

[54] **ANODIC FILM FOR ELECTRON MULTIPLICATION**

[75] Inventors: Howard G. Lasser, Springfield; Bipin C. Almaula, Alexandria, both of Va.

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

[22] Filed: Jan. 25, 1972

[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

[56] **References Cited**

**UNITED STATES PATENTS**

2,975,290	3/1961	Spitzer .....	313/108 A X
3,458,745	7/1969	Shoulders .....	313/104
3,197,662	7/1965	Schneeberger .....	313/104
3,575,628	4/1971	Word .....	313/94 X

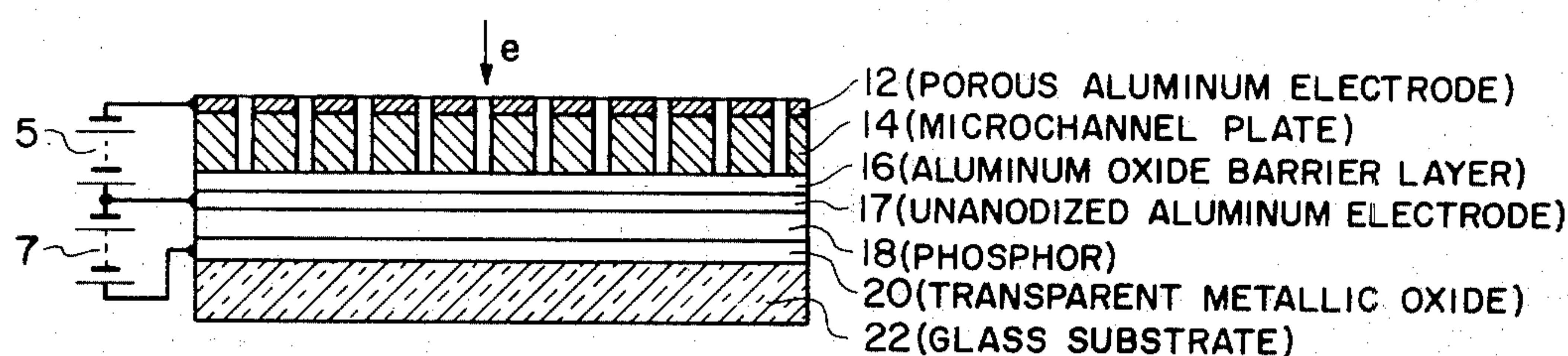
Primary Examiner—Palmer C. Demeo  
Attorney—Harry M. Saragovitz

