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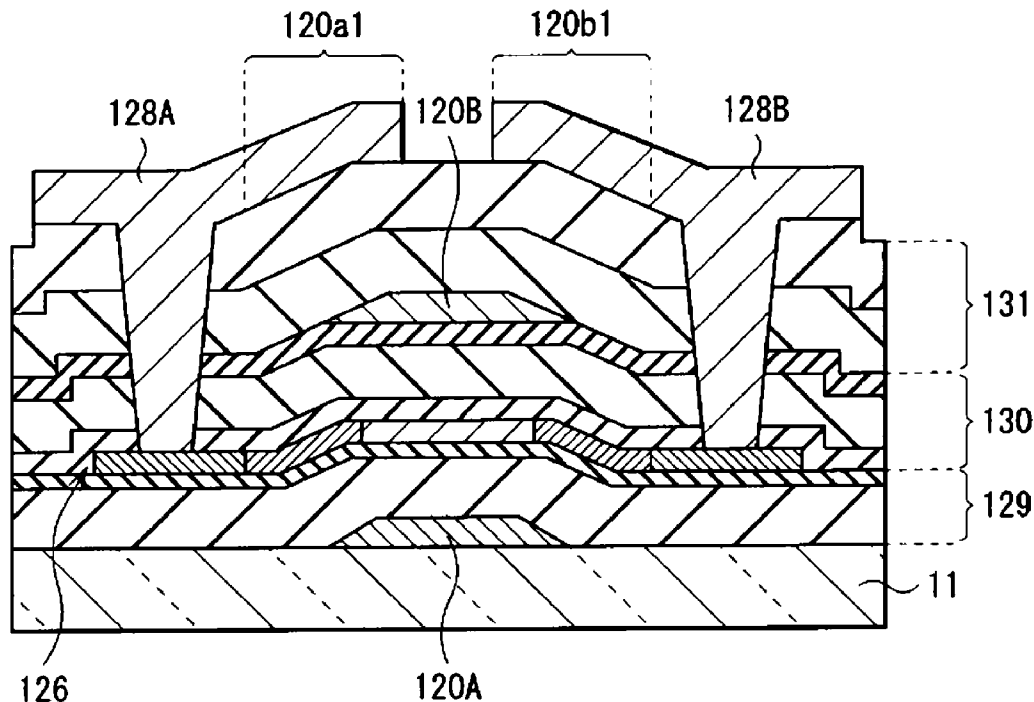




