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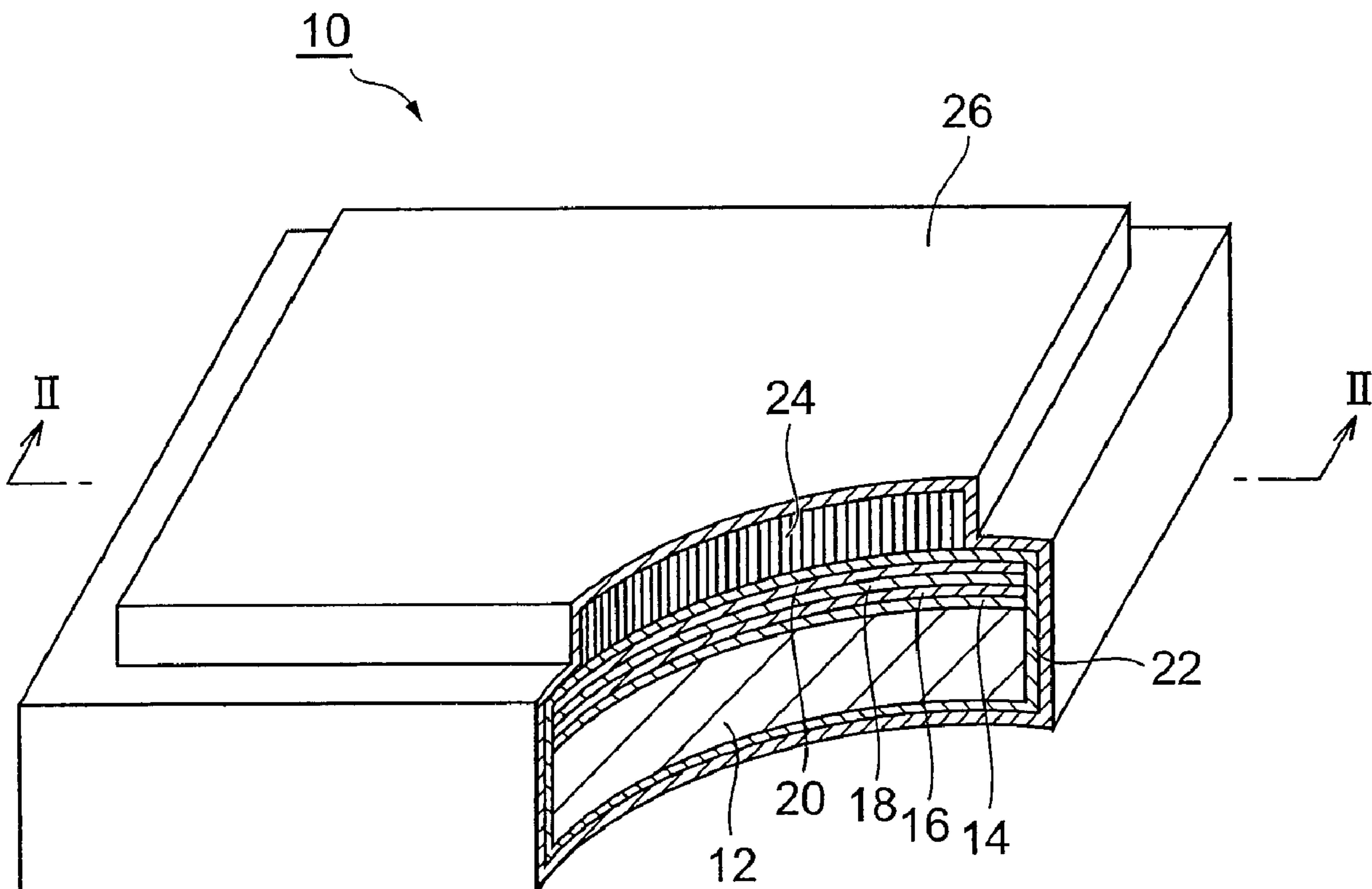
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(54) Title: RADIATION IMAGE CONVERSION PANEL, SCINTILLATOR PANEL, AND RADIATION IMAGE SENSOR



(57) Abrégé/Abstract:

The radiation image conversion panel in accordance with the present invention has an aluminum substrate; an aluminum oxide layer formed on a surface of the aluminum substrate; a metal film, provided on the aluminum oxide layer, having a radiation transparency and a light reflectivity; a protective film covering the metal film and having a radiation transparency and a light transparency; and a converting part provided on the protective film and adapted to convert a radiation image.

ABSTRACT OF THE DISCLOSURE

The radiation image conversion panel in accordance with the present invention has an aluminum substrate; an aluminum oxide layer formed on a surface of the aluminum substrate; a metal film, provided on the aluminum oxide layer, having a radiation transparency and a light reflectivity; a protective film covering the metal film and having a radiation transparency and a light transparency; and a converting part provided on the protective film and adapted to convert a radiation image.

TITLE OF THE INVENTION

Radiation Image Conversion Panel, Scintillator Panel, and Radiation Image Sensor

BACKGROUND OF THE INVENTION5 Field of the Invention

**[0001]** The present invention relates to a radiation image conversion panel, a scintillator panel, and a radiation image sensor which are used in medical and industrial x-ray imaging and the like.

Related Background Art

10 **[0002]** While x-ray sensitive films have conventionally been in use for medical and industrial x-ray imaging, radiation imaging systems using radiation detectors have been coming into widespread use from the viewpoint of their convenience and storability of imaging results. In such a radiation imaging system, pixel data formed by two-dimensional radiations are acquired by a radiation detector as an electric signal, which is then processed by a processor, so as to be displayed on a monitor.

15 **[0003]** Known as a typical radiation detector is one having a structure bonding a radiation image conversion panel (which will be referred to as "scintillator panel" in the following as the case may be), in which a scintillator for converting a radiation into visible light is formed on a substrate such as aluminum, glass, or fused silica, to an image pickup device. In this radiation detector, a radiation incident thereon from the substrate side is converted into light by the scintillator, and thus obtained light is detected by the image pickup device.

25 **[0004]** In the radiation image conversion panels disclosed in

Japanese Patent Application Laid-Open Nos. 2006-113007 and HEI 4-118599, a stimulable phosphor is formed on an aluminum substrate having a surface formed with an aluminum oxide layer. The radiation image conversion panel having a stimulable phosphor formed on a substrate will be referred to as “imaging plate” in the following as the case may be.

#### SUMMARY OF THE INVENTION

**[0005]** In the above-mentioned radiation image conversion panel, however, the aluminum oxide layer has a low reflectance for the light emitted from a scintillator or a phosphor such as stimulable phosphor, whereby the radiation image conversion panel may fail to attain a sufficiently high luminance. Also, cracks, pinholes, and the like may be formed in the aluminum oxide layer by the heat generated when vapor-depositing the scintillator or stimulable phosphor onto the aluminum substrate, for example. As a result, the aluminum substrate and an alkali halide scintillator or stimulable phosphor may react with each other, thereby corroding the aluminum substrate. Though resistant against the corrosion, the aluminum oxide layer may corrode by reacting with the scintillator. The corrosion affects resulting images. Even if only a minute point is corroded, the reliability of a captured image utilized for an image analysis will deteriorate. The corrosion may increase as time passes. While the radiation image conversion panel is required to have uniform luminance and resolution characteristics within the substrate surface, the substrate is harder to manufacture as it is larger in size.

**[0006]** In view of the circumstances mentioned above, it is an

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object of some embodiments of the present invention to provide a radiation image conversion panel, a scintillator panel, and a radiation image sensor which can prevent aluminum substrates from corroding, while having a high luminance.

**[0007]** The radiation image conversion panel in accordance with some 5 embodiments of the present invention comprises an aluminum substrate; an aluminum oxide layer formed on a surface of the aluminum substrate; a metal film, provided on the aluminum oxide layer, having a radiation transparency and a light reflectivity; a protective film covering the metal film and having a radiation transparency and a light transparency; and a converting part provided on the 10 protective film and adapted to convert a radiation image.

**[0008]** In some embodiments, the scintillator panel comprises an aluminum substrate; an aluminum oxide layer formed on a surface of the aluminum substrate; a metal film, provided on the aluminum oxide layer, having a radiation transparency and a light reflectivity; a protective film covering the metal film and having a radiation transparency and a light transparency; and a scintillator 15 provided on the protective film.

**[0009]** In some embodiments, the radiation image sensor comprises a radiation image conversion panel including an aluminum substrate, an aluminum oxide layer formed on a surface of the aluminum substrate, a metal film which is 20 provided on the aluminum oxide layer and has a radiation transparency and a light reflectivity, a protective film covering the metal film and having a radiation transparency and a light transparency, and a converting part provided on the protective film and adapted to convert a radiation image; and an image pickup device for converting light emitted from the converting part of the radiation image 25 conversion panel into an electric signal.

According to an aspect of the present invention, there is provided a radiation image conversion panel comprising: an aluminum substrate; an aluminum oxide layer formed on a surface of the aluminum substrate; a metal film, provided on the aluminum oxide layer, having a light reflectivity, at least a portion 30 of the aluminum oxide layer being positioned between the aluminum substrate and the metal film; a protective film covering the metal film and having a light

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transparency, at least a portion of the metal film being positioned between the aluminum oxide layer and the protective film; a converting part provided on the protective film and adapted to convert a radiation image, the converting part comprising a light emitting surface of the radiation image conversion panel, and at 5 least a portion of the protective film being positioned between the metal film and the converting part; and an oxide layer covering, at least in part, the metal film and having a light transparency, the oxide layer comprising an  $\text{SiO}_2$  film and a  $\text{TiO}_2$  film.

According to another aspect of the present invention, there is 10 provided a scintillator panel comprising: an aluminum substrate comprising a radiation receiving surface of the scintillator panel; an aluminum oxide layer formed on a surface of the aluminum substrate other than the radiation receiving surface; a metal film, provided on the aluminum oxide layer, having a radiation transparency and a light reflectivity, at least a portion of the aluminum oxide layer 15 being positioned between the aluminum substrate and the metal film; a protective film covering the metal film and having a radiation transparency and a light transparency, at least a portion of the metal film being positioned between the aluminum oxide layer and the protective film; a scintillator provided on the protective film, the scintillator comprising a light emitting surface of the scintillator 20 panel, and at least a portion of the protective film being positioned between the metal film and the scintillator; and an oxide layer covering, at least in part, the metal film and having a radiation transparency and a light transparency, the oxide layer comprising an  $\text{SiO}_2$  film and a  $\text{TiO}_2$  film.

According to still another aspect of the present invention, there is 25 provided a radiation image sensor comprising: a radiation image conversion panel including an aluminum substrate; an aluminum oxide layer formed on a surface of the aluminum substrate; a metal film, provided on the aluminum oxide layer, having a light reflectivity, at least a portion of the aluminum oxide layer being positioned between the aluminum substrate and the metal film; a protective film 30 covering the metal film and having a light transparency, at least a portion of the metal film being positioned between the aluminum oxide layer and the protective film; a converting part provided on the protective film and adapted to convert a

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radiation image, the converting part comprising a light emitting surface of the radiation image conversion panel, and at least a portion of the protective film being positioned between the metal film and the converting part; and an oxide layer covering, at least in part, the metal film and having a light transparency, the  
5 oxide layer comprising an  $\text{SiO}_2$  film and a  $\text{TiO}_2$  film; and an image pickup device for converting light emitted from the light emitting surface of the converting part of the radiation image conversion panel into an electric signal.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Fig. 1 is a partly broken perspective view schematically showing a  
10 scintillator panel in accordance with a first embodiment;

Fig. 2 is a sectional view taken along the line II-II shown in Fig. 1;

Fig. 3 is a graph showing an example of AES spectrum of the aluminum oxide layer in the scintillator panel in accordance with the first embodiment;

15 Fig. 4 is a graph showing an example of AES spectrum of the metal film in the scintillator panel in accordance with the first embodiment;

Figs. 5A to 5C are process sectional views schematically showing an example of the method of manufacturing a scintillator panel in accordance with the first embodiment;

20 Figs. 6A to 6D are process sectional views schematically showing the example of the method of manufacturing a scintillator panel in accordance with the first embodiment;

Fig. 7 is a diagram showing an example of radiation image sensor including the scintillator panel in accordance with the first embodiment;

25 Fig. 8 is a view showing another example of radiation image sensor including the scintillator panel in accordance with the first

embodiment;

Fig. 9 is a sectional view schematically showing the scintillator panel in accordance with a second embodiment;

5 Fig. 10 is a sectional view schematically showing the scintillator panel in accordance with a third embodiment;

Fig. 11 is a cross-sectional SEM photograph of an example of the scintillator panel in accordance with the third embodiment;

Fig. 12 is a sectional view schematically showing the scintillator panel in accordance with a fourth embodiment;

10 Fig. 13 is a sectional view schematically showing the scintillator panel in accordance with a fifth embodiment; and

Fig. 14 is a sectional view schematically showing the scintillator panel in accordance with a sixth embodiment.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 [0011] In the following, preferred embodiments of the present invention will be explained in detail with reference to the accompanying drawings. For easier understanding of the explanation, the same constituents in the drawings will be referred to with the same numerals whenever possible while omitting their overlapping descriptions. The dimensions of the drawings include parts exaggerated for explanations and do not always match dimensional ratios in practice.

