



(51) International Patent Classification:

H01L 21/768 (2006.01) *H01L 27/146* (2006.01)
H01L 23/48 (2006.01)

(21) International Application Number:

PCT/JP2016/004369

(22) International Filing Date:

28 September 2016 (28.09.2016)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2015-198347 6 October 2015 (06.10.2015) JP

(71) Applicant: SONY SEMICONDUCTOR SOLUTIONS CORPORATION [JP/JP]; 4-14-1, Asahi-cho, Atsugi-shi, Kanagawa, 2430014 (JP).

(72) Inventor: TOGASHI, Hideaki; c/o SONY CORPORATION, 1-7-1, Konan, Minato-ku, Tokyo, 1080075 (JP).

(74) Agents: NISHIKAWA, Takashi et al.; Nishishin-jukukimuraya Building 9F, 5-25, Nishi-Shinjuku 7-chome, Shinjuku-ku, Tokyo, 1600023 (JP).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,

BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, KE, KG, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

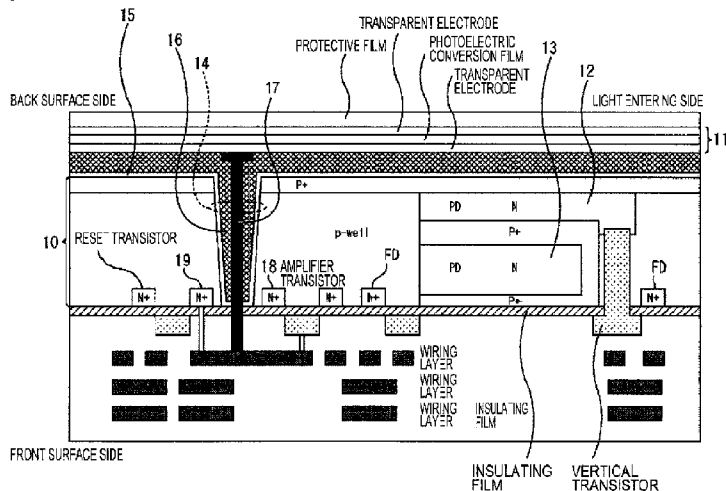
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: SOLID-STATE IMAGE SENSOR, AND ELECTRONIC DEVICE

[Fig. 3]



(57) Abstract: There is provided an image sensor including a semiconductor substrate having a first side and a second side and a photoelectric conversion element disposed at the first side of the semiconductor substrate. In addition, a through electrode is coupled to the photoelectric conversion element, where the through electrode includes a conductive portion and an insulating film. A thickness of the insulating film between the semiconductor substrate and the conductive portion at the first side of the semiconductor substrate is different than the thickness of the insulating film between the semiconductor substrate and the conductive portion at the second side of the semiconductor substrate.

Description

Title of Invention: SOLID-STATE IMAGE SENSOR, AND ELECTRONIC DEVICE

Technical Field

[0001] The present disclosure relates to a solid-state image sensor and an electronic device, and particularly relates to a solid-state image sensor and an electronic device that are preferable to use when providing a through electrode that penetrates a semiconductor substrate.

[0002] <CROSS REFERENCE TO RELATED APPLICATIONS>

This application claims the benefit of Japanese Priority Patent Application JP 2015-198347 filed October 6, 2015, the entire contents of which are incorporated herein by reference.

Background Art

[0003] There is a problem that a false color is likely to be generated in a structure in which each pixel is covered by a color filter of one of R, G, and B, which is widely employed in image sensors of the past.

[0004] As a method that solves this problem, there is a proposal of a structure in which photoelectric conversion regions (photo diode (PD), etc.) that photoelectrically convert light of respective wavelengths of R (RED), G (GREEN), and B (BLUE) are layered in a vertical direction in each pixel region (for example, refer to Patent Literature 1).

[0005] Also, there is a proposal of a structure that provides a photoelectric conversion region (a photoelectric conversion film, etc.) outside a semiconductor substrate (for example, refer to Patent Literature 2 or 3).

[0006] When this structure is applied to a back-side illuminated solid-state image sensor, there is a known structure in which a through electrode that penetrates a semiconductor substrate is provided to transfer electric charge obtained by a photoelectric conversion film of a back surface side to a front surface side of the semiconductor substrate (for example, refer to Patent Literature 4).

Citation List

Patent Literature

[0007] PTL 1: JP 04491323B

PTL 2: JP 2010-278086A

PTL 3: JP 2011-138927A

PTL 4: JP 2011-29337A

Summary of Invention

Technical Problem

- [0008] When the through electrode is provided in the semiconductor substrate of the solid-state image sensor, the following problem can occur.
- [0009] In general, in the through electrode its center part is formed of a conductor, and an insulating film is formed between the conductor and the semiconductor substrate. The through electrode penetrates the semiconductor substrate, and is connected to a modulation transistor and a floating diffusion (FD). Hence, electrostatic capacitance is generated between the through electrode and the semiconductor substrate, and there is a problem: if this electrostatic capacitance is large, conversion efficiency decreases, and the quality of obtained pixel signals decreases. Note that enlarging the distance between the through electrode and the semiconductor substrate is a comparatively easy measure in order to reduce the electrostatic capacitance but, in that case, the area of the through electrode becomes large, and the element area is enlarged.
- [0010] The present disclosure is made in view of the above situation, and can improve pixel characteristics by reducing the electrostatic capacitance of the through electrode.

Solution to Problem

- [0011] According to an embodiment of the present disclosure, there is provided an imaging device including a semiconductor substrate having a first side and a second side. The imaging device includes a photoelectric conversion element disposed at the first side of the semiconductor substrate and a through electrode coupled to the photoelectric conversion element, where the through electrode includes a conductive portion and an insulating film. Further, a thickness of the insulating film between the semiconductor substrate and the conductive portion at the first side of the semiconductor substrate is different than the thickness of the insulating film between the semiconductor substrate and the conductive portion at the second side of the semiconductor substrate.
- [0012] According to an embodiment of the present disclosure, there is provided an electronic device including an image sensor. The image sensor includes a semiconductor substrate having a first side and a second side, a photoelectric conversion element disposed at the first side of a semiconductor substrate, and a through electrode coupled to the photoelectric conversion element, where the through electrode includes a conductive portion and an insulating film. A thickness of the insulating film between the semiconductor substrate and the conductive portion at the first side of the semiconductor substrate is different than the thickness of the insulating film between the semiconductor substrate and the conductive portion at the second side of the semiconductor substrate.
- [0013] According to an embodiment of the present disclosure, there is provided an imaging device including a semiconductor substrate having a first side and a second side and a

photoelectric conversion element disposed at the first side of the semiconductor substrate. A through electrode is coupled to the photoelectric conversion element, where the through electrode includes a conductive portion and an insulating film. A cross-sectional area of the through electrode at the first side of the semiconductor substrate is different than the cross-sectional area of the through electrode at the second side of the semiconductor substrate.

Advantageous Effects of Invention

[0014] According to an embodiment of the present disclosure, the electrostatic capacitance of the through electrode can be reduced, and the pixel characteristics can be improved.

Brief Description of Drawings

[0015] [fig.1]FIG. 1 is a diagram for describing an overview of an embodiment of the present disclosure.

[fig.2]FIG. 2 is a diagram for describing an overview of an embodiment of the present disclosure.

[fig.3]FIG. 3 is a cross-sectional view illustrating a first exemplary configuration of a back-side illuminated solid-state image sensor that employs an embodiment of the present disclosure.

[fig.4]FIG. 4 is a cross-sectional view illustrating a third exemplary configuration of a back-side illuminated solid-state image sensor that employs an embodiment of the present disclosure.

[fig.5]FIG. 5 is a cross-sectional view illustrating a fifth exemplary configuration of a back-side illuminated solid-state image sensor that employs an embodiment of the present disclosure.

[fig.6]FIG. 6 is a cross-sectional view illustrating a seventh exemplary configuration of a back-side illuminated solid-state image sensor that employs an embodiment of the present disclosure.

[fig.7]FIG. 7 is a diagram illustrating an exemplary variant of a shape of a through hole that opens when a through electrode is formed.

[fig.8A]FIG. 8A is a diagram illustrating an exemplary arrangement of a through electrode formed in a taper shape.

[fig.8B]FIG. 8B is a diagram illustrating an exemplary arrangement of a through electrode formed in a taper shape.

[fig.8C]FIG. 8C is a diagram illustrating an exemplary arrangement of a through electrode conductor formed in a taper shape.

[fig.8D]FIG. 8D is a diagram illustrating an exemplary arrangement of a through electrode formed in a taper shape.

[fig.9]FIG. 9 is a diagram illustrating examples of a cross-sectional shape in a

horizontal direction of a through electrode.

[fig.10]FIG. 10 is a cross-sectional view illustrating a production process of a first exemplary configuration of a back-side illuminated solid-state image sensor that employs an embodiment of the present disclosure.

[fig.11]FIG. 11 is a cross-sectional view illustrating a production process of a first exemplary configuration of a back-side illuminated solid-state image sensor that employs an embodiment of the present disclosure.

[fig.12]FIG. 12 is a cross-sectional view illustrating a production process of a first exemplary configuration of a back-side illuminated solid-state image sensor that employs an embodiment of the present disclosure.

[fig.13]FIG. 13 is a cross-sectional view illustrating a production process of a first exemplary configuration of a back side illuminated solid-state image sensor that employs an embodiment of the present disclosure.

[fig.14]FIG. 14 is a cross-sectional view illustrating a production process of a first exemplary configuration of a back-side illuminated solid-state image sensor that employs an embodiment of the present disclosure.

[fig.15]FIG. 15 is a cross-sectional view illustrating a production process of a first exemplary configuration of a back-side illuminated solid-state image sensor that employs an embodiment of the present disclosure.

[fig.16]FIG. 16 is a diagram illustrating a usage example of an electronic device that employs an embodiment of the present disclosure.

[fig.17]FIG. 17 is a diagram illustrating an electronic device that employs an embodiment of the present disclosure.

Description of Embodiments

[0016] In the following, the best mode for carrying out the present disclosure (hereinafter, referred to as "embodiment") will be described in detail with reference to the drawings.

[0017] <Overview of Present Disclosure>

First, an overview of an embodiment of the present disclosure will be described with reference to FIGS. 1 and 2.

[0018] FIG. 1 is a cross-sectional view illustrating a first exemplary configuration of a through electrode that is formed to reduce electrostatic capacitance as compared with previous methods.

[0019] In the first exemplary configuration, the outer diameter of a through electrode 14 formed in the semiconductor substrate 10 is formed thick at a surface side that has a spare element area, and is formed thin at a side that has no spare element area (in FIG. 1, thick at the lower side, and thin at the upper side). That is, the through electrode is formed in a taper shape (a tapering-off shape) in the vertical direction. The angle of the

taper shape is in the range of 90 degrees to 70 degrees.

[0020] With regard to the through electrode 14, an insulating film 16 is formed around a conductor 17 of a constant thickness. In the case of the first exemplary configuration, the area occupied by the through electrode 14 at the upper side in the drawing, which has no spare element area, can be made small. Also, the film thickness of the insulating film 16 at the lower side in the drawing, which has a spare element area, is formed thick, and thereby reduction of electrostatic capacitance is achieved. Moreover, a cross-sectional area of the through electrode 14 may differ from an upper side to a lower side of the semiconductor substrate 10. That is, the cross-sectional area of the through electrode 14 at the first side of the semiconductor substrate 10 is different than the cross-sectional area of the through electrode 14 at the second side of the semiconductor substrate. Such change in cross-sectional area may be due to a change in the cross-sectional area of conductor 17, a change in the cross-sectional area of insulating film 16, or a combination of a change in the cross-sectional area of the conductor 17 and a change in the cross-sectional area of the insulating film 16.

[0021] FIG. 2 is a cross-sectional view illustrating a second exemplary configuration of the through electrode 14 that is formed to reduce the electrostatic capacitance as compared with previous methods.

[0022] In the second exemplary configuration, a through hole of a ring shape (doughnut shape) that has a constant outer diameter and a taper shape (in FIG. 2, the lower side is wide, and the upper side is narrow) is formed on the semiconductor substrate 10, and the insulating film 16 is filled there. Further, the through electrode 14 is formed and includes a conductive part whose resistance value is decreased by doping P impurity 21 into the semiconductor of the center part of the ring shape. In the case of the second exemplary configuration, the film thickness of the insulating film 16 at the upper side of the drawing is formed thick, and thereby reduction of electrostatic capacitance is achieved. Further, the area of the conductive part (the semiconductor in which the P impurity 21 is filled) is made wide at the lower side in the drawing, and thereby an overlap margin with a contact can be enlarged at the lower side in the drawing.

[0023] <First Exemplary Configuration of Back-Side Illuminated Solid-State Image Sensor That Employs Present Disclosure>

Next, an exemplary configuration of a back-side illuminated solid-state image sensor that employs an embodiment of the present disclosure, in which the through electrode 14 illustrated in FIG. 1 or 2 is formed, will be described.

[0024] FIG. 3 illustrates a first exemplary configuration, corresponding to one pixel, of the back-side illuminated solid-state image sensor that employs an embodiment of the present disclosure, which employs the structure of the through electrode 14 illustrated in FIG. 1.