FIG. 2

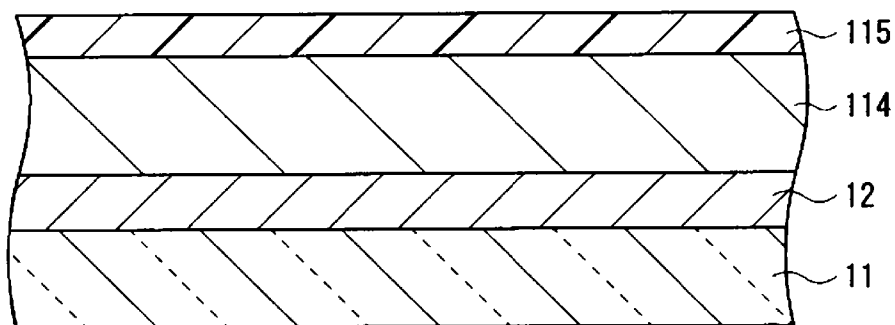


FIG. 3

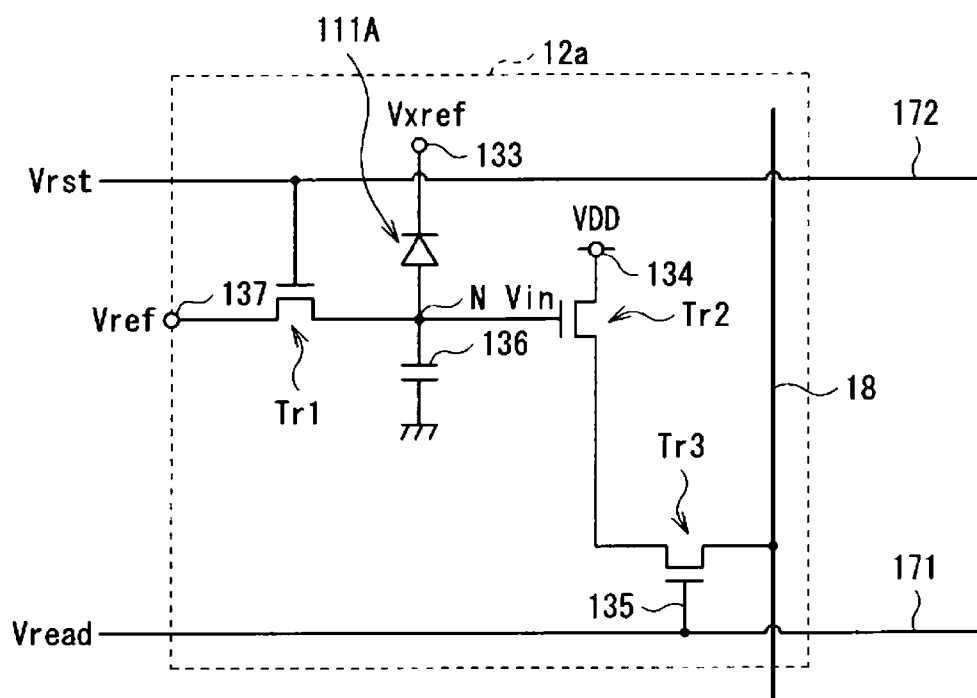


FIG. 4

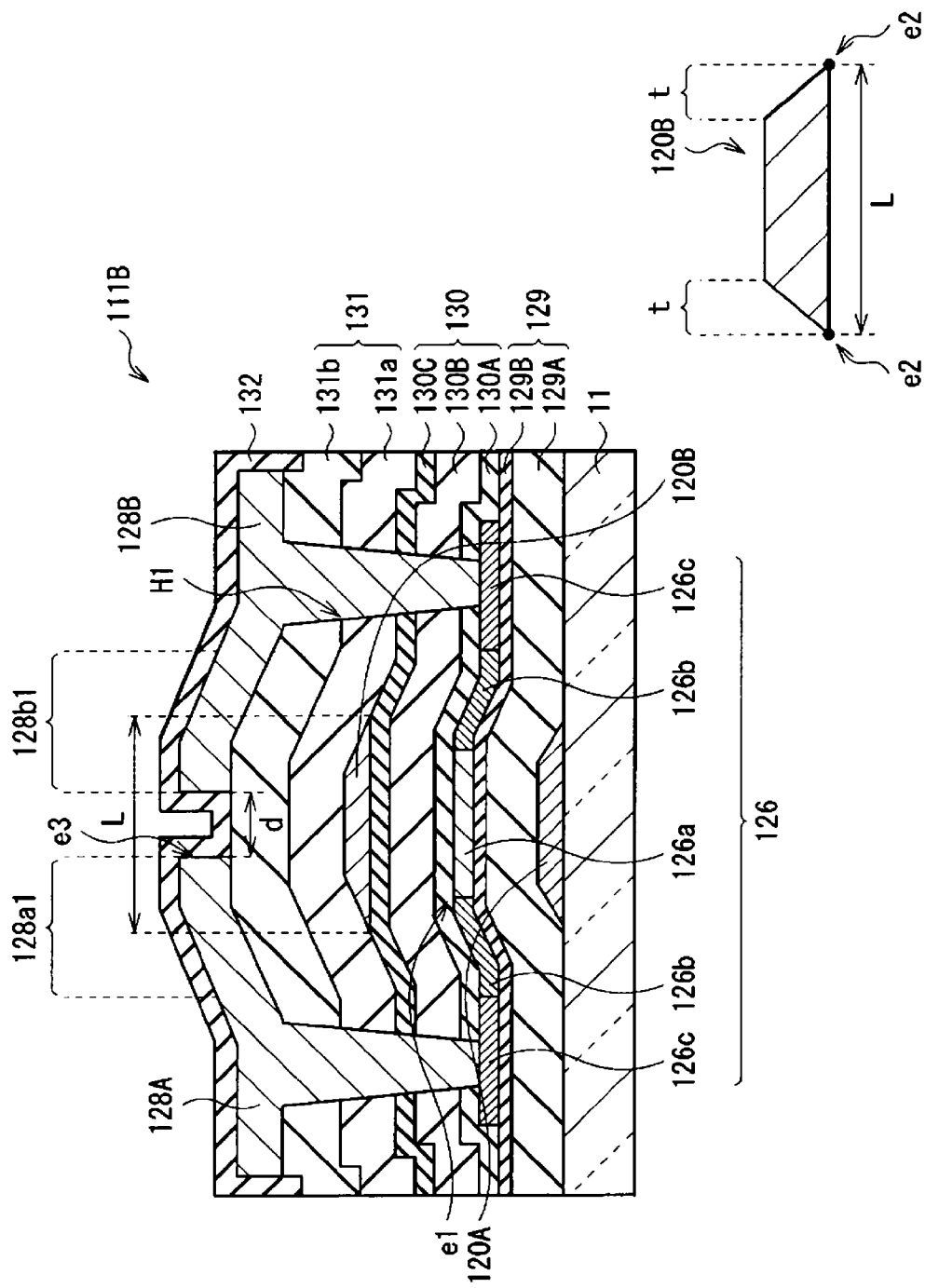


FIG. 5A

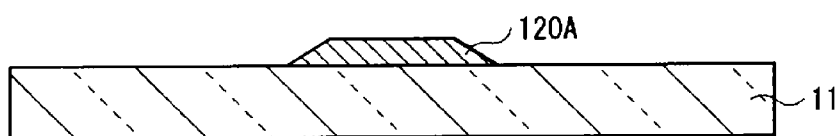


FIG. 5B

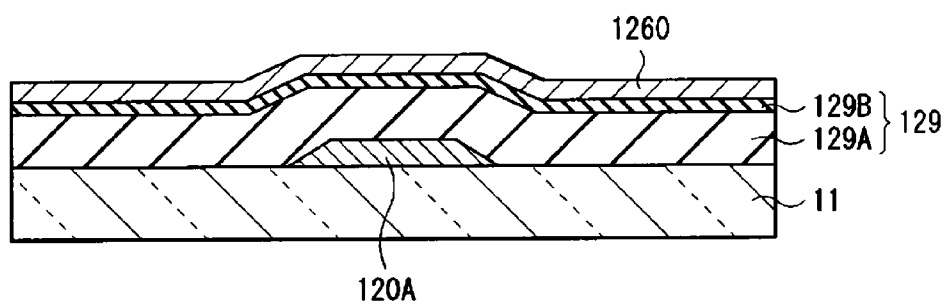


FIG. 5C

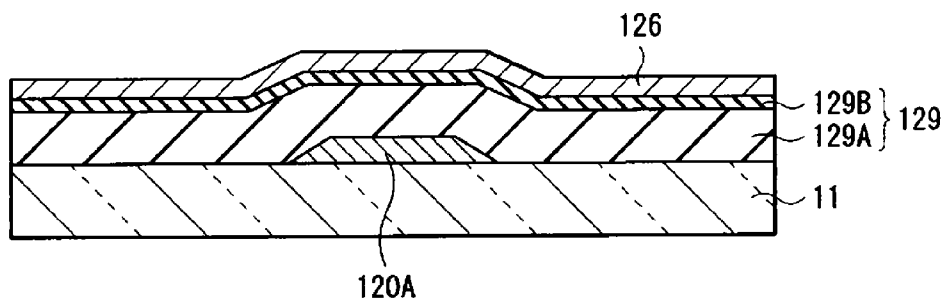


FIG. 5D

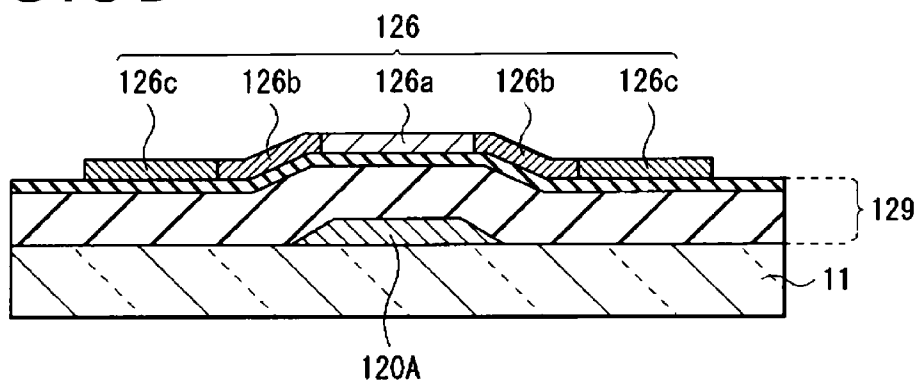


FIG. 5E

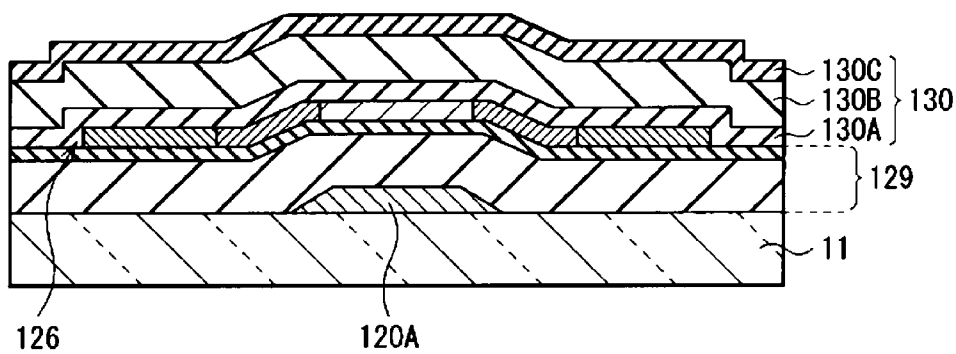
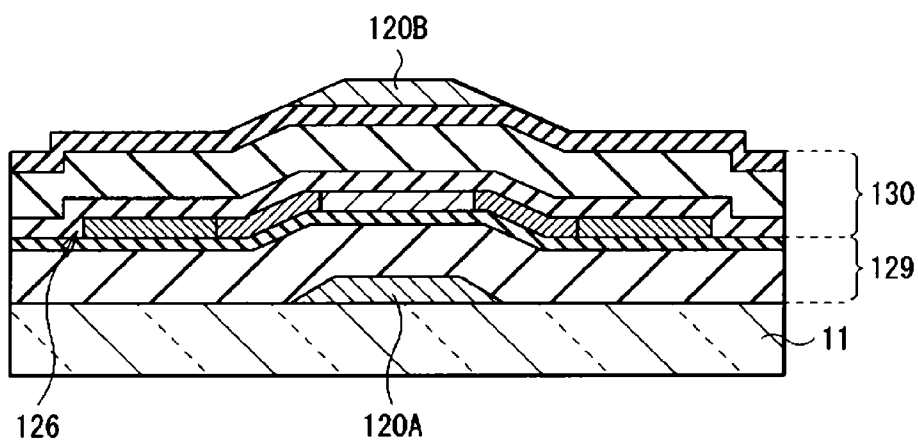
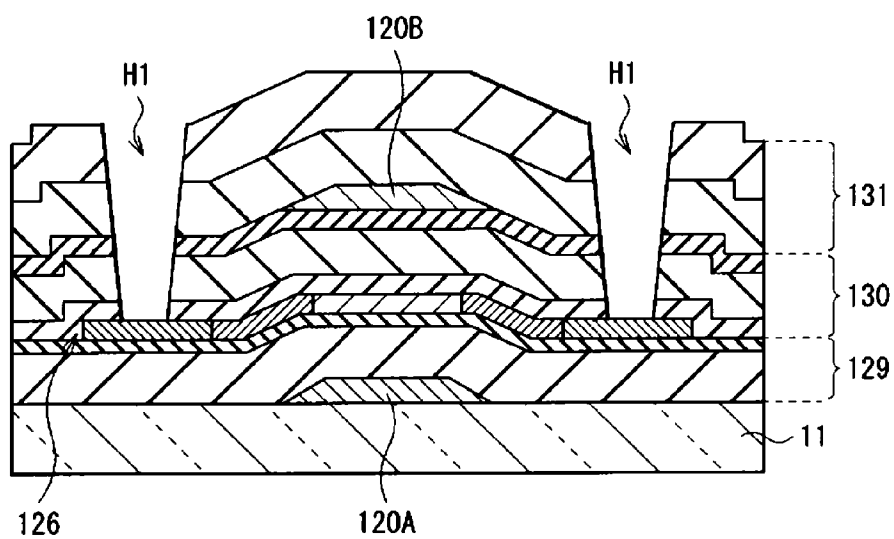
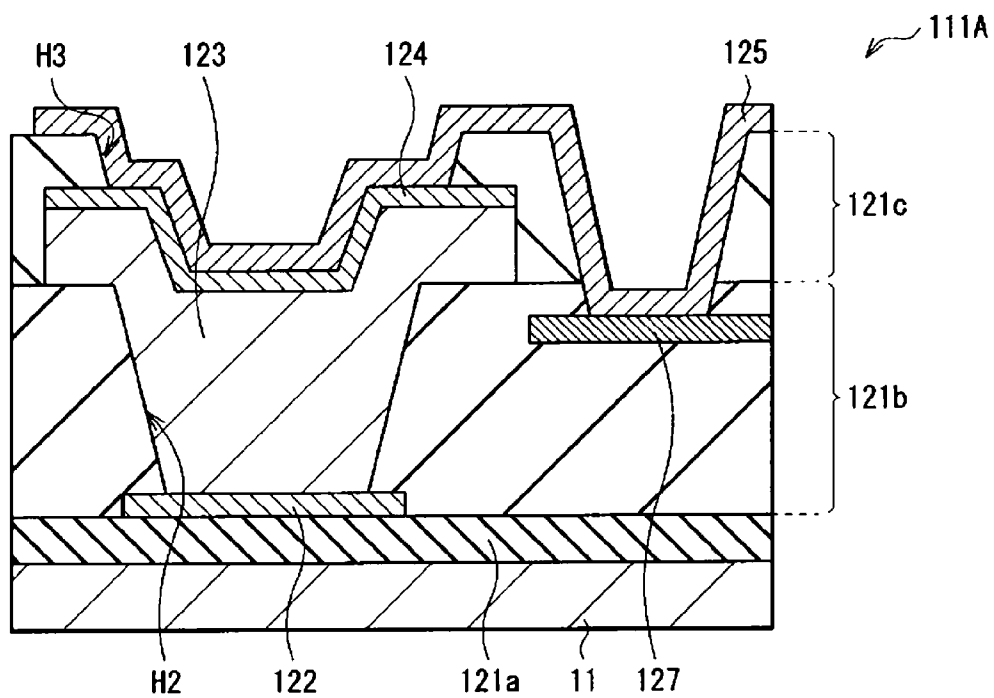


FIG. 5F









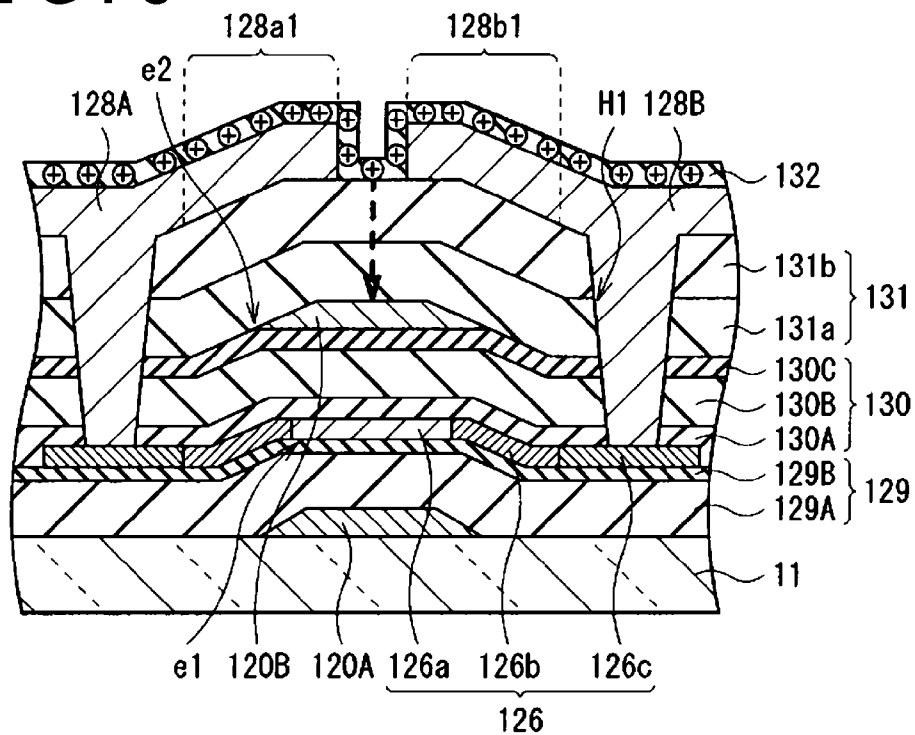
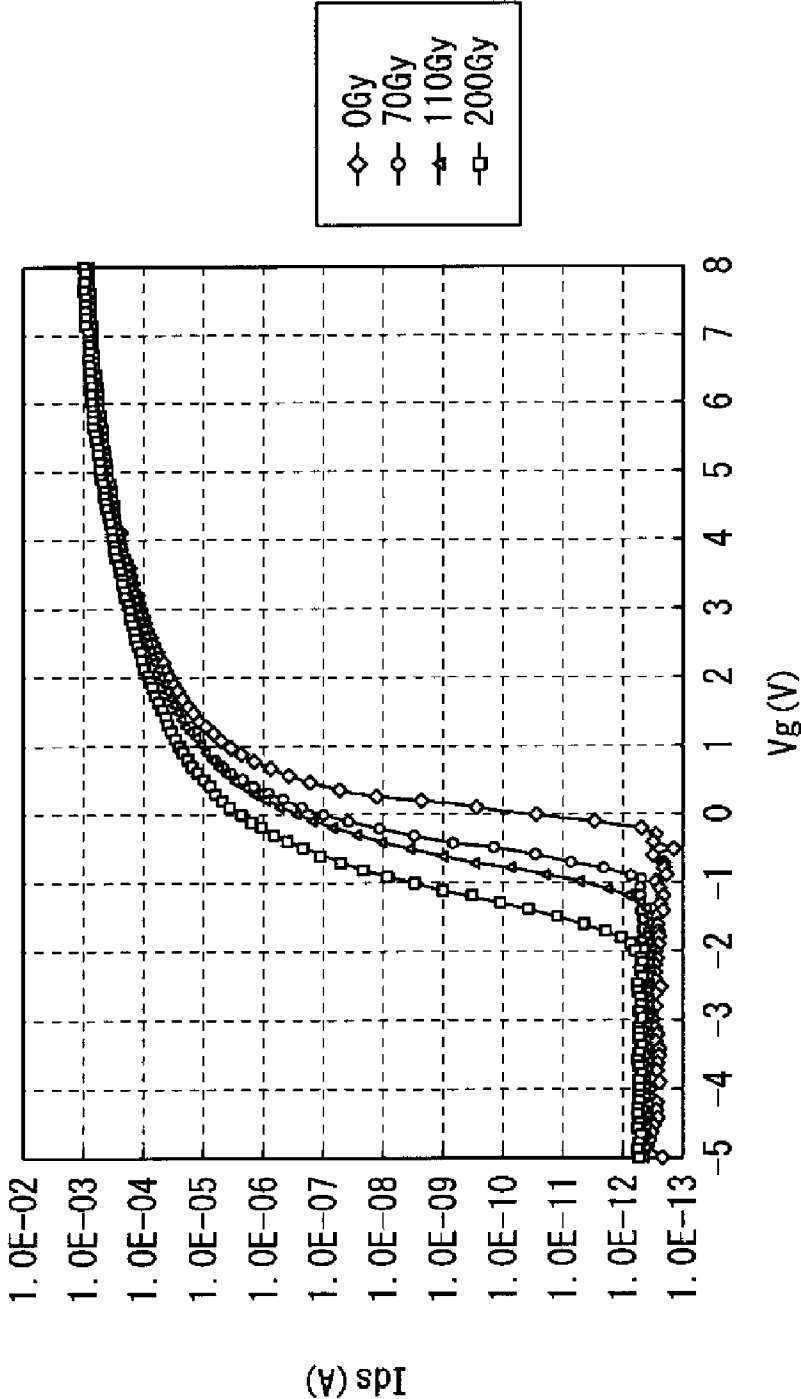