20 [0012] (First Embodiment)

Fig. 1 is a partly broken perspective view showing a scintillator panel (an example of radiation image conversion panel) in accordance with a first embodiment. Fig. 2 is a sectional view taken along the line II-II shown in Fig. 1. As shown in Figs. 1 and 2, the scintillator panel

10 comprises an aluminum substrate 12, an aluminum oxide layer 14 formed on a surface of the aluminum substrate 12, and an intermediate film 16 which is provided on the aluminum oxide layer 14 and has a radiation transparency. The aluminum oxide layer 14 and intermediate film 16 are in close contact with each other. The scintillator panel 10 also includes a metal film 18 which is provided on the intermediate film 16 and has a radiation transparency and a light reflectivity, an oxide layer 20 covering the metal film 18 and having a radiation transparency and a light transparency, a protective film 22 covering the oxide layer 20 and having a radiation transparency and a light transparency, and a scintillator 24 (an example of a converting part adapted to convert a radiation image) provided on the protective film 22. The intermediate film 16, metal film 18, oxide layer 20, protective film 22, and scintillator 24 are in close contact with each other.

15 [0013] In this embodiment, the aluminum substrate 12, aluminum oxide layer 14, intermediate film 16, metal film 18, and oxide layer 20 are totally sealed with the protective film 22. The protective film 22 prevents the metal film 18 from corroding because of pinholes and the like formed in the oxide layer 20. Also, the aluminum substrate 12, aluminum oxide layer 14, intermediate film 16, metal film 18, oxide layer 20, protective film 22, and scintillator 24 are totally sealed with a protective film 26.

20 [0014] When a radiation 30 such as x-ray is incident on the scintillator 24 from the aluminum substrate 12 side, light 32 such as visible light is emitted from the scintillator 24. Therefore, when a radiation image is incident on the scintillator panel 10, the scintillator 24

converts the radiation image into a light image. The radiation 30 successively passes through the protective film 26, protective film 22, aluminum substrate 12, aluminum oxide layer 14, intermediate film 16, metal film 18, oxide layer 20, and protective film 22, thereby reaching the scintillator 24. The light 32 emitted from the scintillator 24 is transmitted through the protective film 26 to the outside, while passing through the protective film 22, so as to be reflected by the metal film 18 and oxide layer 20 to the outside. The scintillator panel 10 is used for medical and industrial x-ray imaging and the like.

[0015] The aluminum substrate 12 is a substrate mainly made of aluminum, but may contain impurities and the like. Preferably, the thickness of the aluminum substrate 12 is 0.3 to 1.0 mm. When the thickness of the aluminum substrate 12 is less than 0.3 mm, the scintillator 24 tends to be easy to peel off as the aluminum substrate 12 bends. When the thickness of the aluminum substrate 12 exceeds 1.0 mm, the transmittance of the radiation 30 tends to decrease.

[0016] The layer 14 is made of a porous aluminum oxide formed by anodic oxidation of aluminum (i.e. alumite). The aluminum oxide layer 14 makes it harder to damage the aluminum substrate 12. If the aluminum substrate 12 is damaged, the reflectance of the aluminum substrate 12 will be less than a desirable value, whereby no uniform reflectance will be obtained within the surface of the aluminum substrate 12. Whether the aluminum substrate 12 is damaged or not can be inspected visually, for example. The aluminum oxide layer 14 may be formed on the aluminum substrate 12 on only one side to be formed with the scintillator 24, on both sides of the aluminum substrate

12, or such as to cover the aluminum substrate 12 as a whole. Forming the aluminum oxide layer 14 on both sides of the aluminum substrate 12 can reduce the warpage and flexure of the aluminum substrate 12, and thus can prevent the scintillator 24 from being unevenly vapor-deposited. Forming the aluminum oxide layer 14 can also erase streaks occurring when forming the aluminum substrate 12 by rolling. Therefore, even when a reflecting film (metal film 18 and oxide layer 20) is formed on the aluminum substrate 12, a uniform reflectance can be obtained within the surface of the aluminum substrate 12 in the reflecting film. Preferably, the thickness of the aluminum oxide layer 14 is 10 to 5000 nm. When the thickness of the aluminum oxide layer 14 is less than 10 nm, the damage prevention effect of the aluminum substrate 12 tends to decrease. When the thickness of the aluminum oxide layer 14 exceeds 5000 nm, the aluminum oxide layer 14 tends to peel off in particular in corner parts of the aluminum substrate 12, thereby causing large cracks in the aluminum oxide layer 14 and deteriorating the moisture resistance of the aluminum oxide layer 14. In one example, the thickness of the aluminum oxide layer 14 is 1000 nm. The thickness of the aluminum oxide layer 14 is appropriately determined according to the size and thickness of the aluminum substrate 12.

[0017] Fig. 3 is a graph showing an example of AES spectrum of the aluminum oxide layer in the scintillator panel in accordance with the first embodiment. This example conducts an element analysis in the thickness direction of the aluminum oxide layer 14 by sputter-etching the aluminum oxide layer 14 with argon ions for 31 minutes. In this

case, aluminum, oxygen, and argon are detected. Here, argon derives from the argon ions at the time of sputter etching, and thus is not an element contained in the aluminum oxide layer 14. Therefore, the aluminum oxide layer 14 in this example contains aluminum and oxygen.

[0018] Reference will be made to Figs. 1 and 2 again. The intermediate film 16 and protective films 22 and 26 are organic or inorganic films, which may be made of materials different from each other or the same material. The intermediate film 16 and protective films 22 and 26 are made of polyparaxylylene, for example, but may also be of xylylene-based materials such as polymonochloroparaxylylene, polydichloroparaxylylene, polytetrachloroparaxylylene, polyfluoroparaxylylene, polydimethylparaxylylene, and polydiethylparaxylylene. The intermediate film 16 and protective films 22 and 26 may be made of polyurea, polyimide, and the like, for example, or inorganic materials such as LiF, MgF<sub>2</sub>, SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>, MgO, and SiN. The intermediate film 16 and protective films 22 and 26 may also be formed by combining inorganic and organic films. In one example, the intermediate film 16 and protective films 22 and 26 have a thickness of 10 µm each. The intermediate film 16 reduces minute irregularities of the aluminum oxide layer 14, thereby advantageously acting for forming the metal film 18 having a uniform thickness on the aluminum oxide layer 14.

[0019] The metal film 18 is constructed by Al, for example, but may also be made of Ag, Cr, Cu, Ni, Ti, Mg, Rh, Pt, Au, or the like.

Among them, Al or Ag is preferred. The metal film 18 may also contain elements such as oxygen other than metal elements. The metal film 18 may be constituted by a plurality of metal films, e.g., a Cr film and an Au film provided on the Cr film. Preferably, the thickness of the metal film 18 is 50 to 200 nm. In one example, the thickness of the metal film 18 is 70 nm. When an aluminum film is used as the metal film 18, it may be analyzed by AES (Auger Electron Spectroscopy) as an incomplete aluminum oxide depending on the vapor deposition condition and the processing after the vapor deposition.

[0020] Fig. 4 is a graph showing an example of AES spectrum of the metal film in the scintillator panel in accordance with the first embodiment. This example conducts an element analysis in the thickness direction of the metal layer 18 by sputter-etching the metal film 18 with argon ions for 20 minutes. In this case, aluminum, oxygen, and argon are detected. Here, argon derives from the argon ions at the time of sputter etching, and is not an element contained in the metal film 18. Though containing oxygen, the metal film 18 can clearly be distinguished from the aluminum oxide layer 14 in view of their AES spectra forms.

[0021] Reference will be made to Figs. 1 and 2 again. The oxide layer 20 is made of a metal oxide,  $\text{SiO}_2$ ,  $\text{TiO}_2$ , or the like, for example. The oxide layer 20 may be constituted by a plurality of oxide layers made of materials different from each other, e.g., an  $\text{SiO}_2$  film and a  $\text{TiO}_2$  film. In one example, the thickness of the  $\text{SiO}_2$  film is 80 nm while the thickness of the  $\text{TiO}_2$  film is 50 nm. The thickness and number of laminated layers of the  $\text{SiO}_2$  and  $\text{TiO}_2$  films are determined

in view of the reflectance for the wavelength of light 32 emitted from the scintillator 24. The oxide layer 20 also functions to prevent the metal film 18 from corroding.

[0022] The scintillator 24 is smaller than the aluminum film 12 when seen in the thickness direction of the aluminum substrate 12. For example, the scintillator 24 is constituted by a phosphor which converts the radiation into visible light, and is made of a columnar crystal or the like of CsI doped with Tl, Na, or the like. The scintillator 24 has a structure provided with a forest of columnar crystals. The scintillator 24 may also be made of Tl-doped NaI, Tl-doped KI, or Eu-doped LiI. A stimulable phosphor such as Eu-doped CsBr may be used in place of the scintillator 24. The thickness of the scintillator 24 is preferably 100 to 1000  $\mu\text{m}$ , more preferably 450 to 550  $\mu\text{m}$ . Preferably, the average column diameter of the columnar crystals constituting the scintillator 24 is 3 to 10  $\mu\text{m}$ .

[0023] As explained in the foregoing, the scintillator panel 10 comprises the aluminum substrate 12; the aluminum oxide layer 14 formed on the surface of the aluminum substrate 12; the metal film 18, provided on the aluminum oxide layer 14, having a radiation transparency and a light reflectivity; the protective film 22 covering the metal film 18 and having a radiation transparency and a light transparency; and the scintillator 24 provided on the protective film 22. Therefore, the light 32 emitted from the scintillator 24 is reflected by the metal film 18, whereby the scintillator panel 10 can attain a high luminance. Since the metal film 18 and protective film 22 are provided between the aluminum oxide layer 14 and scintillator 24, the

aluminum substrate 12 and scintillator 24 can be kept from reacting with each other even if the aluminum oxide layer 14 is formed with cracks, pinholes, and the like. As a consequence, the aluminum substrate 12 can be prevented from corroding. Forming the aluminum oxide layer 14 can further erase damages to the surface of the aluminum substrate 12, whereby uniform luminance and resolution characteristics can be obtained within the surface of the scintillator panel 10.

**[0024]** The scintillator panel 10 further comprises the radiation-transparent intermediate film 16 provided between the aluminum oxide layer 14 and metal film 18. This can flatten the surface of the aluminum oxide layer 14, thereby improving the flatness of the metal film 18. Therefore, the in-surface uniformity in reflectance of the metal film 18 improves. It can also enhance the adhesion between the aluminum oxide layer 14 and metal film 18. It can further prevent moisture, scintillator constituent materials, and the like from passing through cracks, pinholes, and the like formed in the aluminum oxide layer 14. Therefore, the aluminum substrate 12 is further prevented from corroding.