[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**



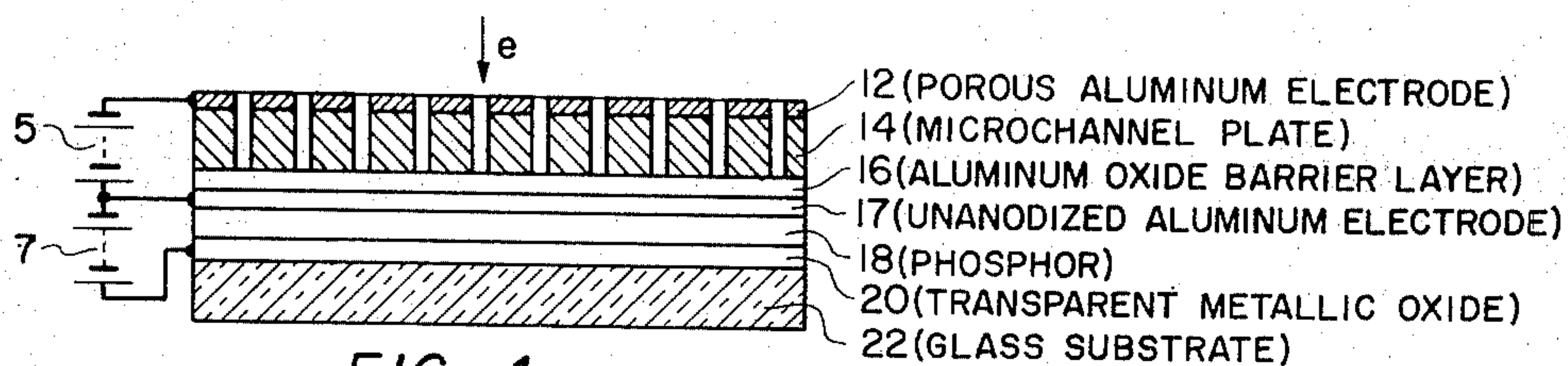


FIG. 1

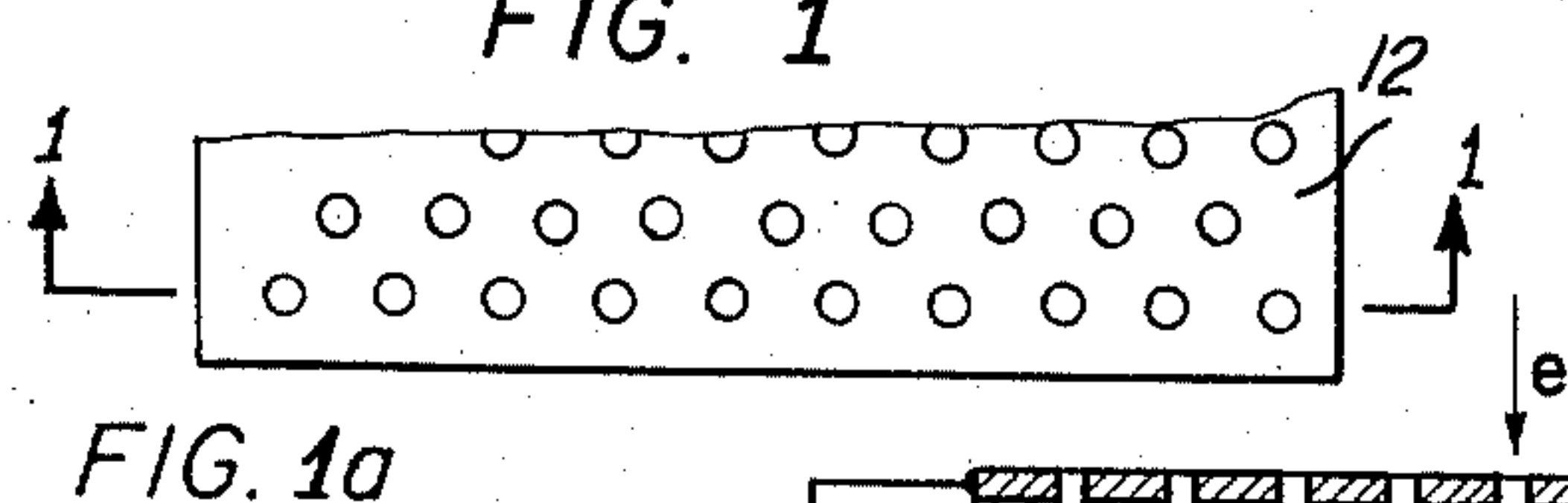


FIG. 1a

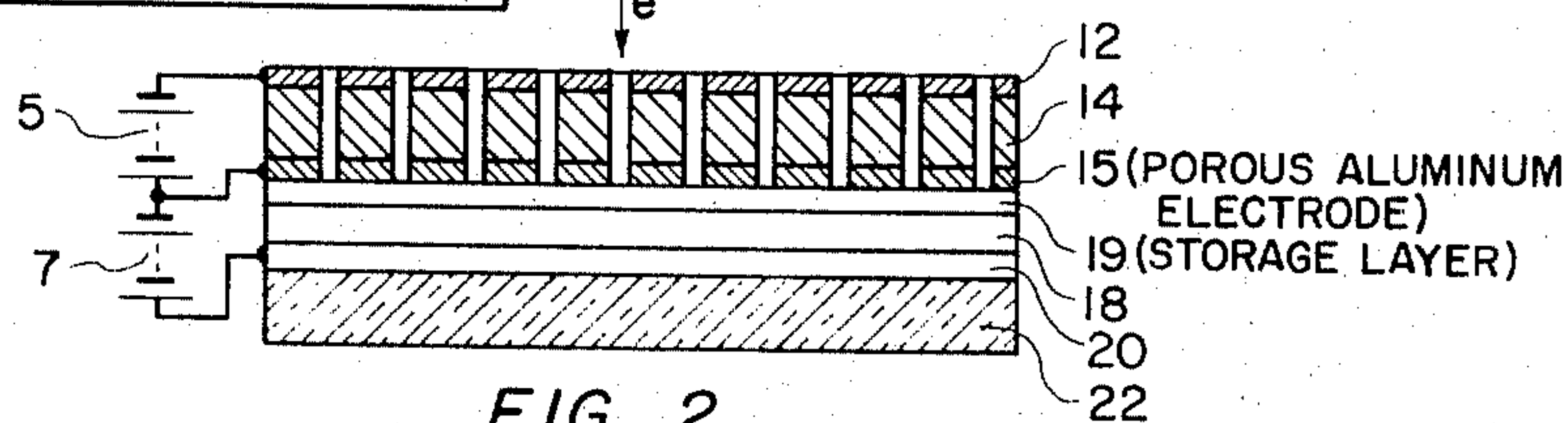


FIG. 2

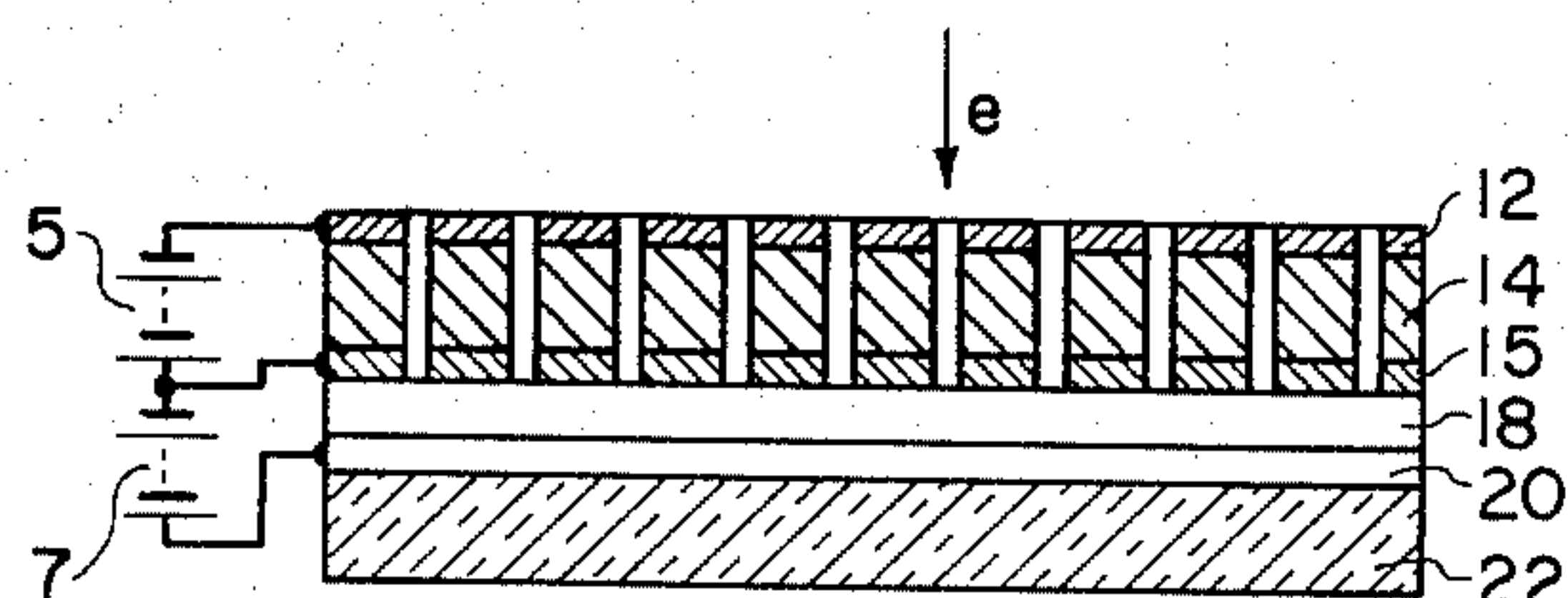