- [0025] In the first exemplary configuration illustrated in FIG. 3, a first photoelectric conversion layer 12 and a second photoelectric conversion layer formed of PDs in the semiconductor substrate 10 is formed, and a fixed charge film 15 that includes a negative fixed charge is formed directly above the first photoelectric conversion layer 12.
- [0026] The fixed charge film 15 can employ hafnium oxide, aluminum oxide, zirconium oxide, tantalum oxide, titanium oxide, lanthanum oxide, praseodymium oxide, cerium oxide, neodymium oxide, promethium oxide, samarium oxide, europium oxide, gadolinium oxide, terbium oxide, dysprosium oxide, holmium oxide, thulium oxide, ytterbium oxide, lutetium oxide, yttrium oxide, aluminum nitride film, hafnium oxynitride film, aluminum oxynitride film, or the like, for example. Note that two or more layers of fixed charge films of different materials may be layered.
- [0027] The insulating film 16 is formed at the upper side of the fixed charge film 15. The insulating film 16 can employ dielectrics that have an insulation property, such as silicon dioxide film, TEOS, silicon nitride film, or silicon oxynitride film, for example.
- [0028] A photoelectric conversion element 11 is formed at the upper side of the insulating film 16. The photoelectric conversion element 11 is formed in such a manner that a transparent electrode sandwiches the top and bottom of the photoelectric conversion film that is sensitive to the light of G. The photoelectric conversion film can employ organic photoelectric conversion materials, such as rhodamine-based dye, merocyanine-based dye, or quinacridone, for example.
- [0029] Also, in the semiconductor substrate 10, there is formed the through electrode 14 of the taper shape for transferring the electric charge converted in the photoelectric conversion element 11 to the opposite surface side of the semiconductor substrate 10. In the center part of the through electrode 14, the conductor 17 of the constant diameter is formed. The conductor 17 can employ metal materials such as aluminium, tungsten, titanium, cobalt, hafnium, and tantalum, in addition to doped silicon materials such as phosphorus doped amorphous silicon (PDAS), for example.
- [0030] Further, in a front surface side (the lower side of the drawing) of the semiconductor substrate 10, there are formed an FD 19 for accumulating the electric charge transferred via the through electrode 14 from the photoelectric conversion element 11 and various types of transistors.
- [0031] The first photoelectric conversion layer 12 and the second photoelectric conversion layer 13 differ in absorption coefficient from each other, and the first photoelectric conversion layer 12 is sensitive to the light of B, and the second photoelectric conversion layer 13 is sensitive to the light of R.
- [0032] The electric charges generated by the photoelectric conversion in the first photoelectric conversion layer 12 and the second photoelectric conversion layer 13 are ac-

cumulated in respective regions, and thereafter is output to the outside by a read circuit (not depicted).

[0033] <Second Exemplary Configuration of Back-Side Illuminated Solid-State Image Sensor That Employs Present Disclosure>

Although not depicted, the second exemplary configuration is a case in which there is a spare element area at the front surface side of the semiconductor substrate 10, and there is no spare element area at the back surface side, as opposed to the first exemplary configuration illustrated in FIG. 3. Also, in this case, the outer diameter of the through electrode 14 is formed thick at the front surface side and thin at the back surface side.

[0034] <Third Exemplary Configuration of Back-Side Illuminated Solid-State Image Sensor That Employs Present Disclosure>

FIG. 4 illustrates a third exemplary configuration, corresponding to one pixel, of the back-side illuminated solid-state image sensor that employs an embodiment of the present disclosure.

[0035] The third exemplary configuration illustrated in FIG. 4 differs in the shape of the through electrode 14, as compared with the first exemplary configuration illustrated in FIG. 3. In the third exemplary configuration, the outer diameter of the through electrode 14 is formed in a stepwise (in FIG. 4, 1 step) tapering-off shape. Other components are the same.

[0036] When the through hole for forming the through electrode 14 is not formed in the taper shape but in the stepwise tapering-off shape, the substrate crystal orientation of the side wall of the through hole is easily aligned, and thus interface state density is reduced, and white spot and dark current characteristics are improved.

[0037] Also, in a production process, the through hole is opened with a wide diameter at the upper surface side, and thus the formation of the fixed charge film 15 and the filling of the insulating film 16 can be performed easily to the front surface of the through hole.

[0038] <Fourth Exemplary Configuration of Back-Side Illuminated Solid-State Image Sensor That Employs Present Disclosure>

Although not depicted, a fourth exemplary configuration is a case in which there is a spare element area at the front surface side of the semiconductor substrate 10, and there is no spare element area at the back surface side, as opposed to the third exemplary configuration illustrated in FIG. 4, and in this case, the outer diameter of the through electrode 14 is formed thick at the front surface side and thin at the back surface side.

[0039] <Fifth Exemplary Configuration of Back-Side Illuminated Solid-State Image Sensor That Employs Present Disclosure>

FIG. 5 illustrates a fifth exemplary configuration, corresponding to one pixel, of the

back-side illuminated solid-state image sensor that employs an embodiment of the present disclosure, which employs the structure of the through electrode 14 illustrated in FIG. 2.

[0040] The fifth exemplary configuration illustrated in FIG. 5 differs in the structure of the through electrode 14, as compared with the first exemplary configuration illustrated in FIG. 3, and other components are the same.

[0041] That is, in the fifth exemplary configuration, an annular through hole is formed in the semiconductor substrate 10, and the P impurity 21 is doped into the semiconductor part that is left in the taper shape at the center, and thereby the resistance value is reduced, and the conductive part is formed. Also, in the semiconductor part that is left in the taper shape at the center of the annular through hole, a high concentration impurity region for reducing contact resistance is formed by doping the P impurity 21. Further, the P impurity 21 is also doped in the outer wall of the annular through hole, and the fixed charge film 15 is formed together on the upper surface, in order to form a hole storage layer. The insulating film 16 is formed on the fixed charge film 15. Note that an air gap may be provided at the center part of the insulating film 16 in the through hole.

[0042] In the case of the fifth exemplary configuration, the width of a groove of the through hole formed in the ring shape is formed to be wide at the back surface side that has a spare element area, as opposed to the front surface side that has no spare element area, and thus the thickness of the insulating film 16 in the through electrode 14 becomes thick at the back surface side to reduce the electrostatic capacitance. Also, the diameter of the conductive part (the semiconductor in which the P impurity 21 is doped) in the through electrode 14 is formed thin at an R surface side and thick at the front surface side, and thus the overlap margin improves between the contact of the front surface side and (the conductor 17 of) the through electrode 14.

[0043] <Sixth Exemplary Configuration of Back-Side Illuminated Solid-State Image Sensor That Employs Present Disclosure>

Although not depicted, a sixth exemplary configuration is a case in which there is a spare element area at the front surface side of the semiconductor substrate 10, and there is no spare element area at the back surface side, as opposed to the fifth exemplary configuration illustrated in FIG. 5. Also, in this case, the outer diameter of the through electrode 14 is formed thick at the front surface side and thin at the back surface side.

[0044] <Seventh Exemplary Configuration of Back-Side Illuminated Solid-State Image Sensor That Employs Present Disclosure>

FIG. 6 illustrates a seventh exemplary configuration, corresponding to one pixel, of the back-side illuminated solid-state image sensor that employs an embodiment of the

present disclosure.

[0045] The seventh exemplary configuration illustrated in FIG. 6 differs in the shape of the through electrode 14, as compared with the fifth exemplary configuration illustrated in FIG. 5. In the seventh exemplary configuration, the outer diameter and the inner diameter of the through hole formed in the ring shape are formed in a stepwise (in FIG. 6, 1 step) tapering-off shape. Other components are the same.

[0046] When the through hole for forming the through electrode 14 is not the taper shape but the stepwise tapering-off shape, the substrate crystal orientation of the side wall of the through hole is easily aligned, and thus the interface state density is reduced, and the white spot and dark current characteristics can be improved.

[0047] <Eighth Exemplary Configuration of Back-Side Illuminated Solid-State Image Sensor That Employs Present Disclosure>

Although not depicted, an eighth exemplary configuration is a case in which there is a spare element area at the front surface side of the semiconductor substrate 10, and there is no spare element area at the back surface side, as opposed to the seventh exemplary configuration illustrated in FIG. 6. Also, in this case, the outer diameter of the through electrode 14 is formed thick at the front surface side and thin at the back surface side.

[0048] <Shape of Through Hole That Opens When Through Electrode 14 is Formed>

Thereafter, FIG. 7 illustrates transformation of the shape of the through hole that is opened to form the through electrode 14.

[0049] As described above, a through hole 31 that is opened to form the through electrode 14 is formed in the taper shape, but the end portion may be opened more widely, as illustrated in FIG. 7A. Also, on the contrary, the end portion may be opened more narrowly, as illustrated in FIG. 7B. Also, although not depicted, only one of the end portions of the through hole 31 is made wider or narrower. Further, one of the end portions of the through hole 31 may be made wider, while the other end is made narrower.

[0050] <Direction of Through Electrode 14 in Taper Shape>

The direction of the taper shape does not need to be aligned when a plurality of through electrodes 14 are provided in the semiconductor substrate 10. For example, as illustrated in FIG. 8A, the taper shape may be changed alternately, depending on the presence or absence of the spare element area at the position where the through electrodes 14 are provided in the semiconductor substrate 10. Also, the outer diameters of the through electrodes 14 of the taper shape and the diameters of the conductors 17 formed at the center part do not need to be equal.

[0051] Moreover, in some embodiments, one or more components of the through electrode 14 may taper. For example, as illustrated in FIG. 8B, the thickness of the insulation

film may remain constant, or about constant. Alternatively, or in addition, the insulating film 16 may taper, the conductor 17 may taper, or both the insulating film 16 and the conductor 17 may taper, as further illustrated in FIG. 8B. As illustrated in FIG. 8C, the through electrode 14 may have a constant, or near constant, width while the conductor 17 may taper. Further, and as illustrated in FIG. 8D, the insulating film 16 may taper in a direction opposite to which the conductor 17 tapers.

[0052] <Cross-Sectional Shape in Horizontal Direction of Through Electrode 14>

FIG. 9 illustrates examples of the cross-sectional shape in the horizontal direction of the through electrode 14.

[0053] FIG. 9A and FIG. 9B are the structures formed by filling the through hole with the insulating film 16 and embedding the conductor 17 in the center part of the insulating film 16. FIG. 9A illustrates an example when the cross section in the horizontal direction is a circle, and FIG. 9B illustrates an example when the cross section in the horizontal direction is a rectangle.

[0054] FIG. 9C and FIG. 9D are the structures of the conductive part formed by filling the insulating film 16 in the through hole formed in the ring shape and doping the P impurity 21 into the semiconductor that is left at the center part of the through hole. FIG. 9C illustrates an example when the cross section in the horizontal direction is a circle, and FIG. 9D illustrates an example when the cross section in the horizontal direction is a rectangle.

[0055] Note that the cross-sectional shape in the horizontal direction of the through electrode 14 is not limited to the illustrated circle or rectangle. Also, the through electrodes 14 of different cross-sectional shapes may be mixed in the same semiconductor substrate 10.

[0056] <Production Method of Back-Side Illuminated Solid-state Image Sensor That Employs Present Disclosure>

Next, a production process of the first exemplary configuration of the back-side illuminated solid-state image sensor illustrated in FIG. 3 will be described.

[0057] FIGS. 10 to 15 illustrate the production process of the first exemplary configuration of the back-side illuminated solid-state image sensor.

[0058] First, as illustrated in FIG. 10, the first photoelectric conversion layer 12, the second photoelectric conversion layer 13, various types of transistors, and the like are formed in the semiconductor substrate 10 such as a silicon on insulator (SOI) substrate, and then a wiring layer is formed.

[0059] Thereafter, as illustrated in FIG. 11, the through hole 31 of the taper shape is formed by dry etching or the like from the back surface side, at the position where the through electrode 14 is provided in the semiconductor substrate 10. Thereafter, as illustrated in FIG. 12, the fixed charge film 15 is layered on the entire semiconductor substrate 10

that includes the through hole 31, and as illustrated in FIG. 13, the insulating film 16 is layered on the fixed charge film 15 in order to fill the through hole 31.

[0060] Thereafter, as illustrated in FIG. 14, the through hole 32 is formed until the through hole 32 reaches the conductor to be connected at the front surface side, at the center part of the insulating film 16 that fills in the through hole 31, and as illustrated in FIG. 15, the conductor 17 is embedded in the through hole 32.

[0061] Although not depicted, thereafter, the conductor 17 on the flat surface at the back surface side is polished and removed by CMP, and an oxide film is deposited, and a contact is formed, and the photoelectric conversion element 11 is layered. A protective film such as silicon nitride may be formed at the upper portion of the photoelectric conversion element. Further, an optical member such as a flat film is formed, and an on-chip lens is formed.

[0062] The first exemplary configuration of the back side illuminated solid-state image sensor is produced by the process described above. Note that the second to eighth exemplary configurations of the back side illuminated solid-state image sensor can also be produced by adding existing production technologies to the same production method as the following description.

[0063] <Usage Example of Back Side Illuminated Solid-state Image Sensor That Employs Present Disclosure>

FIG. 16 is a diagram illustrating a usage example that uses the above back side illuminated solid-state image sensor.

[0064] The back side illuminated solid-state image sensor described above can be used in various cases of, for example, sensing light such as visible light, infrared light, ultraviolet light, and X-rays as is described below.

[0065] -Devices that take images used for viewing, such as a digital camera and a portable appliance with a camera function.

-Devices used for traffic, such as an in-vehicle sensor that takes images of the front and the back of a car, surroundings, the inside of the car, and the like, a monitoring camera that monitors travelling vehicles and roads, and a distance sensor that measures distances between vehicles and the like, which are used for safe driving (e.g., automatic stop), recognition of the condition of a driver, and the like.

-Devices used for home electrical appliances, such as a TV, a refrigerator, and an air conditioner, to take images of a gesture of a user and perform appliance operation in accordance with the gesture.

-Devices used for medical care and health care, such as an endoscope and a device that performs angiography by reception of infrared light.

-Devices used for security, such as a monitoring camera for crime prevention and a camera for personal authentication.

-Devices used for beauty care, such as skin measurement equipment that takes images of the skin and a microscope that takes images of the scalp.

-Devices used for sports, such as an action camera and a wearable camera for sports and the like.

-Devices used for agriculture, such as a camera for monitoring the condition of the field and crops.

[0066] Fig. 17 is a block diagram illustrating a configuration example of a camera apparatus, which is an example of an electronic apparatus to which the present technology is applied.

[0067] A camera apparatus 70 in Fig. 17 includes an optical unit 71 including a lens group and the like, a solid-state imaging element (imaging element) 72 which employs the above-described respective configurations of the pixels 72, and a DSP circuit 73, which is a camera signal processing circuit. In addition, the camera apparatus 70 includes a frame memory 74, a display unit 75, a recording unit 76, an operation unit 77, and a power supply unit 78. The DSP circuit 73, the frame memory 74, the display unit 75, the recording unit 76, the operation unit 77, and the power supply unit 78 are connected to each other via a bus line 79.

