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(54) **MANUFACTURING METHOD OF IMAGE PICKUP APPARATUS FOR ENDOSCOPE, IMAGE PICKUP APPARATUS FOR ENDOSCOPE, AND ENDOSCOPE**

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(57) **ABSTRACT**

A manufacturing method of an image pickup apparatus for endoscope includes: manufacturing two optical wafers each of which has a glass wafer as a base substrate and is a hybrid lens wafer including a plurality of resin lenses, and a spacer wafer including a plurality of spacers and being formed with an inorganic material; manufacturing a bonded wafer in which space in which the plurality of resin lenses are disposed is hermetically sealed by directly bonding the two optical wafers and the spacer wafer at a temperature lower than a softening point of the plurality of resin lenses; disposing a plurality of image pickup members on the bonded wafer; and cutting the bonded wafer on which the plurality of image pickup members are disposed.

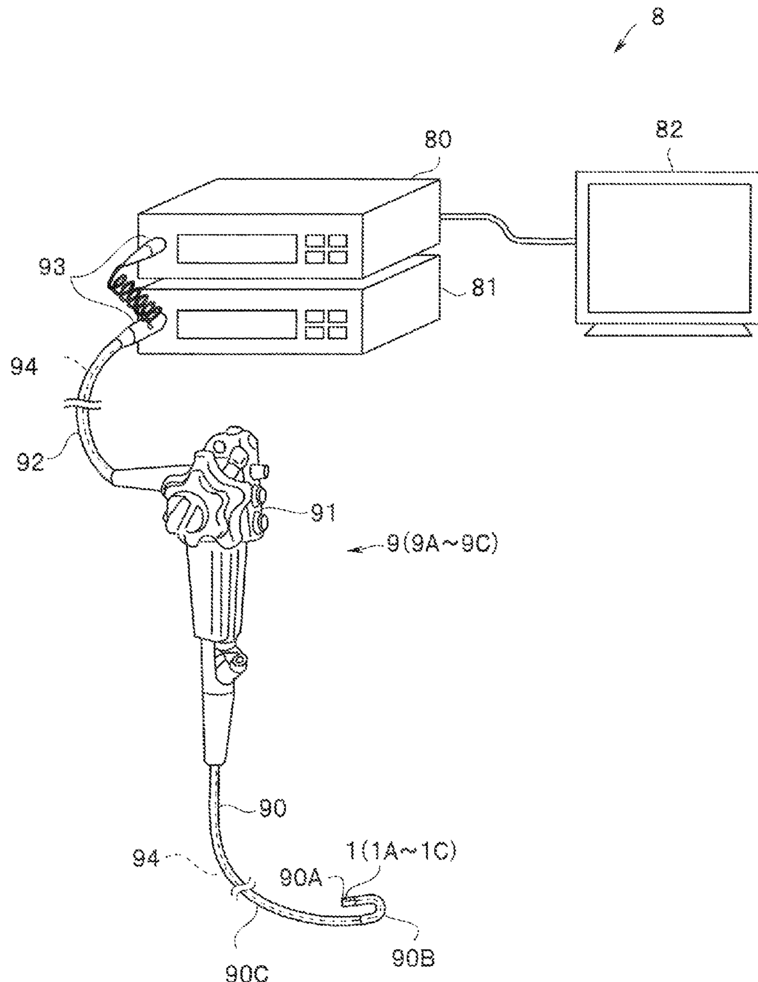


FIG. 1

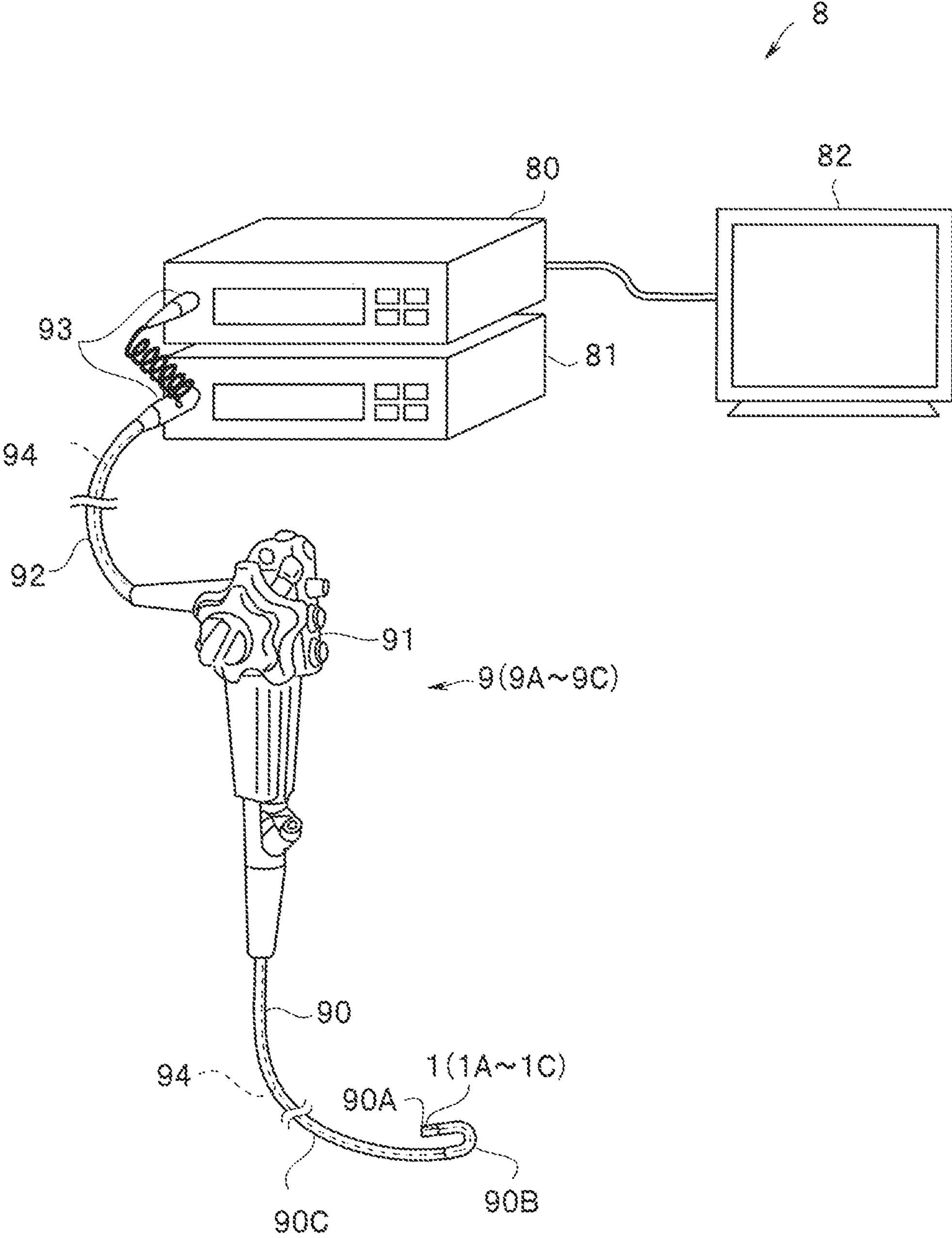


FIG. 2

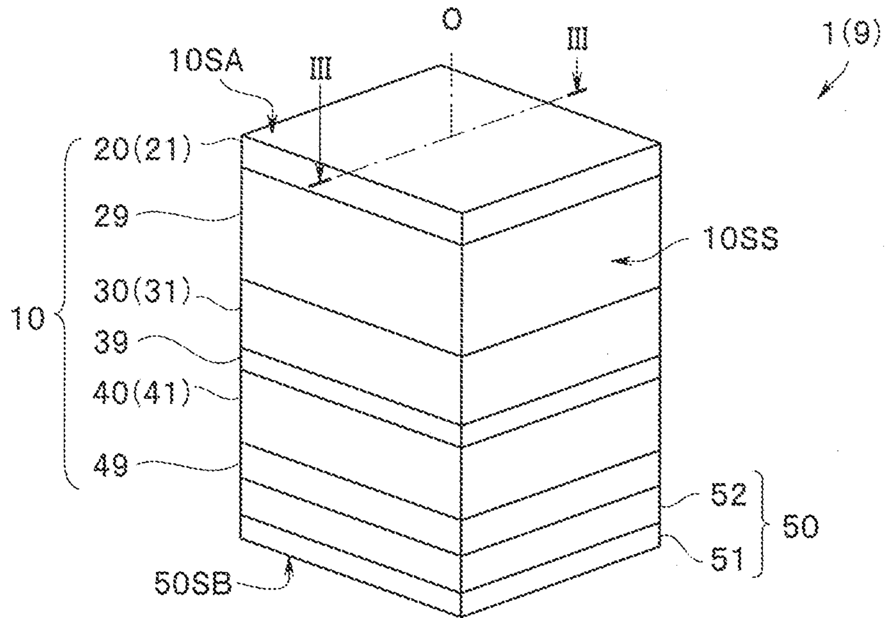


FIG. 3

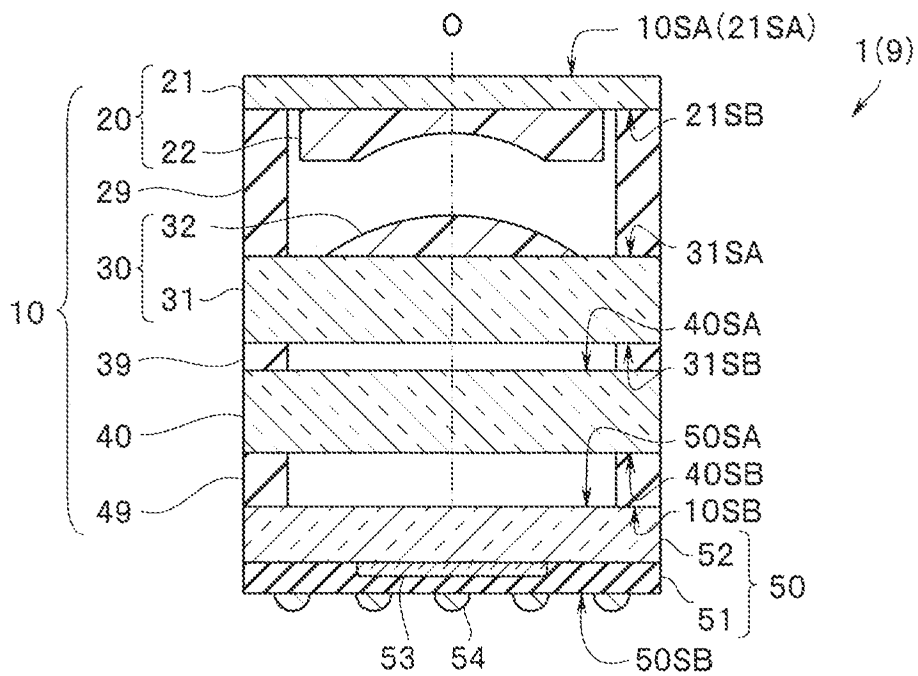


FIG. 4

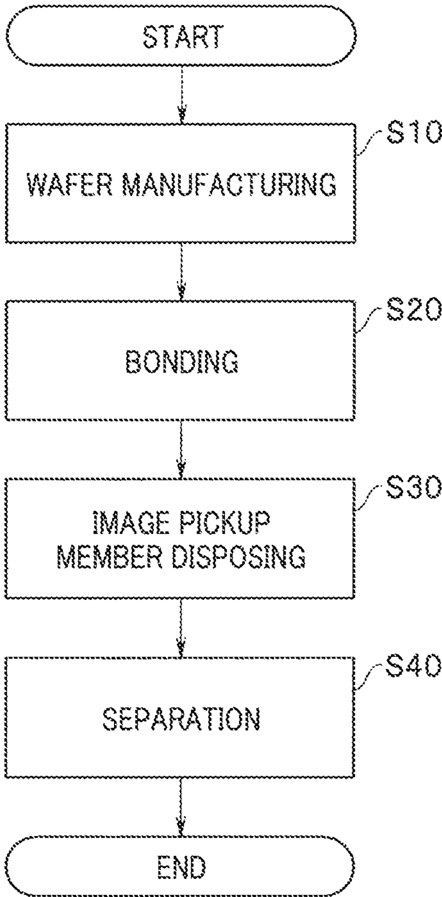


FIG. 5

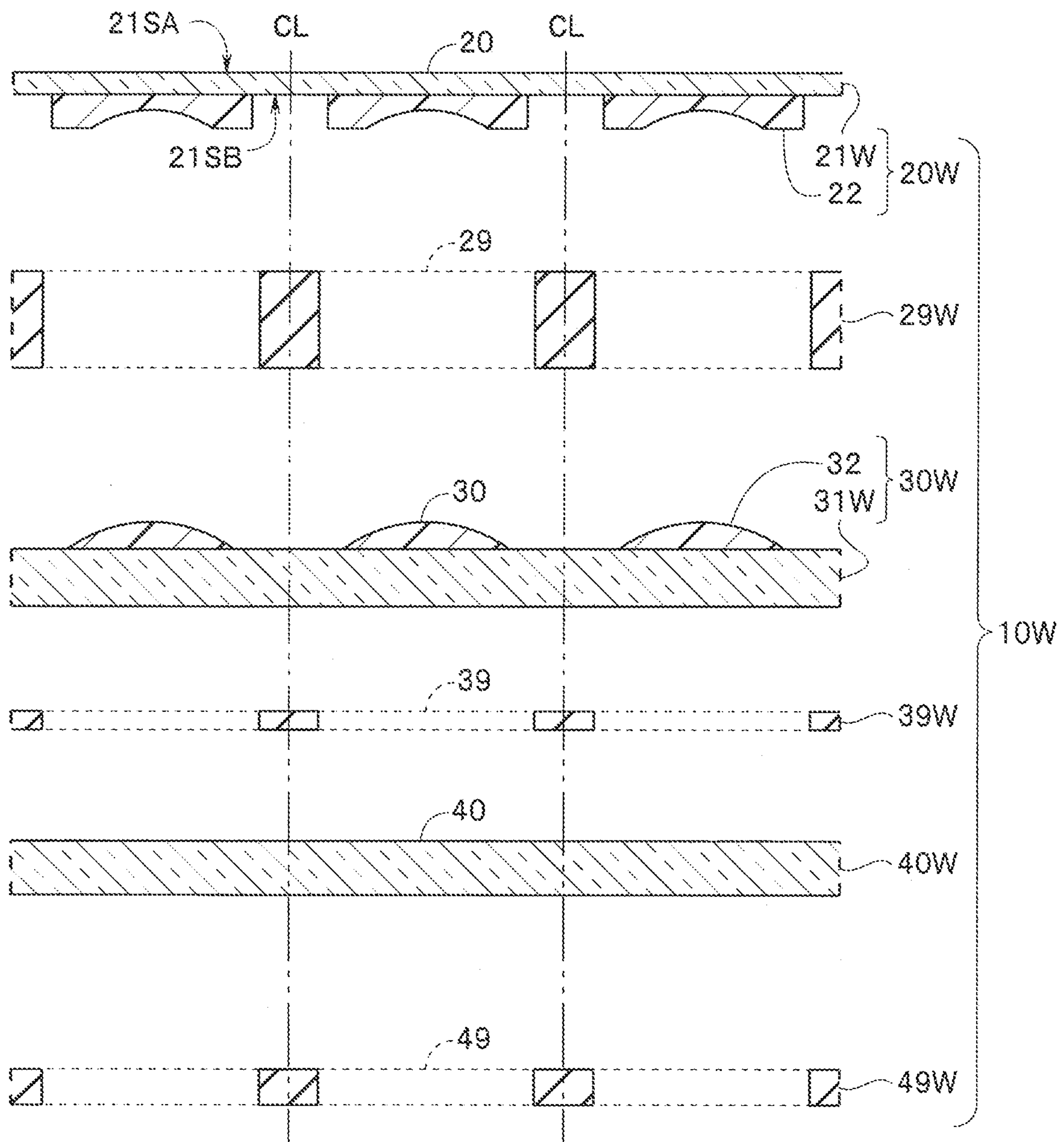


FIG. 6

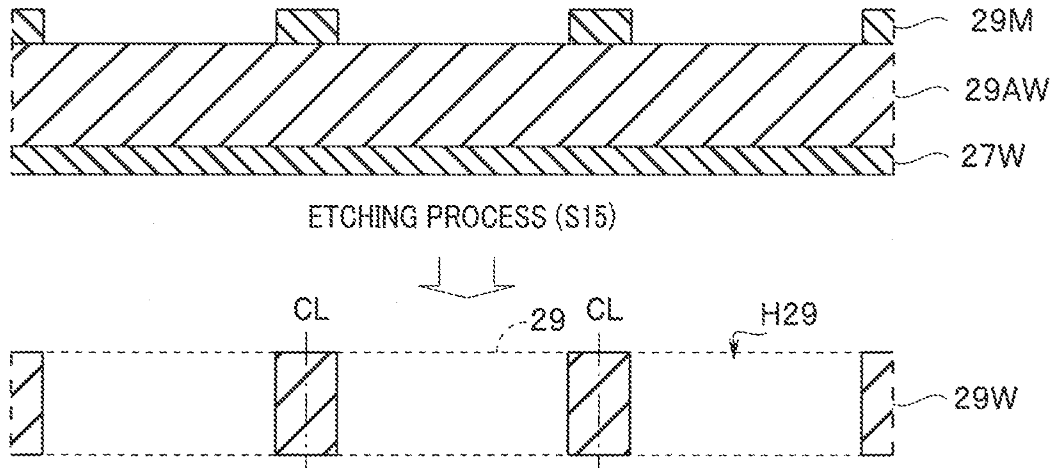


FIG. 7

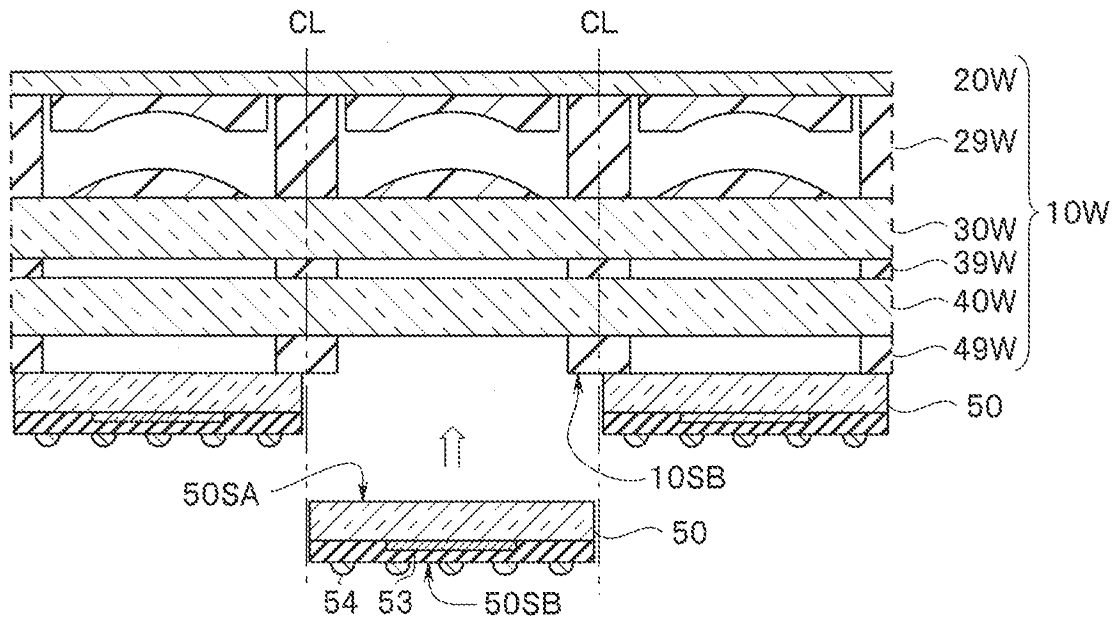