FIG. 9

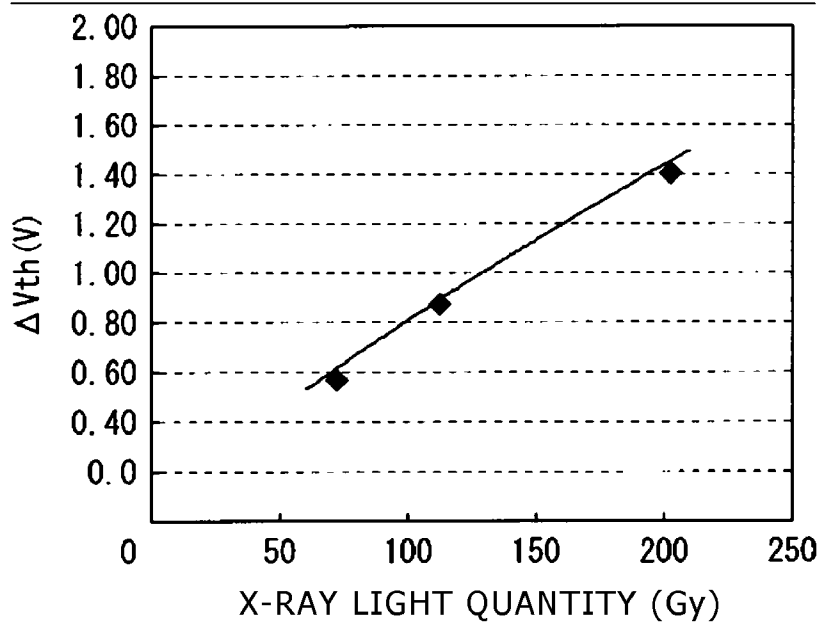
VG-ID CHARACTERISTICS  
(FOR  $V_{ds} = 6.1\text{ V}$ ,  $W = 20.5\mu\text{MICRONS}$  AND  $L = 6\mu\text{MICRONS}$ )



# FIG. 10

LIGHT QUANTITY AND  $V_{th}$  SHIFT

(WITH  $I_{ds} = 1e-11$  (A) TAKEN AS A REFERENCE)



# FIG. 11

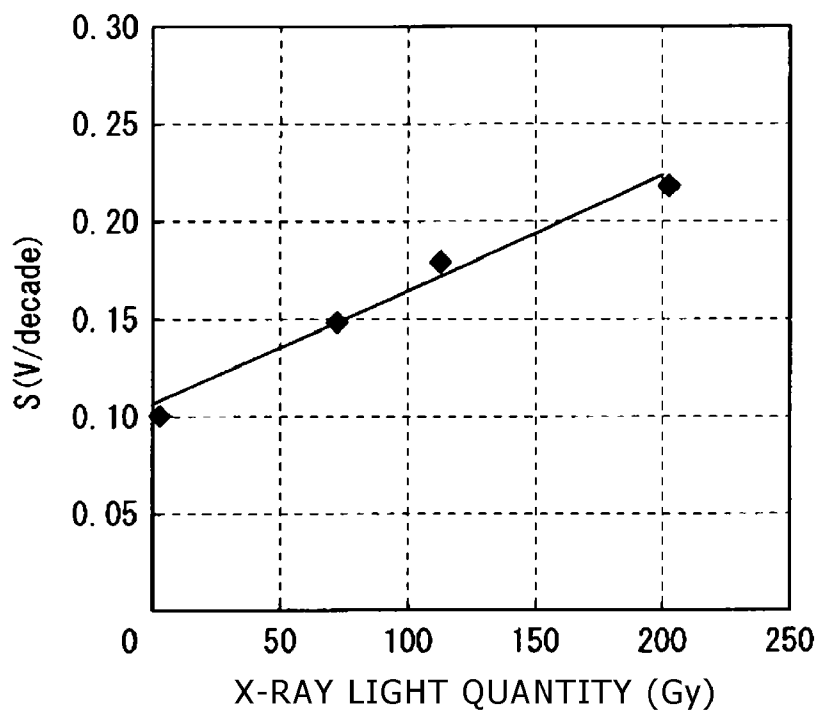
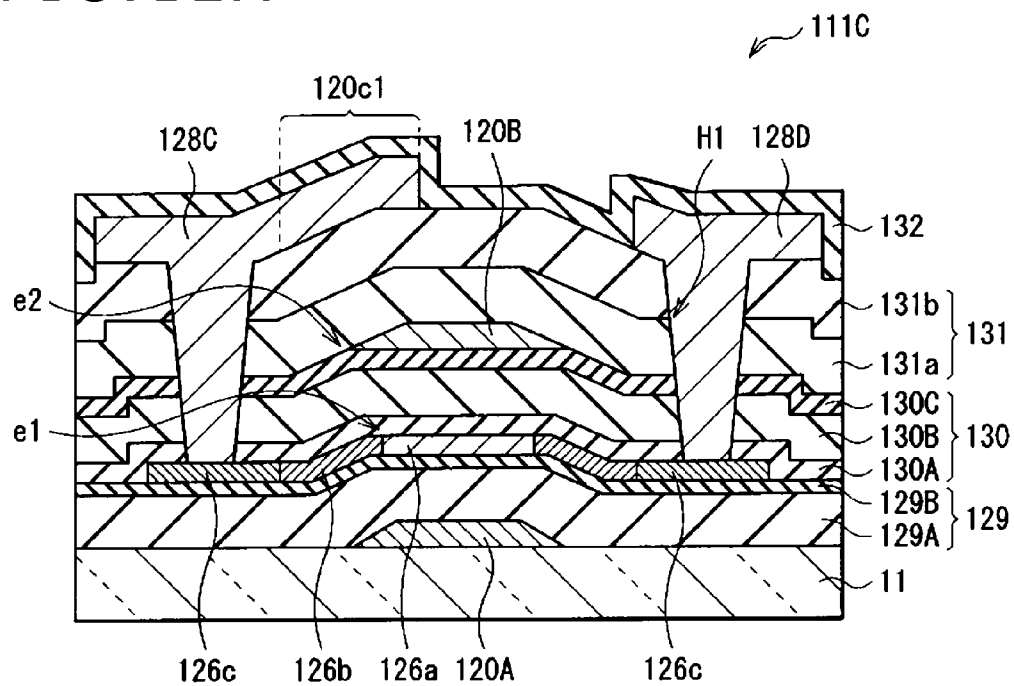


