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**Lasser et al.**

[11] **3,760,216**
[45] **Sept. 18, 1973**

# [54] ANODIC FILM FOR ELECTRON MULTIPLICATION

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[73] Assignee: **The United States of America as represented by the Secretary of the Army**

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[21] Appl. No.: **220,673**

[52] **U.S. Cl.** ................ **313/94,** 313/103, 313/108 A
[51] **Int. Cl.** ........................................ **H01j 43/12**
[58] **Field of Search** ................ 313/108 A, 103, 104, 313/94

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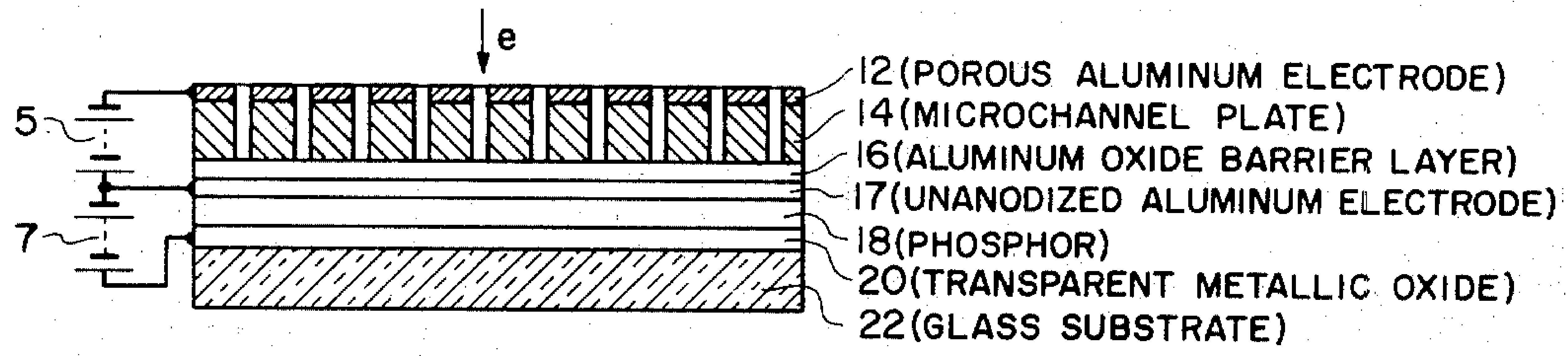
## [57] ABSTRACT

A plurality of electron multipliers which are basically similar in construction but have different specific characteristics. These characteristics include a solid or porous electron producer and/or preamplifier on one side of a microchannel plate with a separately prepared glass substrate having a transparent metallic oxide layer, a phosphor layer, and a transparent cathode, singly or in combination on one side of the glass substrate. The microchannel plate and glass substrate are held together mechanically with the electron producer or preamplifier and the glass substrate on the outermost sides.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment to us of any royalties thereon.

