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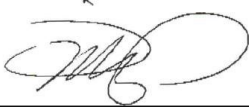
I served as Chief Examiner of the certified court interpreter test for the State of California and as a contract translator and interpreter for various federal agencies through the U.S. Department of State for more than a decade. I served as an instructor at the University of California at Berkeley and the Middlebury Institute of International Studies at Monterey (MIIS) Graduate Program in Translation.

I have more than 30 years of experience reviewing thousands of technical, legal, and business documents from Japanese to English submitted to, among others, Japanese judicial authorities, U.S. federal courts, the U.S. International Trade Commission (ITC), and the USPTO Patent Trial and Appeal Board (PTAB).

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I certify under penalty of perjury that the foregoing is true and correct.

Executed this 28th day of October 2024 in Contra Costa County of the State of California.



By: _____

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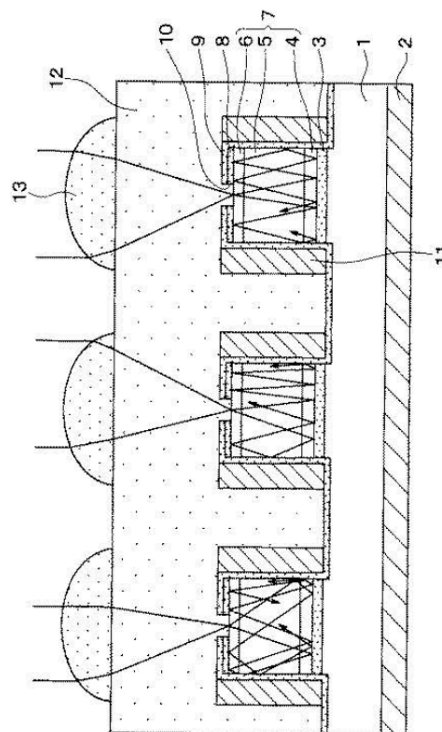
(54) (Title of the Invention) LIGHT RECEIVING ELEMENT

(57) [ABSTRACT]

[PROBLEM] To provide a light receiving element having light receiving sections 7, each of which does not generate optical crosstalk with the neighboring light receiving sections and has high sensitivity regardless of the light absorption coefficient of the material composing the light receiving section 7 and the length thereof.

[MEANS FOR SOLUTION]

A first reflective film 3 is arranged at the bottom surface of a light receiving section 7, a second reflective film 8 is arranged at the front surface, and third reflective films 11 are arranged at the side surfaces. A through-hole 10 exposing the front surface of the light receiving section 7 is formed in the second reflective film 8, and a microlens 13 configured so as to gather light at the exposed portion of the front surface of the light receiving section 7 is arranged at the front surface side of the light receiving section 7. According to such a light receiving element, light that is gathered by the microlens 13 and enters the light receiving section 7 is reflected by the first reflective film 3, the second reflective film 8 and the third reflective films 11 so as to be confined within the light receiving section 7, and therefore the light receiving element can be provided with highly sensitive light receiving sections 7 regardless of the material composing the light receiving sections 7 and the length thereof.



[SELECTED DRAWING] FIG. 1

[SCOPE OF CLAIMS]

[CLAIM 1]

A light receiving element provided with a plurality of light receiving sections (7) formed so as to be adjacent on a semiconductor substrate (2), wherein the light receiving element is provided with

- a first reflective film (3) arranged at a bottom surface of the light receiving section (7),
- a second reflective film (8) arranged opposing the first reflective film (3) at a front surface of the light receiving section (7) and formed with a through-hole (10) exposing a portion of the front surface of the light receiving section (7),
- third reflective films (11) arranged at side surfaces of the light receiving section (7), and
- a microlens (13) arranged at the front surface side of the light receiving section (7), configured so as to gather light at the exposed portion of the front surface of the light receiving section (7) and making the gathered light enter the light receiving section (7), and
- is configured such that when the light gathered by the microlens (13) is made to enter the light receiving section (7) from the exposed portion of the front surface of the light receiving section (7), the entering light incident from an oblique direction with respect to the front surface of the light receiving section (7) is reflected by the first reflective film (3), the second reflective film (8), and the third reflective films (11) so as to be confined inside the light receiving section (7).

[CLAIM 2]

The light receiving element described in claim 1, wherein the first reflective film (3) and the second reflective film (8) are composed of semiconductor multilayer films.