[0068] The optical unit 71 receives incident light (image light) from a subject so as to be imaged on an imaging surface of the solid-state imaging element 72. The solid-state imaging element 72 converts a light amount of the incident light, which is imaged on the imaging surface by the optical unit 71, into an electric signal in the unit of a pixel and outputs the electric signal as a pixel signal. The solid-state imaging device related to the above-described embodiments may be used as the solid-state imaging element 72.

[0069] The display unit 75 includes, for example, a panel-type display device such as a liquid crystal panel or an organic electroluminescence (EL) panel, and displays moving images or still images captured by the solid-state imaging element 72. The recording unit 76 records moving images or still images captured by the solid-state imaging element 72 on a recording medium such as a video tape or a digital versatile disk (DVD).

[0070] The operation unit 77 issues operation commands for various functions of the camera apparatus 70 in response to an operation by a user. The power source unit 78 appropriately supplies a variety of power, which is operation power of the DSP circuit 73, the frame memory 74, the display unit 75, the recording unit 76, and the operation unit 77, to the supply targets.

[0071] In addition, embodiments of the present disclosure are not limited to the above-described embodiments, and various alterations may occur insofar as they are within the scope of the present disclosure.

[0072] Additionally, the present technology may also be configured as below.

(1)

An imaging device, including:

a semiconductor substrate having a first side and a second side;

a photoelectric conversion element disposed at the first side of the semiconductor substrate; and

a through electrode coupled to the photoelectric conversion element, the through electrode including a conductive portion and an insulating film,

wherein a thickness of the insulating film between the semiconductor substrate and the conductive portion at the first side of the semiconductor substrate is different than the thickness of the insulating film between the semiconductor substrate and the conductive portion at the second side of the semiconductor substrate.

(2)

The imaging device according to (1), wherein the through electrode penetrates the semiconductor substrate and transfers the electric charge converted by the photoelectric conversion of the photoelectric conversion element to at least one of an amplifier transistor or a floating diffusion formed at the second side of the semiconductor substrate.

(3)

The imaging device according to (1) or (2), wherein the thickness of the insulating film between the semiconductor substrate and the conductive portion gradually changes from the first side of the semiconductor substrate to the second side of the semiconductor substrate.

(4)

The imaging device according to any of (1) to (3), wherein the thickness of the insulating film between the semiconductor substrate and the conductive portion gradually changes having a slope within a range of 90 degrees to 70 degrees from the first side of the semiconductor substrate to the second side of the semiconductor substrate.

(5)

The imaging device according to any of (1) or (2), wherein the thickness of the insulating film between the semiconductor substrate and the conductive portion changes in a stepwise fashion from the first side of the semiconductor substrate to the second side of the semiconductor substrate.

(6)

The imaging device according to any of (1) to (5), wherein the insulating film includes a dielectric having an insulation property.

(7)

The imaging device according to any of (1) to (6), wherein both end portions of the insulating film at the first side of the substrate and the second side of the semiconductor substrate are tapered with respect to non-end portions of the insulating film.

(8)

The imaging device according to any of (1) to (7), wherein the center portion of the through electrode includes at least one of a metal or conductive material.

(9)

The imaging device according to any of (1) to (8), wherein the through electrode is formed for each pixel.

(10)

The imaging device according to any of (1) to (9), wherein a first through electrode in which the thickness of the insulating film between the semiconductor substrate and a first conductive portion at the first side of the semiconductor substrate is thicker than the thickness of the insulating film between the semiconductor substrate and the first conductive portion at the second side of the semiconductor substrate is disposed in the semiconductor substrate, and

a second through electrode in which the thickness of the insulating film between the semiconductor substrate and a second conductive portion at the second side of the semiconductor substrate is thicker than the thickness of the insulating film between the semiconductor substrate and the second conductive portion at the first side of the semiconductor substrate is disposed in the semiconductor substrate.

(11)

The imaging device according to any of (1) to (10), wherein the semiconductor substrate includes a plurality of through electrodes having differing diameters.

(12)

The imaging device according to any of (1) to (11), wherein a cross-sectional shape of the through electrode in a horizontal direction is a circle or a rectangle.

(13)

The imaging device according any of (1) to (12), further comprising:

a first photoelectric conversion layer formed in the semiconductor substrate and sensitive to light of a wavelength that differs from a wavelength of light to which the photoelectric conversion element is sensitive; and

a second photoelectric conversion layer formed in the semiconductor substrate and sensitive to light of a wavelength that differs from wavelengths of light to which the photoelectric conversion element and the first photoelectric conversion layer are sensitive.

(14)

An electronic device comprising:

an image sensor, the image sensor including:

a semiconductor substrate having a first side and a second side,

a photoelectric conversion element disposed at the first side of a semiconductor substrate, and

a through electrode coupled to the photoelectric conversion element, the through electrode including a conductive portion and an insulating film,

wherein a thickness of the insulating film between the semiconductor substrate and the conductive portion at the first side of the semiconductor substrate is different than the thickness of the insulating film between the semiconductor substrate and the conductive portion at the second side of the semiconductor substrate.

(15)

An imaging device, comprising:

a semiconductor substrate having a first side and a second side;

a photoelectric conversion element disposed at the first side of the semiconductor substrate; and

a through electrode coupled to the photoelectric conversion element, the through electrode including a conductive portion and an insulating film,

wherein a cross-sectional area of the through electrode at the first side of the semiconductor substrate is different than the cross-sectional area of the through electrode at the second side of the semiconductor substrate.

(16)

The imaging device according to (15), wherein a thickness of the insulating film between the semiconductor substrate and the conductive portion at the first side of the semiconductor substrate is different than the thickness of the insulating film between the semiconductor substrate and the conductive portion at the second side of the semiconductor substrate.

(17)

The imaging device according to (15) or (16), wherein a thickness of the conductive portion at the first side of the semiconductor substrate is different than the thickness of the conductive portion at the second side of the semiconductor substrate.

(18)

The imaging device according to any of (15) to (17), wherein a first through electrode in which the cross-sectional area of the first through electrode at the first side of the semiconductor substrate is greater than the cross-sectional area of the first through electrode at the second side of the semiconductor substrate is disposed in the semiconductor substrate, and

a second through electrode in which the cross-sectional area of the second through electrode at the second side of the semiconductor substrate is greater than the cross-

sectional area of the second through electrode at the first side of the semiconductor substrate is disposed in the semiconductor substrate.

(19)

A solid state image sensor including:

a photoelectric conversion element formed in one surface side of front and back surfaces of a semiconductor substrate; and

a through electrode that penetrates the semiconductor substrate, and is configured to transfer electric charge converted by photoelectric conversion of the photoelectric conversion element to another surface side of the front and back surfaces of the semiconductor substrate,

wherein the through electrode includes a center part that transfers the electric charge and an insulating film that surrounds the center part, and

the insulating film that forms the through electrode has different thicknesses at one surface and another surface of the semiconductor substrate.

(20)

The solid state image sensor according to (19), wherein

the through electrode penetrates the semiconductor substrate, and transfers the electric charge converted by the photoelectric conversion of the photoelectric conversion element, to at least one of an amplifier transistor or a floating diffusion formed at the other surface side of the front and back surfaces of the semiconductor substrate.

(21)

The solid state image sensor according to (19) or (20), wherein

the thickness of the insulating film that forms the through electrode gradually changes from the one surface of the semiconductor substrate to the other surface.

(22)

The solid state image sensor according to any of (19) to (21), wherein

the thickness of the insulating film that forms the through electrode gradually changes with a slope within a range of 90 degrees to 70 degrees from the one surface of the semiconductor substrate to the other surface.

(23)

The solid state image sensor according to (19) or (20), wherein

the thickness of the insulating film that forms the through electrode changes in a stepwise fashion from the one surface of the semiconductor substrate to the other surface.

(24)

The solid state image sensor according to any of (19) to (23), wherein

the insulating film that forms the through electrode is made of dielectric that has an insulation property.

(25)

The solid state image sensor according to any of (19) to (24), wherein both end portions of the insulating film that forms the through electrode are formed with a slope that differs from a slope of a straight line part other than the both end portions.

(26)

The solid state image sensor according to any of (19) to (25), wherein the center part of the through electrode is made of metal or conductive material.

(27)

The solid state image sensor according to any of (19) to (26), wherein the through electrode is formed for each pixel.

(28)

The solid state image sensor according to any of (19) to (27), wherein a first through electrode in which the thickness of the insulating film becomes thicker from the one surface of the semiconductor substrate to the other surface, and a second through electrode in which the thickness of the insulating film becomes thicker from the other surface of the semiconductor substrate to the one surface are mixed in the semiconductor substrate.

(29)

The solid state image sensor according to any of (19) to (28), wherein a plurality of the through electrodes that differ in diameter are mixed in the semiconductor substrate.

(30)

The solid state image sensor according to any of (19) to (29), wherein a cross-sectional shape in a horizontal direction of the through electrode is a circle or a rectangle.

(31)

The solid state image sensor according to any of (19) to (30), further including:
a first photoelectric conversion layer formed in the semiconductor substrate, and sensitive to light of a wavelength that differs from a wavelength of light to which the photoelectric conversion element is sensitive; and
a second photoelectric conversion layer formed in the semiconductor substrate, and sensitive to light of a wavelength that differs from wavelengths of light to which the photoelectric conversion element and the first photoelectric conversion layer are sensitive.

(32)

An electronic device including a solid state image sensor,
the solid state image sensor including

a photoelectric conversion element formed in one surface side of front and back surfaces of a semiconductor substrate, and
a through electrode that penetrates the semiconductor substrate, and is configured to transfer electric charge converted by photoelectric conversion of the photoelectric conversion element to another surface side of the front and back surfaces of the semiconductor substrate,
wherein the through electrode includes a center part that transfers the electric charge and an insulating film that surrounds the center part, and
the insulating film that forms the through electrode has different thicknesses at one surface and another surface of the semiconductor substrate.

Reference Signs List

- [0073] 10 semiconductor substrate
- 11 photoelectric conversion element
- 12 first photoelectric conversion layer
- 13 second photoelectric conversion layer
- 14 through electrode
- 15 fixed charge film
- 16 insulating film
- 17 conductor
- 19 FD
- 21 P impurity
- 31 through hole
- 32 through hole

Claims

- [Claim 1] An imaging device, comprising:
a semiconductor substrate having a first side and a second side;
a photoelectric conversion element disposed at the first side of the semiconductor substrate; and
a through electrode coupled to the photoelectric conversion element, the through electrode including a conductive portion and an insulating film,
wherein a thickness of the insulating film between the semiconductor substrate and the conductive portion at the first side of the semiconductor substrate is different than the thickness of the insulating film between the semiconductor substrate and the conductive portion at the second side of the semiconductor substrate.
- [Claim 2] The imaging device according to claim 1, wherein the through electrode penetrates the semiconductor substrate and transfers an electric charge converted by the photoelectric conversion of the photoelectric conversion element to at least one of an amplifier transistor or a floating diffusion formed at the second side of the semiconductor substrate.
- [Claim 3] The imaging device according to claim 2, wherein the thickness of the insulating film between the semiconductor substrate and the conductive portion gradually changes from the first side of the semiconductor substrate to the second side of the semiconductor substrate.
- [Claim 4] The imaging device according to claim 3, wherein the thickness of the insulating film between the semiconductor substrate and the conductive portion gradually changes having a slope within a range of 90 degrees to 70 degrees from the first side of the semiconductor substrate to the second side of the semiconductor substrate.
- [Claim 5] The imaging device according to claim 2, wherein the thickness of the insulating film between the semiconductor substrate and the conductive portion changes in a stepwise fashion from the first side of the semiconductor substrate to the second side of the semiconductor substrate.
- [Claim 6] The imaging device according to claim 2, wherein the insulating film includes a dielectric having an insulation property.
- [Claim 7] The imaging device according to claim 2, wherein both end portions of the insulating film at the first side of the semiconductor substrate and the second side of the semiconductor substrate are tapered with respect

- to non-end portions of the insulating film.
- [Claim 8] The imaging device according to claim 2, wherein a center portion of the through electrode includes at least one of a metal or conductive material.
- [Claim 9] The imaging device according to claim 2, wherein the through electrode is formed for each pixel.
- [Claim 10] The imaging device according to claim 2, wherein a first through electrode in which the thickness of the insulating film between the semiconductor substrate and a first conductive portion at the first side of the semiconductor substrate is thicker than the thickness of the insulating film between the semiconductor substrate and the first conductive portion at the second side of the semiconductor substrate is disposed in the semiconductor substrate, and
a second through electrode in which the thickness of the insulating film between the semiconductor substrate and a second conductive portion at the second side of the semiconductor substrate is thicker than the thickness of the insulating film between the semiconductor substrate and the second conductive portion at the first side of the semiconductor substrate is disposed in the semiconductor substrate.
- [Claim 11] The imaging device according to claim 2, wherein the semiconductor substrate includes a plurality of through electrodes having differing diameters.
- [Claim 12] The imaging device according to claim 2, wherein a cross-sectional shape of the through electrode in a horizontal direction is a circle or a rectangle.
- [Claim 13] The imaging device according to claim 2, further comprising:
a first photoelectric conversion layer formed in the semiconductor substrate and sensitive to light of a wavelength that differs from a wavelength of light to which the photoelectric conversion element is sensitive; and
a second photoelectric conversion layer formed in the semiconductor substrate and sensitive to light of a wavelength that differs from wavelengths of light to which the photoelectric conversion element and the first photoelectric conversion layer are sensitive.
- [Claim 14] An electronic device comprising:
a solid-state image sensor, the solid-state image sensor including:
a semiconductor substrate having a first side and a second side,
a photoelectric conversion element disposed at the first side of the

semiconductor substrate, and
a through electrode coupled to the photoelectric conversion element,
the through electrode including a conductive portion and an insulating
film,
wherein a thickness of the insulating film between the semiconductor
substrate and the conductive portion at the first side of the semi-
conductor substrate is different than the thickness of the insulating film
between the semiconductor substrate and the conductive portion at the
second side of the semiconductor substrate.

