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**Takeuchi et al.**(10) **Pub. No.: US 2007/0274359 A1**(43) **Pub. Date: Nov. 29, 2007**(54) **SEMICONDUCTOR LASER DEVICE AND  
METHOD OF FABRICATING THE SAME**(30) **Foreign Application Priority Data**

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**WASHINGTON, DC 20005-3096 (US)**(57) **ABSTRACT**(73) Assignee: **SANYO ELECTRIC CO., LTD.**, Osaka  
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29, 2004, now Pat. No. 7,260,130.

A semiconductor laser device capable of improving heat dissipativity, simplifying the fabrication process and improving the fabrication yield is obtained. This semiconductor laser device comprises a semiconductor layer formed on an emission layer while constituting a convex ridge portion, a current blocking layer consisting of a semiconductor formed to cover at least the side surfaces of the ridge portion, a first metal electrode formed to be in contact with the upper surface of the ridge portion and convex support portions arranged on both sides of the ridge portion at a prescribed interval from the ridge portion.

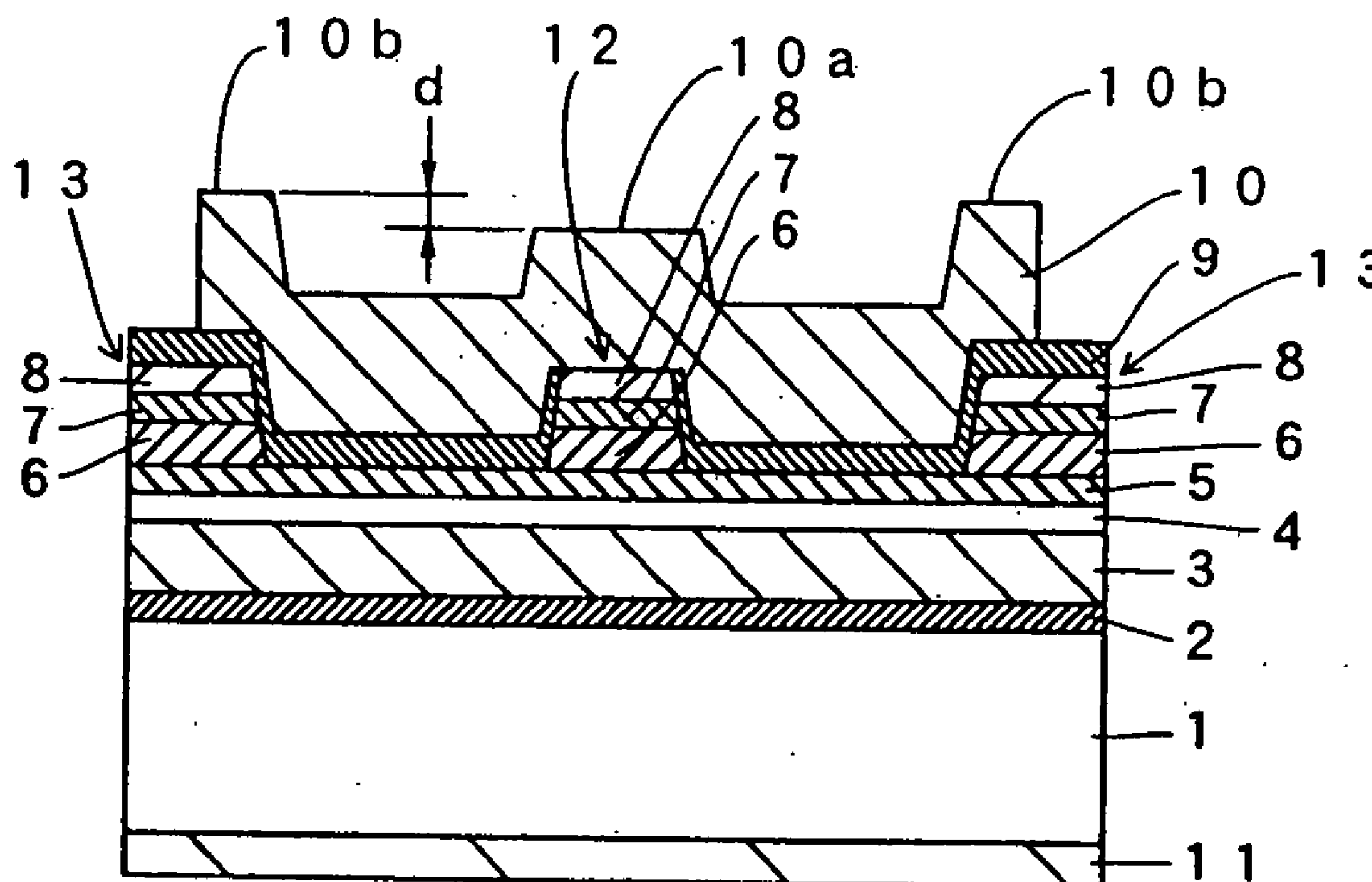


FIG.1

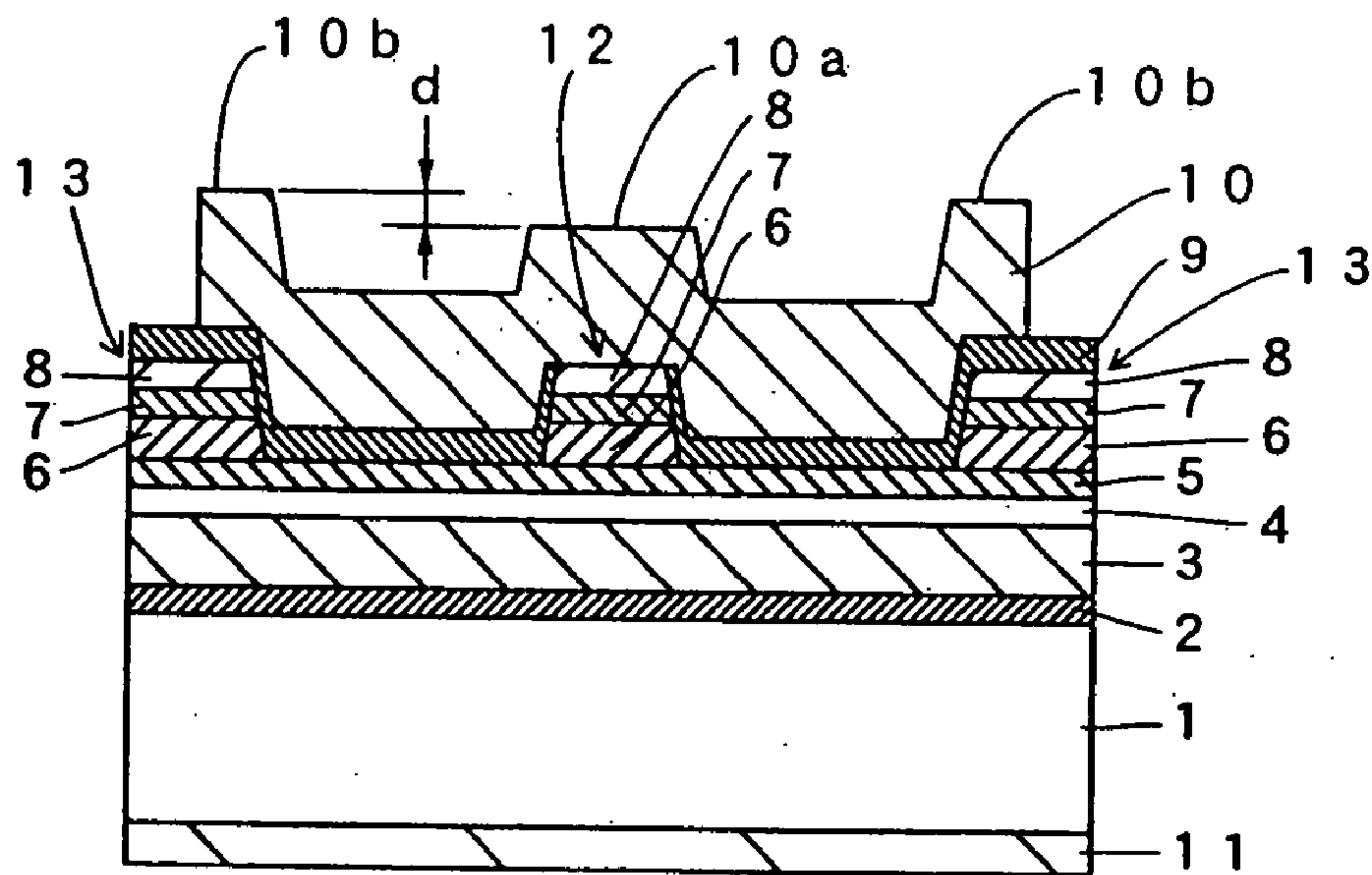
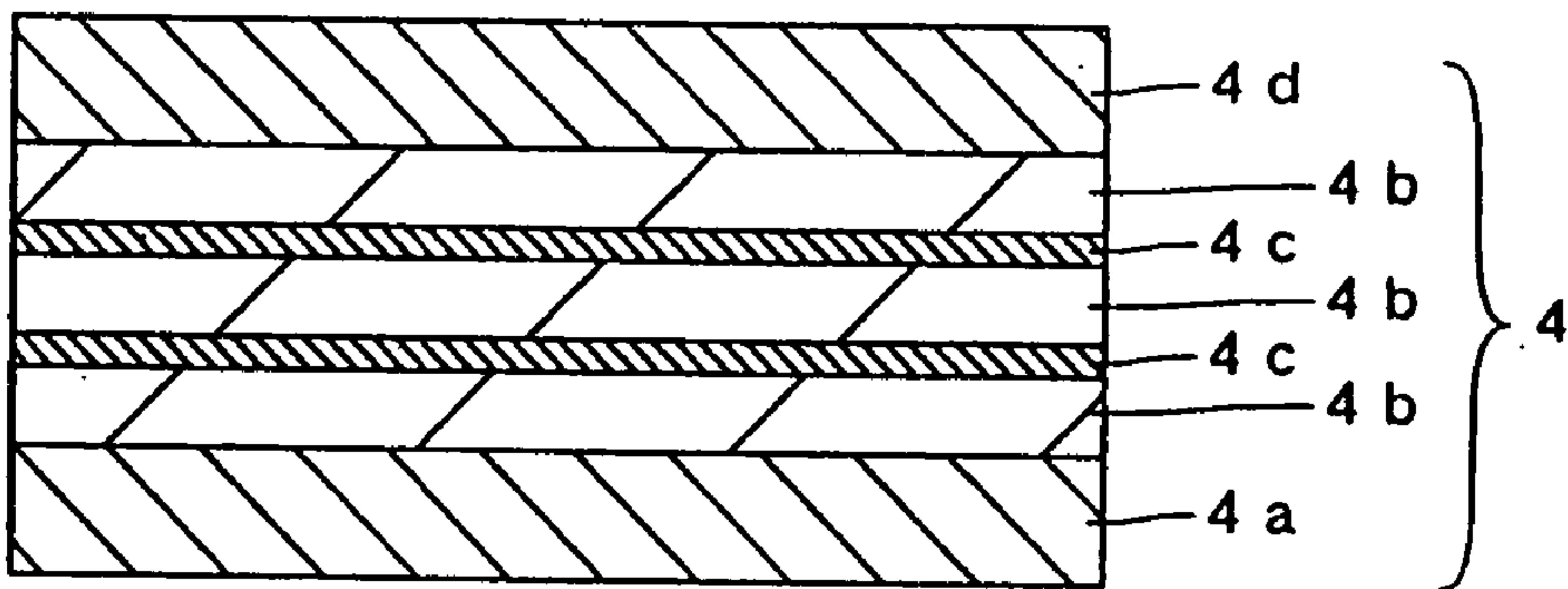
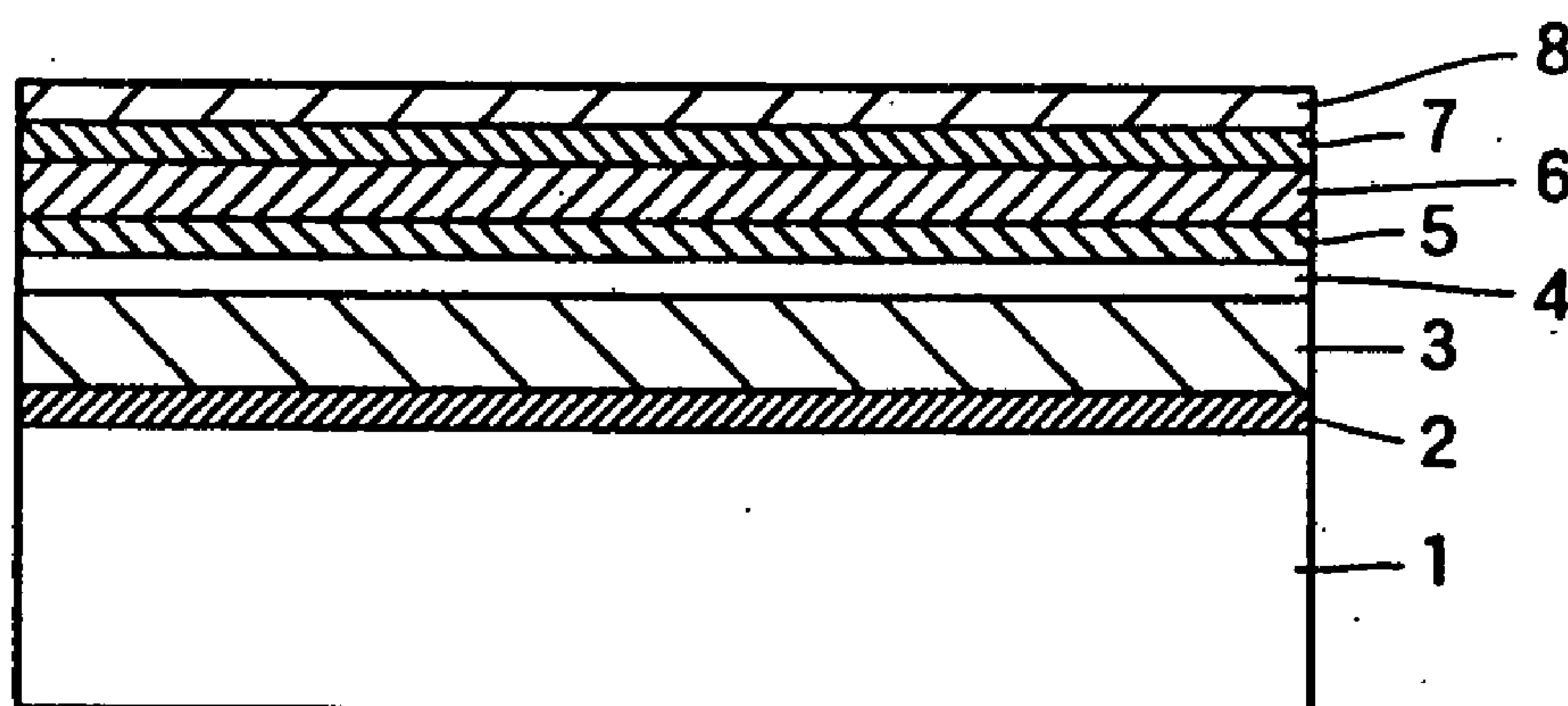