FIG. 12A



**FIG. 12B**

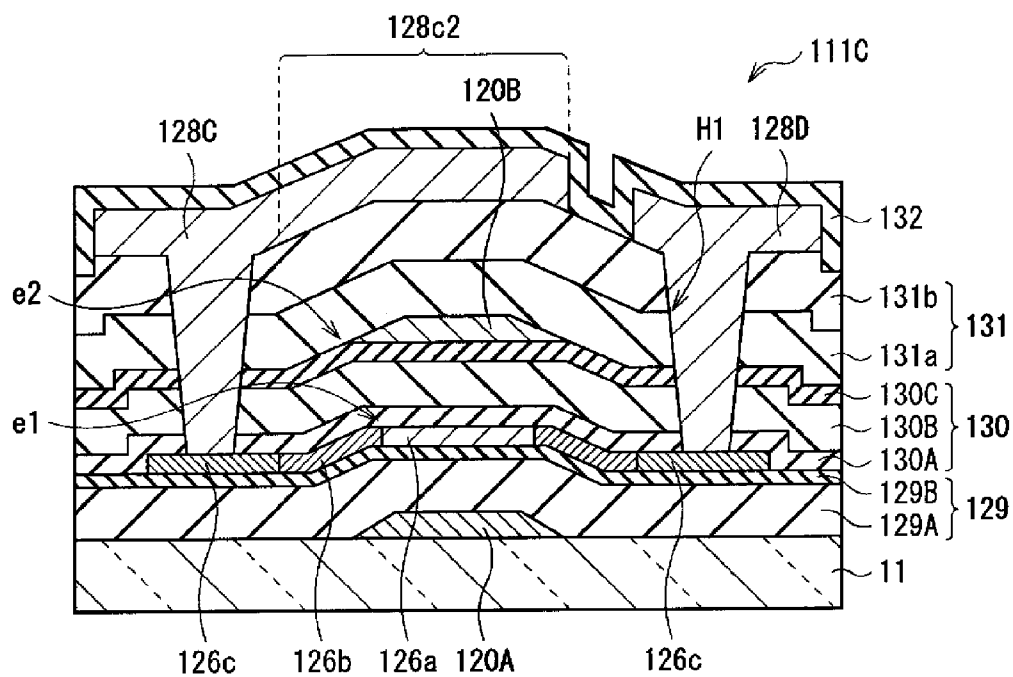


FIG. 13

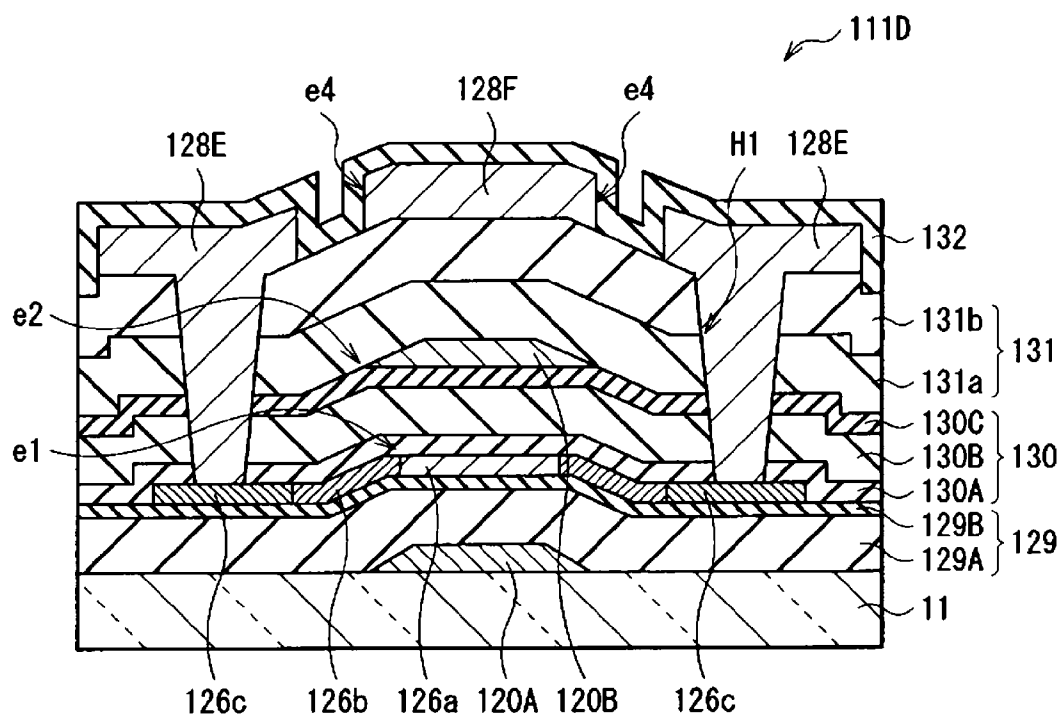


FIG. 14

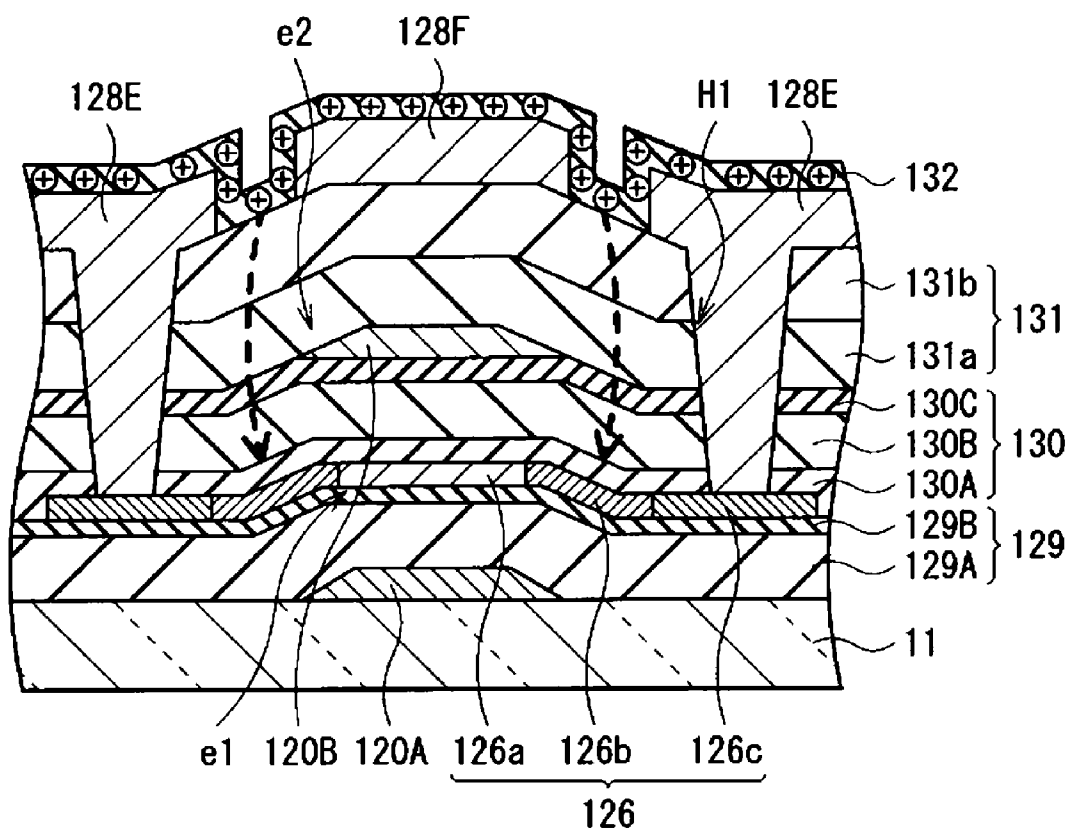
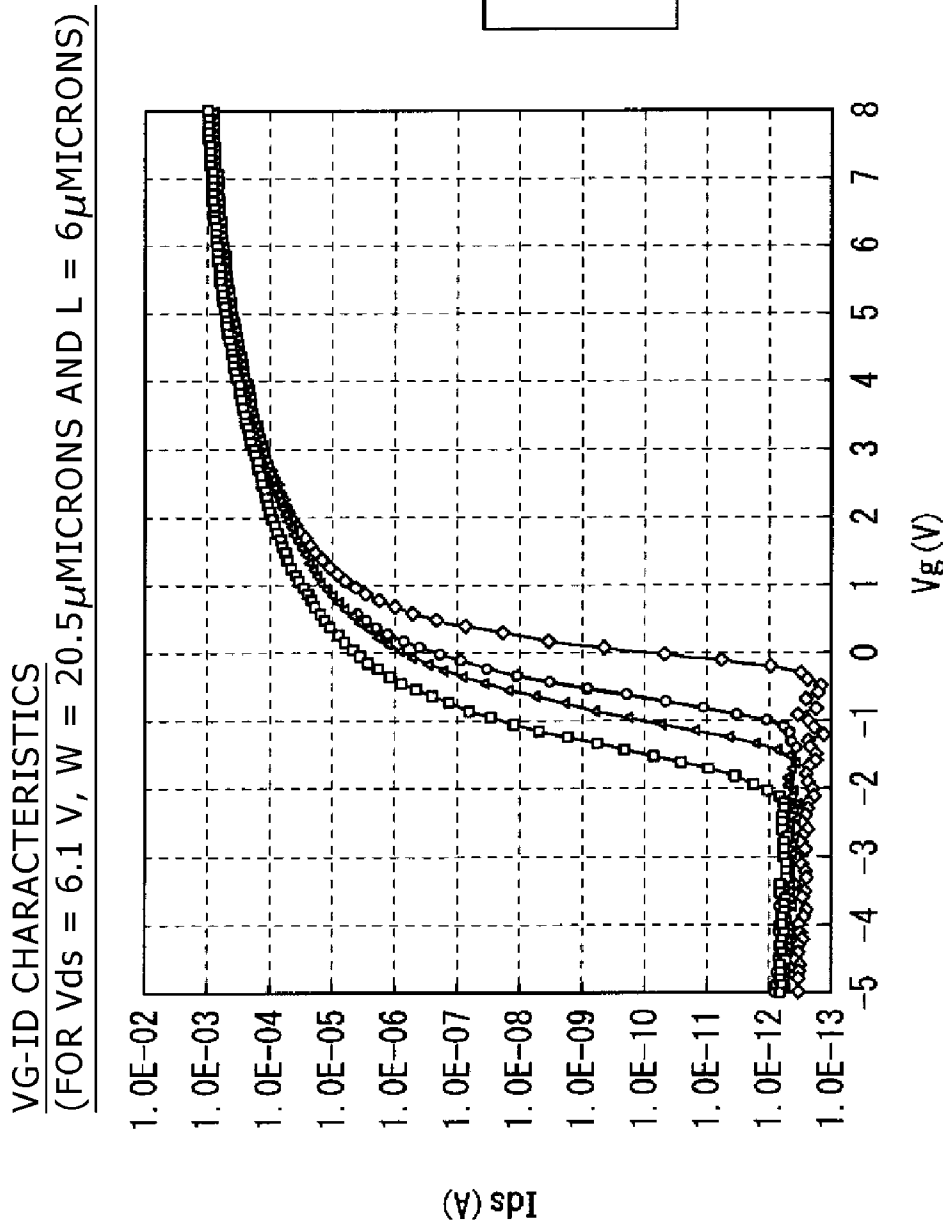


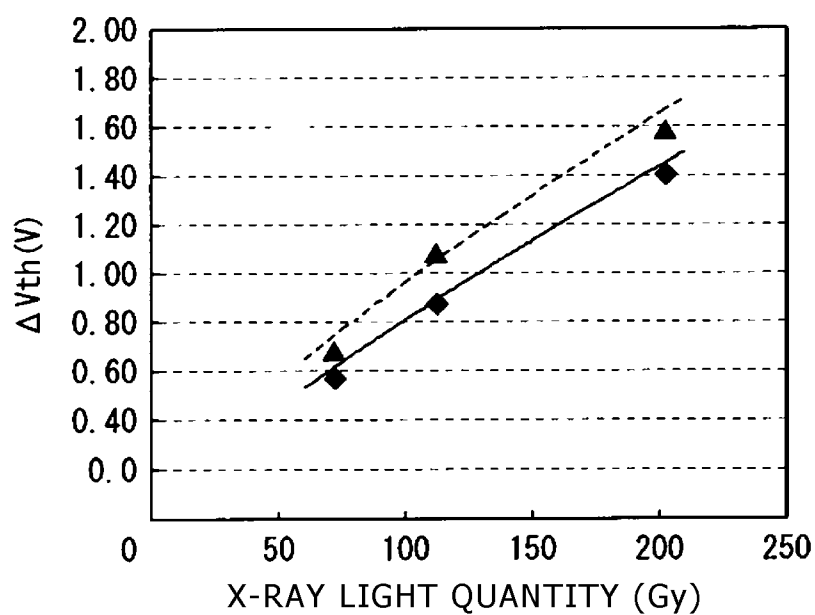
FIG.15



# FIG. 16

LIGHT QUANTITY AND  $V_{th}$  SHIFT

(WITH  $I_{ds} = 1e-11$  (A) TAKEN AS A REFERENCE)