[CLAIM 3]

The light receiving element described in claim 1 or 2, wherein the third reflective film (11) is composed of a metal.

[CLAIM 4]

The light receiving element described in claim 3, wherein the third reflective film (11) is an electrode.

[CLAIM 5]

The light receiving element described in claim 1, wherein the first reflective film (3) is composed of a semiconductor multilayer film and the second reflective film (8) is composed of a metal.

[CLAIM 6]

The light receiving element described in claim 1, wherein the first reflective film (3) and the second reflective film (8) are composed of metals.

[CLAIM 7]

The light receiving element described in any of claims 1 to 6, wherein a groove (14) is formed between neighboring light receiving sections, and the groove (14) is embedded in the third reflective film (11).

[CLAIM 8]

The light receiving element described in any of claims 1 to 7, wherein the light receiving section (7) is composed of a PIN photodiode.

[CLAIM 9]

The light receiving element described in any of claims 1 to 8, wherein the light receiving section (7) is composed of silicon-germanium.

[CLAIM 10]

The light receiving element described in any of claims 1 to 9, wherein the light receiving sections (7) are arranged in a matrix on the semiconductor substrate (2).

[DETAILED DESCRIPTION OF THE INVENTION]

[TECHNICAL FIELD]

[0001]

The present invention relates to a light receiving element capable of preventing optical crosstalk between light receiving sections and improving the sensitivity of the light receiving sections.

[CONVENTIONAL ART]

[0002]

A conventionally known technique for forming a light receiving element is to form PIN photodiodes with excellent, high-speed response to compose light receiving sections on a semiconductor substrate and to arrange these light receiving sections in a two-dimensional array. In such a light receiving element, when light from an oblique direction is incident on the light receiving section formed on the semiconductor substrate, then, for example, light incident from the front surface of the light receiving section may penetrate the side of the light receiving section and enter the neighboring light receiving section as well, potentially causing optical crosstalk between the light receiving sections.

[0003]

In this connection, Patent Document 1, for example, discloses a light receiving element that prevents optical crosstalk in which a groove is formed between neighboring light receiving elements by etching or the like and a light-shielding film is arranged on the surface of the groove.

[0004]

When light is incident from the front surface of the light receiving section in such a light receiving element, light energy is converted into electrical energy inside the light receiving section, and thereby detection is made of the light incident on the light receiving section. If, for example, the light receiving section is composed of a PIN photodiode, light incident to the light receiving section is detected by the generation of a photocurrent due to an electron-hole pair in an I layer while the light travels therethrough. The sensitivity of the light receiving section at this juncture depends on the light conversion efficiency, i.e., the light absorption coefficient of the material used in the light receiving section and the distance the light travels in the light receiving section, and the greater the photocurrent converted while the light travels through the interior of the light receiving section, the higher the sensitivity of the light receiving section.

[0005]

However, in the light receiving element of Patent Document 1, light incident from the front surface of the light receiving section generates a photocurrent in the light receiving section before escaping from the bottom surface of the light receiving section, so to improve the sensitivity of the light receiving section, the photocurrent converted while light travels through the interior of the light receiving section must be increased, which requires the use of a material with a high light absorption coefficient in the light receiving section or to increase the length of the light receiving section (the distance over which light travels in the light receiving section). This causes problems such as a limitation to the materials used to construct the light receiving section and enlargement of the light receiving section.

[0006]

As a method of improving the sensitivity of the light receiving section, a light receiving element has been disclosed in which reflective films are arranged on the bottom surface and side surfaces of the light receiving section to reflect light therein, thereby increasing the distance that the light travels through the interior of the light receiving section (refer to, for example, Patent Document 2).

[Patent Document 1] Patent Appl. Publication No. JP 2002-100796

[Patent Document 2] Patent Appl. Publication No. JP H7-302890

[DISCLOSURE OF THE INVENTION]

[PROBLEM TO BE SOLVED BY THE INVENTION]

[0007]

However, even in the light receiving section of Patent Document 2, there is the problem that reflected light escapes from the front surface of the light receiving section, so light cannot be effectively contained inside the light receiving section.

[0008]

In view of the problems discussed above, it is an object of the present invention to provide a light receiving element provided with light receiving sections having high sensitivity regardless of the light absorption coefficient of the material composing the light receiving sections and the length thereof and not generating optical crosstalk with neighboring light receiving sections.