**[0025]** The scintillator panel 10 further comprises the oxide layer 20 covering the metal film 18 and having a radiation transparency and a light transparency. This can improve the moisture resistance of the metal film 18 and prevent the metal film 18 from being damaged. It can also enhance the reflectance of the metal film 18.

**[0026]** Figs. 5A to 5C and 6A to 6D are process sectional views schematically showing an example of the method of manufacturing a scintillator panel in accordance with the first embodiment. The

method of manufacturing the scintillator panel 10 will now be explained with reference to Figs. 5A to 5C and 6A to 6D.

**[0027]** First, as shown in Fig. 5A, the aluminum substrate 12 is prepared. Subsequently, as shown in Fig. 5B, the aluminum oxide layer 14 is formed by anodic oxidation on a surface of the aluminum substrate 12. For example, the aluminum substrate 12 is electrolyzed by an anode in an electrolyte such as dilute sulfuric acid, so as to be oxidized. This forms the aluminum oxide layer 14 constituted by an assembly of hexagonal columnar cells each having a fine hole at the center. The aluminum oxide layer 14 may be dipped in a dye, so as to be colored. This can improve the resolution or enhance the luminance. After being formed, the aluminum oxide layer 14 is subjected to a sealing process for filling the fine holes.

**[0028]** Next, as shown in Fig. 5C, the intermediate film 16 is formed on the aluminum oxide layer 14 by using CVD. Further, as shown in Fig. 6A, the metal film 18 is formed on the intermediate film 16 by using vacuum vapor deposition. The metal film 18 is made of aluminum having a purity of 99.9%, for example. Thereafter, as shown in Fig. 6B, the oxide layer 20 is formed on the metal film 18. Next, as shown in Fig. 6C, the protective film 22 is formed by using CVD so as to seal the aluminum substrate 12, aluminum oxide layer 14, intermediate film 16, metal film 18, and oxide layer 20 as a whole. Further, as shown in Fig. 6D, the scintillator 24 is formed on the protective film 22 on the oxide layer 20 by using vapor deposition. Subsequently, as shown in Figs. 1 and 2, the protective film 26 is formed by using CVD so as to seal the aluminum substrate 12,

aluminum oxide layer 14, intermediate film 16, metal film 18, oxide layer 20, protective film 22, and scintillator 24 as a whole. Thus, the scintillator panel 10 is manufactured. The sealing with the protective films 22 and 26 can be realized by lifting the side of the aluminum substrate 12 opposite from the scintillator forming surface from a substrate holder at the time of CVD. An example of such method is one disclosed in U.S. Patent No. 6,777,690. This method lifts the aluminum substrate 12 by using pins. In this case, no protective film is formed on minute contact surfaces between the aluminum substrate 12 and the pins.

[0029] Fig. 7 is a diagram showing an example of radiation image sensor including the scintillator panel in accordance with the first embodiment. The radiation image sensor 100 shown in Fig. 7 comprises the scintillator panel 10 and an image pickup device 70 which converts the light 32 emitted from the scintillator 24 of the scintillator panel 10 into an electric signal. The light 32 emitted from the scintillator 24 is reflected by a mirror 50, so as to be made incident on a lens 60. The light 32 is converged by the lens 60, so as to be made incident on the image pickup device 70. One or a plurality of lenses 60 may be provided.

[0030] The radiation 30 emitted from a radiation source 40 such as x-ray source is transmitted through an object to be inspected which is not depicted. The transmitted radiation image is made incident on the scintillator 24 of the scintillator panel 10. As a consequence, the scintillator 24 emits a visible light image (the light 32 having a wavelength to which the image pickup device 70 is sensitive)

corresponding to the radiation image. The light 32 emitted from the scintillator 24 is made incident on the image pickup device 70 by way of the mirror 50 and lens 60. For example, CCDs, flat panel image sensors, and the like can be used as the image pickup device 70. Thereafter, an electronic device 80 receives the electric signal from the image pickup device 70, whereby the electric signal is transmitted to a workstation 90 through a lead 36. The workstation 90 analyzes the electric signal, and outputs an image onto a display.

**[0031]** The radiation image sensor 100 comprises the scintillator panel 10 and the image pickup device 70 adapted to convert the light 32 emitted from the scintillator 24 of the scintillator panel 10 into the electric signal. Therefore, the radiation image sensor 100 can prevent the aluminum substrate 12 from corroding, while having a high luminance.

**[0032]** Fig. 8 is a view showing another example of radiation image sensor including the scintillator panel in accordance with the first embodiment. The radiation image sensor 100a shown in Fig. 8 comprises the scintillator panel 10, and an image pickup device 70 which is arranged so as to oppose the scintillator panel 10 and adapted to convert light emitted from the scintillator 24 into an electric signal. The scintillator 24 is arranged between the aluminum substrate 12 and image pickup device 70. The light-receiving surface of the image pickup device 70 is arranged on the scintillator 24 side. The scintillator panel 10 and image pickup device 70 may be joined together or separated from each other. When joining them, an adhesive may be used, or an optical coupling material (refractive index matching

material) may be utilized so as to reduce the loss of the emitted light 32 in view of the refractive indexes of the scintillator 24 and protective film 26.

**[0033]** The radiation image sensor 100a comprises the scintillator panel 10 and the image pickup device 70 adapted to convert the light 32 emitted from the scintillator 24 of the scintillator panel 10 into the electric signal. Therefore, the radiation image sensor 100a can prevent the aluminum substrate 12 from corroding, while having a high luminance.

**[0034] (Second Embodiment)**

Fig. 9 is a sectional view schematically showing the scintillator panel in accordance with a second embodiment. The scintillator panel 10a shown in Fig. 9 has the same structure as that of the scintillator panel 10 except that the intermediate film 16 totally seals the aluminum substrate 12 and aluminum oxide layer 14. Therefore, the scintillator panel 10a not only exhibits the same operations and effects as those of the scintillator 10, but further improves the moisture resistance of the aluminum substrate 12, and thus can more reliably prevent the aluminum substrate 12 from corroding.

**[0035] (Third Embodiment)**

Fig. 10 is a sectional view schematically showing the scintillator panel in accordance with a third embodiment. The scintillator panel 10b shown in Fig. 10 has the same structure as that of the scintillator panel 10 except that it lacks the intermediate film 16. Therefore, the scintillator panel 10b not only exhibits the same operations and effects as those of the scintillator 10, but can also simplify the structure. Fig.

11 is a cross-sectional SEM photograph of an example of the scintillator panel in accordance with the third embodiment.

**[0036]** When forming the metal film 18 on the aluminum oxide layer 14, the thickness of the metal film 18 is preferably 50 to 200 nm in view of a uniform reflection characteristic, adhesion strength, and the like of the metal film 18. Preferably, for keeping the surface state of the aluminum substrate 12 from affecting the metal film 18, the thickness of the aluminum oxide layer 14 is greater than that of the metal film 18. In one example, the thickness of the aluminum oxide layer 14 is 1000 nm.

**[0037]** (Fourth Embodiment)

Fig. 12 is a sectional view schematically showing the scintillator panel in accordance with a fourth embodiment. The scintillator panel 10c shown in Fig. 12 has the same structure as that of the scintillator panel 10 except that it lacks the oxide layer 20. Therefore, the scintillator panel 10c not only exhibits the same operations and effects as those of the scintillator 10, but can also simplify the structure.

**[0038]** (Fifth Embodiment)

Fig. 13 is a sectional view schematically showing the scintillator panel in accordance with a fifth embodiment. The scintillator panel 10d shown in Fig. 13 has the same structure as that of the scintillator panel 10c except that the intermediate film 16 totally seals the aluminum substrate 12 and aluminum oxide layer 14. Therefore, the scintillator panel 10d not only exhibits the same operations and effects as those of the scintillator 10c, but further improves the moisture resistance of the aluminum substrate 12, and thus can more reliably

prevent the aluminum substrate 12 from corroding.

**[0039] (Sixth Embodiment)**

Fig. 14 is a sectional view schematically showing the scintillator panel in accordance with a sixth embodiment. The scintillator panel 10e shown in Fig. 14 further comprises a radiation-transparent reinforcement plate 28 bonded to the aluminum substrate 12 in addition to the structure of the scintillator panel 10. The aluminum substrate 12 is arranged between the reinforcement plate 28 and scintillator 24.

**[0040]** The reinforcement plate 28 is bonded to the aluminum substrate 12 by a double-sided adhesive tape, an adhesive, or the like, for example. Employable as the reinforcement plate 28 are (1) carbon fiber reinforced plastics (CFRP), (2) carbon boards (made by carbonizing and solidifying charcoal and paper), (3) carbon substrates (graphite substrates), (4) plastic substrates, (5) sandwiches of thinly formed substrates (1) to (4) mentioned above with resin foam, and the like. Preferably, the thickness of the reinforcement plate 28 is greater than the total thickness of the aluminum substrate 12 and aluminum oxide layer 14. This improves the strength of the scintillator panel 10e as a whole. Preferably, the reinforcement plate 28 is larger than the scintillator 24 when seen in the thickness direction of the aluminum substrate 12. Namely, it will be preferred if the reinforcement plate 28 hides the scintillator 24 when seen in the thickness direction of the aluminum substrate 12 from the reinforcement plate 28 side. This can prevent a shadow of the reinforcement plate 28 from being projected. In particular, this can prevent an image from becoming uneven because of the shadow of the reinforcement plate 28 when the radiation image

30 having a low energy is used.

[0041] The scintillator panel 10e not only exhibits the same operations and effects as those of the scintillator panel 10, but can further improve the flatness and rigidity of the scintillator panel 10e. Therefore, the scintillator panel 10e can prevent the scintillator 24 from peeling off as the aluminum substrate 12 bends. Since the radiation image sensor 100 shown in Fig. 7 uses the scintillator panel as a single unit, it is effective to employ the scintillator panel 10e having a high rigidity.

[0042] The reinforcement plate 28 may be bonded to one of the scintillator panels 10a, 10b, 10c, 10d instead of the scintillator panel 10.

[0043] Though preferred embodiments of the present invention are explained in detail in the foregoing, the present invention is not limited to the above-mentioned embodiments and the structures exhibiting various operations and effects mentioned above.

[0044] For example, the radiation image sensors 100, 100a may employ one of the scintillator panels 10a, 10b, 10c, 10d, 10e in place of the scintillator panel 10.

[0045] The scintillator panel 10 is not required to have both of the intermediate film 16 and oxide layer 20. The scintillator panels 10, 10a, 10b, 10c, 10d, 10e may be free of the protective film 26.

[0046] Though the above-mentioned embodiments exemplify the radiation image conversion panel by the scintillator panel, a stimulable phosphor (an example of a converting part adapted to convert a radiation image) may be used in place of the scintillator 24, whereby an imaging plate as the radiation image conversion panel can be made.

The stimulable phosphor converts the radiation image into a latent image. This latent image is scanned with laser light, so as to read a visible light image. The visible light image is detected by a detector (photosensor such as line sensor, image sensor, and photomultiplier).