FIG. 3

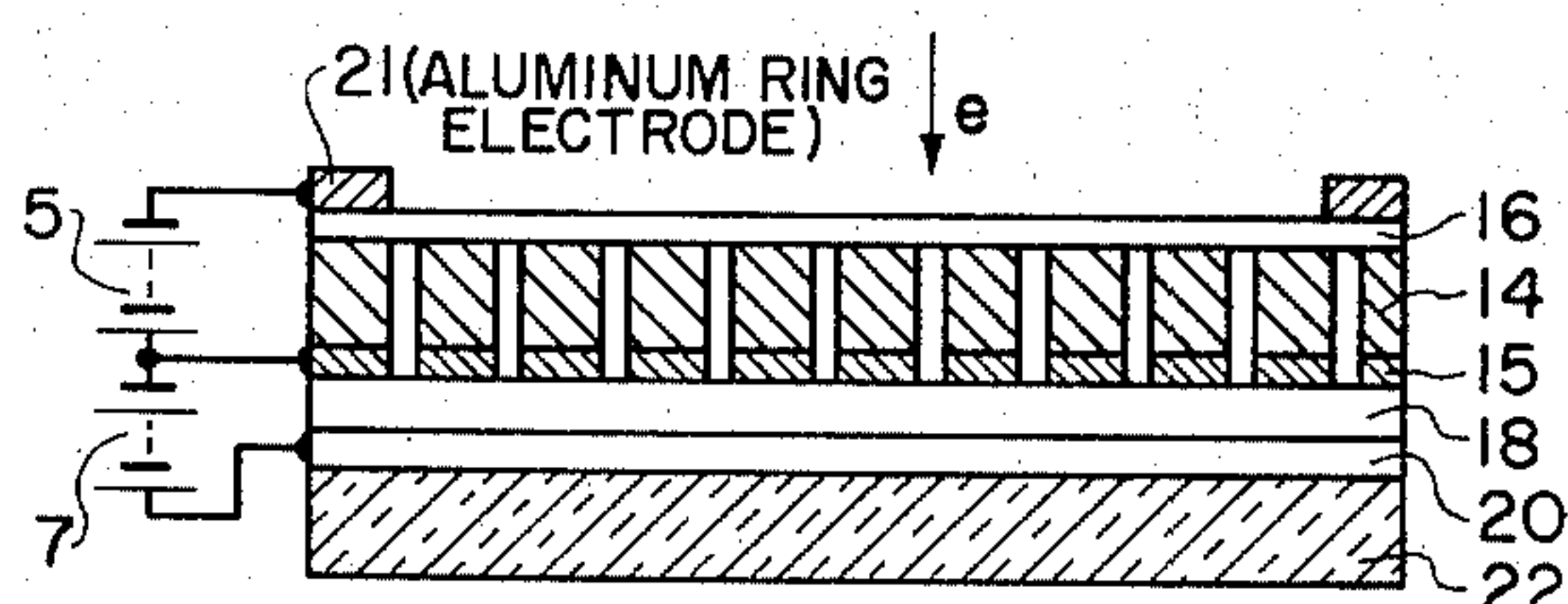


FIG. 4

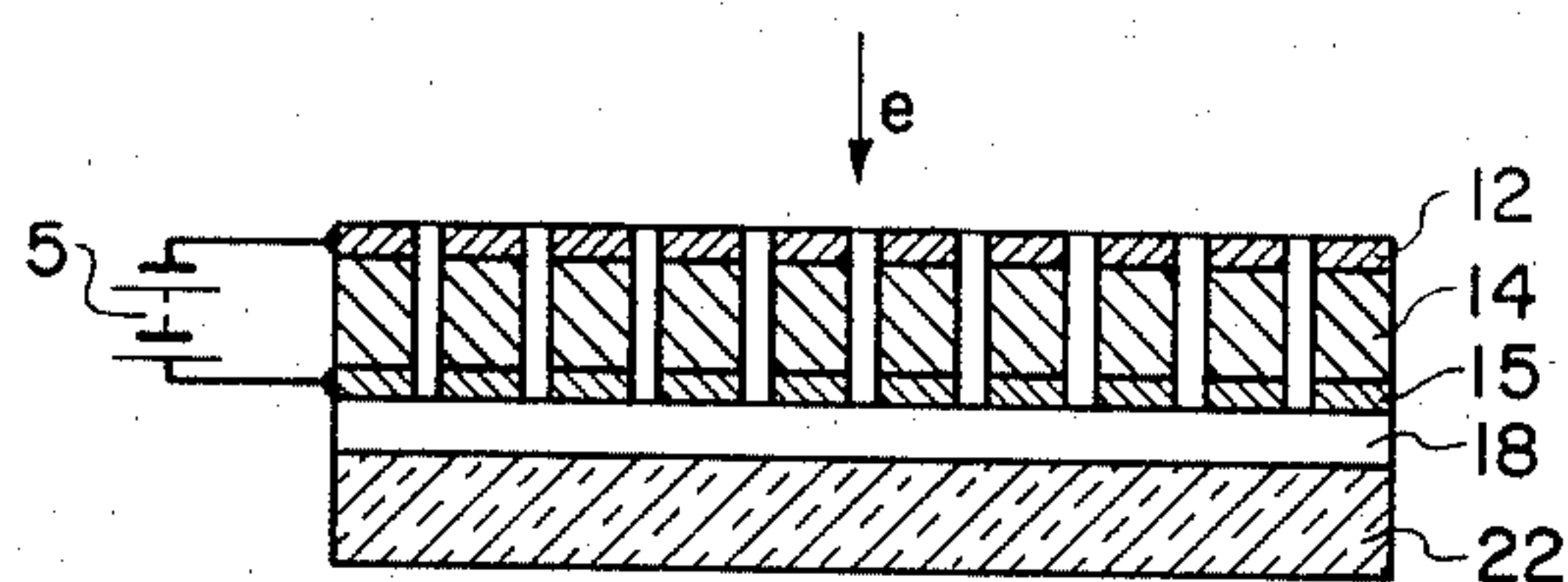


FIG. 5

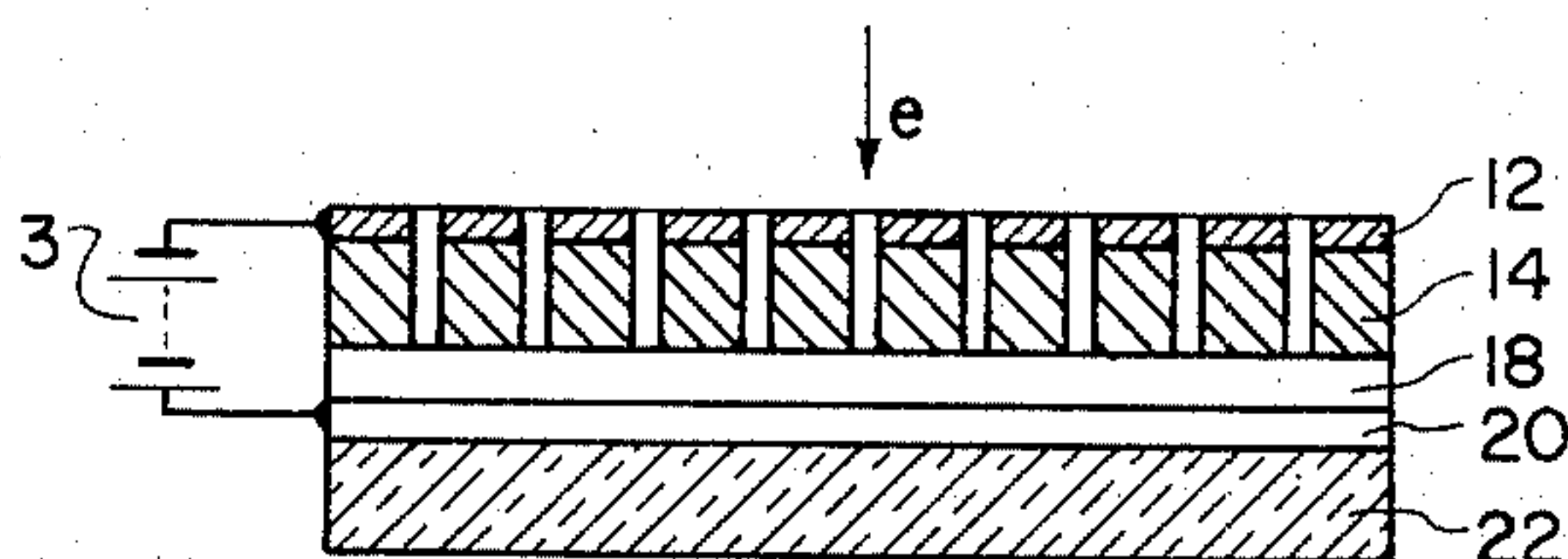
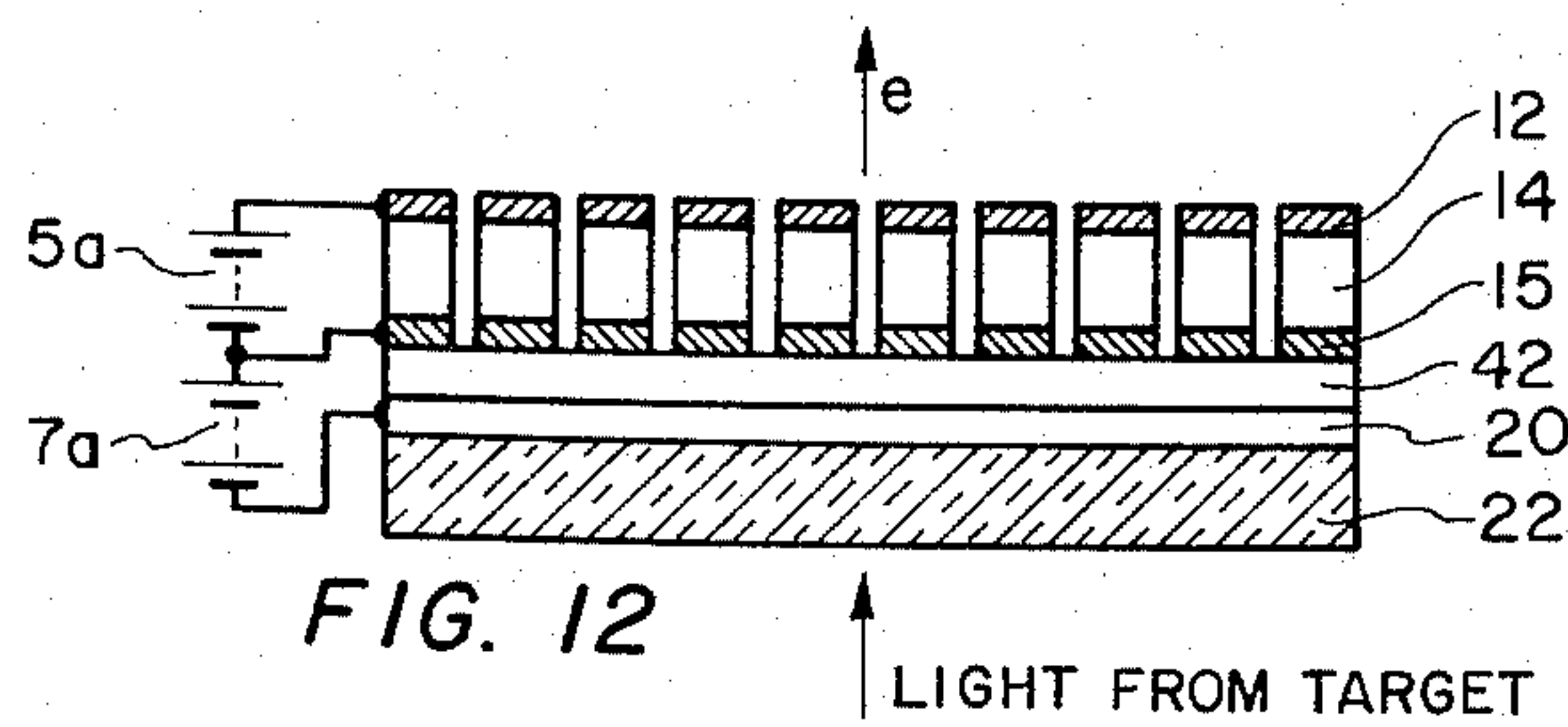
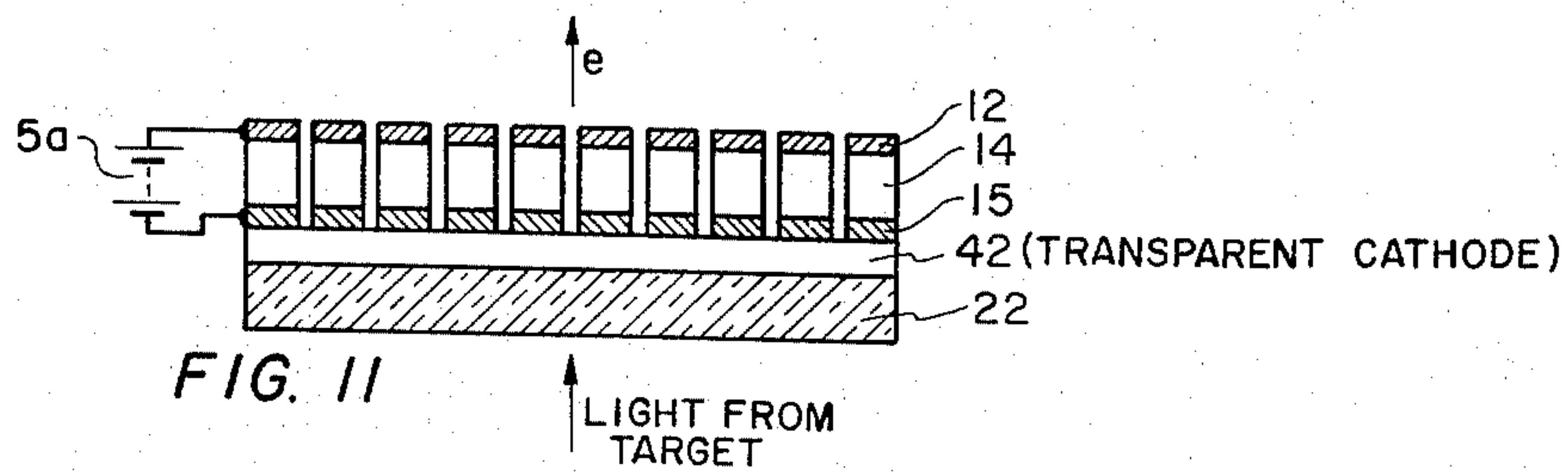
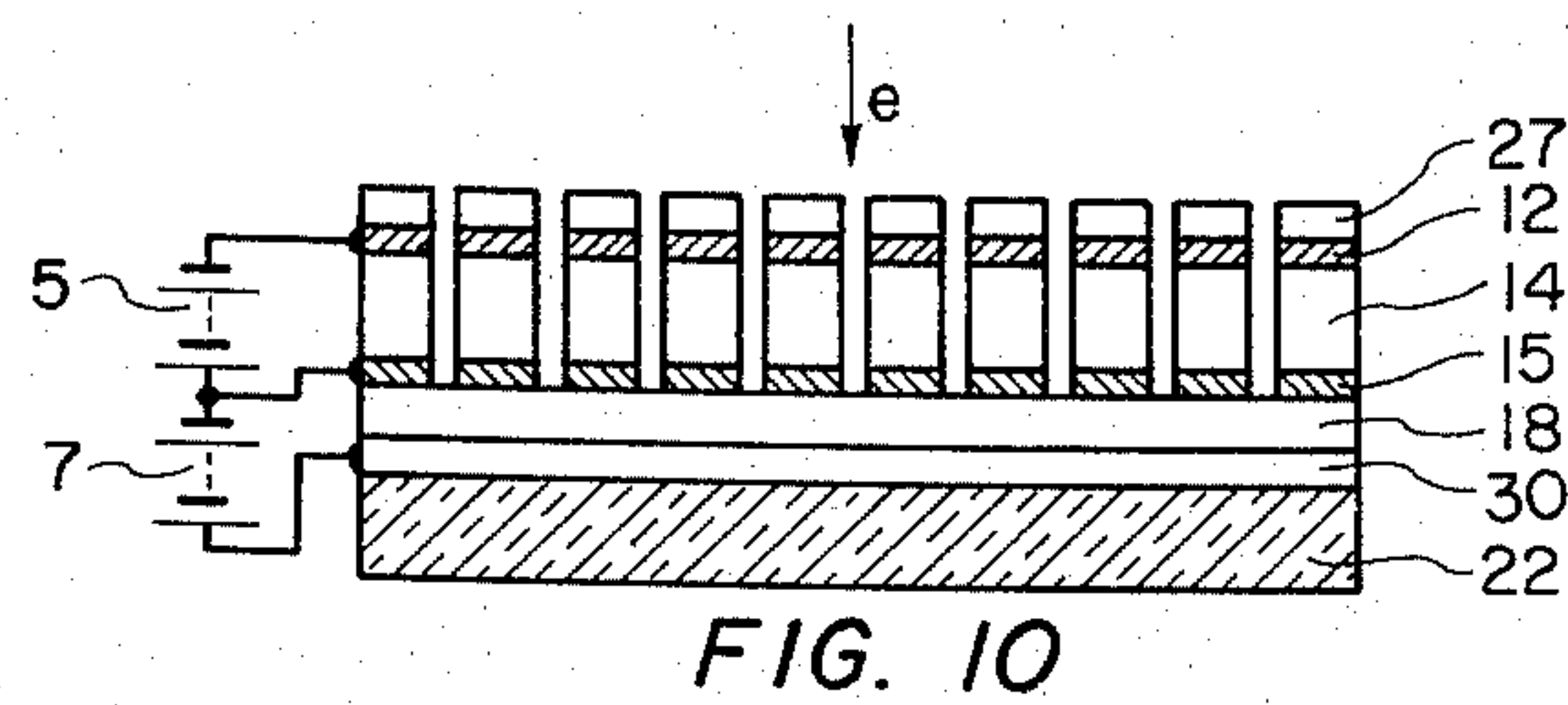