[MEANS TO SOLVE THE PROBLEM]

[0009]

In order to achieve the object, the invention described in claim 1 is a light receiving element provided with a plurality of light receiving sections (7) formed so as to be adjacent on a semiconductor substrate (2), wherein the light receiving element is provided with a first reflective film (3) arranged at a bottom surface of the light receiving section (7), a second reflective film (8) arranged opposing the first reflective film (3) at a front surface of the light receiving section (7) and formed with a through-hole (10) exposing a portion of the front surface of the light receiving section (7), third reflective films (11) arranged at side surfaces of the light receiving section (7), and a microlens (13) arranged at the front surface side of the light receiving section (7), configured so as to gather light at the exposed portion of the front surface of the light receiving section (7), and making the gathered light enter the light receiving section (7), and is configured such that when the light gathered by the microlens (13) is made to enter the light receiving section (7) from the exposed portion of the front surface of the light receiving section (7), the entering light incident from an oblique direction with respect to the front surface of the light receiving section (7) is reflected by the first reflective film (3), the second reflective film (8), and the third reflective films (11) so as to be confined inside the light receiving section (7).

[0010]

According to such a light receiving element, light that enters the light receiving section (7) is reflected by the first reflective film (3), the second reflective film (8) and the third reflective films (11) so as to be confined within the light receiving section 7. As a result, the distance the light travels inside the light receiving section (7) is longer, so the sensitivity of the light receiving section (7) can be improved regardless of the light absorption coefficient of the material composing the light receiving section (7) and the length thereof. In addition, the side surfaces of the light receiving section (7) are covered by the third reflective films (11), preventing optical crosstalk between neighboring light receiving sections.

[0011]

The first reflective film (3) and the second reflective film (8) can be composed of, for example, semiconductor multilayer films as in the invention described in claim 2.

[0012]

The third reflective film (11) can be composed of a metal as in the invention described in claim 3.

[0013]

In this case, the third reflective film (11) can be configured as an electrode as in the invention described in claim 4. According to such a light receiving element, the electrode wire can be drawn from the front surface of the light receiving element, so the wiring is easy.

[0014]

The first reflective film (3) can be composed of a semiconductor multilayer film and the second reflective film (8) composed of a metal as in the invention described in claim 5, or the first reflective film (3) and the second reflective film (8) can be composed of metals as in the invention described in claim 6.

[0015]

A groove (14) can be formed between light receiving sections (7), and the groove (14) embedded in the third reflective film (11) as in the invention described in claim 7. According to such a light receiving element, the density of the light receiving sections (7) can be increased.

[0016]

The light receiving section (7) can be composed of a PIN photodiode as in the invention described in claim 8.

[0017]

The light receiving section (7) can be composed of silicon-germanium as in the invention described in claim 9.

[0018]

The light receiving sections (7) can be arranged in a matrix to compose the light receiving element as described in claim 10.

[0019]

The referential numbers in parentheses in each means described in this description and the claims indicate a corresponding relationship with the specific means described in the embodiments below.

[0020]

(First Embodiment)

A light receiving element is next described in an embodiment of the present invention. FIG. 1 is a cross-section drawing of the light receiving element of the present embodiment. The light receiving element of the present embodiment is described with reference to FIG. 1.

[0021]

As shown in FIG. 1, a rear surface electrode 2 is arranged at the rear surface of a semiconductor substrate 1. A plurality of first reflective films 3 is arranged at the front surface of the semiconductor substrate 1. When the front surface of the semiconductor substrate 1 is viewed from above, the plurality of first reflective films 3 is arranged in a matrix. In the present embodiment, the first reflective film 3 is composed of a semiconductor multilayer film. Si, for example, can be used as the semiconductor substrate 1, and an $\text{Al}_x\text{Ga}_{1-x}\text{P}$ semiconductor multilayer film, for example, can be used as the first reflective film 3. The composition ratio X of $\text{Al}_x\text{Ga}_{1-x}\text{P}$ is changed, as appropriate, and the semiconductor multilayer film is composed by alternating layers of semiconductor films with a low refractive index and a high refractive index.