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CLAIMS:

1. A radiation image conversion panel comprising:
  - an aluminum substrate;
  - an aluminum oxide layer formed on a surface of the aluminum substrate;
  - a metal film, provided on the aluminum oxide layer, having a light reflectivity, at least a portion of the aluminum oxide layer being positioned between the aluminum substrate and the metal film;
  - a protective film covering the metal film and having a light transparency, at least a portion of the metal film being positioned between the aluminum oxide layer and the protective film;
  - a converting part provided on the protective film and adapted to convert a radiation image, the converting part comprising a light emitting surface of the radiation image conversion panel, and at least a portion of the protective film being positioned between the metal film and the converting part; and
  - an oxide layer covering, at least in part, the metal film and having a light transparency, the oxide layer comprising an  $\text{SiO}_2$  film and a  $\text{TiO}_2$  film.
2. The radiation image conversion panel according to claim 1, wherein said aluminum oxide layer is porous aluminum oxide formed by anodic oxidation.
- 20 3. The radiation image conversion panel according to claim 1 or 2, wherein the protective film seals all of the aluminum substrate, the aluminum oxide layer, the metal layer and the oxide layer.
4. A scintillator panel comprising:
  - an aluminum substrate comprising a radiation receiving surface of the scintillator panel;

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an aluminum oxide layer formed on a surface of the aluminum substrate other than the radiation receiving surface;

5 a metal film, provided on the aluminum oxide layer, having a radiation transparency and a light reflectivity, at least a portion of the aluminum oxide layer being positioned between the aluminum substrate and the metal film;

a protective film covering the metal film and having a radiation transparency and a light transparency, at least a portion of the metal film being positioned between the aluminum oxide layer and the protective film;

10 a scintillator provided on the protective film, the scintillator comprising a light emitting surface of the scintillator panel, and at least a portion of the protective film being positioned between the metal film and the scintillator; and

an oxide layer covering, at least in part, the metal film and having a radiation transparency and a light transparency, the oxide layer comprising an  $\text{SiO}_2$  film and a  $\text{TiO}_2$  film.

15 5. The scintillator panel according to claim 4, wherein the protective film seals all of the aluminum substrate, the aluminum oxide layer, the metal layer and the oxide layer.

20 6. The scintillator panel according to claim 4, further comprising a radiation-transparent intermediate film provided between the aluminum oxide layer and the metal film.

7. The scintillator panel according to claim 6, wherein the protective film seals all of the aluminum substrate, the aluminum oxide layer, the radiation-transparent intermediate film, the metal layer and the oxide layer.

25 8. The scintillator panel according to any one of claims 4 to 7, further comprising a radiation-transparent reinforcement plate bonded to the aluminum substrate, the aluminum substrate being arranged between the reinforcement plate and the scintillator.

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9. The scintillator panel according to any one of claims 4 to 8, wherein said aluminum oxide layer is porous aluminum oxide formed by anodic oxidation.

10. A radiation image sensor comprising:

a radiation image conversion panel including an aluminum substrate;

5 an aluminum oxide layer formed on a surface of the aluminum substrate;

a metal film, provided on the aluminum oxide layer, having a light reflectivity, at least a portion of the aluminum oxide layer being positioned between the aluminum substrate and the metal film;

10 a protective film covering the metal film and having a light transparency, at least a portion of the metal film being positioned between the aluminum oxide layer and the protective film;

15 a converting part provided on the protective film and adapted to convert a radiation image, the converting part comprising a light emitting surface of the radiation image conversion panel, and at least a portion of the protective film being positioned between the metal film and the converting part; and

an oxide layer covering, at least in part, the metal film and having a light transparency, the oxide layer comprising an  $\text{SiO}_2$  film and a  $\text{TiO}_2$  film; and

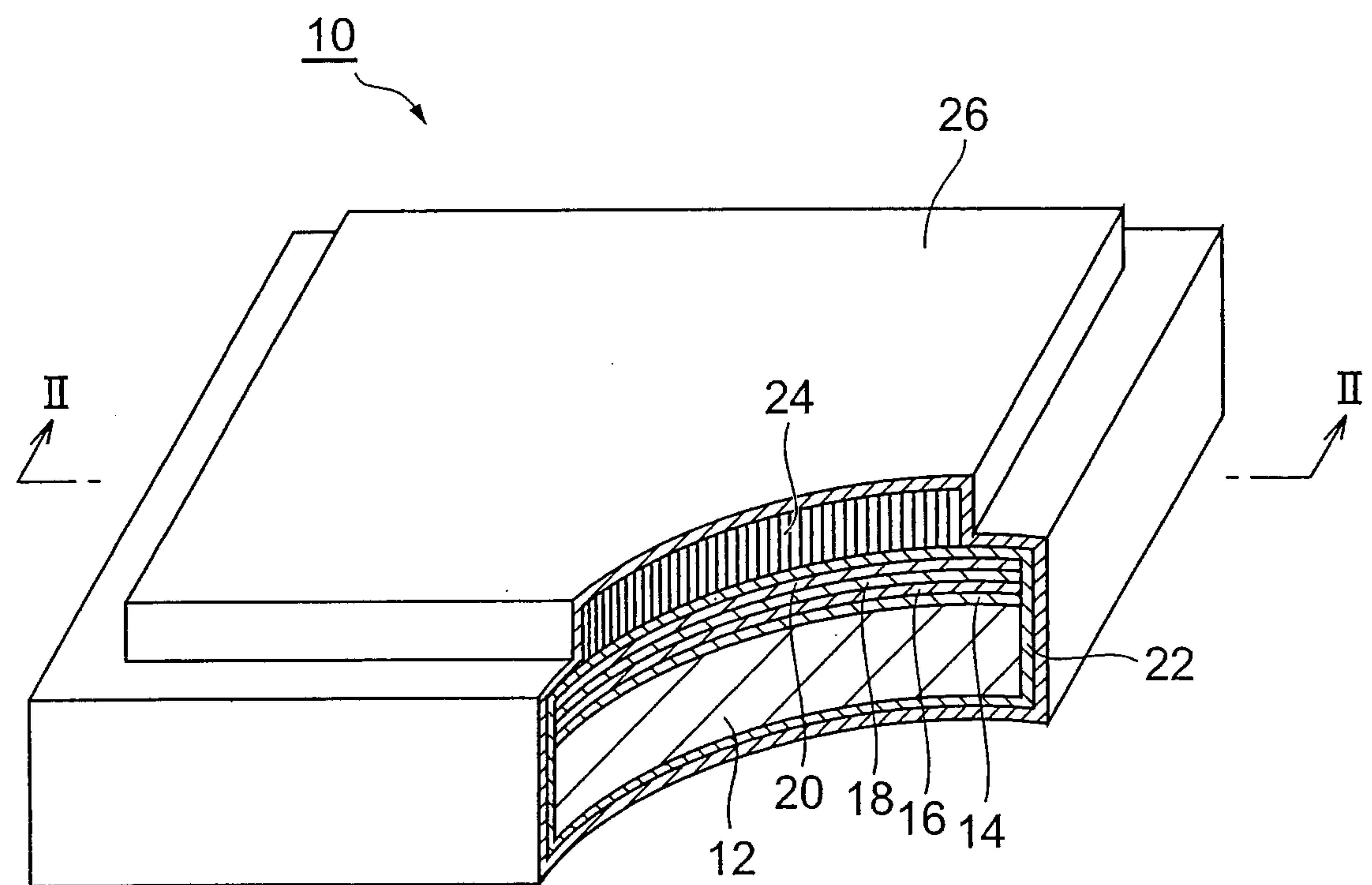
20 an image pickup device for converting light emitted from the light emitting surface of the converting part of the radiation image conversion panel into an electric signal.

11. The radiation image sensor according to claim 10, wherein said aluminum oxide layer is porous aluminum oxide formed by anodic oxidation.

12. The radiation image sensor according to claim 10 or 11, wherein the 25 protective film seals all of the aluminum substrate, the aluminum oxide layer, the metal layer and the oxide layer.

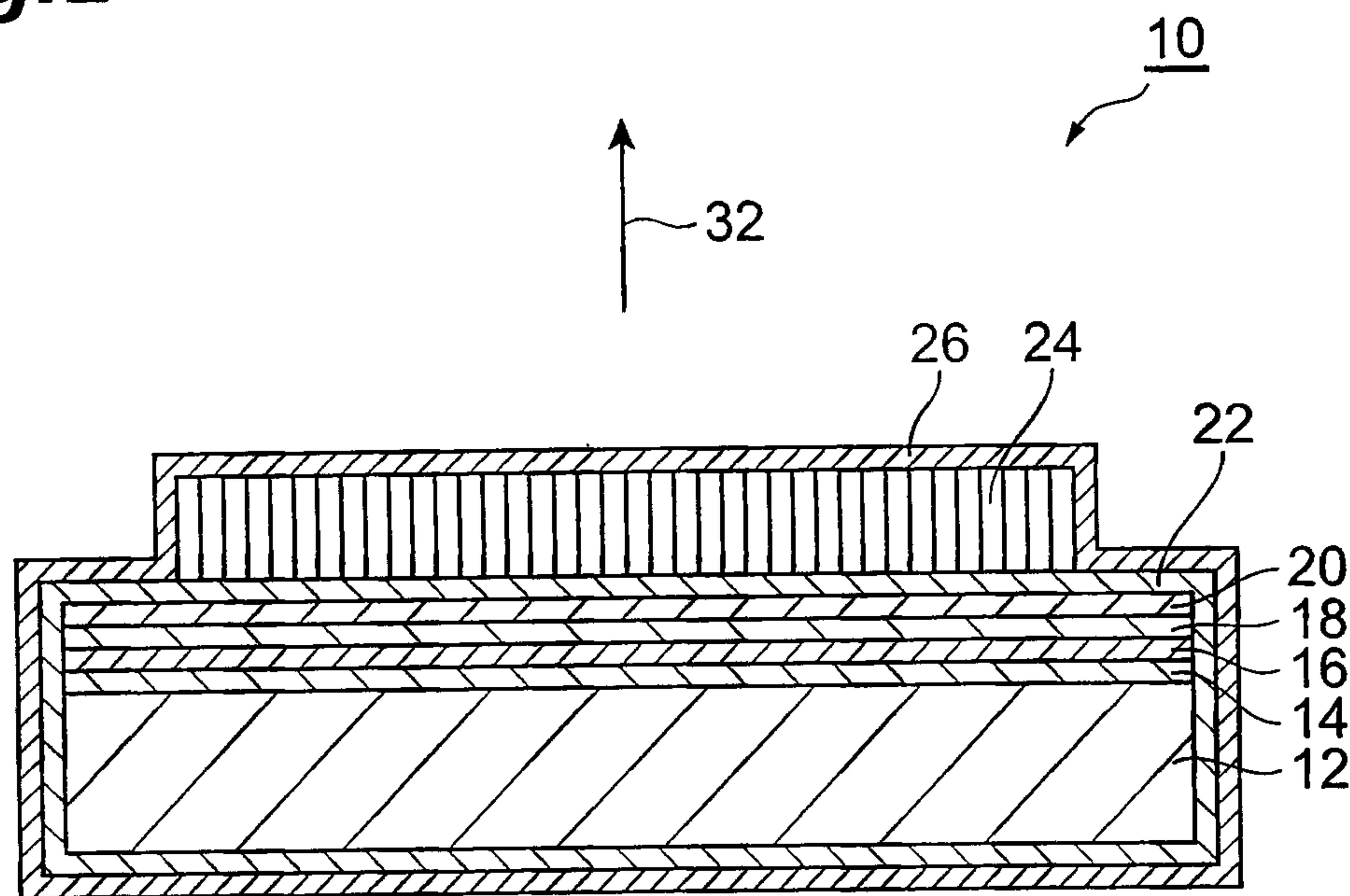
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***Fig. 1***