FIG.2



**FIG.3**



**FIG.4**

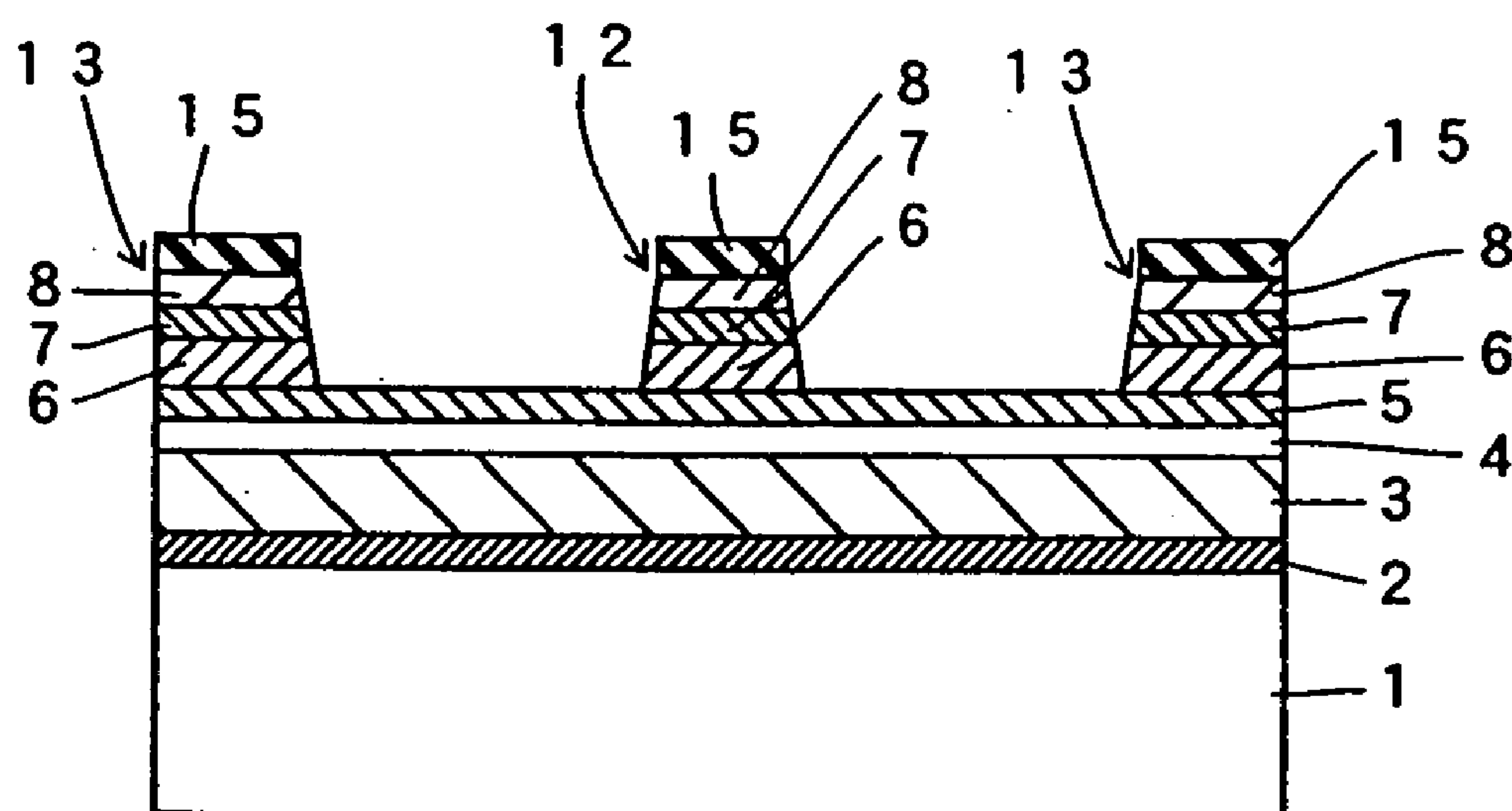






FIG.7

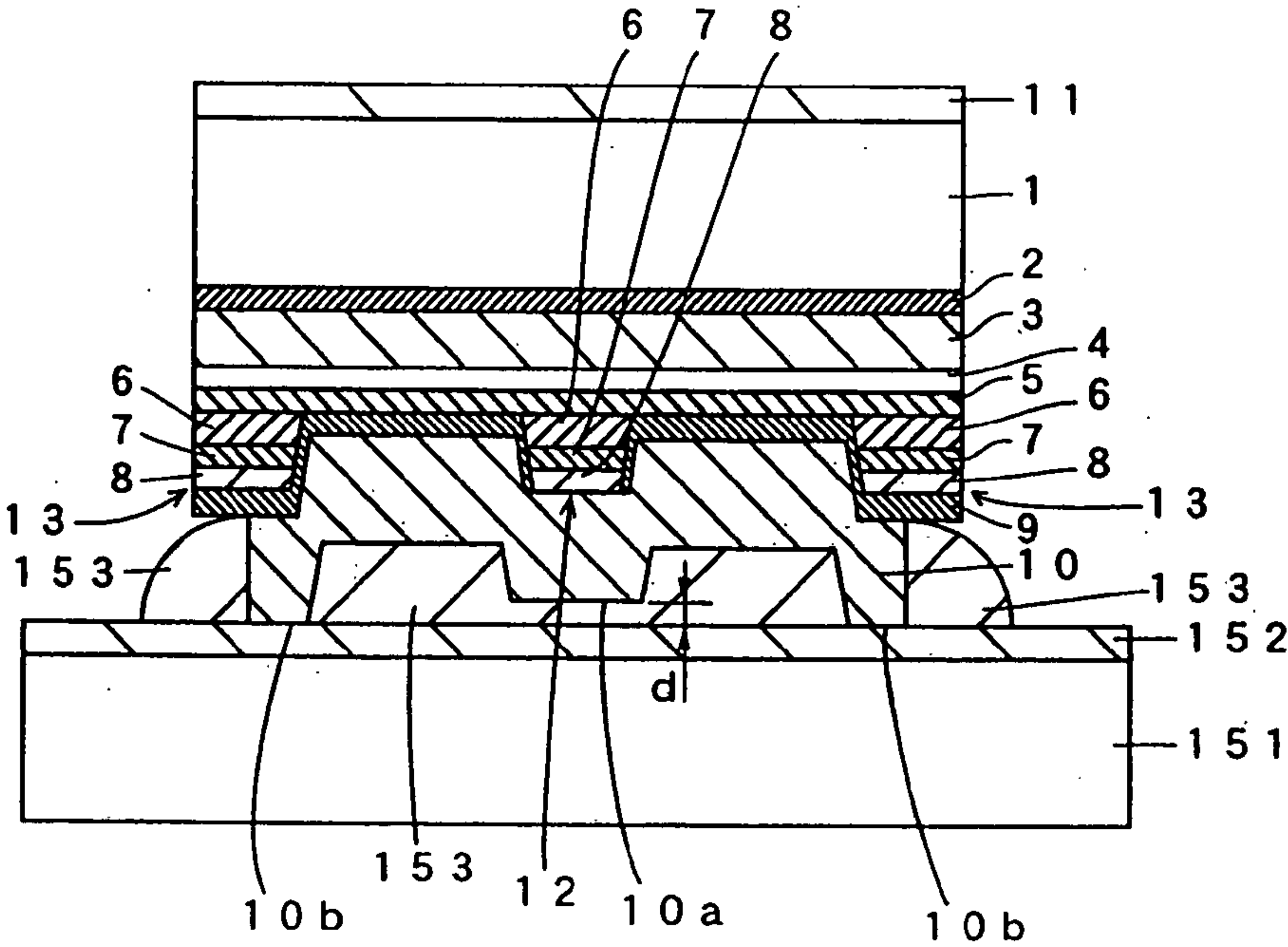


FIG.8

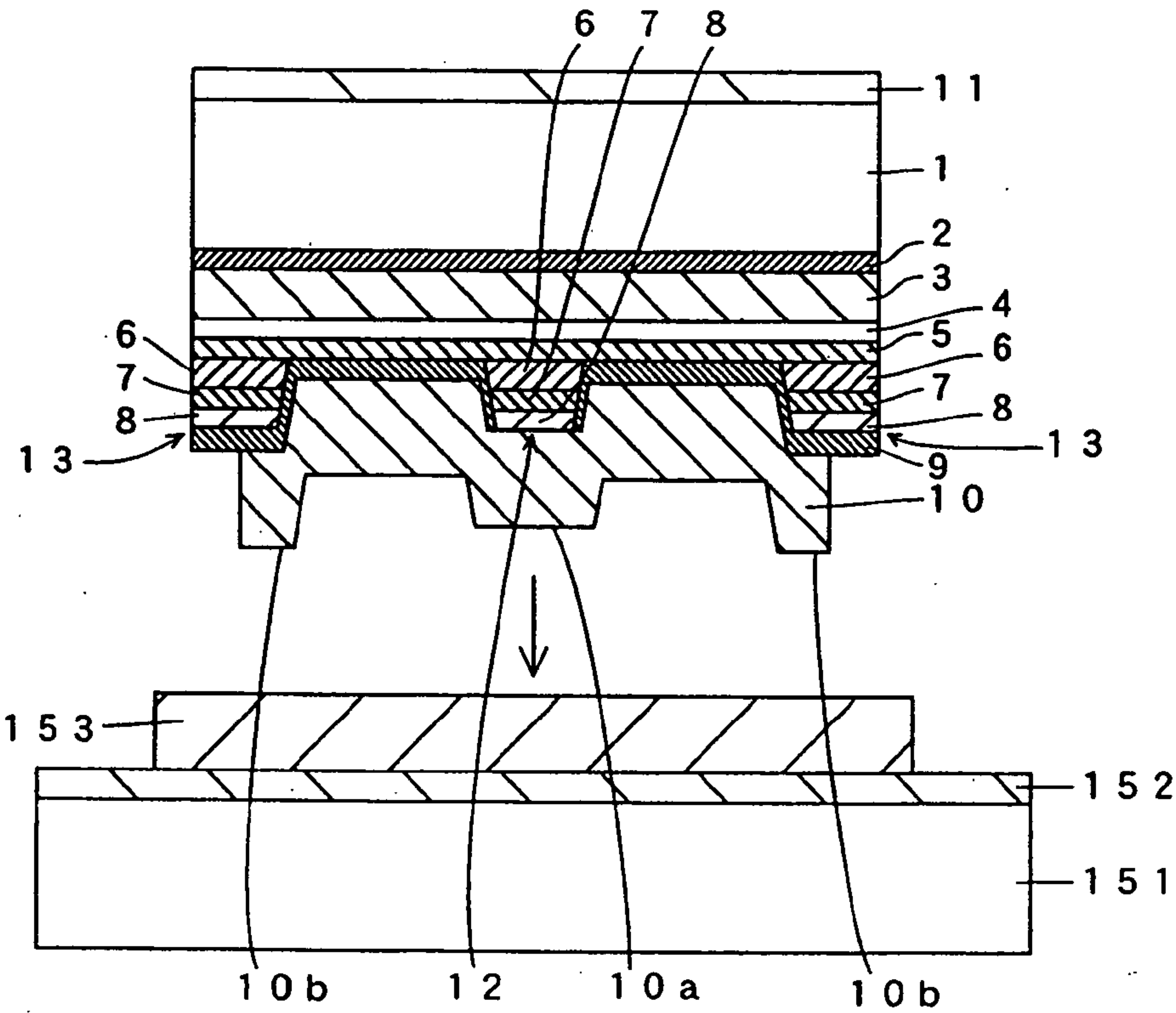






FIG. 13

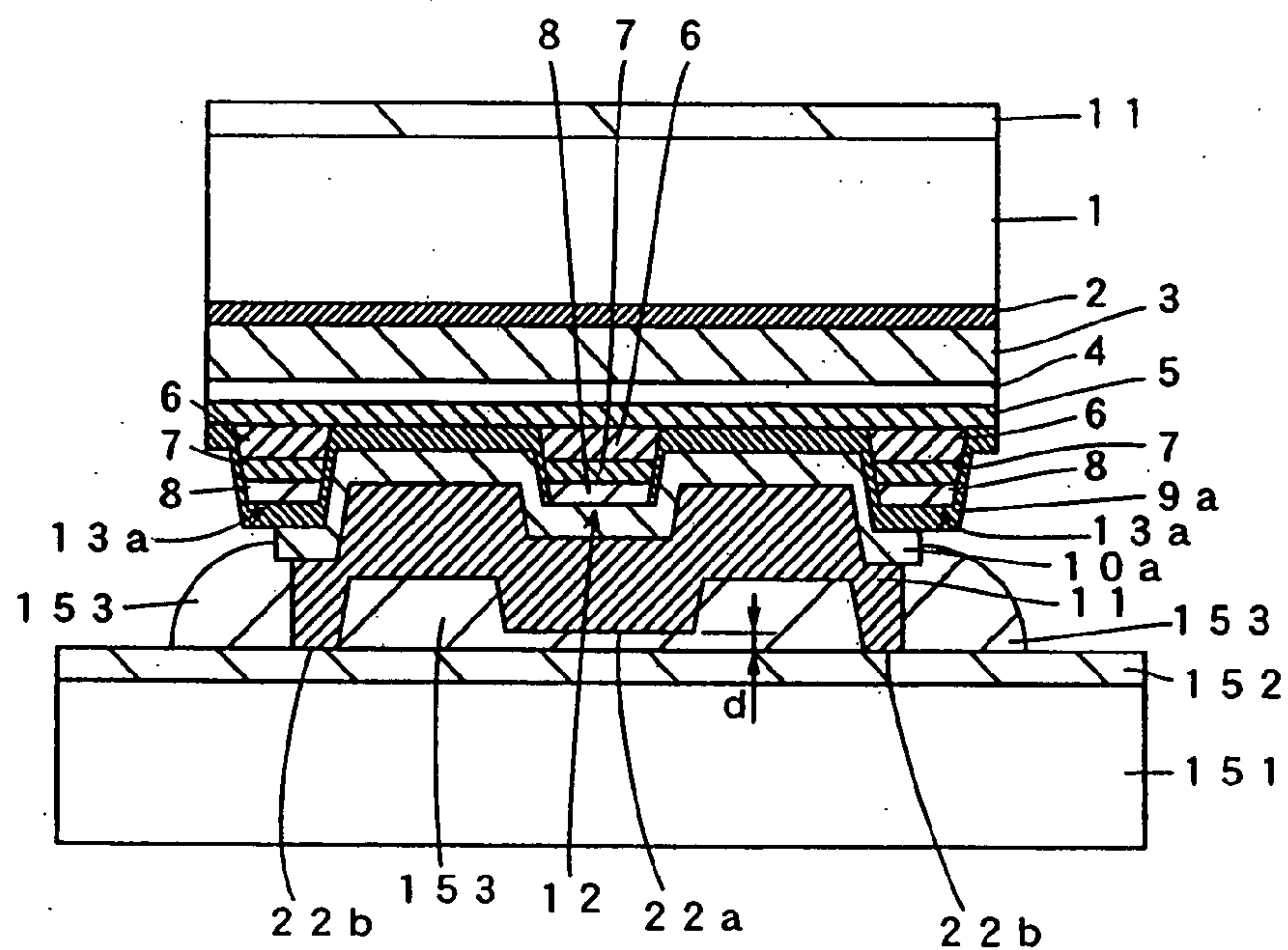


FIG.14

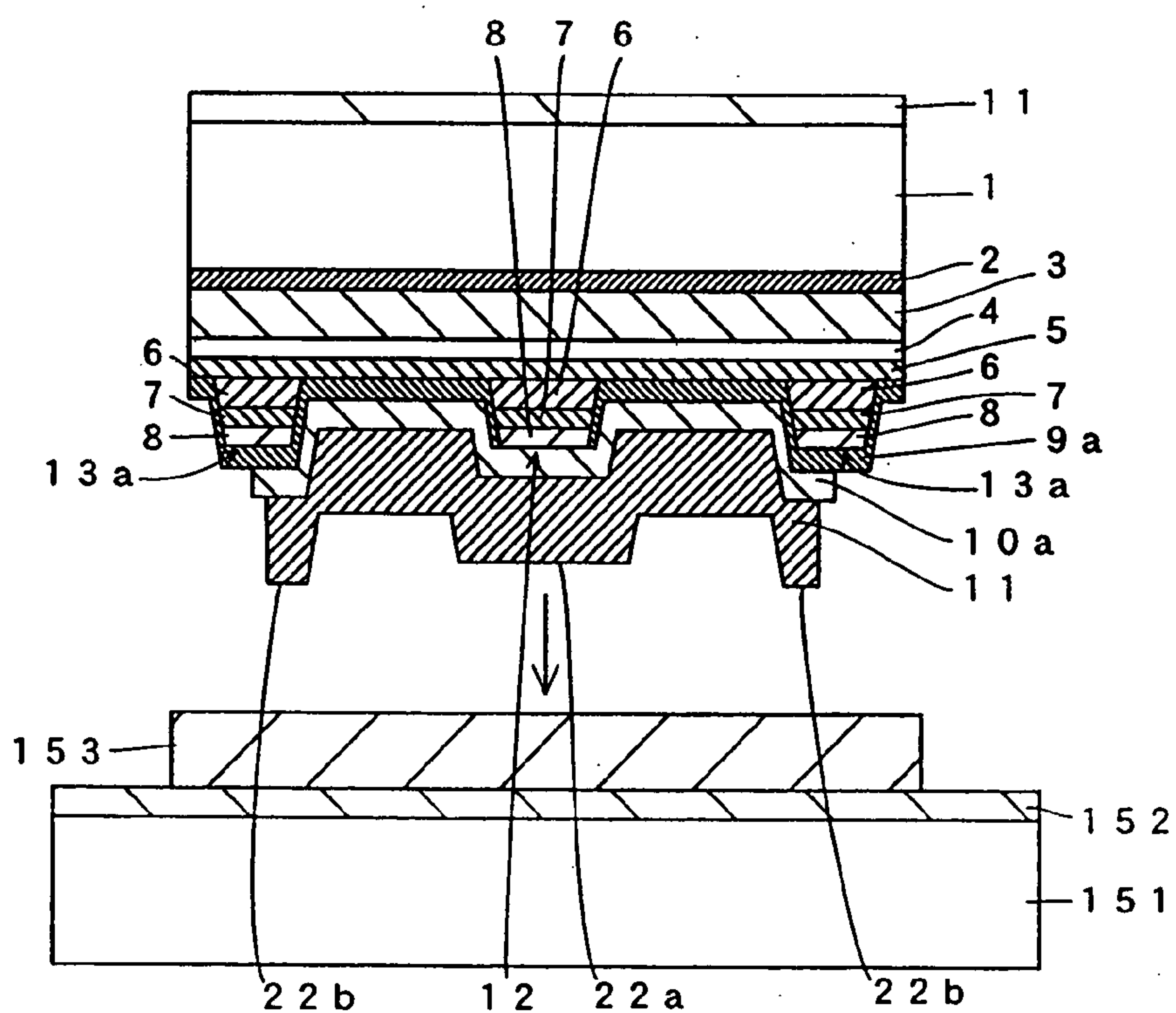




FIG.15

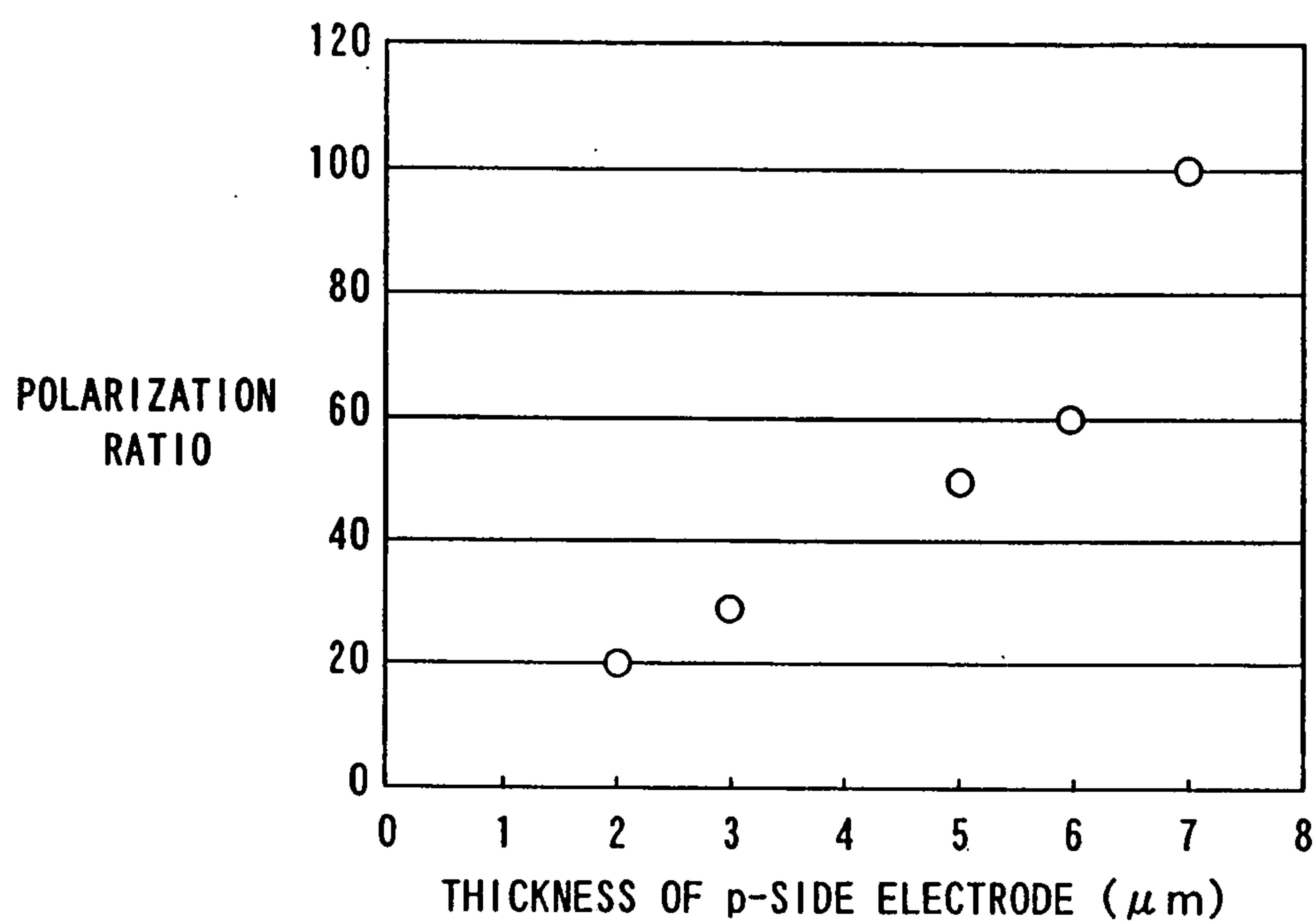


FIG.16

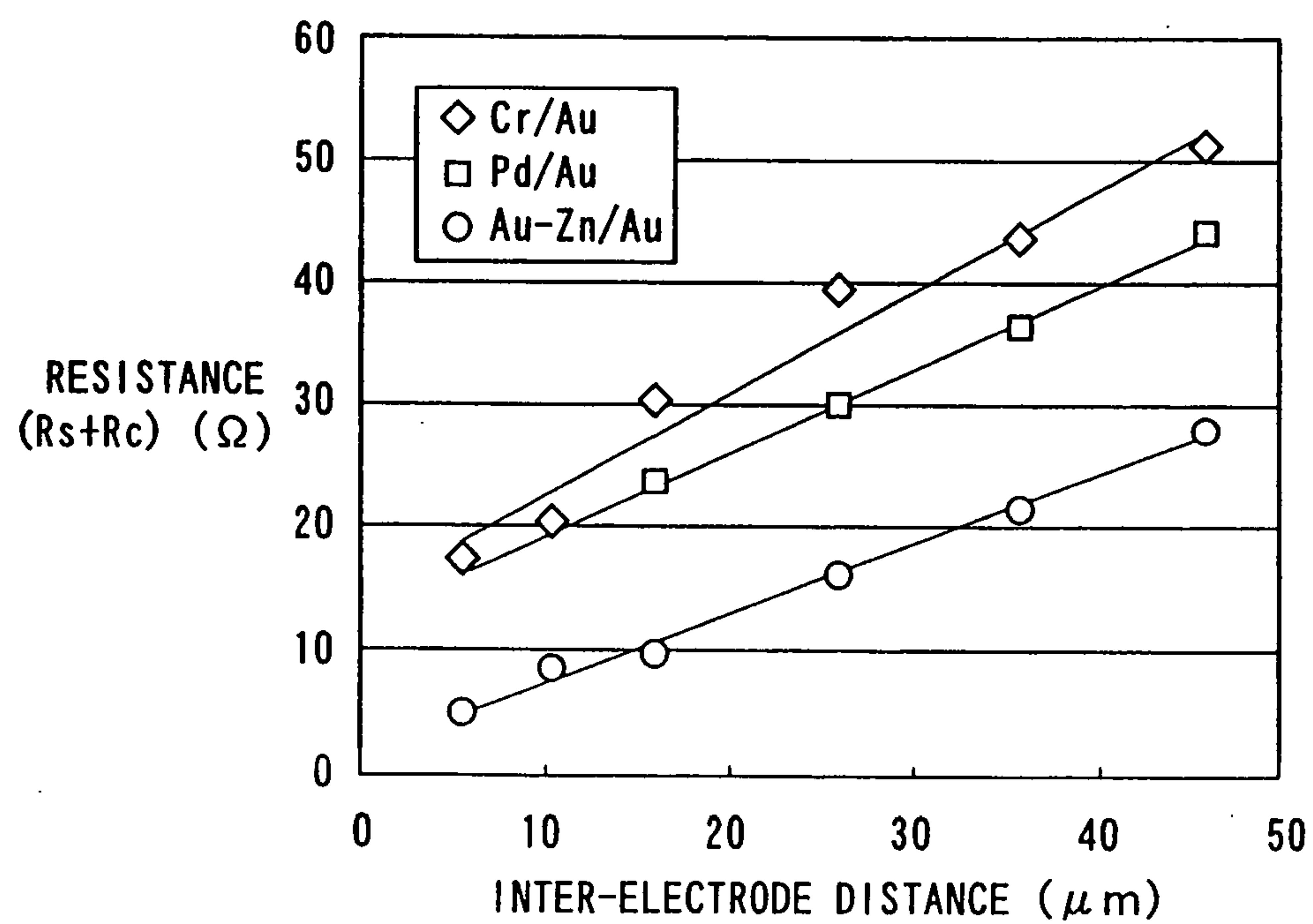


FIG.17

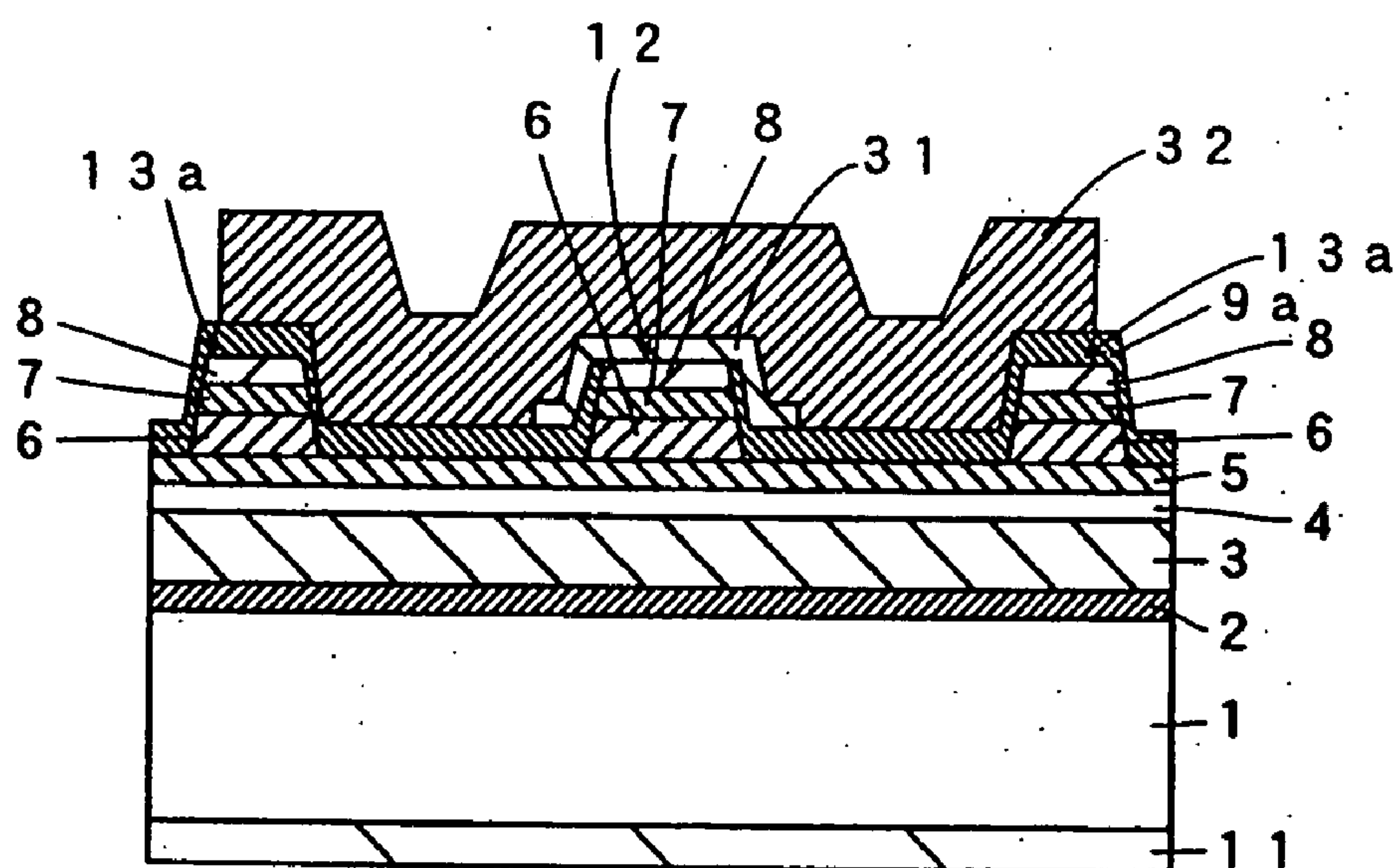


FIG. 18

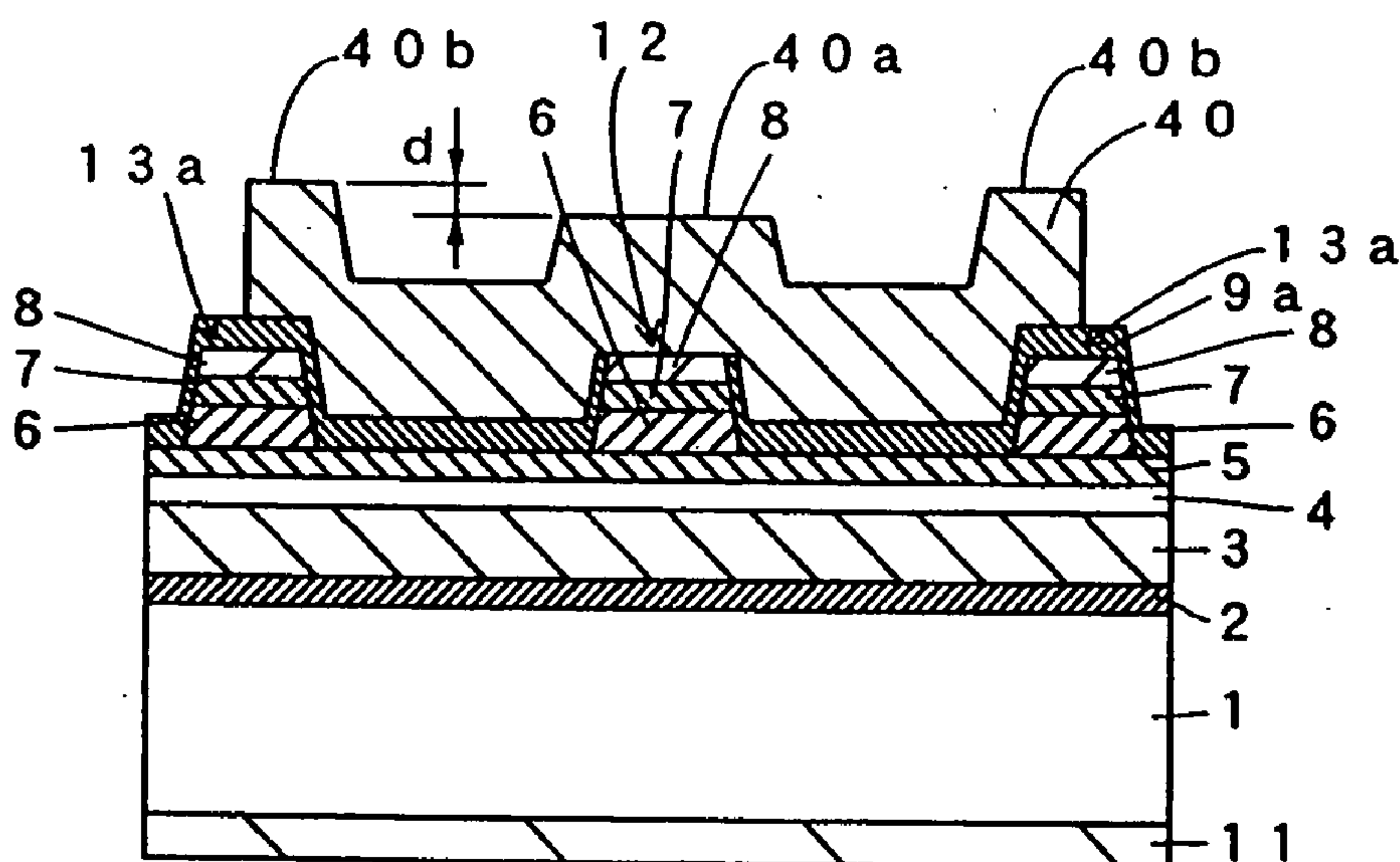




FIG.21

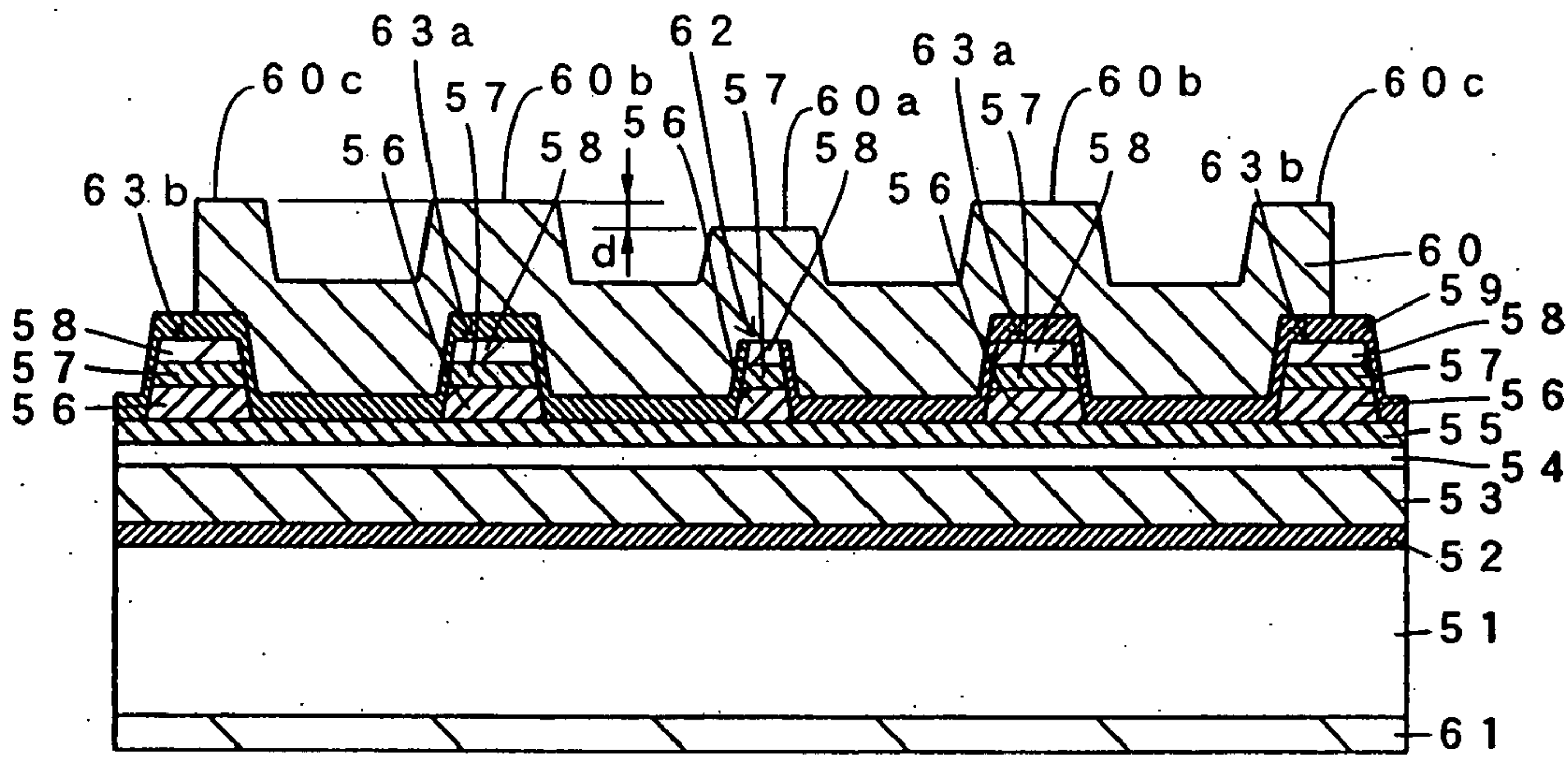


FIG.22

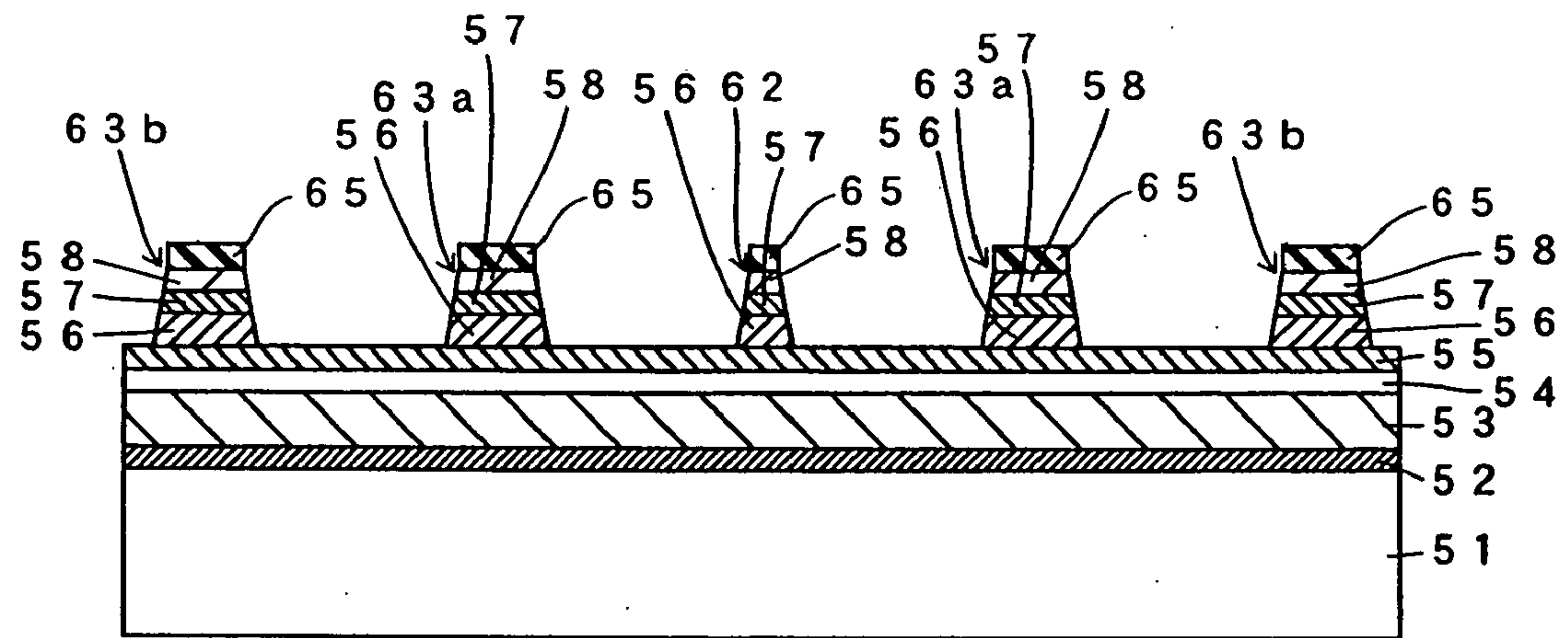




FIG.23

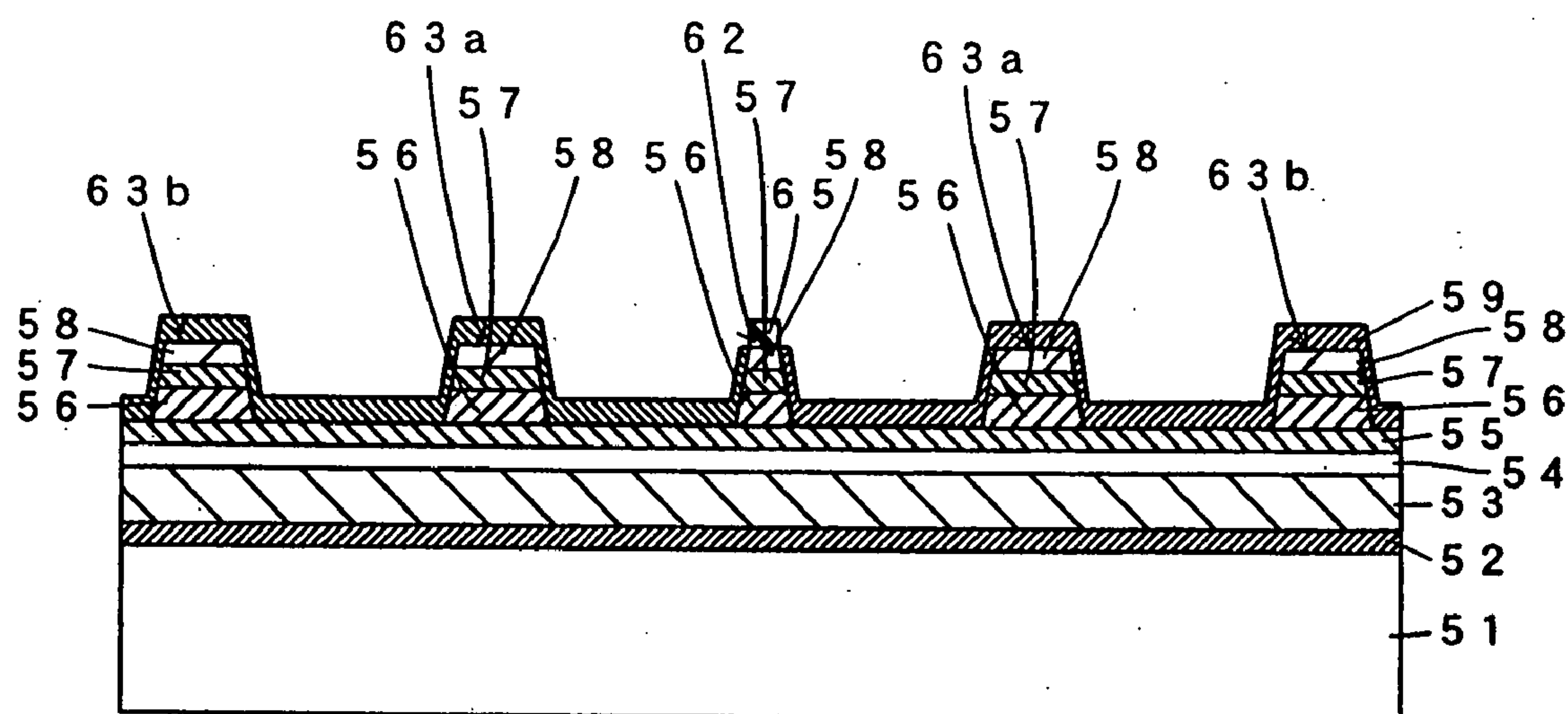


FIG.24

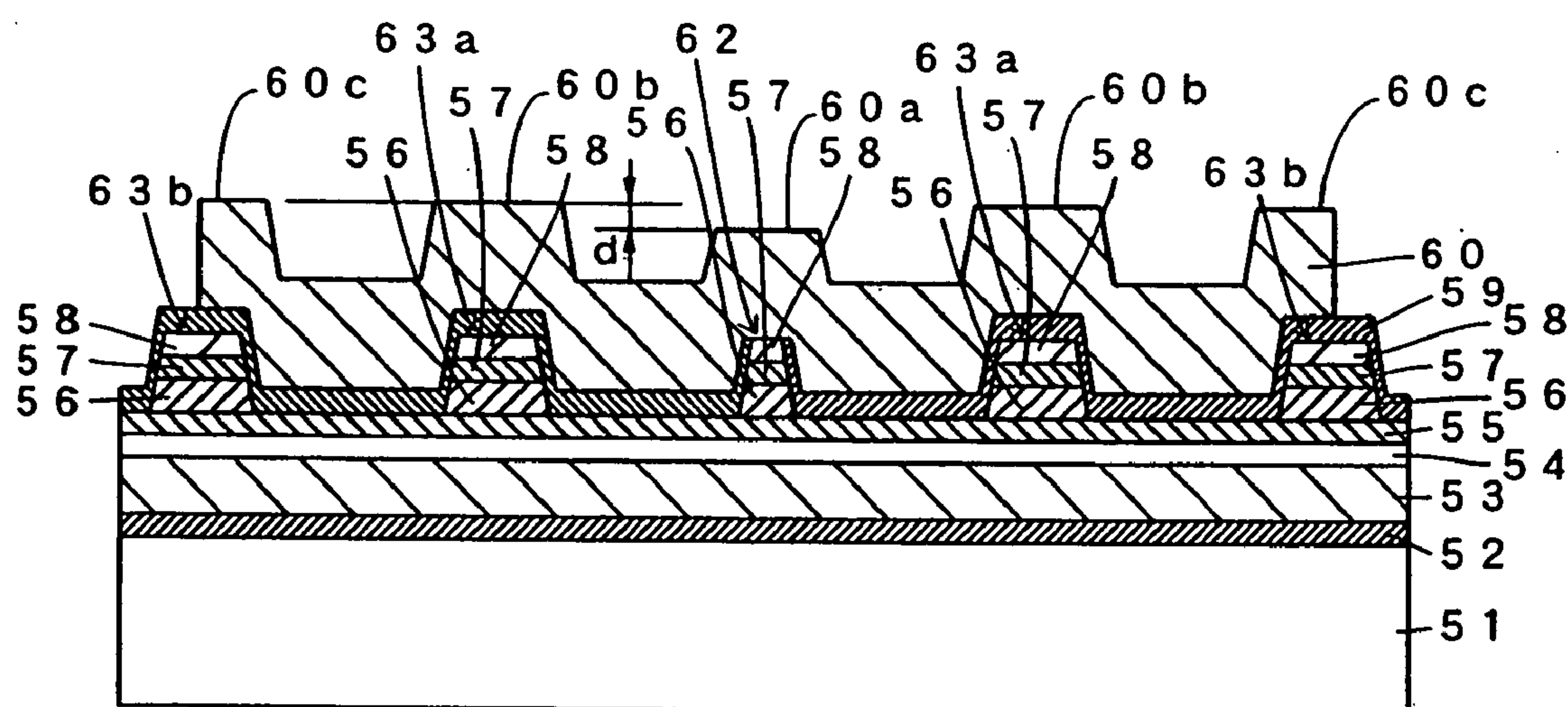


FIG.25

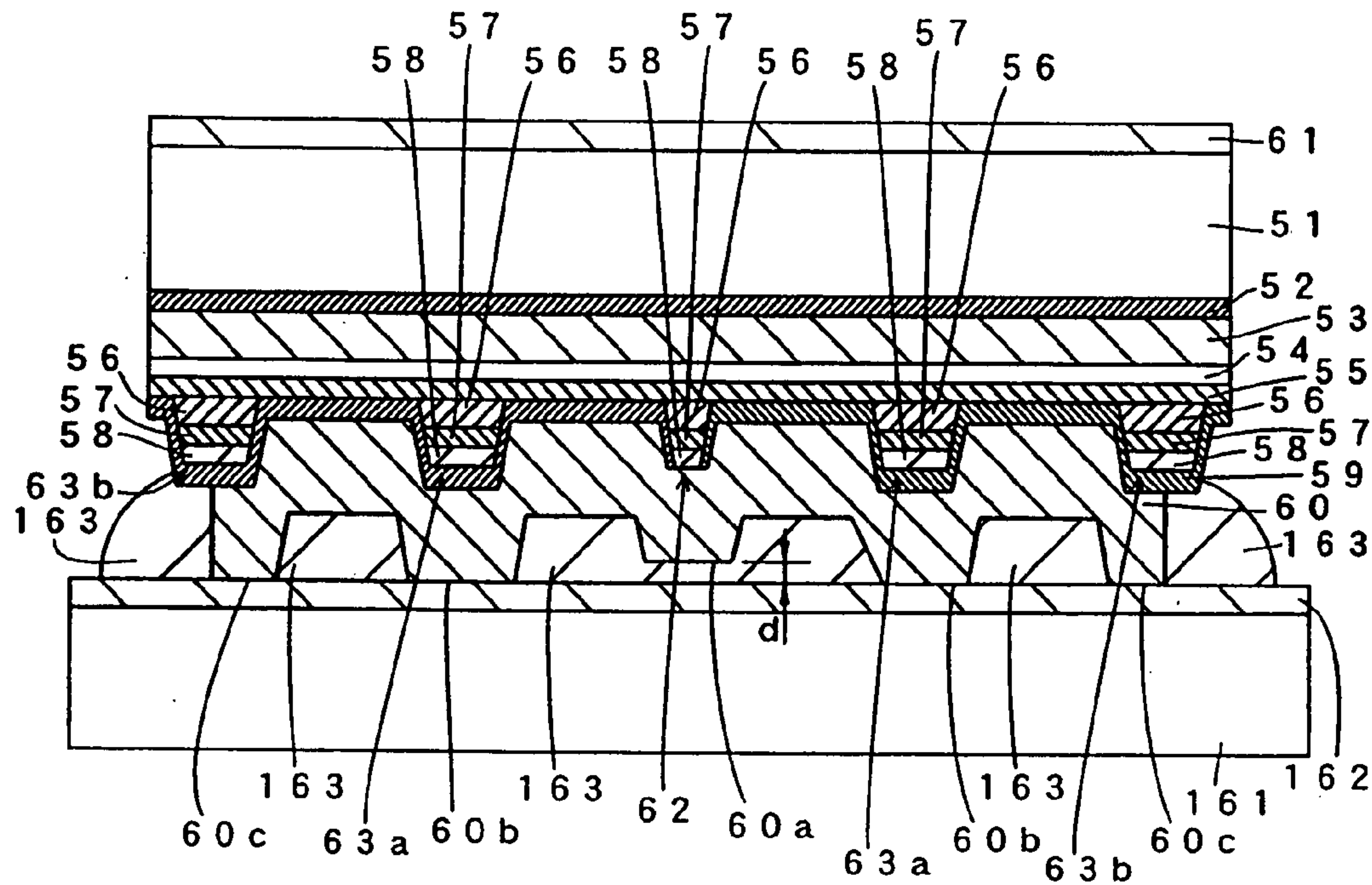


FIG.26

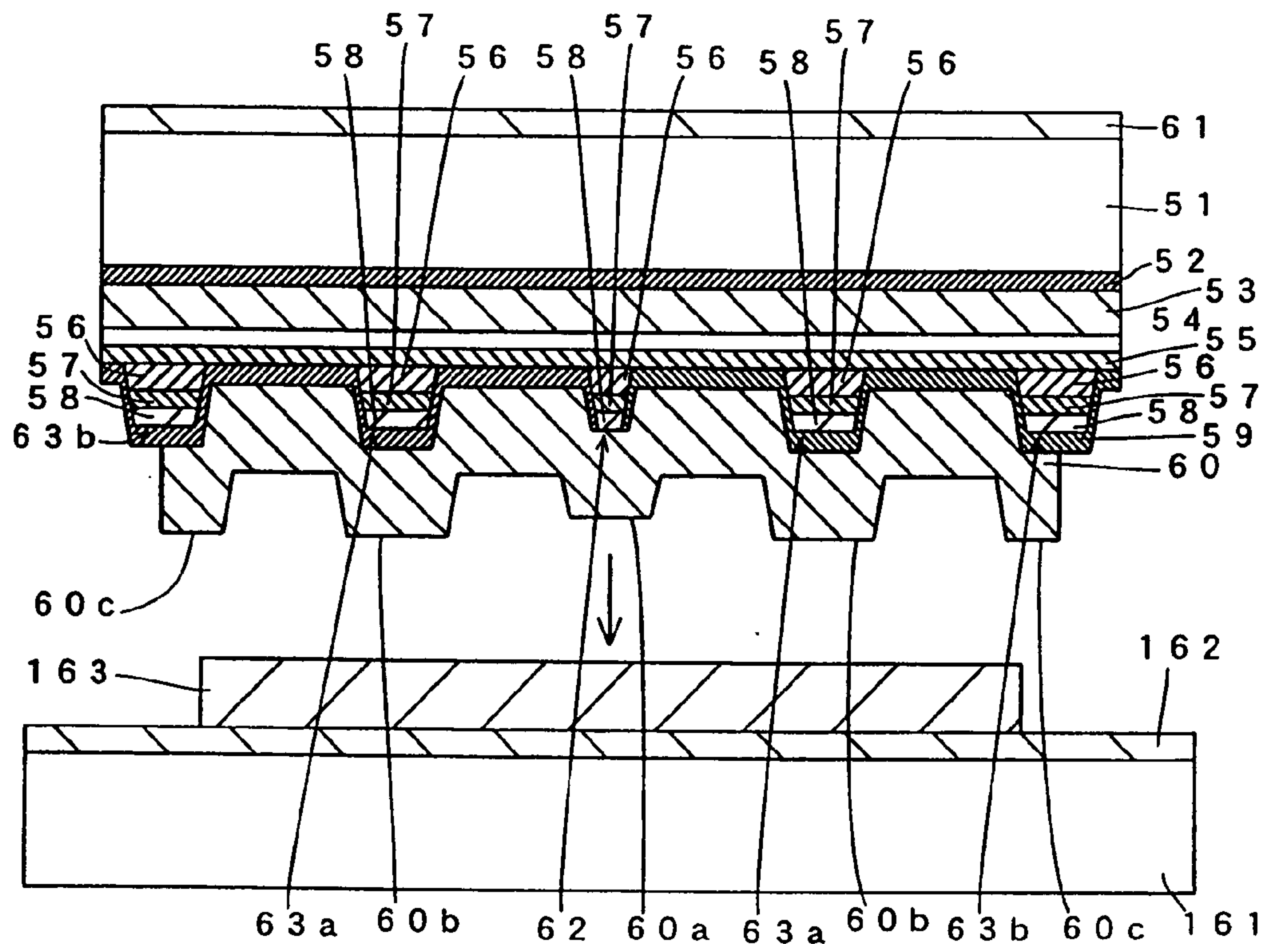


FIG.27

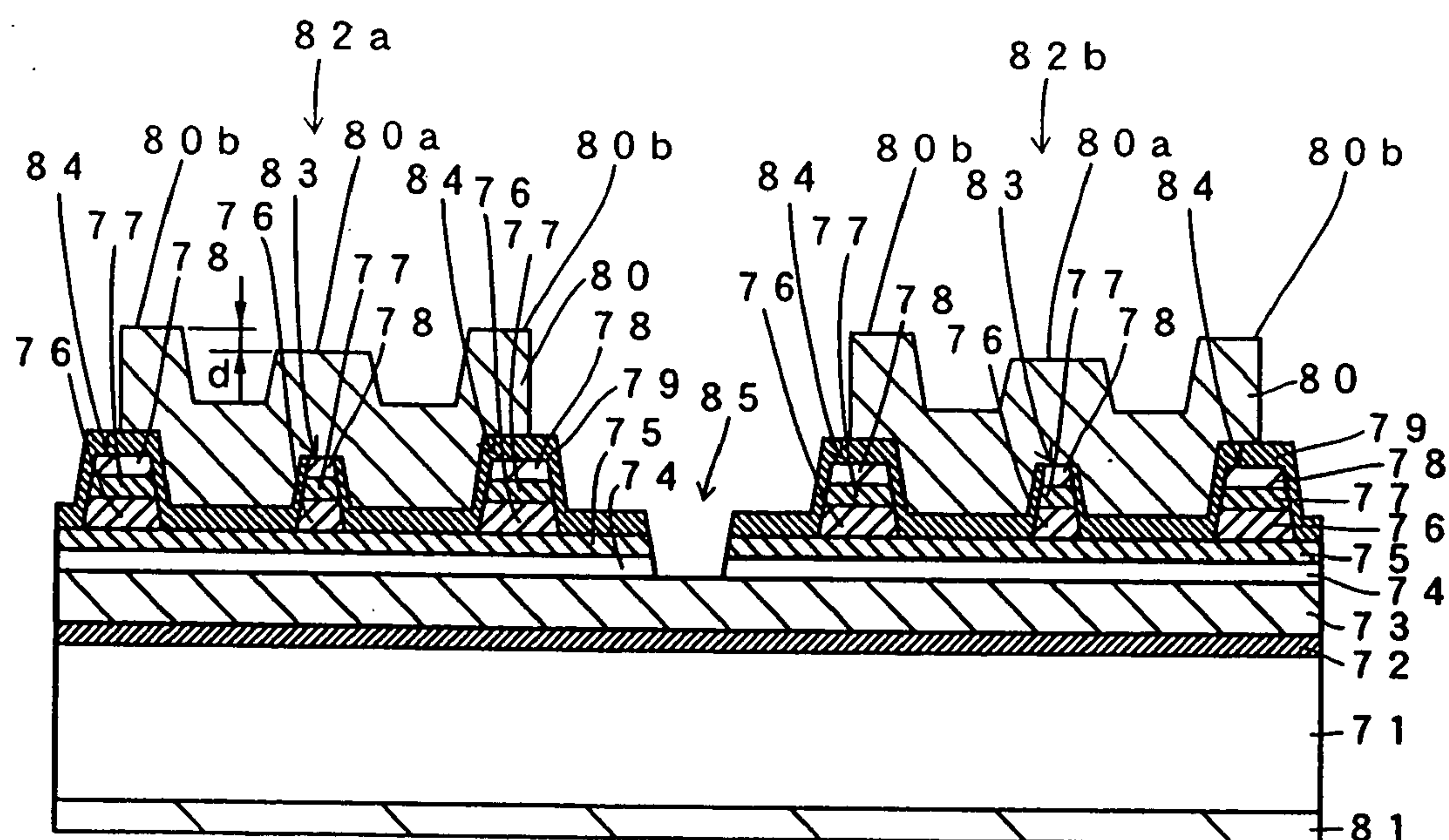


FIG.28

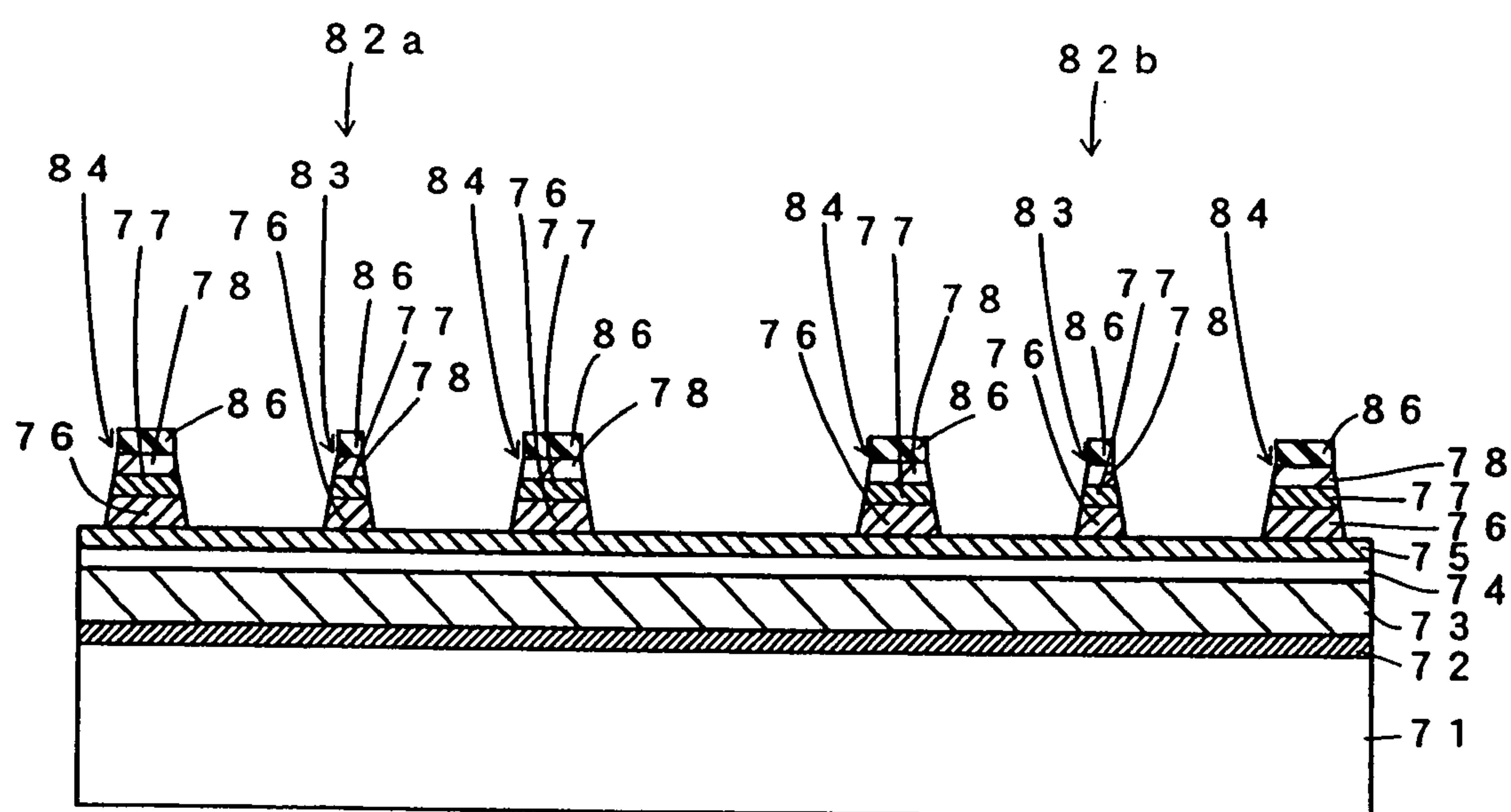




FIG.29

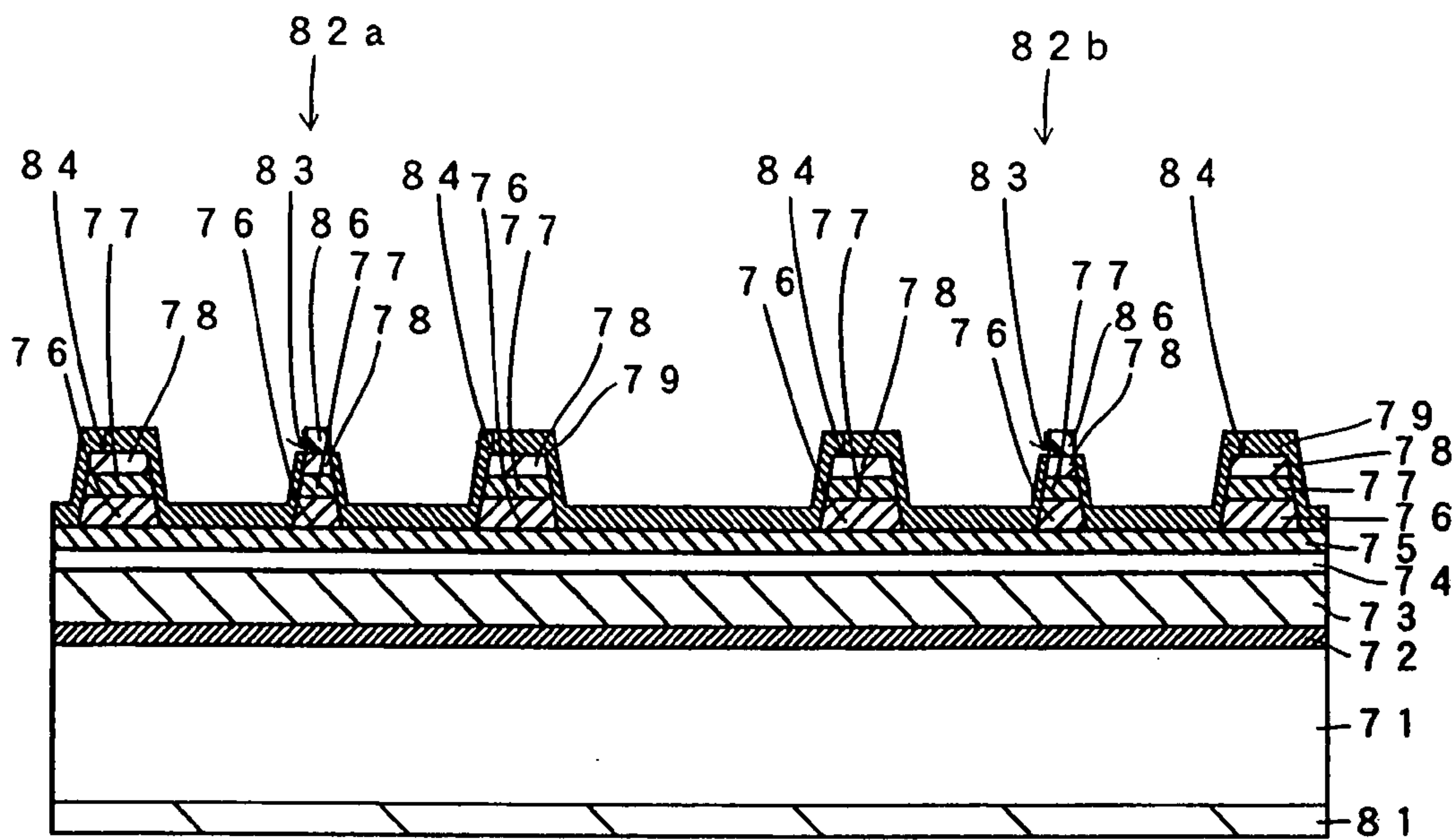


FIG.30

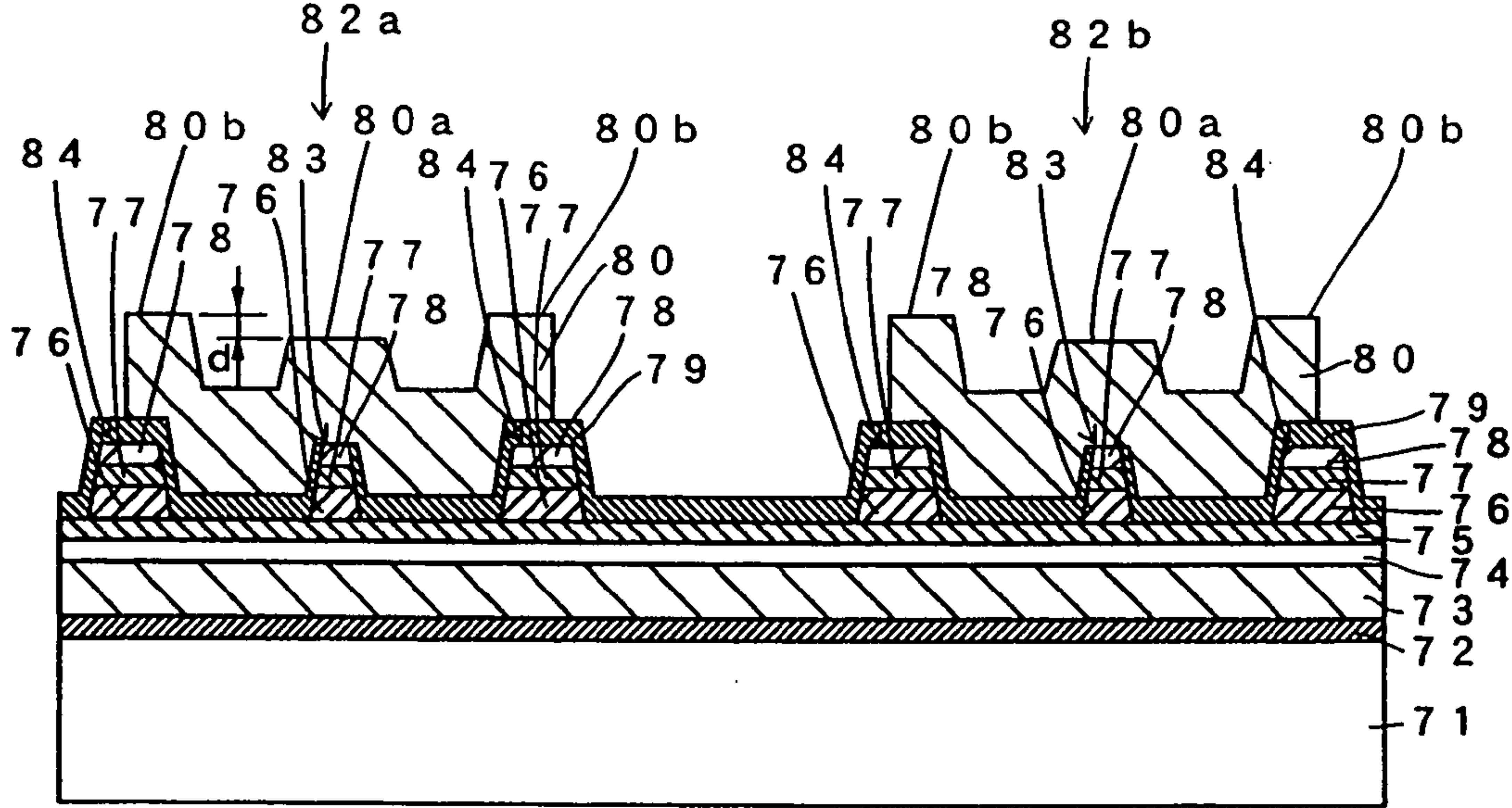




FIG.31

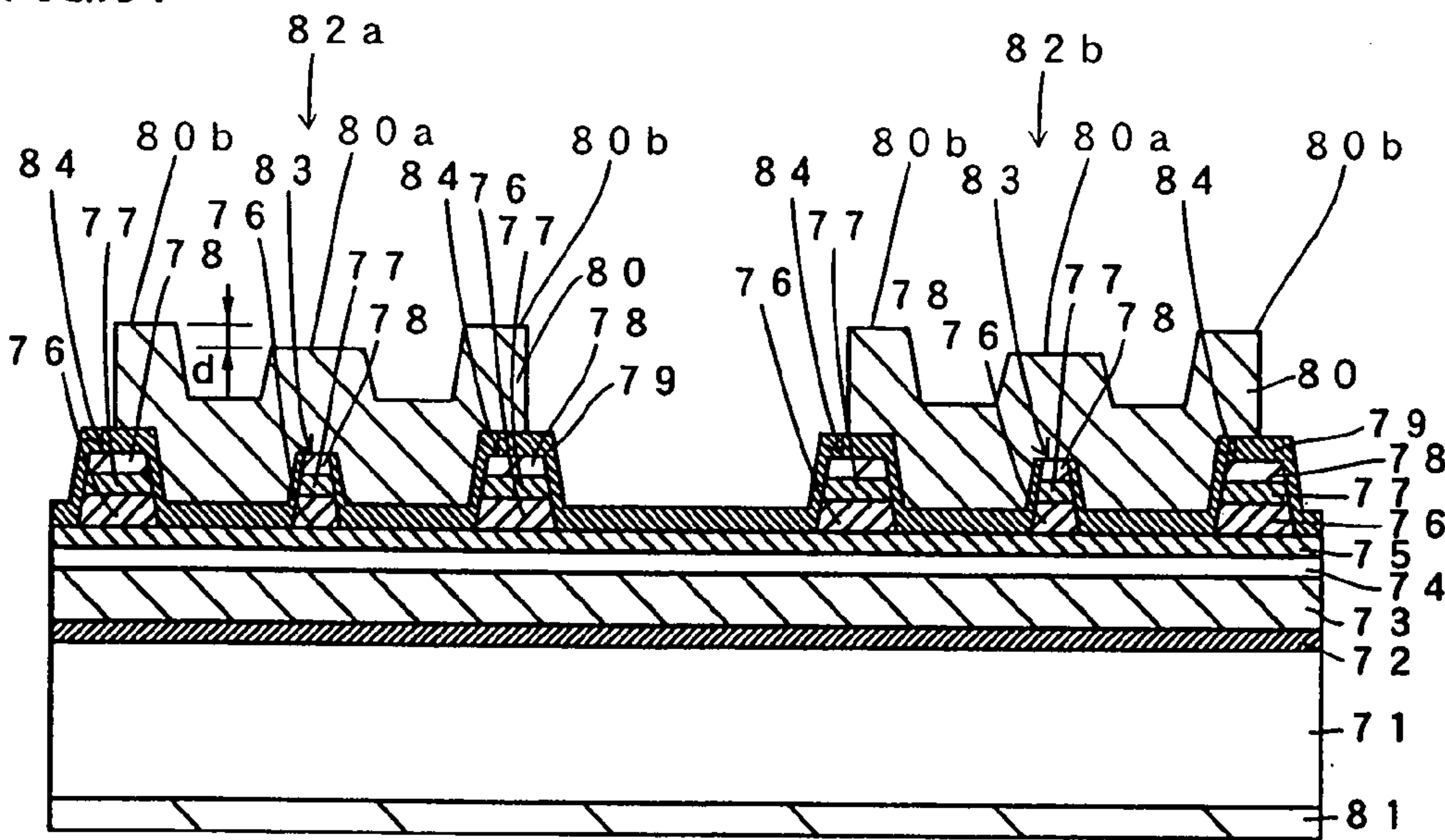


FIG.32

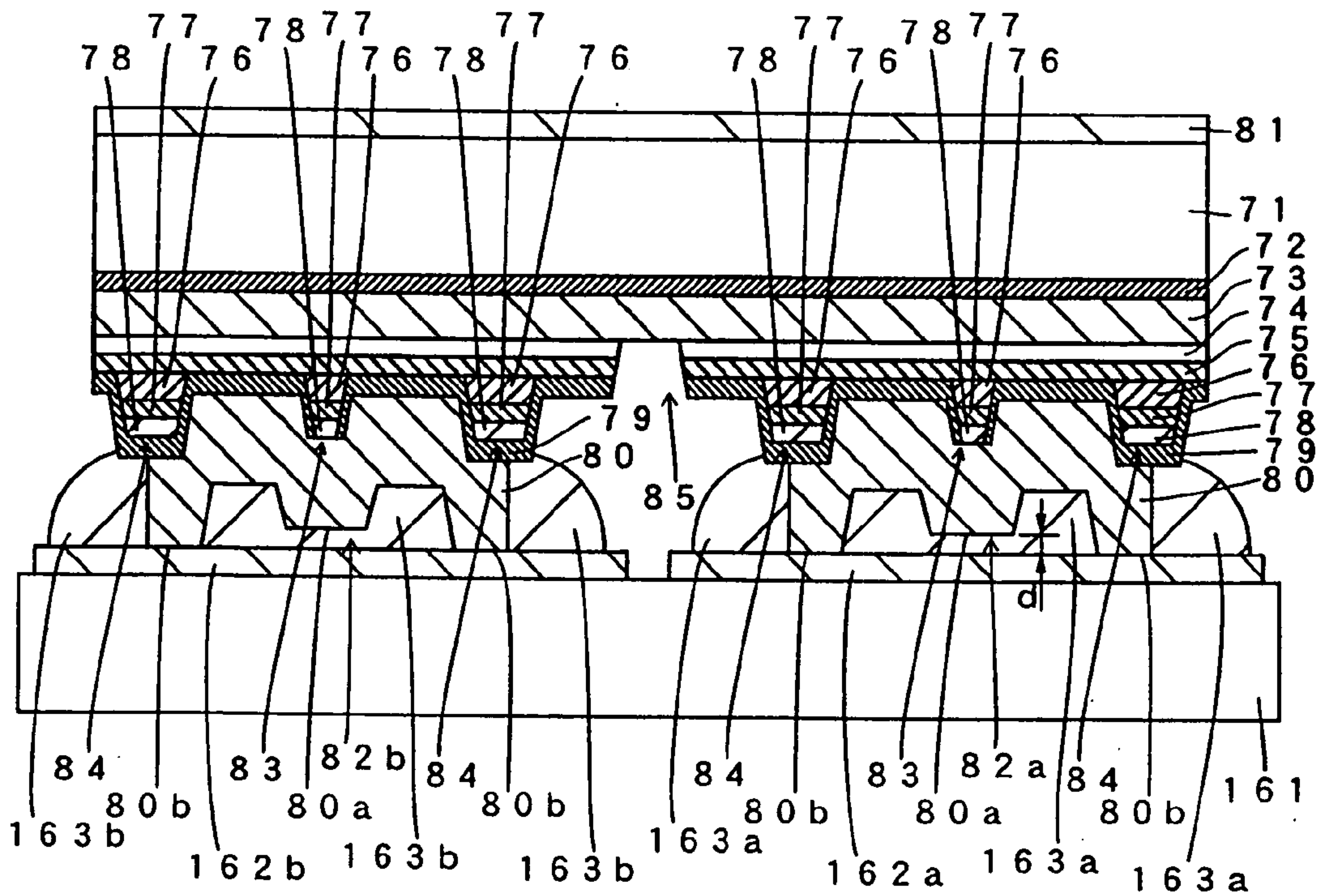


FIG.33

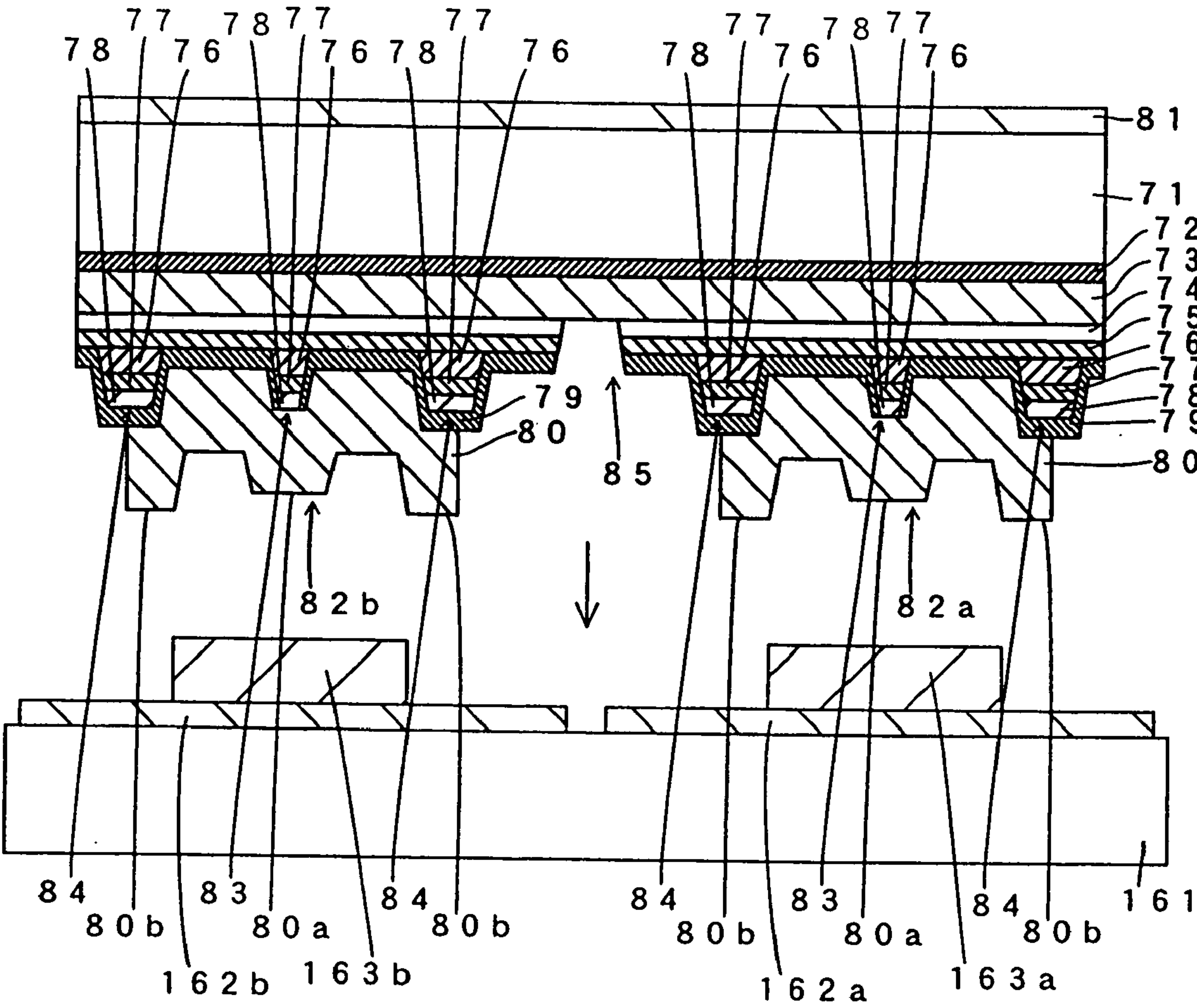


FIG.34

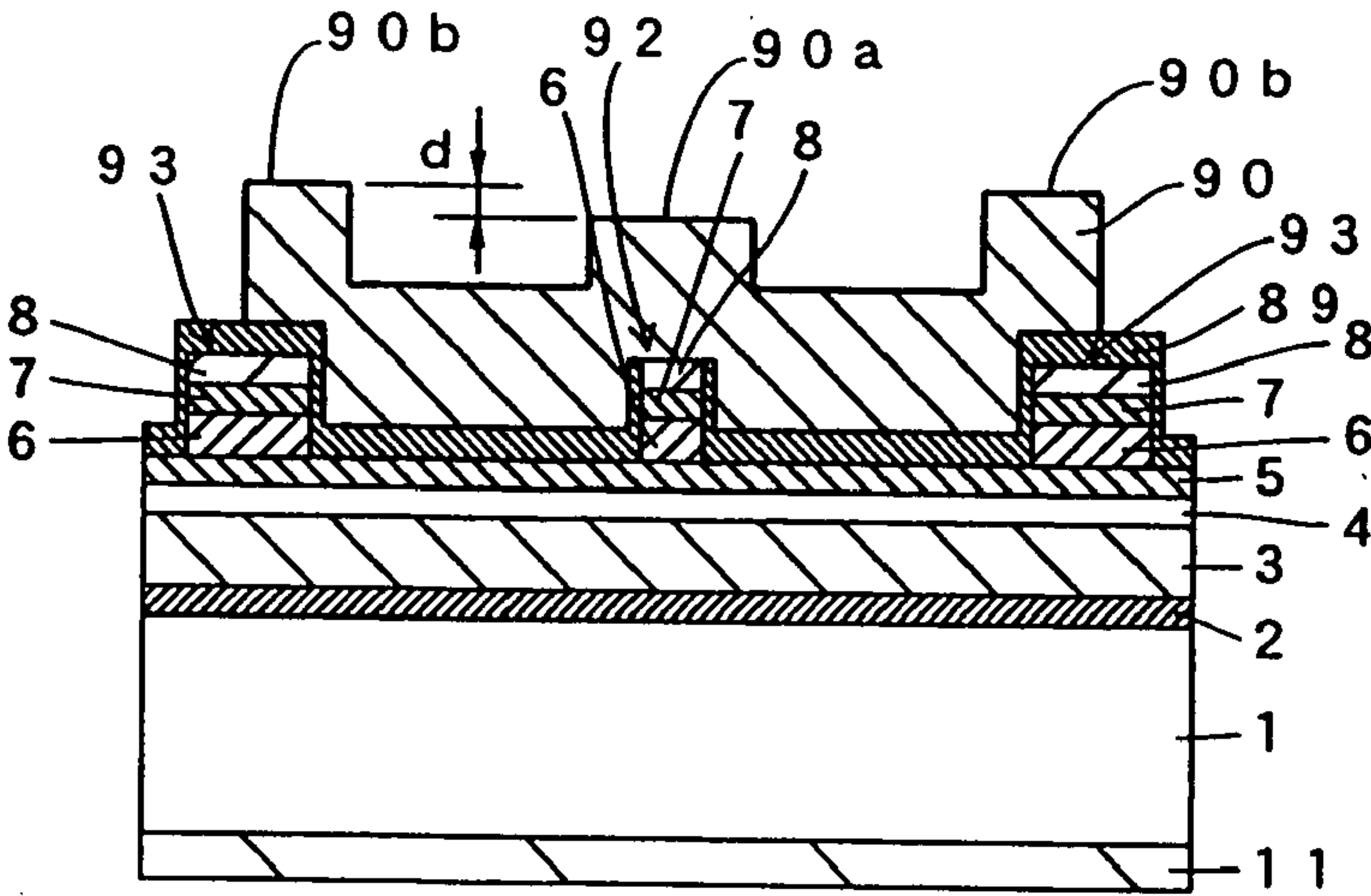


FIG.35

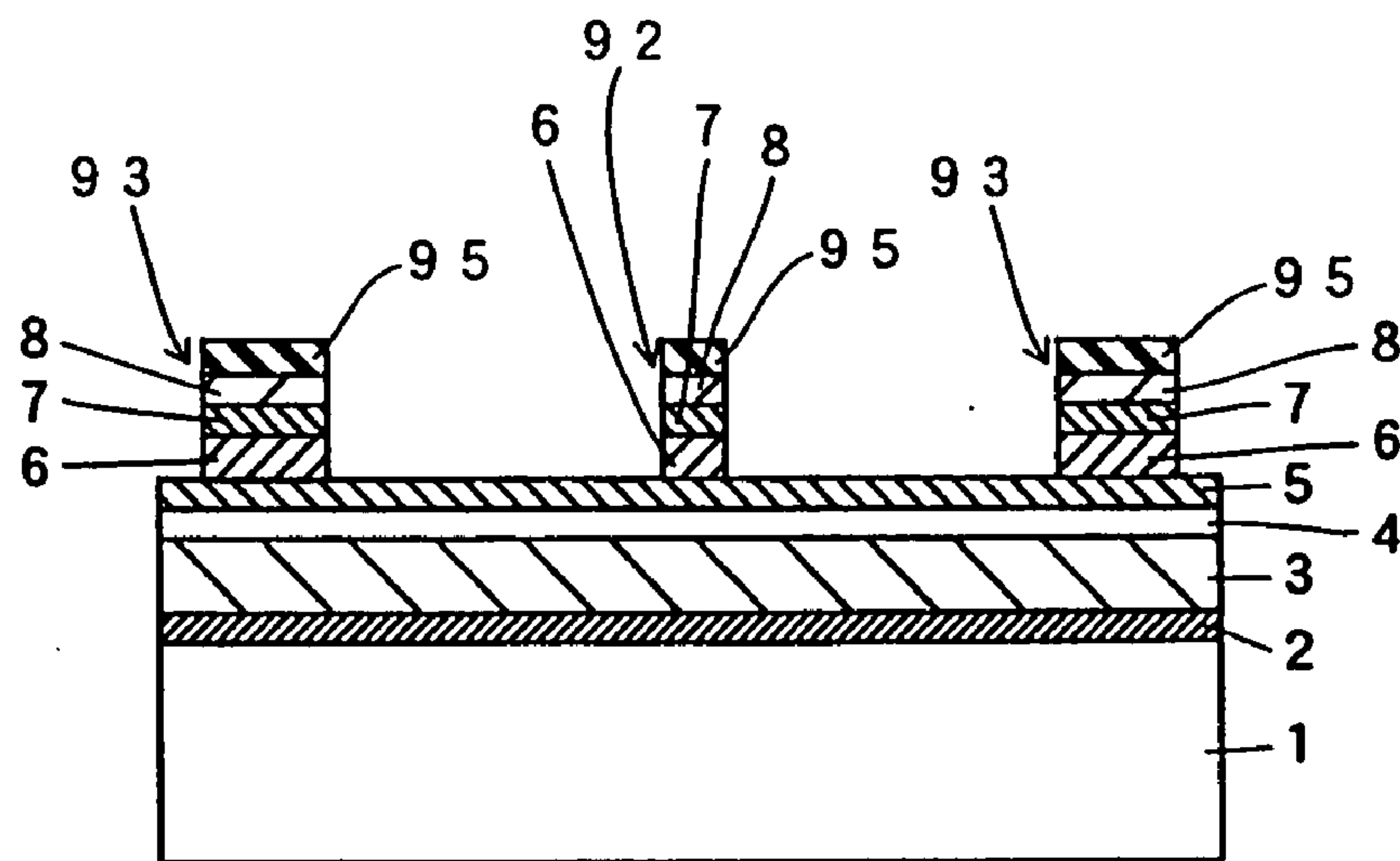


FIG.36

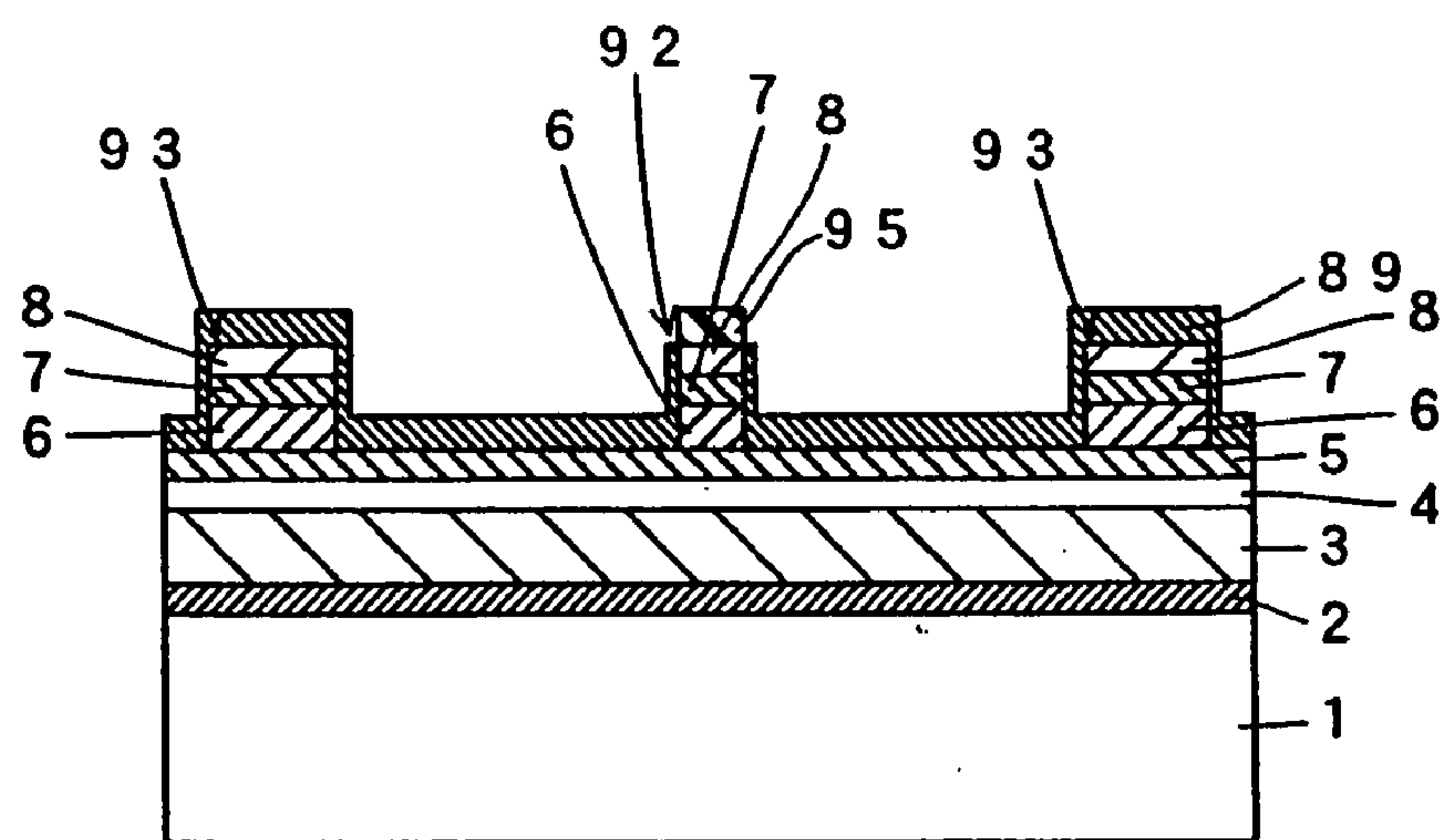




FIG.37

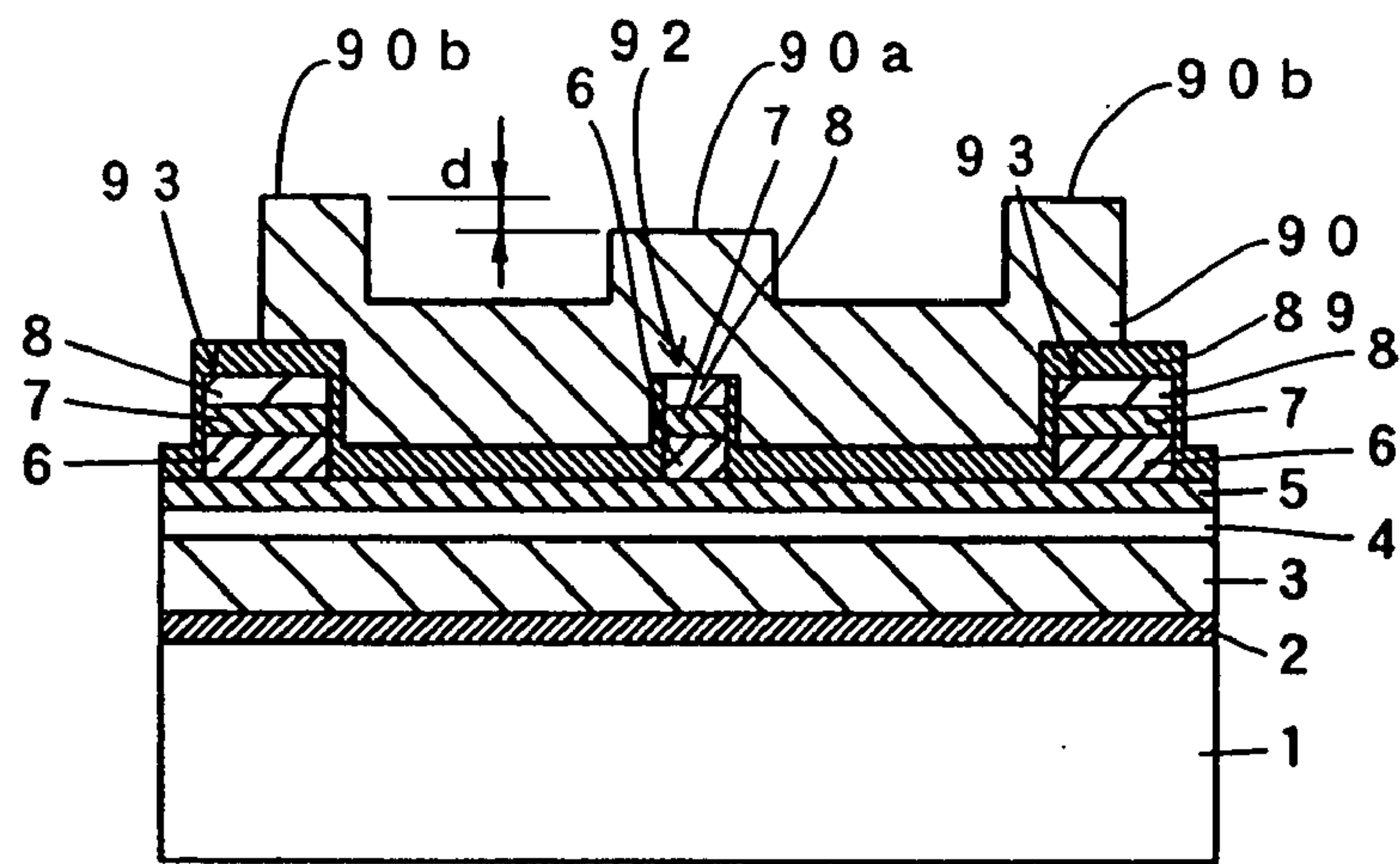


FIG.38

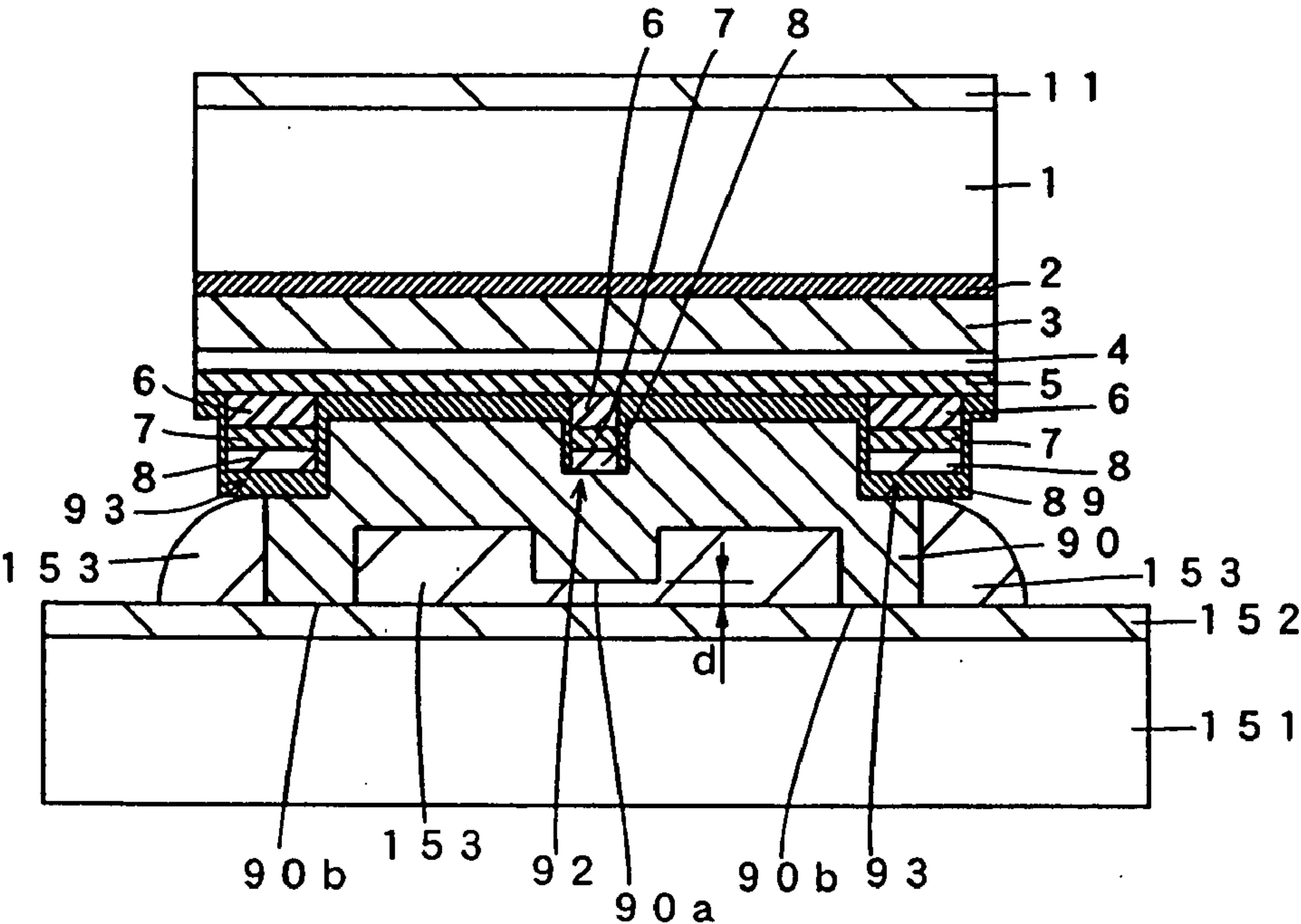




FIG.39

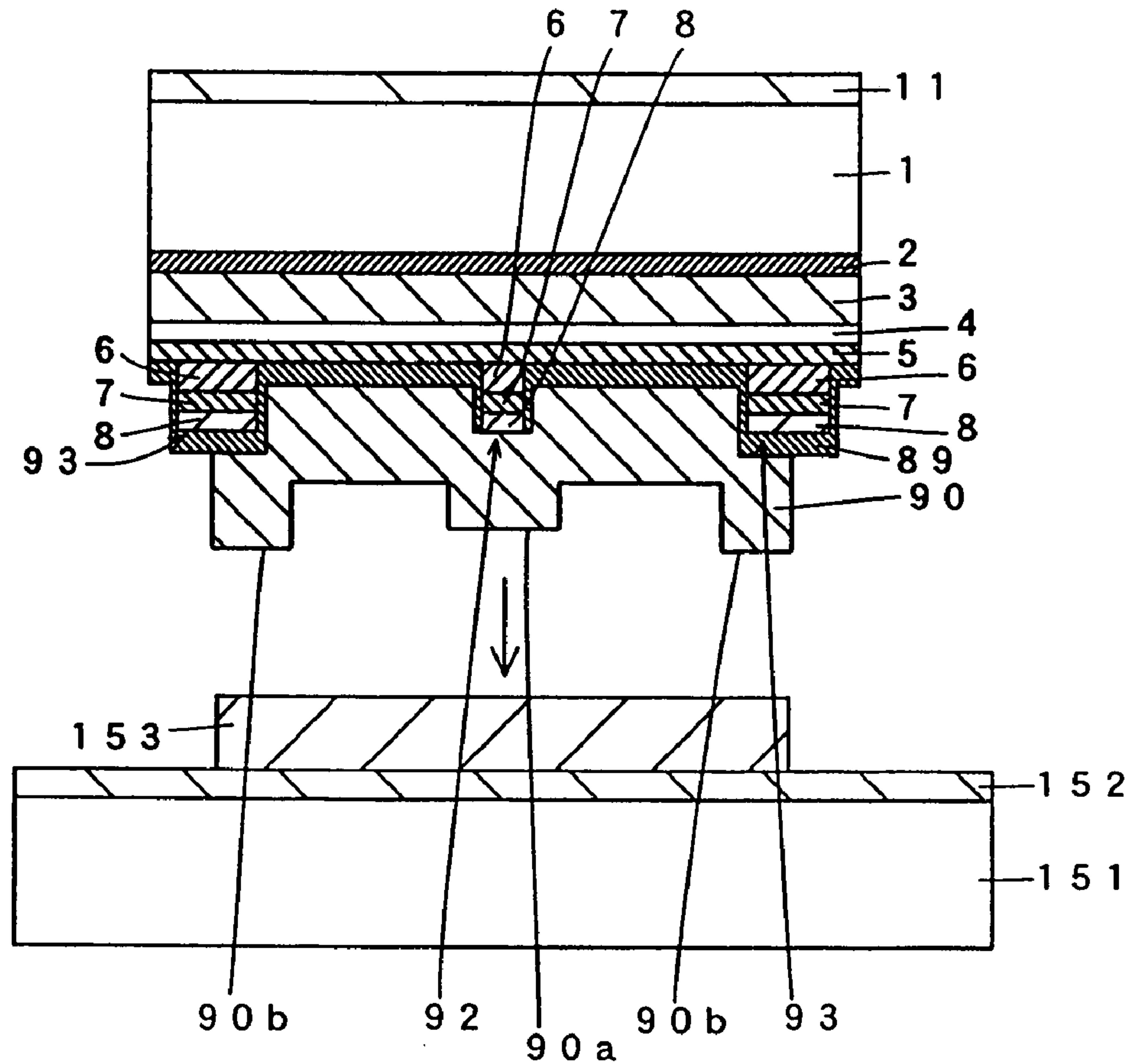


FIG.40

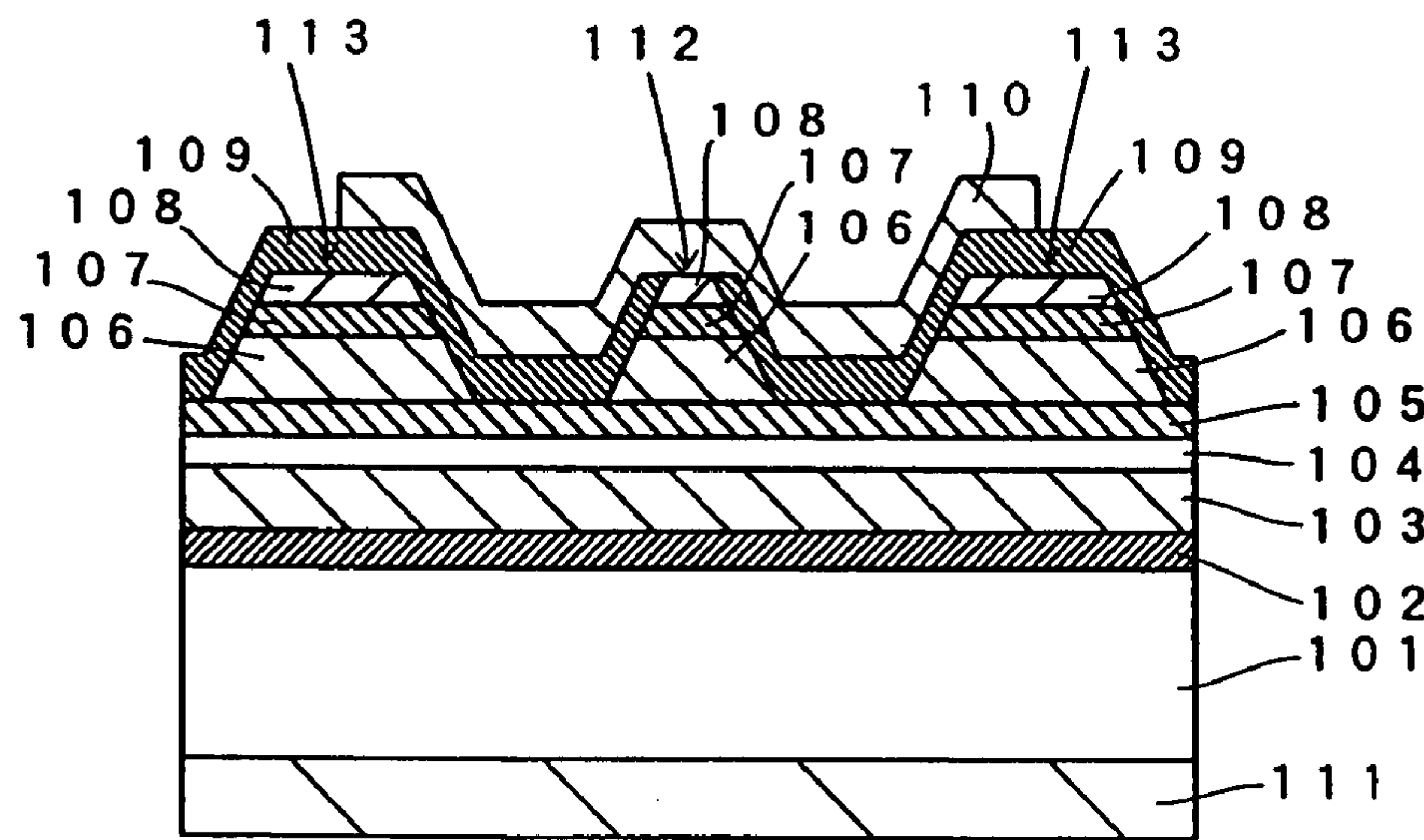


FIG.41

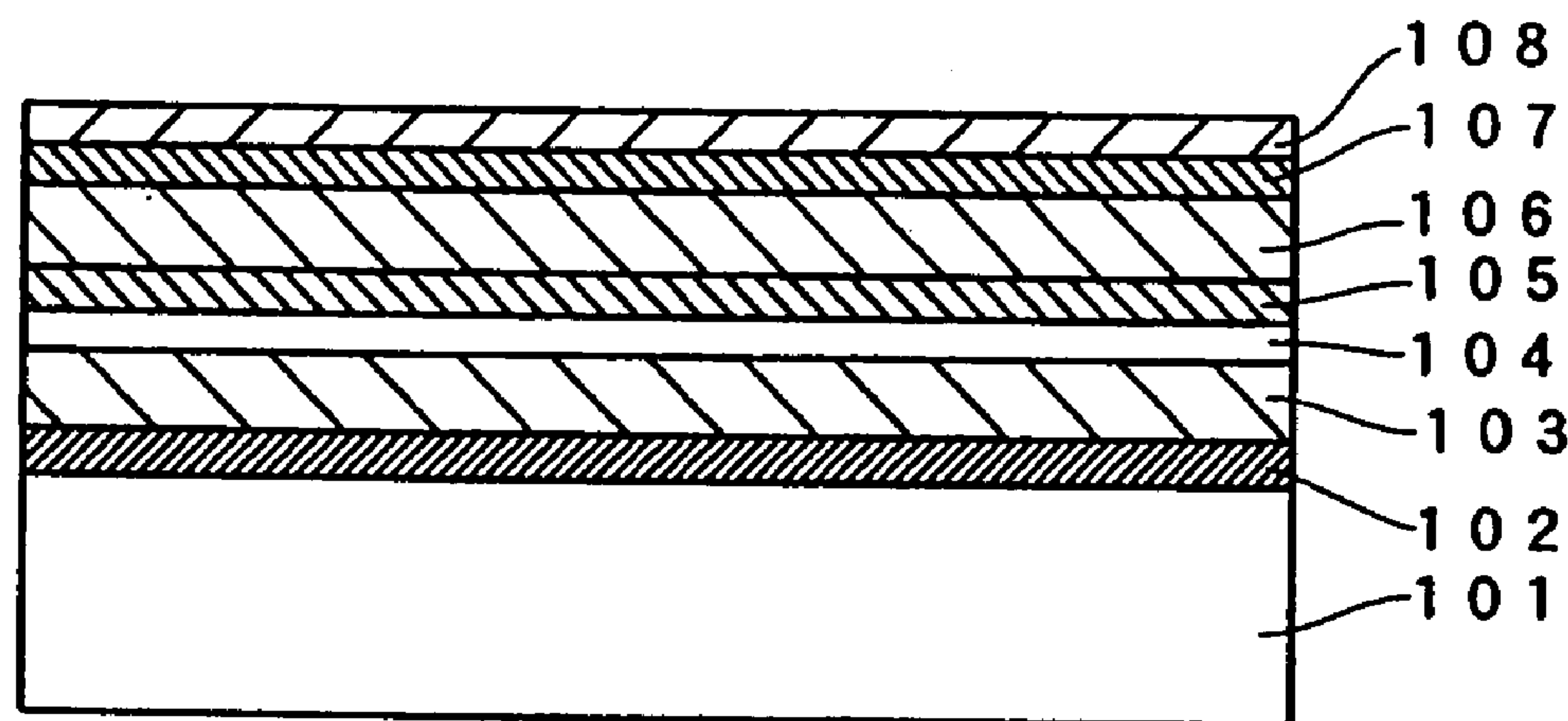


FIG.42

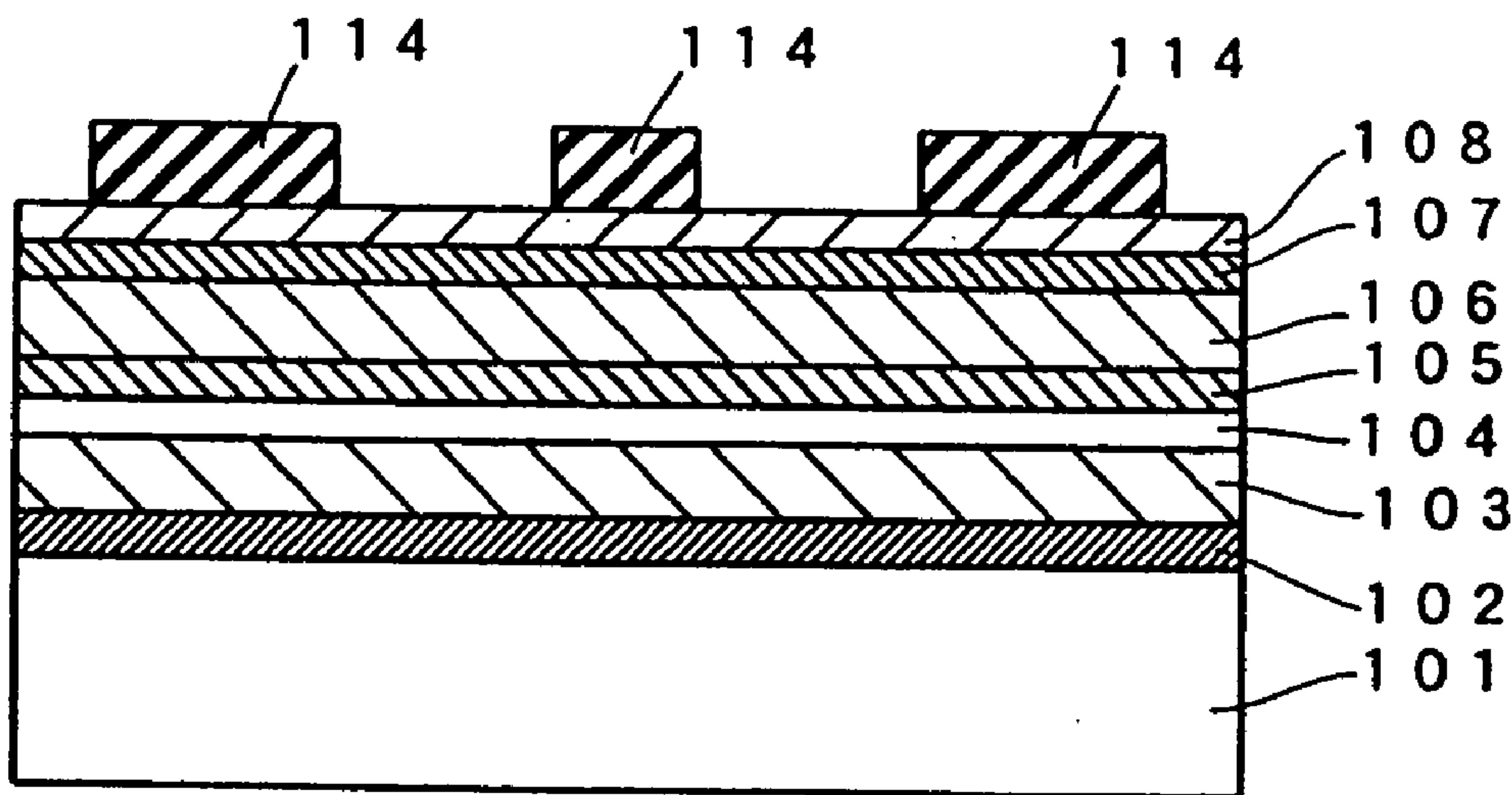


FIG.43

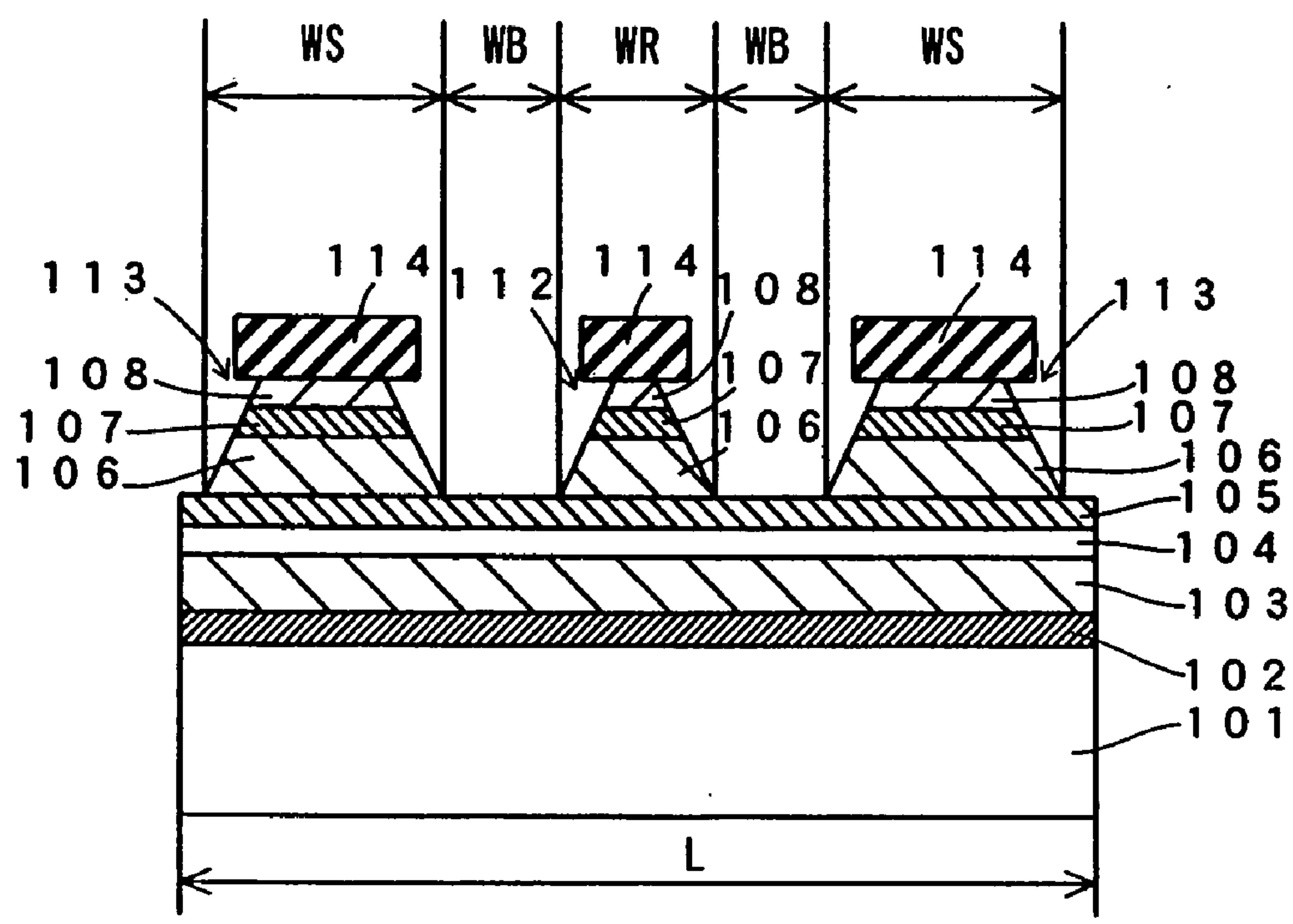


FIG.44

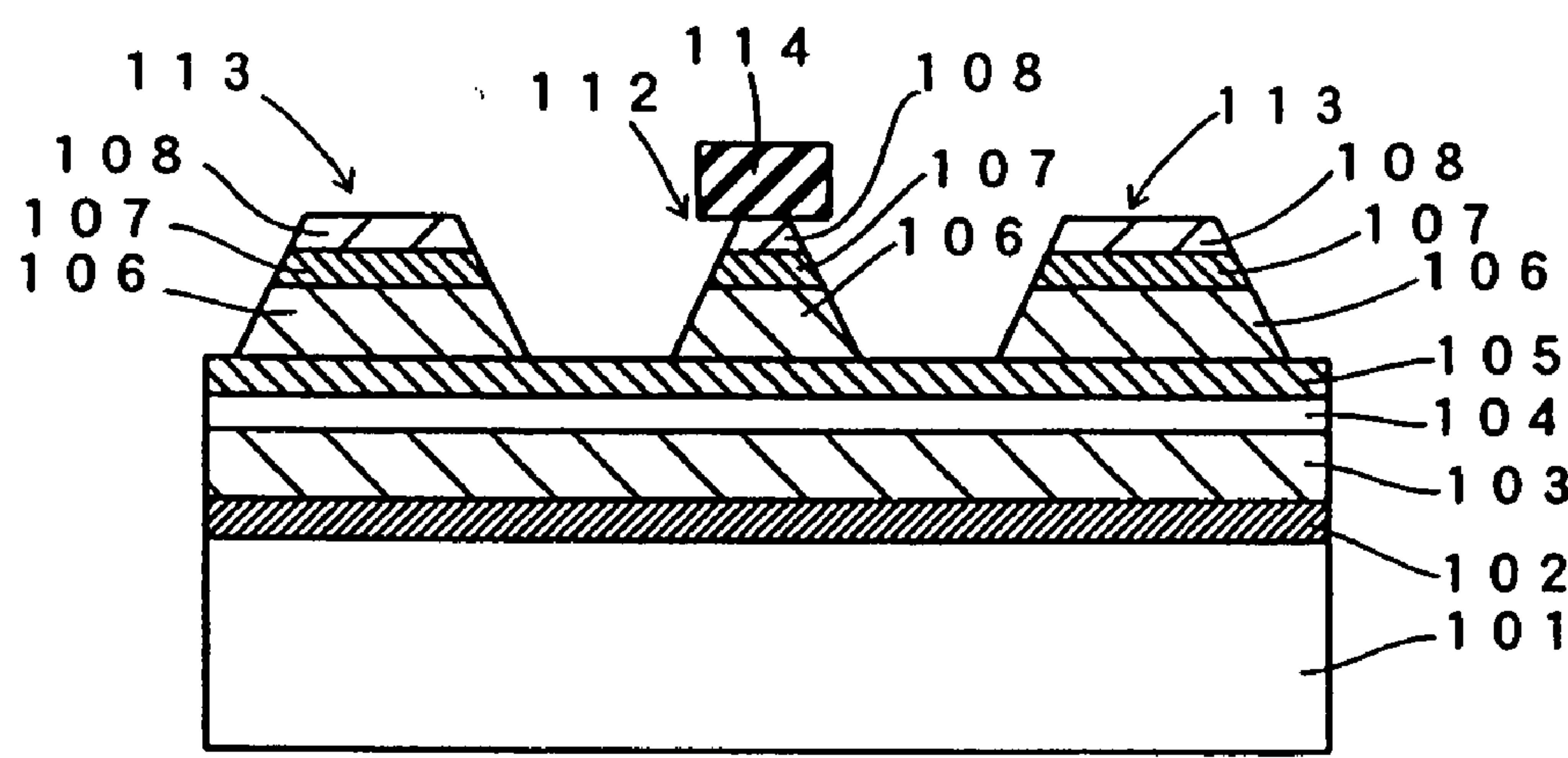


FIG.45

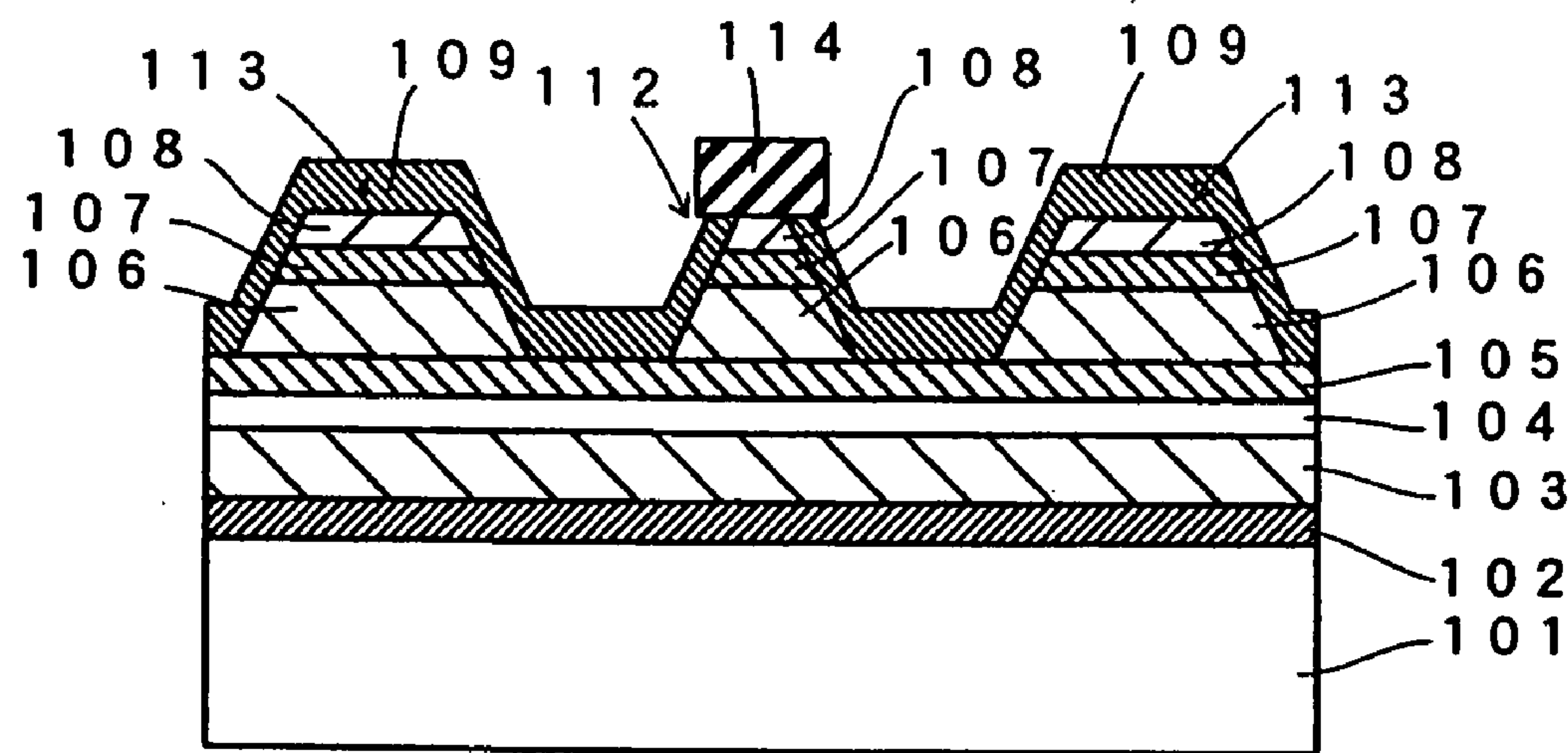


FIG.46

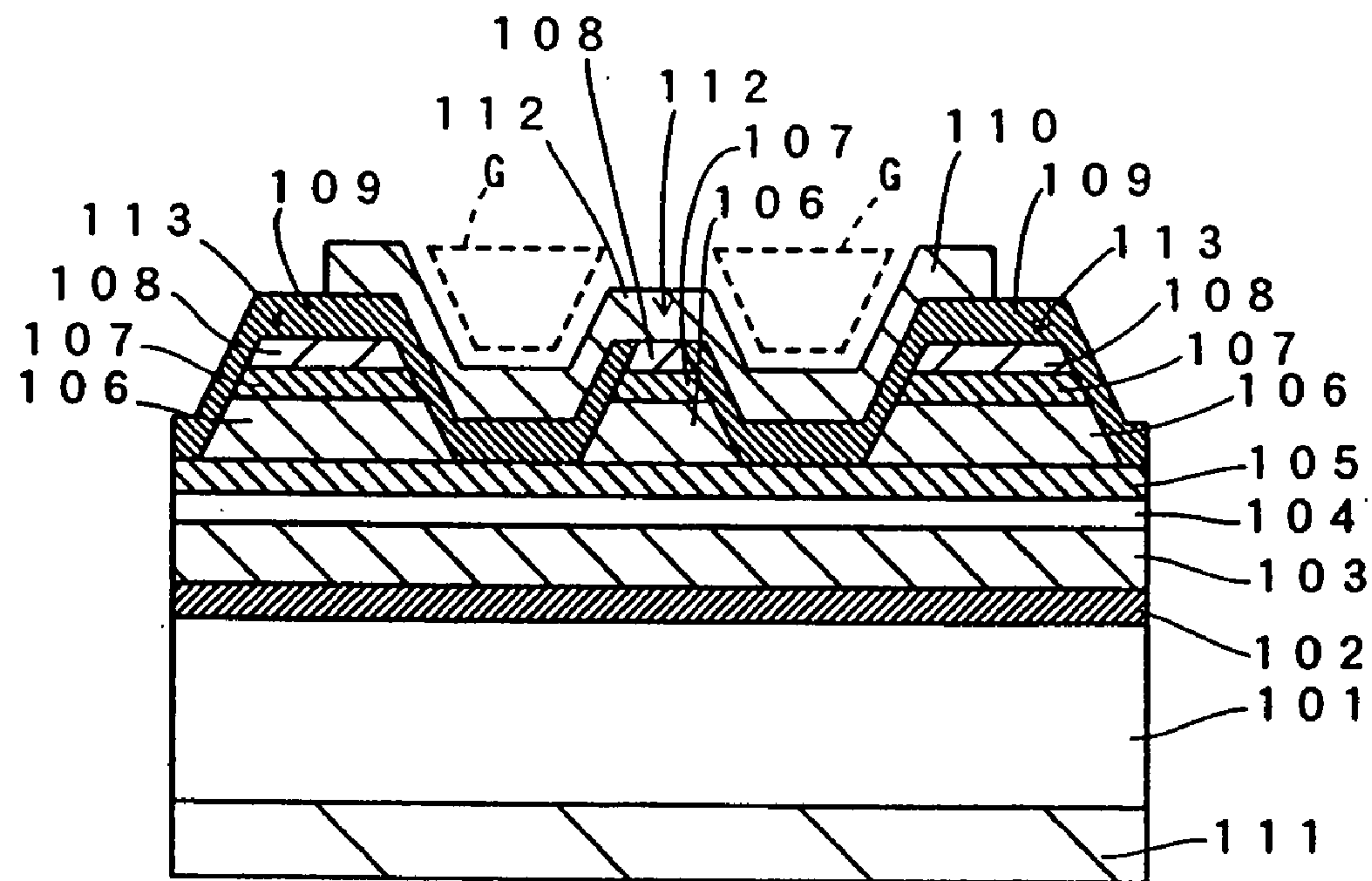




FIG.47

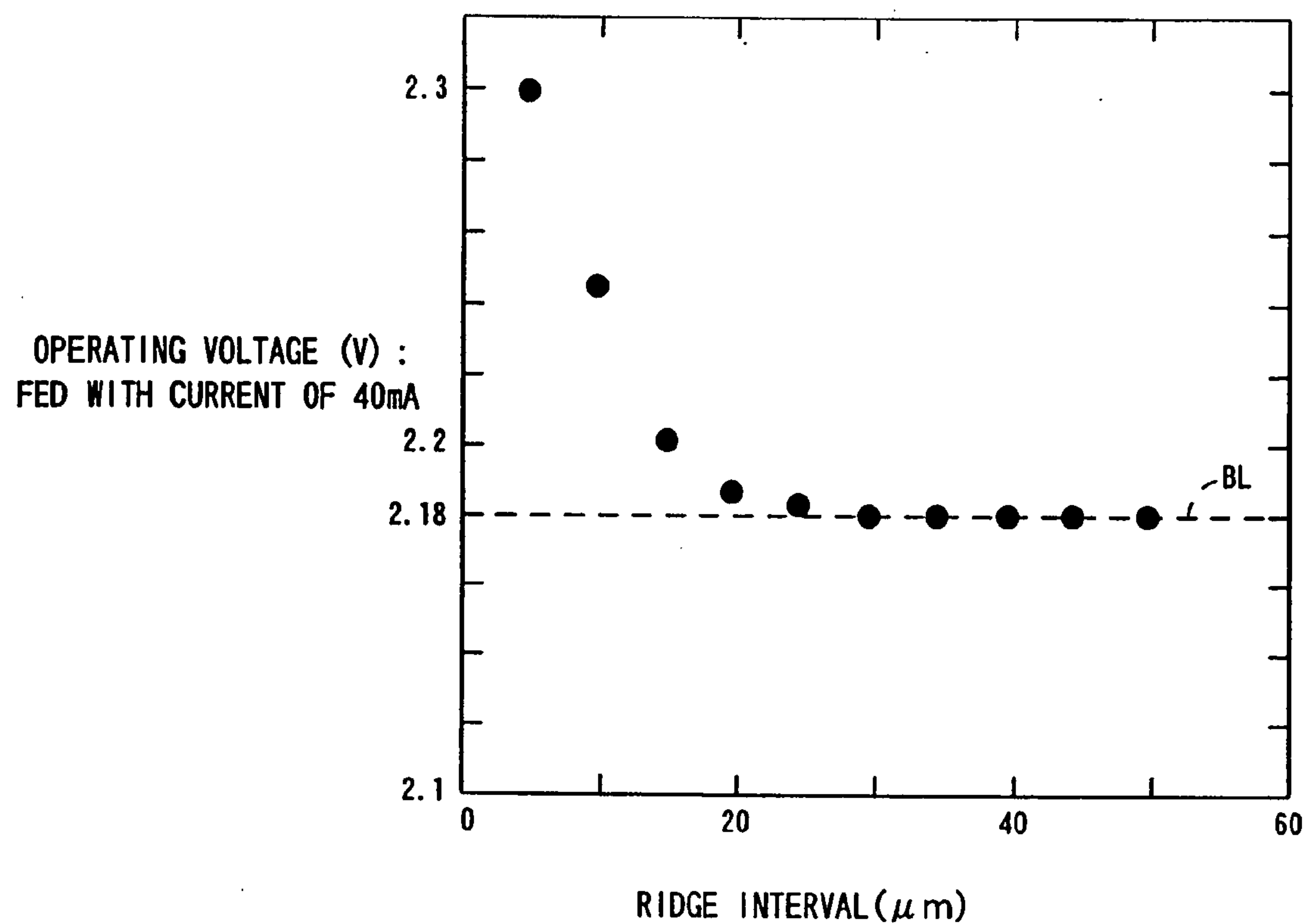


FIG.48

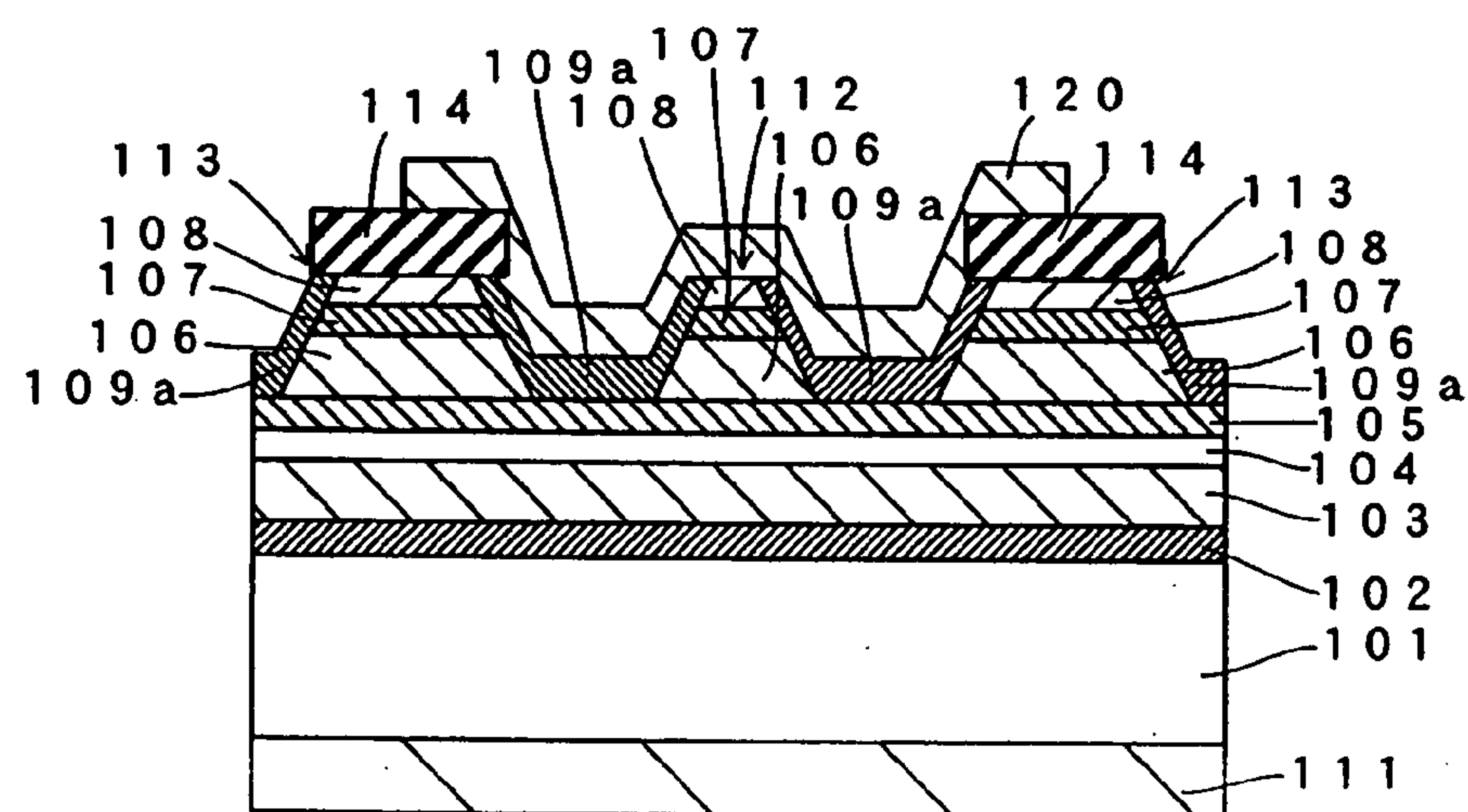


FIG.49

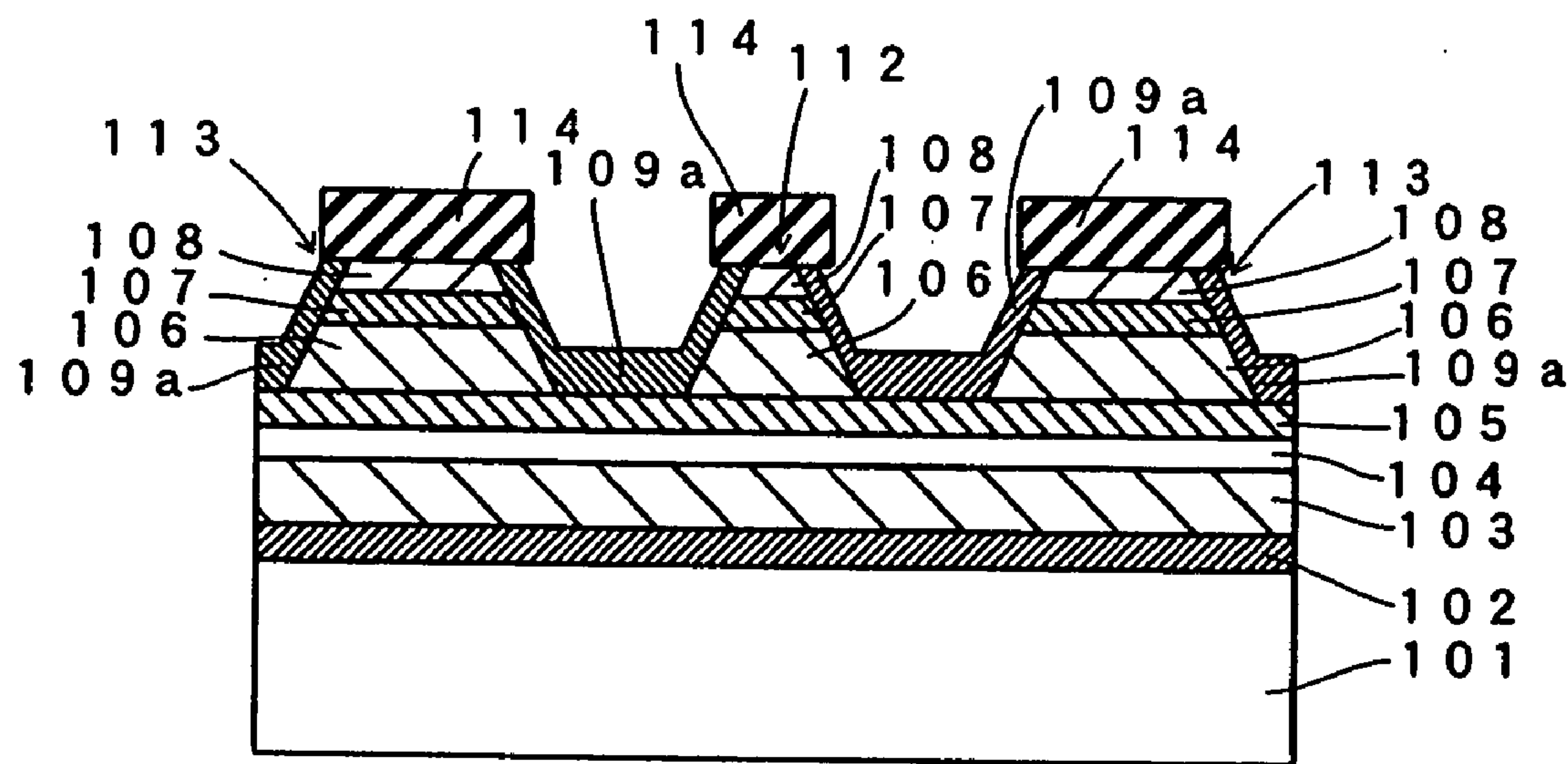


FIG.50 PRIOR ART

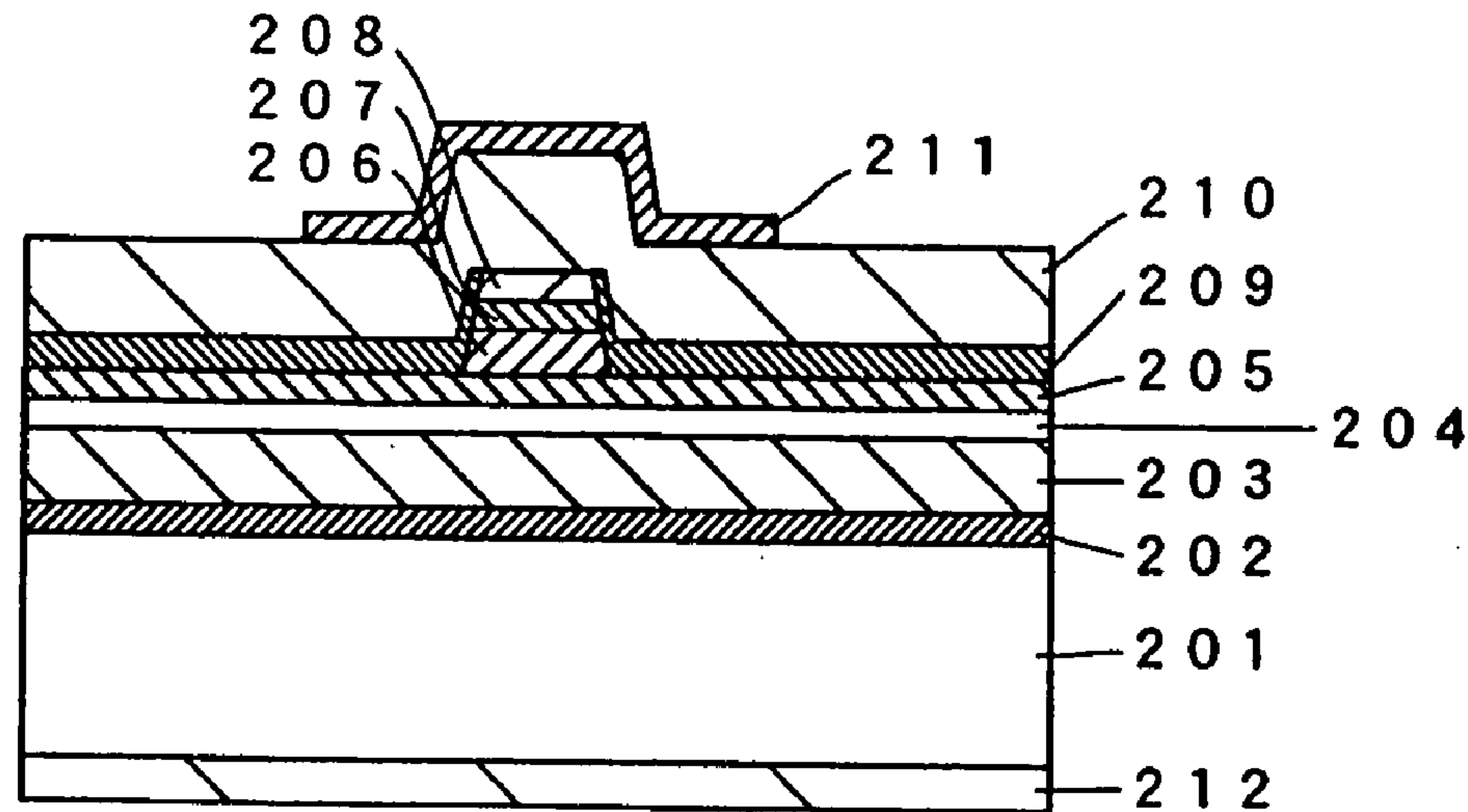
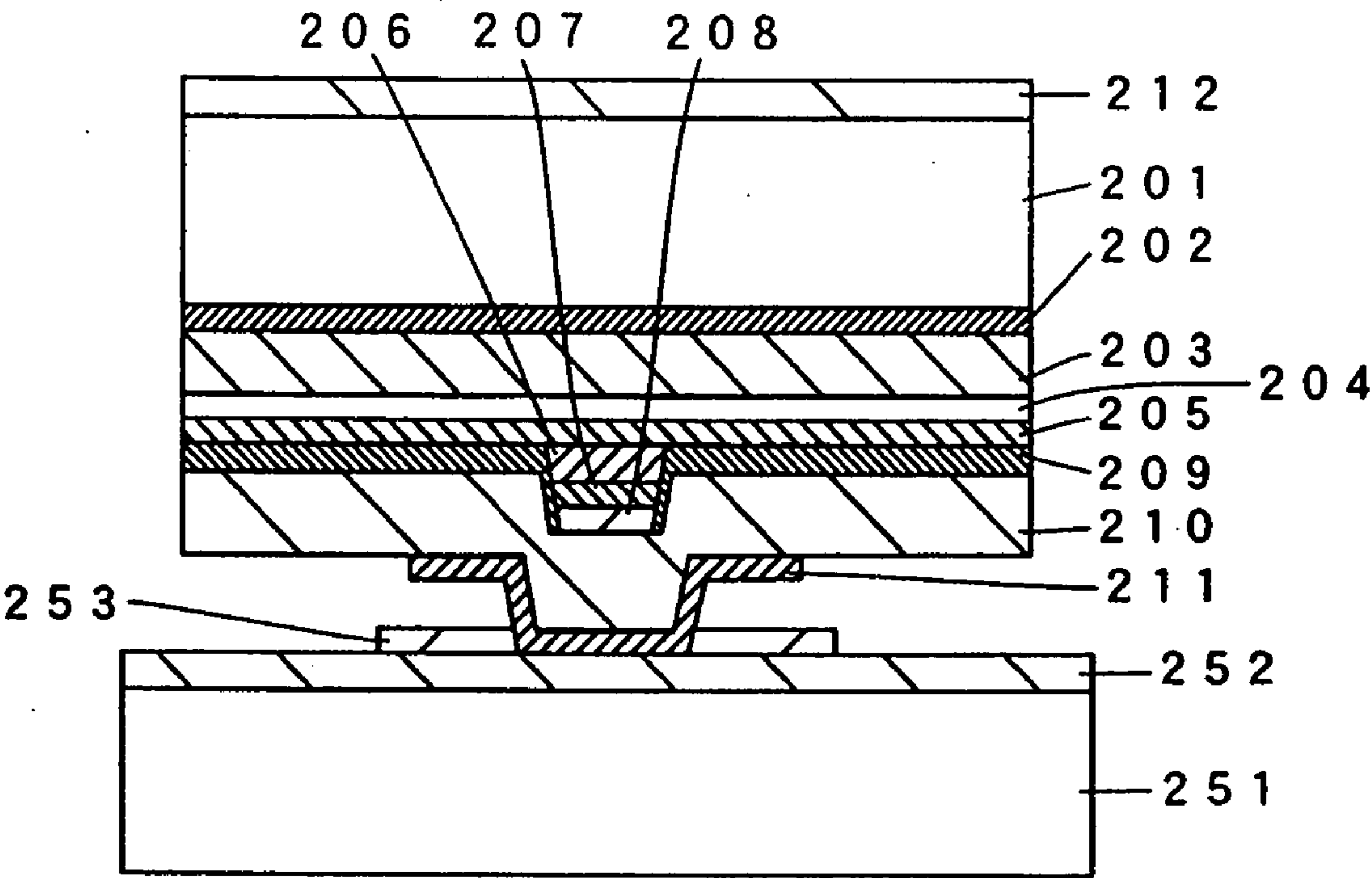


FIG.51 PRIOR ART





# SEMICONDUCTOR LASER DEVICE AND METHOD OF FABRICATING THE SAME

## BACKGROUND OF THE INVENTION

### [0001] 1. Field of the Invention

[0002] The present invention relates to a semiconductor laser device and a method of fabricating the same, and more particularly, it relates to a semiconductor laser device having a convex ridge portion and a method of fabricating the same.

### [0003] 2. Description of the Background Art

[0004] A semiconductor laser device having a convex ridge portion serving as a current path is known in general. For example, Japanese Patent Laying-Open No. 2002-252421 discloses this type of semiconductor laser device.

[0005] FIG. 50 is a sectional view for illustrating a conventional semiconductor laser device having a ridge portion. The structure of the conventional semiconductor laser device having a ridge portion is described with reference to FIG. 50.

[0006] In the conventional semiconductor laser device having a ridge portion, an n-type buffer layer 202 of n-type GaInP, an n-type cladding layer 203 of n-type AlGaInP, an emission layer 204 including a multiple quantum well (MQW) active layer of GaInP/AlGaInP and a p-type first cladding layer 205 of p-type AlGaInP are successively formed on an n-type GaAs substrate 201, as shown in FIG. 50.

[0007] A mesa (trapezoidal) ridge portion constituted of a p-type second cladding layer 206 of p-type AlGaInP, an intermediate layer 207 of p-type GaInP and a contact layer 208 of p-type GaAs is formed on a prescribed region of the upper surface of the p-type first cladding layer 205. This ridge portion is formed in a striped (elongated) shape.

[0008] Current blocking layers 209 prepared by stacking n-type AlInP layers and n-type GaAs layers are formed to cover the upper surface of the p-type first cladding layer 205 and both side surfaces of the ridge portion while exposing only the upper surface of the ridge portion (contact layer 208). A p-type cap layer 210 of p-type GaAs is formed to cover the exposed upper surface of the ridge portion and the upper surfaces of the current blocking layers 209.