FIG. 8

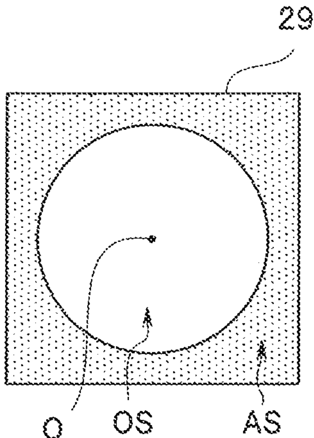


FIG. 9

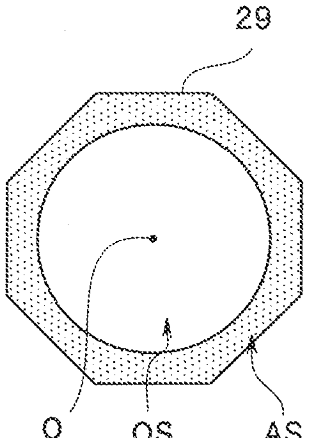


FIG. 10

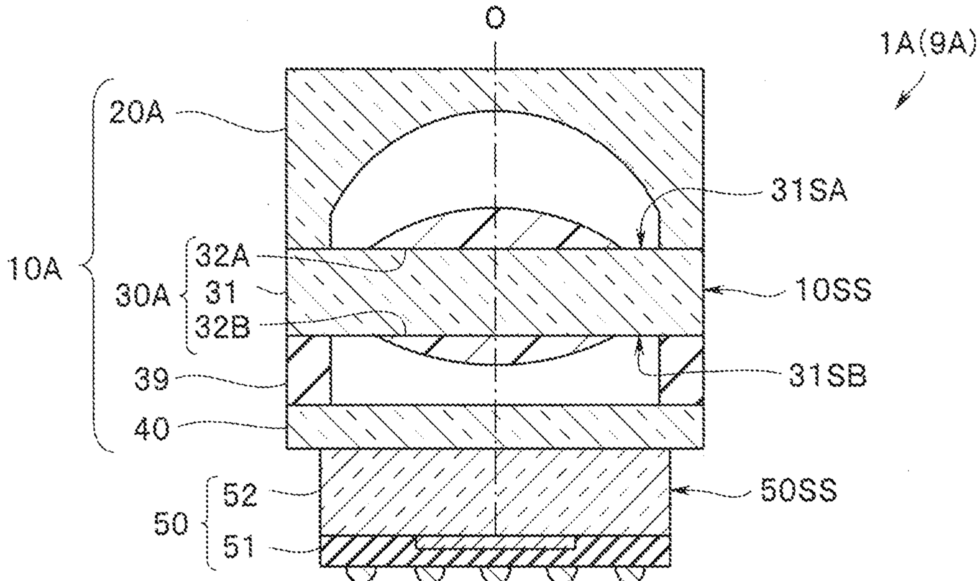


FIG. 11

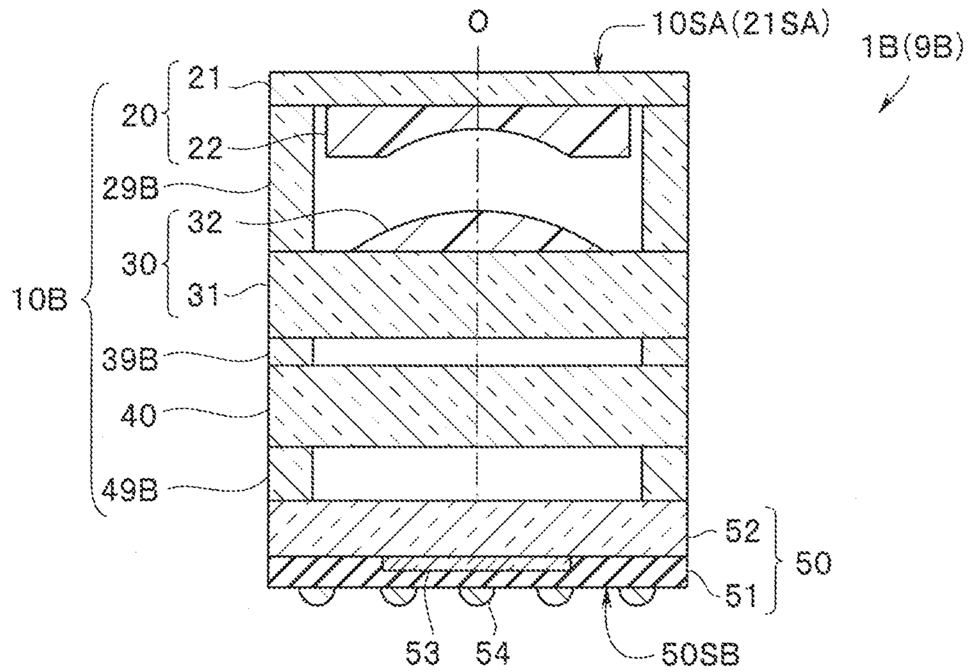


FIG. 12

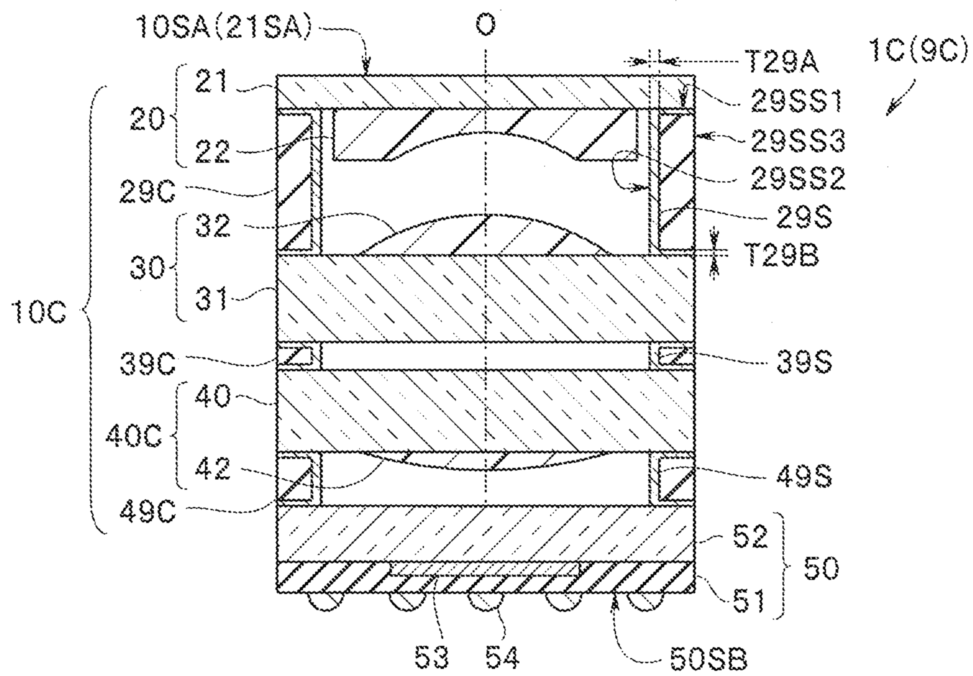
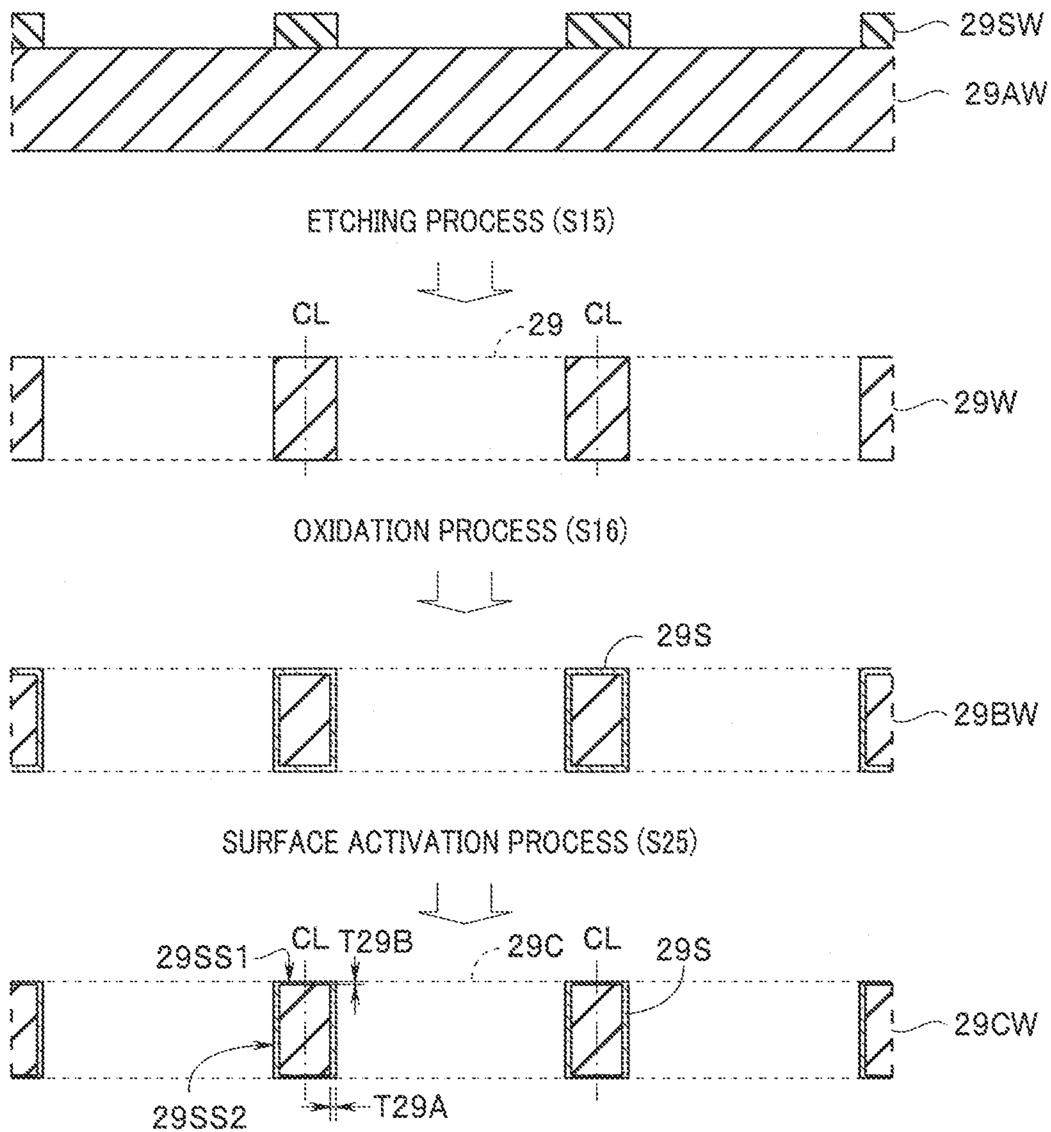


FIG. 13



MANUFACTURING METHOD OF IMAGE PICKUP APPARATUS FOR ENDOSCOPE, IMAGE PICKUP APPARATUS FOR ENDOSCOPE, AND ENDOSCOPE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation application of PCT/JP2019/001883 filed on Jan. 22, 2019, entire contents of which are incorporated herein by this reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to a manufacturing method of an image pickup apparatus for endoscope including an optical member including a resin lens, the image pickup apparatus for endoscope including the optical member including the resin lens, and the endoscope including the image pickup apparatus for endoscope including the optical member including the resin lens.

2. Description of the Related Art

[0003] Making an image pickup apparatus for endoscope smaller is important to achieve a less-invasive endoscope.

[0004] Examples of a method for efficiently manufacturing a small image pickup apparatus can include a wafer level manufacturing method in which a bonded wafer obtained by bonding a plurality of device wafers each including a plurality of optical devices is cut.