**17 Claims, 13 Drawing Figures**



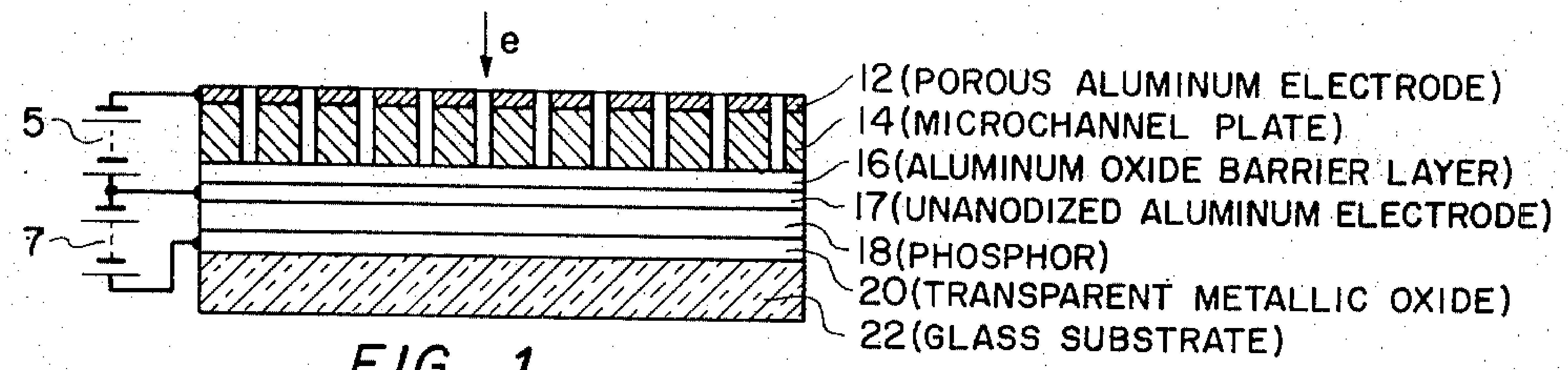


FIG. 1

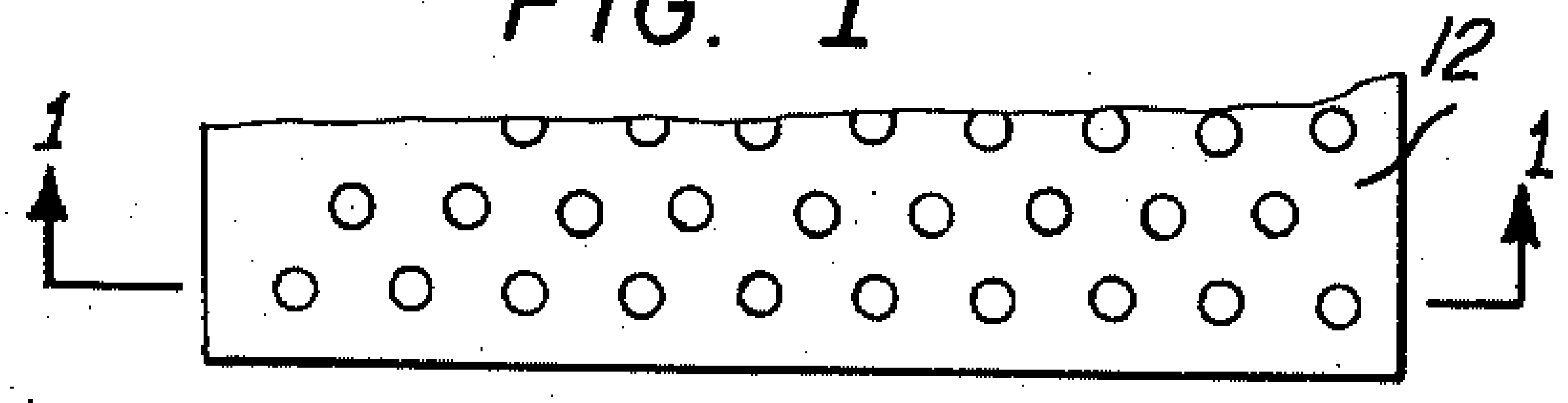


FIG. 1a

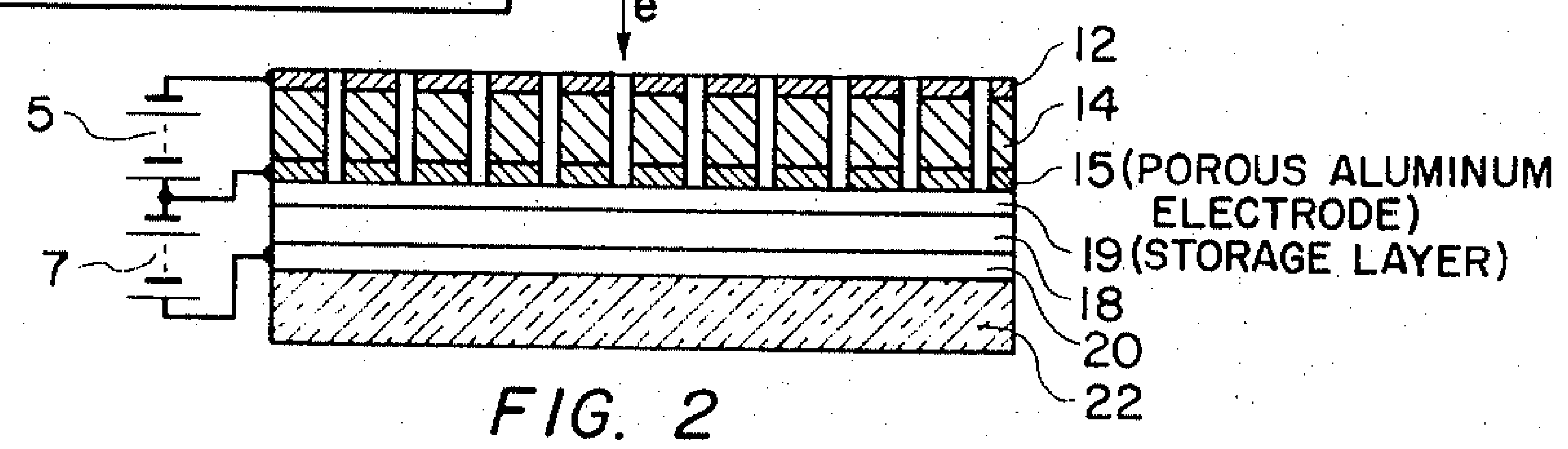


FIG. 2

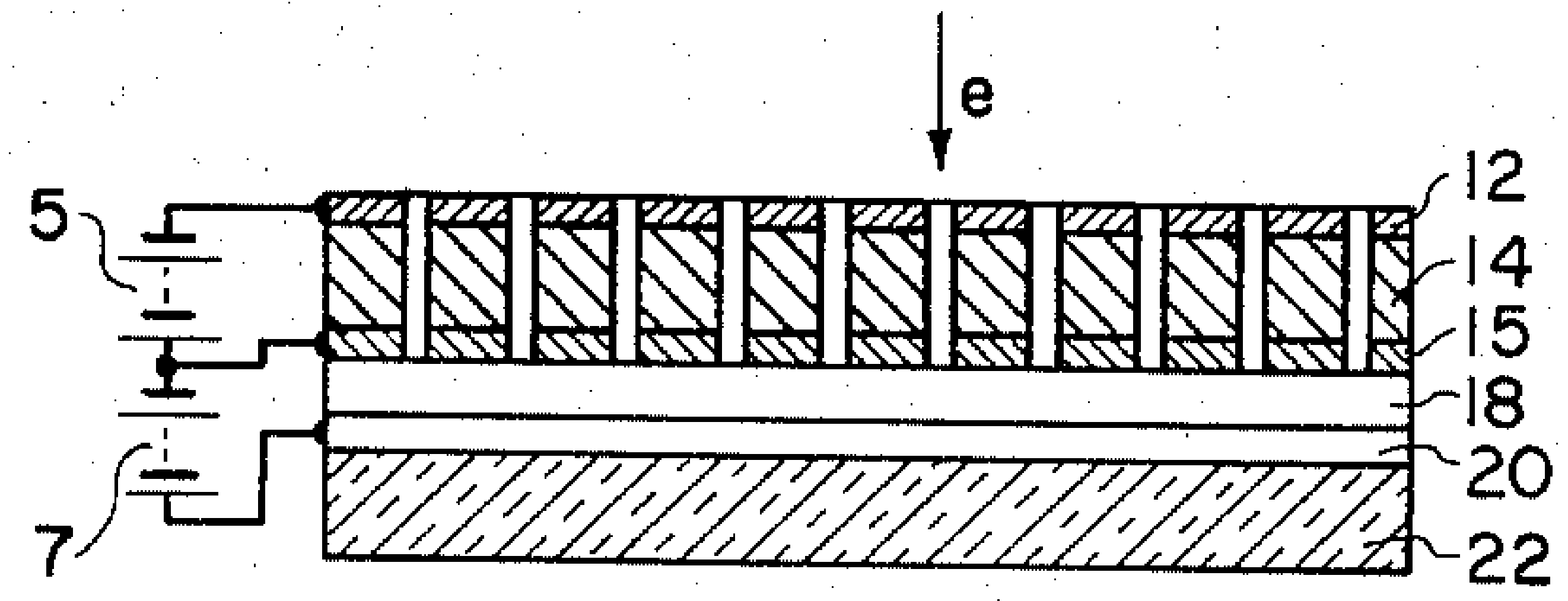


FIG. 3

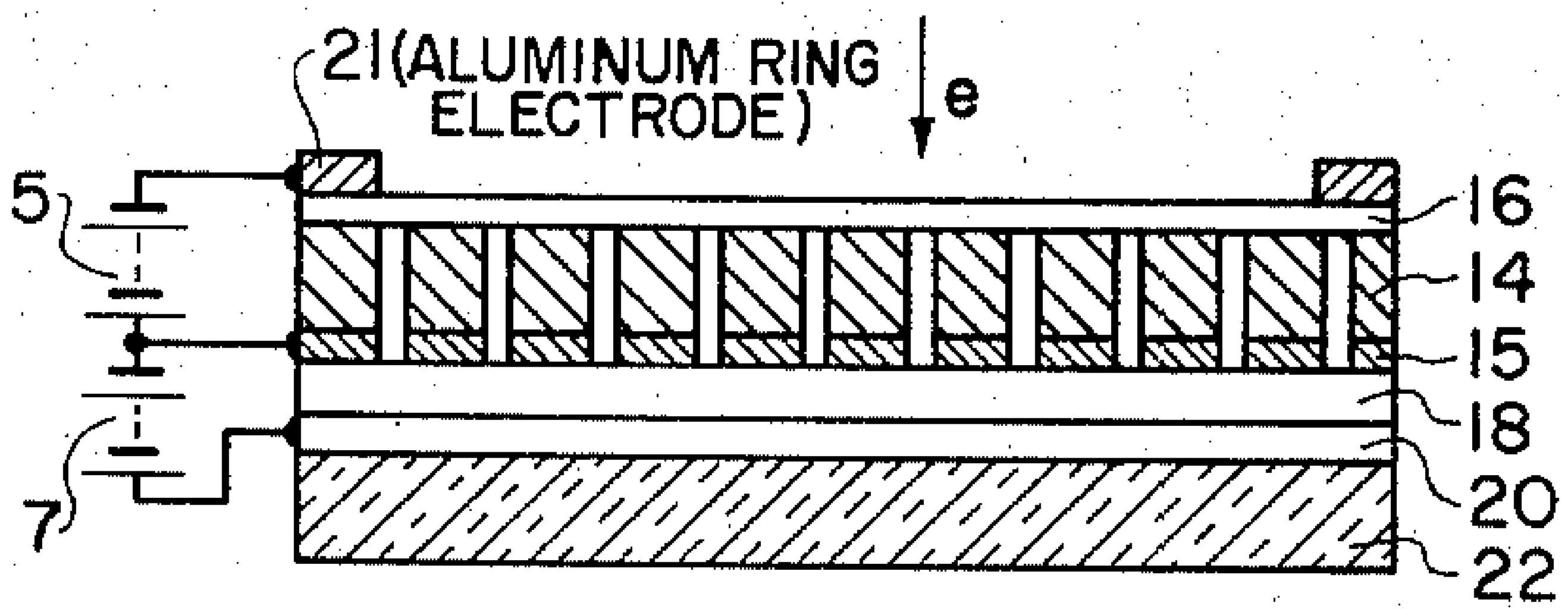


FIG. 4

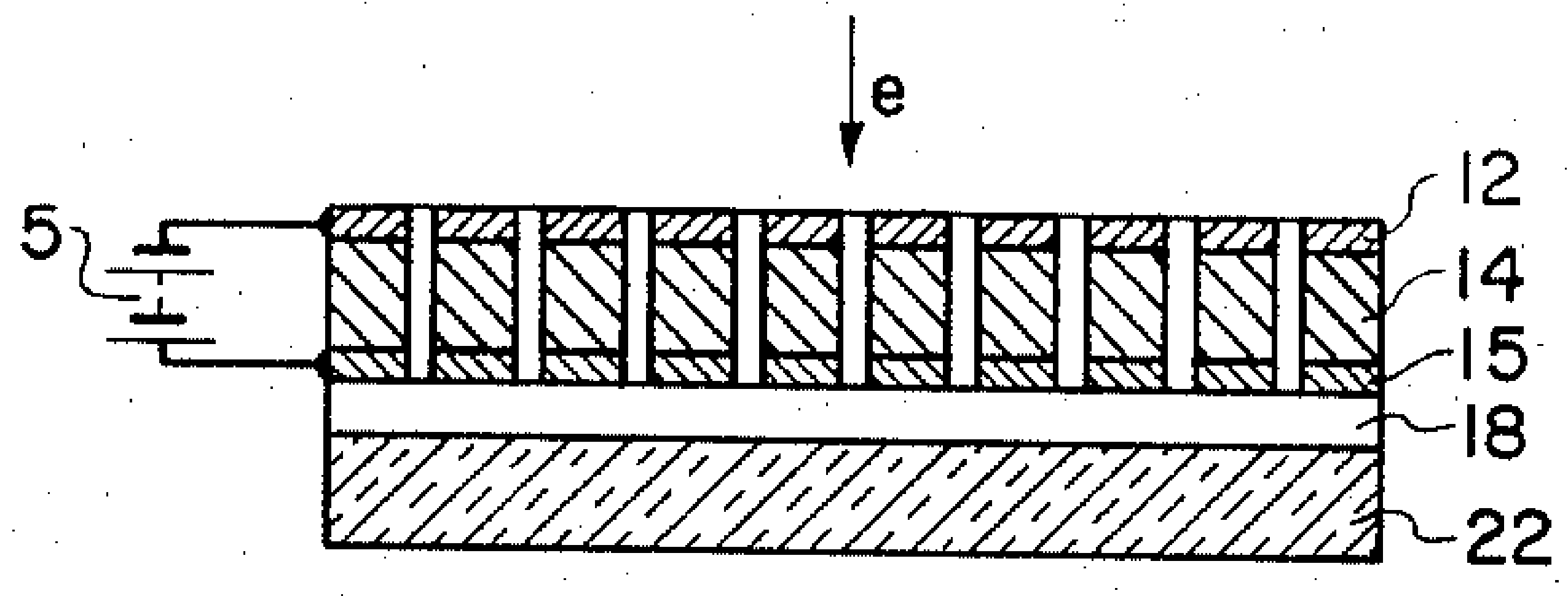


FIG. 5

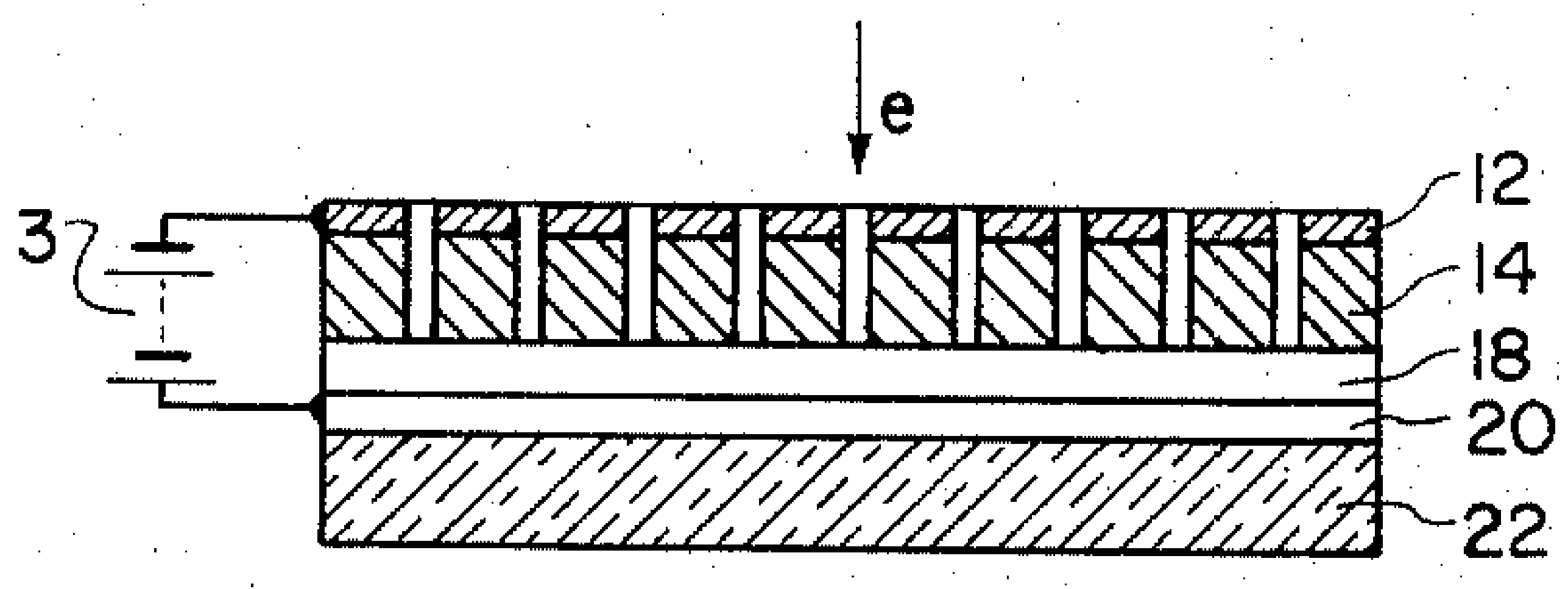


FIG. 6

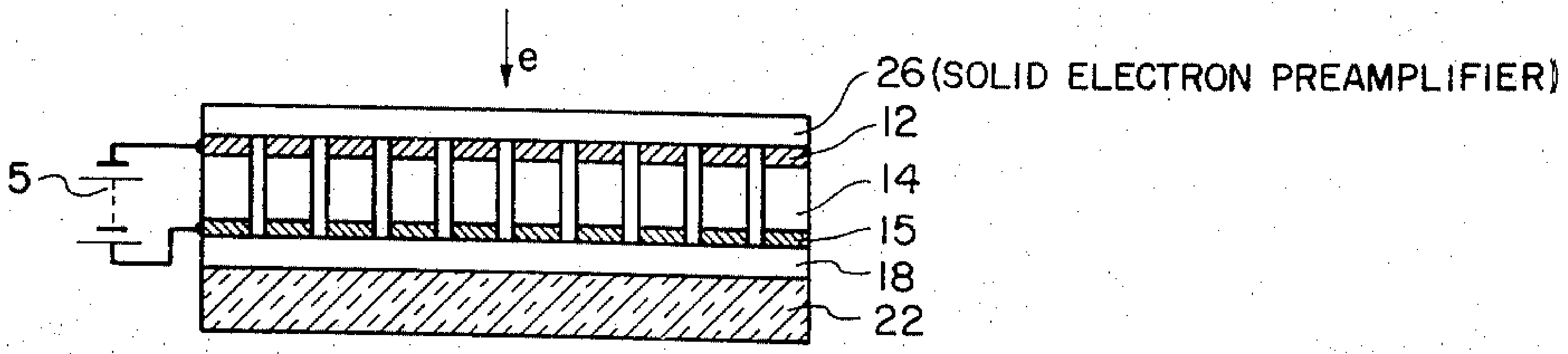


FIG. 7

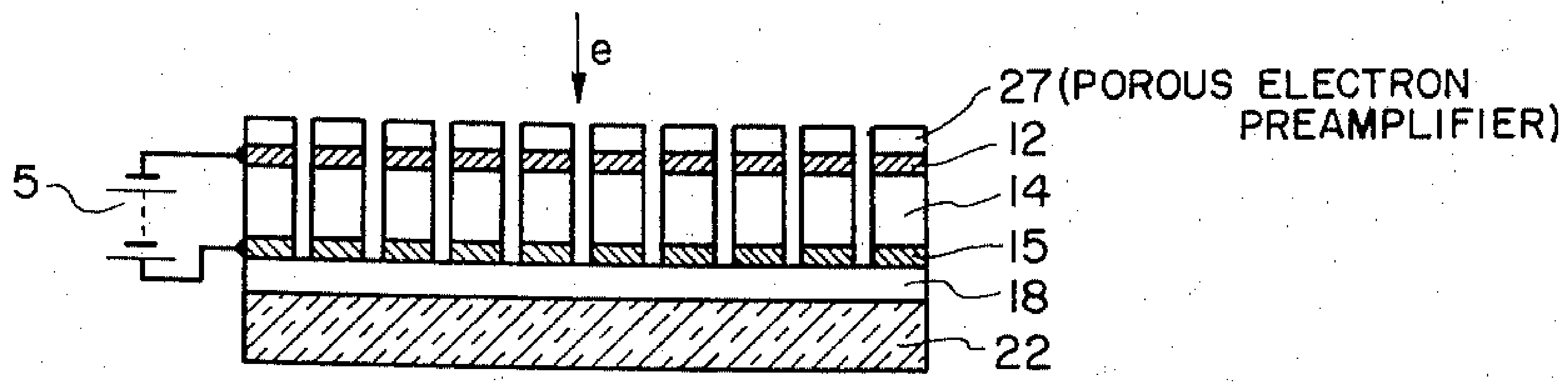


FIG. 8

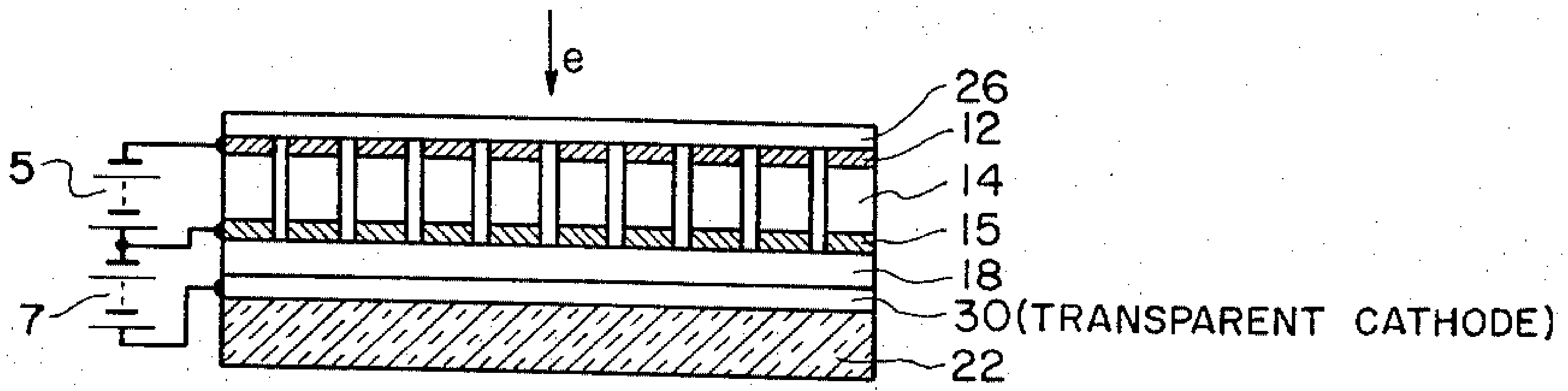


FIG. 9

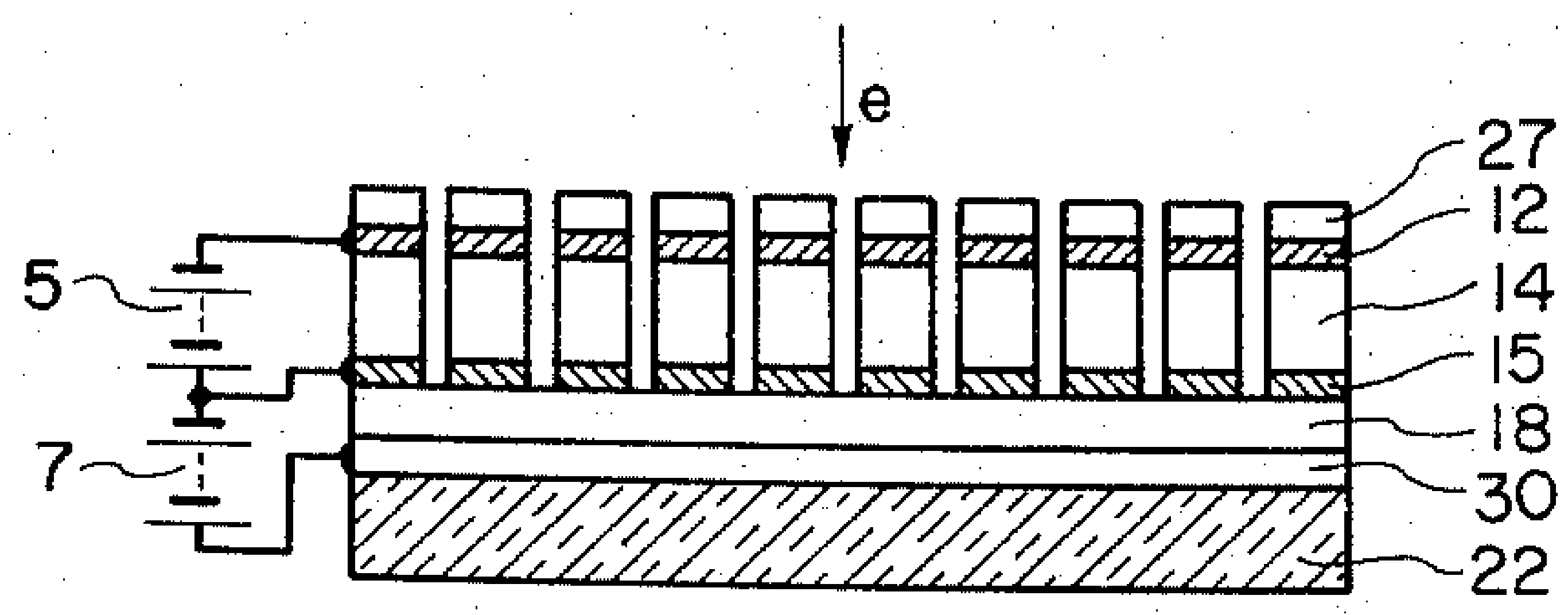


FIG. 10

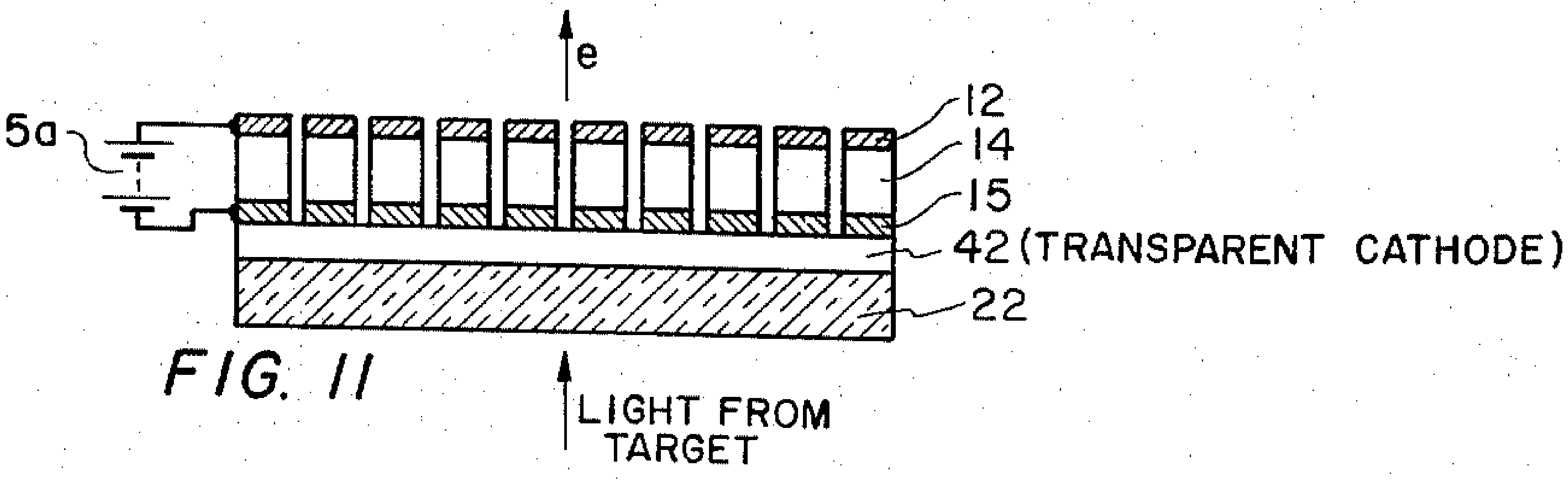


FIG. 11

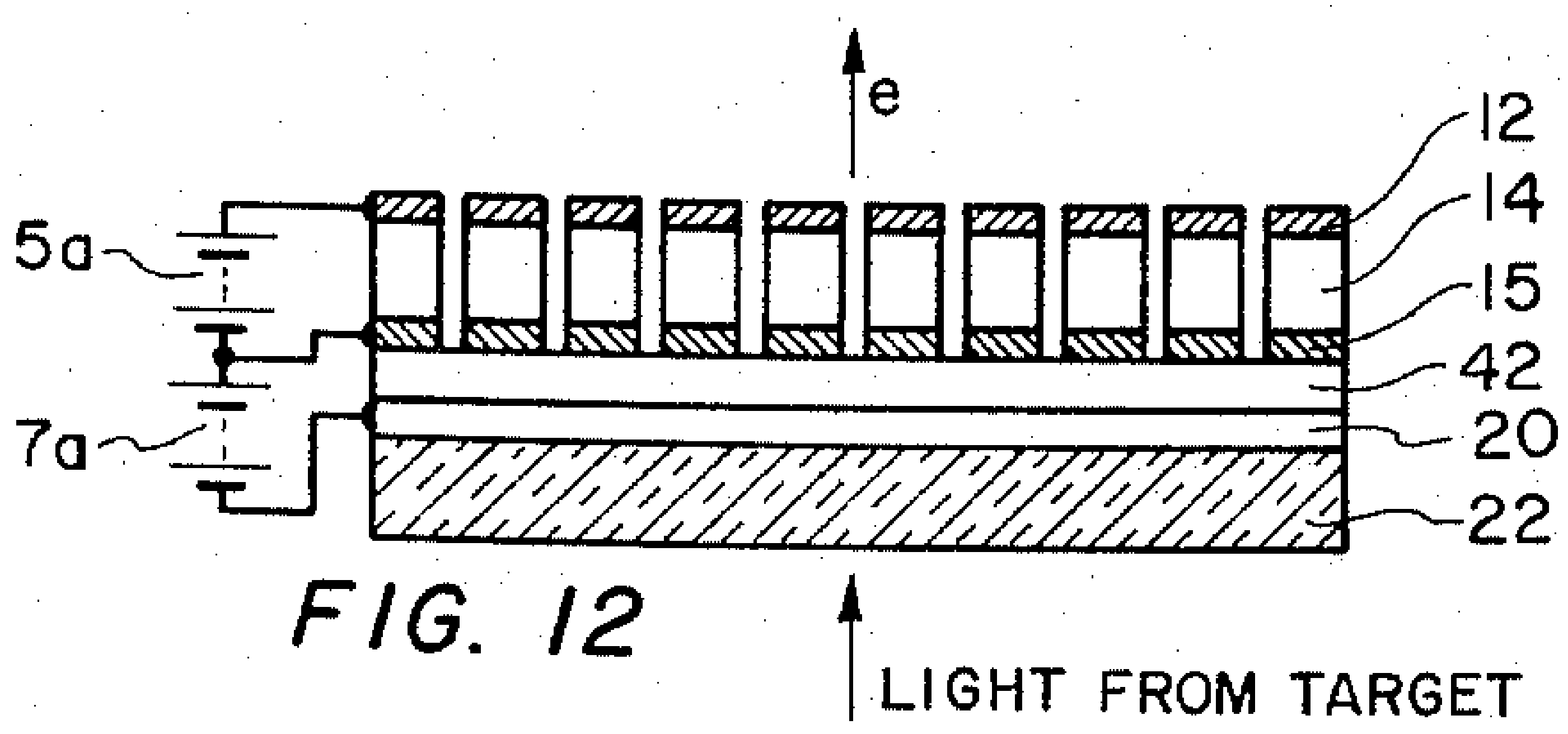


FIG. 12

# ANODIC FILM FOR ELECTRON MULTIPLICATION

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment to us of any royalties thereon.

## BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates to improved anodic films having electron multiplication and tunneling phenomenon and the methods for producing them. These anodic films may be used in photomultiplier or image intensifier tubes, and are an improvement over prior microchannel electron multipliers used in amplifying an image.