[0022]

This first reflective film 3 is configured so that the light to be detected is reflected with a high reflectance of at least 99 percent. In further detail, the configuration is as follows. The semiconductor multilayer film reflects light of wavelengths existing in the reflection wavelength band of the semiconductor multilayer film when light is incident from the orthogonal direction, but when light is incident from the oblique direction, the reflection wavelength band of the semiconductor multilayer film shifts to the short wavelength side and reflects light of wavelengths existing in the shifted reflection wavelength band (refer to, for example, “Optical Technology Dictionary,” The Optronics Co., Ltd., 2004, pp. 411–412). Therefore, the thickness of the semiconductor multilayer film in the present embodiment is adjusted such that adequate reflected light to be detected is obtained even if the reflection wavelength band shifts to the short wavelength side. That is, the thickness of the semiconductor multilayer film is adjusted so that the wavelength of light to be detected is on the short wavelength side of the reflection wavelength band of the semiconductor multilayer film, and the structure is capable of reflecting light with high reflectance even when light is incident on the semiconductor multilayer film from the oblique direction.

[0023]

On the surface of each of the first reflective films 3, an N layer 4 with a high concentration of N-type impurities, an I layer 5 with a low impurity concentration, and a P layer 6 with a high concentration of P-type impurities are sequentially stacked to form a PIN photodiode 7. In the present embodiment, this PIN photodiode 7 corresponds to the light receiving section. Various materials can be used to compose the PIN photodiode 7, and $\text{Si}_x\text{Ge}_{1-x}$, for example, which has a lower light absorption coefficient than In_xGaAs , which is commonly used as a light receiving section for infrared light with a wavelength of $1.5\ \mu\text{m}$, can be used. If, for example, SiGe is used in the PIN photodiode 7, the absorption length of SiGe is approximately $200\ \mu\text{m}$ when light with a wavelength of $1.5\ \mu\text{m}$ is incident on the SiGe, but in the present embodiment, the light intensity can be attenuated to $1/e$ even if the I layer that absorbs light is much thinner than $200\ \mu\text{m}$. Here, the absorption length is set so as to attenuate the light intensity to $1/e$.

[0024]

On the surface of the P layer 6, a second reflective film 8 composed of a semiconductor multilayer film is arranged in opposition to the first reflective film 3. Like the first reflective film 3, this second reflective film 8 can also be made of an $\text{Al}_x\text{Ga}_{1-x}\text{P}$ semiconductor multilayer film, and is configured so that the light to be detected is reflected with a high reflectance of at least 99 percent.

[0025]

A first insulating film 9 is arranged so as to cover the PIN photodiode 7 provided with the first reflective film 3 and the second reflective film 8 and the portion of the semiconductor substrate 1 where the first reflective film 3 is not arranged. $\text{Si}_x\text{N}_{1-x}$, for example, can be used for this first insulating film 9. The second reflective film 8 and the first insulating film 9 arranged on the surface of the second reflective film 8 have a through-hole 10 that exposes a portion of the surface of the P layer 6.

[0026]

Third reflective films 11 composed of a metal such as Al is arranged on the side surfaces of the PIN photodiode 7 with the first insulating film 9 interposed. A second insulating film 12 is arranged so as to cover the first insulating film 9 and the PIN photodiode 7 provided with the first reflective film 3, the second reflective film 8 and the third reflective films 11. Further, a microlens 13 having the same central axis as the PIN photodiode 7 is arranged on the surface of this second insulating film 12. This microlens 13 can be composed of SiO_2 , for example, and is configured to collect light at the exposed portion of the surface of the P layer 6.

[0027]

Next, the method for manufacturing the light receiving element of the present embodiment is described.

[0028]

FIG. 2 and FIG. 3 are cross-section views showing the manufacturing process of the present embodiment. First, as shown in FIG. 2(a), the first reflective film 3 is deposited on the surface of the semiconductor substrate 1. Then, the N layer 4, the I layer 5, and the P layer 6 are sequentially stacked as shown in FIG. 2(b), and the second reflective film 8 is deposited on the surface of the P layer 6 so as to oppose the first reflective film 3 as shown in FIG. 2(c).

[0029]

As shown in FIG. 2(d), photolithography and etching are used to form a matrix of a plurality of PIN photodiodes 7 with the first reflective film 3 and the second reflective film 8. Then, as shown in FIG. 2(e), the first insulating film 9 is arranged so as to cover the PIN photodiode 7 with the first reflective film 3 and the second reflective film 8 and the portion of the surface of the semiconductor substrate 1 where the first reflective film 3 is not arranged.