[0005] Japanese Patent Application Laid-Open Publication No. 2012-18993 discloses an image pickup module including a wafer level stacked body. The image pickup module is manufactured by bonding an optical wafer including a plurality of optical devices and an image pickup wafer including a plurality of image pickup devices and cutting and separating the bonded wafer into pieces.

[0006] Japanese Patent Application Laid-Open Publication No. 2015-38538 discloses a so-called hybrid lens device in which a lens formed with a resin is disposed on a parallel flat glass plate.

[0007] By manufacturing an optical member including a plurality of hybrid lens devices using a wafer level method, it is possible to efficiently manufacture a small-diameter image pickup apparatus having a small external size in an optical axis orthogonal direction.

SUMMARY OF THE INVENTION

[0008] A manufacturing method of an image pickup apparatus for endoscope of an embodiment of the present invention includes manufacturing two optical wafers each having a glass wafer as a base substrate, at least one of the two optical wafers being a hybrid lens wafer including a plurality of resin lenses, and a spacer wafer which includes a plurality of spacers and which is formed with an inorganic material, manufacturing a bonded wafer in which space in which the plurality of resin lenses are respectively disposed is hermetically sealed, and which includes the two optical wafers and the spacer wafer by directly bonding the spacer wafer to the two optical wafers at a temperature lower than a softening point of the plurality of resin lenses in a state where the spacer wafer is put between the two optical wafers, disposing a plurality of image pickup members on the bonded wafer, and manufacturing the image pickup apparatus for endoscope including an optical member which includes two optical devices each having a glass plate as a base substrate and a spacer which is disposed between the two optical devices, and each of the plurality of image pickup members by cutting the bonded wafer in which the image pickup member in plurality are disposed.

[0009] An image pickup apparatus for endoscope of another embodiment of the present invention includes an optical member which includes two optical devices each having a glass plate as a base substrate, and a spacer which is disposed between the two optical devices and which is formed with an inorganic material, at least one of the two optical devices being a hybrid lens device including a resin lens, and an image pickup member configured to receive light of an object image, the light being focused by the optical member, and space in which the resin lens is disposed is hermetically sealed by the optical device being directly bonded to the spacer.

