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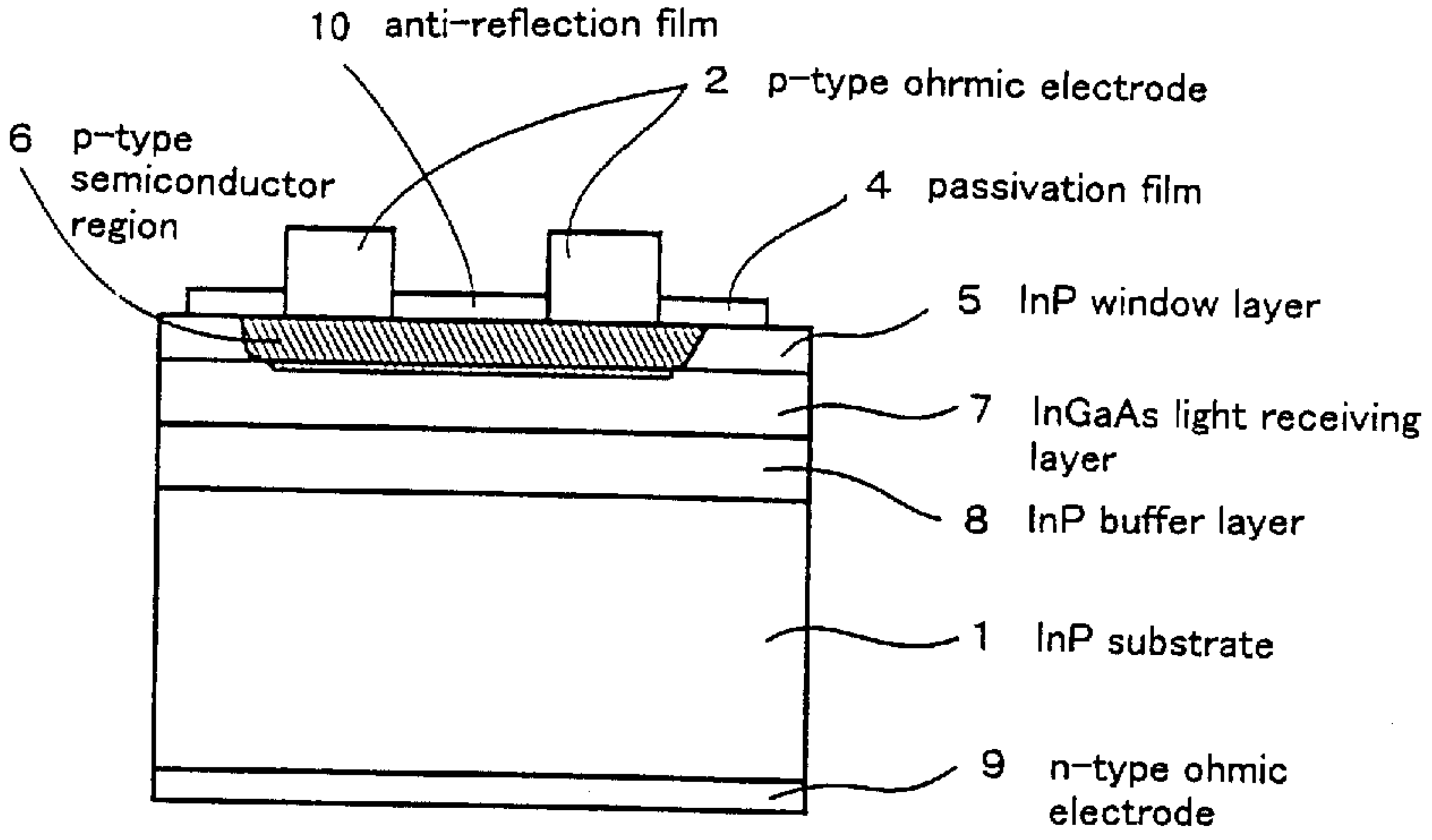
(54) CONTACT OHMIQUE ET PROCESSUS DE FABRICATION DE CE GENRE DE CONTACT

(54) OHMIC CONTACT AND PROCESS FOR PRODUCING THE SAME



(57) An ohmic contact accumulated on a substrate of a p-type InP based compound semiconductor crystal is disclosed, comprising plural metallic layers comprising, in this sequence from a side of the substrate, a first layer comprising a transitional metal, a second layer comprising Zn, and a third layer comprising a transitional metal. A process for producing an ohmic contact accumulated on a substrate of a p-type InP based compound semiconductor crystal is also disclosed, comprising: accumulating plural metallic layers comprising, in this sequence from the substrate, a first layer comprising a transitional metal, a second layer comprising Zn, and a third layer comprising a transitional metal; and then conducting heat treatment at a temperature within a range of 350 to 400 °C.

ABSTRACT OF THE DISCLOSURE

An ohmic contact accumulated on a substrate of a p-type InP based compound semiconductor crystal is disclosed, comprising plural metallic layers comprising, in this sequence from a side of the substrate, a first layer comprising a transitional metal, a second layer comprising Zn, and a third layer comprising a transitional metal. A process for producing an ohmic contact accumulated on a substrate of a p-type InP based compound semiconductor crystal is also disclosed, comprising: accumulating plural metallic layers comprising, in this sequence from the substrate, a first layer comprising a transitional metal, a second layer comprising Zn, and a third layer comprising a transitional metal; and then conducting heat treatment at a temperature within a range of 350 to 400°C.

OHMIC CONTACT AND PROCESS FOR PRODUCING THE SAME

FIELD OF THE INVENTION

The present invention relates to an ohmic contact suitable for an InP based compound semiconductor device, particularly for a semiconductor device using a p-type InP based compound semiconductor as a substrate, and a semiconductor device comprising the contact.

BACKGROUND OF THE INVENTION

An ohmic contact comprising Au-Zn metals has been employed as an ohmic contact for a semiconductor device using a p-type InP based compound semiconductor as a substrate, such as photodiode, laser diode and light emitting diode. Au is used in the laminated electrode comprising Au-Zn metals because Au reacts with the InP based compound semiconductor substrate through heating (heat treatment) at a temperature range of 400 to 450°C to diffuse into the substrate materiel through a native oxide film present on the surface of the substrate. As a result, electrical contact between the substrate and the metallic film is obtained. In order to obtain electrical contact between the substrate and the metallic film, it is therefore necessary to select a metal that reacts with the substrate at a high temperature and thermally diffuses as a metal constituting the metallic film. Zn is used in the electrode because Zn functions as a p-type impurity with respect to the substrate. That is, Zn diffuses into the substrate through heating after the film formation to form a p-type doped layer of a high concentration at the surface of the substrate. As a result, tunneling of a hole through a Schottky barrier forms at the interface to the substrate after accumulation of the metallic film, so as to obtain good ohmic characteristics. In this case, the use of only Au can provide electrical contact as described above. However, because the p-type carrier concentration at the surface of the substrate is low (generally about 10^{18} cm^{-3}), ohmic electrical contact resistivity characteristics at the contact interface between the metallic film and the substrate (this electrical contact resistivity is hereinafter called for as contact resistivity) cannot be obtained, and thus it is necessary for Zn as a p-type impurity to be diffused on the surface of the substrate to increase the carrier concentration at the surface of the substrate.

