in mutual axial alignment;

sealing said closing element on said bearing element by means of hermetic closure means to define a hermetically closed housing seat of said electro-optic active element.

33. The assembly method according to claim 32, further comprising photolithographically realizing on said bearing element at least one positioning and fixing pad **(8)** of said at least one electro-optic active element and wherein said electro-optic active element is placed in correspondence with said metallic pad.

34. The assembly method according to claim 33, wherein photolithographically realizing further realizes a pair of positioning and fixing metallic pads of at least a second and a third electro-optic active element, said pair of pads being arranged symmetrically with respect to said metallic pad and wherein said at least a second an a third electro-optic active element are placed in correspondence with said pair of metallic pads by means of a pick-and-place machine.

35. The assembly method according to claim 32, wherein surmounting, in axial alignment, of said bearing and closing elements comprises aligning a plurality of projections **(16)** of said closing element with a plurality of seats of said bearing element, said projections and seats having a conjugated shape.

36. The assembly method according to claim 32, wherein surmounting, in axial alignment, of said bearing with said closing element comprises surmounting a first metallization loop defined in said bearing element with a second loop defined in said closing element.

37. The assembly method according to claim 36, further comprising depositing of welding paste in correspondence with said first metallization loop before surmounting of said first with said second metallization loop.

38. The assembly method according to claim 32, wherein surmounting, in axial alignment of said bearing element, with a closing element of said package comprises positioning a plurality of elements of said closing element.

39. The assembly method according to claim 32, further comprising positioning of a lens on said closing element in axial alignment with said electro-optic active element on said bearing element.

40. The assembly method according to claim 32, wherein the method is realized on a wafer comprising a plurality of packages.

41. A package for housing an electro-optic active element, comprising:

a base having a surface to which the electro-optic active element is mounted;

a first peripheral metallization loop formed on the base surface around electro-optic active element;

a cover having a cavity and a peripheral rim surface;

a second peripheral metallization loop formed on the cover peripheral rim surface and having a shape matching the first peripheral metallization loop; and

alignment means associated with the base surface and the cover peripheral rim surface for aligning the first and second peripheral metallization loops with each other when the cover is placed on the base to enclose the electro-optic active element.

42. The package of claim 41 wherein the aligned first and second peripheral metallization loops assist in providing a hermetic seal between the cover and base.

43. The package of claim 41 wherein the cover further includes a lens that is aligned with the electro-optic active element when the cover is placed on the base.

44. The package of claim 41 further including a welding paste interposed between the aligned first and second peripheral metallization loops assist in providing a hermetic seal between the cover and base.

45. The package of claim 41 further including means for optically coupling an optical fiber to the electro-optic active element.

46. The package of claim 45 wherein the means for optically coupling comprises a bearing body having a first opening for receiving an end of the optical fiber and an opposed second opening in communication with the first opening that forms a seat that is sized and shaped to receive the cover.

47. The package of claim 46 wherein the cover further includes a lens that is aligned with the electro-optic active element when the cover is placed on the base and further which is aligned with the first opening for receiving the end of the optical fiber.

48. The package of claim 46 further including a sleeve positioned within the first opening a partially extending into the second opening.

49. The package of claim 48 wherein the cover has a recess formed in a top surface of the cover in alignment with the electro-optic active element when the cover is placed on the base, the recess being sized and shaped to receive the partially extending sleeve when the seat of the bearing body receives the cover to thus align the electro-optic active element with the first opening.

50. The package of claim 41 wherein the cover comprises:

a peripheral rim defining the cavity and the peripheral rim surface; and

an overlying plate.

51. The package of claim 50 further comprising second alignment means associated with a top surface of the peripheral rim and a bottom surface of the overlying plate for aligning the plate with the electro-optic active element when the cover is placed on the base to enclose the electro-optic active element.

52. The package of claim 51 further comprising:

a third peripheral metallization loop formed on the bottom surface of the overlying plate;

a fourth peripheral metallization loop formed on the top surface of the peripheral rim and having a shape matching the third peripheral metallization loop the second alignment means further for aligning the third and fourth peripheral metallization loops with each other when the overlying plate is attached to the peripheral rim to form the cover.

53. The package of claim 52 further including a welding paste interposed between the aligned third and fourth peripheral metallization loops assist in providing a hermetic seal between the overlying plate and the peripheral rim.

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