[0030]

Then, as shown in FIG. 3(a), a through-hole 10 is formed by photolithography and etching in the second reflective film 8 and the first insulating film 9 arranged on the surface of the second reflective film 8 so as to expose a portion of the surface of the P layer 6.

[0031]

Then, as shown in FIG. 3(b), the second insulating film 12 is deposited so as to embed the intervals between the PIN photodiodes 7. Then, as shown in FIG. 3(c), a portion of the second insulating film 12 that is deposited on the surface of the first insulating film 9 arranged on the surface of the PIN photodiode 7 is removed by a chemical mechanical polishing (CMP) method or the like to leave the second insulating film 12 between the PIN photodiodes 7 and at the through-hole 10, flattening the front surface side of the semiconductor substrate 1.

[0032]

Next, as shown in FIG. 3(d), grooves 14 are formed at the side surfaces of the PIN photodiode 7 in the deposited second insulating film 12 so as to surround the first insulating film 9, and the third reflective films 11 are deposited in the grooves 14 and arranged with the CMP method or by photolithography and etching at the side surfaces of the PIN photodiode 7 with the first insulating film 9 interposed.

[0033]

Finally, as shown in FIG. 3(e), the second insulating film 12 is again arranged at the front surface side of the semiconductor substrate 1, the material that constitutes the microlens 13 is deposited on the surface of the second insulating film 12, and photolithography and etching are used to compose the microlens 13. The rear surface electrode 2 is then arranged on the rear surface of the semiconductor substrate 1.

[0034]

The basic operation of such a light receiving element is described.

[0035]

First, the microlens 13 collects light at the exposed portion of the surface of the PIN photodiode 7. When light enters the PIN photodiode 7, the light incident from an oblique direction with respect to the surface of the PIN photodiode 7 is reflected by the first reflective film 3, the second reflective film 8, and the third reflective films 11 so as to be confined within the PIN photodiode 7. In this process, the light energy is converted into electrical energy inside the PIN photodiode 7 and a photocurrent caused by an electron-hole pair is generated to detect the light incident on the PIN photodiode 7.

[0036]

According to such a light receiving element, the PIN photodiode 7 is surrounded by the first reflective film 3, the second reflective film 8, and the third reflective films 11, so when light is incident to the PIN photodiode 7, that light is reflected by the first reflective film 3, the second reflective film 8, and the third reflective films 11 so as to be confined within the PIN photodiode 7. This allows the distance that the incident light travels in the PIN photodiode 7 to be lengthened, which increases the photocurrent and thus improves the sensitivity of the PIN photodiode 7.

[0037]

That is, according to the light receiving element of the present embodiment, the sensitivity of the PIN photodiode 7 can be improved without using a material with a high light absorption coefficient in the PIN photodiode 7, and the sensitivity of the PIN photodiode 7 can be improved without increasing the length of the PIN photodiode 7 since the distance the light travels inside the PIN photodiode 7 is lengthened.

[0038]

Further, since the sides of the PIN photodiode 7 are covered with the third reflective films 11, no incident light escapes from the sides of the PIN photodiode 7 and no optical crosstalk occurs between neighboring PIN photodiodes 7.

[0039]

SiGe, for example, can be used as the material of the PIN photodiode 7 in the present embodiment, and when light with a wavelength of 1.5 μm is incident on the SiGe, the absorption length thereof is approximately 200 μm , but the incident light is confined within the PIN photodiode 7, so in the present embodiment, the light intensity can be attenuated to $1/e$ even if the I layer absorbing the light is much thinner than 200 μm .

[0040]

(Second Embodiment)

The second embodiment of the present invention is described. The light receiving element of the present embodiment uses a third reflective film 11 as an electrode instead of the rear surface electrode 2 used in the first embodiment. Other details are the same as in the first embodiment and are not explained here.

[0041]

FIG. 4 is a cross-section view of the light receiving element according to the present embodiment. As shown in FIG. 4, in the light receiving element of the present embodiment, the first insulating film 9 arranged between the third reflective film 11 and the semiconductor substrate 1 is removed, and the PIN photodiode 7 and the third reflective film 11 are connected electrically. Therefore the third reflective film 11 can be used as the electrode.