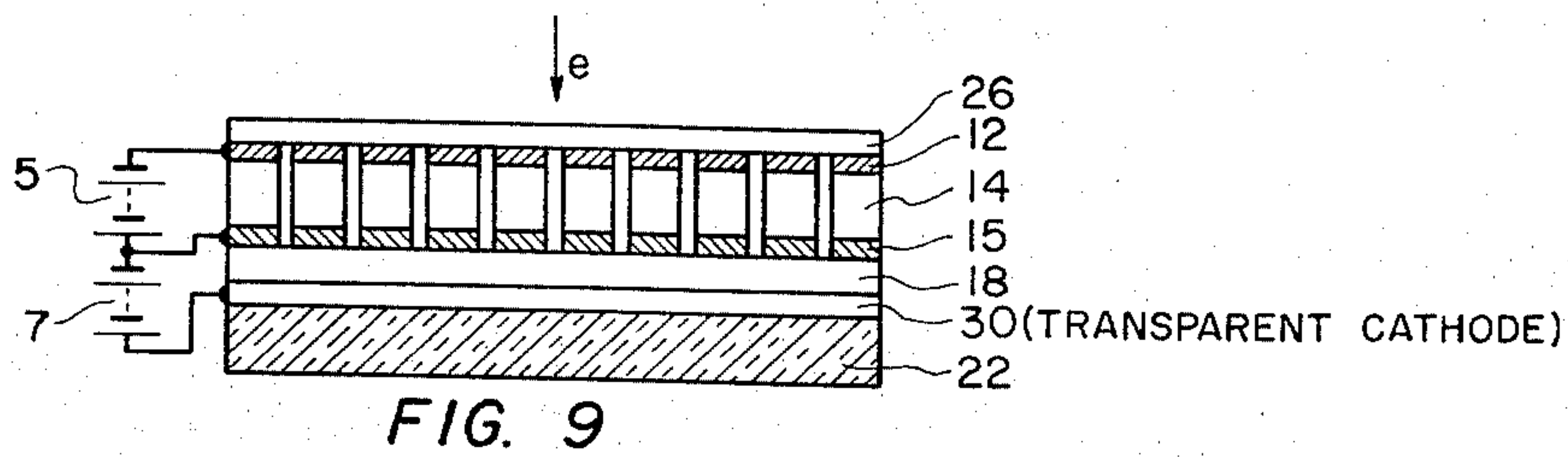
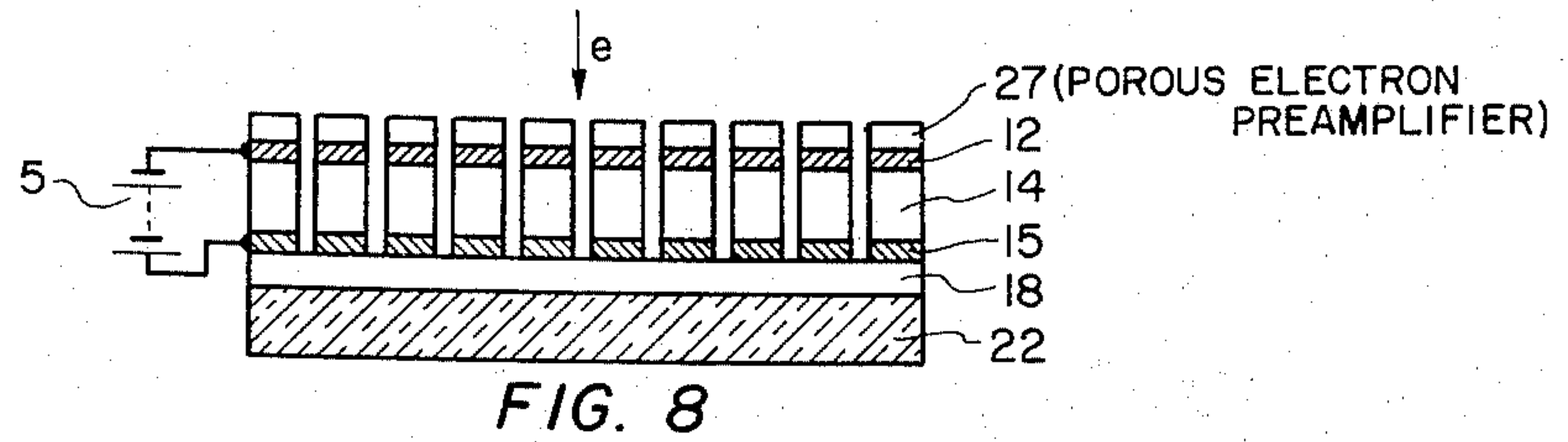
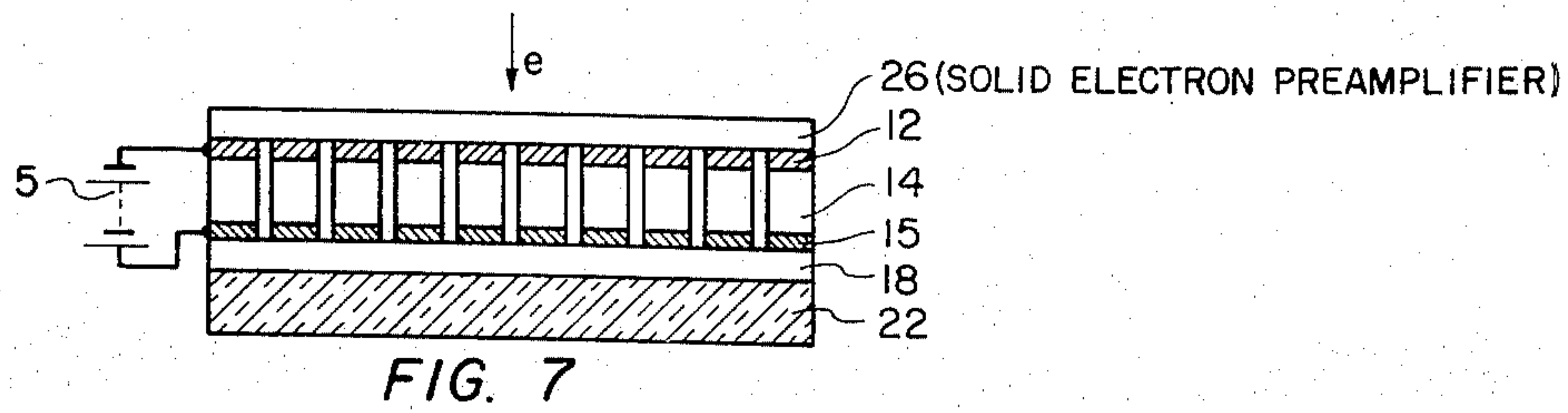


FIG. 6





## 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 metallic 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 or 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. 1a 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 phenomenon 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 accelerated 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 gallium phosphide, either of which is rich in secondary electrons for use in the multiplication process of a direct view image intensifier. Electrons striking preamplifier 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 arsenide. 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 arsenide 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 posi-

tive 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 electrodes 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 accelera-



tion 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 there-through 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 contain-

ing a plurality of microscopic channels there-through 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.

\* \* \* \* \*

35

40

45

50

55

60

65