The anodic films comprise a glass substrate with subsequent layers of a transparent conductor, phosphor and metalic oxide deposited thereon, either singly or in combinations, and a thin plate of partially conducting material with microscopic channels therethrough having a first electrode and a second electrode on opposite sides of the thin plate of partially conducting material. The second electrode is mechanically held contiguous with one of the layers built up on the separately prepared glass substrate. A voltage source is connected across the first and second electrodes with the first electrode being at some negative voltage and the second electrode being at ground potential. Electrons entering the channels through the first electrode side are accelerated through the microscopic channels to the second electrode side. It is possible that a small number of the electrons that enter the channel may pass all the way through without striking the side thereof. Normally, though, an electron entering the channel will strike the side of the channel and dislodge on the order three of four secondary electrons. These secondary electrons gain a high electrical potential very quickly due to the electric field within the channel produced by the voltage source. Each of these secondary electrons normally strikes the channel wall and thus dislodges three or four more secondary electrons. This effect is repeated through the channel with subsequent electron multiplication at the output of the channel. The loss of electrons along the channel wall, due to secondary emission, are replenished by a small current flow, through the partially conducting wall coating, caused by the voltage source connected between the first and second electrodes. Thus, a very large multiple of electrons exit the microscopic channels.

The electrons emitted from the channels are injected into the phosphor layer. The phosphor emits light according to the intensity and number of the electrons injected therein. The transparent conductor layer is included so that a second voltage source may be applied across the phosphor to increase the intensity of electrons even more when entering the phosphor, and further to easily allow illumination of the phosphor to pass through the transparent conductor layer. The image of an electron beam swept across the first electrode of the microchannel plate is therefore, amplified by electron multiplication within the channels and is displayed by illumination of the phosphor through the glass substrate.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a sectional view of an anodic film for a direct image intensifier using a microchannel plate with its related electrodes and a phosphor layer, a metallic oxide layer, and glass substrate in accordance with the invention;

FIG. 1*a* is a top view of the anodic film illustrated in FIG. 1;

FIG. 2 shows a modification of FIG. 1 in which an electron storage layer is included;

FIG. 3 shows a slight modification of FIG. 1;