[0009] A p-side electrode 211 is formed on a portion of the p-type cap layer 210 around the aforementioned ridge portion. An n-side electrode 212 is formed on the back surface of the n-type GaAs substrate 201.

[0010] A process of fabricating the conventional semiconductor laser device having a ridge portion is now described with reference to FIG. 50. First, the n-type buffer layer 202 of n-type GaInP, the n-type cladding layer 203 of n-type AlGaInP, the emission layer 204 including the multiple quantum well (MQW) active layer of GaInP/AlGaInP, the p-type first cladding layer 205 of p-type AlGaInP, the p-type second cladding layer 206 of p-type AlGaInP, the intermediate layer 207 of p-type GaInP and the contact layer 208 of p-type GaAs are successively formed on the n-type GaAs substrate 201 by MOVPE (metal organic vapor phase epitaxy).

[0011] Then, SiO<sub>2</sub> layers (not shown) are formed on the contact layer 208 by photolithography and etching at a

prescribed interval. The SiO<sub>2</sub> layers are employed as masks for etching the p-type second cladding layer 206, the intermediate layer 207 and the contact layer 208, thereby forming the mesa (trapezoidal) ridge portion consisting of the p-type second cladding layer 206, the intermediate layer 207 and the contact layer 208 in the striped shape on the central portion of the p-type first cladding layer 205.

[0012] Then, an SiO<sub>2</sub> layer (not shown) formed on the ridge portion is employed as a mask for growing the current blocking layers 209 consisting of the n-type AlInP layers and the n-type GaAs layers to cover the upper surface of the p-type first cladding layer 205 and both side surfaces of the ridge portion. Thereafter the SiO<sub>2</sub> layer (not shown) is removed from the ridge portion.

[0013] Thereafter the p-type cap layer 210 of p-type GaAs is formed by MOVPE to cover the exposed upper surface of the ridge portion and the upper surfaces of the current blocking layers 209. The p-side electrode 211 is formed on the portion of the p-type cap layer 210 around the aforementioned ridge portion by the lift off method.

[0014] The back surface of the n-type GaAs substrate 201 is etched for thereafter forming the n-side electrode 212 on this back surface. The conventional semiconductor laser device having a ridge portion is formed in the aforementioned manner.

[0015] FIG. 51 is a sectional view illustrating the conventional semiconductor laser device shown in FIG. 50 in a state mounted on a submount 251 in a junction-down system. According to the junction-down system, the semiconductor laser device is mounted on the submount 251 from the surface closer to the emission layer (active layer) 204. Referring to FIG. 51, a projecting portion of the p-side electrode 211 provided on the surface of the aforementioned conventional semiconductor laser device is directed downward and mounted on a metal film (electrode) 252 of the submount 251 through a welding material 253 consisting of a low melting point metal such as solder. In this case the submount 251 also has a function of a heat sink absorbing heat of the semiconductor laser device and dissipating the same outward in general. Therefore, the heat generated from the semiconductor laser device is dissipated by the submount 251 from the aforementioned ridge portion through the p-type cap layer 210, the p-side electrode 211, the welding material 253 and the metal film 252.

[0016] When the aforementioned conventional semiconductor laser device is mounted on the submount 251 in the junction-down system, however, the heat generated from the semiconductor laser device is dissipated by the submount 251 through the p-type cap layer 210 of p-type GaAs having lower thermal conductivity than the welding material 253 of a low melting point metal such as solder, to disadvantageously reduce heat dissipativity. Therefore, the conventional semiconductor laser device is disadvantageously reduced in reliability (lifetime).