Sumitomo Denki, vol. 141, p. 100 to 104 (published in September of 1992) discloses a p-type InP based compound semiconductor comprising an impurity-free InP based compound crystal as a substrate that is equipped with an Au/Zn/Au based metallic electrode. In this literature, the film thickness of the first Au layer and that of the second Zn layer are 50 nm and 30 nm, respectively, with the film thickness of the third Au layer being changed to the range of 20 to 500 nm, and the dependence of the contact resistivity on the film thickness of the third layer is discussed. It is disclosed that good electrical contact to the substrate can be obtained when the film thickness of the third layer becomes 100 nm or more, and since Zn as the second layer forms a layer of a high carrier concentration within the surface of the substrate, a good ohmic contact having a contact resistivity in an order of 10^{-5} Ωcm^2 is obtained. Furthermore, this literature discloses in the second column on page 100 that the contact resistivity can be minimized by such a manner that a Ti film having a film thickness of 100 nm as the fourth layer is formed on the third layer, and an Au film having a film thickness of 250 to 350 nm as the fifth layer is formed on the fourth layer, followed by heating at a temperature of 435°C in a nitrogen atmosphere, so that the accumulated layers are alloyed. However, while obtaining a product having a good contact resistivity by using the accumulated film as the third layer having a thickness of 100 nm or more, the thickness of the alloyed layer at the surface part (hereinafter called a reaction layer) becomes non-uniform, and protrusions having a pyramid shape of a height of about 0.5 μm biting into the substrate are formed in spots. Figure 1 schematically shows the state described above. The protrusions may grow to reach the operation layer of the semiconductor device, which results in damage of the device. Thus, the Au/Zn based electrode can be a good ohmic contact having a small contact resistivity by making the reaction layer thick, but involves the problem described above.

In order to solve the problem and to make the thickness of the reaction layer relatively thin, various structures of an ohmic contact have been proposed. For example, according to J. Electron. Matter., vol. 20, p. 237 (1991), D.G. Ivey et al obtain an ohmic contact having a good contact resistivity with a shallow reaction layer of the same metallic layers by adding a Pd layer. They provide an Au/Pd/Zn/Pd based metallic electrode on a substrate of a p-type InP based compound semiconductor, followed by heating at a temperature range of 420 to 425°C, to obtain a device having a good contact resistivity of 7 x 10^{-5} Ωcm^2. As another example, according to Appl. Phys. Lett., vol. 66, p. 3310 (1995), L.C. Wang et al obtain an ohmic contact having a contact resistivity of an order of 10^{-5} Ωcm^2 by providing a Ge/Pd/Zn/Pd metallic layer, followed by heating at a temperature of 420°C. Furthermore, according to Appl. Phys. Lett., vol. 70, p. 99 (1997), Moon-Ho Park et al obtain a thin ohmic contact having a thickness of 10 to 15 nm with a low contact resistivity by providing a Pd/Sb/Zn/Pd based metallic electrode, followed by heating at 500°C.

These ohmic contacts have a thin reaction layer with a depth of 0.1 μm or less from the surface of the substrate, but they require heating (heat treatment) at a high temperature exceeding 400°C. A p-type electrode and an n-type electrode are often provided simultaneously in one semiconductor wafer, in which the suitable heating temperature on forming an Au/Ge/Ni based metallic film, which is widely used as an n-type ohmic contact for the InP based compound semiconductor, is from 350 to 400°C. In this case, therefore, it must be heated to a high temperature exceeding 400°C to adapt to the heating temperature of the p-type electrode. When the n-type electrode is heated at such a high temperature, the reaction with the substrate is concentrated in the n-type electrode side, and as a result exceeds the reaction diffusion of the metallic layer component into the substrate, and the component invades deeply into the wafer, so that the practical characteristics inherent to the wafer deteriorate. In an ohmic contact, an Au layer is provided further on the third layer to improve the bonding property of a connecting wire by suppressing the sheet resistance at the contact part. However, when the heating temperature on the film formation exceeds 400°C, diffusion of Au from the uppermost layer proceeds abnormally, and characteristic deterioration of the semiconductor wafer may arise. According to JP-A-3-16176, an attempt to suppress the deterioration of a wafer due to the abnormal diffusion of Au is done by providing a stopper layer having a thickness of 50 to 500 nm comprising Ti or Cr on an Au/Zn/Au based electrode having a thickness of 50 to 500 nm with a low contact resistivity of an order of 10^{-5} Ωcm^2, and further providing a thick Au uppermost layer thereon. However, this electrode still requires heating at a high temperature of 430 to 450°C.

According to the conventional techniques described above, a thin reaction layer cannot be formed by low temperature heating at 400°C or lower to obtain good ohmic characteristics, simultaneously with the formation of an n-type semiconductor electrode.

SUMMARY OF THE INVENTION

The object of the invention is to solve the problems associated with the conventional techniques, that is, to provide a structure of a metallic electrode of a p-type InP based compound semiconductor with a reaction layer of 0.1 μm or less exhibiting a low contact resistivity in an order of 10^{-5} Ωcm^2.

The invention relates to an ohmic contact having a multi-layer structure accumulated on a substrate of a p-type InP based compound semiconductor crystal (hereinafter called as a substrate), the ohmic contact comprising plural metallic layers comprising, in this sequence from a side of the substrate, a first layer comprising a transitional metal, a second layer comprising Zn, and a third layer comprising a transitional metal. It is preferred that the first layer has a thickness of from 2 to 10 nm, the second layer has a thickness of from 5 to 20 nm, and the third layer has a thickness of from 10 to 200 nm.

In the ohmic contact according to the invention, based on the basic structure described above, a fourth layer comprising a high melting point metal and a fifth layer comprising Au may be formed in this sequence on the third layer. It is preferred in this case that the fourth layer have a thickness of 20 to 200 nm, and the fifth layer a thickness of 100 to 500 nm.