FIG. 4 illustrates a modification of FIG. 1 in which the barrier layer of the microchannel plate is inverted and a ring electrode is connected around the barrier layer;

FIG. 5 illustrates an anodic film with the phosphor layer contiguous with the microchannel plate;

FIG. 6 is a slight modification of FIG. 5;

FIG. 7 is a modification of FIG. 5 in which a solid electron preamplifier is added thereto;

FIG. 8 shows a porous preamplifier substituted for the solid preamplifier;

FIG. 9 shows a modification of FIG. 7 in which an electron storage layer is added thereto;

FIG. 10 shows a modification of FIG. 8 in which an electron storage layer is added thereto;

FIG. 11 illustrates an embodiment in which a transparent cathode is contiguous with both the glass substrate and one side of the microchannel plate; and

FIG. 12 shows a modification of FIG. 11 in which a transparent metallic oxide layer is added thereto.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, FIG. 1 shows a microchannel plate **14**, also called a thin plate of partially conducting material in this application, with other elements of a direct view image intensifier attached thereto. The microchannel plate **14** is prepared separately and is then attached to the glass substrate **22** and the various layers built up on substrate **22.** Microchannel plate **14,** including the barrier layer **16,** is made of tungsten doped aluminum oxide, and is prepared in accordance with the method disclosed in copending patent application entitled "Method of Preparing a Semiporous Film of Aluminum Oxide by High Voltage Anodization," filed Dec. 22, 1971 and having Ser. No. 210,909 by co-inventor, Howard G. Lasser. An alloying constituent of tungsten is applied in the base aluminum metal by the substitutional doping method prior to anodizing and remains there unanodized until anodized by the process disclosed in the above noted application. After preparation of the microchannel plate **14** with barrier layer **16** thereon, a coat of aluminum is vapor deposited on both the porous side and the barrier layer **16** side of the microchannel plate **14.** Aluminum layer **12,** deposited on the porous side of plate **14,** is designated as a first electrode, and aluminum layer **17,** which is formed on barrier layer **16,** is designated as a second electrode. A voltage source **5** is connected across electrodes **12** and **17** with electrode **17** being at ground potential and electrode **12** being at a negative 1,000 to 1,500 volts. The voltage on electrode **12** that is required for proper electron multiplication depends upon the thickness of the microchannel plate **14** and its barrier layer **16** along with the diameter of the microscopic channels.