[0017] In the aforementioned conventional semiconductor laser device, further, three crystal growth steps must be carried out in total by MOVPE for growing the layers from the n-type buffer layer 202 to the contact layer 208, the current blocking layers 209 and the p-type cap layer 210 respectively. Consequently, the fabrication process for the semiconductor laser device is disadvantageously complicated.



[0018] When mounted on the submount **251** in the junction-down system, further, the aforementioned conventional semiconductor laser device is so easily inclined with respect to the submount **251** that the welding material **253** such as solder adheres to the side end surfaces of the inclined semiconductor laser device to easily electrically short the n-type semiconductor layers **202** and **203** and the p-type semiconductor layers **205** to **208** holding the emission layer **204** including the MQW active layer therebetween. Consequently, the fabrication yield is disadvantageously reduced.

[0019] When the aforementioned semiconductor laser device is mounted on the submount **251** in the junction-down system, in addition, only the projecting portion of the p-side electrode **211** comes into contact with the metal film **252** of the submount **251**, to disadvantageously easily apply stress to the ridge portion located under the projecting portion of the p-side electrode **211**. When stress is applied to the ridge portion, the operating current and the operating voltage are disadvantageously increased. When stress is applied to the ridge portion, further, the intensity ratio of polarization between a TE mode having an electric field component in a direction parallel to the emission layer **204** including the MQW active layer and a TM mode having an electric field component in a direction perpendicular to the emission layer **204** (intensity of TE mode/intensity of TM mode: polarization ratio) is disadvantageously reduced in light emitted from the semiconductor laser device.

#### SUMMARY OF THE INVENTION

[0020] An object of the present invention is to provide a semiconductor laser device capable of improving heat dissipativity and reliability (lifetime), simplifying the fabrication process and improving the fabrication yield.

[0021] In order to attain the aforementioned object, a semiconductor laser device according to a first aspect of the present invention comprises an emission layer formed on a substrate, a semiconductor layer formed on the emission layer while constituting a convex ridge portion, a current blocking layer consisting of a semiconductor formed to cover at least the side surfaces of the ridge portion, a first metal electrode formed to be in contact with the upper surface of the ridge portion and convex support portions arranged on both sides of the ridge portion at a prescribed interval from the ridge portion.

[0022] In the semiconductor laser device according to the first aspect, as hereinabove described, the first metal electrode is formed to be in contact with the upper surface of the ridge portion so that heat generated from the semiconductor laser device in a driven state can be more easily dissipated as compared with a case of forming a cap layer of a semiconductor having lower thermal conductivity than a metal on the upper surface of the ridge portion. Thus, the semiconductor laser device can be inhibited from temperature rise in the driven state, whereby the reliability (lifetime) thereof can be improved. The convex support portions are so arranged on both sides of the ridge portion that the semiconductor laser device is not inclined when the same is mounted on a submount through a welding layer of solder or the like. Thus, solder hardly reaches the side surfaces of the semiconductor laser device, whereby the semiconductor laser device can be inhibited from a short between p- and n-type semiconductor layers or generation of a leakage