In the ohmic contact of the invention having the structure described above, the compound semiconductor crystal as an objective substrate may be either InP or $Ga_xIn_{1-x}As_yP_{1-y}$ (where x and y each represents a positive number of 1 or less, provided that y is a number satisfying equation $y=1-2.1x$). The first layer and the third layer may comprise a metal selected from Pd, Co, Pt, Rh, Ni or Ir.

The ohmic contact of the invention may be produced by a process comprising steps of: accumulating plural metallic layers comprising, in this sequence from the substrate, a first layer comprising a transitional metal, a second layer comprising Zn, and a third layer comprising a transitional metal; from 350 to 400°C. The process for producing an ohmic contact according to the invention may further comprise a step of accumulating a fourth layer comprising a high melting point metal and a fifth layer comprising Au may be formed in this sequence the third layer during the accumulation of plural metallic layers.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic cross sectional view of a conventional p-type ohmic contact;

Figure 2 is a schematic cross sectional view showing the basic constitution of the p-type ohmic contact according to the invention;

Figure 3 is a graph showing the relationship between the contact resistivity and the heat treatment temperature of the ohmic contact of Sample 1;

Figure 4 is an enlarged cross sectional view schematically showing the ohmic contact of Sample 1; and

Figure 5 is a schematic cross sectional view showing a light receiving device using the p-type ohmic contact according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

The ohmic contact of the invention will be described in detail below.

The ohmic contact provided by the invention comprises a p-type InP based compound semiconductor crystal as an objective substrate, and a metallic multi-layer structure accumulated thereon. The objective substrate includes InP and p-type semiconductor crystals comprising mixed crystals of

InP and other III-V semiconductors. The latter is not limited, but one having a composition of $Ga_xIn_{1-x}As_yP_{1-y}$ (where x and y each represents a positive number of 1 or less, provided that y is a number satisfying the equation $y=1-2.1x$) as a mixed crystal with GaAs may be generally used as the substrate.

The metallic multi-layer structure formed on the substrate comprises, in this sequence from the substrate side, the first layer comprising a transition metal, the second layer comprising Zn, and the third layer comprising a transition metal. The transition metal used as the first layer is capable of reacting with the substrate at a lower temperature than Au described above through the native oxide film, so as to form a uniform reaction layer having a uniform thickness. The film thickness of the first layer is preferably from 2 to 10 nm. When it is less than 2 nm, a uniform film cannot be obtained but the film becomes an island form, and the film is unable to cover the whole surface of the substrate. The ability of Zn adhere directly on the surface of the InP substrate diminishes, and there is a possibility that the doping amount becomes too small, so as to exhibit in sufficient ohmic contact characteristics as an object of the invention. When the thickness of the first layer exceeds 10 nm, Zn of the second layer tends to diminish its ability to diffuse into the substrate. A metal selected from Pd, Co, Pt, Rh, Ni and Ir may preferably be used as the first layer.

The second layer formed on the first layer comprises Zn. Zn diffuses into the substrate to dope a p-type carrier in a high concentration on the surface of the substrate, and the formation of an ohmic contact with a low contact resistivity is accelerated. The thickness of the second layer is preferably from 5 to 20 nm. When it is less than 5 nm, there is a tendency of diminishing the obtainablity of the sufficient ohmic contact characteristics as an object of the invention. When it exceeds 20 nm, a Zn-P based compound is liable to be formed by the reaction of excess Zn and P, and there is a possibility of deteriorating the semiconductor.

The third layer formed on the second layer comprises a transition metal. Specific examples of the transition metal include metals such as Pd, Co, Pt, Rh, Ni and Ir. The third layer reacts with the surface of the substrate in relation to Zn of the second layer, and has a function of controlling the diffusion of Zn of the second layer. The thickness of the third layer is preferably from 10 to 200 nm. When it is less than 10 nm, the underlying layer comprising Zn is liable to be oxidized by the heat treatment atmosphere, and as a result there is a tendency of inhibiting the diffusion of Zn into the substrate. That is, there is a possibility that the function of protecting the Zn layer from the outer atmosphere is deteriorated. When the thickness of the third layer exceeds 200 nm, diffusion of Zn in the direction toward the surface of the electrode is liable to occur, which is the reverse of the direction toward the substrate.

In the ohmic contact according to the invention, in which the first to third metallic layers are accumulated in this sequence, and preferably the thicknesses of the layers are controlled into the ranges described above, the functions of the layers described above act synergistically, to be capable of simultaneously providing the ohmic contact by heat treatment at a temperature of 400°C or lower with the formation of an n-type metallic electrode and a metallic electrode of a p-type InP based compound semiconductor that is excellent in practical use having a contact resistivity in an order of 10^{-5} Ωcm^2 , and a thickness of the reaction layer of 0.1 μm or less can be provided.

The ohmic contact according to the invention involves those having the basic structure comprising the first to third layers that further comprise the fourth layer comprising a high melting point metal and the fifth layer comprising Au formed in this sequence on the third layer. Examples of the high melting point metal constituting the fourth layer include Nb, W, Mo, Ta, Ti and Pt. In this case, the high melting point metal layer as the fourth layer prevents Au of the uppermost layer provided thereon from contact with the transition metal layer as the third layer, so as to prevent their mutual diffusion of them upon heat treatment. The preferred thickness of this layer is from 20 to 200 nm. When it is less than 20 nm, it is difficult to suppress the mutual diffusion of Au of the fifth layer and the transition metal of the third layer. When it exceeds 200 nm, since the total thickness of the electrode becomes large, the reproducibility of the pattern on the lift-off method, which is often used for fine processing, diminishes, and at the same time, the efficiency of vapor deposition tends to decrease. The Au layer as the uppermost layer has a function of lowering the sheet resistance of the electrode and improving the wire bonding property. In order to sufficiently achieve the function, the thickness thereof is preferably controlled to the range of 100 to 500 nm.

According to the ohmic contact of the invention, by accumulating the fourth and fifth layers on the electrode comprising the first to third layers, and particularly, preferably by setting the thicknesses of the fourth and fifth layers to the ranges described above, the functions of the fourth and fifth layers act synergistically, so that a p-type metallic electrode can be provided through a heat treatment at a temperature of 400°C or lower simultaneously with the provision of an n-type metallic electrode. An excellent metallic electrode for a p-type InP based compound semiconductor having a contact resistivity of less than 10^{-4} Ωcm^2 and a thickness of the reaction layer of 0.1 μm or less, and exhibiting a low sheet resistance to provide excellent wire bonding property can be provided.