[Claim 15]

An imaging device, comprising:
a semiconductor substrate having a first side and a second side;
a photoelectric conversion element disposed at the first side of the
semiconductor substrate; and
a through electrode coupled to the photoelectric conversion element,
the through electrode including a conductive portion and an insulating
film,
wherein a cross-sectional area of the through electrode at the first side
of the semiconductor substrate is different than the cross-sectional area
of the through electrode at the second side of the semiconductor
substrate.

[Claim 16]

The imaging device according to claim 15, wherein a thickness of the
insulating film between the semiconductor substrate and the conductive
portion at the first side of the semiconductor substrate is different than
the thickness of the insulating film between the semiconductor substrate
and the conductive portion at the second side of the semiconductor
substrate.

[Claim 17]

The imaging device according to claim 15, wherein a thickness of the
conductive portion at the first side of the semiconductor substrate is
different than the thickness of the conductive portion at the second side
of the semiconductor substrate.

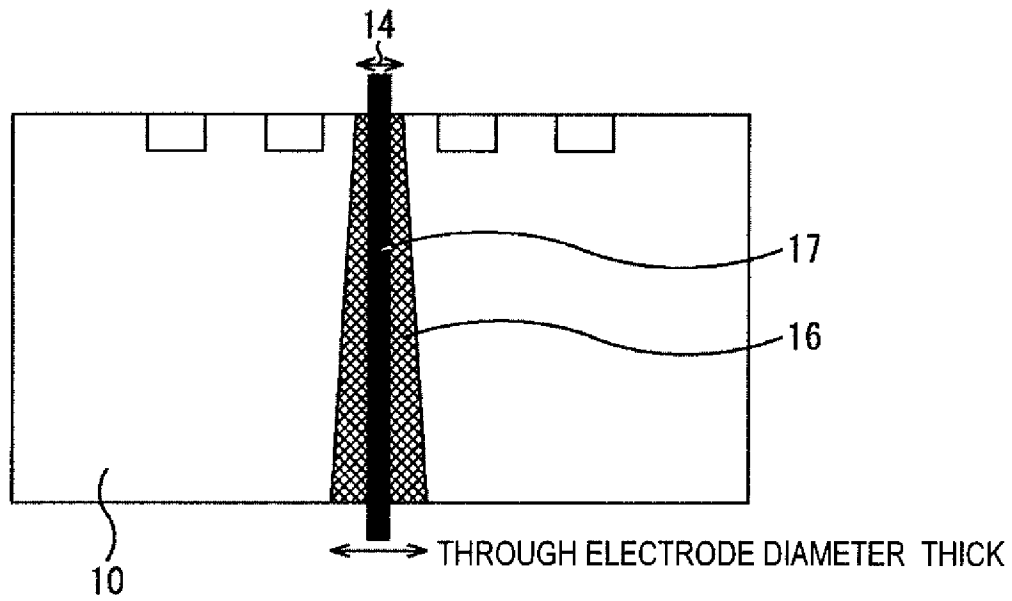
[Claim 18]

The imaging device according to claim 15, wherein a first through
electrode in which the cross-sectional area of the first through electrode
at the first side of the semiconductor substrate is greater than the cross-
sectional area of the first through electrode at the second side of the
semiconductor substrate is disposed in the semiconductor substrate, and
a second through electrode in which the cross-sectional area of the
second through electrode at the second side of the semiconductor
substrate is greater than the cross-sectional area of the second through

electrode at the first side of the semiconductor substrate is disposed in the semiconductor substrate.

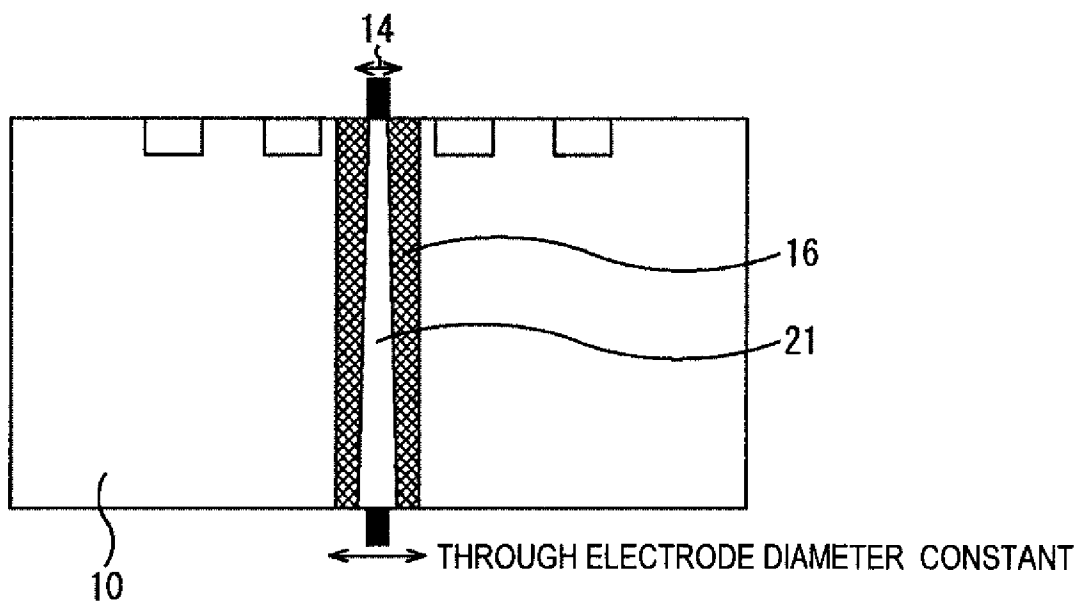
[Fig. 1]

[Fig. 1]



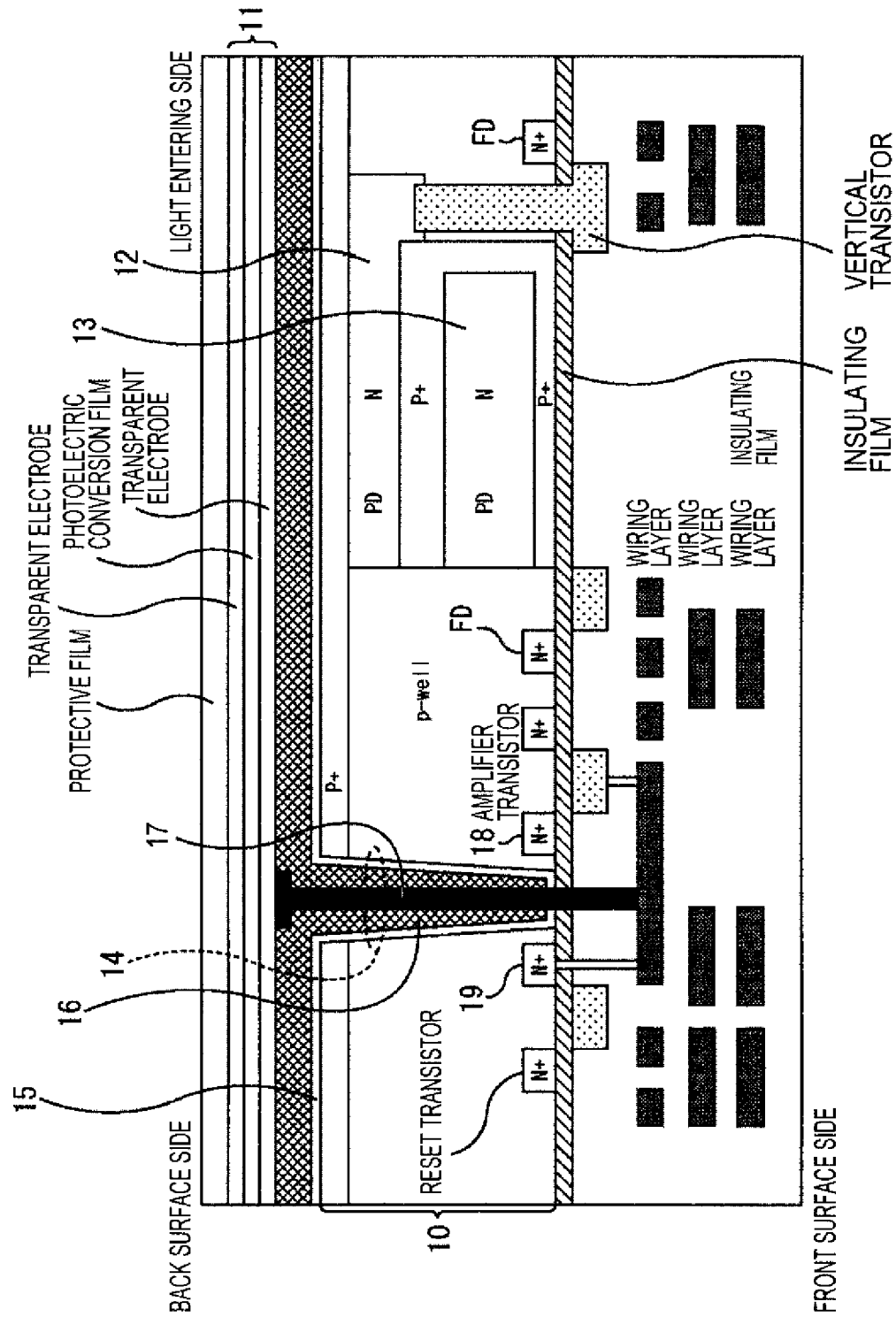
[Fig. 2]

[Fig. 2]



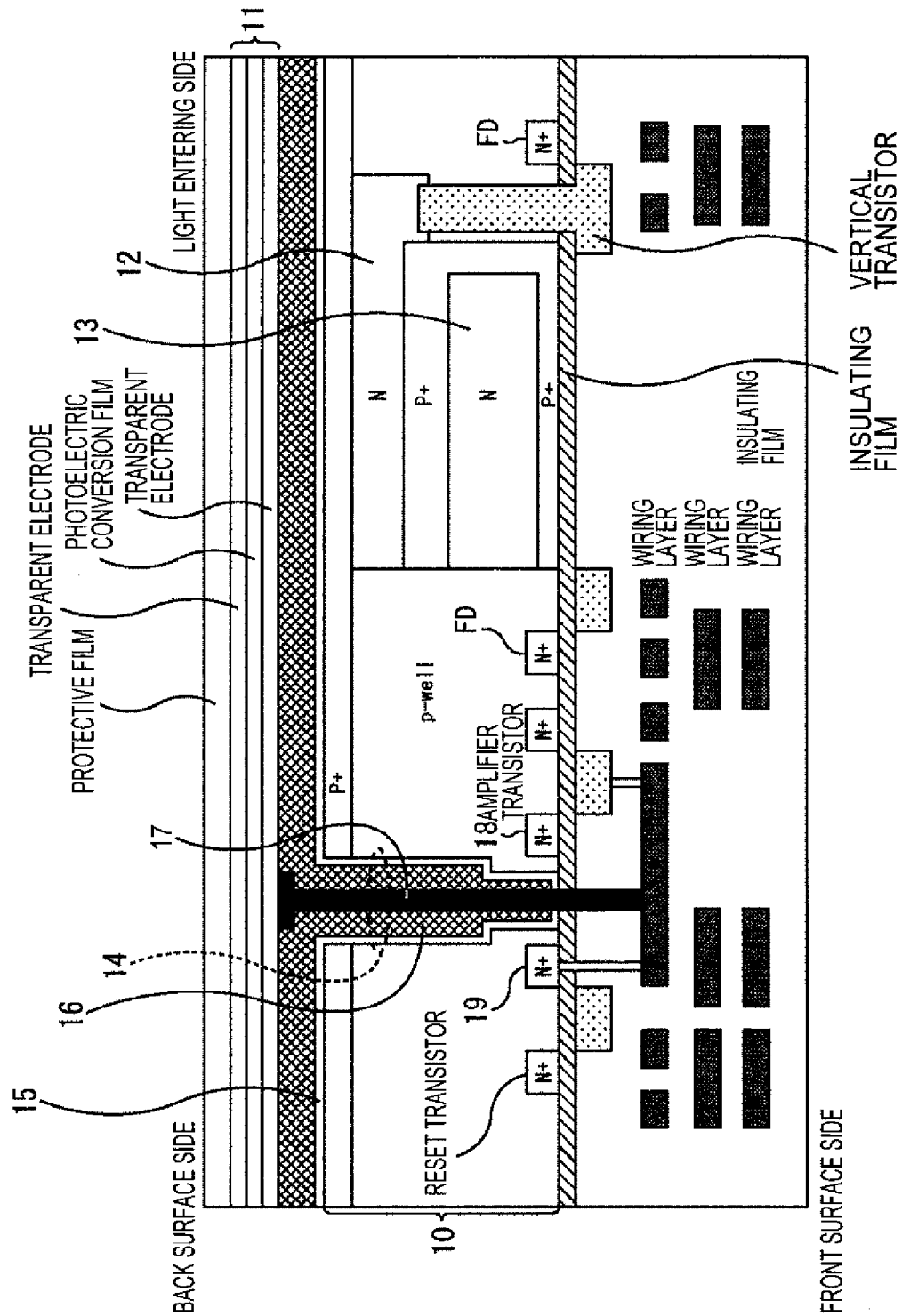
[Fig. 3]

[Fig. 3]