current through the support portions. Thus, the semiconductor laser device can be so inhibited from a short or a leakage current as to improve the fabrication yield and the reliability (lifetime). Further, no semiconductor cap layer may be formed on the upper surfaces of the ridge portion and the current blocking layer, whereby the number of steps of growing semiconductor layers can be reduced by one. Thus, the fabrication process can be simplified. Consequently, the semiconductor laser device can improve heat dissipativity and reliability (lifetime), simplify the fabrication process and improve the fabrication yield.

[0023] In the aforementioned semiconductor laser device according to the first aspect, the current blocking layer of a semiconductor is preferably formed not on the upper surface of the ridge portion but on the upper surfaces of the support portions. According to this structure, the height of the support portions exceeds that of the ridge portion by the thickness of the current blocking layer if the thicknesses of the ridge portion and the support portions are identical to each other, whereby the height of portions of the first metal electrode located on the support portions exceeds that of the remaining portion when the first metal electrode is formed on the ridge portion and the support portions. When the first metal electrode is mounted on a submount, therefore, the portions of the first metal electrode located on the support portions come into contact with the submount while the remaining portion located on the ridge portion is not in contact with the submount, whereby stress applied to the ridge portion can be reduced. Thus, the semiconductor laser device can be prevented from deterioration of the characteristics resulting from stress, whereby the reliability (lifetime) of the semiconductor laser device can be improved. If stress applied to the ridge portion is small, the polarization ratio of a laser beam emitted from the semiconductor laser device is so increased that a polarization ratio of at least 50 necessary for recording in a recording-type optical disk can be easily obtained. In this case, the support portions are preferably substantially flush with the upper surface of the ridge portion.

[0024] In the aforementioned semiconductor laser device according to the first aspect, the first metal electrode may include a plurality of metal electrode layers.

[0025] In the aforementioned semiconductor laser device according to the first aspect, the first metal electrode preferably includes an upper surface having an irregular shape reflecting the shape of the convex ridge portion, the shape of the support portions and the shape of the current blocking layer. According to this structure, the semiconductor laser device can be easily prevented from inclination when the first metal electrode is mounted on the submount, due to the portions of the first metal electrode located on the support portions.

[0026] In this case, the height of portions of the first metal electrode located on the support portions preferably exceeds that of a portion located on the ridge portion. According to this structure, the first metal electrode can be so easily mounted on the submount that the portions located on the support portions are in contact with the submount and the remaining portion located on the ridge portion is not in contact with the submount, whereby stress applied to the ridge portion can be reduced.

[0027] In the aforementioned semiconductor laser device according to the first aspect, the convex ridge portion and the



support portions may be mounted on a submount through a welding layer. According to this structure, heat generated in the ridge portion can be dissipated through the submount.

[0028] In this case, the first metal electrode is so mounted on the submount that portions of the first metal electrode located on the support portions are in contact with the submount and a portion of the first metal electrode located on the ridge portion is not in contact with the submount. According to this structure, stress applied to the ridge portion can be easily reduced.