The process for producing the ohmic contact of the invention will be described in detail below. Upon producing the ohmic contact of the invention, a p-type InP based compound semiconductor crystal is prepared as the objective substrate. The p-type InP based compound semiconductor substrate has been described above. The plural metallic layers comprising the first layer comprising a transition metal, the second layer comprising Zn and the third layer comprising a transition metal are accumulated on the substrate in this sequence. The accumulation of the layers is conducted individually from the first layer to control the thicknesses of the layers. The accumulation may be conducted by any conventional thin film formation methods. For example, the vapor deposition method, the sputtering method and the ion plating method can be applied, and in general, the layers are preferably accumulated individually by the vapor deposition method. As source materials for the metallic layers in this case, metallic wires and metallic particles are used when the vapor deposition is conducted by resistance heating, or a metallic mass, such as particles, rods or ingots, is used when the vapor deposition is conducted by the electron beam vapor deposition method. In any case, the purity of the material is preferably 3N (99.9%) or higher.

The heat treatment at a temperature in the range of 350 to 400°C is then conducted. The atmosphere of the heat treatment is a non-oxidative gas atmosphere or a reduced pressure atmosphere containing such a gas to prevent oxidation of the metallic accumulated layers and the substrate. As the atmospheric gas, for example, an inert gas, such as argon, nitrogen and helium, a reducing gas, such as hydrogen, and their mixed gases are generally employed. The pressure of the atmospheric gas is preferably from 10^{-2} Torr to the atmospheric pressure. When it is lower than 10^{-2} Torr, it is possibly due to the influence of the mixing of external oxygen which may arise in the case where the air tightness of the vessel is insufficient. When it exceeds the atmospheric pressure, there arises the necessity of increasing the pressure resistance of the vessel, and therefore the possibility of increasing the production cost. Upon preparation of the atmosphere in any case, it is preferred that the vessel is once evacuated to a vacuum of about 10^{-3} Torr, and then the prescribed atmospheric gas is introduced at the prescribed pressure, so as to prevent oxidation of the metallic accumulated layers and the substrate.

The duration of maintaining the temperature range described above (heat treatment time) may be generally from 30 seconds to 10 minutes.

EXAMPLE 1

An example of the invention is described with reference to Figures 2 and 4. Figure 2 is a schematic cross sectional view showing the basic structure of the ohmic contact of an example according to the invention. In the figure, numeral 1 denotes a substrate comprising a p-type InP based compound semiconductor crystal, and 2 denotes an ohmic contact according to the invention comprising a first layer 21 comprising a transition metal provided on the substrate, a second layer 22 comprising Zn provided thereon, and a third layer 23 comprising a transition metal provided further thereon.

As Sample 1, an electrode having the structure described above, in which the first layer comprising Pd, the second layer comprising Zn, and the third layer comprising Pd, was produced. An InP compound semiconductor crystal having a length, a width and a thickness of 9 mm, 18 mm and 0.4 mm, respectively was prepared as the substrate, and Pd having a purity of 99.95% and Zn having a purity of 99.999% were prepared as sources of the respective layers of the electrode. After the substrate was placed in a vapor deposition apparatus, the first layer was formed by using the Pd source to achieve a thickness of 3 nm, and subsequently the second layer was formed by using the Zn source to achieve a thickness of 10 nm, and the third layer was formed by using the Pd source to achieve a thickness of 30 nm. The substrate having the metallic layers accumulated thereon was then subjected to heat treatment in a nitrogen atmosphere containing 5% hydrogen gas with an adjusted gas pressure so as to make the total pressure 1 atm at a temperature of 340°C, 350°C, 375°C, 400°C or 420°C for 2 minutes. Figure 3 is a graph showing the relationship between the contact resistivity of the resulting electrode and the heat treatment temperature. In the figure, the numerals attached to the data are the values of contact resistivity. A contact resistivity of 7×10^{-5} Ωcm^2 was obtained with heat treatment at 375°C. The contact resistivity was confirmed by the transmission line model method. Figure 4 is an enlarged cross sectional view schematically showing the ohmic contact of Sample 1. In this figure, numeral 2 denotes the ohmic contact and 3 denotes a reaction layer. It can be understood that the reaction layer has a thickness of 0.1 μm or less and the thickness is uniform, which is different from the reaction layer shown in Figure 1, which has the non-uniform thickness and protrusions having a height of 0.5 μm or more.

The p-type accumulated layer was provided on the same substrate as the above, and at the same time, an n-type AuGeNi based accumulated layer was provided on another part of the substrate. As a result, a normal reaction layer on the n-type layer having a contact resistance in an order of 10^{-5} Ωcm^2 and a uniform thickness equivalent to the case of the p-type was obtained. An ohmic contact was produced by using the same conditions for accumulation of the metallic layers and the heat treatment as in Sample 1, except that $Ga_{0.15}In_{0.85}As_{0.33}P_{0.67}$ (x=0.15, y=0.33), which was a mixed crystal composition of

InP and GaAs, was used as the substrate instead of InP. As a result, the resulting ohmic contact exhibited evaluation results equivalent to Sample 1.

The first layer, the second layer and the third layer were formed on the same substrate as above by using the same metal sources for the layers as above in the same manner as above. The substrate having the metallic layer accumulated thereon was subjected to heat treatment at 375°C for 2 minutes. The thicknesses of the layers are shown in Table 1 below. The values of contact resistivity and the state of the reaction layer of the resulting samples are shown in Table 1 along with Sample 1 described above. In Samples 15, 16, 17 and 18, the metal for the first layer and the third layer was changed to Rh, Ni, Ir and Au, respectively, where the film thickness was the same as in the case using Pd. It is understood from the results shown in Table 1 that by controlling the thicknesses of the first layer, the second layer and the third layer to the range of 2 to 10 nm, 5 to 20 nm and having 10 to 200 nm respectively, an excellent ohmic contact can be obtained having a low contact resistivity in an order of 10^{-5} Ωcm^2 and a thickness of the reaction layer of 0.1 µm or less, having a uniform thickness in comparison to those in which the thicknesses of the layers are not controlled to those ranges.

TABLE 1

Sample	First layer		Second layer		Third layer		Reaction layer		Contact resistivity
	Specie	Thickness	Species	Thickness	Species	Thickness	Thickness	Uniformity	
1	Pd	3	Zn	10	Pd	30	0.05	A	7
2	Pd	1	Zn	10	Pd	50	0.05	A	20
3	Pd	2	Zn	10	Pd	50	0.05	A	10
4	Pd	10	Zn	10	Pd	50	0.06	A	10
5	Pd	12	Zn	10	Pd	50	0.06	A	10
6	Pd	5	Zn	4	Pd	100	0.1	A	15
7	Pd	5	Zn	5	Pd	100	0.1	A	8
8	Pd	5	Zn	20	Pd	100	0.1	A	10
9	Pd	5	Zn	22	Pd	100	0.1	A	10
10	Pd	5	Zn	10	Pd	9	0.01	A	10
11	Pd	5	Zn	10	Pd	10	0.01	A	7
12	Pd	5	Zn	10	Pd	100	0.1	A	10
13	Pd	5	Zn	10	Pd	200	0.2	A	10
14	Pd	5	Zn	10	Pd	210	0.2	A	15
15	Rh	7	Zn	15	Pd	150	0.15	A	20
16	Ni	7	Zn	15	Pd	150	0.15	A	5
17	Ir	7	Zn	15	Pd	150	0.15	A	20
18*	Au	7	Zn	15	Pd	150	0.2	B	5

Note: * Comparative example

Uniformity of thickness:

A: No protrusion having the maximum depth of 0.1 μm or more is present at the cross section.