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**Fig.2**

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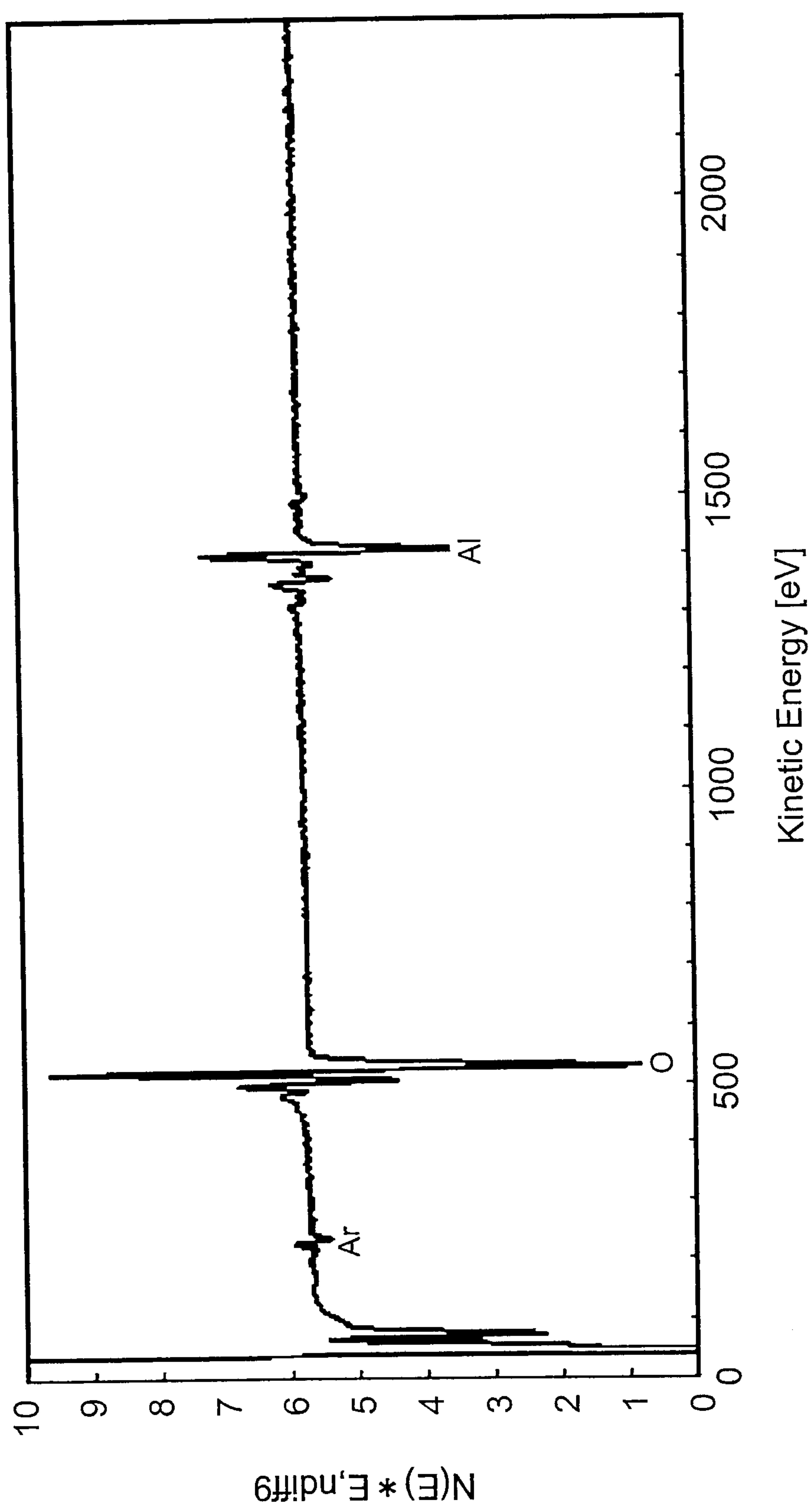


Fig. 3

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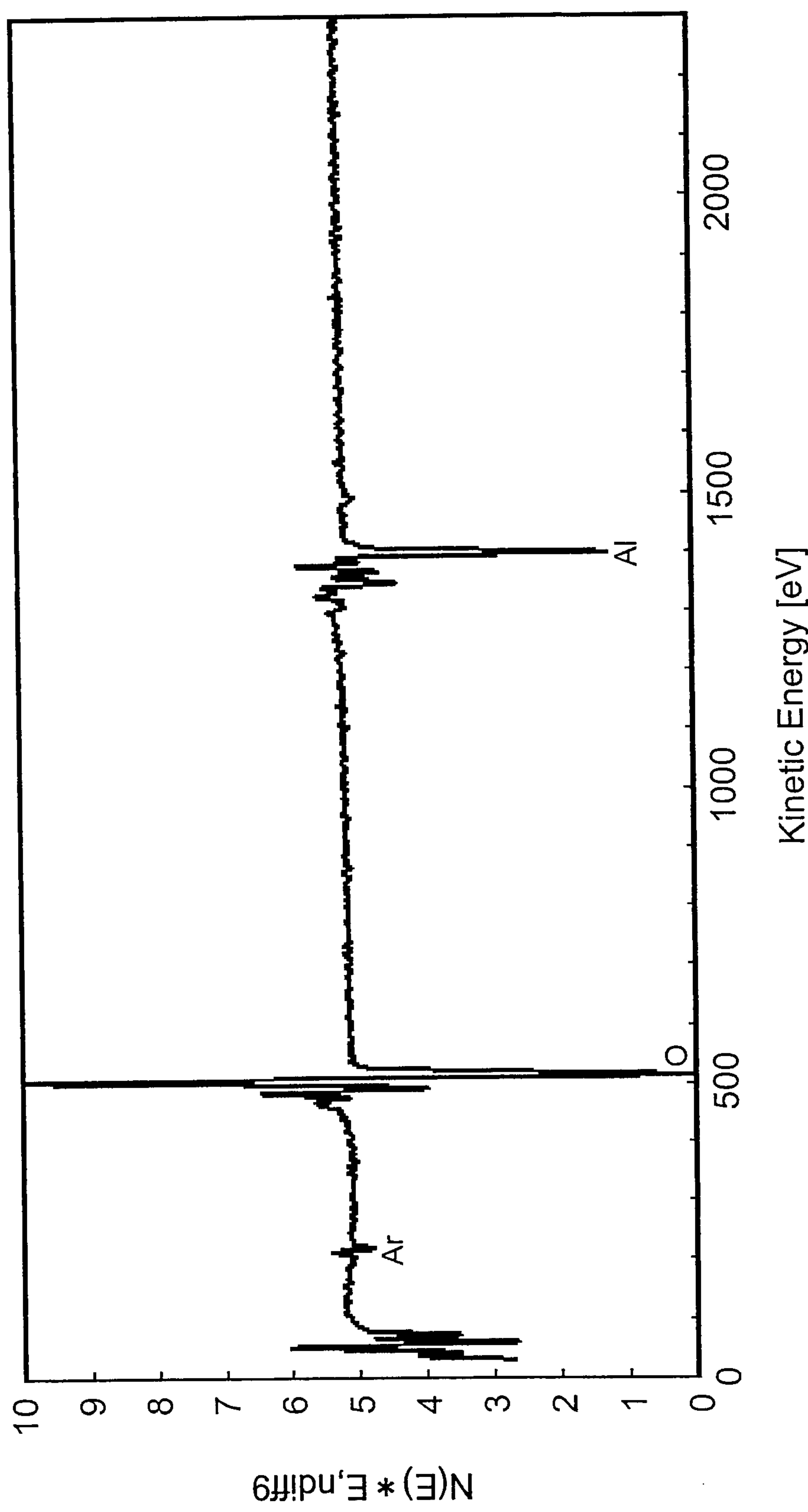
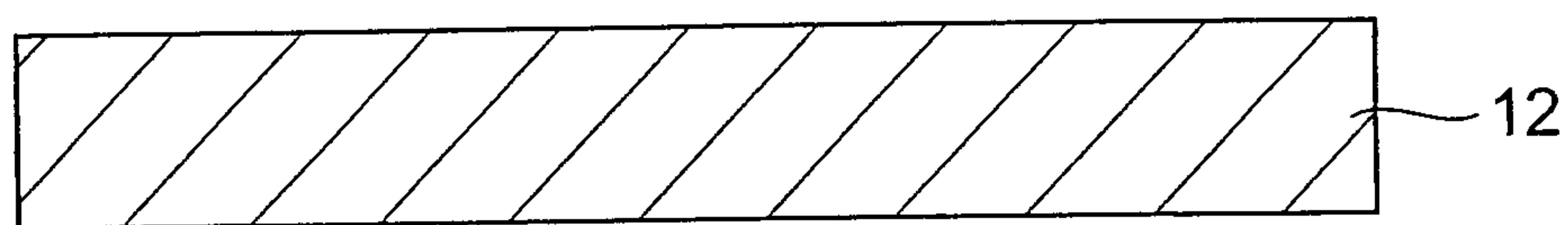


Fig.4

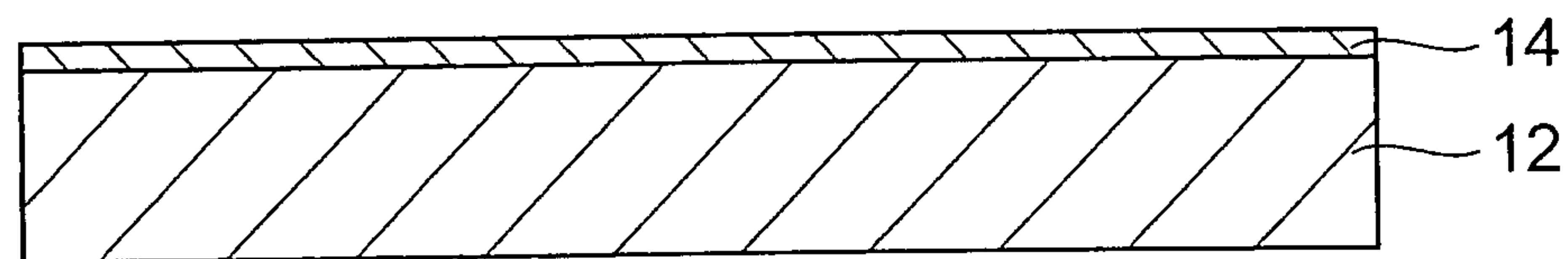
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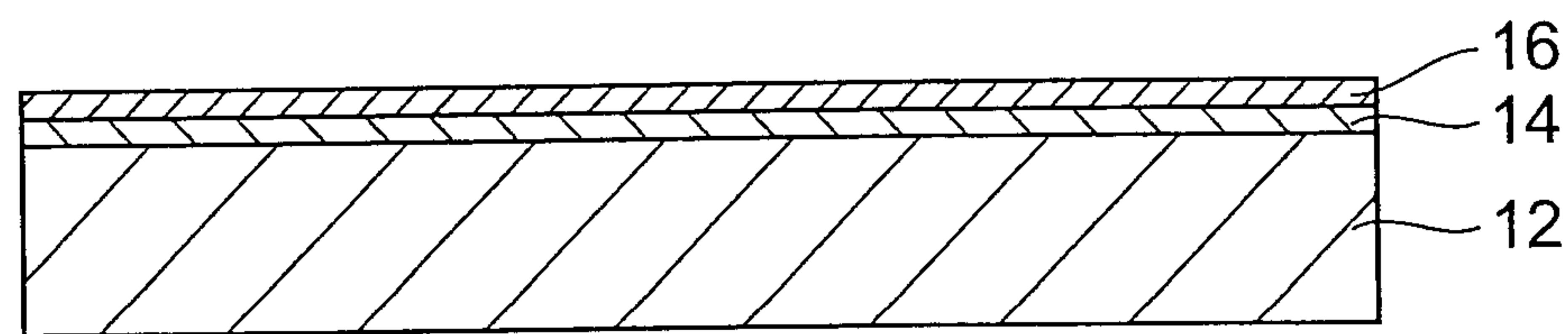
**Fig.5A**