[0042]

According to such a light receiving element, in addition to the effect of the first embodiment, it is possible to form the light receiving element without using the rear surface electrode 2, and the electrode wire can be drawn from the front surface, making wiring easy.

[0043]

The light receiving element of the present embodiment is manufactured by forming the grooves 14 in the step shown in Figure 3(d) until the surface of the semiconductor substrate 1 is exposed.

[0044]

(Third Embodiment)

The third embodiment of the present invention is described. In the light receiving element of the present embodiment, the second reflective film 8 has a configuration modified from the first embodiment. Other details are the same as in the first embodiment and are not described here.

[0045]

FIG. 5 is a cross-section view of the light receiving element of the present embodiment. As shown in FIG. 5, the light receiving element of the present embodiment is configured such that the first insulating film 9 is arranged on the surface of the P layer 6, and the second reflecting film 8 composed with a metal such as Al is arranged on the surface of the first insulating film 9. The first insulating film 9 arranged on the surface of the P layer 6 and the second reflective film 8 arranged on this first insulating film 9 are formed with a through-hole 10 so as to expose a portion of the surface of the P layer 6.

[0046]

According to such a light receiving element, in addition to the same effect as the first embodiment, the second reflecting film 8 and the third reflecting film 11 are both composed of metals, so it is possible to manufacture the second reflecting film 8 and the third reflecting film 11 at the same time in the manufacturing step of FIG. 3(d), and the manufacturing step of depositing the second reflecting film 8 in the step of FIG. 2(b) can be eliminated.

[0047]

(Fourth Embodiment)

The fourth embodiment of the present invention is described. In the light receiving element of the present embodiment, the first reflective film 3 has a configuration modified from the third embodiment. Other details are the same as in the third embodiment and are not described here.

[0048]

FIG. 6 is a cross-section view of the light receiving element of the present embodiment. As shown in FIG. 6, the light receiving element of the present embodiment is configured such that the first reflecting film 3 is made of a metal such as Al. The same effect as in the first embodiment can be obtained with such a light receiving element.

[0049]

(Fifth Embodiment)

The fifth embodiment of the present invention is described. The light receiving element of the present embodiment is configured to share the third reflecting film 11 between neighboring light receiving sections in contrast to the first embodiment. Other details are the same as in the first embodiment and are not described here.

[0050]

FIG. 7 is a cross-section view of the light receiving element of the present embodiment. As shown in FIG. 7, the light receiving element of the present embodiment is configured such that an interval between neighboring PIN photodiodes is embedded in the third reflecting film 11.

[0051]

According to such a light receiving element, the density of the PIN photodiodes 7 can be increased while obtaining the same effect as in the first embodiment.

[0052]

(Sixth Embodiment)

The sixth embodiment of the present invention is described. In the light receiving element of the present embodiment, the location where the microlens 13 is arranged differs from that in the first embodiment. Other details are the same as in the first embodiment and are not described here.

[0053]

FIG. 8 is a cross-section view of the light receiving element of the present embodiment. As shown in FIG. 8, the central axis of the microlens 13 is shifted from the central axis of the PIN photodiode 7 in the light receiving element of the present embodiment. In such a light receiving element, if the microlens 13 is configured so as to collect light at the exposed portion of the surface of the P layer 6, the same effect as in the first embodiment can be obtained.

[0054]

(Other Embodiments)

In the first embodiment, an example was described using Si as the semiconductor substrate 1, $\text{Al}_x\text{Ga}_{1-x}\text{P}$ as the first reflective film 3 and the second reflective film 8, and $\text{Si}_x\text{Ge}_{1-x}$ as the PIN photodiode 7, but the present invention is not limited to this. For example, GaAs, InP, or the like may be used as the semiconductor substrate 1, a semiconductor multilayer film using $\text{Al}_x\text{Ga}_{1-x}\text{As}$ or $\text{In}_x\text{Ga}_{1-x}\text{As}$ may be used as the first reflective film 3 and the second reflective film 8, and $\text{In}_x\text{Ga}_{1-x}\text{As}$ may be used as the PIN photodiode 8.

[0055]

In the third, fourth, and sixth embodiments, as in the second embodiment, the first insulating film 9 arranged between the third reflective film 11 and the semiconductor substrate 1 may be removed to electrically connect the third reflective film 11 and the PIN photodiode 7, and the third reflective film 11 used as the electrode.