[0010] An endoscope of another embodiment of the present invention includes an image pickup apparatus for endoscope, the image pickup apparatus for endoscope including an optical member which includes two optical devices each having a glass plate as a base substrate and a spacer which is disposed between the two optical devices and which is formed with an inorganic material, at least one of the two optical devices being a hybrid lens device including a resin lens, and an image pickup member configured to receive light of an object image, the light being focused by the optical member, and space in which the resin lens is disposed is hermetically sealed by the optical devices being directly bonded to the spacer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a perspective view of an endoscope system including an endoscope of embodiments;

[0012] FIG. **2** is a perspective view of an image pickup apparatus for endoscope of a first embodiment;

[0013] FIG. **3** is a cross-sectional diagram of the image pickup apparatus for endoscope of the first embodiment, cut along a line in FIG. **2**;

[0014] FIG. **4** is a flowchart of a manufacturing method of the image pickup apparatus for endoscope of the first embodiment;

[0015] FIG. **5** is a cross-sectional diagram for explaining the manufacturing method of the image pickup apparatus for endoscope of the first embodiment;

[0016] FIG. **6** is a cross-sectional diagram for explaining a manufacturing method of a spacer of the image pickup apparatus for endoscope of the first embodiment;

[0017] FIG. **7** is a cross-sectional diagram for explaining the manufacturing method of the image pickup apparatus for endoscope of the first embodiment;

[0018] FIG. **8** is a cross-sectional diagram of the spacer of the image pickup apparatus for endoscope of the first embodiment;

[0019] FIG. **9** is a cross-sectional diagram of the spacer of the image pickup apparatus for endoscope of the first embodiment;

[0020] FIG. **10** is a cross-sectional diagram of an image pickup apparatus for endoscope of a second embodiment;

[0021] FIG. **11** is a cross-sectional diagram of an image pickup apparatus for endoscope of a third embodiment;

[0022] FIG. **12** is a cross-sectional diagram of an image pickup apparatus for endoscope of a fourth embodiment; and

[0023] FIG. **13** is a cross-sectional diagram for explaining a manufacturing method of a spacer of the image pickup apparatus for endoscope of the fourth embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

<Endoscope>

[0024] As illustrated in FIG. **1**, an endoscope system **8** including an endoscope **9** of an embodiment includes a processor **80**, a light source apparatus **81**, and a monitor **82**. The endoscope **9** photographs inside of a body of a subject by an insertion portion **90** being inserted into a body cavity of the subject, and outputs an image pickup signal.

[0025] An operation portion **91** at which various kinds of buttons for operating the endoscope **9** are provided is disposed at a proximal end portion of the insertion portion **90** of the endoscope **9**. The insertion portion **90** includes a rigid distal end portion **90**A at which an image pickup apparatus for endoscope **1** is disposed, a bending portion **90**B which is connected to the proximal end portion of the rigid distal end portion **90**A and which can freely bend, and a flexible portion **90**C connected to a proximal end portion of the bending portion **90**B. The bending portion **90**B bends through operation at the operation portion **91**.

[0026] A universal cord **92** extending from the operation portion **91** is connected to the processor **80** and the light source apparatus **81** by way of a connector **93**. The insertion portion **90**, the operation portion **91** and the universal cord **92** allow insertion of a signal cable **94** which transmits an electrical signal outputted from the image pickup apparatus for endoscope **1**.

[0027] The processor **80** controls the whole of the endoscope system **8**, performs signal processing on an image pickup signal outputted from the image pickup apparatus for endoscope **1**, and outputs the image pickup signal subjected to the signal processing as an image signal. The monitor **82** displays the image signal outputted from the processor **80**.

[0028] The light source apparatus **81** includes, for example, a white LED. Illumination light emitted from the light source apparatus **81** is guided to the rigid distal end portion **90**A by way of a light guide (not illustrated) which passes through the universal cord **92** and the insertion portion **90** and illuminates an object.

[0029] The image pickup apparatus for endoscope **1** of the endoscope **9** has a small diameter as will be described later, and has excellent resistance to moisture, and thus, the endoscope **9** is less invasive and has excellent resistance to moisture.

[0030] Note that while the endoscope **9** is a medical flexible endoscope, an endoscope of another embodiment may be an industrial endoscope or a rigid endoscope.

<First Embodiment>

[0031] As illustrated in FIG. **2** and FIG. **3**, the image pickup apparatus for endoscope **1** (hereinafter, also referred to as an "image pickup apparatus **1**") of the present embodiment includes an optical member **10** and an image pickup member **50**.

[0032] In the following description, the drawings based on the respective embodiments schematically illustrate the image pickup apparatus. Relationship between a thickness and a width of each portion, a ratio of thicknesses of respective portions, or the like, are different from actual relationship, ratio, or the like. Part of relationship of dimensions and ratios are different between the drawings. Illustration of part of components and assignment of reference numerals will be omitted. A direction of an object will be referred to a "front" direction.

[0033] The optical member **10** is a quadrangular prism having an entrance surface **10**SA, a rear surface **10**SB facing the entrance surface **10**SA, and four side surfaces **10**SS. The optical member **10** is a wafer level stacked body in which a plurality of optical devices **20**, **30** and **40** and a plurality of spacers **29**, **39** and **49** are bonded. The spacers **29**, **39** and **49** respectively have through-holes which become optical path regions. As will be described later, the optical member **10** is manufactured by cutting a bonded wafer **10**W obtained by bonding a plurality of optical wafers **20**W, **30**W and **40**W and a plurality of spacer wafers **29**W, **39**W and **49**W (see FIG. **5**), and thus, a plurality of optical devices **20**, or the like, have the same external size in a direction orthogonal to an optical axis O, and the four side surfaces **10**SS are cut surfaces.

[0034] The optical devices **20** and **30** are hybrid lens devices which have glass plates **21** and **31** as base substrates and in which resin lenses **22** and **32** are disposed. The resin lenses **22** and **32** are formed with a transparent resin for lens, for example, an acrylic resin or an epoxy resin.

[0035] The image pickup member **50** includes a front surface **50**SA and a back surface **50**SB facing the front surface **50**SA. The image pickup member **50** includes an image pickup device **51** and a cover glass **52**. The front surface **50**SA of the cover glass **52** is bonded to the rear surface **10**SB of the optical member **10**. An object image, light of which is focused by the optical member **10** is converted into an electrical signal by a light receiving region **53** of the image pickup device **51**, and the electrical signal is outputted from an external electrode **54** on the back surface **50**SB.

[0036] Intervals between the optical devices **20** and **30**, between optical devices **30** and **40** and between the optical device **40** and the image pickup member **50** are respectively defined by the spacers **29**, **39** and **49**. The spacers **29**, **39** and **49** are formed with silicon which has low moisture permeability and which is an inorganic material, and a region constituting an optical path is a cylindrical space.

[0037] Note that as will be described later, materials of the spacers **29**, **39** and **49** may be ceramics such as glass and silicon nitride, or a metal such as gold, titanium and aluminum if the materials are inorganic materials which can be respectively directly bonded to the optical devices **20**, **30** and **40** and the cover glass **52** and which have low moisture permeability. Further, types of glass of the glass plates **21** and **31**, the optical device **40** and the cover glass **52** are not limited to borosilicate glass or silica glass and may be, for example, sapphire glass if the glass is a transparent inorganic material which can be directly bonded to the spacers **29**, **39** and **49** and which has low moisture permeability.

[0038] The optical device **20** is a hybrid lens device including a glass plate **21** having a first principal surface **21**SA and a second principal surface **21**SB facing the first principal surface **21**SA, and an aspheric concave lens **22** which is disposed on the second principal surface **21**SB and which is formed with a resin. The first principal surface

21SA is the entrance surface **10**SA of the optical member **10**. The optical device **30** is a hybrid lens device including a glass plate **31** having a third principal surface **31**SA and a fourth principal surface **31**SB facing the third principal surface **31**SA, and an aspheric convex lens **32** which is disposed on the third principal surface **31**SA and which is formed with a resin.

[0039] The optical device **40** having a fifth principal surface **40**SA and a sixth principal surface **40**SB facing the fifth principal surface **40**SA is an infrared cut filter device which has a function of blocking infrared light and which is formed with glass, and does not include a resin lens. In other words, the optical member **10** only requires to include optical devices, at least one of which is a hybrid lens device.

[0040] Note that a configuration of the optical member **10**, that is, a type, the number and stacking order of the optical devices can be variously modified in accordance with specifications. For example, a patterned light shielding film having an aperture function may be disposed on a principal surface of the optical device.

[0041] In other words, the optical member **10** includes at least two optical devices and a spacer disposed between the two optical devices. However, the optical member of the embodiment of the present invention only requires to include at least two optical devices respectively having glass plates as base substrates, and one spacer which is disposed between the two optical devices and which is formed with an inorganic material, at least one of the two optical devices being a hybrid lens device including a resin lens.

[0042] Note that a resin lens is not disposed on the first principal surface **21**SA of the optical device **20** which is a first optical device disposed at a fore most part closest to the object among the plurality of optical devices **20**, **30** and **40**, that is, on the entrance surface **10**SA of the optical member **10**.

[0043] The side surface **10**SS of the optical member **10** is not exposed outside in a case where the image pickup apparatus **1** is stored in the rigid distal end portion **90**A of the endoscope **9**. However, the entrance surface **10**SA of the optical member **10** (the first principal surface **21**SA of the optical device **20**) is exposed. In other words, the image pickup apparatus **1** is disposed at the endoscope **9** in a state where the optical device on the most distal end side of the image pickup apparatus **1** is exposed from a distal end surface of the endoscope **9**. Reliability of the resin lens is not sufficient compared to reliability of a glass lens. Further, there is a possibility that the exposed resin lens may be broken.