**Fig.5B**

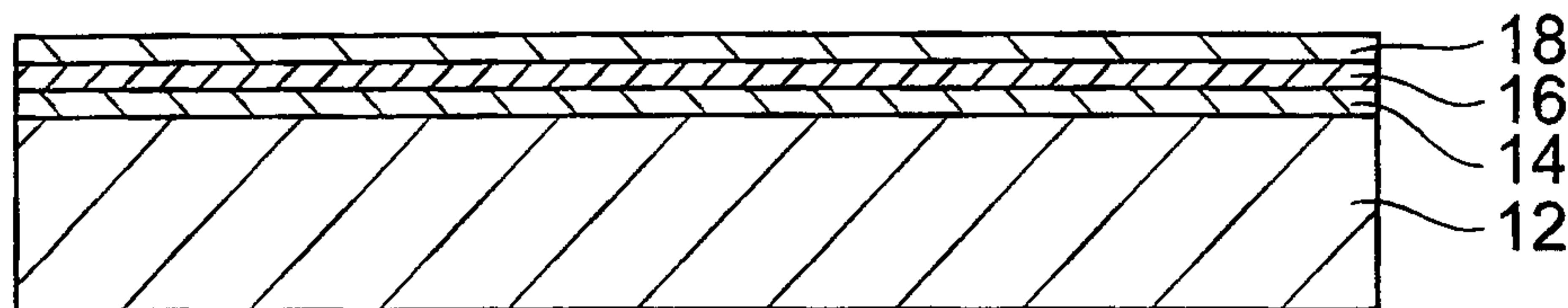
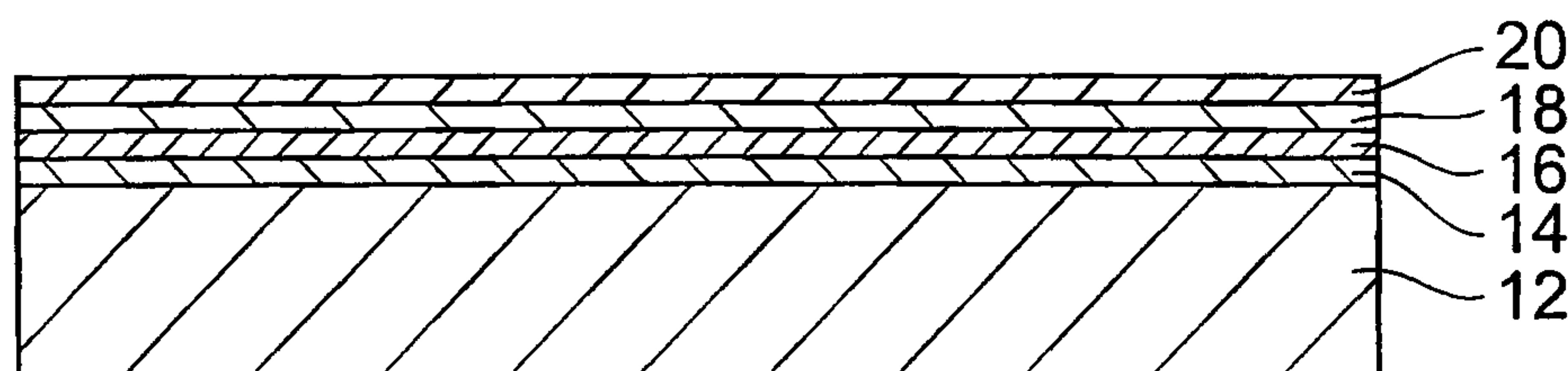
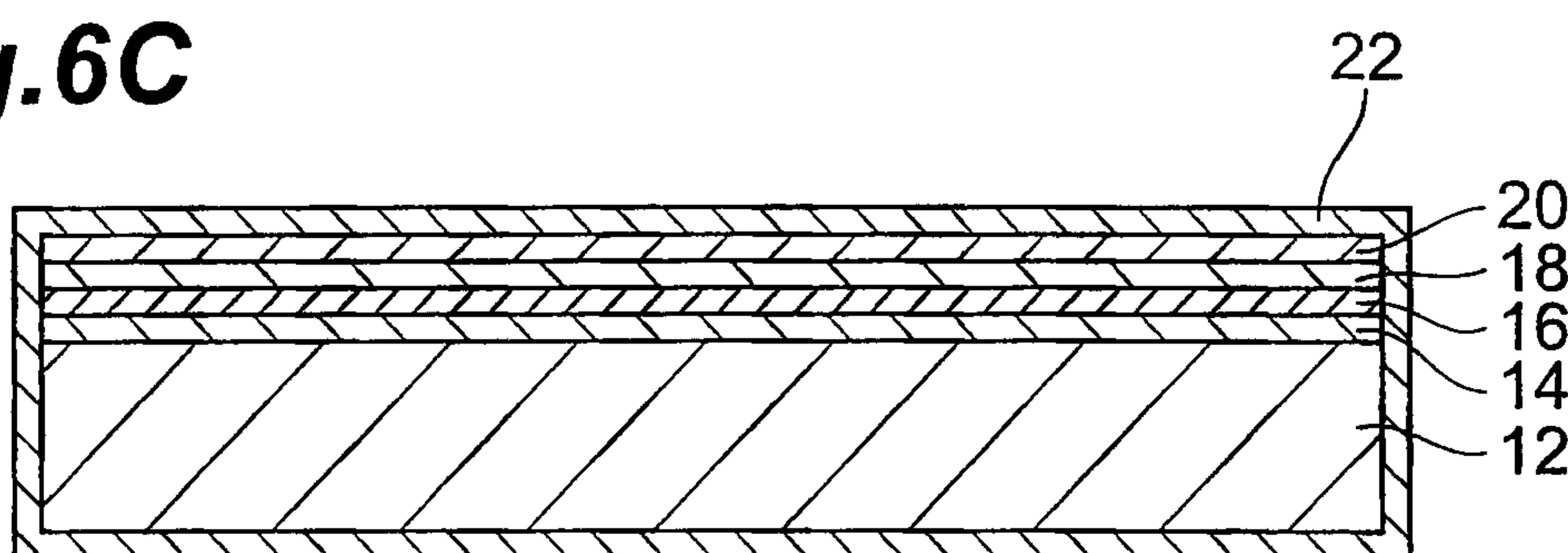
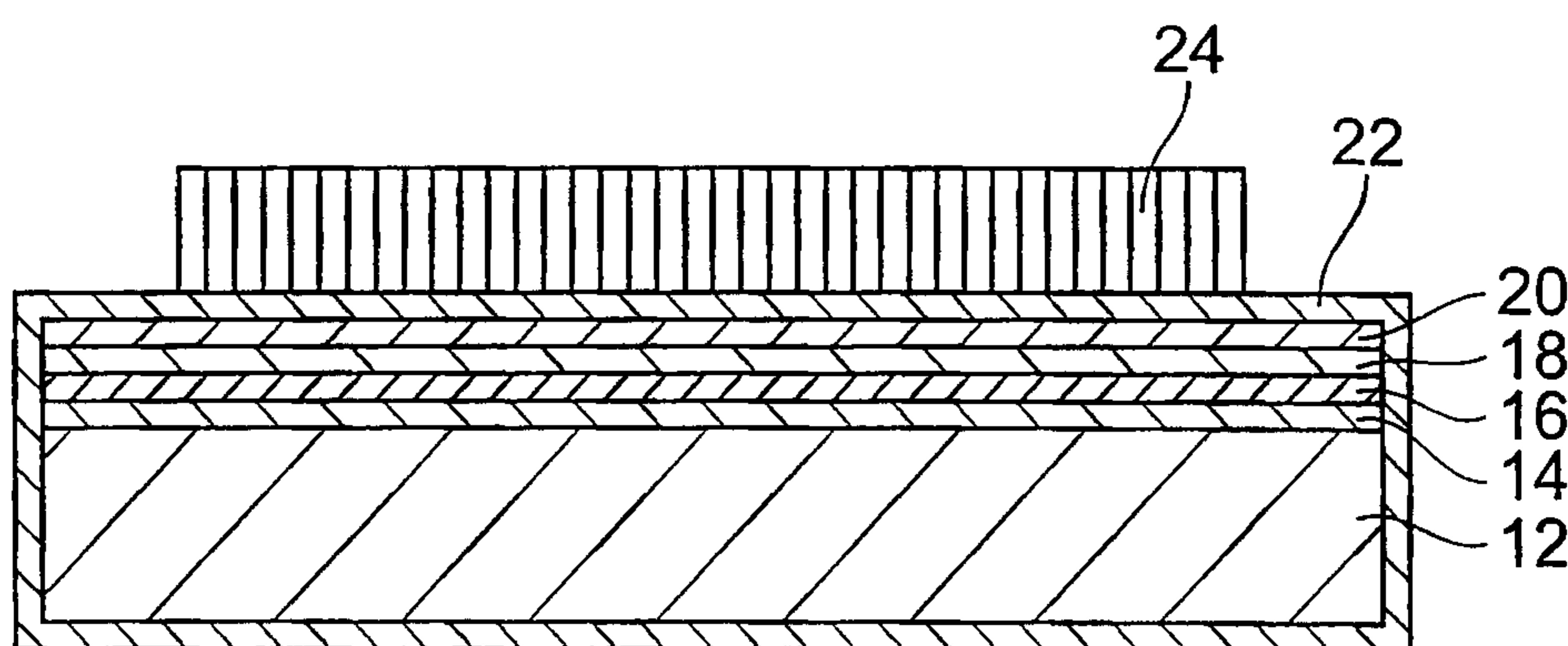


**Fig.5C**



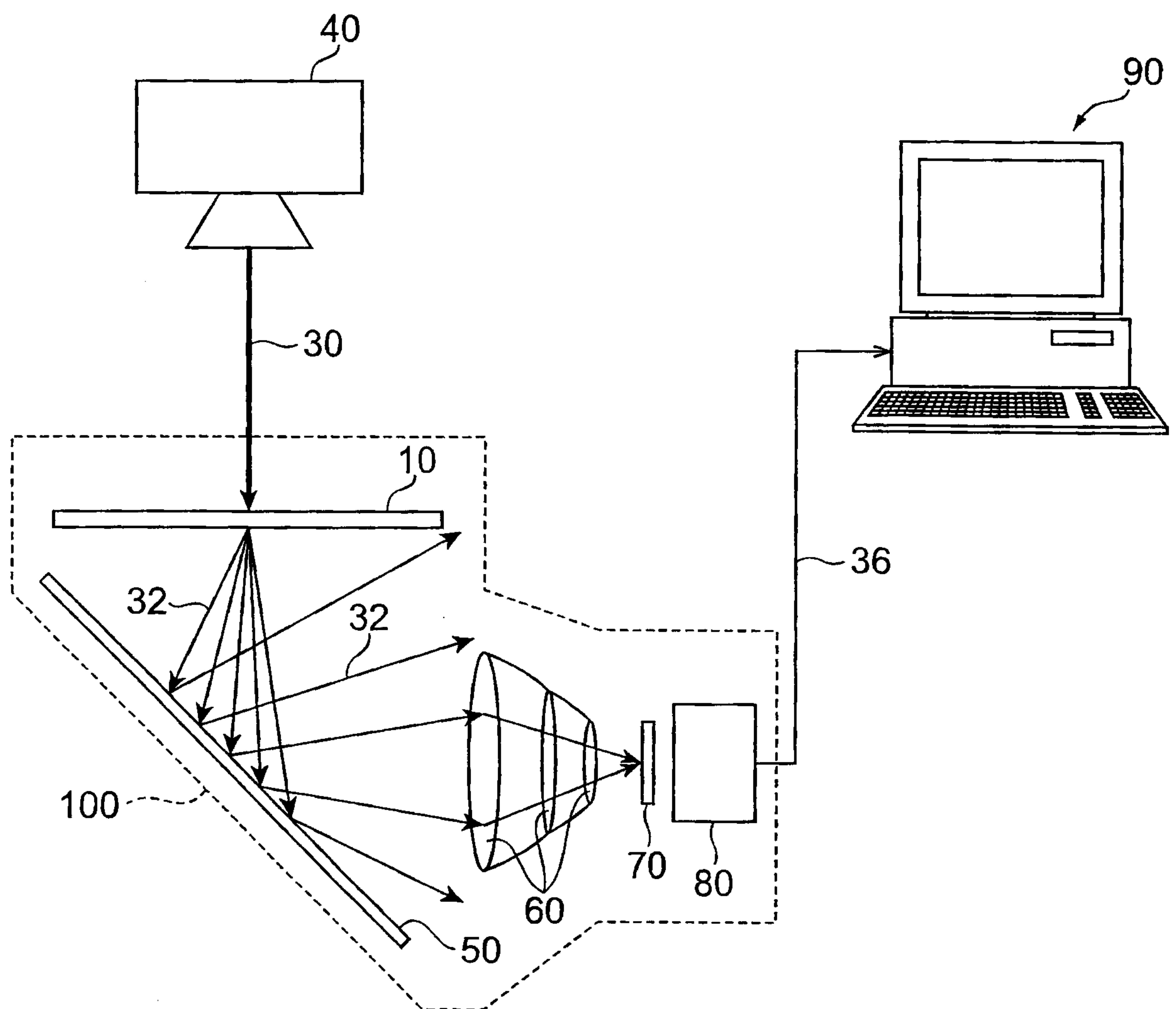
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**Fig.6A****Fig.6B****Fig.6C****Fig.6D**