[0056]

Each of the embodiments is configured such that the entire side surfaces of the PIN photodiode 7 is covered by the third reflective films 11, but a configuration can also be used in which the entire side surface is not covered. In this case, light reflected inside the PIN photodiode 7 may exit from the portion of the side surface of the PIN photodiode 7 that is not covered by the third reflective film 11, so consideration is needed for how the third reflective film 11 is arranged such that this light does not enter the side surface of the neighboring PIN photodiode 7 from the portion not covered by the third reflective film 11.

[0057]

Further, the light receiving section is naturally not limited to the PIN photodiode 7, but can be, for example, a PN photodiode.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0058]

[FIG. 1] FIG. 1 shows a cross-section view of the light receiving element in the first embodiment of the present invention.

[FIG. 2] FIG. 2 shows the manufacturing process of the light receiving element shown in FIG. 1.

[FIG. 3] FIG. 3 shows the manufacturing process of the light receiving element shown in FIG. 1.

[FIG. 4] FIG. 4 shows a cross-section view of the light receiving element in the second embodiment.

[FIG. 5] FIG. 5 shows a cross-section view of the light receiving element in the third embodiment.

[FIG. 6] FIG. 6 shows a cross-section view of the light receiving element in the fourth embodiment.

[FIG. 7] FIG. 7 shows a cross-section view of the light receiving element in the fifth embodiment.

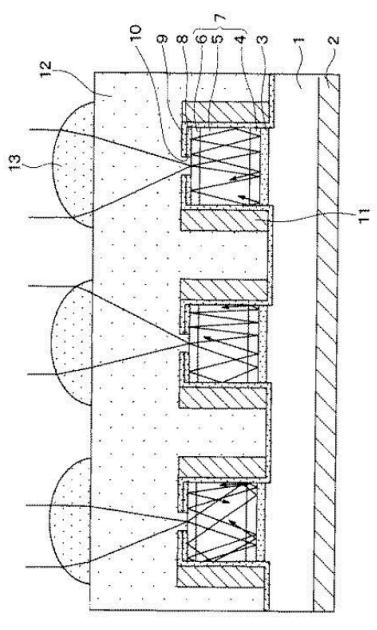
[FIG. 8] FIG. 8 shows a cross-section view of the light receiving element in the sixth embodiment.

[DESCRIPTION OF THE REFERENTIAL NUMBERS]

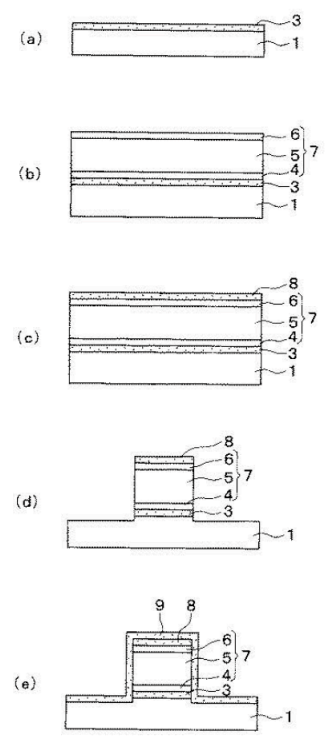
[0059]

- 1 semiconductor substrate
- 3 first reflecting film
- 7 PIN photodiode
- 8 second reflecting film
- 10 through-hole
- 11 third reflecting film
- 13 microlens
- 14 groove

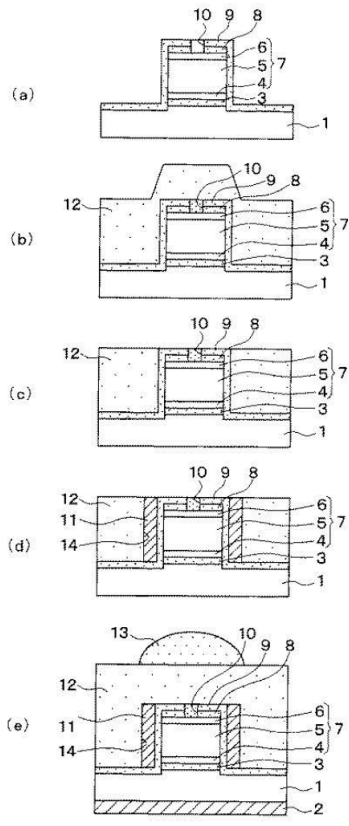
(FIG. 1)