[0044] The image pickup apparatus **1**, in which a resin lens is not disposed on the entrance surface **10**SA of the optical device **20**, has high reliability.

[0045] Further, as will be described later, portions to be bonded of the plurality of optical devices **20**, **30** and **40** are respectively directly bonded to portions to be bonded of the plurality of spacers **29**, **39** and **49**. Here, direct bonding refers to a form in which atoms exposed on respective bonding surfaces bind to each other on a bonding interface of two members to be bonded without use of a bonding member such as an adhesive.

[0046] As a method for direct bonding, for example, an SAB (surface-activated bonding) or Anodic Bonding is used as will be described later.

[0047] Note that other members such as an adhesive are not put between the bonding surfaces of the two members which are directly bonded. In other words, two members between which other members are not put can be regarded as being directly bonded.

[0048] The image pickup apparatus **1** includes the optical member **10** constituted with a wafer level stacked body, and thus, has a small diameter. Further, the resin lenses **22** and **32** can be easily manufactured and are inexpensive. While the resin lenses **22** and **32** have high moisture absorbency, space in which the resin lenses **22** and **32** are disposed is surrounded by the glass plates **21** and **31** which are directly bonded to the spacer **29** formed with silicon and hermetically sealed, and thus, the image pickup apparatus **1** excels in resistance to moisture. The endoscope **9** including the image pickup apparatus **1** is less invasive and excels in resistance to moisture.

[0049] It is necessary to dispose a moisture-resistant film on the side surfaces to secure moisture resistance in the image pickup apparatus in which the optical devices of the optical member are bonded to the spacers with an adhesive. The image pickup apparatus **1** of the present embodiment has high resistance to moisture, which eliminates necessity of disposing a moisture-resistant film or which only requires a thin moisture-resistant film, so that a small-diameter image pickup apparatus **1** can be achieved.

[0050] Note that a thermal expansion coefficient α**29** of the spacer **29** is preferably equal to or greater than 50% and equal to or less than 200% of thermal expansion coefficients α**21** and α**31** of the glass plates **21** and **31**. The thermal expansion coefficient a within such a range makes thermal stress applied on the bonding surface small even if a temperature changes upon bonding or when used, so that high reliability of the image pickup apparatus **1** can be achieved.

[0051] For example, the thermal expansion coefficient α**29** of the spacer **29** formed with silicon is 3.9 ppm/° C. In this case, glass of a type which makes the thermal expansion coefficients α**21** and α**31** equal to or greater than 1.95 ppm/° C. and equal to or less than 7.8 ppm/° C., for example, borosilicate glass is preferably selected as the glass plates **21** and **31**.

<Manufacturing Method of Image Pickup Apparatus>

[0052] A manufacturing method of the image pickup apparatus for endoscope **1** will be described next along a flowchart illustrated in FIG. **4**.

<Step S**10**> Wafer Manufacturing Process

[0053] As illustrated in FIG. **5**, for example, the glass wafer **21**W is prepared. A thickness of the glass wafer **21**W is determined in accordance with specifications of the image pickup apparatus **1**, and is preferably, for example, equal to or greater than 50 μm and equal to or less than 1 mm to achieve a small image pickup apparatus. Note that if the glass wafer **21**W is cut along cut lines CL, glass plates **21** of the optical devices **20** are obtained.

[0054] Then, a plurality of resin lenses **22** are respectively disposed at predetermined positions on the second principal surface **21**SB of the glass wafer **21**W. For example, molded resin lenses **22** are disposed on the second principal surface **21**SB by applying a transparent resin for lens and curing the transparent resin for lens by irradiating the transparent resin with ultraviolet light (UV) in a direction from the first principal surface **21**SA in a state where a mold (not illus-

trated) having a predetermined shape is pressed against the second principal surface **21**SB.

[0055] Note that the resin lenses **22** and **32** formed with different resins may be disposed on the optical wafers **20**W and **30**W.

[0056] On the other hand, as illustrated in FIG. **6**, in a manufacturing process of the spacer wafer **29**W which become a plurality of spacers **29**, an etching mask **29**M for forming space which becomes an optical path is disposed on a principal surface of a silicon wafer **29**AW. A support wafer **27**W is bonded to a principal surface (back surface) facing the principal surface on which the etching mask **29**M is disposed.

[0057] In an etching process (step S**15**), the spacer wafer **29**W including a plurality of through-holes H**29** which are space which becomes optical paths is manufactured. For example, dry etching using an ICP-RIE method, or the like, or wet etching using an alkali solution such as potassium hydroxide (KOH) and tetramethylammonium hydroxide (TMAH) is performed. After the etching process S**15**, the etching mask **29**M and the support wafer **27**W are removed. The through-holes H**29** may be formed through sandblasting or laser machining

[0058] Spacer wafers **39**W and **49**W which become a plurality of spacers **39** and **49** are manufactured using a method similar to the manufacturing method of the spacer wafer **29**W (see FIG. **5**).

[0059] A material of the spacer wafers **29**W, **39**W and **49**W is not limited to silicon and may be, for example, ceramics such as silicon nitride, glass or a metal such as gold, titanium and aluminum if the material is an inorganic material which has low moisture permeability and which can be directly bonded to the glass wafers.

[0060] As described above, in the wafer manufacturing process S**10**, two optical wafers **20**W and **30**W which respectively have the glass wafers **21**W and **31**W as base substrates, and at least one of which is a hybrid lens wafer including a plurality of resin lenses **22** and **32**, and the spacer wafers **29**W, **39**W and **49**W which include a plurality of spacers **29**, **39** and **49** and which are formed with an inorganic material, are manufactured.

[0061] Note that as already described above, for example, the thermal expansion coefficient $\alpha 29$ of the spacer wafer **29**W which becomes the spacer **29** is preferably equal to or greater than 50% or equal to or less than 200% of the thermal expansion coefficients $\alpha 21$ and $\alpha 31$ of the glass wafers **21**W and **31**W which become the glass plates **21** and **31**.

[0062] Further, a configuration of the optical member **10** can be variously modified in accordance with specifications. In other words, in the wafer manufacturing process of the embodiment, a plurality of optical wafers which respectively have glass wafers as base substrates, and at least one of which is a hybrid lens wafer including a plurality of resin lenses, and at least one spacer wafer, each of which includes a plurality of spacers and which is formed with an inorganic material, are manufactured.

<Step S**20**> Bonding Process

[0063] As illustrated in FIG. **5**, the bonded wafer **10**W in which space in which a plurality of resin lenses **22** and **32** are respectively disposed is hermetically sealed is manufactured by directly bonding the optical wafers **20**W, **30**W and **40**W to the spacer wafers **29**W, **39**W and **49**W at a temperature lower than a softening point of the resin lenses **22** and **32**. For example, the spacer wafer **29**W is directly bonded in a state where the spacer wafer **29**W is put between the two optical wafers **20**W and **30**W.

[0064] For example, in a case where surface activated bonding is used as direct bonding, for example, first, a surface is activated by performing ion milling treatment in which the bonding surfaces of the optical wafers **20**W and **30**W and the spacer wafer **29**W are irradiated with, for example, argon atom beams for three minutes.

[0065] Then, the optical wafers **20**W and **30**W are stacked in a state where the spacer wafer **29**W is put between the optical wafers **20**W and **30**W in high vacuum in which ultimate vacuum is equal to or less than 10^{-4} Pa, and after the optical wafers **20**W and **30**W and the spacer wafer **29**W are bonded by a pressure ($1N/mm^2$) being applied for ten minutes at an ambient temperature, heat treatment is performed for one hour at 120° C.

[0066] A bonding temperature is lower than the softening point of the resin lenses **22** and **32**, and thus, optical characteristics do not degrade due to change of shapes of the resin lenses **22** and **32**.

[0067] Note that the bonding surfaces are preferably polished to be smooth at the atomic level through CMP (chemical mechanical polishing), or the like. For example, the respective bonding surfaces are processed so as to have surface roughness in which a maximum height (Rmax) defined in JIS-B0601:2001 is equal to or less than 10 nm or center line average roughness (Ra) is equal to or less than 1 nm.

[0068] On the other hand, in a case where anodic bonding is used as direct bonding, for example, the optical wafers **20**W and **30**W are stacked in a state where the spacer wafer **29**W is put between the optical wafers **20**W and **30**W, and a negative voltage of approximately 400 V is applied to the optical wafers **20**W and **30**W in a state where the optical wafers **20**W and **30**W are bonded by a pressure ($1N/mm^2$) being applied and heated to 150° C., and the spacer wafer **29**W is set at a ground potential.

[0069] In a case of anodic bonding, lithium doped glass is preferably used as the glass wafers **21**W and **31**W of the optical wafers **20**W and **30**W. The lithium doped glass can be anodically bonded to silicon in a heated state at lower than, for example, 250° C. which is lower than the softening point of the glass resin lenses **22** and **32**.