# FIG. 17

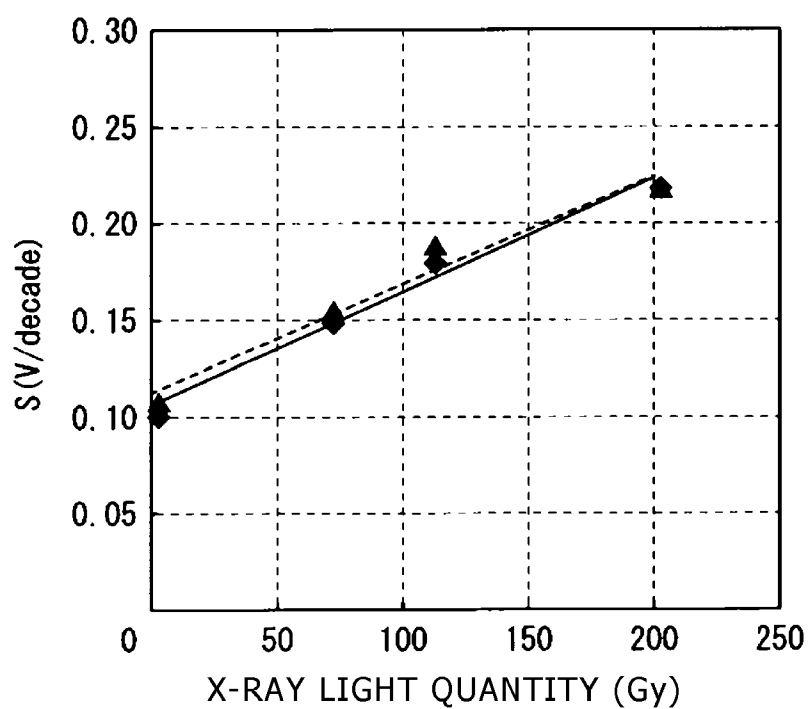




FIG. 18

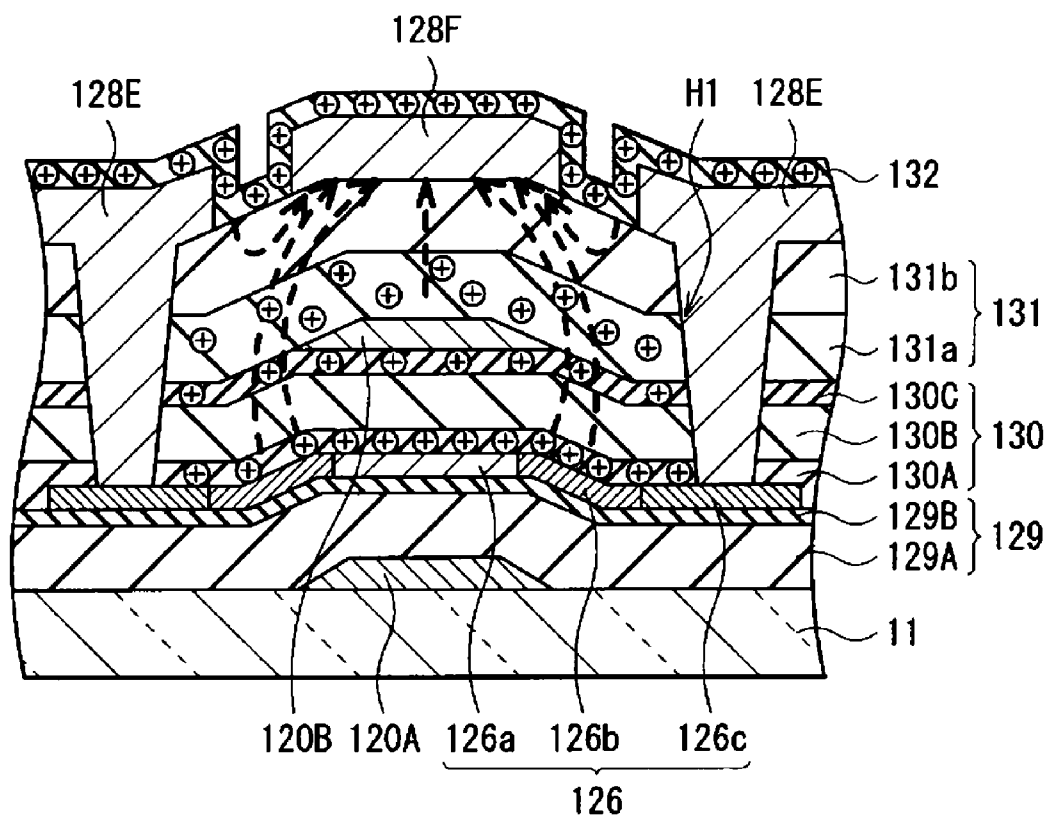




FIG. 20

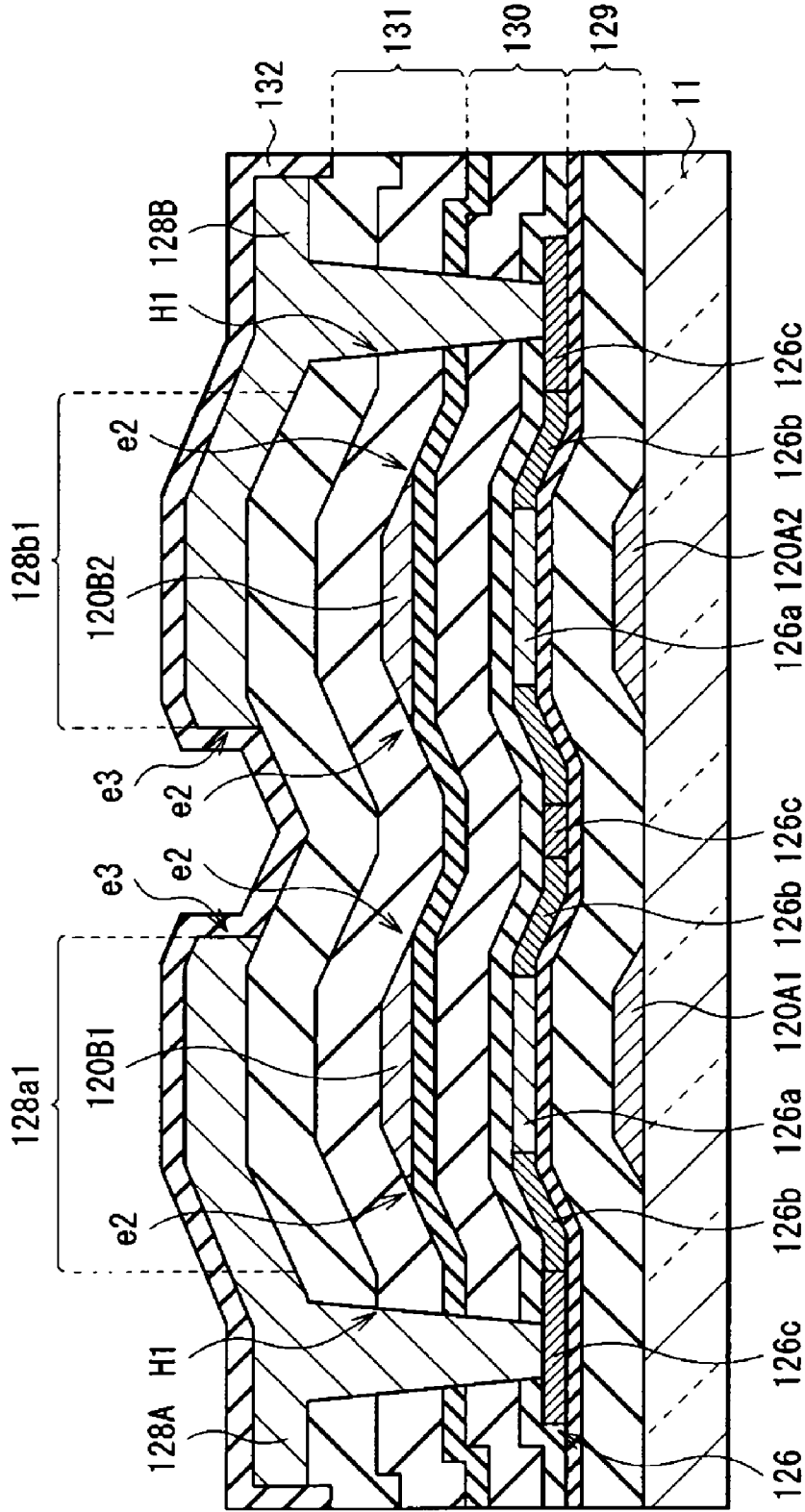
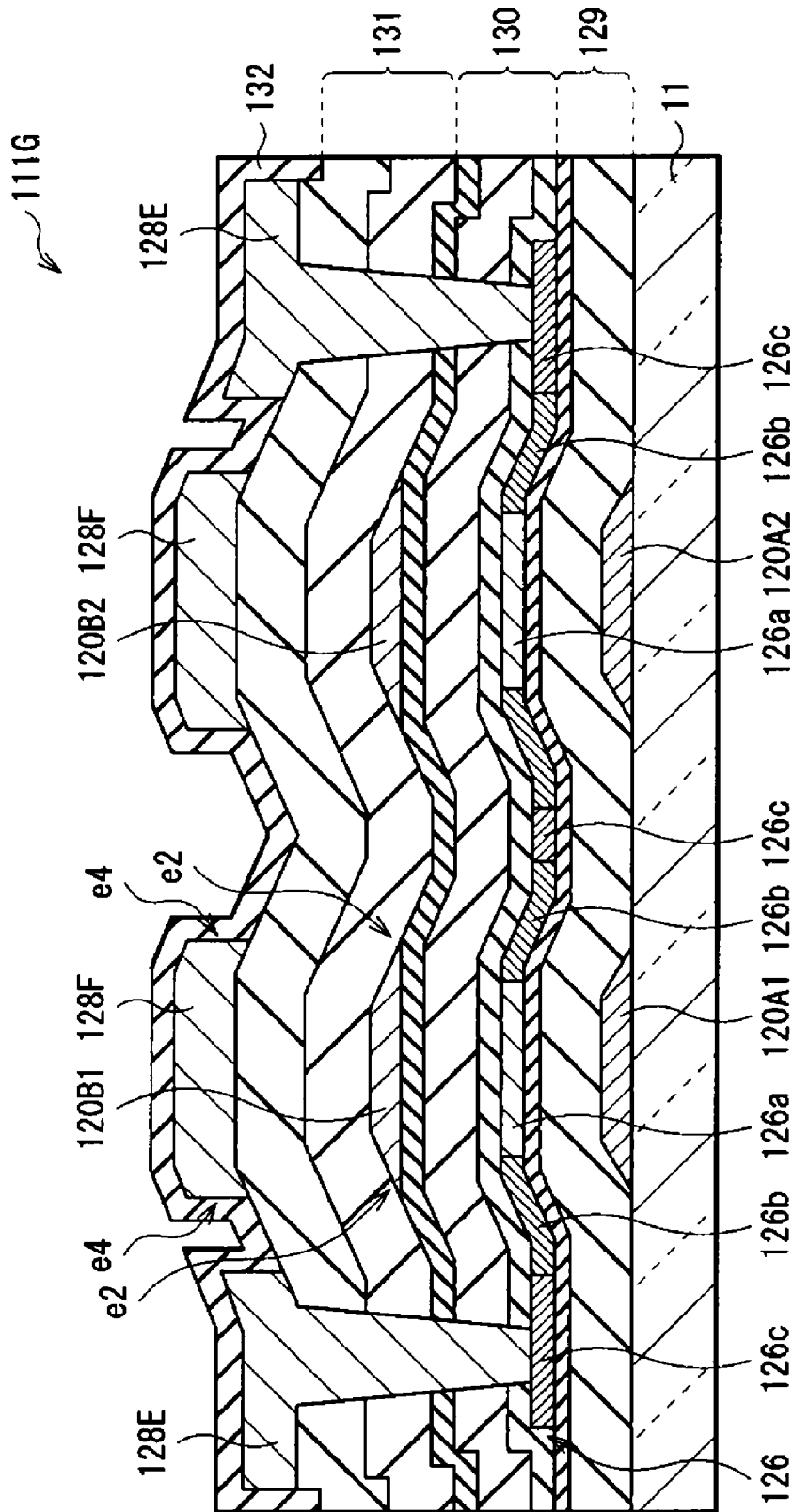




FIG. 22



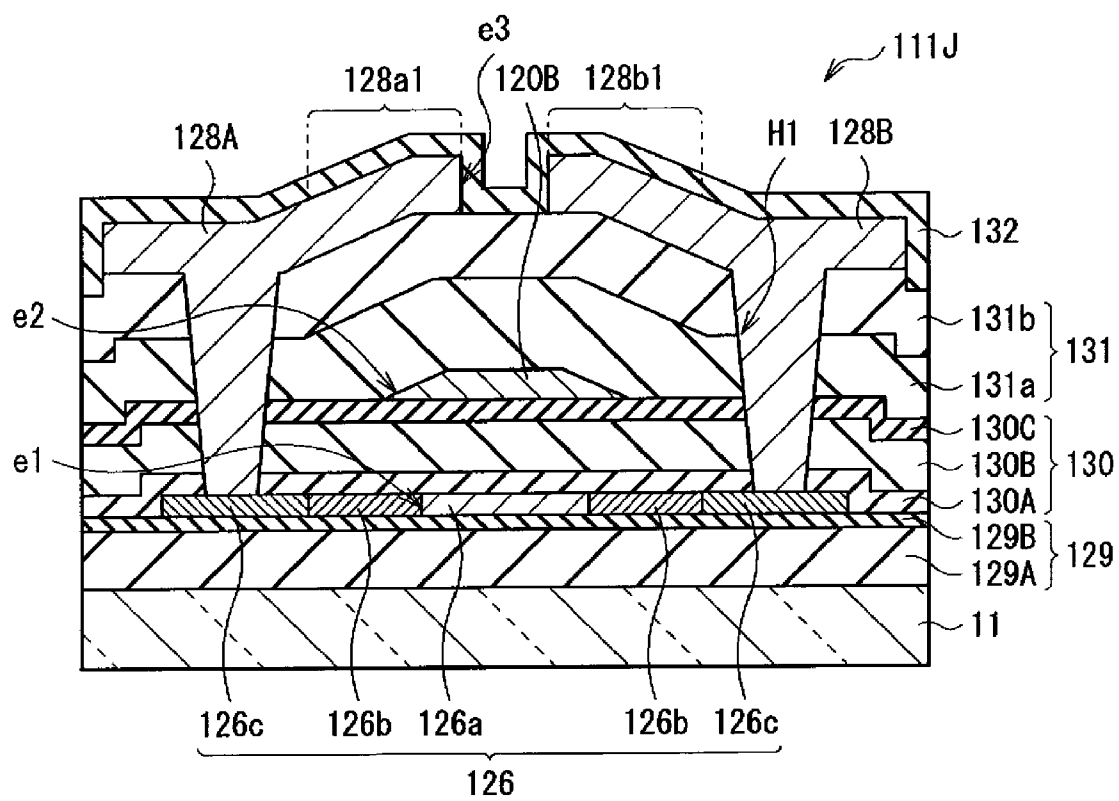


FIG. 24A

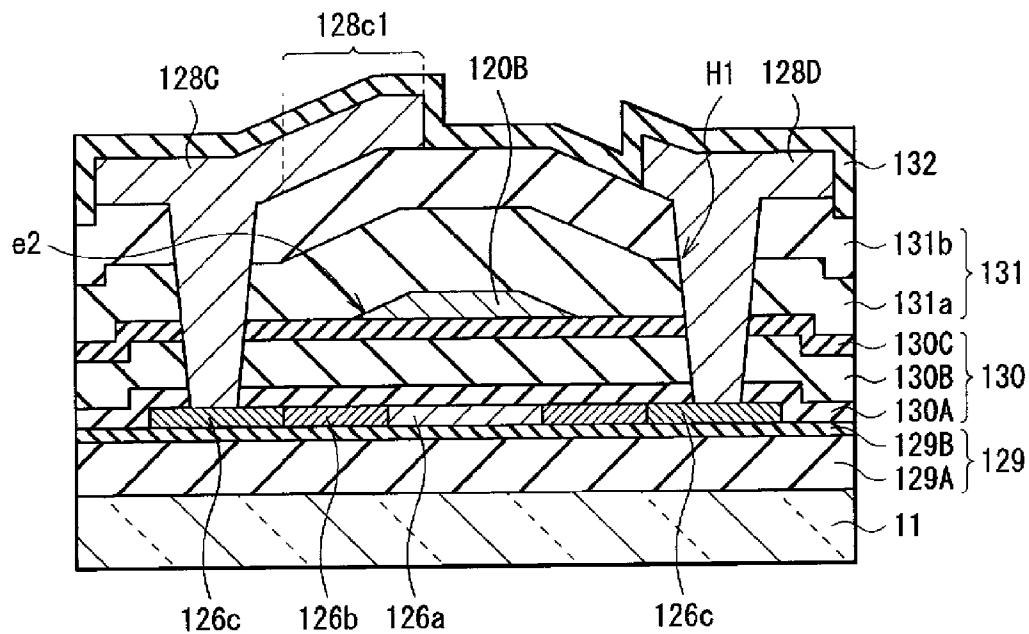
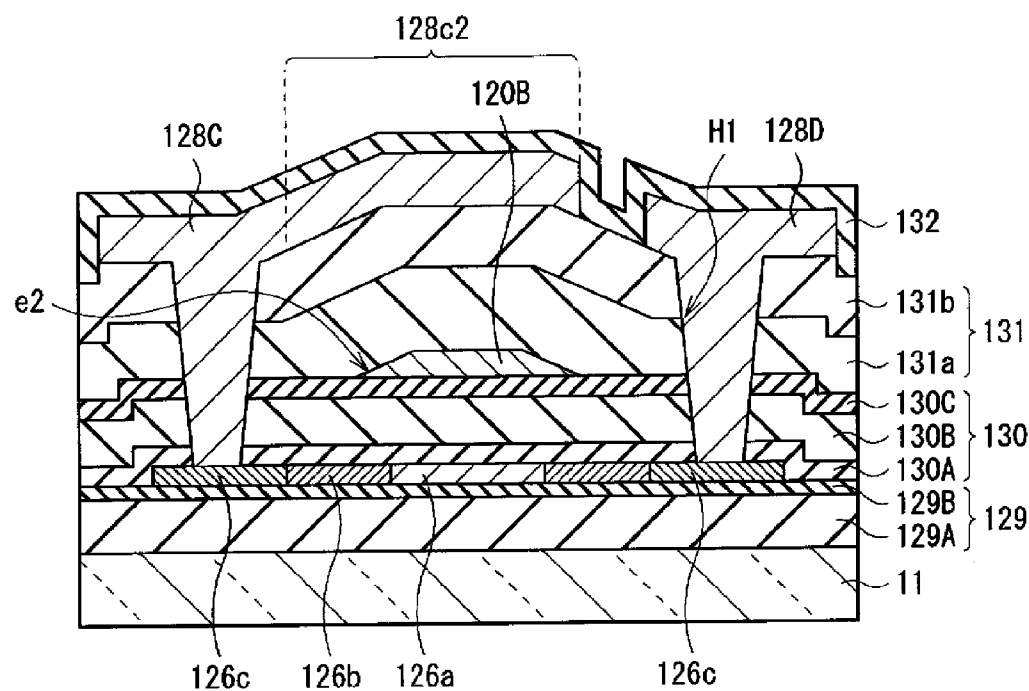