A layer of transparent metallic conductor **20,** such as tin oxide or indium oxide, is vapor deposited on one side of glass substrate **22**. A layer of luminous material **18**, such as phosphor, is then deposited on layer **20**. The phosphor **18** may be evaporated on layer **20** or applied by a slurry method. The glass substrate **22** may be fiber optics or a solid transparent layer of glass. The microchannel plate assembly and the glass substrate assembly are held together by mechanical means, such as clamping. A second voltage source **7** is then applied between aluminum anode **17** and the transparent metallic conductor layer **20** to produce a strong electric field across the phosphor layer **18**. This voltage is generally from 5,000 to 6,000 positive volts with the positive terminal on the metallic conductor layer **20**.

In the operation of the direct view image intensifier of FIG. **1**, assume that an electron, *e*, from a photocathode (not shown) goes through the porous aluminum electrode **12**, designated as the first electrode, and into one of the channels of microchannel plate **14**. When this electron strikes the wall inside the channel it generally dislodges three or four secondary electrons therefrom that, in turn, are accelerated down the channel toward the aluminum oxide barrier layer **16**. Voltage source **5**, connected between first electrode **12** and second electrode **17** accelerate these secondary electrons through the channel causing many additional collisions, with a resulting electron multiplying effect. For each electron that enters one of the channels of plate **14** as many as a thousand or more electrons are emitted therefrom. These thousand or more electrons enter barrier layer **16** and are transferred therethrough by a voltage gradient caused by voltage source **5** applied between electrodes **12** and **17**. The aluminum oxide material of the microchannel plate **14** is doped with tungsten so that potential source **5** causes a small current to flow along the channel walls to replenish the secondary electrons that are dislodged therefrom.

In the embodiment of FIG. **2**, the transparent metallic conductor **20** and phosphor layer **18** deposited on glass substrate layer **22** are prepared under the same method as that explained above for FIG. **1**. FIG. **2** shows a modification of FIG. **1** in which the barrier layer is removed from plate **14** and a porous aluminum electrode **15** is deposited thereon. In this embodiment, storage layer **19** is also added thereto. The barrier layer may be removed by simply shaving it off. After the barrier layer is shaved off, porous aluminum electrodes **12** and **15** are vapor deposited on each side of the microchannel plate **14**. Aluminum is evaporated over plate **14** for a limited period of time such that deposits are only built up on the solid portion and leave the channels open. A storage layer **19**, made of a material such as cadmium sulfide, is vapor deposited over porous aluminum electrode **15** until layer **19** is solid, i.e., layer **19** closes that end of the microchannels. A voltage source **5** is connected across the microchannel plate **14** in the same manner as discussed in FIG. **1** above with the ground terminal connected to electrode **15**. The second voltage source **7** is connected across storage layer **19** and phosphor layer **18** with its terminals attached to electrode **15** and layer **20**. Voltage source **7** is between 4,000 and 6,000 positive volts on layer **20** for proper acceleration of the electrons into storage layer **19** and on into the phosphor layer **18**. Storage layer **19** requires that about 10 times the number of electrons be stored therein for illumination of phosphor **18** than that required in the configuration of FIG. **1** where the electrons moved directly through the aluminum electrode **17** into the phosphor layer **18**. Plate **14**, with storage layer **19** thereon, is mechanically held to glass substrate **22** assembly, with layers **19** and **18** being contiguous with each other.

FIG. **3** is a modification of FIG. **1**. Plate **14** is porous and has first and second electrodes **12** and **15**, respectively, as in FIG. **2**. Storage layer **19** is removed. Therefore, the electrons passing through microchannel plate **14** are transferred directly into phosphor layer **18**. Electrons enter the channels of plate **14** and go through the process of dislodging secondary electrons therefrom under the influence of an electric field that is established by voltage source **5**. Phosphor layer **18** is contiguous with second electrode **15**, with substrate assembly **22** and plate **14** held together mechanically. A second voltage source **7** is connected between second electrode **15** and layer **20**. This second voltage source creates an electric field across the phosphor layer **18** for further energizing the electrons ejected out plate **14**. This phenomen provides a much higher illumination level of the phosphor **18** when viewed through glass substrate **22** than the two previous configurations. The voltage on electrodes **12** and **15** are the same as above, i.e., 1,000 to 1,500 volts with electrode **15** at ground potential. The potential of source **7** is not nearly as high as the two previous configurations. It can easily be seen that the electrons emitted from microchannel plate **14** already possess a good amount of energy, therefore, less voltage is required to accelerate the electrons into the phosphor layer **18**.

FIG. **4** shows another modification of the embodiment in FIG. **1**. In this configuration, microchannel plate **14** is inverted in the anodic film, i.e., barrier layer **16** is facing toward the photocathode (not shown) from which a typical electron, e, enters the anodic film. An aluminum ring electrode **21**, designated as the first electrode, encircles barrier layer **16**. In this configuration barrier layer **16** acts as an electron preamplifier. The transparent metallic conductor layer **20** and phosphor layer **18** are deposited on glass substrate **22** as explained above. Phosphor layer **18** is mechanically held against electrode **15**. First voltage source **5**, of from 1,000 to 1,500 volts, is applied between the first electrode **21** and second electrode **15**. Electrons entering barrier layer **16** are accelerated through the channels of plate **14** by voltage source **5**. In this embodiment, as in the embodiment of FIG. **3**, electrons emitted out of the channels of plate **14** are injected directly into phosphor **18**. Voltage source **7**, having the same value as that of the configuration of FIG. **3**, insures that the electrons entering phosphor **18** have sufficient energy to emit light out glass substrate **22**.

In the configuration of FIG. **5**, since phosphor layer **18** on glass substrate **22** is held contiguous with electrode **15**, electrons entering the channels of plate **14** are accelerate therethrough by voltage source **5** with sufficient energy to illuminate phosphor layer **18**.

The embodiment of FIG. **6** shows a porous microchannel plate **14** with first electrode **12** deposited thereon. Phosphor layer **18** is contiguous with plate **14** opposite first electrode **12**. A voltage source **3** is applied between electrode **12** and metallic conductor **20**, with **20** being designated the second electrode. Source **3** accelerates electrons through the plate **14** and into phosphor layer **18** with sufficient energy to light the phosphor and emit the light therefrom through glass substrate **22.** Source 3 has a voltage of about 5,000 to 6,000 volts.