B: Protrusions having the maximum depth of 0.1 μm or more are present at the cross section.

EXAMPLE 2

The first layer, the second layer and the third layer having the same metallic species and the same thickness as Samples 1, 12 and 17 were accumulated in the same manner as in Example 1, as were a fourth layer and a fifth layer each comprising the metallic species and having the thickness shown in Table 2 below. The substrates having the metallic layers thereon were subjected to heat treatment in the same atmosphere as in Example 1 at 375°C for 1 minute. The numerals in the column of the underlayer material in Table 2 mean the sample numbers in Example 1 that have the same first, second and third layers. The contact resistivity values and the state of the reaction layers of the resulting electrode samples were measured, and it was found that Samples 19 to 33 according to the invention had the same contact resistivity and the same state of the reaction layers as in the corresponding underlayer material samples. The wire bonding property was measured in such a manner that an Au wire having a diameter of 20 μm was attached to the outer surface of the Au layer by pressure welding with heat, and the wire was pulled in a direction perpendicular to the substrate with the substrate held in a fixed position. As a result, it was found that all the samples endured a tensile load exceeding 2 g, which was the practical level. Particularly, by setting the thicknesses of the fourth and fifth layers in the range of 20 to 200 nm and the range of 100 to 500 nm, respectively, it is understood that an ohmic contact having a small sheet resistance and excellent wire bonding property can be obtained. In the column under wire bonding property in Table 2, A means that the wire is peeled off at a load exceeding 4g, B means that the wire is peeled off at a load of 3 g or more but less than 4 g, and C means that the wire is peeled off at a load of 2 g or more but less than 3 g.

By using the same first to third layers as in Sample 26 in Table 2, an n-type Au/Ge/Ni based accumulated layer was formed on another part of the substrate, and Nb as the fourth layer and Au as the fifth layer were accumulated further thereon with the same thicknesses as in Sample 26. The substrate having the metallic layers of p-type and n-type thereon was then subjected to heat treatment in the same atmosphere as above at 375°C. A normal ohmic contact was obtained, in which a p-type electrode had the quality equivalent to Sample 26, and the reaction layer in the n-type layer side had a thickness equivalent to the p-type layer, and a contact resistivity in an order of 10^{-5} Ωcm^2. Furthermore, an ohmic contact was produced by using the same conditions for the accumulation of the metallic layer and the heat treatment as in Sample 26 except that $Ga_{0.15}In_{0.85}As_{0.33}P_{0.67}$ ($x=0.15$, $y=0.33$), which was a mixed crystal composition of InP and GaAs, was used as the substrate instead of InP. As a result, the resulting ohmic contact exhibited evaluation results equivalent to Sample 26.

TABLE 2

Sample	Underlayer material	Fourth layer		Fifth layer		Sheet resistance	Wire bonding
		Species	Thickness	Species	Thickness		
19	1	Nb	18	Au	150	0.01	C
20	1	Nb	20	Au	150	0.01	A
21	1	Nb	100	Au	150	0.01	A
22	1	Nb	200	Au	150	0.01	A
23	1	Nb	220	Au	150	0.01	B
24	1	Nb	100	Au	90	0.05	C
25	1	Nb	100	Au	100	0.01	A
26	1	Nb	100	Au	350	0.01	A
27	1	Nb	100	Au	500	0.01	A
28	1	Nb	100	Au	520	0.01	B
29	1	Ta	100	Au	200	0.01	A
30	1	Mo	100	Au	200	0.01	A
31	1	W	100	Au	200	0.01	A
32	7	Nb	100	Au	200	0.01	A
33	17	Nb	100	Au	200	0.01	A

EXAMPLE 3

A light receiving device (InGaAs/InP photodiode) shown in Figure 5 was produced by using the ohmic contact of Sample 26 produced in Example 2. In Figure 5, numeral 1 denotes an InP substrate, 2 denotes a p-type ohmic contact according to the invention, 4 denotes a passivation film, 5 denotes an InP window layer, 6 denotes a p-type semiconductor region, 7 denotes an InGaAs light receiving layer, 8 denotes an InP buffer layer, and 9 denotes an n-type ohmic contact comprising an Au/Ge/Ni based metallic film formed on the substrate. As shown in the figure, the device comprises the n-type InP semiconductor substrate having accumulated thereon the buffer layer 8 comprising an n-type InP, the light receiving layer 7 comprising an n-type InGaAs, and the window layer 5 comprising an n-type InP. In the prescribed region in the layers, the p-type semiconductor region is formed by the diffusion of Zn. A pair of p-type ohmic contacts 2 according to the invention are formed on the p-type semiconductor region 6, and the n-type ohmic contact 9 is formed on the reverse surface of the semiconductor substrate 1. An anti-reflection film 10 is provided inside the p-type ohmic contacts 2, and the passivation film 4 is provided outside the p-type ohmic contacts 2. The p-type ohmic contacts 2 are equipped with the electrode of Sample 26 according to the invention.

The resulting diode was subjected to a high temperature continuous operation test of −15 V bias under a temperature of 200°C. As a result, deterioration of the device did not occur after 2,000 hours, and it was found that the device has practical reliability higher than the AuZn based ohmic contact.

As described in detail above, the p-type ohmic contact of the invention can be provided on an InP based compound semiconductor substrate simultaneously with an n-type ohmic contact by heat treatment at 400°C or lower. Because the contact resistivity of the ohmic contact of the invention is as small as an order of 10^{-5} Ωcm^2, and the thickness of the reaction layer is uniform and as thin as 0.1 μm or less, a metallic electrode for an InP based compound semiconductor having substantially higher practical reliability than the conventional p-type ohmic contact can be provided.

WHAT IS CLAIMED IS:

1. An ohmic contact accumulated on a substrate of a p-type InP based compound semiconductor crystal, said ohmic contact comprising plural metallic layers comprising, in this sequence from a side of said substrate, a first layer comprising a transitional metal, a second layer comprising Zn, and a third layer comprising a transitional metal.