FIG. 24B



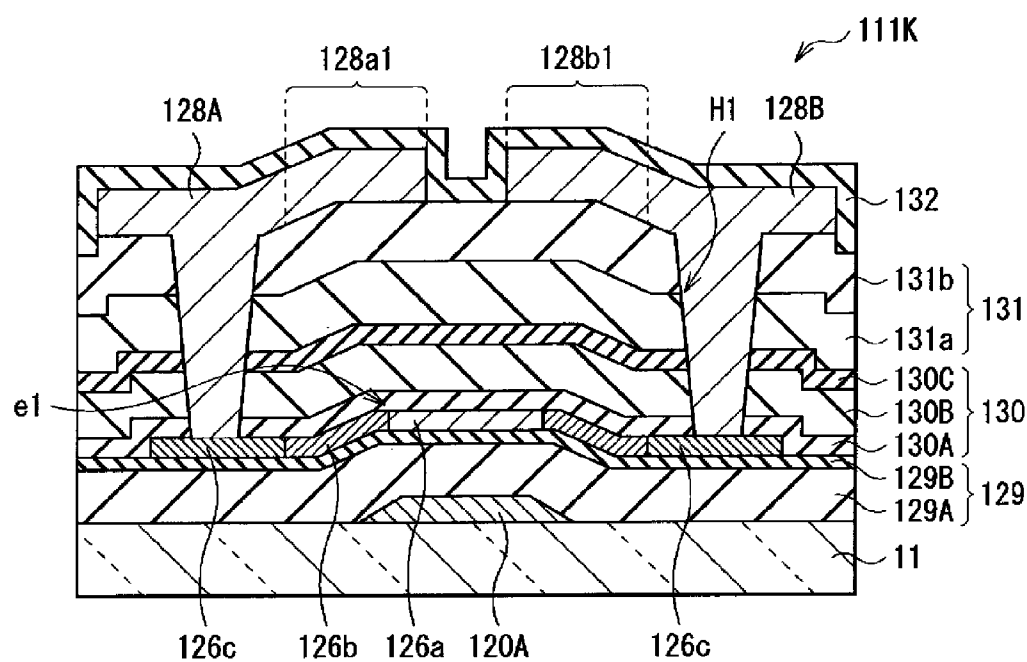
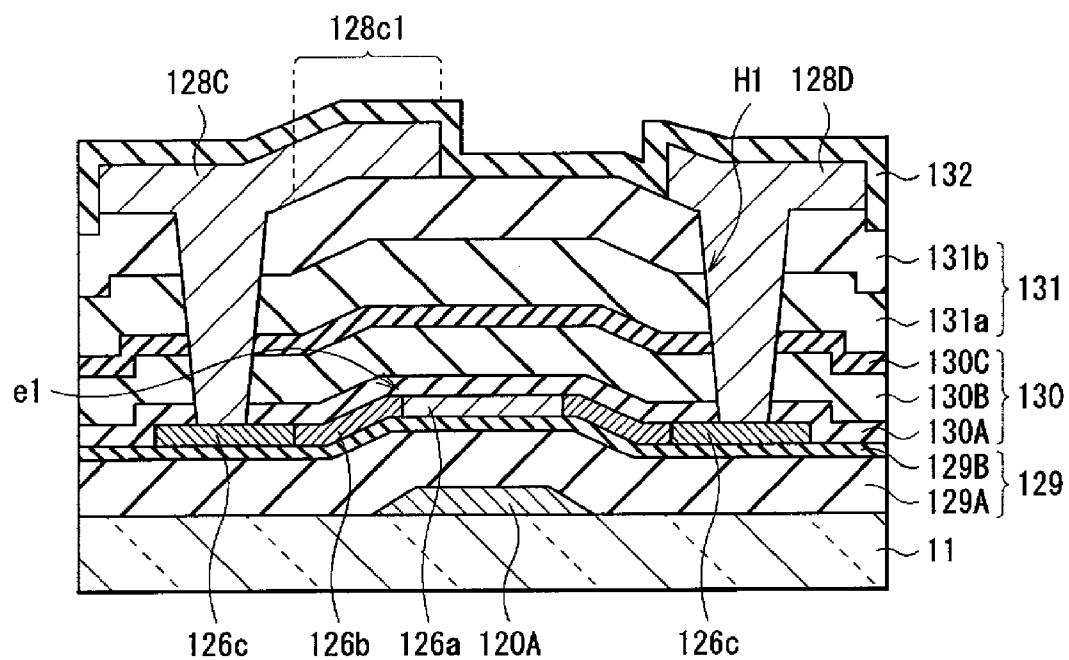