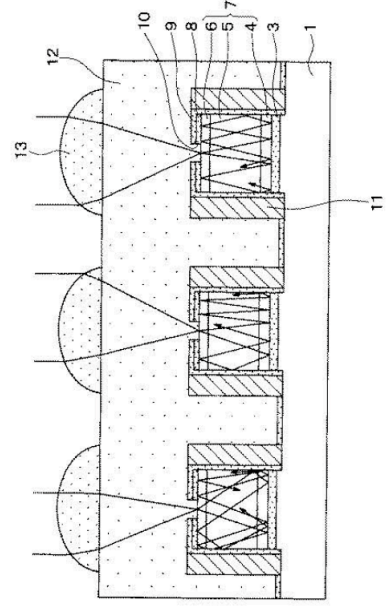
(FIG. 2)



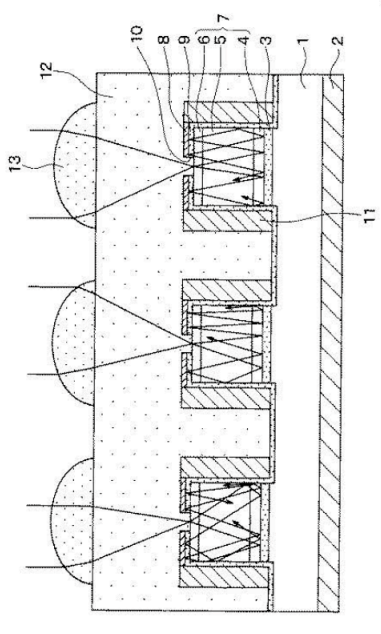
(FIG. 3)



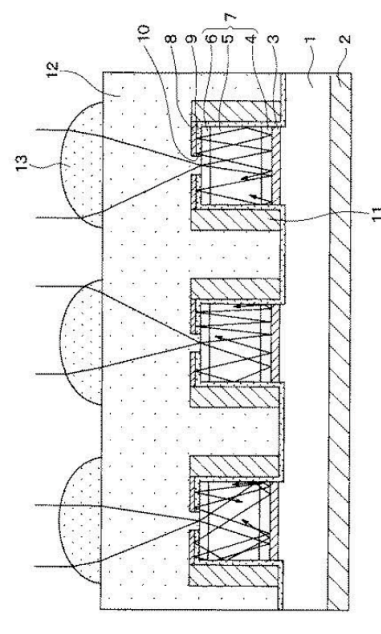
(FIG. 4)



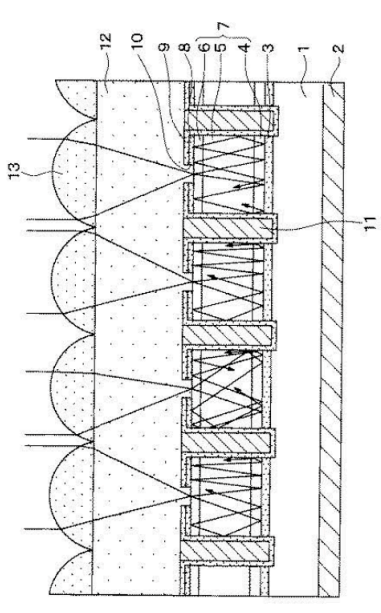
(FIG. 5)



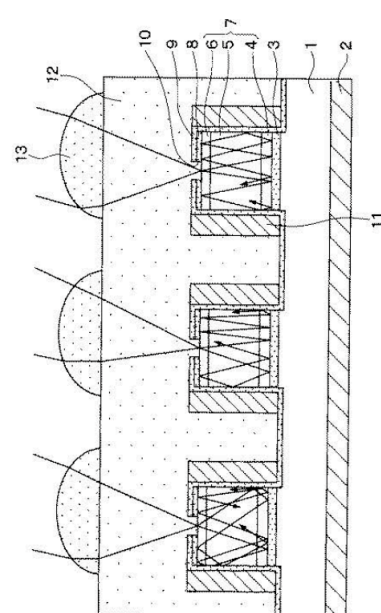
(FIG. 6)



(FIG. 7)



(FIG. 8)



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