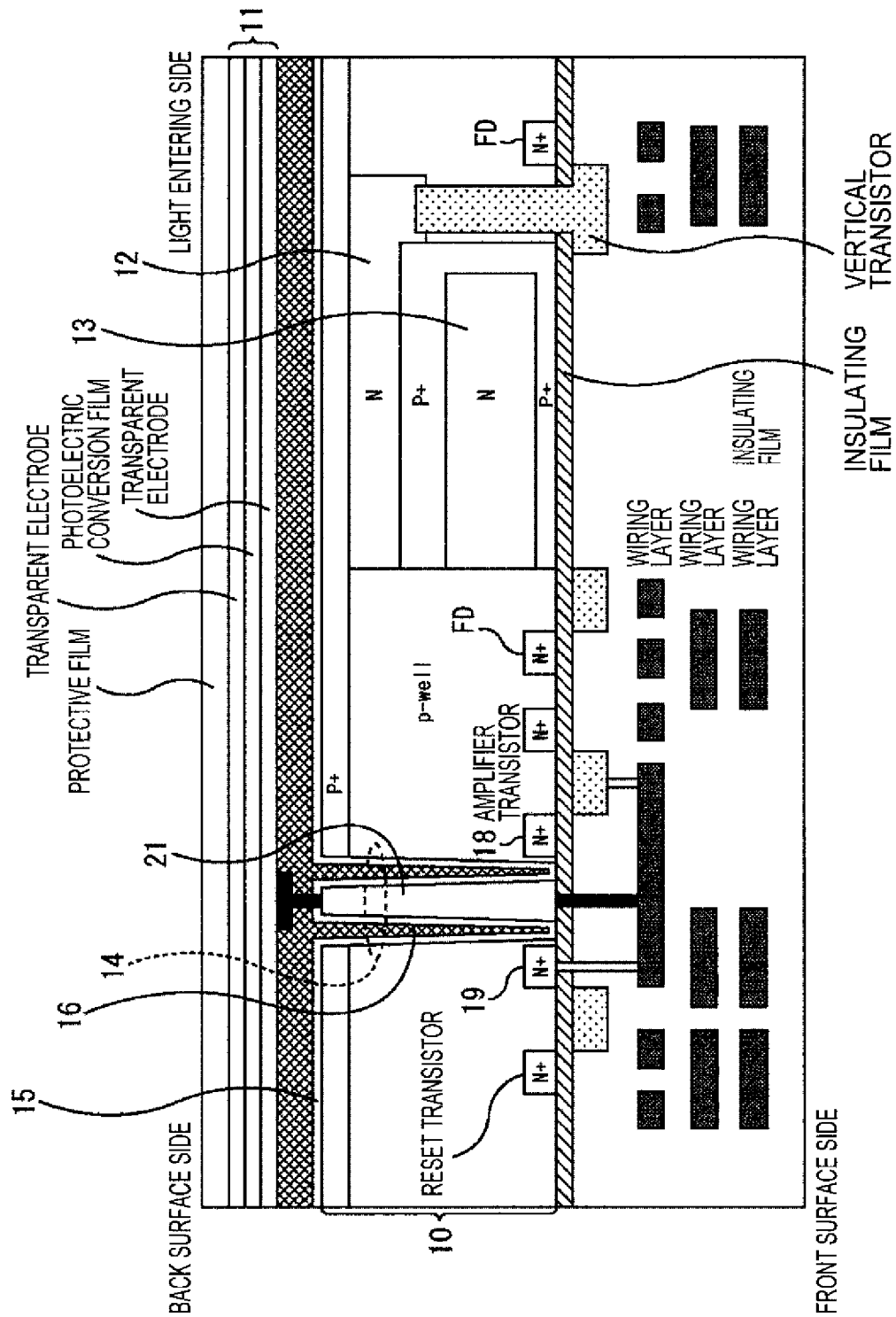
[Fig. 4]

[Fig. 4]

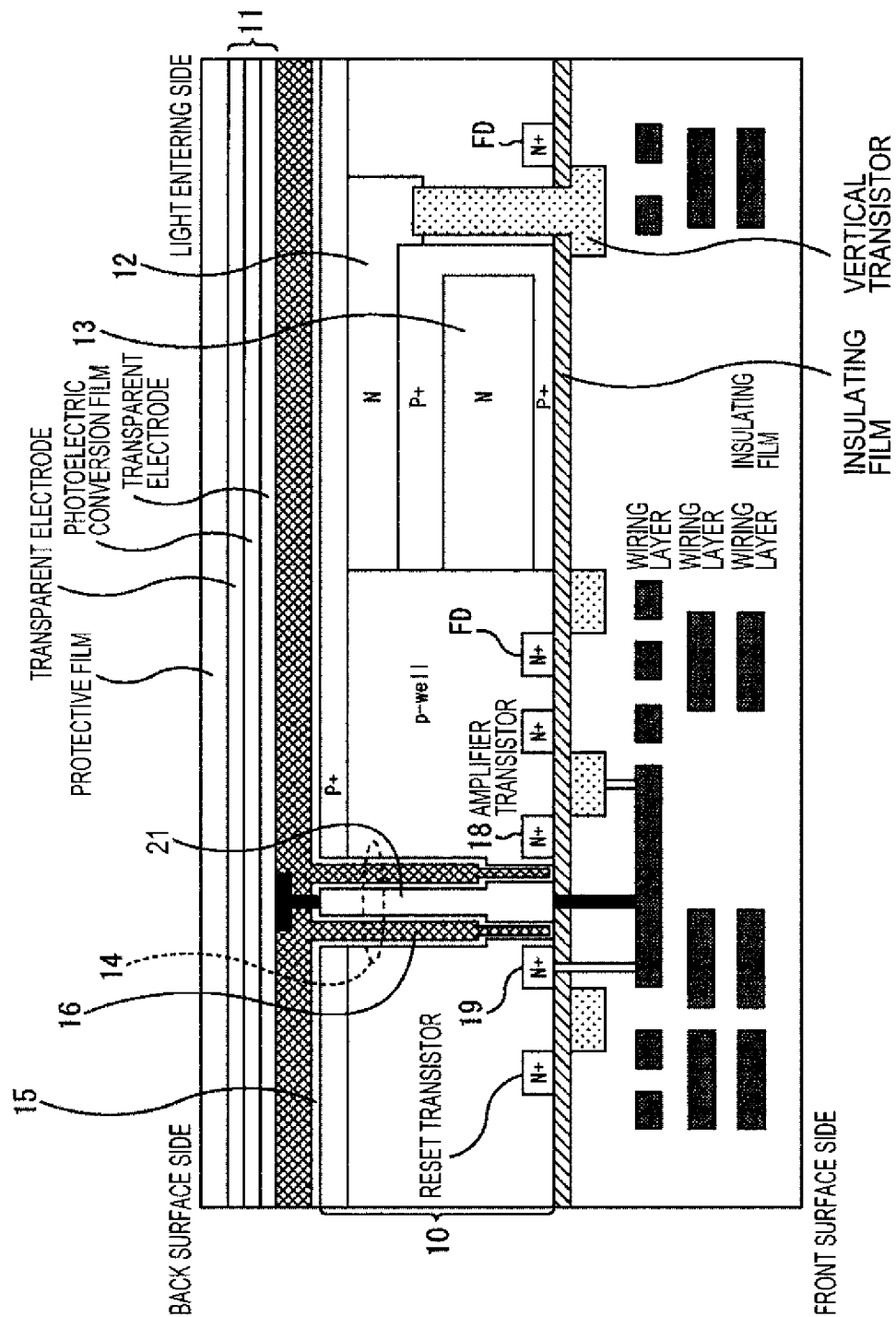


[Fig. 5]

[Fig. 5]

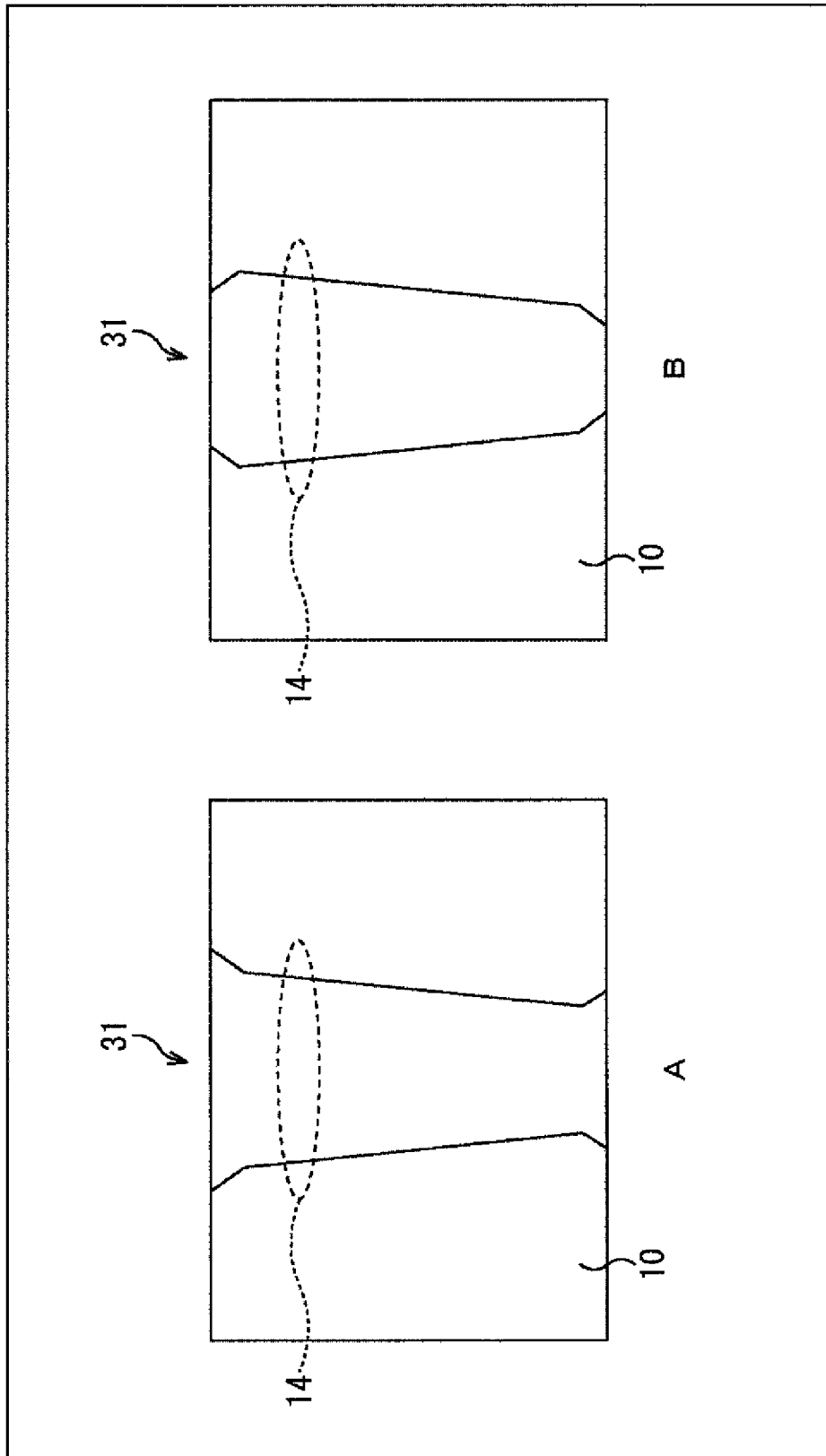


[Fig. 6]



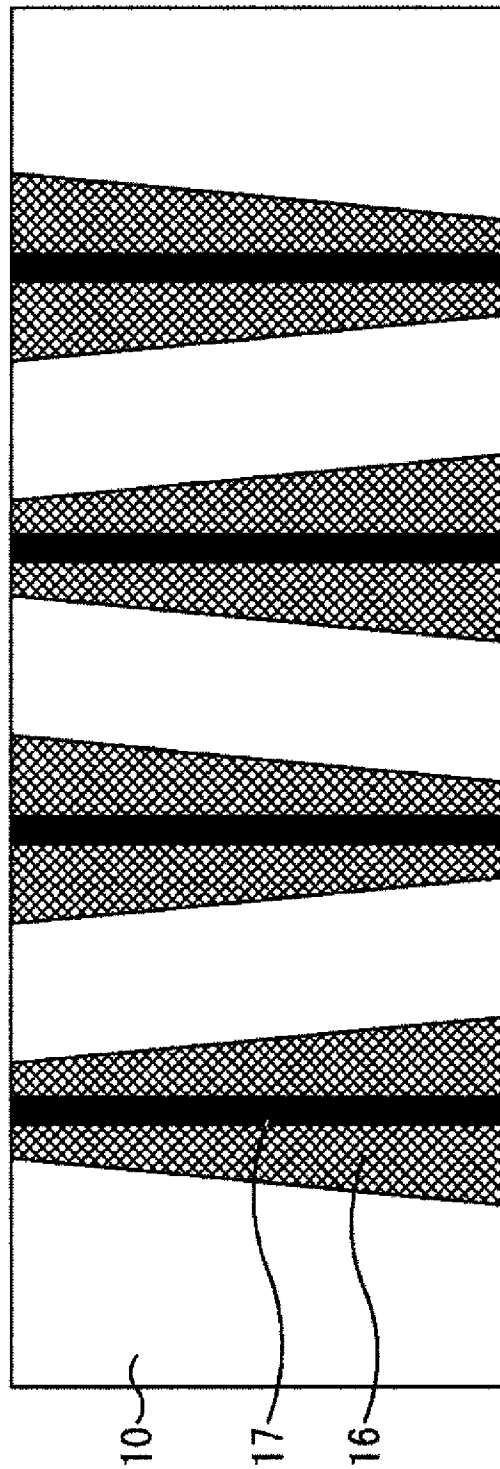
[Fig. 7]

[Fig. 7]



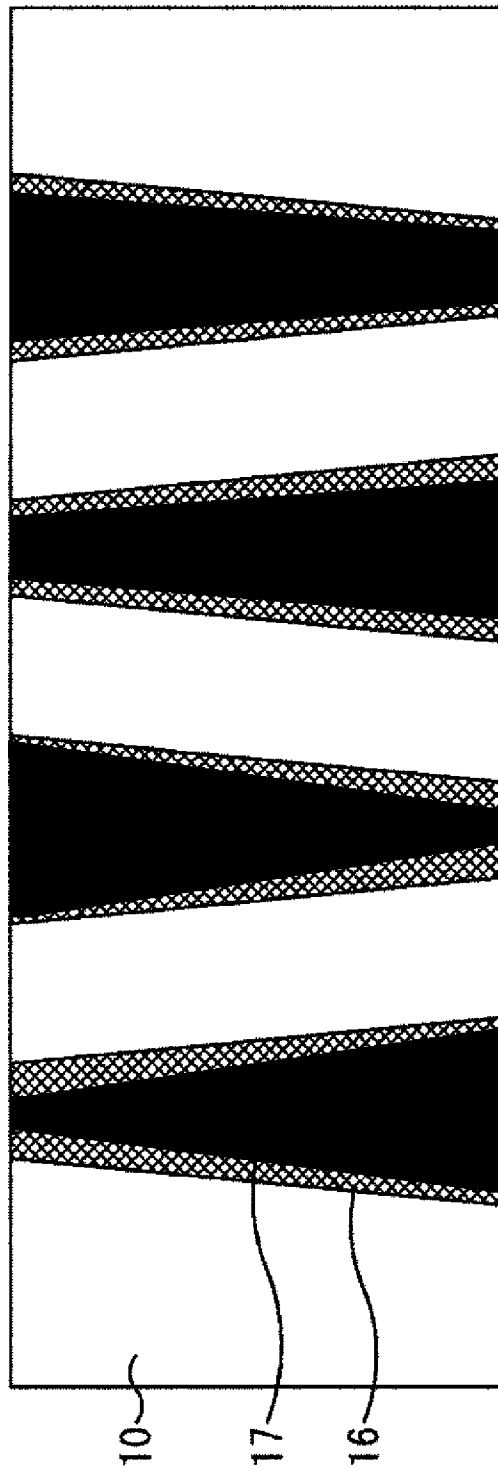
[Fig. 8A]