FIG. 27A



**FIG. 27 B**

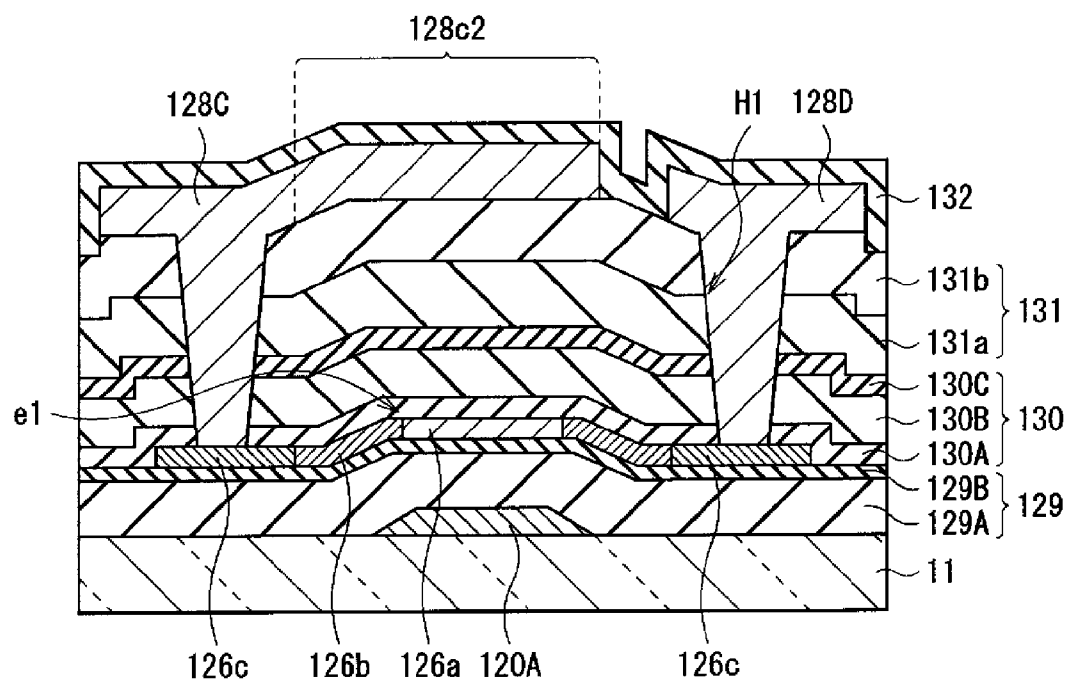


FIG. 28

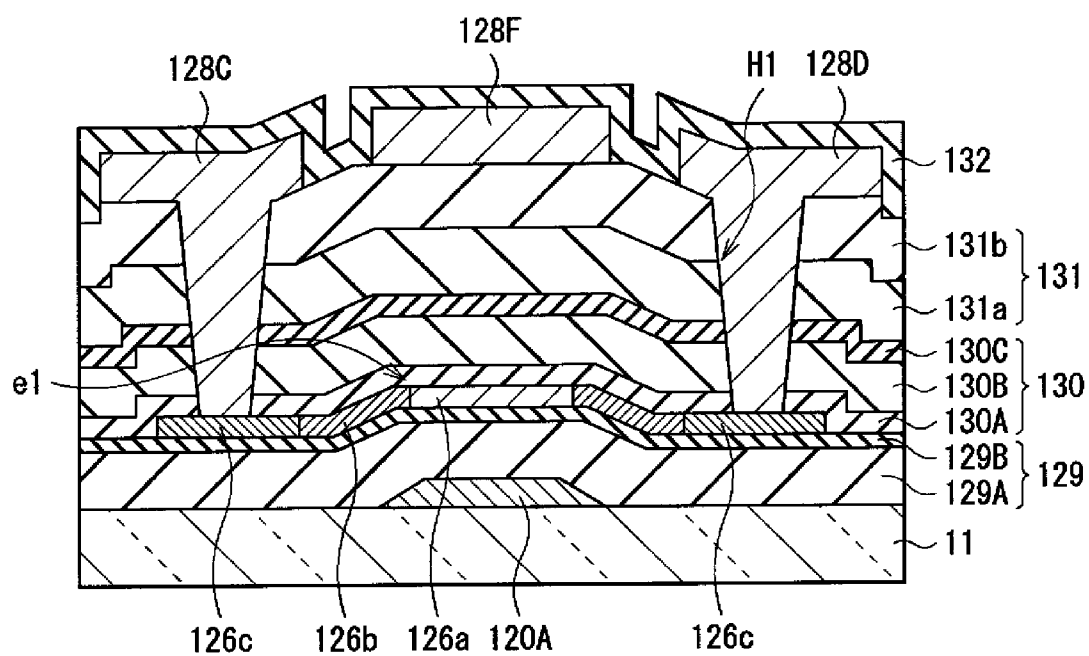


FIG. 29

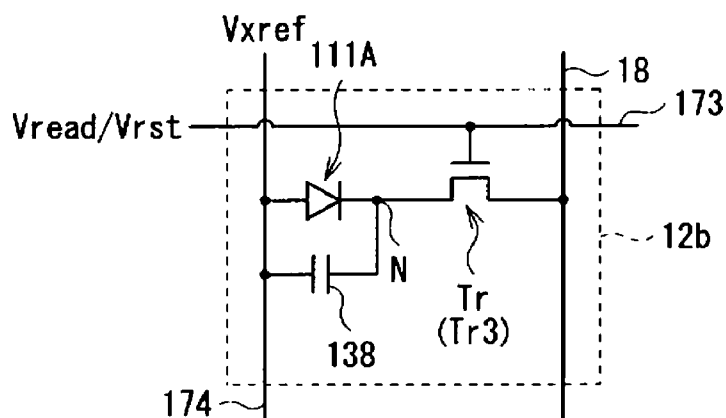


FIG. 30

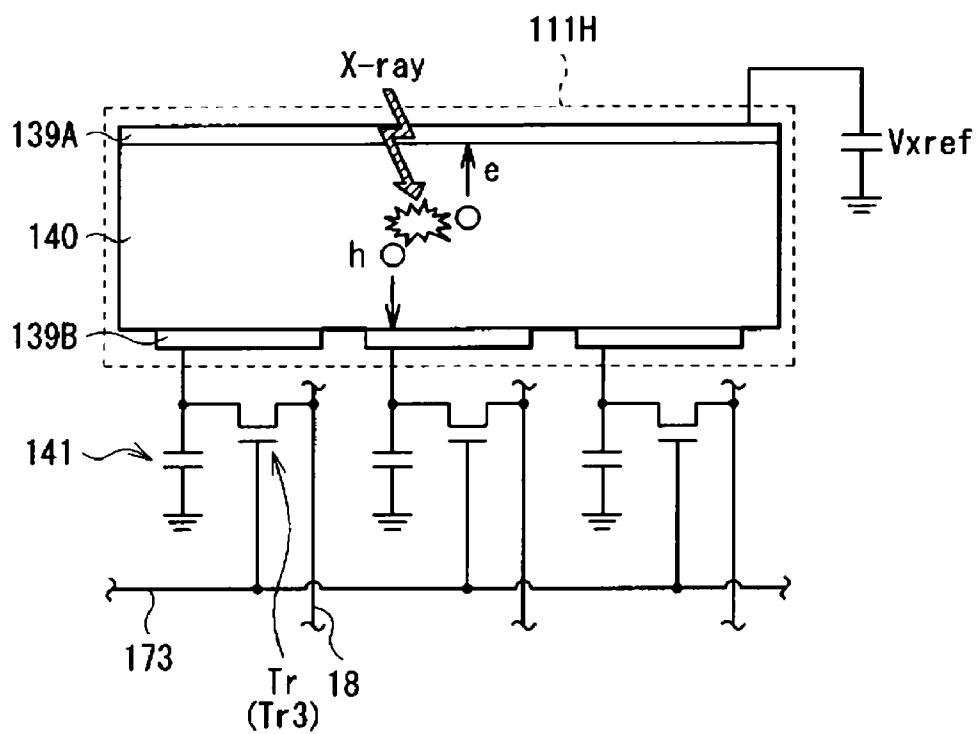


FIG. 31

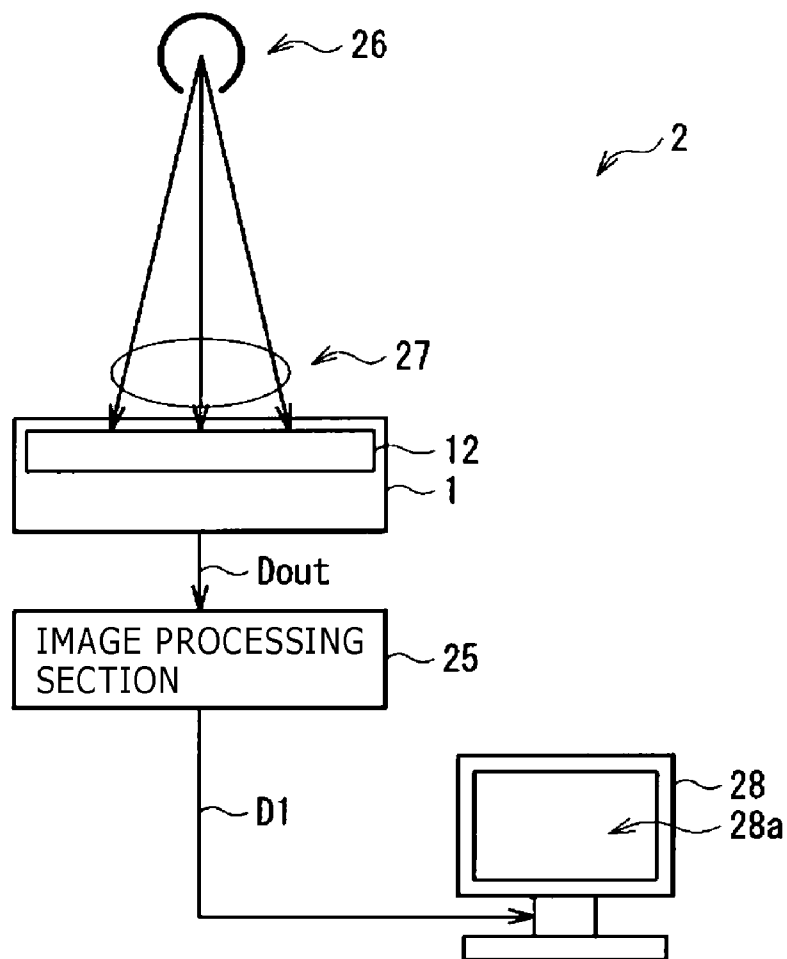
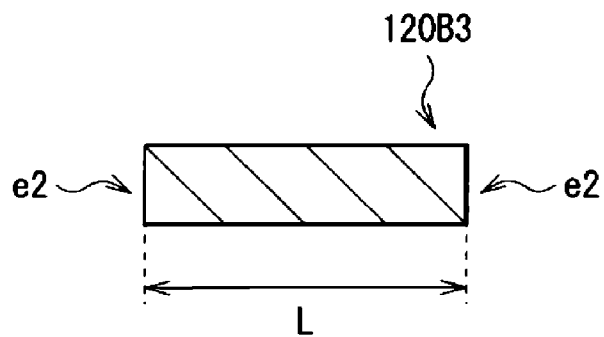


FIG. 32



# **RADIOACTIVE-RAY IMAGING APPARATUS, RADIOACTIVE-RAY IMAGING DISPLAY SYSTEM AND TRANSISTOR**

## **BACKGROUND**

**[0001]** The present disclosure relates to a radioactive-ray imaging apparatus proper for X-ray imaging operations for typically medical cares and nondestructive inspections and relates to a radioactive-ray imaging display system employing such an apparatus as well as transistors employed in the apparatus and the system.

**[0002]** In recent years, a technique making use of a CCD (Charge Coupled Device) image sensor and/or a CMOS (Complementary Metal Oxide Semiconductor) image sensor is the mainstream of imaging techniques based on photoelectric conversion. The imaging technique based on photoelectric conversion is a technique for acquiring an image as an electrical signal. The imaging area of the imaging sensor is limited by the size of a crystal substrate or a silicon wafer. In the field of the medical care carried out by making use of an X ray in particular, however, there are demands for an imaging area having a large size, and the number of demands for a good moving-picture performance is also increasing.

**[0003]** A radioactive-ray imaging apparatus for obtaining an image based on radioactive rays as an electrical signal without making use of a radioactive-ray photographic film is being developed as an imaging apparatus required to have an imaging area with a large size. A typical example of the imaging apparatus required to have an imaging area with a large size is the X-ray imaging apparatus for taking an image of the chest of a human body. Such a radioactive-ray imaging apparatus is an apparatus having a wavelength conversion layer (serving as a fluorescent material) on a circuit substrate including photoelectric conversion devices such as photodiodes and TFTs (thin-film transistors). In the radioactive-ray imaging apparatus, after an incident radioactive ray has been converted into a visible ray, the visible ray is received by the photoelectric conversion device for converting the visible ray into an electrical signal. Then, a circuit employing the TFT reads out the electrical signal, the magnitude of which is determined by the quantity of the visible ray.

**[0004]** In this case, the transistor is created as follows. A plurality of layers are created on a substrate to form a laminated stack having the so-called top-gate structure or the so-called bottom-gate structure. The layers include an electrode layer for the gate, source and drain electrodes of the transistor and the like, a semiconductor layer used for creating the channel of the transistor, a gate insulation film and an interlayer insulation film. However, if a silicon-oxide film is used as the gate insulation film in the transistor having such a structure for example, an X ray may propagate to the inside of the film. If an X ray propagates to the inside of the silicon-oxide film, holes are generated in the film so that a threshold voltage  $V_{th}$  of the transistor is shifted to the negative side as is generally known. (Refer to documents such as Japanese Patent Laid-open No. 2008-252074.)

**[0005]** On the other hand, there has been proposed a transistor allowing the length of the shift of the threshold voltage  $V_{th}$  to be reduced by adoption of a dual-gate structure in which two gate electrodes are provided to sandwich a semiconductor layer. (Refer to Japanese Patent Laid-open No. 2004-265935.)

## **SUMMARY**

**[0006]** Also in the case of the transistor adopting the dual-gate structure, however, the threshold voltage  $V_{th}$  is shifted in

no small measure due to the effect of the holes generated in the silicon-oxide film by radiation of radioactive rays. It is thus desirable to repress such characteristic deteriorations attributed to radioactive rays in order to implement a transistor capable of demonstrating higher reliability.

**[0007]** It is thus an aim of the present disclosure addressing the problems described above to provide a transistor capable of repressing characteristic deteriorations attributed to radioactive rays in order to improve reliability, a radioactive-ray imaging apparatus employing the transistor and a radioactive-ray imaging display system including the apparatus.

**[0008]** A transistor according to the embodiment of the present disclosure includes:

**[0009]** a semiconductor layer;

**[0010]** a first gate insulation film and a first interlayer insulation film which are provided on a specific surface side of the semiconductor layer;

**[0011]** a first gate electrode provided at a location between the first gate insulation film and the first interlayer insulation film;

**[0012]** an insulation film provided on the other surface side of the semiconductor layer;

**[0013]** source and drain electrodes provided by being electrically connected to the semiconductor layer; and

**[0014]** a shield electrode layer provided in such a way that at least portions of the shield electrode layer face edges of the first gate electrode.

**[0015]** In the transistor, at least one of the first gate insulation film, the first interlayer insulation film and the insulation film include a silicon-oxide film.

**[0016]** A radioactive-ray imaging apparatus according to the embodiments of the present disclosure has a pixel section including the transistor according to the embodiments of the present disclosure and a photoelectric conversion device.

**[0017]** As described above, in the transistor and the radioactive-ray imaging apparatus according to the embodiments of the present disclosure, the silicon-oxide film, which is included in at least one of the first gate insulation film, the first interlayer insulation film, and the insulation film, is electrically charged with positive electrical charge of holes generated by radiation of radioactive rays to the silicon-oxide film and the positive electric charge shifts the threshold voltage  $V_{th}$  of the transistor. By providing the shield electrode layer in such a way that at least portions of the shield electrode layer face the edges of the first gate electrode, however, it is possible to reduce the effect of the positive electric charge particularly in the vicinity of a channel edge of the semiconductor layer and, thus, repress the shift of the threshold voltage  $V_{th}$ .

**[0018]** A radioactive-ray imaging display system according to the embodiments of the present disclosure includes an imaging apparatus (that is, the radioactive-ray imaging apparatus according to the embodiments of the present disclosure) for acquiring an image based on radioactive rays and a display apparatus for displaying the image acquired by the imaging apparatus.

**[0019]** In the transistor and the radioactive-ray imaging apparatus which are provided by the embodiment of the present disclosure, at least one of the first gate insulation film and the first interlayer insulation film which are provided on the specific surface side of the semiconductor layer and the insulation film provided on the other surface side of the semiconductor layer include a silicon-oxide film. The shield electrode layer provided in such a way that at least portions of the

shield electrode layer face the edges of the first gate electrode. Thus, it is possible to repress a threshold-voltage shift caused by radiation of radioactive rays. As a result, it is possible to repress characteristic deteriorations attributed to the radiation of radioactive rays and, therefore, improve the reliability.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. 1 is a functional block diagram showing the whole configuration of a radioactive-ray imaging apparatus according to a first embodiment of the present disclosure;

[0021] FIG. 2 is a model diagram showing a cross-sectional structure of a pixel section shown in FIG. 1 (as a section having an indirect conversion type);

[0022] FIG. 3 is a diagram showing a typical pixel circuit employed in the pixel section shown in FIG. 2 (to serve as an active-driven circuit);

[0023] FIG. 4 is a cross-sectional diagram showing a rough configuration of a transistor shown in FIG. 3;

[0024] FIGS. 5A to 5C are explanatory cross-sectional model diagrams to be referred to in description of a process sequence according to a method for manufacturing the transistor shown in FIG. 4;

[0025] FIGS. 5D to 5F are explanatory cross-sectional model diagrams showing a process sequence serving as the continuation of the process sequence described by referring to FIG. 5C;

[0026] FIGS. 5G to 5H are explanatory cross-sectional model diagrams showing a process sequence serving as the continuation of the process sequence described by referring to FIG. 5F;

[0027] FIG. 5I is an explanatory cross-sectional model diagram to be referred to in description of a process serving as the continuation of the process sequence described by referring to FIG. 5H;

[0028] FIG. 6 is a model diagram showing a cross-sectional structure of a photodiode shown in FIG. 3;

[0029] FIG. 7 is an explanatory model diagram to be referred to in description of an effect given by positive electric charge in a typical comparison transistor;

[0030] FIG. 8 is an explanatory model diagram to be referred to in description of an effect given by positive electric charge in the transistor shown in FIG. 4;

[0031] FIG. 9 is a diagram showing the effect of an X-ray radiation quantity on the current-voltage characteristic of the transistor shown in FIG. 4;

[0032] FIG. 10 is a characteristic diagram showing a relation between the X-ray radiation quantity and the threshold-voltage shift of the transistor shown in FIG. 4;

[0033] FIG. 11 is a characteristic diagram showing a relation between the X-ray radiation quantity and the S value in the current-voltage characteristic of the transistor shown in FIG. 4;

[0034] FIGS. 12A and 12B are cross-sectional diagrams showing a rough configuration of a transistor according to first typical modification;

[0035] FIG. 13 is a cross-sectional diagram showing a rough configuration of a transistor according to a second embodiment of the present disclosure;

[0036] FIG. 14 is an explanatory model diagram to be referred to in description of the effect of positive electric charge in the transistor shown in FIG. 13;