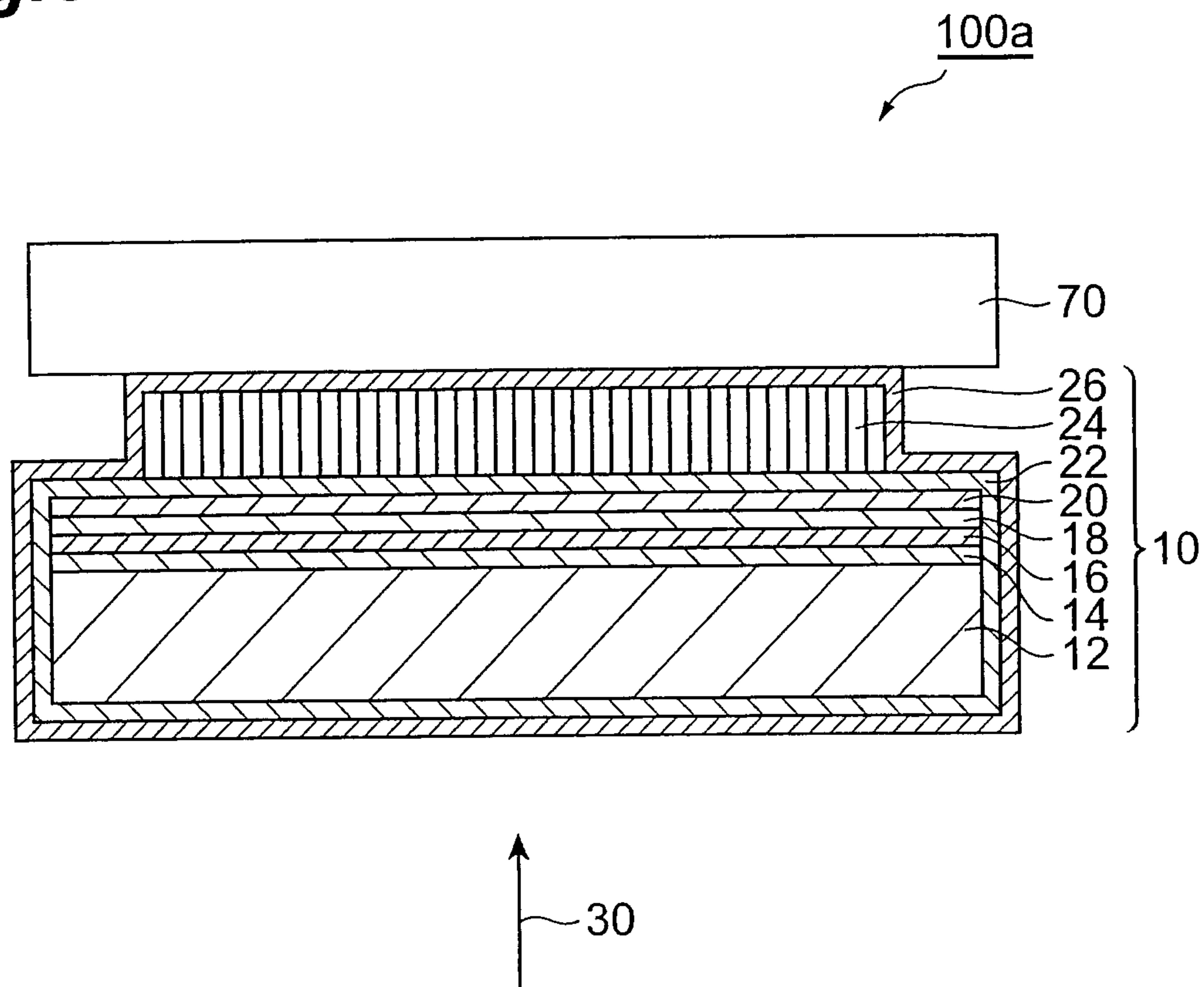
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**Fig.7**

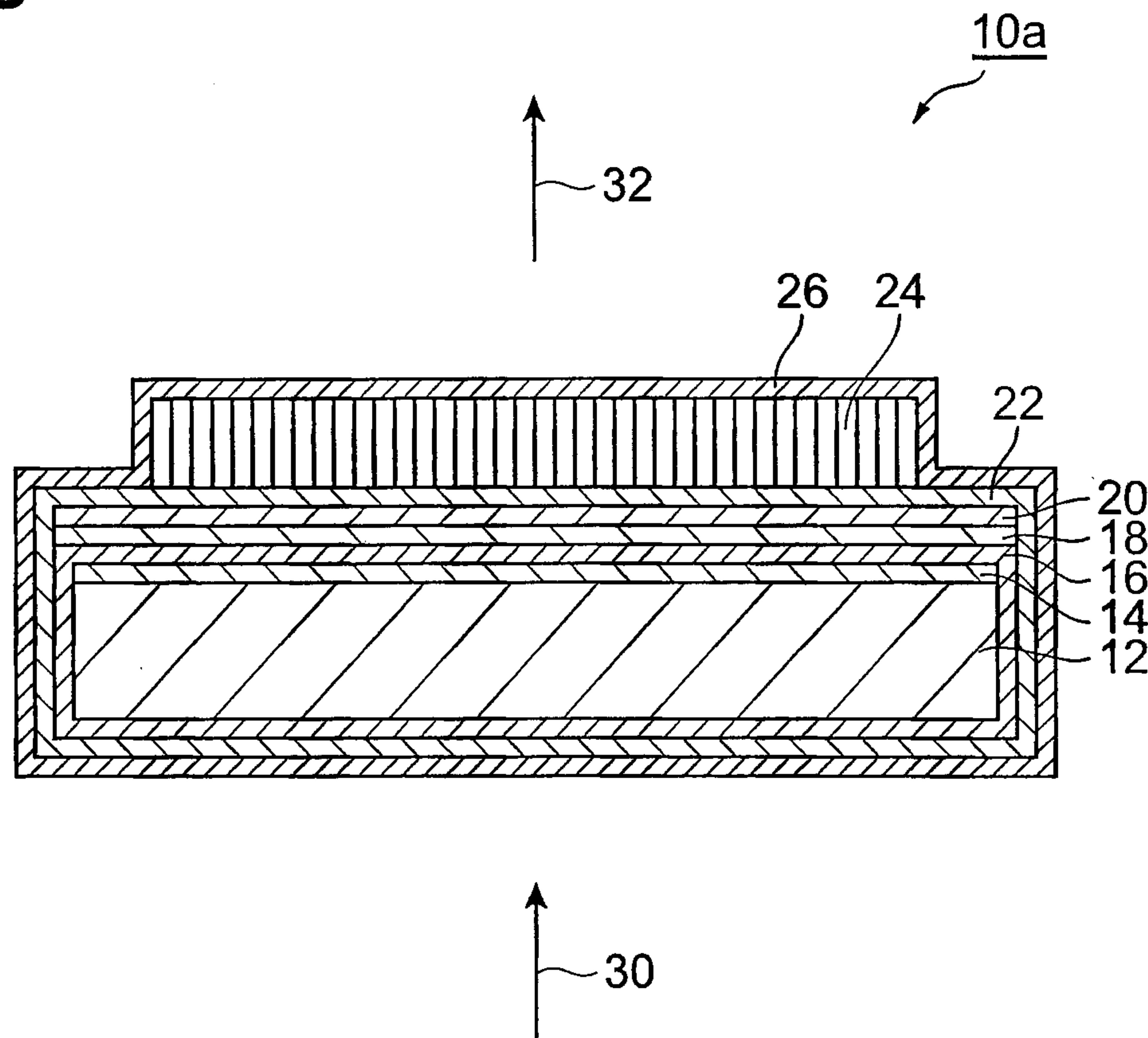
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**Fig.8**

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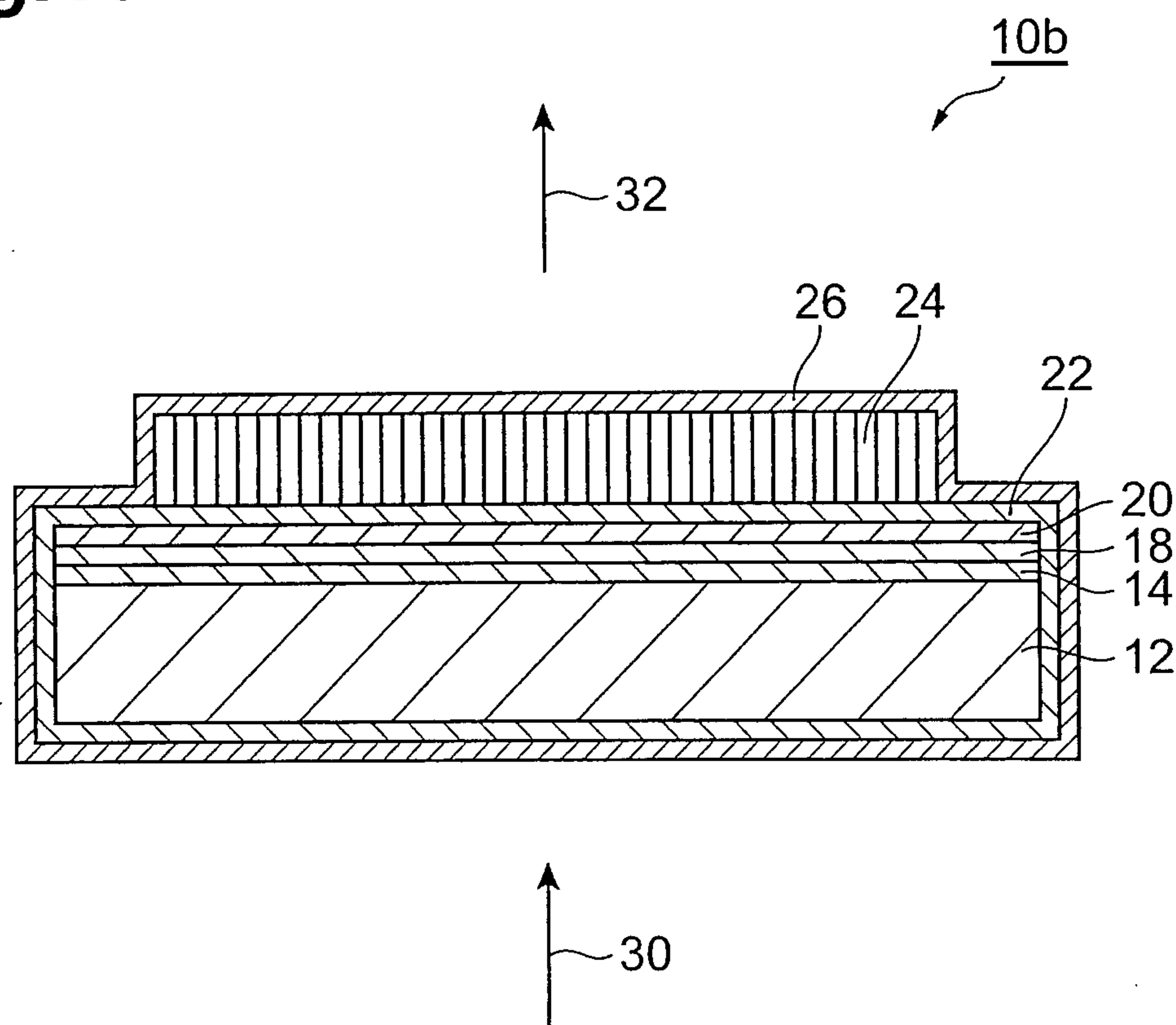
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**Fig.9**