[Fig. 8A]



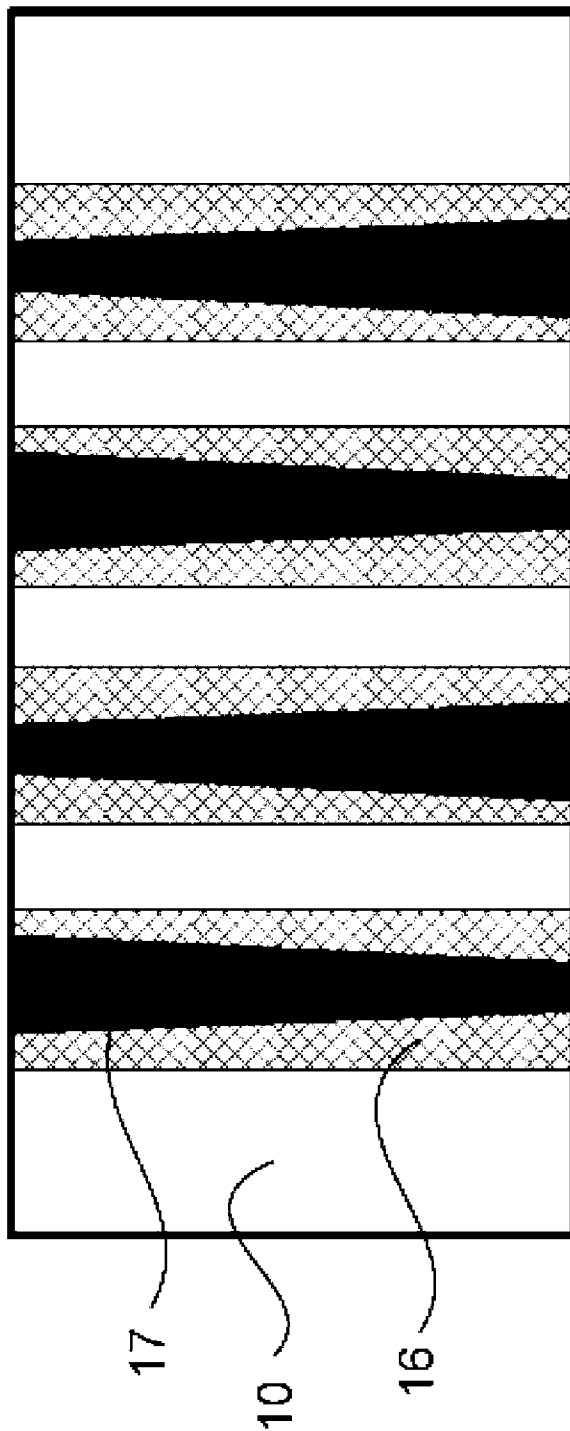
[Fig. 8B]

[Fig. 8B]



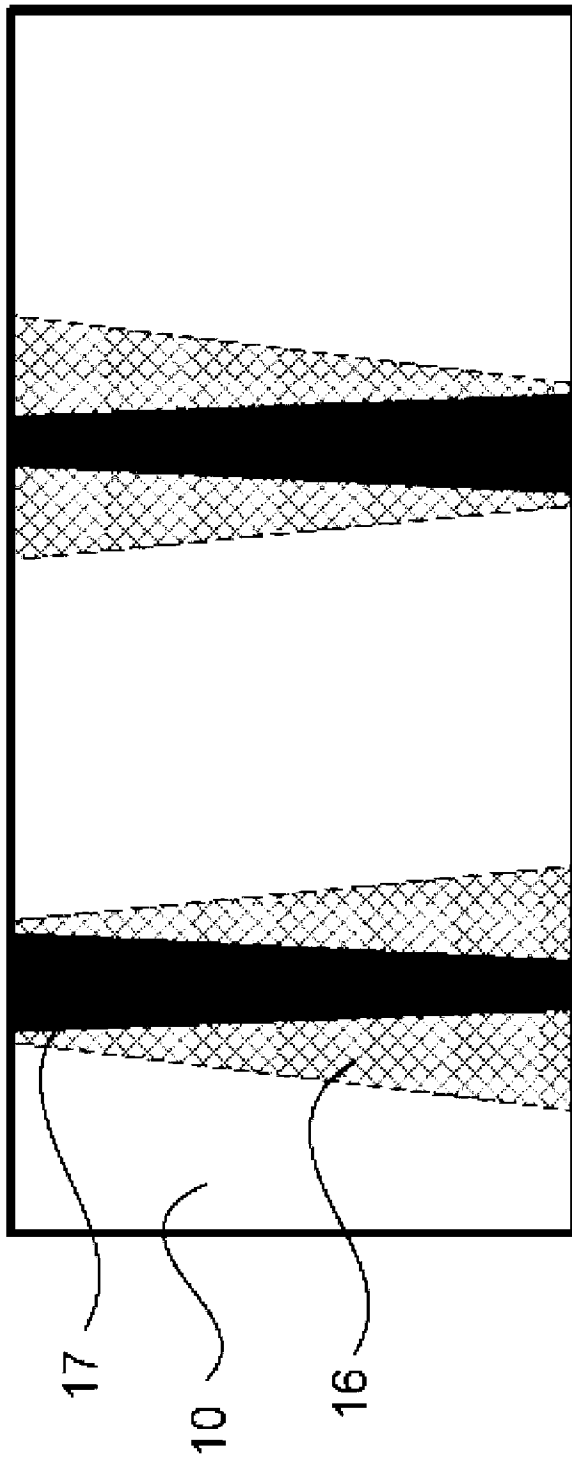
[Fig. 8C]

[Fig. 8C]



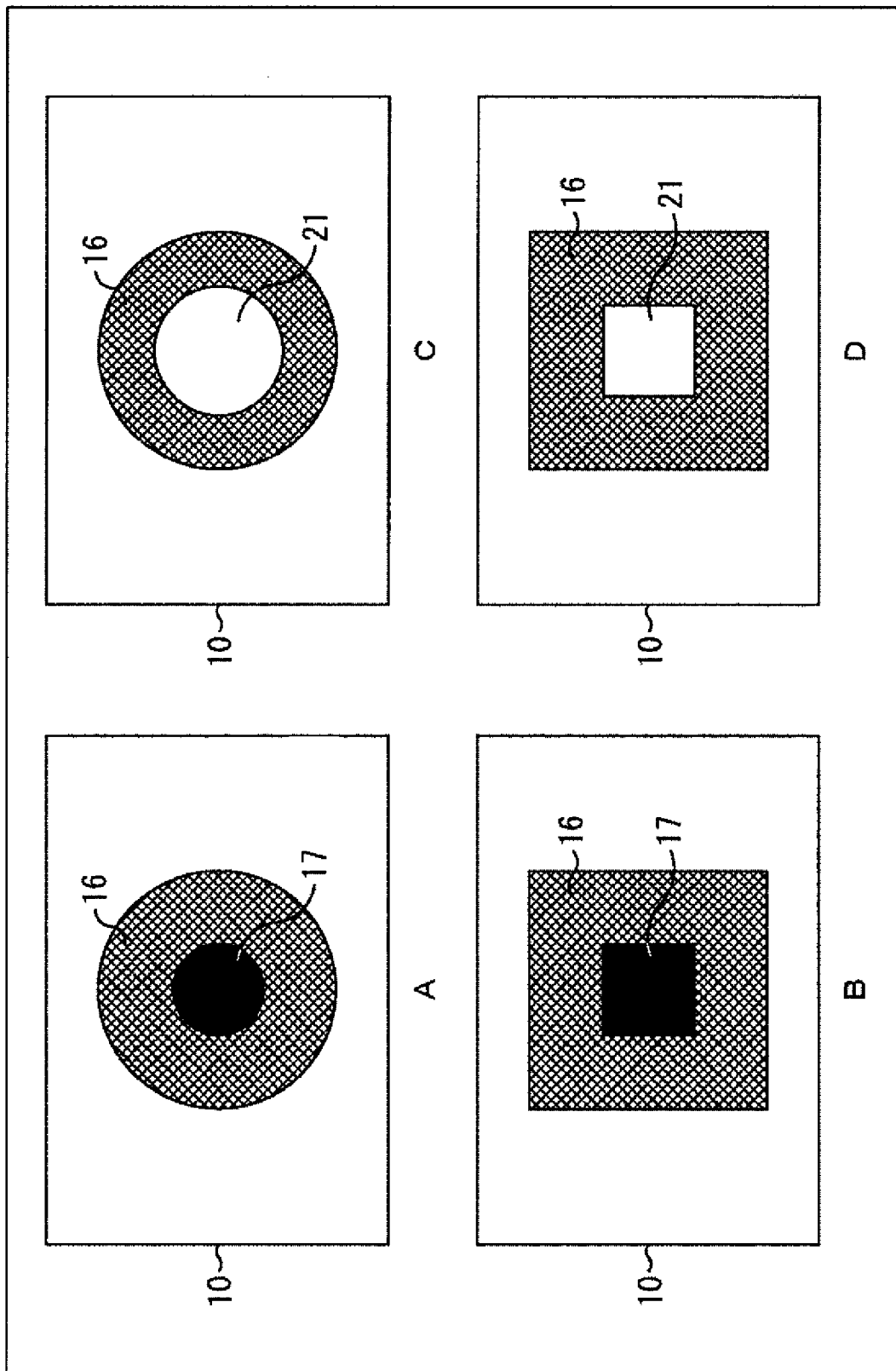
[Fig. 8D]

[Fig. 8D]



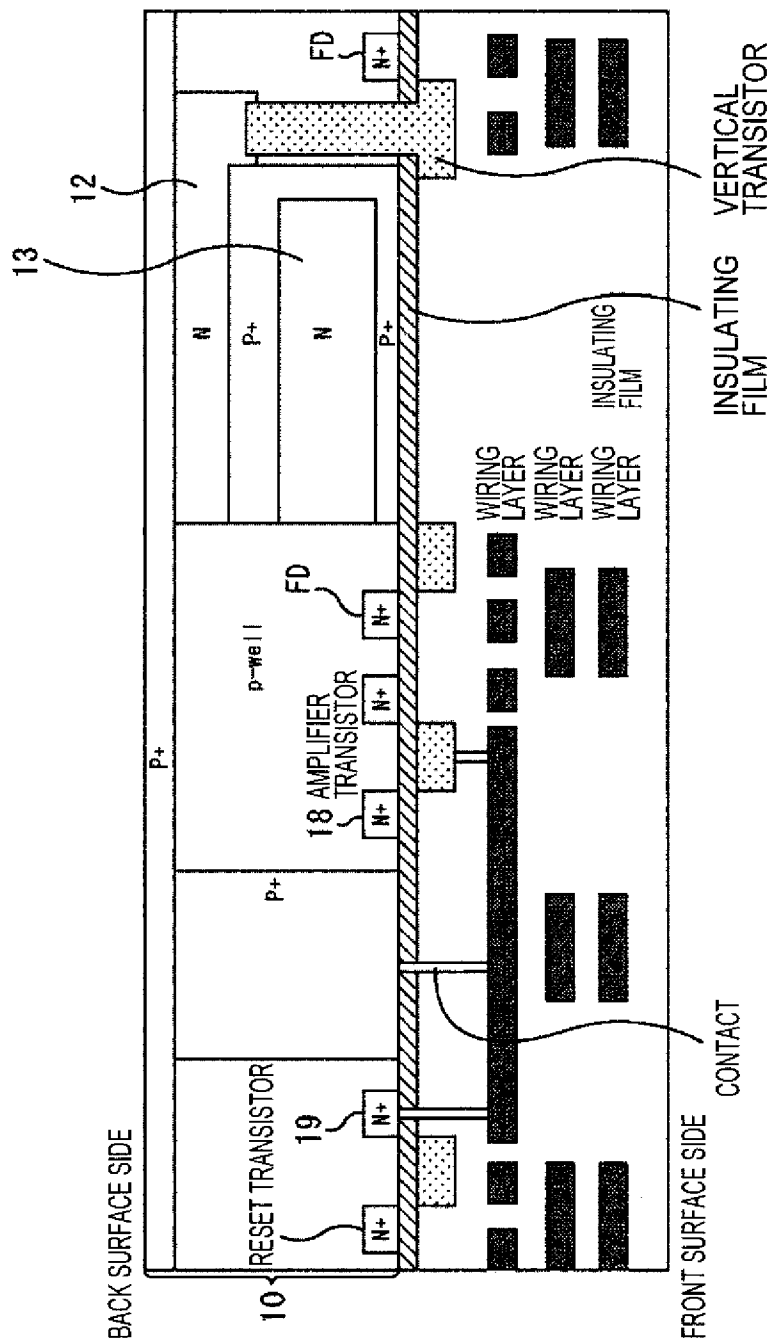
[Fig. 9]

[Fig. 9]