[0029] In the aforementioned semiconductor device according to the first aspect, side surfaces of the support portions closer to end surfaces of the semiconductor laser device (side surfaces of the semiconductor laser device perpendicular to cavity facets are preferably arranged inward beyond the end surfaces of the semiconductor laser device at a prescribed interval. According to this structure, the end surfaces of the semiconductor laser device are provided with no support portions, whereby a welding layer of solder or the like can be inhibited from reaching the end surfaces of the semiconductor laser device through outer side surfaces of support portions located on the end surfaces of the semiconductor laser device. Thus, p- and n-type layers can be prevented from a disadvantageous short resulting from the welding layer of solder or the like reaching the end surfaces of the semiconductor laser device.

[0030] In the aforementioned semiconductor laser device according to the first aspect, the current blocking layer preferably covers side surfaces of the support portions closer to end surfaces of the semiconductor laser device, the upper surfaces of the support portions and side surfaces of the support portions closer to the ridge portion. According to this structure, current for energizing the semiconductor laser device flows only to the ridge portion also when the first metal electrode is mounted on a submount and a welding layer of solder or the like adheres to the side surfaces of the support portions since no current flows to the support portions. Thus, the semiconductor laser device can attain high quantum efficiency.

[0031] In the aforementioned semiconductor laser device according to the first aspect, the thickness of the first metal electrode may be at least 5  $\mu\text{m}$ . According to this structure, flexibility of the first metal electrode is improved due to the large thickness, whereby stress acting on the ridge portion can be reduced. Consequently, the polarization ratio of the laser beam emitted from the semiconductor laser device can be so increased that a polarization ratio of at least 50 necessary for a recording-type optical disk can be easily obtained.

[0032] In the aforementioned semiconductor device according to the first aspect, the first metal electrode preferably contains a dopant having the same conductivity type as the semiconductor layer constituting the ridge portion. According to this structure, the first metal electrode and the semiconductor layer constituting the ridge portion can be brought into ohmic contact with each other, whereby contact resistance can be reduced. Consequently, the semiconductor laser device can be further inhibited from heat generation.

[0033] In this case, the semiconductor layer constituting the ridge portion preferably consists of a group III-V compound semiconductor, and the dopant, contained in the first

metal electrode, having the same conductivity type as the semiconductor layer constituting the ridge portion preferably includes at least one element selected from a group consisting of Zn, Cd, Be, Mg, Ca and Ba. According to this structure, the group III-V compound semiconductor layer constituting the ridge portion can be easily converted to a p type due to the aforementioned element, and the first metal electrode and the aforementioned ridge portion converted to the p type can be easily brought into ohmic contact with each other.

[0034] In the aforementioned semiconductor laser device according to the first aspect, a plurality of convex support portions may be arranged on each side of the ridge portion. According to this structure, a contact area between the semiconductor laser device mounted on a submount with a welding layer of solder or the like and the submount is so increased that the semiconductor laser device can be more stably mounted.

[0035] In the aforementioned semiconductor laser device according to the first aspect, the emission layer includes a plurality of emission layers, formed on the substrate at a prescribed interval, each having an emission portion, and the semiconductor layer constituting the convex ridge portion, the current blocking layer, the first metal electrode and the convex support portions are formed on each of the plurality of emission layers. According to this structure, improvement of heat conduction and reliability (lifetime), simplification of a fabrication process and improvement of the fabrication yield can be attained in a multi-beam laser (semiconductor laser device) having a plurality of emission portions.

[0036] In the aforementioned semiconductor laser device according to the first aspect, the interval between the lower end of the ridge portion and the lower ends of the support portions is preferably at least 20  $\mu\text{m}$ . According to this structure, the degree of adhesion of a polycrystalline growth film to a mask formed on the upper surface of the ridge portion is reduced in formation of the current blocking layer, whereby resistance can be inhibited from increase resulting from adhesion of the polycrystalline growth film to the mask formed on the upper surface of the ridge portion. Thus, the operating voltage can be inhibited from increase. Further, the interval between the lower end of the ridge portion and those of the support portions is so set to at least 20  $\mu\text{m}$  that the resistance can be inhibited from increase without complicating the structure.

[0037] In the aforementioned semiconductor laser device setting the interval between the lower end of the ridge portion and those of the support portions to at least 20  $\mu\text{m}$ , the interval between the lower end of the ridge portion and the lower ends of the support portions may be not more than 100  $\mu\text{m}$ . According to this structure, a welding material of solder or the like smoothly reaches a trench portion of an electrode formed between the ridge portion and the support portions in junction-down assembling. Thus, no space is defined between the electrode and a submount or a heat sink. Consequently, heat generated in the semiconductor laser device can be sufficiently dissipated to the submount or the heat sink.

[0038] In the aforementioned semiconductor laser device setting the interval between the lower end of the ridge portion and those of the support portions to at least 20  $\mu\text{m}$ , the current blocking layer may consist of a compound



semiconductor containing aluminum. When the interval between the lower end of the ridge portion and those of the support portions is set to at least 20  $\mu\text{m}$  in formation of the current blocking layer consisting of the compound semiconductor containing aluminum, the effect of reducing the degree of adhesion of the polycrystalline growth film to the mask formed on the upper surface of the ridge portion is remarkable.

[0039] A semiconductor laser device according to a second aspect of the present invention comprises an emission layer formed on a substrate, a semiconductor layer formed on the emission layer while constituting a convex ridge portion, a current blocking layer formed on a side of the ridge portion, a first metal electrode formed to be in contact with the upper surface of the ridge portion and a second metal electrode, formed on the first metal electrode, superior in adhesiveness to the first metal electrode.

[0040] In the semiconductor laser device according to the second aspect, as hereinabove described, the first metal electrode is so formed to be in contact with the upper surface of the ridge portion that heat generated from the semiconductor laser device under operation can be more easily dissipated as compared with a case of forming a semiconductor cap layer having lower thermal conductivity than a metal on the upper surface of the ridge portion. Thus, the semiconductor laser device can be inhibited from temperature rise in the driven state, whereby the reliability (lifetime) thereof can be improved. Further, the second metal electrode superior in adhesiveness to the first metal electrode is so formed on the first metal electrode that the first metal electrode can be inhibited from separating from the upper surface of the ridge portion also when adhesiveness between the first metal electrode and the semiconductor layer constituting the ridge portion is low. Thus, the reliability (lifetime) of the semiconductor laser device can be improved. In addition, no semiconductor cap layer may be formed on the upper surfaces of the ridge portion and the current blocking layer, whereby the number of steps of growing semiconductor layers can be reduced by one. Thus, the fabrication process can be simplified. Consequently, the semiconductor laser device can improve heat dissipativity and reliability (lifetime), simplify the fabrication process and improve the fabrication yield.

[0041] In the aforementioned semiconductor laser device including the first and second metal electrodes, the second metal electrode is preferably formed to be in contact with the current blocking layer. According to this structure, the first metal electrode can be easily inhibited from separating from the upper surface of the ridge portion also when adhesiveness between the first metal electrode and the semiconductor layer constituting the ridge portion is low.

[0042] In the aforementioned semiconductor laser device including the first and second metal electrodes, the first metal electrode preferably contains a dopant having the same conductivity type as the semiconductor layer constituting the ridge portion. According to this structure, the first metal electrode and the semiconductor layer constituting the ridge portion can be brought into ohmic contact with each other, whereby contact resistance can be reduced. Consequently, the semiconductor laser device can be further inhibited from heat generation.

[0043] In this case, the semiconductor layer constituting the ridge portion preferably consists of a group III-V com-

pound semiconductor, and the dopant, contained in the first metal electrode, having the same conductivity type as the semiconductor layer constituting the ridge portion preferably includes at least one element selected from a group consisting of Zn, Cd, Be, Mg, Ca and Ba. According to this structure, the group III-V compound semiconductor layer constituting the ridge portion can be easily converted to a p type due to the aforementioned element, and the first metal electrode and the aforementioned ridge portion converted to the p type can be easily brought into ohmic contact with each other.

[0044] In the aforementioned semiconductor laser device according to the second aspect, the sum of the thicknesses of the first metal electrode and the second metal electrode is preferably at least 5  $\mu\text{m}$ . According to this structure, the first and second metal electrodes are so improved in flexibility that stress acting on the ridge portion can be reduced. Consequently, the polarization ratio of a laser beam emitted from the semiconductor laser device can be so increased that a polarization ratio of at least 50 necessary for a recording-type optical disk can be easily obtained.

[0045] A method of fabricating a semiconductor laser device according to a third aspect of the present invention comprises steps of forming an emission layer on a substrate, forming a semiconductor layer constituting a convex ridge portion on the emission layer, forming a current blocking layer consisting of a semiconductor to cover at least the side surfaces of the ridge portion and forming a convex support portion so that the interval between the lower end of the ridge portion and the lower end of the support portion is at least 20  $\mu\text{m}$ .

[0046] In the method of fabricating a semiconductor laser device according to the third aspect, as hereinabove described, the convex support portion is so formed that the interval between the lower end of the ridge portion and that of the support portion is at least 20  $\mu\text{m}$ , whereby the degree of adhesion of a polycrystalline growth film to a mask formed on the upper surface of the ridge portion is reduced in formation of the current blocking layer and resistance can be inhibited from increase resulting from adhesion of the polycrystalline growth film to the mask formed on the upper surface of the ridge portion. Thus, the operating voltage can be inhibited from increase. Further, the interval between the lower end of the ridge portion and that of the support portion is so set to at least 20  $\mu\text{m}$  that the resistance can be inhibited from increase without complicating the structure.

[0047] In the aforementioned method of fabricating a semiconductor laser device according to the third aspect, the step of forming the support portion preferably includes a step of forming the support portion so that the interval between the lower end of the ridge portion and the lower end of the support portion is not more than 100  $\mu\text{m}$ . According to this structure, a welding material of solder or the like smoothly reaches a trench portion of an electrode formed between the ridge portion and the support portion in junction-down assembling. Thus, no space is defined between the electrode and a submount or a heat sink. Consequently, heat generated in the semiconductor laser device can be sufficiently dissipated to the submount or the heat sink.

[0048] In the aforementioned method of fabricating a semiconductor laser device according to the third aspect, the step of forming the current blocking layer preferably



includes steps of forming a mask consisting of a dielectric substance on the upper surface of the ridge portion and crystal-growing the current blocking layer consisting of a semiconductor on a portion other than the mask. According to this structure, the current blocking layer can be selectively grown on both side surfaces of the ridge portion, upper and both side surfaces of the support portion and a region between the ridge portion and the support portion through the mask consisting of a dielectric substance. Further, the interval between the lower end of the ridge portion and that of the support portion is so set to at least 20  $\mu\text{m}$  that a polycrystalline growth film can be inhibited from adhering to the mask formed on the upper surface of the ridge portion.

[0049] The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0050] FIG. 1 is a sectional view for illustrating a semiconductor laser device according to a first embodiment of the present invention;

[0051] FIG. 2 is a sectional view for illustrating the structure of an emission layer of the semiconductor laser device according to the first embodiment of the present invention;

[0052] FIGS. 3 to 6 are sectional views for illustrating a process of fabricating the semiconductor laser device according to the first embodiment of the present invention;

[0053] FIG. 7 is a sectional view illustrating the semiconductor laser device according to the first embodiment shown in FIG. 1 in a state mounted on a submount in a junction-down system;

[0054] FIG. 8 is a sectional view for illustrating a method of mounting the semiconductor laser device according to the first embodiment shown in FIG. 1 on the submount in the junction-down system;

[0055] FIG. 9 is a sectional view for illustrating a semiconductor laser device according to a second embodiment of the present invention;

[0056] FIGS. 10 to 12 are sectional views for illustrating a process of fabricating the semiconductor laser device according to the second embodiment of the present invention;

[0057] FIG. 13 is a sectional view illustrating the semiconductor laser device according to the second embodiment shown in FIG. 9 in a state mounted on a submount in a junction-down system;

[0058] FIG. 14 is a sectional view for illustrating a method of mounting the semiconductor laser device according to the second embodiment shown in FIG. 9 on the submount in the junction-down system;

[0059] FIG. 15 is a characteristic diagram showing the relation between the thickness of a p-side electrode of the semiconductor laser device according to the second embodiment and a polarization ratio;

[0060] FIG. 16 is a characteristic diagram showing the relation between resistance between p-type GaAs layers doped with Zn and metal layers and inter-electrode distances;

[0061] FIG. 17 is a sectional view for illustrating a semiconductor laser device according to a third embodiment of the present invention;

[0062] FIG. 18 is a sectional view for illustrating a semiconductor laser device according to a fourth embodiment of the present invention;

[0063] FIG. 19 is a sectional view illustrating the semiconductor laser device according to the fourth embodiment shown in FIG. 18 in a state mounted on a submount in a junction-down system;

[0064] FIG. 20 is a sectional view for illustrating a method of mounting the semiconductor laser device according to the fourth embodiment shown in FIG. 18 on the submount in the junction-down system;

[0065] FIG. 21 is a sectional view for illustrating a semiconductor laser device according to a fifth embodiment of the present invention;

[0066] FIGS. 22 to 24 are sectional views for illustrating a process of fabricating the semiconductor laser device according to the fifth embodiment of the present invention;

[0067] FIG. 25 is a sectional view illustrating the semiconductor laser device according to the fifth embodiment shown in FIG. 21 in a state mounted on a submount in a junction-down system;

[0068] FIG. 26 is a sectional view for illustrating a method of mounting the semiconductor laser device according to the fifth embodiment shown in FIG. 21 on the submount in the junction-down system;

[0069] FIG. 27 is a sectional view for illustrating a semiconductor laser device according to a sixth embodiment of the present invention;

[0070] FIGS. 28 to 31 are sectional views for illustrating a process of fabricating the semiconductor laser device according to the sixth embodiment of the present invention;

[0071] FIG. 32 is a sectional view illustrating the semiconductor laser device according to the sixth embodiment shown in FIG. 27 in a state mounted on a submount in a junction-down system;

[0072] FIG. 33 is a sectional view for illustrating a method of mounting the semiconductor laser device according to the sixth embodiment shown in FIG. 27 on the submount in the junction-down system;

[0073] FIG. 34 is a sectional view for illustrating a semiconductor laser device according to a seventh embodiment of the present invention;

[0074] FIGS. 35 to 37 are sectional views for illustrating a process of fabricating the semiconductor laser device according to the seventh embodiment of the present invention;

[0075] FIG. 38 is a sectional view illustrating the semiconductor laser device according to the seventh embodiment shown in FIG. 34 in a state mounted on a submount in a junction-down system;



[0076] FIG. 39 is a sectional view for illustrating a method of mounting the semiconductor laser device according to the seventh embodiment shown in FIG. 34 on the submount in the junction-down system;

[0077] FIG. 40 is a sectional view for illustrating a semiconductor laser device according to an eighth embodiment of the present invention;

[0078] FIGS. 41 to 46 are sectional views for illustrating a process of fabricating the semiconductor laser device according to the eighth embodiment of the present invention;

[0079] FIG. 47 is a correlation diagram showing the relation between ridge intervals and operating voltages;

[0080] FIG. 48 is a sectional view for illustrating a semiconductor laser device according to a ninth embodiment of the present invention;

[0081] FIG. 49 is a sectional view for illustrating a process of fabricating the semiconductor laser device according to the ninth embodiment of the present invention;

[0082] FIG. 50 is a sectional view for illustrating a conventional semiconductor laser device having a ridge portion; and

[0083] FIG. 51 is a sectional view illustrating the conventional semiconductor laser device shown in FIG. 50 in a state mounted on a submount in a junction-down system.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0084] Embodiments of the present invention are now described with reference to the drawings.

##### First Embodiment

[0085] The structure of a semiconductor laser device according to a first embodiment is described with reference to FIGS. 1 and 2.

[0086] In the semiconductor laser device according to the first embodiment, an n-type buffer layer 2, an n-type cladding layer 3, an emission layer 4 and a p-type first cladding layer 5 are successively formed on an n-type GaAs substrate 1 inclined from the (100) plane by  $9^\circ$  in the direction, as shown in FIG. 1. The n-type buffer layer 2 has a thickness of about  $0.3\ \mu\text{m}$ , and consists of n-type GaInP doped with Si. The n-type cladding layer 3 has a thickness of about  $2\ \mu\text{m}$ , and consists of n-type AlGaInP (Al composition ratio: 0.7) doped with Si by a dose of  $3 \times 10^{17}\ \text{cm}^{-3}$ .

[0087] As shown in FIG. 2, the emission layer 4 is constituted of a first light guide layer 4a of AlGaInP (Al composition ratio: 0.2) having a thickness of about 20 nm, an active layer having a multiple quantum well (MQW) structure obtained by alternately stacking three well layers 4b of AlGaInP (Al composition ratio: 0) (GaInP) each having a thickness of 8 nm and two barrier layers 4c of AlGaInP (Al composition ratio: 0.6) each having a thickness of 5 nm and a second light guide layer 4d of AlGaInP (Al composition ratio: 0.5) having a thickness of about 20 nm. Compression strain is introduced into the well layers 4b in order to reduce threshold current and improve laser characteristics. Further, tensile strain is introduced into the barrier layers 4c oppositely to the well layers 4b, so that the

emission layer 4 including the MQW active layer has a strain compensatory structure. The p-type first cladding layer 5 has a thickness of about  $0.25\ \mu\text{m}$ , and consists of p-type AlGaInP (Al composition ratio: 0.7) doped with Zn by a dose of  $1 \times 10^{18}\ \text{cm}^{-3}$ .

[0088] As shown in FIG. 1, a mesa (trapezoidal) ridge portion 12 and a pair of dummy ridge portions 13 constituted of p-type second cladding layers 6, intermediate layers 7 and contact layers 8 respectively are formed on the upper surface of the p-type first cladding layer 5. The dummy ridge portions 13 are examples of the “support portion(s)” in the present invention. The p-type second cladding layers 6 have a thickness of about  $1.3\ \mu\text{m}$ , and consist of p-type AlGaInP (Al composition ratio: 0.7) doped with Zn by a dose of  $1 \times 10^{18}\ \text{cm}^{-1}$ . The intermediate layers 7 have a thickness of about  $0.1\ \mu\text{m}$ , and consist of p-type GaInP doped with Zn by a dose of  $1 \times 10^{18}\ \text{cm}^{-3}$ . The contact layers 8 have a thickness of about  $0.3\ \mu\text{m}$ , and consist of p-type GaAs doped with Zn by a dose of  $2 \times 10^{19}\ \text{cm}^{-3}$ . The ridge portion 12 is formed in a striped shape (elongated shape) having a bottom portion of about  $2.5\ \mu\text{m}$  in width and an upper portion of about  $1.5\ \mu\text{m}$  in width. The dummy ridge portions 13 are formed at an interval of about  $50\ \mu\text{m}$  from the ridge portion 12, to hold the ridge portion 12 therebetween.

[0089] Current blocking layers 9 prepared by stacking n-type AlInP layers, doped with Se, having a thickness of about  $0.5\ \mu\text{m}$  and n-type GaAs layers having a thickness of about  $0.3\ \mu\text{m}$  are formed to cover the upper surface of the p-type first cladding layer 5, both side surfaces of the ridge portion 12, the upper surfaces of the dummy ridge portions 13 and first side surfaces of the dummy ridge portions 13 facing the ridge portion 12. In other words, the upper surface of the ridge portion 12 and second side surfaces of the dummy ridge portions 13 opposite to the ridge portion 12 are covered with no current blocking layers 9.

[0090] According to the first embodiment, the current blocking layers 9 are formed not on the upper surface of the ridge portion 12 but on the upper surfaces of the dummy ridge portions 13, whereby the height of the upper surfaces of the dummy ridge portions 13 exceeds that of the upper surface of the ridge portion 12 by the thickness (=d) (about  $0.8\ \mu\text{m}$ ) of the current blocking layers 9. A first p-side electrode 10 consisting of a Cr/Au layer, having a total thickness of about  $3\ \mu\text{m}$ , prepared by stacking a Cr layer and an Au layer successively from the side closer to the p-type first cladding layer 5 is formed to cover the exposed upper surface of the ridge portion 12 (contact layer 8) and the upper surfaces of the current blocking layers 9. The first p-side electrode 10 is formed in an irregular shape reflecting the shapes of the ridge portion 12, the dummy ridge portions 13 and the current blocking layers 9. Therefore, the height of portions lob of the first p-side electrode 10 located on the dummy ridge portions 13 exceeds that of a portion 10a located on the ridge portion 12 by the thickness (=d) of the current blocking layers 9. The first p-side electrode 10 is an example of the “first metal electrode” in the present invention.

[0091] An n-side electrode 11 consisting of an Au—Ge/Au layer prepared by stacking an Au—Ge layer and an Au layer successively from the side closer to the n-type GaAs substrate 1 is formed on the back surface of the n-type GaAs substrate 1.



[0092] An impurity such as Zn is diffused into the ridge portion 12 and the dummy ridge portions 13 in the vicinity of cavity facets of the semiconductor laser device according to the first embodiment over the layers from the contact layer 8 to the emission layer 4 including the MQW active layer, thereby forming a window structure disordering the MQW active layer in the vicinity of the cavity facets. Further, the current blocking layers 9 are formed on the upper surface of the ridge portion 12 in the vicinity of the cavity facets constituting the aforementioned window structure, thereby forming non-injection structure for injecting no unnecessary current into the ridge portion 12 in the vicinity of the aforementioned cavity facets.

[0093] A process of fabricating the semiconductor laser device according to the first embodiment of the present invention having the aforementioned structure is described with reference to FIGS. 1 to 6. As shown in FIG. 3, the semiconductor layers 2 to 8 are formed on the n-type GaAs substrate 1 inclined from the (100) plane by  $9^\circ$  in the direction by MOVPE. More specifically, the n-type buffer layer 2 of n-type GaInP doped with Si is formed on the n-type GaAs substrate 1 with the thickness of about  $0.3\text{ }\mu\text{m}$ . Thereafter the n-type cladding layer 3 of n-type AlGaInP doped with Si by the dose of  $3 \times 10^{17}\text{ cm}^{-3}$  is formed on the n-type buffer layer 2 with the thickness of about  $2\text{ }\mu\text{m}$ . Thereafter the emission layer 4 including the MQW active layer consisting of GaInP/AlGaInP is formed on the n-type cladding layer 3. The p-type first cladding layer 5 of p-type AlGaInP (Al composition ratio: 0.7) doped with Zn by the dose of  $1 \times 10^{18}\text{ cm}^{-3}$  is formed on the emission layer 4 with the thickness of about  $0.25\text{ }\mu\text{m}$ . Further, the p-type second cladding layers 6 of p-type AlGaInP (Al composition ratio: 0.7) doped with Zn by the dose of  $1 \times 10^{18}\text{ cm}^{-3}$  are formed on the p-type first cladding layer 5 with the thickness of about  $1.3\text{ }\mu\text{m}$ . Thereafter the intermediate layers 7 of p-type GaInP doped with Zn by the dose of  $1 \times 10^{18}\text{ cm}^{-3}$  are formed on the p-type second cladding layers 6 with the thickness of about  $0.1\text{ }\mu\text{m}$ . Then, the contact layers 8 of p-type GaAs doped with Zn by the dose of  $2 \times 10^{19}\text{ cm}^{-3}$  are formed with the thickness of about  $0.3\text{ }\mu\text{m}$ .

[0094] As shown in FIG. 2, the emission layer 4 is formed by successively stacking the first light guide layer 4a of AlGaInP (Al composition ratio: 0.2) having the thickness of about  $20\text{ nm}$ , the active layer having the multiple quantum well (MQW) structure consisting of the three well layers 4b of AlGaInP (Al composition ratio: 0) (GaInP) each having the thickness of  $8\text{ nm}$  and the two barrier layers 4c of AlGaInP (Al composition ratio: 0.6) each having the thickness of  $5\text{ nm}$  and the second light guide layer 4d of AlGaInP (Al composition ratio: 0.5) having the thickness of about  $20\text{ nm}$ .

[0095] As shown in FIG. 4,  $\text{SiO}_2$  layers 15 are formed on the contact layer 8 by photolithography and etching at prescribed intervals. The  $\text{SiO}_2$  layers 15 are employed as masks for etching the p-type second cladding layers 6, the intermediate layers 7 and the contact layers 8 thereby forming the mesa (trapezoidal) ridge portion 12 and the dummy ridge portions 13. The ridge portion 12 is formed in the striped shape so that the bottom portion thereof has the width of about  $2.5\text{ }\mu\text{m}$ .

[0096] As shown in FIG. 5, the  $\text{SiO}_2$  layers 15 formed on the dummy ridge portions 13 are removed while leaving

only the  $\text{SiO}_2$  layer 15 formed on the ridge portion 12. The  $\text{SiO}_2$  layer 15 formed on the ridge portion 12 is employed as a mask for forming the n-type current blocking layers 9 consisting of the AlInP layers, doped with Se, having the thickness of about  $0.5\text{ }\mu\text{m}$  and the n-type GaAs layers having the thickness of about  $0.3\text{ }\mu\text{m}$  to cover the upper surface of the p-type first cladding layer 5, both side surfaces of the ridge portion 12, the upper surfaces of the dummy ridge portions 13 and the first side surfaces of the dummy ridge portions 13 facing the ridge portion 12. In other words, the upper surface of the ridge portion 12 and the second side surfaces of the dummy ridge portions 13 opposite to the ridge portion 12 are exposed from the current blocking layers 9.

[0097] Then, the mask of the  $\text{SiO}_2$  layer 15 is removed from the ridge portion 12. Thereafter heat treatment is performed in a nitrogen atmosphere at  $520^\circ\text{C}$ . for 10 minutes, thereby converting the p-type first cladding layer 5, the p-type second cladding layers 6 and the intermediate layers 7 to the p types.

[0098] As shown in FIG. 6, the first p-side electrode 10 consisting of the Cr/Au layer, prepared by stacking the Cr layer and the Au layer successively from the side closer to the p-type first cladding layer 5, having the total thickness of about  $3\text{ }\mu\text{m}$  is formed to cover the exposed upper surface of the ridge portion 12 and the upper surfaces of the current blocking layers 9. The first p-side electrode 10 is formed in the irregular shape reflecting the shapes of the ridge portion 12, the dummy ridge portions 13 and the current blocking layers 9, whereby the height of the portions lob of the first p-side electrode 10 located on the dummy ridge portions 13 exceeds that of the portion 10a located on the ridge portion 12 by the thickness ( $=d$ ) of the current blocking layers 9.

[0099] Thereafter the back surface of the n-type GaAs substrate 1 is etched so that the thickness of the n-type GaAs substrate 1 is about  $100\text{ }\mu\text{m}$ , and the n-side electrode 11 consisting of the Au—Ge/Au layer prepared by stacking the Au—Ge layer and the Au layer successively from the side closer to the n-type GaAs substrate 1 is formed on the back surface of the n-type GaAs substrate 1, as shown in FIG. 1. Thereafter heat treatment is performed in  $\text{H}_2/\text{N}_2$  ambient at  $430^\circ\text{C}$ . for 5 minutes, thereby attaining ohmic contact between the first p-side electrode 10 and the n-side electrode 11. The semiconductor laser device according to the first embodiment of the present invention is formed in the aforementioned manner.

[0100] Referring to FIGS. 7 and 8, the semiconductor laser device according to the first embodiment is mounted on a metal film (electrode) 152 of a submount 151 through a welding material 153 of a low melting point metal such as solder while directing a projecting portion of the first p-side electrode 10 formed on the front surface of the semiconductor laser device downward. The height of the portions lob of the first p-side electrode 10 located on the dummy ridge portions 13 exceeds that of the portion 10a located on the ridge portion 12 by the thickness ( $=d$ ) of the current blocking layers 9, and hence a prescribed gap ( $=d$ ) is defined between the metal film 152 of the submount 151 and the portion 10a of the first p-side electrode 10 formed on the ridge portion 12 when the aforementioned semiconductor laser device according to the first embodiment is mounted on the submount 151 in a junction-down system.



[0101] According to the first embodiment, as hereinabove described, the first p-side electrode **10** is so formed to be in contact with the upper surface of the ridge portion **12** that heat generated from the semiconductor laser device in a driven state can be more easily dissipated as compared with a case of forming a p-type cap layer **210** (see FIG. 50) of a semiconductor on the upper surface of the ridge portion **12**. Thus, the semiconductor laser device can be inhibited from temperature rise in the driven state, whereby the reliability (lifetime) thereof can be improved. Further, no p-type cap layer **210** (see FIG. 50) of a semiconductor may be formed on the upper surfaces of the ridge portion **12** and the current blocking layers **9** dissimilarly to the conventional semiconductor laser device, whereby the number of steps of growing semiconductor layers by MOVPE can be reduced by one. Thus, the fabrication process can be simplified.

[0102] The dummy ridge portions **13** are so provided on both sides of the ridge portion **12** that the semiconductor laser device is not inclined when mounted on the submount **151** in the junction-down system. Thus, solder hardly reaches the side surfaces of the semiconductor laser device, whereby the p- and n-type semiconductor layers can be inhibited from a short. Thus, the fabrication yield and the reliability of the semiconductor laser device can be improved. Further, the height of the portions lobe of the first p-side electrode **10** located on the dummy ridge portions **13** exceeds that of the portion **10a** located on the ridge portion **12** by the thickness (=d) of the current blocking layers **9**, whereby the prescribed gap (=d) (see FIG. 7) can be defined between the submount **151** and the portion **10a** of the first p-side electrode **10** formed on the ridge portion **12** when the semiconductor laser device is mounted on the submount **151**. Thus, stress applied to the ridge portion **12** can be reduced when the semiconductor laser device is mounted on the submount **151** in the junction-down system as shown in FIGS. 7 and 8. Therefore, the semiconductor laser device can be inhibited from deterioration of the characteristics resulting from stress. Consequently, the reliability and the fabrication yield of the semiconductor laser device can be improved.

#### Second Embodiment

[0103] Referring to FIG. 9, p-side electrodes are provided in a two-layer structure while current blocking layers are formed on the upper surfaces and both side surfaces of dummy ridge portions in a semiconductor laser device according to a second embodiment of the present invention.

[0104] The structure of the semiconductor laser device according to the second embodiment of the present invention is described with reference to FIG. 9. In the semiconductor laser device according to the second embodiment, an n-type buffer layer **2**, an n-type cladding layer **3**, an emission layer **4** and a p-type first cladding layer **5** are successively formed on an n-type GaAs substrate **1**, similarly to the semiconductor laser device according to the first embodiment shown in FIG. 1. A mesa (trapezoidal) ridge portion **12** and dummy ridge portions **13a** constituted of p-type second cladding layers **6**, intermediate layers **7** and contact layers **8** respectively are formed on the upper surface of the p-type first cladding layer **5**. The dummy ridge portions **13a** are examples of the “support portion(s)” in the present invention.

[0105] According to the second embodiment, the dummy ridge portions **13a** are formed slightly inward beyond end

portions of the n-type GaAs substrate **1**. Thus, regions partially exposing the upper surface of the p-type first cladding layer **5** are formed between the dummy ridge portions **13a** and the end portions of the n-type GaAs substrate **1**. Current blocking layers **9a** prepared by stacking n-type AlInP layers, doped with Se, having a thickness of about 0.5  $\mu\text{m}$  and n-type GaAs layers having a thickness of about 0.3  $\mu\text{m}$  are formed to cover the upper surface of the p-type first cladding layer **5**, both side surfaces of the ridge portion **12** and the upper surfaces and both side surfaces of the dummy ridge portions **13a**. The layers **2** to **8** of the semiconductor device according to the second embodiment are similar in composition and thickness to the layers **2** to **8** of the semiconductor laser device according to the first embodiment respectively.

[0106] According to the second embodiment, a first p-side electrode **21** consisting of a Cr/Au layer, having a total thickness of about 1  $\mu\text{m}$ , prepared by stacking a Cr layer and an Au layer successively from the side closer to the p-type first cladding layer **5** and a second p-side electrode **22** consisting of a Pd/Au layer, having a total thickness of about 2  $\mu\text{m}$ , prepared by stacking a Pd layer and an Au layer successively from the side closer to the first p-side electrode **21** are formed to cover the exposed upper surface of the ridge portion **12** and the upper surfaces of the current blocking layers **9a**. The first and second p-side electrodes **21** and **22** are formed in irregular shapes reflecting the shapes of the ridge portion **12**, the dummy ridge portions **13a** and the current blocking layers **9a**. Therefore, the height of portions **22b** of the second p-side electrode **22** located on the dummy ridge portions **13a** exceeds that of a portion **22a** located on the ridge portion **12** by the thickness (=d) of the current blocking layers **9a**. The first and second p-side electrodes **21** and **22** are examples of the “first metal electrode” in the present invention.

[0107] An n-side electrode **11** consisting of an Au—Ge/Au layer prepared by stacking an Au—Ge layer and an Au layer successively from the side closer to the n-type GaAs substrate **1** is formed on the back surface of the n-type GaAs substrate **1**, similarly to the first embodiment. Thus, the semiconductor laser device according to the second embodiment is formed.

[0108] The semiconductor laser device according to the second embodiment is formed with a window structure disordering an MQW active layer in the vicinity of cavity facets, similarly to the first embodiment. Further, the current blocking layers **9a** are formed on the upper surface of the ridge portion **12** in the vicinity of the cavity facets constituting the aforementioned window structure, thereby forming non-injection structure similarly to the first embodiment.

[0109] FIGS. 10 to 12 are sectional views for illustrating a process of fabricating the semiconductor laser device according to the second embodiment of the present invention. The process of fabricating the semiconductor laser device according to the second embodiment is described with reference to FIGS. 9 to 12. First, the n-type buffer layer **2**, the n-type cladding layer **3**, the emission layer **4**, the p-type first cladding layer **5**, the p-type second cladding layers **6**, the intermediate layers **7** and the contact layers **8** are successively formed on the n-type GaAs substrate **1** through a fabrication step similar to that of the first embodiment shown in FIG. 3. As shown in FIG. 10, SiO<sub>2</sub> layers **15a**



are thereafter formed on the contact layer **8** by photolithography and etching at prescribed intervals. The SiO<sub>2</sub> layers **15a** are employed as masks for etching the p-type second cladding layers **6**, the intermediate layers **7** and the contact layers **8** thereby forming the mesa (trapezoidal) ridge portion **12** and the dummy ridge portions **13a**. At this time, the dummy ridge portions **13a** are formed slightly inward beyond the end portions of the n-type GaAs substrate **1**, thereby forming the regions partially exposing the upper surface of the p-type first cladding layer **5** between the dummy ridge portions **13a** and the end portions of the n-type GaAs substrate **1**.

[0110] As shown in FIG. **11**, the SiO<sub>2</sub> layers **15a** are removed from the dummy ridge portions **13a** while leaving only the central SiO<sub>2</sub> layer **15a** on the ridge portion **12**. The SiO<sub>2</sub> layer **15a** left on the ridge portion **12** is employed as a mask for growing the current blocking layers **9a** consisting of the n-type AlInP layers, doped with Se, having the thickness of about 0.5  $\mu\text{m}$  and the n-type GaAs layers having the thickness of about 0.3  $\mu\text{m}$  to cover the upper surface of the p-type first cladding layer **5**, both side surfaces of the ridge portion **12** and the upper surfaces and both side surfaces of the dummy ridge portions **13a**.

[0111] Then, the mask of the SiO<sub>2</sub> layer **15a** left on the ridge portion **12** is removed. Thereafter heat treatment is performed in a nitrogen atmosphere at 520° C. for 10 minutes, thereby converting the p-type first and second cladding layers **5** and **6** and the intermediate layers **7** to the p types.