[0070] Direct bonding conditions are selected as appropriate in accordance with the material of the optical wafers **20**W and **30**W and the material of the spacer wafer **29**W. For example, plasma irradiation treatment may be used in activation in surface activated bonding. Further, compression bonding conditions are selected from conditions of, for example, a pressure: from 0.1 N/mm^2 to 10 N/mm^2, a time period: from one minute to one hour, a temperature: from an ambient temperature to 200° C.

[0071] The optical wafer **40**W and the spacer wafers **39**W and **49**W are also directly bonded using a method similar to the bonding method of the optical wafer **30**W, or the like. All the wafers may be bonded at the same time or the wafers may be sequentially bonded. Further, a plurality of wafers of the bonded wafer **10**W may be directly bonded using different methods. For example, the optical wafers **20**W and **30**W and the spacer wafer **29**W are bonded using surface activated bonding, and the optical wafers **30**W and **40**W and the spacer wafers **39**W and **49**W may be anodically bonded.

Still further, a resin lens may be disposed on the glass wafer to which the spacer wafer is bonded in advance.

[0072] Note that the spacer wafers **39**W and **49**W in which a resin lens is not disposed and which constitute an optical path may be bonded using an adhesive. However, the spacer wafers **39**W and **49**W are preferably directly bonded in a similar manner to the optical wafer **30**W to prevent moisture from entering the optical path.

<Step S**30**> Image Pickup Member Disposing Process

[0073] As illustrated in FIG. **7**, front surfaces **50**SA of a plurality of image pickup members **50** are bonded to the rear surface **10**SB of the bonded wafer **10**W.

[0074] In the manufacturing method of the image pickup member **50**, first, a light receiving member **53** such as a CMOS light receiving element is formed at a semiconductor wafer using a publicly known semiconductor manufacturing method. Then, an image pickup device wafer (not illustrated) in which the light receiving member **53** is connected to the external electrode **54** of the back surface **50**SB is manufactured by manufacturing a through wiring (not illustrated).

[0075] The image pickup member **50** including the image pickup device **51** and the cover glass **52** is manufactured by the cover glass wafer being bonded to the image pickup device wafer using an adhesive layer (not illustrated) and cut. The cover glass wafer may be bonded to the image pickup device wafer before the through wiring is manufactured.

<Step S**40**> Separation Process

[0076] The image pickup apparatus **1** including the optical member **10** and the image pickup member **50** illustrated in FIG. **3** is manufactured by cutting the bonded wafer **10**W in which a plurality of image pickup members **50** are bonded. The four side surfaces **10**SS of the optical member **10** which is separated into pieces using a dicing saw, or the like, have notches which are minute irregularities. In other words, the four side surfaces **10**SS of the optical member **10** which is a wafer level structure are cut surfaces. The plurality of optical devices and spacers constituting the optical member **10** have the same external shape and the same external size of cross-sections orthogonal to the optical axis O. All of the plurality of optical devices **20**, or the like, have a rectangular parallelepiped shape and have the same shape and the same size of cross-sections in the optical axis orthogonal direction, and thus, the optical member **10** is a quadrangular prism.

[0077] The separation process may be, for example, a process of cutting through laser dicing or a process of forming a cut groove through sandblasting or etching.

[0078] Note that while, in the image pickup apparatus **1**, the cross-section in the optical axis orthogonal direction of the image pickup member **50** has substantially the same shape and substantially the same size as a shape and a size of the cross-section in the optical axis orthogonal direction of the optical member **10**, at least one of the shape and the size may be different.

[0079] The cross-section in the optical axis orthogonal direction of the image pickup member **50** preferably has a size equal to or less than a size of the cross-section in the optical axis orthogonal direction of the optical member **10**, and the image pickup member **50** is preferably stored within space which is an extension of the entrance surface **10**SA of the optical member **10** in the optical axis direction to make the diameter of the image pickup apparatus **1** smaller

[0080] Further, the image pickup apparatus **1** may be manufactured by directly bonding or joining the image pickup wafer including a plurality of image pickup members to the bonded wafer **10**W and cutting the bonded wafer **10**W. In other words, the image pickup wafer including a plurality of image pickup members may be disposed on the bonded wafer **10**in the image pickup member disposing process S**30**, and the image pickup wafer including the plurality of image pickup members and the bonded wafer **10** may be cut in the separation process S**40**. In this case, the cross-section in the optical axis orthogonal direction of the image pickup member **50** has the same shape and the same size as a shape and a size of the cross-section in the optical axis orthogonal direction of the optical member **10**.

[0081] The above-described manufacturing method enables a large number of image pickup apparatuses **1** which have a small diameter and which excel in resistance to moisture to be easily manufactured. The image pickup apparatus **1** is disposed at the rigid distal end portion **90**A of the endoscope **9**.

[0082] Note that the cover glass **52** corresponds to an optical device having a glass plate as a base substrate. In other words, the cover glass wafer is also an optical wafer.

[0083] In other words, the bonded wafer in which space in which a plurality of resin lenses are disposed is hermetically sealed is manufactured by directly bonding the spacer wafer, the cover glass wafer and the hybrid lens wafer including a plurality of resin lenses in a state where the spacer wafer is put between the cover glass wafer and the hybrid lens wafer at a temperature lower than a softening point of the resin lenses.

[0084] The bonded wafer including the cover glass wafer may be separated into pieces after a plurality of image pickup devices **51** which do not include a cover glass are bonded to the bonded wafer. Further, the bonded wafer may be manufactured by bonding a cover glass wafer in which a plurality of image pickup devices **51** are provided in advance to the hybrid lens wafer, and the bonded wafer may be separated into pieces.

[0085] Note that the side surfaces of the image pickup apparatus **1** are preferably covered with a light shielding material to prevent external light from entering the optical path. In a case where the light shielding material also serves as a moisture resistant material, the image pickup apparatus **1** excels in resistance to moisture, so that it is possible to make the light shielding material (moisture resistant material) thinner and achieve a smaller diameter.

[0086] As illustrated in FIG. **8**, while a cross-section orthogonal to the optical axis O of the spacer **29**, or the like, has a rectangular external shape, an inner shape of a through-hole which is an optical path region OS has a cylindrical shape. Further, the whole of upper and lower surfaces of the spacer **29** are bonded surfaces AS, and the spacer **29** is bonded to the optical devices **20** and **30** without other members such as an adhesive being put between the spacer **29** and the optical devices **20** and **30**. Note that the optical path region OS defined by the spacer **29** is not limited to the cylindrical shape and may be, for example, a prismatic shape, an oval cylindrical shape or other shapes.

[0087] In a case where the spacer is bonded to the two optical devices using an adhesive, there is a possibility that

the adhesive may enter the optical path region OS, and thus it is necessary to make an external size larger to secure a wide adhesive area.

[0088] In the image pickup apparatus **1**, the whole of the upper and lower surfaces of the spacer become the bonded surfaces, and thus, high bonding strength can be achieved, and an adhesive does not enter the optical path region OS on an inner periphery side. An interval between the optical path region OS and the bonded surface AS can be designed to be small in the image pickup apparatus **1**, and thus, the image pickup apparatus having a small external size and a small diameter can be achieved. For example, the interval between the optical path region OS and the bonded surface AS can be set at several μm to 100 μm which is positioning tolerance. The endoscope **9** including the image pickup apparatus **1** has a small-diameter rigid distal end portion **90**A, and thus, is less invasive.

[0089] Note that as illustrated in FIG. **9**, the cross-section orthogonal to the optical axis O of the spacer **29** may have a polygonal (octagonal) external shape in which corner portions are chamfered or a circular external shape. In other words, the image pickup apparatus **1** may have a polygonal prism external shape or a cylindrical external shape having a smaller cross-section orthogonal to the optical axis O than a cross-section of a quadrangular prism.

<Second Embodiment>

[0090] Image pickup apparatuses for endoscope **1**A to **1**C and endoscopes **9**A to **9**C including the image pickup apparatuses **1**A to **1**C of a second embodiment to a fourth embodiment described below are similar to the image pickup apparatus **1** and the endoscope **9** and have the same functions, and thus, the same reference numerals will be assigned to components having the same functions, and description will be omitted.

[0091] In the image pickup apparatus for endoscope **1**A of the second embodiment illustrated in FIG. **10**, the optical member **10**A includes three optical devices **20**A, **30**A and **40**, and one spacer **39**. The optical device **20**A is a glass member having functions of a concave lens and a spacer. In the optical device **30**A which has the glass plate **31** as a base substrate, the resin lens **32**A is disposed on the third principal surface **31**SA, and the resin lens **32**B is disposed on the fourth principal surface **31**SB. The optical device **40** is an infrared cut filter device having a function of blocking infrared light.