2. An ohmic contact as claimed in claim 1, wherein said first layer has a thickness of 2 to 10 nm, said second layer has a thickness of 5 to 20 nm, and said third layer has a thickness of 10 to 200 nm.

3. An ohmic contact as claimed in claim 1, wherein a fourth layer comprising a high melting point metal and a fifth layer comprising Au are formed in this sequence on said third layer.

4. An ohmic contact as claimed in claim 3, wherein said fourth layer has a thickness of 20 to 200 nm, and said fifth layer has a thickness of 100 to 500 nm.

5. An ohmic contact as claimed in one of claims 1, wherein said compound semiconductor crystal comprises either InP or $Ga_xIn_{1-x}As_yP_{1-y}$, wherein x and y each represents a positive number of 1 or less, provided that y is a number satisfying the equation $y=1-2.1x$.

6. An ohmic contact as claimed in one of claims 1, wherein said first layer and third layer comprise a metal selected from Pd, Co, Pt, Rh, Ni or Ir.

7. A process for producing an ohmic contact accumulated on a substrate of a p-type InP based compound semiconductor crystal, said process

comprising: accumulating plural metallic layers comprising, in this sequence from said substrate, a first layer comprising a transitional metal, a second layer comprising Zn, and a third layer comprising a transitional metal; and then conducting heat treatment at a temperature within a range of 350 to 400°C.

8. A process for producing an ohmic contact as claimed in claim 7, wherein said process further comprises the accumulation of a fourth layer comprising a high melting point metal and a fifth layer comprising Au may be formed in this sequence on said third layer.