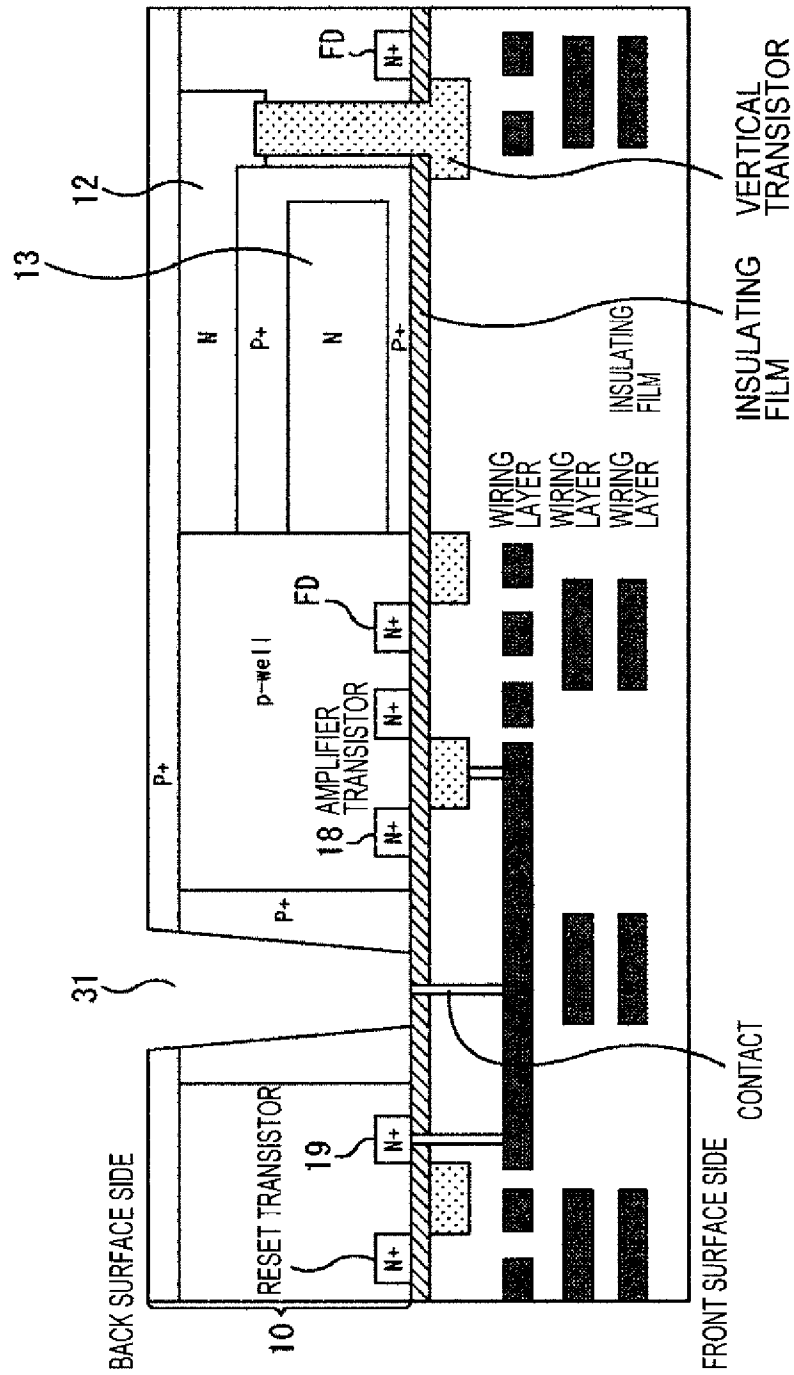
[Fig. 10]

[Fig. 10]



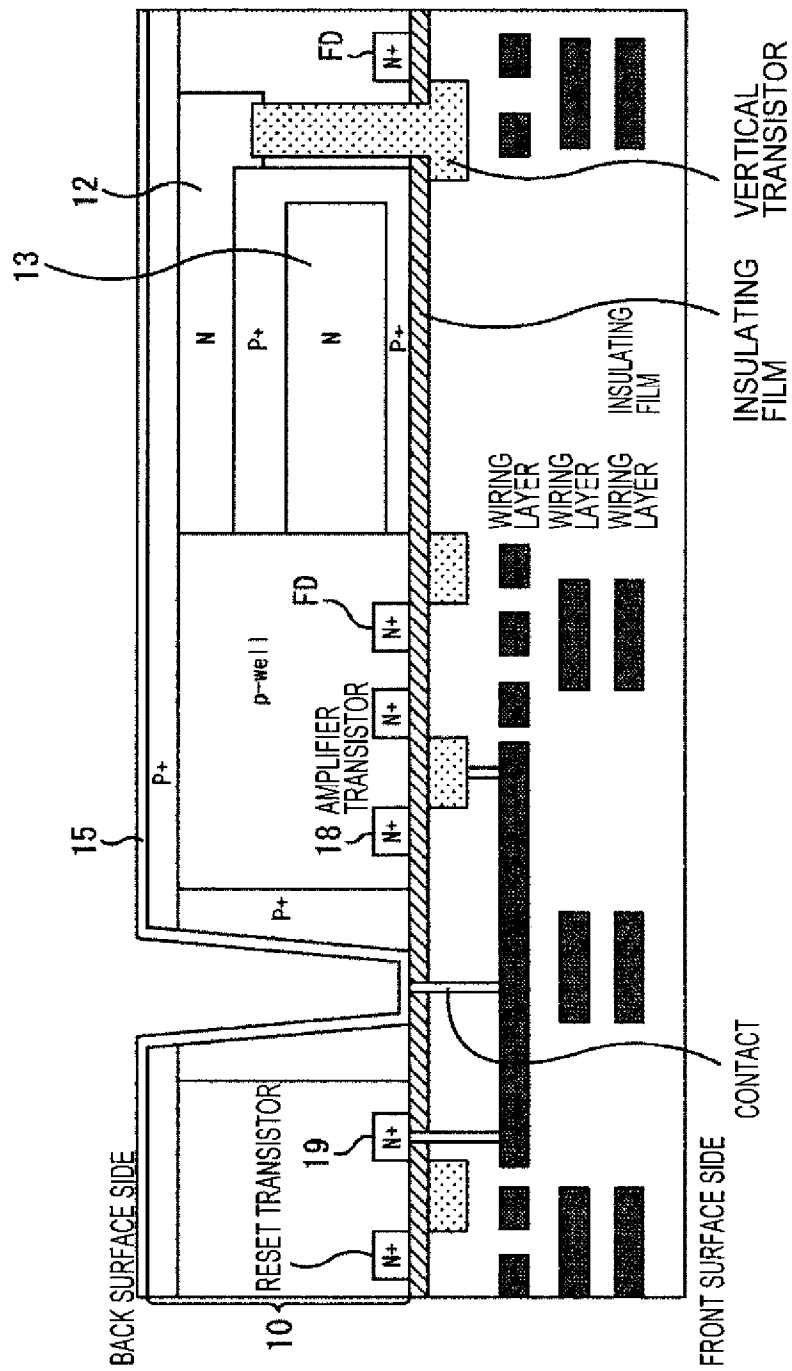
[Fig. 11]

[Fig. 11]



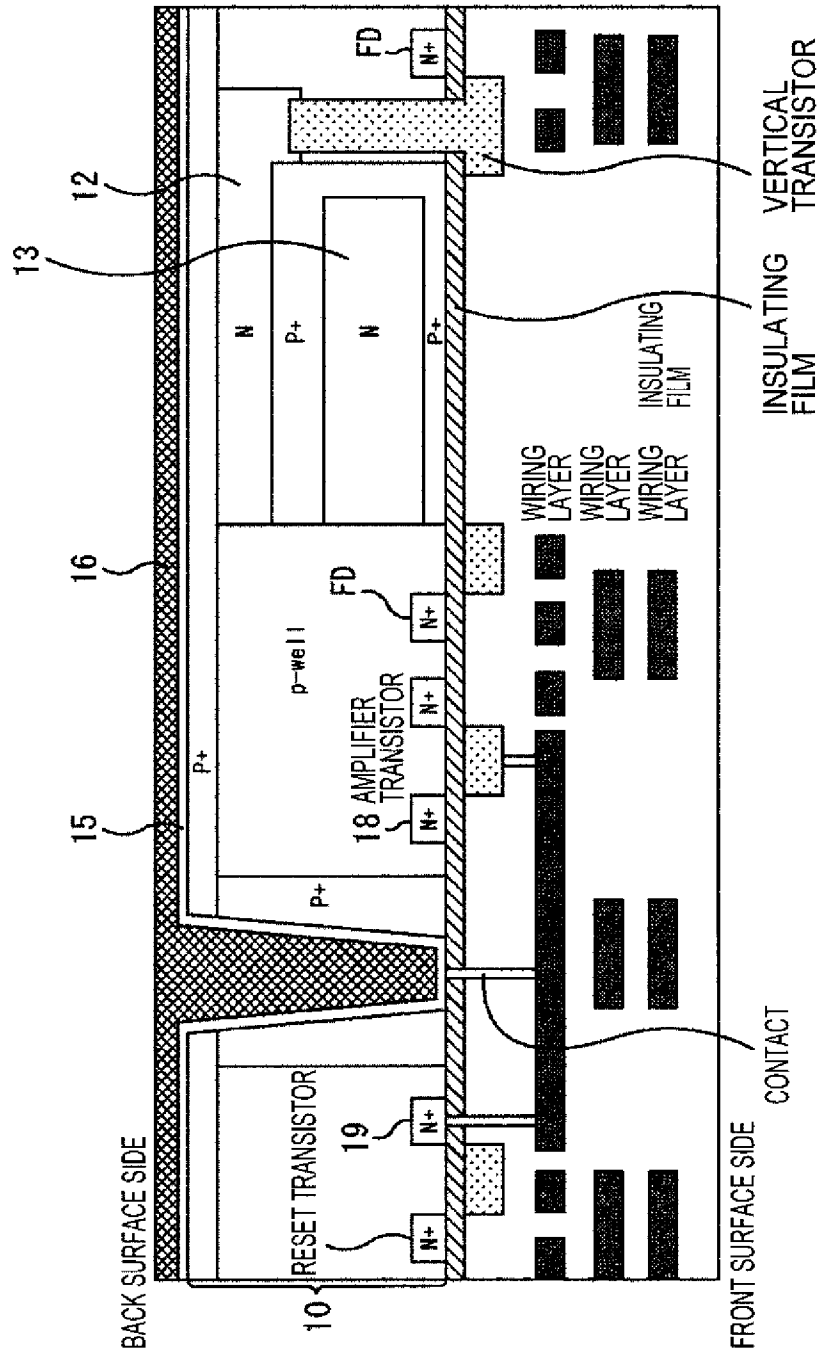
[Fig. 12]

[Fig. 12]

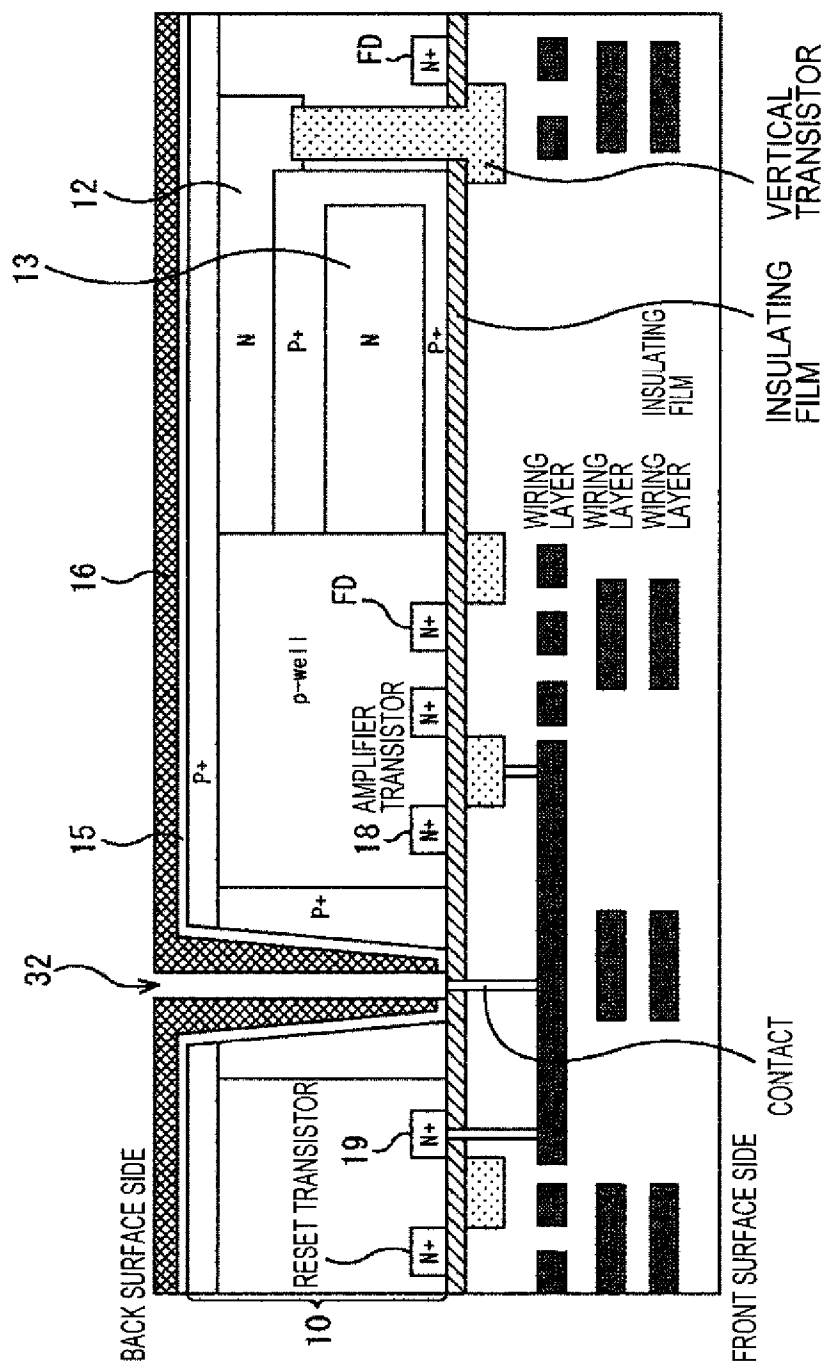


[Fig. 13]

[Fig. 13]