The embodiment of FIG. 7 includes a solid electron preamplifier material **26** that is vapor deposited on the input side contiguous with deposited first electrode **12** of microchannel plate **14.** When the channels within **14** are made very small, say **25** microns or less in diameter, very little of preamplifier material **26** filters into the channels. This preamplifier material may be gallium arsenide or galium phosphide, either of which is rich in secondary electrons for use in the multiplication process of a direct view image intensifier. Electrons striking peramplifier **26** excite the secondary electrons therein whereupon some of the excited electrons are ejected into the channels within microchannel plate **14** for multiplication. The electrons ejected from plate **14** strike phosphor layer **18** with sufficient energy to emit light through glass substrate **22.**

The embodiment shown in FIG. **8** is the same as that shown in FIG. **7** except that the electron preamplifier is porous, and is designated as numeral **27.** Porous preamplifier **27** is also vapor deposited in the manner as for the configuration of FIG. **7.** The deposition is ceased, however, before the channels are sealed. More electrons enter the channels of plate **14** because of the electron rich preamplifier material emitting many primary electrons causing more secondary electrons to be emitted from the tungsten doped aluminum oxide than when the preamplifier material is not used as shown in the embodiments of FIGS. **1–6.** In the embodiment of FIG. **8,** about 20–40 secondary electrons are emitted from the walls of material **27** when one electron strikes the wall. This added number of electrons travel through the channel, accelerated by the voltage of voltage source **5,** and strike the phosphor layer **18** immediately after passing through the channel. The voltage of source **5** is, again, between 1,000 and 1,500 volts. This voltage proves to be sufficient for causing illumination of the phosphor layer.

The embodiment of FIG. **9** is the same as the embodiment shown in FIG. **7** but with an added layer of transparent cathode **30.** This transparent cathode, or transparent cathodic film may be, for instance, a solid layer of gallium aresnide. Transparent cathode **30** is vapor deposited on glass substrate **22.** The phosphor layer is then deposited on transparent cathode **30** in the same manner as described above. The value of voltage source **5** is again 1,000 to 1,500 volts. Source **7** may be about 4,000 to 5,000 volts.

The configuration of FIG. **10** is the same as that for FIG. **8** except that transparent cathode **30** is deposited on glass substrate **22** prior to deposit of the phosphor layer **18.** Source **7** may be about 4,000 to 5,000 volts.

Both of the embodiments shown in FIG. **11** and **12** are illustrated differently from the embodiments illustrated in FIGS. **1–10.** In these embodiments, photons entering glass substrate **22** are converted to electrons exiting plate **14.** FIG. **11** shows light from a target entering glass substrate **22** and, in turn, emission of electrons from transparent cathode **42.** Transparent cathode **42** is a solid layer of gallium arsendie or gallium phosphide that is vapor deposited on glass substrate **22.** The electrons emitted from transparent cathode **42** enter into the channels of microchannel plate **14** and are accelerated therethrough by a voltage source ***5a.*** Voltage source ***5a*** is from 1,000 to 1,500 volts. In this embodiment the polarity of voltage source ***5a*** is positive on electrode **12** and is at ground potential on electrode **15.**

In FIG. **12,** two voltages sources, *5a* and *7a*, are connected with polarities as shown. Source ***7a*** has its negative lead connected to a layer of transparent metallic conductor **20** and its positive lead connected to electrode **15.** Source ***5a*** has its positive lead connected to electrode **12** and its negative lead connected to terminal **15.** The electric field produced by source ***7a*** causes secondary electrons to be more readily ejected from material **42** than was the case in the embodiment of FIG. **11** which does not have a voltage source across layer **42.** Photons passing through glass substrate **22** into the transparent cathode **42,** of both embodiments shown in FIGS. **11** and **12,** cause ejection of electrons from cathode **42** into microchannel plate **14.** These electrons start the multiplication process within plate **14** that results in an electron image emitted from the electrode **12** side according to the intensity of photon input through glass substrate **22.**

We claim:

**1.** A direct view image intensifier anodic film for electron multiplication comprising:

a thin plate of partially conducting material containing a plurality of microscopic channels therethrough and having a first electrode on one side and a second electrode on the other side thereof;

a layer of luminous material contiguous with said second electrode;

a transparent metallic conductor contiguous with said layer of luminous material;

a glass substrate contiguous with said transparent metallic conductor; and

a voltage supply connected between said first and second electrodes and between said transparent metallic conductor and said second electrode whereby electrons passing through said microscopic channels are accelerated and multiplied by the electrical potential difference provided by said voltage supply.

**2.** An anodic film as set forth in claim **1** wherein said thin plate of partially conductive material is aluminum oxide that is doped with tungsten to provide replenishing electrons removed from the walls of said microscopic channels by secondary emission and wherein said first and second electrons are aluminum.

**3.** An anodic film as set forth in claim **2** wherein said layer of luminous material is phosphor.

**4.** An anodic film as set forth in claim **3** wherein said transparent metallic conductor is tin oxide.

**5.** An anodic film as set forth in claim **3** wherein said transparent metallic conductor is indium oxide.

**6.** A direct view image intensifier anodic film for electron multiplication comprising:

a thin plate of partially conductive material containing a plurality of microscopic channels therethrough and having a first electrode on one side and a second electrode on the other side thereof;

a layer of luminous material contiguous with said second electrode;

a transparent metallic conductor contiguous with said layer of luminous material;

a glass substrate contiguous with said transparent metallic conductor; and

a voltage supply connected between said first and second electrodes for providing electron accelration and multiplication through said small channels.

**7.** A direct view image intensifier anodic film as set forth in claim **6** wherein said layer of luminous material is phosphor.

**8.** A direct view image intensifier anodic film for electron multiplication comprising:

a thin plate of partially conducting material containing a plurality of microscopic channels therethrough and having a first electrode on one side and a second electrode on the other side thereof;

a layer of luminous material contiguous with said second electrode;

an electron preamplifier material contiguous with said first electrode;

a glass substrate contiguous with said layer of luminous material; and

a voltage supply connected between said first and second electrodes for providing electron acceleration and multiplication through said small channels.

**9.** A direct view image intensifier anodic film as set forth in claim **8** wherein said layer of luminous material is phosphor.

**10.** A direct view image intensifier anodic film as set forth in claim **9** wherein said electron preamplifier material is a solid layer of gallium arsenide.

**11.** A direct view image intensifier anodic film as set forth in claim **9** wherein said electron preamplifier material is a porous layer of gallium arsenide.

**12.** A direct view image intensifier anodic film for electron multiplication comprising;

a thin plate of partially conductive material containing a plurality of microscopic channels therethrough and having a first electrode on one side and a second electrode on the other side thereof;

a layer of luminous material contiguous with said second electrode;

an electron preamplifier material contiguous with said first electrode;

a transparent cathodic film contiguous with said layer of luminous material;

a glass substrate contiguous with said transparent cathodic film; and

a voltage supply connected between said first and second electrodes and between said transparent cathodic film and said second electrode whereby electrons passing through said small channels are accelerated and multiplied by the electrical potential difference provided by said voltage supplies.

**13.** A direct view image intensifier anodic film as set forth in claim **12** wherein said layer of luminous material is phosphor.

**14.** A direct view image intensifier anodic film as set forth in claim **13** wherein said electron preamplifier material is a solid layer of gallium arsenide.

**15.** A direct view image intensifier anodic film as set forth in claim **13** wherein said electron preamplifier material is a porous layer of gallium arsenide.

**16.** A direct view image intensifier anodic film as set forth in claim **14** wherein said transparent cathodic film is a solid layer of gallium arsenide.

**17.** A direct view image intensifier anodic film as set forth in claim **15** wherein said transparent cathodic film is a solid layer of gallium arsenide.

* * * * *