9. A semiconductor device comprising an ohmic contact as claimed in one of claims 1 to 6.

Fig. 1

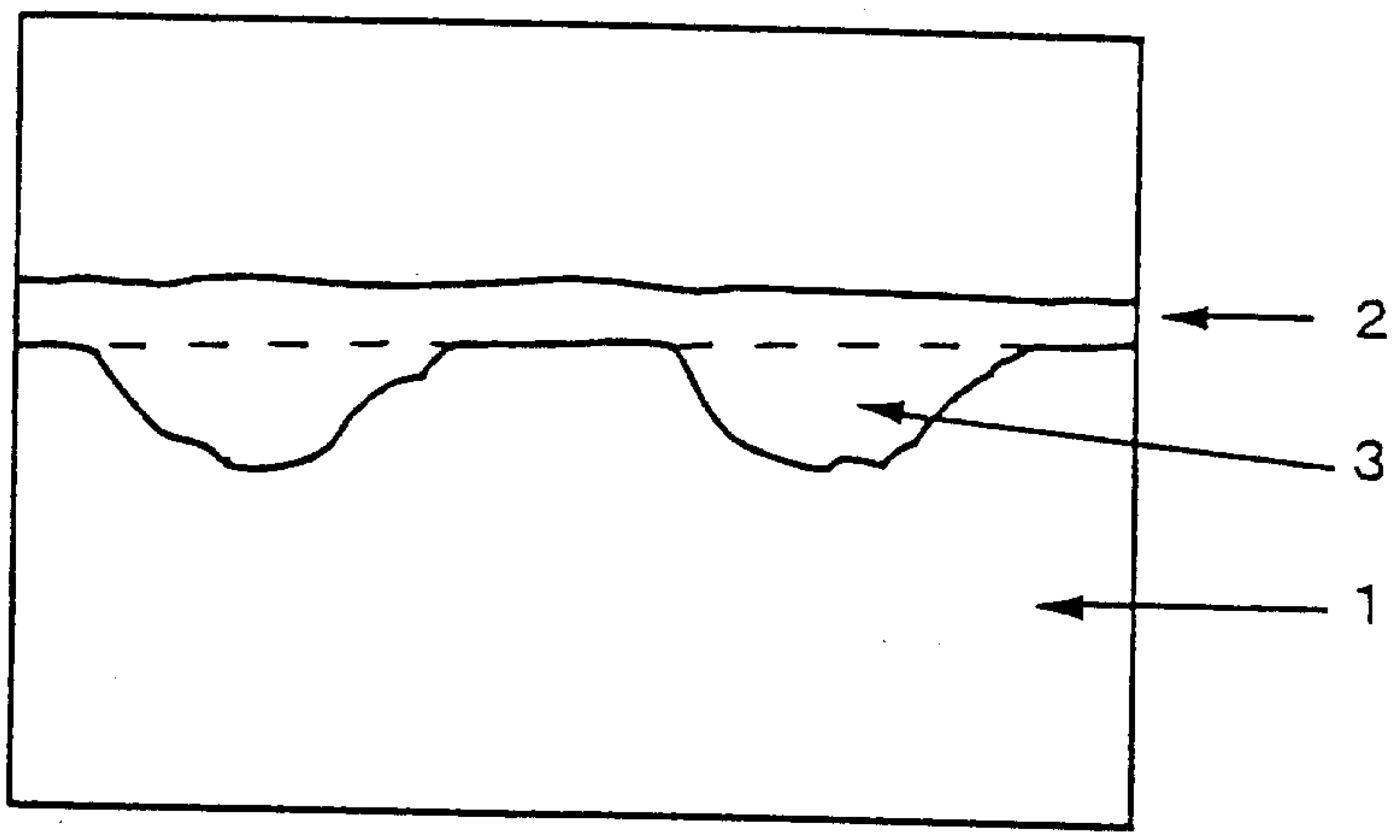


Fig. 2

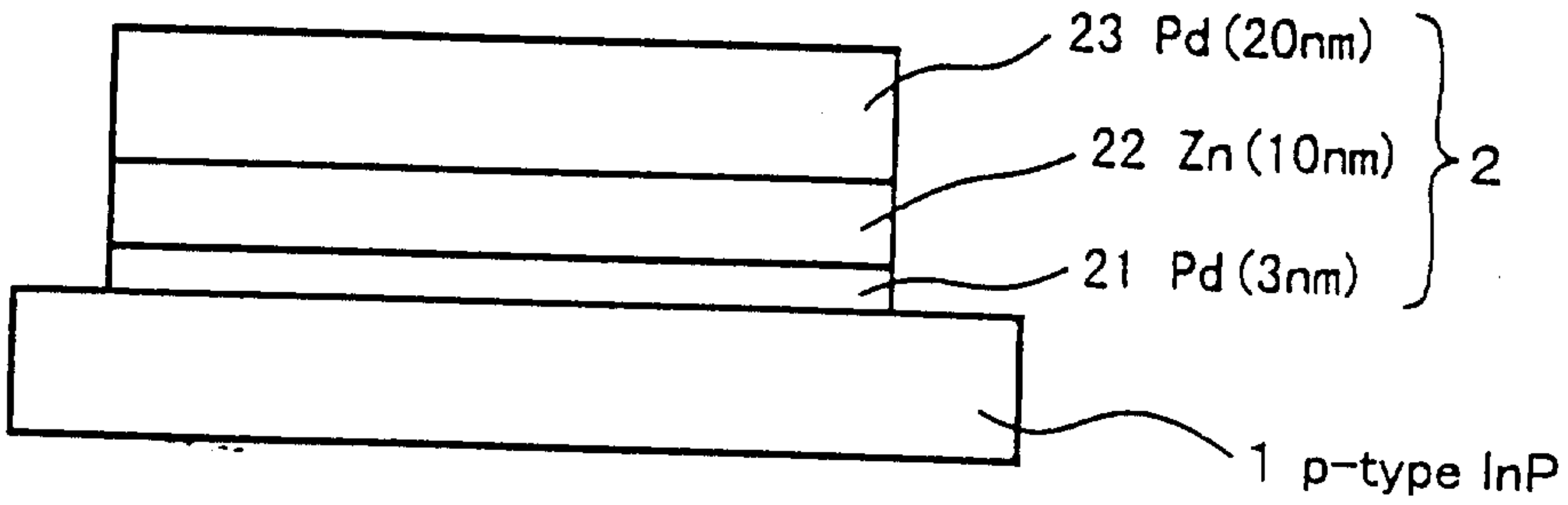


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Fig. 3

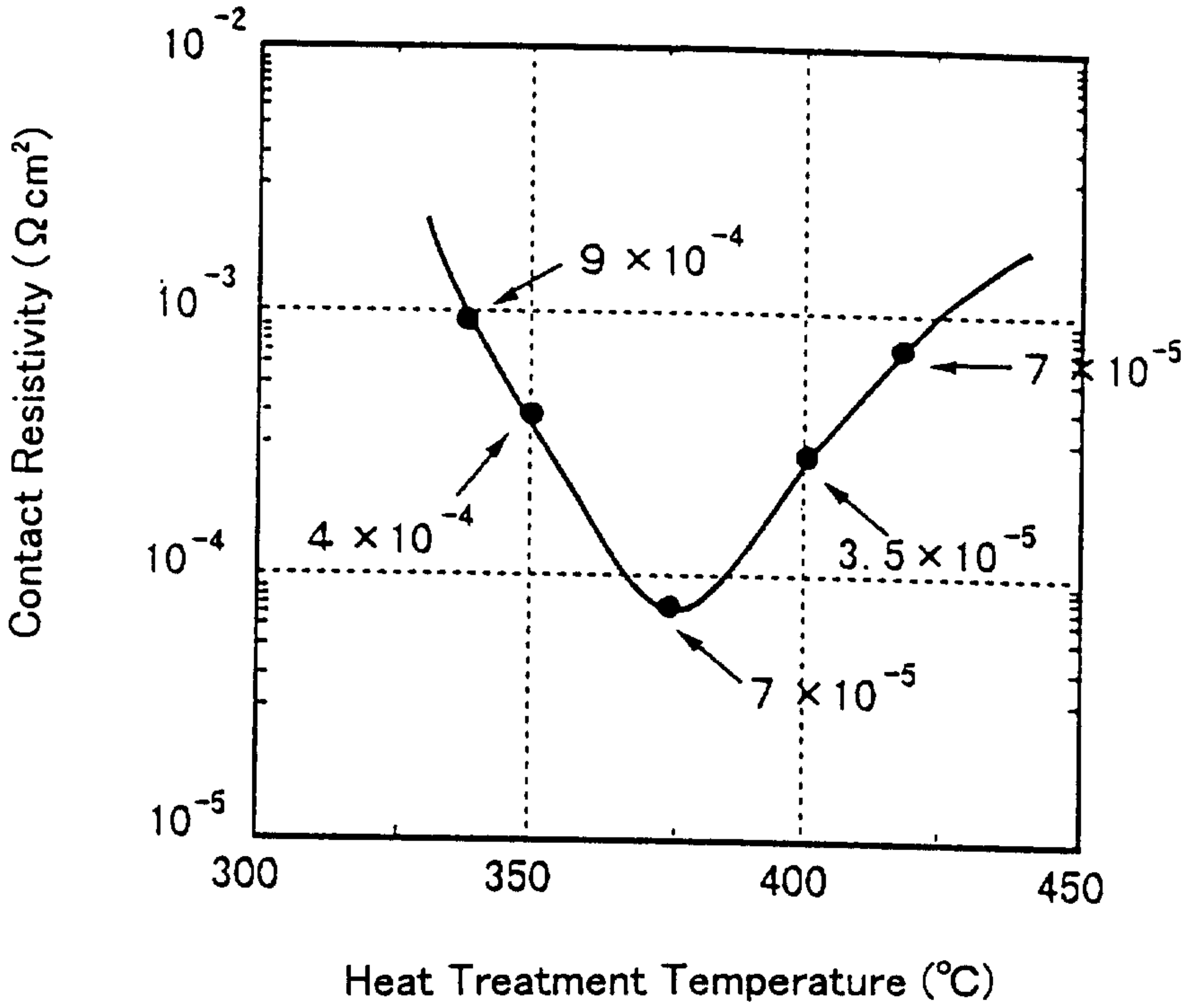

Fig. 4

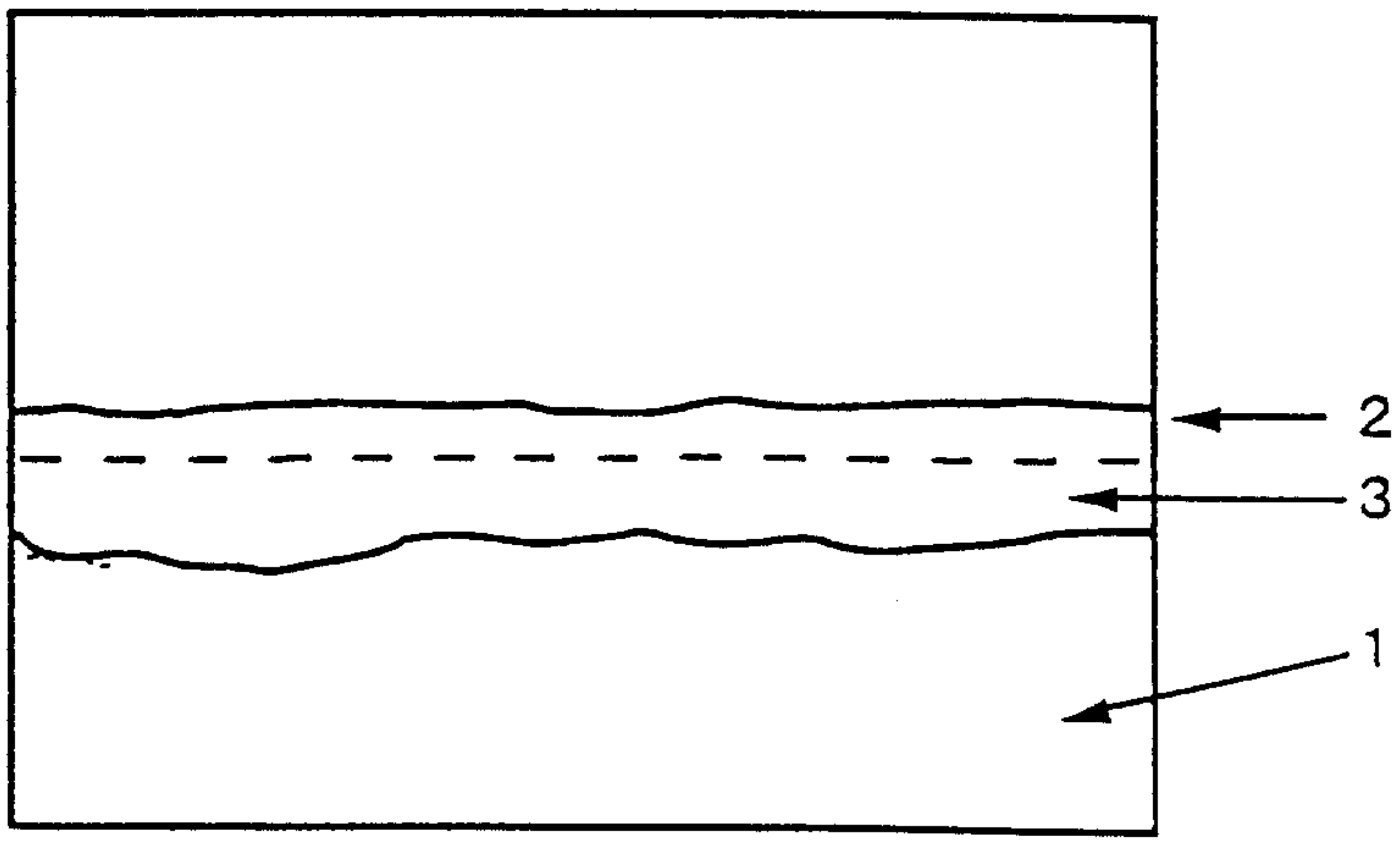