[0112] As shown in FIG. **12**, the first p-side electrode **21** is formed by vacuum evaporation or the like to cover the exposed upper surface of the ridge portion **12** and the upper surfaces of the current blocking layers **9a**. The second p-side electrode **22** consisting of the Pd/Au layer, having the total thickness of about 2  $\mu\text{m}$ , prepared by stacking the Pd layer and the Au layer successively from the side closer to the first p-side electrode **21** is formed on the first p-side electrode **21**. The first and second p-side electrodes **21** and **22** are formed in the irregular shapes reflecting the shapes of the ridge portion **12**, the dummy ridge portions **13a** and the current blocking layers **9a**, whereby the height of the portions **22b** of the second p-side electrode **22** located on the dummy ridge portions **13a** exceeds that of the portion **22a** located on the ridge portion **12** by the thickness (=d) of the current blocking layers **9a**.

[0113] Thereafter the back surface of the n-type GaAs substrate **1** is etched for forming the n-side electrode **11** thereon as shown in FIG. **9**. Thereafter heat treatment is performed in H<sub>2</sub>/N<sub>2</sub> ambient at 430° C. for 5 minutes, thereby attaining ohmic contact between the first and second p-side electrodes **21** and **22** and the n-side electrode **11**. The semiconductor laser device according to the second embodiment of the present invention is formed in the aforementioned manner.

[0114] Referring to FIGS. **13** and **14**, the semiconductor laser device according to the second embodiment of the present invention is mounted on a metal film (electrode) **152** of a submount **151** through a welding material **153** of a low melting point metal such as solder while directing a projecting portion of the second p-side electrode **22** formed on the front surface of the semiconductor laser device downward. The height of the portions **22b** of the second p-side

electrode **22** located on the dummy ridge portions **13a** exceeds that of the portion **22a** located on the ridge portion **12** by the thickness (=d) of the current blocking layers **9a**, and hence a prescribed gap (=d) is defined between the submount **151** and the portion **22a** of the second p-side electrode **22** formed on the ridge portion **12** when the aforementioned semiconductor laser device according to the second embodiment is mounted on the submount **151** in a junction-down system.

[0115] The operating characteristics of the semiconductor laser device according to the second embodiment and the conventional semiconductor laser device (comparative example) shown in FIG. **50** were evaluated. When a continuous-wave (CW) oscillation output at 70° C. was 50 mW, the conventional semiconductor laser device (comparative example) exhibited an operating current (I<sub>op</sub>) of 107.9 mA, while the semiconductor laser device according to the second embodiment exhibited an operating current (I<sub>op</sub>) of 88.4 mA, which was smaller by about 20%. Therefore, it has been proved that the semiconductor laser device according to the second embodiment can suppress increase of the operating current as compared with the conventional semiconductor laser device (comparative example). Thus, the quantity of heat generation resulting from increase of the operating current can be suppressed according to the second embodiment.

[0116] According to the second embodiment, as hereinabove described, the p-side electrodes are formed in the multilayer structure of the first and second p-side electrodes **21** and **22** to be easily increased in thickness, whereby stress applied to the ridge portion **12** can be controlled. Thus, the polarization ratio of a laser beam emitted from the semiconductor laser device can be controlled. In order to confirm this effect, influence exerted by a p-side electrode thickness on the optical output of the semiconductor laser device according to the second embodiment was evaluated.

[0117] FIG. **15** shows the relation between the p-side electrode thickness and the polarization ratio of the semiconductor laser device according to the second embodiment of the present invention. In this case, the p-side electrode thickness corresponds to the sum of the thicknesses of the first and second p-side electrodes **21** and **22**. Referring to FIG. **15**, the polarization ratio tends to increase following increase of the p-side electrode thickness. Thus, it is understood that the polarization ratio is increased as the p-side electrode thickness is increased, suitably for recording in a recording-type optical disk. When the p-side electrode thickness was set to about 6  $\mu\text{m}$  by stacking first and second p-side electrodes having thicknesses of about 1  $\mu\text{m}$  and about 5  $\mu\text{m}$  respectively with each other, for example, the polarization ratio was increased to 60. Thus, it has been recognized that a polarization ratio of at least 50 necessary for recording in a recording-type optical disk is obtained by setting the p-side electrode thickness to at least about 5  $\mu\text{m}$ .

[0118] According to the second embodiment, as hereinabove described, the current blocking layers **9a** are formed on the upper surfaces and both side surfaces of the dummy ridge portions **13a** to cover the dummy ridge portions **13a** so that no current flows to the dummy ridge portions **13a** also when the welding material **153** of solder for mounting the semiconductor laser device on the submount **151** in the junction-down system adheres to the side surfaces of the



dummy ridge portions **13a**. Thus, the current fed to the semiconductor laser device flows only to the ridge portion **12**, whereby the semiconductor laser device can attain high quantum efficiency.

[0119] According to the second embodiment, further, the dummy ridge portions **13a** are formed slightly inward beyond the end portions of the n-type GaAs substrate **1** so that not the dummy ridge portions **13a** but the current blocking layers **9a** having upper surfaces parallel to the n-type GaAs substrate **1** are formed on the end portions of the n-type GaAs substrate **1**. Thus, the welding material **153** of solder for mounting the semiconductor laser device on the submount **151** hardly reaches the p-type first cladding layer **5**, the emission layer **4** and the n-type cladding layer **3** from the current blocking layers **9a** on the end portions of the n-type GaAs substrate **1**. Consequently, end portions of the p- and n-side semiconductor layers further hardly cause a short, whereby the reliability of the semiconductor laser device can be further improved.

#### Third Embodiment

[0120] Referring to FIGS. **16** and **17**, a semiconductor laser device according to a third embodiment of the present invention employs a first metal electrode containing a p-type dopant and a second metal electrode having higher adhesiveness than the first metal electrode.

[0121] FIG. **16** shows values of resistance between electrodes consisting of metal layers formed on p-type GaAs layers doped with Zn measured at various inter-electrode distances. The p-type GaAs layers and the metal layers were brought into ohmic contact with each other by performing heat treatment in  $H_2/N_2$  ambient at 430° C. for 5 minutes after forming the metal layers on the p-type GaAs layers. Referring to FIG. **16**, it is understood that the resistance between the p-type GaAs layer and an Au—Zn/Au layer formed by stacking an Au—Zn layer containing Zn, the dopant for the p-type GaAs layer, and an Au layer successively from the side closer to the p-type GaAs layer was smaller than that between the p-type GaAs layer and a Cr/Au layer formed by stacking a Cr layer and an Au layer successively from the side closer to the p-type GaAs layer and that between the p-type GaAs layer and a Pd/Au layer formed by stacking a Pd layer and an Au layer successively from the side closer to the p-type GaAs layer at any inter-electrode distance. Thus, it has been recognized that excellent ohmic constant can be attained with small contact resistance when a metal electrode contains a dopant (Zn) of the same conductivity type as a semiconductor layer (p-type GaAs layer). As a result of evaluation of adhesion strength to the p-type GaAs layers, it has also been recognized that the Au—Zn/Au layer exhibited weak adhesion strength with respect to the p-type GaAs layer with a possibility of separation, while the Cr—Au layer and the Pd/Au layer exhibited sufficient adhesion strength with respect to the p-type GaAs layers.

[0122] The structure of the semiconductor laser device according to the third embodiment of the present invention is described with reference to FIG. **17**. Referring to FIG. **17**, portions identical to those shown in FIG. **9** are denoted by the same reference numerals, and redundant description is not repeated. In the semiconductor laser device according to the third embodiment, an n-type buffer layer **2**, an n-type

cladding layer **3**, an emission layer **4** and a p-type first cladding layer **5** are successively formed on an n-type GaAs substrate **1**, similarly to the semiconductor laser device according to the second embodiment shown in FIG. **9**. A mesa (trapezoidal) ridge portion **12** and dummy ridge portions **13a** constituted of p-type second cladding layers **6**, intermediate layers **7** and contact layers **8** respectively are formed on the upper surface of the p-type first cladding layer **5**. Current blocking layers **9a** prepared by stacking n-type AlInP layers, doped with Se, having a thickness of about 0.5  $\mu m$  and n-type GaAs layers having a thickness of about 0.3  $\mu m$  are formed to cover the upper surface of the p-type first cladding layer **5**, both side surfaces of the ridge portion **12** and the upper surfaces and both side surfaces of the dummy ridge portions **13a**. The layers **2** to **8** of the semiconductor laser device according to the third embodiment are similar in composition and thickness to the layers **2** to **8** of the semiconductor laser device according to the second embodiment respectively.

[0123] According to the third embodiment, a first p-side electrode **31** consisting of an Au—Zn/Au layer, having a thickness of about 1  $\mu m$ , prepared by successively stacking an Au—Zn layer and an Au layer is formed on the upper surfaces of the ridge portion **12** and the current blocking layers **9a** to cover the exposed upper surface of the ridge portion **12**. Further, a second p-side electrode **32** consisting of a Cr/Au layer, having a total thickness of about 5  $\mu m$ , prepared by forming a Cr layer and an Au layer successively from the side closer to the p-type first cladding layer **5** is formed on the upper surfaces of the current blocking layers **9a**, the upper surface and both side surfaces of the first p-side electrode **31** and the upper surfaces and both side surfaces of the dummy ridge portions **13a** to cover the first p-side electrode **31**. The first p-side electrode **31** is an example of the “first metal electrode” in the present invention, and the second p-side electrode **32** is an example of the “second metal electrode” in the present invention. Further, Zn is an example of the “dopant having the same conductivity type as said semiconductor layer constituting said ridge portion” in the present invention.

[0124] An n-side electrode **11** consisting of an Au—Ge/Au layer prepared by stacking an Au—Ge layer and an Au layer successively from the side closer to the n-type GaAs substrate **1** is formed on the back surface of the n-type GaAs substrate **1**, similarly to the second embodiment. Thus, the semiconductor laser device according to the third embodiment is formed.

[0125] The semiconductor laser device according to the third embodiment is formed with a window structure (not shown) disordering an MQW active layer in the vicinity of cavity facets, similarly to the first embodiment. Further, the current blocking layers **9a** are formed on the upper surface of the ridge portion **12** in the vicinity of the cavity facets constituting the aforementioned window structure thereby forming non-injection structure, similarly to the first embodiment.

[0126] A process of fabricating the semiconductor laser device according to the third embodiment is now described. First, the layers up to the current blocking layers **9a** are formed through steps similar to those of the second embodiment shown in FIGS. **10** and **11**, and a mask of a central  $SiO_2$  layer **15a** (see FIG. **11**) is removed from the ridge portion **12**.



Thereafter heat treatment is performed in a nitrogen atmosphere at 520° C. for 10 minutes, thereby converting the p-type first and second cladding layers **5** and **6** and the intermediate layers **7** to the p types.

[0127] Thereafter the first p-side electrode **31** consisting of the Au—Zn/Au layer, having the thickness of about 1  $\mu\text{m}$ , prepared by successively stacking the Au—Zn layer and the Au layer is formed on the upper surfaces of the ridge portion **12** and the current blocking layers **9a** by vacuum evaporation or the like to cover the exposed upper surface of the ridge portion **12**, and thereafter patterned to remain only in the vicinity of the ridge portion **12**. Further, the second p-side electrode **32** consisting of the Cr/Au layer, having the total thickness of about 5  $\mu\text{m}$ , prepared by forming the Cr layer and the Au layer successively from the side closer to the p-type first cladding layer **5** is formed on the upper surfaces of the current blocking layers **9a**, the upper surface and both side surfaces of the first p-side electrode **31** and the upper surfaces and both side surfaces of the dummy ridge portions **13a** to cover the first p-side electrode **31**.

[0128] Similarly to the second embodiment, the back surface of the n-type GaAs substrate **1** is etched for thereafter forming the n-side electrode **11** on this back surface. Thereafter heat treatment is performed in  $\text{H}_2/\text{N}_2$  ambient at 430° C. for 5 minutes, thereby attaining ohmic contact between the first and second p-side electrodes **31** and **32** and the n-side electrode **11**. The semiconductor laser device according to the third embodiment of the present invention is formed in the aforementioned manner.

[0129] According to the third embodiment, the first p-side electrode **31** contains Zn of the same conductivity type as the contact layers **8**, whereby contact resistance between the first p-side electrode **31** and the contact layers **8** is so reduced that excellent ohmic contact can be attained. Thus, the semiconductor laser device can be further inhibited from heat generation in operation. Further, the p-side electrode **32** having high adhesiveness is formed to cover the first p-side electrode **31** and the current blocking layers **9a** having small adhesiveness to the contact layers **8**, whereby the first p-side electrode **31** can be inhibited from separation. Thus, the semiconductor laser device can be improved in reliability.

#### Fourth Embodiment

[0130] Referring to FIG. **18**, a semiconductor laser device according to a fourth embodiment of the present invention has a one-layer first p-side electrode in a structure similar to that of the aforementioned semiconductor laser device according to the second embodiment. The remaining structure of the fourth embodiment is similar to that of the aforementioned second embodiment.

[0131] The structure of the semiconductor laser device according to the fourth embodiment is described with reference to FIG. **18**. In the semiconductor laser device according to the fourth embodiment, an n-type buffer layer **2**, an n-type cladding layer **3**, an emission layer **4** and a p-type first cladding layer **5** are successively formed on an n-type GaAs substrate **1**, similarly to the semiconductor laser device according to the second embodiment shown in FIG. **9**. A mesa (trapezoidal) ridge portion **12** and dummy ridge portions **13a** constituted of p-type second cladding layers **6**, intermediate layers **7** and contact layers **8** respectively are formed on the upper surface of the p-type first cladding layer **5**.

[0132] According to the fourth embodiment, the dummy ridge portions **13a** are formed slightly inward beyond end portions of the n-type GaAs substrate **1**, similarly to the second embodiment. Thus, regions partially exposing the upper surface of the p-type first cladding layer **5** are formed between the dummy ridge portions **13a** and the end portions of the n-type GaAs substrate **1**. Current blocking layers **9a** prepared by stacking n-type AlInP layers, doped with Se, having a thickness of about 0.5  $\mu\text{m}$  and n-type GaAs layers having a thickness of about 0.3  $\mu\text{m}$  are formed to cover the upper surface of the p-type first cladding layer **5**, both side surfaces of the ridge portion **12** and the upper surfaces and both side surfaces of the dummy ridge portions **13a**. The layers **2** to **8** of the semiconductor device according to the fourth embodiment are similar in composition and thickness to the layers **2** to **8** of the semiconductor laser device according to the second embodiment respectively.

[0133] According to the fourth embodiment, a first p-side electrode **40** consisting of a Cr/Au layer, having a total thickness of about 3  $\mu\text{m}$ , prepared by stacking a Cr layer and an Au layer successively from the side closer to the p-type first cladding layer **5** is formed to cover the exposed upper surface of the ridge portion **12** and the upper surfaces of the current blocking layers **9a**. The first p-side electrode **40** is formed in an irregular shape reflecting the shapes of the ridge portion **12**, the dummy ridge portions **13a** and the current blocking layers **9a**. Therefore, the height of portions **40b** of the first p-side electrode **40** located on the dummy ridge portions **13a** exceeds that of a portion **40a** located on the ridge portion **12** by the thickness (=d) of the current blocking layers **9a**. The first p-side electrode **40** is an example of the “first metal electrode” in the present invention.

[0134] An n-side electrode **11** consisting of an Au—Ge/Au layer prepared by stacking an Au—Ge layer and an Au layer successively from the side closer to the n-type GaAs substrate **1** is formed on the back surface of the n-type GaAs substrate **1**, similarly to the second embodiment. Thus, the semiconductor laser device according to the fourth embodiment is formed.

[0135] The semiconductor laser device according to the fourth embodiment is fabricated through a process similar to that for fabricating the aforementioned semiconductor laser device according to the second embodiment except a step of fabricating the first p-side electrode **40**. The first p-side electrode **40** consisting of the Cr/Au layer, having the total thickness of about 3  $\mu\text{m}$ , prepared by stacking the Cr layer and the Au layer successively from the side closer to the p-type first cladding layer **5** is formed by vacuum evaporation or the like to cover the exposed upper surface of the ridge portion **12** and the upper surfaces of the current blocking layers **9a**. In this case, the first p-side electrode **40** is formed in the irregular shape reflecting the shapes of the ridge portion **12**, the dummy ridge portions **13a** and the current blocking layers **9a**, whereby the height of the portions **40b** of the first p-side electrode **40** located on the dummy ridge portions **13a** exceeds that of the portion **40a** located on the ridge portion **12** by the thickness (=d) of the current blocking layers **9a**.

[0136] Referring to FIGS. **19** and **20**, the semiconductor laser device according to the fourth embodiment is mounted on a metal film (electrode) **152** of a submount **151** through



a welding material **153** of a low melting point metal such as solder while directing a projecting portion of the first p-side electrode **40** formed on the front surface of the semiconductor laser device downward. The height of the portions **40b** of the first p-side electrode **40** located on the dummy ridge portions **13a** exceeds that of the portion **40a** located on the ridge portion **12** by the thickness ( $=d$ ) of the current blocking layers **9a**, and hence a prescribed gap ( $=d$ ) is defined between the submount **151** and the portion **40a** of the first p-side electrode **40** formed on the ridge portion **12** when the aforementioned semiconductor laser device according to the fourth embodiment is mounted on the submount **151** in a junction-down system. Thus, stress applied to the ridge portion **12** can be reduced.

[0137] According to the fourth embodiment, the current blocking layers **9a** are formed on the upper surfaces and both side surfaces of the dummy ridge portions **13a** similarly to the aforementioned second embodiment so that no current flows to the dummy ridge portions **13a** also when the welding material **153** of solder or the like for mounting the semiconductor laser device on the submount **151** in the junction-down system adheres to the side surfaces of the dummy ridge portions **13a**. Thus, the current fed to the semiconductor laser device flows only to the ridge portion **12**, whereby the semiconductor laser device can attain high quantum efficiency.

[0138] According to the fourth embodiment, further, the dummy ridge portions **13a** are formed slightly inward beyond the end portions of the n-type GaAs substrate **1** similarly to the aforementioned second embodiment so that not the dummy ridge portions **13a** but the current blocking layers **9a** having upper surfaces parallel to the n-type GaAs substrate **1** are formed on the end portions of the n-type GaAs substrate **1**. Thus, the welding material **153** of solder for mounting the semiconductor laser device on the submount **151** hardly reaches the p-type first cladding layer **5**, the emission layer **4** and the n-type cladding layer **3** from the current blocking layers **9a** on the end portions of the n-type GaAs substrate **1**. Consequently, end portions of the p- and n-side semiconductor layers further hardly cause a short, whereby the reliability of the semiconductor laser device can be further improved.

[0139] The remaining effects of the fourth embodiment are similar to those of the aforementioned second embodiment.

#### Fifth Embodiment

[0140] Referring to FIG. 21, a semiconductor laser device according to a fifth embodiment of the present invention is provided with a plurality of (two) dummy ridge portions on each side of a ridge portion in a structure similar to that of the aforementioned semiconductor laser device according to the fourth embodiment.

[0141] The structure of the semiconductor laser device according to the fifth embodiment is described with reference to FIG. 21. In the semiconductor laser device according to the fifth embodiment, an n-type buffer layer **52**, an n-type cladding layer **53**, an emission layer **54** and a p-type first cladding layer **55** are successively formed on an n-type GaAs substrate **51**. A mesa (trapezoidal) ridge portion **62** having a width (lower end width) of about 2.5  $\mu\text{m}$  and mesa (trapezoidal) dummy ridge portions **63a** and **63b** having a width (lower end width) of about 30  $\mu\text{m}$  are formed on the

upper surface of the p-type first cladding layer **55**. The dummy ridge portions **63a** and **63b** are examples of the “support portion(s)” in the present invention. The ridge portion **62** and the dummy ridge portions **63a** and **63b** are constituted of p-type second cladding layers **56**, intermediate layers **57** and contact layers **58** respectively. According to the fifth embodiment, two dummy ridge portions **63a** and **63b** are formed on each side of the ridge portion **62**. The center distance between the ridge portion **62** and the inner dummy ridge portion **63a** closer to the ridge portion **62** is about 70  $\mu\text{m}$ , and that between the ridge portion **62** and the outer dummy ridge portion **63b** is about 120  $\mu\text{m}$ . The chip width (width of the n-type GaAs substrate **51** shown in FIG. 21) is about 300  $\mu\text{m}$ . The outer dummy ridge portion **63b** is formed slightly inward beyond an end portion of the n-type GaAs substrate **51**. Thus, a region partially exposing the upper surface of the p-type first cladding layer **55** is formed between the outer dummy ridge portion **63b** and the end portion of the n-type GaAs substrate **51**. Current blocking layers **59** prepared by stacking n-type AlInP layers, doped with Se, having a thickness of about 0.5  $\mu\text{m}$  and n-type GaAs layers having a thickness of about 0.3  $\mu\text{m}$  are formed to cover the upper surface of the p-type first cladding layer **55**, both side surfaces of the ridge portion **62** and the upper surfaces and both side surfaces of the dummy ridge portions **63a** and **63b**. The layers **52** to **58** of the semiconductor laser device according to the fifth embodiment are similar in composition and thickness to the layers **2** to **8** of the semiconductor laser device according to the first embodiment respectively.

[0142] According to the fifth embodiment, a first p-side electrode **60** consisting of a Cr/Au layer, having a total thickness of about 3  $\mu\text{m}$ , prepared by stacking a Cr layer and an Au layer successively from the side closer to the p-type first cladding layer **55** is formed to cover the exposed upper surface of the ridge portion **62** and the upper surfaces of the current blocking layers **59**. The first p-side electrode **60** is formed in an irregular shape reflecting the shapes of the ridge portion **62**, the dummy ridge portions **63a** and **63b** and the current blocking layers **59**. Therefore, the height of portions **60b** and **60c** of the first p-side electrode **60** located on the dummy ridge portions **63a** and **63b** exceeds that of a portion **60a** located on the ridge portion **62** by the thickness ( $=d$ ) of the current blocking layers **59**. The first p-side electrode **60** is an example of the “first metal electrode” in the present invention.

[0143] An n-side electrode **61** consisting of an Au—Ge/Au layer prepared by stacking an Au—Ge layer and an Au layer successively from the side closer to the n-type GaAs substrate **51** is formed on the back surface of the n-type GaAs substrate **51**. Thus, the semiconductor laser device according to the fifth embodiment is formed.

[0144] A process of fabricating the semiconductor laser device according to the fifth embodiment is described with reference to FIGS. 21 to 24. The n-type buffer layer **52**, the n-type cladding layer **53**, the emission layer **54**, the p-type first cladding layer **55**, the p-type second cladding layers **56**, the intermediate layers **57** and the contact layers **58** are successively formed on the n-type GaAs substrate **51** through a step similar to that of the first embodiment shown in FIG. 3. Thereafter SiO<sub>2</sub> layers **65** are formed on the contact layers **58** by photolithography and etching at prescribed intervals, as shown in FIG. 22. The SiO<sub>2</sub> layers **65**



are employed as masks for etching the p-type second cladding layers **56**, the intermediate layers **57** and the contact layers **58**, thereby forming the mesa (trapezoidal) ridge portion **62** and the mesa (trapezoidal) inner and outer dummy ridge portions **63a** and **63b**. At this time, the outer dummy ridge portions **63b** are formed slightly inward beyond the end portions of the n-type GaAs substrate **51**, thereby forming the regions partially exposing the upper surface of the p-type cladding layer **55** between the dummy ridge portions **63b** and the end portions of the n-type GaAs substrate **51**.

[0145] As shown in FIG. 23, the SiO<sub>2</sub> layers **65** formed on the dummy ridge portions **63a** and **63b** are removed while leaving only the SiO<sub>2</sub> layer **65** formed on the ridge portion **62**. The SiO<sub>2</sub> layer **65** left on the ridge portion **62** is employed as a mask for growing the current blocking layers **59** prepared by stacking the n-type AlInP layers, doped with Se, having the thickness of about 0.5 μm and the n-type GaAs layers having the thickness of about 0.3 μm to cover the upper surface of the p-type first cladding layer **55**, both side surfaces of the ridge portion **62** and the upper surfaces and both side surfaces of the dummy ridge portions **63a** and **63b**.

[0146] Then, the mask of the SiO<sub>2</sub> layer **65** left on the ridge portion **62** is removed. Thereafter heat treatment is performed in a nitrogen atmosphere at 520° C. for 10 minutes, thereby converting the p-type first cladding layer **55**, the p-type second cladding layers **56** and the intermediate layers **57** to the p types.

[0147] As shown in FIG. 24, the first p-side electrode **60** is formed by vacuum evaporation or the like to cover the exposed upper surface of the ridge portion **62** and the upper surfaces of the current blocking layers **59**. The first p-side electrode **60** is formed in the irregular shape reflecting the shapes of the ridge portion **62**, the dummy ridge portions **63a** and **63b** and the current blocking layers **59**. Therefore, the height of the portions **60b** and **60c** of the first p-side electrode **60** located on the dummy ridge portions **63a** and **63b** exceeds that of the portion **60a** located on the ridge portion **62** by the thickness (=d) of the current blocking layers **59**.

[0148] Thereafter the back surface of the n-type GaAs substrate **51** is etched for forming the n-side electrode **61** on this back surface, as shown in FIG. 21. Thereafter heat treatment is performed in H<sub>2</sub>/N<sub>2</sub> ambient at 430° C. for 5 minutes, thereby attaining ohmic contact between the first p-side electrode **60** and the n-side electrode **61**. The semiconductor laser device according to the fifth embodiment is formed in the aforementioned manner.

[0149] Referring to FIGS. 25 and 26, the semiconductor laser device according to the fifth embodiment is mounted on a metal film (electrode) **162** of a submount **161** through a welding material **163** of a low melting point metal such as solder while directing a projecting portion of the first p-side electrode **60** formed on the front surface of the semiconductor laser device downward. The height of the portions **60b** and **60c** of the first p-side electrode **60** located on the dummy ridge portions **63a** and **63b** exceeds that of the portion **60a** located on the ridge portion **62** by the thickness (=d) of the current blocking layers **59**, and hence a prescribed gap (=d) is defined between the submount **161** and the portion **60a** of the first p-side electrode **60** formed on the

ridge portion **62** when the aforementioned semiconductor laser device according to the fifth embodiment is mounted on the submount **161** in a junction-down system. Thus, stress applied to the ridge portion **62** can be reduced.

[0150] According to the fifth embodiment, as hereinabove described, the two dummy ridge portions **63a** and **63b** are provided on each side of the ridge portion **62** so that the contact area between the semiconductor laser device and the submount **161** is increased when the former is mounted on the latter in the junction-down system, whereby the semiconductor laser device can be more stably mounted.

[0151] According to the fifth embodiment, as hereinabove described, the current blocking layers **59** are formed on the upper surfaces and both side surfaces of the dummy ridge portions **63a** and **63b** so that no current flows to the dummy ridge portions **63a** and **63b** also when the welding material **163** of solder for mounting the semiconductor laser device on the submount **161** in the junction-down system as shown in FIGS. 25 and 26 adheres to the side surfaces of the dummy ridge portions **63a** and **63b**. Thus, the current fed to the semiconductor laser device flows only to the ridge portion **62**, whereby the semiconductor laser device can attain high quantum efficiency.

[0152] According to the fifth embodiment, further, the outer dummy ridge portions **63b** are formed slightly inward beyond the end portions of the n-type GaAs substrate **51** so that not the outer dummy ridge portions **63b** but the current blocking layers **59** having upper surfaces parallel to the n-type GaAs substrate **51** are formed on the end portions of the n-type GaAs substrate **51**. Thus, the welding material **163** of solder for mounting the semiconductor laser device on the submount **161** hardly reaches the p-type first cladding layer **55**, the emission layer **54** and the n-type cladding layer **53** from the current blocking layers **59** on the end portions of the n-type GaAs substrate **51**. Consequently, end portions of the p- and n-side semiconductor layers further hardly cause a short, whereby the reliability of the semiconductor laser device can be further improved.

#### Sixth Embodiment

[0153] Referring to FIG. 27, the present invention is applied to a semiconductor laser device (multi-beam laser) having two emission portions according to a sixth embodiment of the present invention.

[0154] The structure of the semiconductor laser device according to the sixth embodiment is described with reference to FIG. 27. The semiconductor laser device according to the sixth embodiment is provided with two emission portions **82a** and **82b**. More specifically, an n-type buffer layer **72** and an n-type cladding layer **73** are successively formed on an n-type GaAs substrate **71**. Two emission layers **74** are formed on the n-type cladding layer **73** on positions corresponding to the two emission portions **82a** and **82b** respectively. P-type first cladding layers **75** are formed on the emission layers **74** respectively. Mesa (trapezoidal) ridge portions **83** having a width (lower end width) of about 2.5 μm and mesa (trapezoidal) dummy ridge portions **84** having a width (lower end width) of about 30 μm are formed on the upper surfaces of the emission layers **74** respectively. The dummy ridge portions **84** are examples of the "support portion(s)" in the present invention. The ridge portions **83** and the dummy ridge portions **84** are constituted of p-type



second cladding layers **76**, intermediate layers **77** and contact layers **78** respectively. The center distance between the ridge portions **83** and the dummy ridge portions **84** is about 60  $\mu\text{m}$ . The overall chip width (width of the n-type GaAs substrate **71** shown in FIG. 27) is about 400  $\mu\text{m}$ , and the width of regions corresponding to the emission portions **82a** and **82b** is about 200  $\mu\text{m}$ . An element isolation trench **85** having a width of about 10  $\mu\text{m}$  to about 50  $\mu\text{m}$  is formed for isolating the emission portions **82a** and **82b** from each other.

[0155] According to the sixth embodiment, the dummy ridge portions **84** are formed slightly inward beyond end portions of the n-type GaAs substrate **71**. Thus, regions partially exposing the upper surface of the p-type first cladding layer **55** are formed between the dummy ridge portions **84** and the end portions of the n-type GaAs substrate **71**. Current blocking layers **79** prepared by stacking n-type AlInP layers, doped with Se, having a thickness of about 0.5  $\mu\text{m}$  and n-type GaAs layers having a thickness of about 0.3  $\mu\text{m}$  are formed to cover the upper surface of the p-type first cladding layer **55**, both side surfaces of the ridge portions **83** and the upper surfaces and both side surfaces of the dummy ridge portions **84**. The layers **72** to **78** of the semiconductor laser device according to the sixth embodiment are similar in composition and thickness to the layers **2** to **8** of the semiconductor laser device according to the first embodiment respectively.

[0156] According to the sixth embodiment, first p-side electrodes **80** consisting of Cr/Au layers, having a total thickness of about 3  $\mu\text{m}$ , prepared by stacking Cr layers and Au layers successively from the sides closer to the p-type first cladding layers **75** are formed to cover the exposed upper surfaces of the ridge portions **83** and the upper surfaces of the current blocking layers **79**. The first p-side electrodes **80** are formed in irregular shapes reflecting the shapes of the ridge portions **83**, the dummy ridge portions **84** and the current blocking layers **79**. Therefore, the height of portions **80b** of the first p-side electrodes **80** located on the dummy ridge portions **84** exceeds that of portions **80a** located on the ridge portions **83** by the thickness (=d) of the current blocking layers **79**. The first p-side electrodes **80** are examples of the “first metal electrode” in the present invention.

[0157] An n-side electrode **81** consisting of an Au—Ge/Au layer prepared by stacking an Au—Ge layer and an Au layer successively from the side closer to the n-type GaAs substrate **71** is formed on the back surface of the n-type GaAs substrate **71**. Thus, the semiconductor laser device according to the sixth embodiment is formed.

[0158] A process of fabricating the semiconductor laser device according to the sixth embodiment is described with reference to FIGS. 27 to 31. The n-type buffer layer **72**, the n-type cladding layer **73**, the emission layers **74**, the p-type first cladding layers **75**, the p-type second cladding layers **76**, the intermediate layers **77** and the contact layers **78** are successively formed on the n-type GaAs substrate **71** through a step similar to that of the first embodiment shown in FIG. 3. Thereafter SiO<sub>2</sub> layers **86** are formed on the contact layers **78** by photolithography and etching at prescribed intervals, as shown in FIG. 28. The SiO<sub>2</sub> layers **86** are employed as masks for etching the p-type second cladding layers **76**, the intermediate layers **77** and the contact layers **88**, thereby forming the mesa (trapezoidal) ridge

portions **83** and the pairs of dummy ridge portions **84** on the regions corresponding to the emission portions **82a** and **82b** respectively. At this time, the dummy ridge portions **84** are formed slightly inward beyond the end portions of the n-type GaAs substrate **71**, thereby forming the regions partially exposing the upper surfaces of the p-type cladding layers **75** between the dummy ridge portions **84** and the end portions of the n-type GaAs substrate **71**.

[0159] As shown in FIG. 29, the SiO<sub>2</sub> layers **86** formed on the dummy ridge portions **84** are removed while leaving only the SiO<sub>2</sub> layers **86** formed on the ridge portions **83**. The SiO<sub>2</sub> layers **86** left on the ridge portions **83** are employed as masks for growing the current blocking layers **79** prepared by stacking the n-type AlInP layers, doped with Se, having the thickness of about 0.5  $\mu\text{m}$  and the n-type GaAs layers having the thickness of about 0.3  $\mu\text{m}$  to cover the upper surfaces of the p-type first cladding layers **75**, both side surfaces of the ridge portions **83** and the upper surfaces and both side surfaces of the dummy ridge portions **84**.

[0160] Then, the masks of the SiO<sub>2</sub> layers **86** left on the ridge portions **83** are removed. Thereafter heat treatment is performed in a nitrogen atmosphere at 520° C. for 10 minutes, thereby converting the p-type first cladding layers **75**, the p-type second cladding layers **76** and the intermediate layers **77** to the p types.

[0161] As shown in FIG. 30, the first p-side electrodes **80** are formed by vacuum evaporation or the like to cover the exposed upper surfaces of the ridge portions **83** and the upper surfaces of the current blocking layers **79**. The first p-side electrodes **80** are formed in the irregular shapes reflecting the shapes of the ridge portions **83**, the dummy ridge portions **84** and the current blocking layers **79**, whereby the height of the portions **80b** of the first p-side electrodes **80** located on the dummy ridge portions **84** exceeds that of the portions **80a** located on the ridge portions **83** by the thickness (=d) of the current blocking layers **79**.

[0162] Thereafter the back surface of the n-type GaAs substrate **71** is etched for forming the n-side electrode **81** on this back surface, as shown in FIG. 31. Thereafter heat treatment is performed in H<sub>2</sub>/N<sub>2</sub> ambient at 430° C. for 5 minutes, thereby attaining ohmic contact between the first p-side electrodes **80** and the n-side electrode **81**.

[0163] Thereafter the current blocking layer **79**, the p-type first cladding layers **75** and the emission layers **74** are etched by photolithography and etching thereby forming the element isolation trench **85** having the width of about 10  $\mu\text{m}$  to about 50  $\mu\text{m}$ , as shown in FIG. 27. The semiconductor laser device according to the sixth embodiment having the two emission portions **82a** and **82b** is formed in the aforementioned manner.