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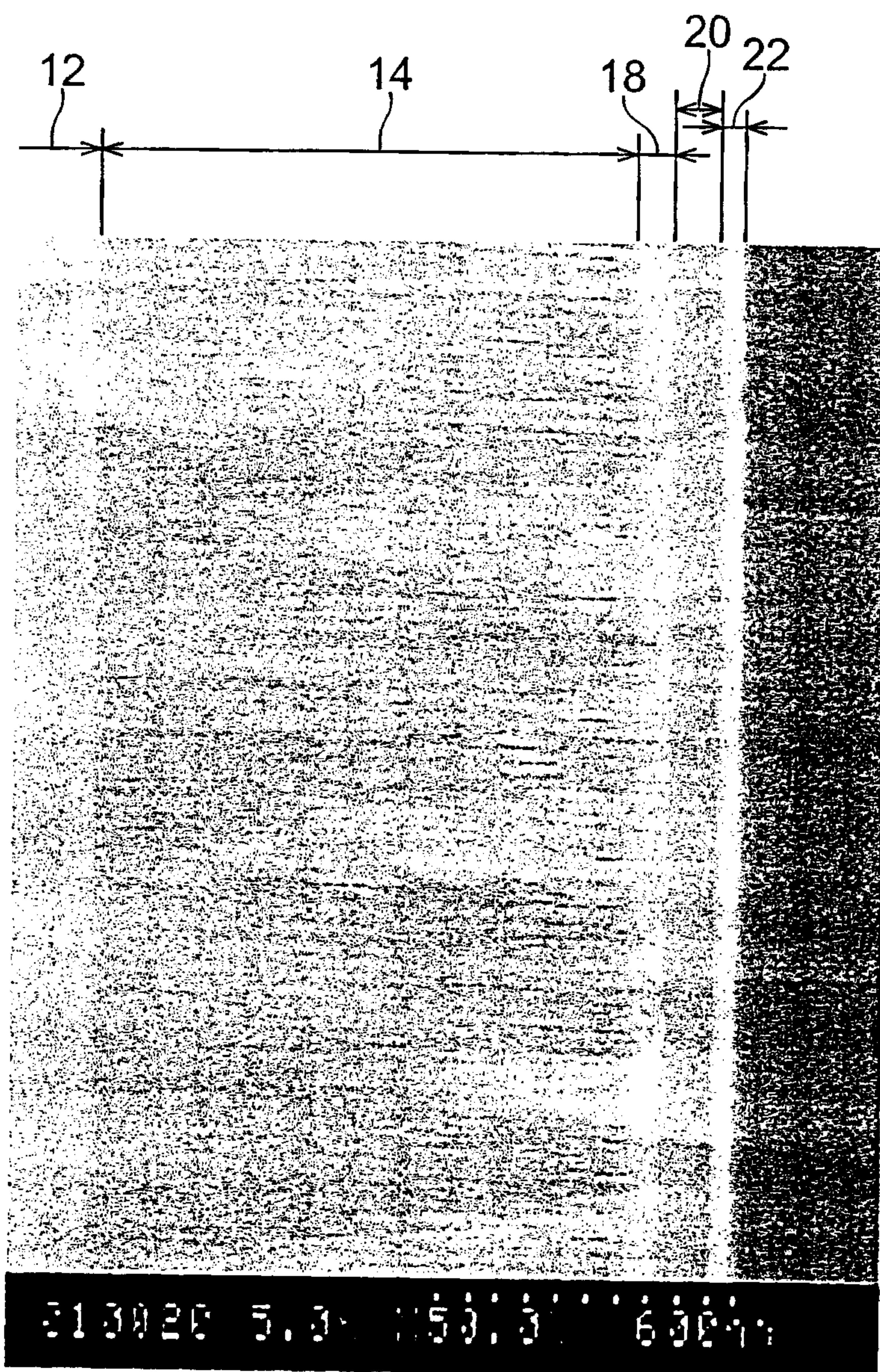
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***Fig. 10***

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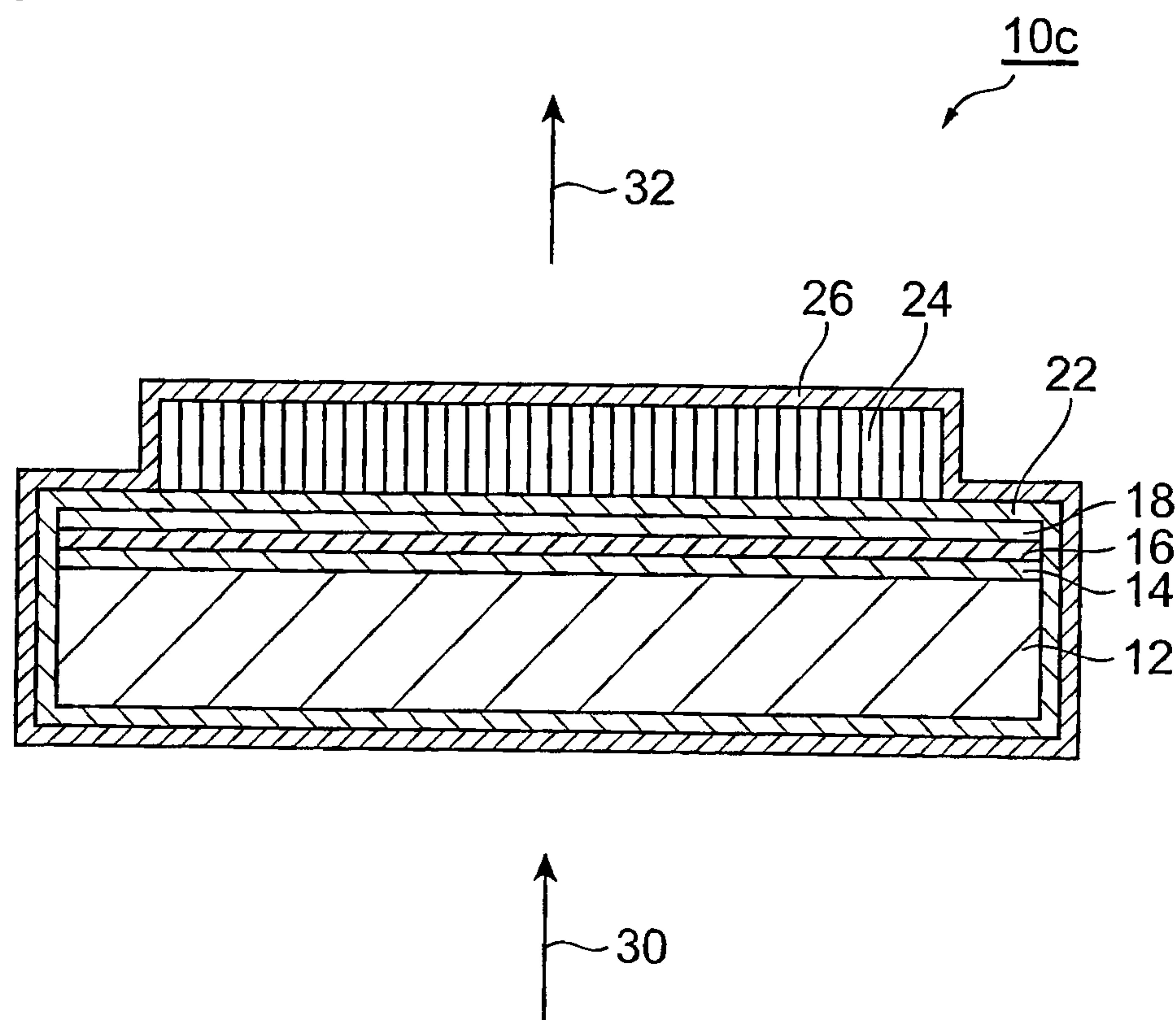
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**Fig.11**



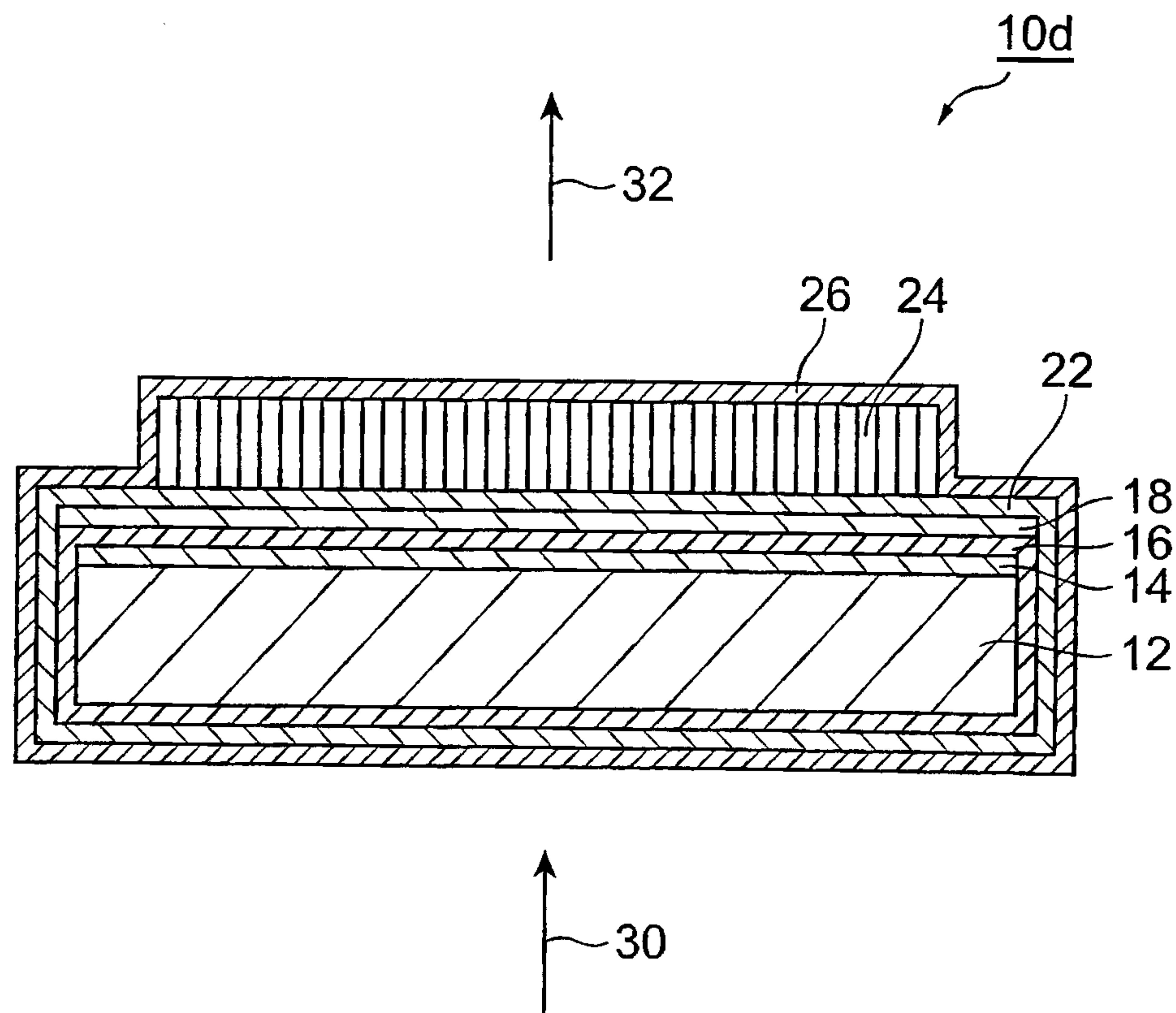
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**Fig.12**

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**Fig.13**

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**Fig.14**