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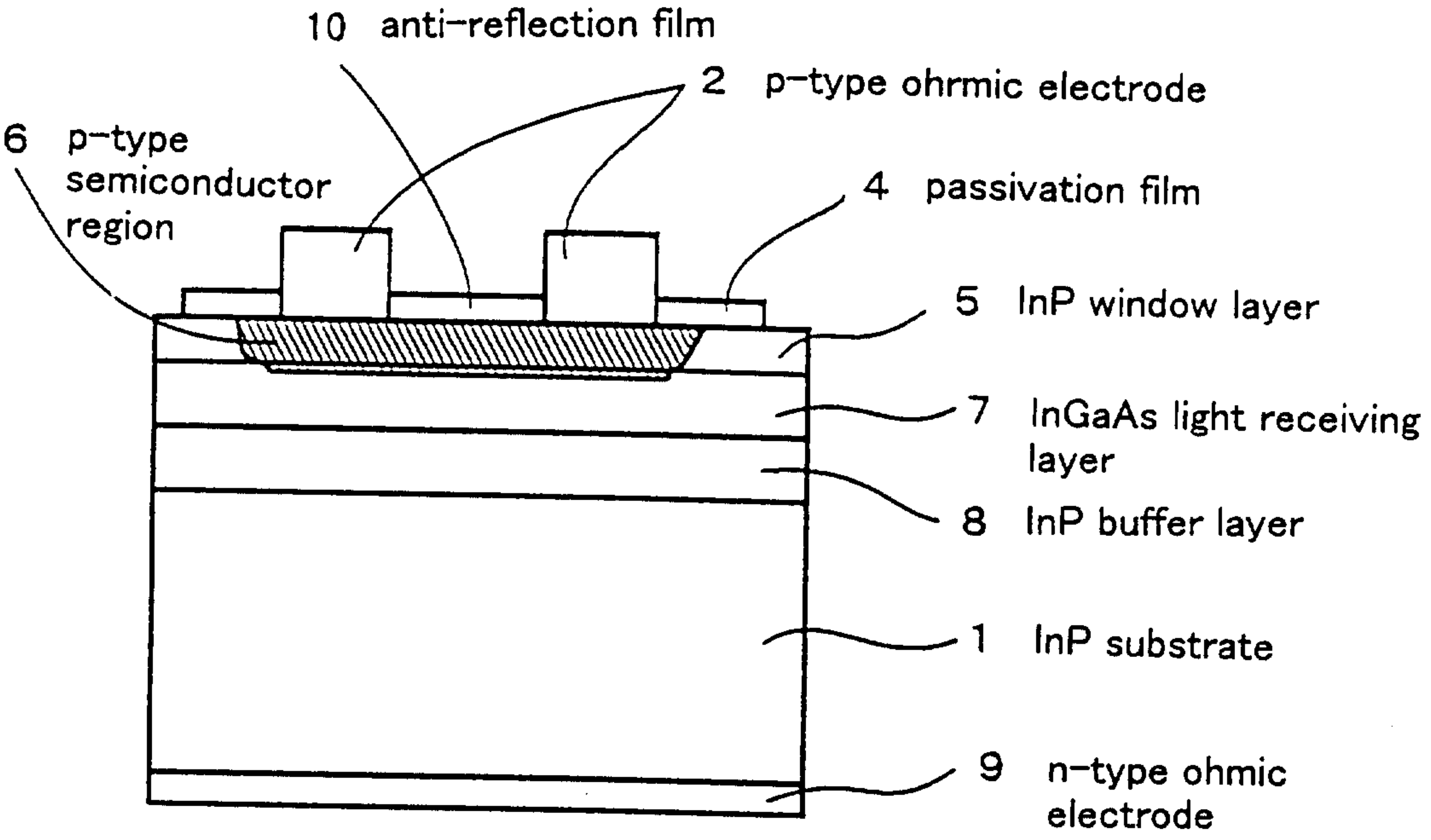
Fig. 5


10 anti-reflection film
2 p-type ohrmic electrode
6 p-type semiconductor region
4 passivation film
5 InP window layer
7 InGaAs light receiving layer
8 InP buffer layer
1 InP substrate
9 n-type ohmic electrode