[0164] Referring to FIGS. 32 and 33, the semiconductor laser device according to the sixth embodiment is mounted on metal films (electrodes) **162a** and **162b** of a submount **161** through welding materials **163a** and **163b** of a low melting point metal such as solder while directing projecting portions of the first p-side electrodes **80** formed on the front surface of the semiconductor laser device downward. The height of the portions **80b** of the first p-side electrodes **80** located on the dummy ridge portions **84** exceeds that of the portions **80a** located on the ridge portions **83** by the thickness (=d) of the current blocking layers **79**, and hence



prescribed gaps (=d) are defined between the submount **161** and the portions **80a** of the first p-side electrodes **80** located on the ridge portions **83** when the aforementioned semiconductor laser device according to the sixth embodiment is mounted on the submount **161** in a junction-down system. Thus, stress applied to the ridge portions **83** can be reduced.

[0165] According to the sixth embodiment, as hereinabove described, the current blocking layers **79** are formed on the upper surfaces and both side surfaces of the dummy ridge portions **84** so that no current flows to the dummy ridge portions **84** also when the welding materials **163a** and **163b** of solder for mounting the semiconductor laser device on the submount **161** in the junction-down system adhere to the side surfaces of the dummy ridge portions **84**. Thus, the current fed to the semiconductor laser device flows only to the ridge portions **83**, whereby the semiconductor laser device (multi-beam laser) having the two emission portions **82a** and **82b** can attain high quantum efficiency.

[0166] According to the sixth embodiment, further, the dummy ridge portions **84** are formed slightly inward beyond the end portions of the n-type GaAs substrate **71** so that not the dummy ridge portions **84** but the current blocking layers **79** having upper surfaces parallel to the n-type GaAs substrate **71** are formed on the end portions of the n-type GaAs substrate **71**. Thus, the welding materials **163a** and **163b** of solder for mounting the semiconductor laser device on the submount **161** hardly reach the p-type first cladding layers **75**, the emission layers **74** and the n-type cladding layers **73** from the current blocking layers **79** on the end portions of the n-type GaAs substrate **71**. Consequently, end portions of the p- and n-side semiconductor layers further hardly cause a short, whereby the reliability of the semiconductor laser device can be further improved.

#### Seventh Embodiment

[0167] Referring to FIG. 34, a ridge portion and dummy ridge portions have perpendicular side surfaces in a semiconductor laser device according to a seventh embodiment of the present invention, dissimilarly to the aforementioned first to sixth embodiments.

[0168] The structure of the semiconductor laser device according to the seventh embodiment is described with reference to FIG. 34. In the semiconductor laser device according to the seventh embodiment, an n-type buffer layer **2**, an n-type cladding layer **3**, an emission layer **4** and a p-type first cladding layer **5** are successively formed on an n-type GaAs substrate **1**, similarly to the first embodiment. Further, a ridge portion **92** having a width (lower end width) of about 2.5  $\mu\text{m}$  and dummy ridge portions **93** having a width (lower end width) of about 50  $\mu\text{m}$  are formed on the upper surface of the p-type first cladding layer **5**. The dummy ridge portions **93** are examples of the “support portion(s)” in the present invention. The ridge portion **92** and the dummy ridge portions **93** are constituted of p-type second cladding layers **6**, intermediate layers **7** and contact layers **8** respectively.

[0169] According to the seventh embodiment, the ridge portion **92** and the dummy ridge portions **93** are formed to have perpendicular side surfaces. The center distance between the ridge portion **92** and the dummy ridge portions **93** is about 100  $\mu\text{m}$ . The chip width (width of the n-type GaAs substrate **1** shown in FIG. 34) is about 300  $\mu\text{m}$ . The

dummy ridge portions **93** are formed slightly inward beyond end portions of the n-type GaAs substrate **1**. Thus, regions partially exposing the upper surface of the p-type first cladding layer **5** are formed between the dummy ridge portions **93** and the end portions of the n-type GaAs substrate **1**. Current blocking layers **89** prepared by stacking n-type AlInP layers, doped with Se, having a thickness of about 0.5  $\mu\text{m}$  and n-type GaAs layers having a thickness of about 0.3  $\mu\text{m}$  are formed to cover the upper surface of the p-type first cladding layer **5**, both side surfaces of the ridge portion **92** and the upper surfaces and both side surfaces of the dummy ridge portions **93**. The layers **2** to **8** in the semiconductor laser device according to the seventh embodiment are similar in composition and thickness to the layers **2** to **8** of the semiconductor laser device according to the first embodiment respectively.

[0170] According to the seventh embodiment, a first p-side electrode **90** consisting of a Cr/Au layer, having a total thickness of about 3  $\mu\text{m}$ , prepared by stacking a Cr layer and an Au layer successively from the side closer to the p-type first cladding layer **5** is formed to cover the exposed upper surface of the ridge portion **92** and the upper surfaces of the current blocking layers **89**. The first p-side electrode **90** is formed in an irregular shape reflecting the shapes of the ridge portion **92**, the dummy ridge portions **83** and the current blocking layers **89**. Therefore, the height of portions **90b** of the first p-side electrode **90** located on the dummy ridge portions **93** exceeds that of a portion **90a** located on the ridge portion **92** by the thickness (=d) of the current blocking layers **89**. The first p-side electrode **90** is an example of the “first metal electrode” in the present invention.

[0171] An n-side electrode **11** consisting of an Au—Ge/Au layer prepared by stacking an Au—Ge layer and an Au layer successively from the side closer to the n-type GaAs substrate **1** is formed on the back surface of the n-type GaAs substrate **1**. Thus, the semiconductor laser device according to the seventh embodiment is formed.

[0172] A process of fabricating the semiconductor laser device according to the seventh embodiment is described with reference to FIGS. 34 to 37. First, the n-type buffer layer **2**, the n-type cladding layer **3**, the emission layer **4**, the p-type first cladding layer **5**, the p-type second cladding layers **6**, the intermediate layers **7** and the contact layers **8** are successively formed on the n-type GaAs substrate **1** through a step similar to that of the first embodiment shown in FIG. 3. As shown in FIG. 35, SiO<sub>2</sub> layers **95** are formed on the contact layers **8** by photolithography and etching at prescribed intervals. The SiO<sub>2</sub> layers **95** are employed as masks for etching the p-type second cladding layers **6**, the intermediate layers **7** and the contact layers **8** thereby forming the ridge portion **92** and the dummy ridge portions **93** having the perpendicular side surfaces respectively. The ridge portion **92** and the dummy ridge portions **93** having the perpendicular side surfaces can be easily formed by adjusting etching conditions. At this time, the dummy ridge portions **93** are formed slightly inward beyond the end portions of the n-type GaAs substrate **1**, thereby forming the regions partially exposing the upper surface of the p-type first cladding layer **5** between the dummy ridge portions **93** and the end portions of the n-type GaAs substrate **1**.

[0173] As shown in FIG. 36, the SiO<sub>2</sub> layers **95** are removed from the dummy ridge portions **93** while leaving



only the central SiO<sub>2</sub> layer **95** on the ridge portion **92**. The SiO<sub>2</sub> layer **95** left on the ridge portion **92** is employed as a mask for growing the current blocking layers **89** prepared by stacking the n-type AlInP layers, doped with Se, having the thickness of about 0.5  $\mu\text{m}$  and the n-type GaAs layers having the thickness of about 0.3  $\mu\text{m}$  to cover the upper surface of the p-type first cladding layer **5**, both side surfaces of the ridge portion **92** and the upper surfaces and both side surfaces of the dummy ridge portions **93**.

[0174] Then, the mask of the SiO<sub>2</sub> layer **95** left on the ridge portion **92** is removed. Thereafter heat treatment is performed in a nitrogen atmosphere at 520° C. for 10 minutes, thereby converting the p-type first and second cladding layers **5** and **6** and the intermediate layers **7** to the p types.

[0175] As shown in FIG. 37, the first p-side electrode **90** is formed by vacuum evaporation or the like to cover the exposed upper surface of the ridge portion **92** and the upper surfaces of the current blocking layers **89**. The first p-side electrode **90** is formed in the irregular shape reflecting the shapes of the ridge portion **92**, the dummy ridge portions **83** and the current blocking layers **89**. Therefore, the height of the portions **90b** of the first p-side electrode **90** located on the dummy ridge portions **93** exceeds that of the portion **90a** located on the ridge portion **92** by the thickness (=d) of the current blocking layers **89**. The first p-side electrode **90** is formed to have perpendicular side surfaces reflecting the perpendicular side surfaces of the ridge portion **92** and the dummy ridge portions **93**.

[0176] Thereafter the back surface of the n-type GaAs substrate **1** is etched for forming the n-side electrode **11** on this back surface as shown in FIG. 34. Thereafter heat treatment is performed in H<sub>2</sub>/N<sub>2</sub> ambient at 430° C. for 5 minutes, thereby attaining ohmic contact between the first p-side electrode **90** and the n-side electrode **11**. The semiconductor laser device according to the seventh embodiment of the present invention is formed in the aforementioned manner.

[0177] Referring to FIGS. 38 and 39, the semiconductor laser device according to the seventh embodiment is mounted on a metal film (electrode) **152** of a submount **151** through a welding material **153** of a low melting point metal such as solder while directing a projecting portion of the first p-side electrode **90** formed on the front surface of the semiconductor laser device downward. The height of the portions **90b** of the first p-side electrode **90** located on the dummy ridge portions **93** exceeds that of the portion **90a** located on the ridge portion **92** by the thickness (=d) of the current blocking layers **89**, and hence a prescribed gap (=d) is defined between the submount **151** and the portion **90a** of the first p-side electrode **90** located on the ridge portion **92** when the aforementioned semiconductor laser device according to the seventh embodiment is mounted on the submount **151** in a junction-down system. Thus, stress applied to the ridge portion **92** can be reduced.

[0178] According to the seventh embodiment, as hereinabove described, the dummy ridge portions **93** are formed to have the perpendicular side surfaces so that the first p-side electrode **90** also has the perpendicular side surfaces reflecting those of the dummy ridge portions **93**, whereby the welding material **153** of solder is easily collected between the perpendicular inner side surfaces of the dummy ridge

portions **93**. Thus, the welding material **153** of solder can be embedded between the perpendicular inner side surfaces of the dummy ridge portions **93** with excellent reproducibility, while the welding material **153** of solder can be prevented from extruding toward the end surfaces of the semiconductor laser device. Consequently, the semiconductor laser device can be further inhibited from a short resulting from the welding material **153** of solder reaching the end surfaces thereof.

[0179] According to the seventh embodiment, further, the dummy ridge portions **93** are formed slightly inward beyond the end portions of the n-type GaAs substrate **1** so that not the dummy ridge portions **93** but the current blocking layers **89** having upper surfaces parallel to the n-type GaAs substrate **1** are formed on the end portions of the n-type GaAs substrate **1**. Thus, the welding material **153** of solder for mounting the semiconductor laser device on the submount **151** hardly reaches the p-type first cladding layer **5**, the emission layer **4** and the n-type cladding layer **3** from the current blocking layers **89** on the end portions of the n-type GaAs substrate **1**. Consequently, end portions of the p- and n-side semiconductor layers further hardly cause a short, whereby the reliability of the semiconductor laser device can be further improved.

[0180] According to the seventh embodiment, as hereinabove described, the current blocking layers **89** are formed on the upper surfaces and both side surfaces of the dummy ridge portions **93** so that no current flows to the dummy ridge portions **93** also when the welding material **153** of solder for mounting the semiconductor laser device on the submount **151** in the Junction-down system adheres to the side surfaces of the dummy ridge portions **93**. Thus, the current fed to the semiconductor laser device flows only to the ridge portion **92**, whereby the semiconductor laser device can attain high quantum efficiency.

#### Eighth Embodiment

[0181] Referring to FIG. 40, the interval between the lower ends of a ridge portion and dummy ridge portions is set to at least about 20  $\mu\text{m}$  and not more than about 100  $\mu\text{m}$  in a semiconductor laser device according to an eighth embodiment of the present invention.

[0182] In the semiconductor laser device according to the eighth embodiment, a buffer layer **102** of n-type GaInP having a thickness of about 0.3  $\mu\text{m}$ , an n-type cladding layer **103** of n-type AlGaInP having a thickness of about 2  $\mu\text{m}$ , an MQW active layer (quantum well active layer) **104** of GaInP/AlGaInP and a p-type first cladding layer **105** of p-type AlGaInP having a thickness of about 0.3  $\mu\text{m}$  are successively formed on an n-type GaAs substrate **101**. A mesa (trapezoidal) ridge portion **112** and a pair of dummy ridge portions **113** are formed on the p-type first cladding layer **105**. The ridge portion **112** and the pair of dummy ridge portions **113** are constituted of p-type second cladding layers **106** of p-type AlGaInP having a thickness of about 1.2  $\mu\text{m}$ , intermediate layers **107** of p-type GaInP having a thickness of about 0.1  $\mu\text{m}$  and contact layers **108** of p-type GaAs having a thickness of about 0.3  $\mu\text{m}$  respectively. The dummy ridge portions **113** are examples of the "support portion(s)" in the present invention.



[0183] According to the eighth embodiment, the interval between the lower ends of the ridge portion 112 and the dummy ridge portions 113 is set to at least about 20  $\mu\text{m}$  and not more than about 100  $\mu\text{m}$ .

[0184] Current blocking layers 109 of n-type AlInP having a thickness of about 0.3  $\mu\text{m}$  are formed to cover both side surfaces of the ridge portion 112, the upper surface of the p-type first cladding layer 105 and both side surfaces and the upper surfaces of the dummy ridge portions 113. A p-side ohmic electrode 110 is formed on the ridge portion 112 (contact layer 108) and prescribed regions of the current blocking layers 109. An n-side ohmic electrode 111 is formed on the back surface of the n-type GaAs substrate 101. The aforementioned p-side ohmic electrode 110 is preferably prepared from a material having high thermal conductivity and excellent heat dissipativity such as Au (gold) having thermal conductivity of 315 W/m·K (27° C.). This p-side ohmic electrode 110 is an example of the “first metal electrode” in the present invention.

[0185] In the semiconductor laser device according to the eighth embodiment having the aforementioned structure, a voltage is applied to the p- and n-side ohmic electrodes 110 and 111 thereby injecting electrons and holes into the MQW active layer 104 from the n-type cladding layer 103 and the p-type first cladding layer 105 respectively. Consequently, the MQW active layer 104 emits a red laser beam.

[0186] A process of fabricating the semiconductor laser device according to the eighth embodiment is described with reference to FIGS. 40 to 46.

[0187] As shown in FIG. 41, the buffer layer 102 of n-type GaInP having the thickness of about 0.3  $\mu\text{m}$ , the n-type cladding layer 103 of n-type AlGaInP having the thickness of about 2  $\mu\text{m}$ , the MQW active layer (quantum well active layer) 104 of GaInP/AlGaInP, the p-type first cladding layer 105 of p-type AlGaInP having the thickness of about 0.3  $\mu\text{m}$ , the p-type second cladding layers 106 of p-type AlGaInP having the thickness of about 1.2  $\mu\text{m}$ , the intermediate layers 107 of p-type GaInP having the thickness of about 0.1  $\mu\text{m}$  and the contact layers 108 of p-type GaAs having the thickness of about 0.3  $\mu\text{m}$  are successively grown on the n-type GaAs substrate 101 by MOVPE (metal organic vapor phase epitaxy).

[0188] As shown in FIG. 42, the SiO<sub>2</sub> layers 114 having the thickness of about 0.2  $\mu\text{m}$  are formed on the contact layer 108 by sputtering, vacuum evaporation or electron beam evaporation, thereafter patterning the SiO<sub>2</sub> layers 114 by photolithography and etching. The SiO<sub>2</sub> layers 114 are etched with buffered hydrofluoric acid. These SiO<sub>2</sub> layers 114 are examples of the “mask consisting of a dielectric substance” in the present invention.

[0189] As shown in FIG. 43, the SiO<sub>2</sub> layers 114 are employed as masks for etching the p-type second cladding layers 106, the intermediate layers 107 and the contact layers 108 thereby forming the striped (elongated) ridge and dummy ridge portions 112 and 113. This etching step is carried out by wet-etching prescribed regions of the contact layers 108, the intermediate layers 107 and the p-type second cladding layers 106 with a tartaric acid-based or phosphoric acid-based etching solution. In this case, the etching depth is about 1.3  $\mu\text{m}$ , for example. Thus, the striped dummy ridge portions 113 are parallelly formed on both sides of the striped ridge portion 112 at a prescribed interval.

[0190] As shown in FIG. 44, the SiO<sub>2</sub> layers 114 formed on the dummy ridge portions 113 are removed by photolithography and etching with buffered hydrofluoric acid.

[0191] As shown in FIG. 45, the SiO<sub>2</sub> layer 114 left on the ridge portion 112 is employed as a selective growth mask for crystal-growing the current blocking layers 109 of n-type AlInP on the upper surface of the p-type first cladding layer 105, the upper surfaces and both side surfaces of the dummy ridge portions 113 and both side surfaces of the ridge portion 112 by MOVPE with the thickness of about 0.3  $\mu\text{m}$ . As to the crystal growth conditions for the current blocking layers 109, the growth temperature is preferably at least about 600° C. and not more than about 700° C., and the growth pressure is preferably at least about 50 Torr and not more than about 100 Torr. The SiO<sub>2</sub> layer 114 left on the ridge portion 112 is thereafter removed by etching.

[0192] Finally, the p-side ohmic electrode 110 is formed on the ridge portion 112 (contact layer 108) and the prescribed regions of the current blocking layers 109 by sputtering, vacuum evaporation or electron beam evaporation, as shown in FIG. 46. The back surface of the n-type GaAs substrate 101 is so etched as to reduce the thickness between the back surface of the n-type GaAs substrate 101 and the upper surface of the p-side ohmic electrode 110 to about 100  $\mu\text{m}$ . Further, the n-side ohmic electrode 111 is formed on the back surface of the n-type GaAs substrate 101 by sputtering, vacuum evaporation or electron beam evaporation. The semiconductor laser device according to the eighth embodiment is formed in the aforementioned manner.

[0193] The aforementioned SiO<sub>2</sub> layers 114 formed on the contact layer 108 are patterned in response to the shapes of the ridge portion 112 and the dummy ridge portions 113 set as described below.

[0194] The shapes of the ridge portion 112 and the dummy ridge portions 113 are now described. In the following description, the widths of the lower ends of the ridge portion 112 and the dummy ridge portions 113 are defined as a ridge width WR and a dummy ridge width WS respectively, as shown in FIG. 43. The width of the semiconductor laser device (chip: the width of the n-type GaAs substrate 101) is defined as a chip width L. Further, the interval between the ridge portion 112 and the dummy ridge portion 113 provided on each side thereof, i.e., the interval between the lower ends of the ridge portion 112 and each dummy ridge portion 113 is defined as a ridge interval WB. Indentations of the p-side ohmic electrode 110 defined between the ridge portion 112 and the dummy ridge portions 113 are defined as electrode trenches G.

[0195] According to the eighth embodiment, the ridge width WR, the dummy ridge width WS, the ridge interval WB and the chip width L shown in FIG. 43 are set to satisfy the following expression:

$$L \geq 2WS + WR + 2WB \quad (1)$$

[0196] For example, the chip width L, the dummy ridge width WS, the ridge width WR and the ridge interval WB are set to 300  $\mu\text{m}$ , 50  $\mu\text{m}$ , 2.5  $\mu\text{m}$  and 50  $\mu\text{m}$  respectively. In this case, the right-hand side of the above expression (1) is 202.5  $\mu\text{m}$ , to satisfy the condition.

[0197] The aforementioned ridge interval WB is preferably set to at least 20  $\mu\text{m}$  and not more than 100  $\mu\text{m}$ . The



ridge interval WB is preferably at least 20  $\mu\text{m}$  for a reason based on a graph shown in FIG. 47 obtained by the following experiment:

[0198] The inventor has noted that the current blocking layers 109 of n-type AlInP are grown to extend on the  $\text{SiO}_2$  layers 114 or polycrystalline-grown on the  $\text{SiO}_2$  layers 114 to vary the operating voltage of the semiconductor laser device, and made the following experiment:

[0199] First, a plurality of semiconductor laser devices were prepared through the aforementioned fabrication process according to the eighth embodiment while varying the ridge interval WB (see FIG. 43). The ridge intervals WB of the plurality of semiconductor laser devices were set at pitches of 5  $\mu\text{m}$  in the range of 5  $\mu\text{m}$  to 50  $\mu\text{m}$ . In each of the plurality of semiconductor laser devices prepared in the aforementioned manner, the chip width L, the dummy ridge width WS and the ridge width WR were 300  $\mu\text{m}$ , 50  $\mu\text{m}$  and 2.5  $\mu\text{m}$  respectively. The operating voltages of the plurality of semiconductor laser devices were measured while feeding a current of 40 mA thereto.

[0200] FIG. 47 shows influence exerted by the ridge intervals WB on the operating voltages of the semiconductor laser devices. Referring to FIG. 47, the operating voltages of the semiconductor laser devices were abruptly reduced as the ridge intervals WB were increased from 5  $\mu\text{m}$  to 20  $\mu\text{m}$ . In other words, resistance values of the semiconductor laser devices were reduced as the ridge intervals WB were increased in the range of 5  $\mu\text{m}$  to 20  $\mu\text{m}$ . The operating voltages of the semiconductor laser devices stably remained substantially constant in the range of the ridge intervals WB of 20  $\mu\text{m}$  to 50  $\mu\text{m}$ , as shown by the broken line BL.

[0201] It is understood from the results of the aforementioned experiment that the selective growth property of the current blocking layers 109 of n-type AlInP with respect to the  $\text{SiO}_2$  layers 114 serving as the selective growth masks and the semiconductor layers located under the same is so reduced that polycrystalline films remarkably adhere to the  $\text{SiO}_2$  layers 114 to consequently increase the operating voltage if the ridge interval WB is not more than 20  $\mu\text{m}$ . When the ridge interval WB is set to at least 20  $\mu\text{m}$ , adhesion of polycrystalline-grown films to the current blocking layers 109 of n-type AlInP with respect to the contact layers 108 ( $\text{SiO}_2$  layers 114) is so suppressed as to inhibit increase of the resistance resulting from adhesion of polycrystalline-grown films to the contact layers 108 ( $\text{SiO}_2$  layers 114). Therefore, the ridge interval WB is preferably set to at least 20  $\mu\text{m}$ .

[0202] On the other hand, the ridge interval WB is preferably set to not more than 100  $\mu\text{m}$ , for the following reason:

[0203] When the semiconductor laser device according to the eighth embodiment is assembled in a junction-down system, the p-side ohmic electrode 110 is mounted onto a submount (not shown) or a heat sink (not shown) through a welding material of solder or the like.

[0204] In the semiconductor laser device according to the eighth embodiment, the electrode trenches G are formed on the p-side ohmic electrode 110, as shown in FIG. 46. If the ridge interval WB exceeds 100  $\mu\text{m}$ , therefore, solder may not smoothly enter the electrode trenches G. In this case, spaces are defined between the p-side ohmic electrode 110 of the semiconductor laser device and the submount (not shown) or the heat sink (not shown) and heat generated from the

semiconductor laser device is not sufficiently dissipated to the submount or the heat sink. Therefore, the ridge interval WB is preferably set to not more than 100  $\mu\text{m}$ .

[0205] As hereinabove described, the ridge interval WB is preferably set to at least 20  $\mu\text{m}$  and not more than 100  $\mu\text{m}$  in the semiconductor laser device according to the eighth embodiment.

[0206] According to the eighth embodiment, as hereinabove described, the ridge interval WB is so set to at least 20  $\mu\text{m}$  that the current blocking layers 109 of n-type AlInP containing an Al component are inhibited from extending onto and growing on or polycrystalline-growing on the  $\text{SiO}_2$  layers 114 in formation of the current blocking layers 109. Thus, the  $\text{SiO}_2$  layers 114 can be inhibited from adhesion of polycrystalline-grown films of the current blocking layers 109 consisting of n-type AlInP, whereby the resistance can be inhibited from increase resulting from adhesion of polycrystalline-grown films to the  $\text{SiO}_2$  layers 114. Consequently, the semiconductor laser device can be inhibited from a voltage buildup. Therefore, power consumption can be reduced in employment of the semiconductor laser device.

[0207] According to the eighth embodiment, further, the ridge interval WB is set in the range of at least 20  $\mu\text{m}$  and not more than 100  $\mu\text{m}$ , whereby the resistance can be inhibited from increase without complicating the structure of the semiconductor laser device.

[0208] According to the eighth embodiment, in addition, the ridge interval WB is set to not more than 100  $\mu\text{m}$  so that the welding material of solder can smoothly enter the electrode trenches G when the semiconductor laser device is assembled in the junction-down system, whereby the semiconductor laser device can be inhibited from defining spaces between the p-side ohmic electrode 110 and the submount (not shown) or the heat sink (not shown). Thus, the heat generated from the semiconductor laser device can be sufficiently dissipated to the submount or the heat sink, while the former can be stably and reliably mounted on the latter.

#### Ninth Embodiment

[0209] Referring to FIG. 48 a p-side ohmic electrode is formed while leaving  $\text{SiO}_2$  layers on dummy ridge portions in a semiconductor laser device according to a ninth embodiment of the present invention, dissimilarly to the aforementioned eighth embodiment. The remaining structure of the ninth embodiment is similar to that of the eighth embodiment.

[0210] In the semiconductor laser device according to the ninth embodiment, a buffer layer 102, an n-type cladding layer 103, an MQW active layer (quantum well active layer) 104 and a p-type first cladding layer 105 are successively formed on an n-type GaAs substrate 101, similarly to the aforementioned eighth embodiment. A mesa (trapezoidal) ridge portion 112 and a pair of dummy ridge portions 113 are formed on the p-type first cladding layer 105. The ridge portion 112 and the pair of dummy ridge portions 113 are constituted of p-type second cladding layers 106, intermediate layers 107 and contact layers 108 respectively, similarly to the aforementioned eighth embodiment. The layers 102 to 108 of the semiconductor laser device according to the ninth embodiment are similar in composition and thick-



ness to the layers **102** to **108** of the semiconductor laser device according to the eighth embodiment respectively.

[0211] According to the ninth embodiment, the interval between the lower ends of the ridge portion **112** and the dummy ridge portions **113** is set to at least about 20  $\mu\text{m}$  and not more than about 100  $\mu\text{m}$ , similarly to the aforementioned eighth embodiment. Further,  $\text{SiO}_2$  layers **114** are formed on the upper surfaces of the pair of dummy ridge portions **113**. Current blocking layers **109a** of n-type AlInP having a thickness of 0.3  $\mu\text{m}$  are formed to cover both side surfaces of the ridge portion **112**, the upper surface of the p-type first cladding layer **105** and both side surfaces of the dummy ridge portions **113**. A p-side ohmic electrode **120** is formed on the ridge portion **112** (contact layer **108**), the current blocking layers **109a** and the  $\text{SiO}_2$  layers **114**.

[0212] The aforementioned p-side ohmic electrode **120** is preferably prepared from a material having high thermal conductivity and excellent heat dissipativity such as Au (gold) having thermal conductivity of 315 W/m·K (27° C.). This p-side ohmic electrode **120** is an example of the “first metal electrode” in the present invention. An n-side ohmic electrode **111** is formed on the back surface of the n-type GaAs substrate **101**.

[0213] A method of fabricating the semiconductor laser device according to the ninth embodiment is described with reference to FIGS. 48 and 49.

[0214] First, the ridge portion **112** and the pair of dummy ridge portions **113** are formed through steps similar to those of the eighth embodiment shown in FIGS. 41 to 43.

[0215] According to the ninth embodiment, the current blocking layers **109a** of n-type AlInP are formed without removing the  $\text{SiO}_2$  layers **114** from the pair of dummy ridge portions **113**. In other words, the  $\text{SiO}_2$  layers **114** formed on the ridge portion **112** and the pair of dummy ridge portions **113** are employed as selective growth masks for crystal-growing the current blocking layers **109a** of n-type AlInP having the thickness of about 0.3  $\mu\text{m}$  on the upper surface of the p-type first cladding layer **105** and both side surfaces of the ridge portion **112** and the pair of dummy ridge portions **113** by MOVPE. As to the crystal growth conditions for the aforementioned current blocking layers **109a** of n-type AlInP, the growth temperature is preferably at least about 600° C. and not more than about 700° C., and the growth pressure is preferably at least 50 Torr and not more than about 100 Torr. Thereafter the  $\text{SiO}_2$  layer **114** formed on the ridge portion **112** is removed by etching.

[0216] Finally, the p-side ohmic electrode **120** is formed on the ridge portion **112** (contact layer **108**) and prescribed regions of the current blocking layers **109** by sputtering, vacuum evaporation or electron beam evaporation. The back surface of the n-type GaAs substrate **101** is etched for setting the thickness between the back surface of the n-type GaAs substrate **101** and the upper surface of the p-side ohmic electrode **110** to about 100  $\mu\text{m}$ . Further, the n-side ohmic electrode **111** is formed on the back surface of the n-type GaAs substrate **101** by sputtering, vacuum evaporation or electron beam evaporation. The semiconductor laser device according to the ninth embodiment is formed in the aforementioned manner.

[0217] According to the ninth embodiment, as hereinabove described, the ridge interval WB is so set to at least

20  $\mu\text{m}$  that the current blocking layers **109a** of n-type AlInP containing an Al component are inhibited from extending onto and growing on or polycrystalline-growing on the  $\text{SiO}_2$  layers **114** in formation of the current blocking layers **109a**. Thus, the  $\text{SiO}_2$  layer **114** formed on the ridge portion **112** can be inhibited from adhesion of polycrystalline-grown films of the current blocking layers **109a** consisting of n-type AlInP, whereby the resistance can be inhibited from increase resulting from adhesion of polycrystalline-grown films to the  $\text{SiO}_2$  layer **114** formed on the ridge portion **112**. Consequently, the semiconductor laser device can be inhibited from a voltage buildup. Therefore, power consumption can be reduced in employment of the semiconductor laser device.

[0218] According to the ninth embodiment, further, the ridge interval WB is set in the range of at least 20  $\mu\text{m}$  and not more than 100  $\mu\text{m}$ , whereby the resistance can be inhibited from increase without complicating the structure of the semiconductor laser device.

[0219] According to the ninth embodiment, in addition, the ridge interval WB is set to not more than 100  $\mu\text{m}$  so that a welding material of solder can smoothly enter electrode trenches G when the semiconductor laser device is assembled in a junction-down system, whereby the semiconductor laser device can be inhibited from defining spaces between the same and a submount (not shown) or a heat sink (not shown). Thus, heat generated from the semiconductor laser device can be sufficiently dissipated to the submount or the heat sink, while the former can be stably and reliably mounted on the latter.

[0220] Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

[0221] For example, while the semiconductor layers constituting the semiconductor laser device are made of AlGaInP in each of the aforementioned first to ninth embodiments, the present invention is not restricted to this but a group III-V compound semiconductor such as AlGaAs, AlGaInAs, GaInAsP or GaN may alternatively be employed.

[0222] While the first p-side electrode **31** is formed by the metal layer containing Zn in the aforementioned third embodiment, the present invention is not restricted to this but the first p-side electrode **31** may contain a dopant having the same conductivity type as the semiconductor layer constituting the ridge portion **12**. If the semiconductor layer constituting the ridge portion **12** is made of a group III-V compound semiconductor, the first p-side electrode **31** may contain at least one element selected from a group consisting of Cd, Be, Mg, Ca and Ba.

[0223] While the first p-side electrode **10** or **21** is formed by the Cr/Au layer prepared by stacking the Cr layer and the Au layer successively from the side closer to the p-type first cladding layer **5** and the second p-side electrode **22** is formed by the Pd/Au layer prepared by stacking the Pd layer and the Au layer successively from the side closer to the p-type first cladding layer **5** in each of the aforementioned first and second embodiments, the present invention is not restricted to this but another metal material such as a Ti/Pt/Au layer prepared by stacking a Ti layer, a Pt layer and



an Au layer successively from the side closer to the p-type first cladding layer **5** can also be employed for the p-side electrode **10**, **21** or **22**. Further, the metal electrode may have at least two layers.

[0224] While the current blocking layers **9**, **9a**, **59**, **79** or **89** are formed by multilayer films of the n-type AlInP layers doped with Se and the n-type GaAs layers in each of the aforementioned first to seventh embodiments, the present invention is not restricted to this but the current blocking layers **9**, **9a**, **59**, **79** or **89** may alternatively be formed by insulating layers of SiN or SiO<sub>2</sub>.

[0225] While the interval between the ridge portion **12** and each dummy ridge portion **13** or **13a** is about 50 μm in each of the aforementioned first to third embodiments, the present invention is not restricted to this but the dummy ridge portion **13** or **13a** may alternatively be arranged at an interval of at least about 20 μm from the ridge portion **12**. Thus, the SiO<sub>2</sub> films **15** or **15a** employed as the masks for forming the current blocking layers **9** or **9a** can be inhibited from growth of polycrystalline films, whereby the semiconductor laser device can be inhibited from increase of the resistance.

[0226] While the p-type second cladding layers **6**, **56**, **76** or **106** are removed by etching by the thickness (=d) for leaving the p-type first cladding layer(s) **5**, **55**, **75** or **105** in formation of the ridge portion(s) **12**, **62**, **83**, **92** or **112** and the dummy ridge portions **13**, **13a**, **63a** and **63b**, **84**, **93** or **113** in each of the aforementioned first to ninth embodiments, the present invention is not restricted to this but an etching stop layer of GaInP or the like may alternatively be provided between the p-type first cladding layer(s) **5**, **55**, **75** or **105** and the p-type second cladding layers **6**, **56**, **76** or **106**. Thus, etching controllability can be improved.

[0227] While the emission layer(s) **4**, **54** or **74** has the strain compensatory structure obtained by introducing compression strain into the well layers **4b** in each of the aforementioned first to seventh embodiments, the present invention is not restricted to this but the emission layer(s) **4**, **54** or **74** may alternatively have a strain compensatory structure obtained by introducing tensile strain into the well layers **4b**, or may have no strain.

[0228] The solder constituting the welding material(s) **153** or **163** employed for the present invention may be prepared from PbSn, AuSn, AgSn or SnAgCu.

**1-18.** (canceled)

**19.** A semiconductor laser device comprising:

an emission layer formed on a substrate;

a semiconductor layer formed on said emission layer while constituting a convex ridge portion;

a current blocking layer formed on a side of said ridge portion;

a first metal electrode formed to be in contact with the upper surface of said ridge portion; and

a second metal electrode, formed on said first metal electrode, superior in adhesiveness to said first metal electrode.

**20.** The semiconductor laser device according to claim 19, wherein

said second metal electrode is formed to be in contact with said current blocking layer.

**21.** The semiconductor laser device according to claim 19, wherein

said first metal electrode contains a dopant having the same conductivity type as said semiconductor layer constituting said ridge portion.

**22.** The semiconductor laser device according to claim 21, wherein

said semiconductor layer constituting said ridge portion consists of a group III-V compound semiconductor, and

said dopant, contained in said first metal electrode, having the same conductivity type as said semiconductor layer constituting said ridge portion includes at least one element selected from a group consisting of Zn, Cd, Be, Mg, Ca and Ba.

**23.** The semiconductor laser device according to claim 19, wherein

the sum of the thicknesses of said first metal electrode and said second metal electrode is at least 5 μm.

**24-26.** (canceled)

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