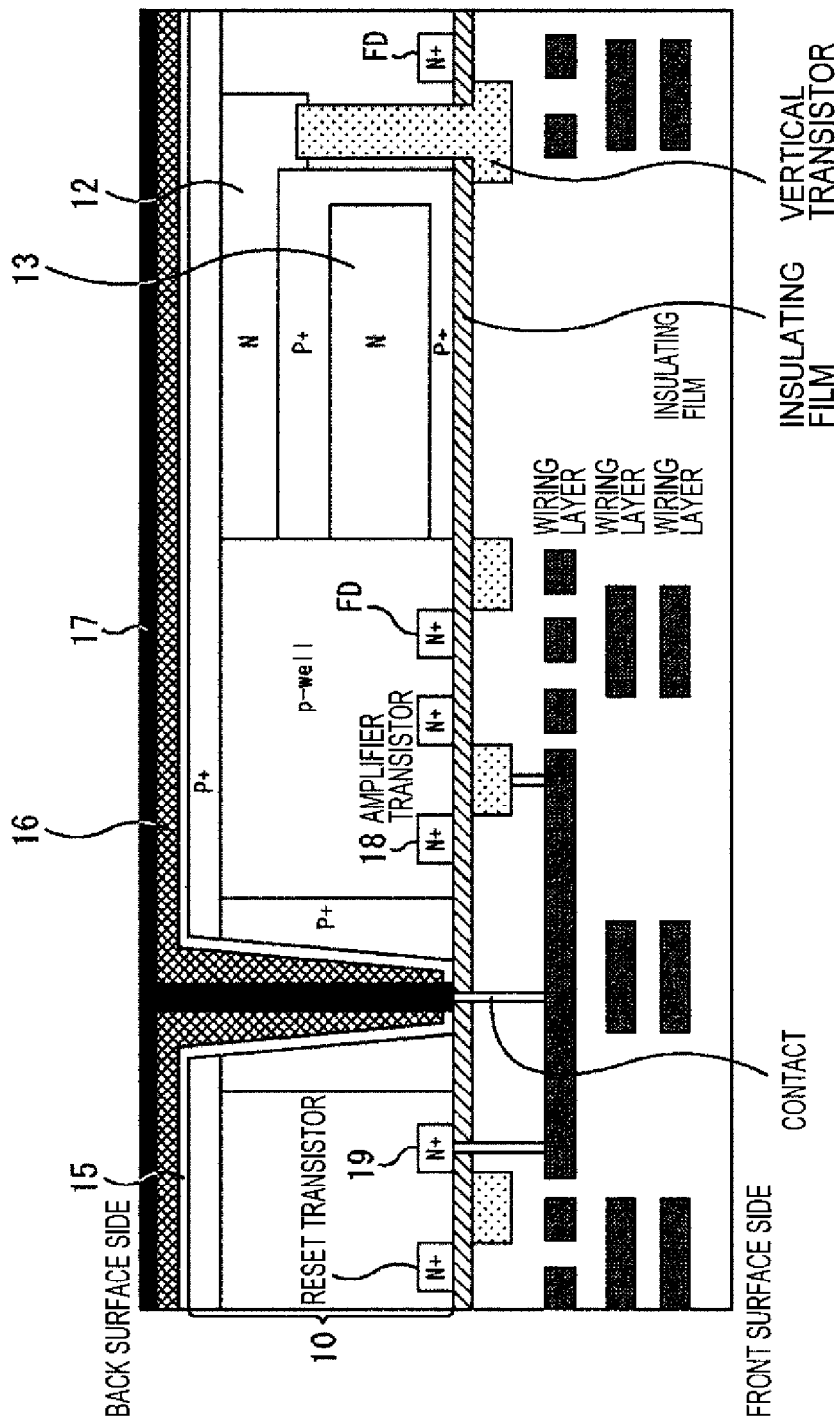


[Fig. 14]



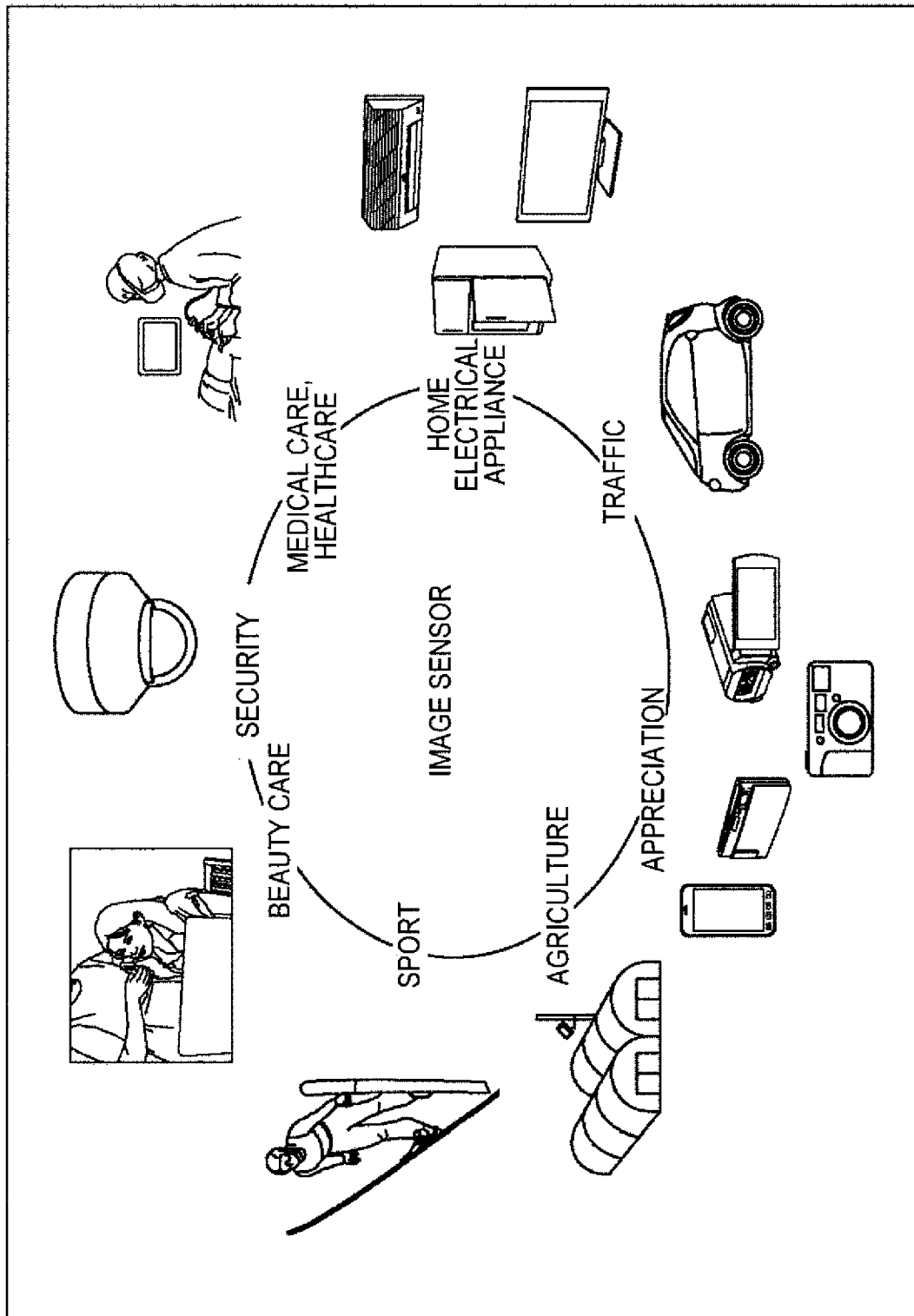
[Fig. 15]

[Fig. 15]



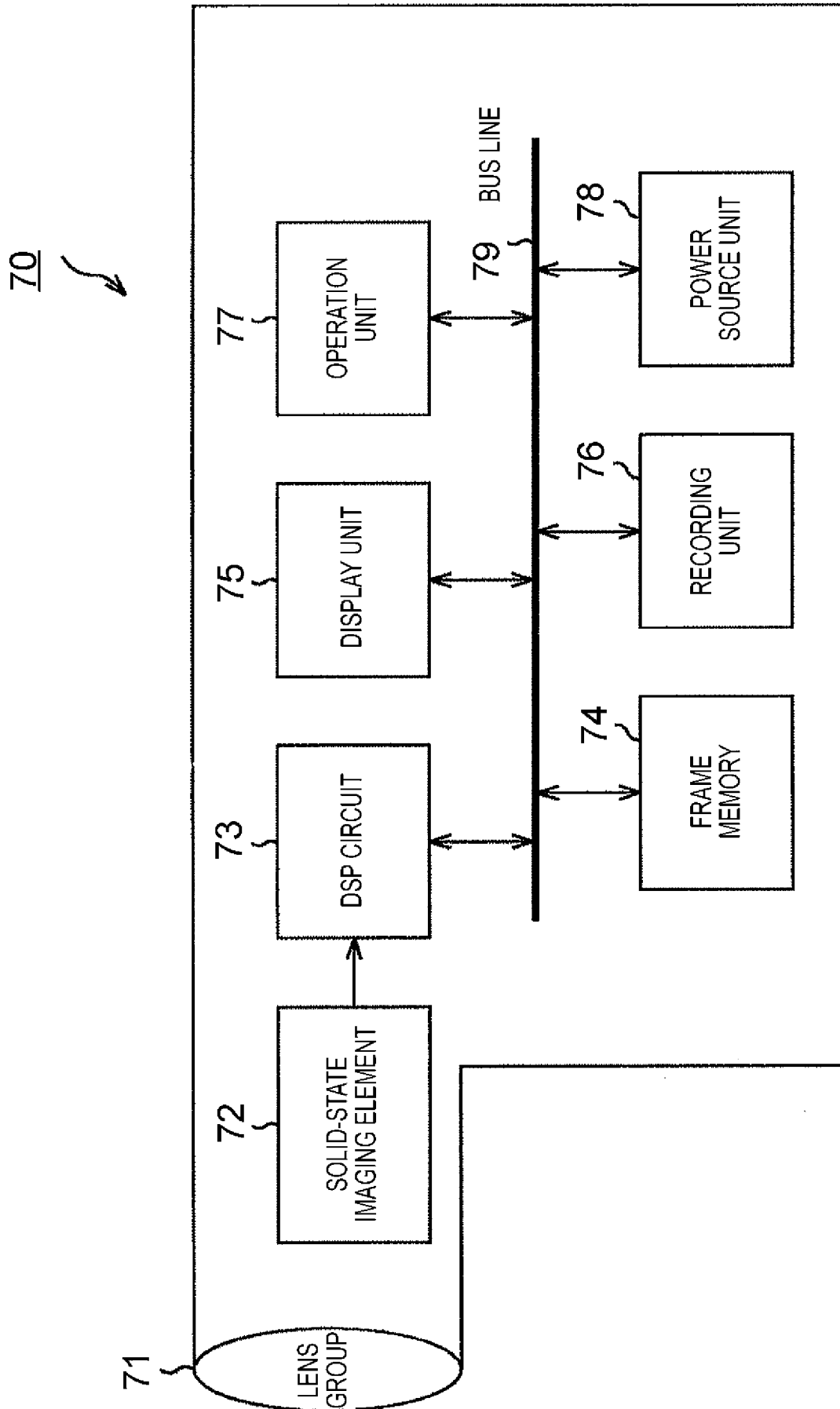
[Fig. 16]

[Fig. 16]



[Fig. 17]

[Fig. 17]



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2016/004369

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L21/768 H01L23/48 H01L27/146
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/283951 A1 (NABE YOSHIHIRO [JP] ET AL) 20 November 2008 (2008-11-20)	1,14
Y	paragraph [0048] - paragraph [0119] figures 1-8	1,2,5-14
X	----- EP 2 802 005 A1 (TOPPAN PRINTING CO LTD [JP]) 12 November 2014 (2014-11-12)	1,14
	paragraph [0024] - paragraph [0039] paragraph [0050] - paragraph [0075] figure 1	
X	----- US 2015/188065 A1 (TAKIMOTO KAORI [JP]) 2 July 2015 (2015-07-02)	1-4,6-14
Y	paragraph [0095] - paragraph [0109] figures 1, 4	1,2,5-14
	----- -/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

7 December 2016

Date of mailing of the international search report

08/02/2017

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Bruckmayer, Manfred

INTERNATIONAL SEARCH REPORT

International application No

PCT/JP2016/004369

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JEFFREY P. GAMBINO ET AL: "An overview of through-silicon-via technology and manufacturing challenges", MICROELECTRONIC ENGINEERING., vol. 135, 8 January 2015 (2015-01-08), pages 73-106, XP055326419, NL ISSN: 0167-9317, DOI: 10.1016/j.mee.2014.10.019 the whole document -----	1-4,6-14
A	US 2013/168750 A1 (IKHLEF ABDELAZIZ [US] ET AL) 4 July 2013 (2013-07-04) paragraph [0018] - paragraph [0040] figures 1-5 -----	1,14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/004369

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-14

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-14

A device comprising a through electrode including a conductive portion and an insulating film wherein a thickness of the insulating film is different at both sides of the substrate

2. claims: 15-18

A device comprising a through electrode including a conductive portion and an insulating film wherein a cross-sectional area of the through electrode is different at both sides of the substrate

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/JP2016/004369

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008283951	A1	20-11-2008	CN 101308845 A 19-11-2008
		JP 4483896 B2 16-06-2010	
		JP 2008288309 A 27-11-2008	
		KR 20080101662 A 21-11-2008	
		TW 200908220 A 16-02-2009	
		US 2008283951 A1 20-11-2008	
EP 2802005	A1	12-11-2014	CN 104054164 A 17-09-2014
		EP 2802005 A1 12-11-2014	
		JP 5810921 B2 11-11-2015	
		JP 2013140916 A 18-07-2013	
		KR 20140099316 A 11-08-2014	
		TW 201340272 A 01-10-2013	
		US 2014312506 A1 23-10-2014	
		WO 2013103136 A1 11-07-2013	
US 2015188065	A1	02-07-2015	JP WO2014021177 A1 21-07-2016
		US 2015188065 A1 02-07-2015	
		WO 2014021177 A1 06-02-2014	
US 2013168750	A1	04-07-2013	DE 102012113168 A1 04-07-2013
		JP 2013140975 A 18-07-2013	
		US 2013168750 A1 04-07-2013	