[0092] Further, the image pickup member **50** has a smaller external size of a cross-section orthogonal to the optical axis O than an external size of a cross-section of the optical member **10**A. Thus, the side surfaces **10**SS of the optical member **10**A are not positioned on the same planes as planes of the side surfaces **50**SS of the image pickup member **50**.

[0093] The image pickup apparatus **1**A has the same effects as the effects of the image pickup apparatus **1** of the first embodiment, and the spacer **29** can be omitted, so that it is possible to simplify a structure and easily manufacture the image pickup apparatus **1**A.

<Third Embodiment>

[0094] In the image pickup apparatus for endoscope **1**B of the present embodiment illustrated in FIG. **11**, the spacers **29**B, **39**B and **49**B are constituted with the same type (same composition) of glass as a type of glass of the glass plates **21**, **31** and **40**.

[0095] Thus, the glass plates **21**, **31** and **40** can be easily directly bonded to the spacers **29**B, **39**B and **49**B. Further, the glass plates **21**, **31** and **40** and the spacers **29**B, **39**B and **49**B have the same thermal expansion coefficient α, and thus, reliability of the image pickup apparatus **1**B and the endoscope **9**B does not degrade by temperature change upon manufacturing and when used.

[0096] Note that in the third embodiment, it is only necessary that at least the spacer **29**B in which space in which the resin lenses **22** and **32** are disposed is hermetically sealed be constituted with the same type of glass as a type of the glass of the glass plates **21** and **31**. For example, the spacers **39**B and **49**B may be constituted with silicon.

[0097] Note that spacers except the spacer **29**B may be various kinds of inorganic materials, for example, ceramics such as silicon nitride or a metal such as gold, titanium and aluminum if the spacers can be easily directly bonded to glass plates of optical devices and have thermal expansion coefficients a equal to or greater than 50% and equal to or less than 200% of thermal expansion coefficients a of the glass plates.

<Fourth Embodiment>

[0098] In the image pickup apparatus for endoscope **1**C of the present embodiment illustrated in FIG. **12**, for example, silicon oxide layers **29**S, **39**S and **49**S are formed on the bonded surfaces of the spacers **29**C, **39**C and **49**C having silicon as a base material.

[0099] For example, as illustrated in FIG. **13**, a manufacturing method of the spacer **29**C includes an oxidation process (step S**16**) in which a surface of the spacer wafer **29**W is oxidized to make the spacer wafer **29**BW after the etching process S**15** in the wafer manufacturing process S**10**.

[0100] The oxidation process S**16** is oxygen plasma treatment or heating treatment under an oxidizing atmosphere.

[0101] Then, in a surface activation process (step S**25**) of the bonding process, a surface of the bonded surface **29SS1** of the spacer wafer **29**BW on which the silicon oxide layer **29**S is formed is slightly removed. Thus, a thickness T**29**B of the silicon oxide layer **29**S of the bonded surface **29SS1** of the spacer wafer **29**CW is thinner than a thickness T**29**A of the silicon oxide layer **29**S of an inner surface **29SS2**.

[0102] In other words, the spacer in which a thickness of an oxide layer on the bonded surface is thinner than a thickness of an oxide layer on the inner surface can be regarded as being bonded through surface activated bonding. Further, the optical member **10**C in which the oxide layer is not formed on the side surfaces of the spacer can be regarded as a wafer level optical member manufactured by separating the bonded wafer into pieces.

[0103] In the image pickup apparatus for endoscope **1**C, for example, the glass plates **21** and **31** which are oxides, can be easily bonded to the oxide layer of the spacer **29**C or the like through direct bonding, particularly, surface activated bonding, and high bonding reliability can be achieved. Note that the oxide layer of the spacer **29**C or the like is a layer in which silicon of the spacer **29**C is oxidized and is not regarded as other members of the spacer **29**C. In other words, the glass plates **21** and **31** are bonded to the spacer

29C without other members being put between the glass plates **21** and **31** and the spacer **29**C.

[0104] In the image pickup apparatus for endoscope **1**C, a resin lens **42** is disposed on an infrared cut filter substrate **40** formed with glass in the optical device **40**C. Further, the cover glass **52** of the image pickup member **50** is directly bonded to the spacer **49**S.

[0105] In other words, the resin lens **42** is hermetically sealed in space surrounded by the infrared cut filter substrate **40**, the cover glass **52** and the spacer **49**S.

[0106] Note that the spacer wafer **29**C, or the like, is not limited to silicon and may be, for example, aluminum or titanium if the spacer wafer **29**C, or the like, is an inorganic material which allows an oxide layer to be formed on a surface in the oxidation process S**16**.

[0107] It goes without saying that the endoscopes **9**A to **9**C including the image pickup apparatuses **1**A to **1**C have effects of the image pickup apparatuses **1**A to **1**C in addition to the effects of the endoscope **9**.

[0108] The present invention is not limited to the above-described embodiments, or the like, and various changes, combinations and application are possible within a range not deviating from the gist of the invention.

What is claimed is:

1. A manufacturing method of an image pickup apparatus for endoscope, comprising:

manufacturing two optical wafers each having a glass wafer as a base substrate, at least one of the two optical wafers being a hybrid lens wafer including a plurality of resin lenses, and a spacer wafer which includes a plurality of spacers and which is formed with an inorganic material;

manufacturing a bonded wafer in which space in which the plurality of resin lenses are respectively disposed is hermetically sealed, and which includes the two optical wafers and the spacer wafer by directly bonding the spacer wafer to the two optical wafers at a temperature lower than a softening point of the plurality of resin lenses in a state where the spacer wafer is put between the two optical wafers;

disposing a plurality of image pickup members on the bonded wafer; and

manufacturing the image pickup apparatus for endoscope including an optical member which includes two optical devices each having a glass plate as a base substrate and a spacer which is disposed between the two optical devices, and each of the plurality of image pickup members by cutting the bonded wafer in which the plurality of image pickup members are disposed.

2. The manufacturing method of the image pickup apparatus for endoscope according to claim **1**,

wherein a thermal expansion coefficient of the spacer wafer is equal to or greater than 50% and equal to or less than 200% of a thermal expansion coefficient of the glass wafer.

3. The manufacturing method of the image pickup apparatus for endoscope according to claim **1**,

wherein the spacer wafer is constituted with a same type of glass as a type of glass of the glass wafer.

4. The manufacturing method of the image pickup apparatus for endoscope according to claim **1**,

wherein the spacer wafer is manufactured by etching a silicon wafer when the wafer is manufactured.

5. The manufacturing method of the image pickup apparatus for endoscope according to claim **4**,

wherein the spacer wafer is manufactured by oxidizing a surface of the spacer wafer after the etching when the wafer is manufactured.

6. An image pickup apparatus for endoscope comprising:

an optical member which includes two optical devices each having a glass plate as a base substrate, and a spacer which is disposed between the two optical devices and which is formed with an inorganic material, at least one of the two optical devices being a hybrid lens device including a resin lens; and

an image pickup member configured to receive light of an object image, the light being focused by the optical member,

wherein space in which the resin lens is disposed is hermetically sealed by the optical devices being directly bonded to the spacer.

7. The image pickup apparatus for endoscope according to claim **6**,

wherein the optical devices and the spacer have a same external size of cross-sections orthogonal to an optical axis,

side surfaces of the optical devices and the spacer are cut surfaces, and the spacer includes a through-hole which becomes an optical path region.

8. The image pickup apparatus for endoscope according to claim **7**,

wherein the through-hole has a cylindrical shape.

9. The image pickup apparatus for endoscope according to claim **7**,

wherein a thermal expansion coefficient of the spacer is equal to or greater than 50% and equal to or less than 200% of a thermal expansion coefficient of the glass plate.

10. The image pickup apparatus for endoscope according to claim **6**,

wherein the spacer is constituted with a same type of glass as a type of glass of the glass plate.

11. The image pickup apparatus for endoscope according to claim **6**,

wherein the spacer is constituted with silicon.

12. The image pickup apparatus for endoscope according to claim **11**,

wherein a silicon oxide layer is formed on a bonded surface and an inner surface of the spacer, and the silicon oxide layer is not formed on side surfaces of the spacer.

13. The image pickup apparatus for endoscope according to claim **12**,

wherein a thickness of the silicon oxide layer on the bonded surface of the spacer is thinner than a thickness of the silicon oxide layer on the inner surface.

14. An endoscope comprising an image pickup apparatus for endoscope, the image pickup apparatus for endoscope comprising:

an optical member which includes two optical devices each having a glass plate as a base substrate and a spacer which is disposed between the two optical devices and which is formed with an inorganic material, at least one of the two optical devices being a hybrid lens device including a resin lens; and

an image pickup member configured to receive light of an object image, the light being focused by the optical member,

wherein space in which the resin lens is disposed is hermetically sealed by the optical devices being directly bonded to the spacer.

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