[0037] FIG. 15 is a diagram showing the effect of the X-ray radiation quantity on the current-voltage characteristic of the transistor shown in FIG. 13;

[0038] FIG. 16 is a characteristic diagram showing a relation between the X-ray radiation quantity and the threshold-voltage shift for each of the transistors shown in FIG. 13;

[0039] FIG. 17 is a characteristic diagram showing a relation between the X-ray radiation quantity and the S value in the current-voltage characteristic for each of the transistors shown in FIG. 13;

[0040] FIG. 18 is an explanatory cross-sectional diagram to be referred to in description of a rough configuration of the transistor according to second modification and the effect of positive electric charge in the transistor;

[0041] FIG. 19 is a cross-sectional diagram showing a rough configuration of a transistor according to third typical modification;

[0042] FIG. 20 is a cross-sectional diagram showing another example of the transistor shown in FIG. 19;

[0043] FIG. 21 is a cross-sectional diagram showing a rough configuration of a transistor according to fourth typical modification;

[0044] FIG. 22 is a cross-sectional diagram showing a rough configuration of a transistor according to fifth typical modification;

[0045] FIG. 23 is a cross-sectional diagram showing a rough configuration of a transistor according to sixth typical modification;

[0046] FIGS. 24A and 24B are cross-sectional diagrams showing another rough configuration of the transistor shown in FIG. 23;

[0047] FIG. 25 is a cross-sectional diagram showing another rough configuration of the transistor shown in FIG. 23;

[0048] FIG. 26 is a cross-sectional diagram showing a rough configuration of a transistor according to seventh typical modification;

[0049] FIGS. 27A and 27B are cross-sectional diagrams showing another rough configuration of the transistor shown in FIG. 26;

[0050] FIG. 28 is a cross-sectional diagram showing another rough configuration of the transistor shown in FIG. 26;

[0051] FIG. 29 is a diagram showing a typical example of a pixel driving circuit (also referred to as a passive driving circuit) according to eighth typical modification;

[0052] FIG. 30 is an explanatory model diagram to be referred to in description of a radioactive-ray imaging apparatus provided in accordance with ninth modification to serve as an apparatus having a direct conversion type;

[0053] FIG. 31 is a model diagram showing the whole configuration of a radioactive-ray imaging display system serving as a typical application; and

[0054] FIG. 32 is a cross-sectional model diagram showing another typical shape of a gate electrode.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0055] Embodiments of the present disclosure are explained below by referring to diagrams. It is to be noted that the explanation is divided into topics arranged in the following order.

1: First Embodiment (A radioactive-ray imaging apparatus designed into an indirect conversion type to employ a transistor in which portions of both the source and drain electrodes forming a pair are each used as a shield electrode layer)

- 2: First Modification (A typical configuration in which a portion of the drain electrode is used as a shield electrode layer)
- 3: Second Embodiment (A typical configuration in which a shield electrode layer is provided separately from a pair of source and drain electrodes)
- 4: Second Modification (A typical configuration in which a shield electrode layer is held at a negative electric potential)
- 5: Third Modification (A typical transistor having a double-gate structure)
- 6: Fourth Modification (Another typical transistor having a double-gate structure)
- 7: Fifth Modification (A further typical transistor having a double-gate structure)
- 8: Sixth Modification (A typical transistor having a top-gate structure)
- 9: Seventh Modification (A typical transistor having a bottom-gate structure)
- 10: Eighth Modification (A typical pixel circuit adopting the passive driving method)
- 11: Ninth Modification (A typical radioactive-ray imaging apparatus of the direct conversion type)
- 12: Typical Application (A typical radioactive-ray imaging display system)

#### 1: First Embodiment

Whole Configuration of Radioactive-Ray Imaging Apparatus  
**[0056]** FIG. 1 is a functional block diagram showing the whole configuration of a radioactive-ray imaging apparatus 1 according to a first embodiment of the present disclosure. The radioactive-ray imaging apparatus 1 is the so-called indirect-conversion-type FPD (Flat Panel Detector) which receives radioactive rays after the rays have been subjected to a wavelength conversion process and obtains image information based on the radioactive rays as an electrical signal. In this case, typical radioactive rays are the  $\alpha$ ,  $\beta$ ,  $\gamma$  and X rays. For example, the radioactive-ray imaging apparatus 1 is an X-ray imaging apparatus which is proper for mainly medical cares and other nondestructive inspections such as baggage inspections.

**[0057]** As shown in the figure, the radioactive-ray imaging apparatus 1 employs a pixel section 12 created on a substrate 11 and peripheral circuits (also referred to as driving circuits) provided in areas surrounding the pixel section 12. The peripheral circuits typically include a row scanning section 13, a horizontal select section 14, a column scanning section 15 and a system control section 16.

**[0058]** The pixel section 12 is the imaging area of the radioactive-ray imaging apparatus 1. The pixel section 12 includes unit pixels P (each also referred to hereafter merely as a pixel P) which are laid out 2-dimensionally to form typically a pixel matrix. The unit pixel P may also be referred to hereafter merely as a pixel P in some cases. The unit pixels P are connected to pixel driving lines 17. Typically, two pixel driving lines 17 are connected to the unit pixels P on each pixel row in the pixel matrix. To put it concretely, the two pixel driving lines 17 connected to the unit pixels P on each pixel row are a row select line and a reset control line. Every pixel P includes a photoelectric conversion device for generating electric charge having an amount according to the quantity of light incident to the pixel P and storing the electric charge internally in the pixel P. In the following description, the quantity of light incident to the pixel P is also referred to as a

received-light quantity whereas the electrical charge is also referred to as an optical electric charge. By the way, a photodiode 111A to be explained later is used as the photoelectric conversion device cited above.

**[0059]** In the pixel section 12, the two pixel driving lines 17 provided for every pixel row are stretched in the row direction. In addition, for every pixel column, the unit pixels P in the pixel section 12 are also connected to a vertical signal line 18 stretched in the column direction. The pixel driving line 17 conveys a driving signal for reading out a signal from a pixel P connected to the pixel driving line 17. In FIG. 1, a pixel driving line 17 is shown as a line even though the pixel driving line 17 is by no means limited to one line. One end of the pixel driving line 17 is connected to an output terminal of the row scanning section 13. This output terminal connected to a pixel driving line 17 is a terminal specially provided for a row along which the pixel driving line 17 is stretched. The configuration of the pixel section 12 will be described later.

**[0060]** As shown in FIG. 2, a scintillator layer 114 (serving as a wavelength conversion layer) is created on the pixel section 12 and is covered by a protection layer 115.

**[0061]** The scintillator layer 114 carries out a wavelength conversion process to change the wavelength of an incident radioactive ray to a value in a sensitive region of the photodiode 111A to be described later. The scintillator layer 114 makes use of a fluorescent material for typically converting an X ray into a visible ray. Typical examples of the fluorescent material are cesium iodide (CsI) doped with thallium (Tl), sulfur-cadmium oxide ( $\text{Gd}_2\text{O}_2\text{S}$ ) doped with terbium (Tb) and BaFx (where X can be Cl, Br, I or the like). A desirable thickness of the scintillator layer 114 is in a range of 100 microns to 600 microns. For example, the thickness of the scintillator layer 114 can be set at 600 microns. Such a scintillator layer 114 can be created on a flattening film 113 typically by adoption of a vacuum evaporation method.

**[0062]** The protection layer 115 is typically an organic film made of parylene C or the like. The fluorescent material (such as particularly CsI) used for making the scintillator layer 114 is prone to deterioration caused by moistures. It is thus desirable to provide the protection layer 115 serving as a moisture barrier layer on the scintillator layer 114.

**[0063]** The row scanning section 13 is configured to include a shift register and an address decoder. The row scanning section 13 functions as a pixel driving section for driving the unit pixels P in the pixel section 12 in typically row units. Signals output by pixels P on a pixel row selected by the row scanning section 13 in a scanning operation are supplied to the horizontal select section 14 through the vertical signal lines 18 connected to the pixels P. The horizontal select section 14 is configured to include amplifiers each provided for one of the vertical signal lines 18 and horizontal select switches also each provided for one of the vertical signal lines 18.

**[0064]** The column scanning section 15 is configured to include a shift register and an address decoder. The column scanning section 15 scans the horizontal select switches of the horizontal select section 14 in order to sequentially select the switches on a one-switch-after-another basis. The column scanning section 15 scans and selects the horizontal select switches in order to supply the signals asserted by pixels P on the vertical signal lines 18 on a one-signal-after-another basis on a horizontal select line 19 connected to sections external to the substrate 11.

[0065] Circuit portions serving as the row scanning section 13, the horizontal select section 14, the column scanning section 15 and the horizontal select line 19 may be created directly above the substrate 11 or provided in an external control IC. As an alternative, these circuit portions can also be created on another substrate which is connected to the substrate 11 by a cable or the like.

[0066] The system control section 16 receives, among others, a clock signal from a source external to the substrate 11 and data specifying an operating mode. In addition, the system control section 16 outputs data such as internal information of the radioactive-ray imaging apparatus 1. On top of that, the system control section 16 also has a timing generator for generating a variety of timing signals and carries out control to drive the peripheral circuits such as the row scanning section 13, the horizontal select section 14 and the column scanning section 15 on the basis of the timing signals generated by the timing generator.

#### Detailed Configuration of the Pixel Section 12

[0067] The pixel section 12 includes pixel circuits 12a created on the substrate 11. The pixel circuit 12a is shown in FIG. 3. Each of the pixel circuits 12a employs a photodiode 111A and transistors 111B. The photodiode 111A and the transistors 111B will be described later. It is to be noted that an organic insulation film serving as a flattening film not shown in the figure is typically provided on the pixel circuit 12a. In addition, a protection film also not shown in the figure may also be provided on the flattening film. Detailed configurations of components composing the pixel section 12 are explained as follows.

#### Pixel Circuit

[0068] FIG. 3 is a diagram showing a typical pixel circuit 12a in a photoelectric conversion layer 112. As shown in the figure, the pixel circuit 12a employs a photodiode 111A serving as the photoelectric conversion device mentioned before as well as transistors Tr1, Tr2 and Tr3 which are the transistors 111B cited above. The pixel circuit 12a is connected to the vertical signal line 18 described before, a row select line 171 and a reset control line 172 which function as the pixel driving lines 17.

[0069] The photodiode 111A is typically a PIN (Positive Intrinsic Negative) diode. Typically, the sensitive region of the photodiode 111A is a visible-light region. That is to say, the received-light wavelength region of the photodiode 111A is a visible-light region. When a reference electric potential  $V_{xref}$  is applied to a terminal 133 connected to a specific end of the photodiode 111A, the photodiode 111A generates signal electric charge having an amount corresponding to the quantity of light incident to the photodiode 111A. The other end of the photodiode 111A is connected to an accumulation node N. The accumulation node N has a capacitor 136 for accumulating the signal electric charge generated by the photodiode 111A. Note that it is also possible to provide a configuration in which the photodiode 111A is connected between the accumulation node N and the ground. A cross-sectional structure of the photodiode 111A will be described later.

[0070] Each of the transistors Tr1, Tr2 and Tr3 is typically a FET (Field Effect Transistor) of N-type or P-type in which a semiconductor layer for channel creation is made typically from LTPS (Low-Temperature Polysilicon). This semicon-

ductor layer is a semiconductor layer 126 to be described later. However, the material used for making the semiconductor layer does not have to be the LTPS. For example, the semiconductor layer can also be made of a silicon-group semiconductor such as microcrystal silicon or polysilicon. As an alternative, the semiconductor layer can also be made of a semiconductor oxide such as indium-gallium-zinc oxide (In-GaZnO) or zinc oxide (ZnO).

[0071] The transistor Tr1 is a reset transistor connected between a terminal 137 for receiving a reference electric potential  $V_{ref}$  and the accumulation node N. When the reset transistor Tr1 is turned on in response to a reset signal  $V_{rst}$ , the reset transistor Tr1 resets the electric potential appearing at the accumulation node N to the reference electric potential  $V_{ref}$ .

[0072] The transistor Tr2 is a read transistor. The gate electrode of the read transistor Tr2 is connected to the accumulation node N whereas the drain electrode of the read transistor Tr2 is connected to a terminal 134 which is connected to a power supply VDD. The gate electrode of the read transistor Tr2 receives a signal representing signal electric charge accumulated in the photodiode 111A whereas the source electrode of the read transistor Tr2 outputs a signal voltage according to the signal electric charge.

[0073] The transistor Tr3 is a row select transistor connected between the source electrode of the read transistor Tr2 and the vertical signal line 18. When the row select transistor Tr3 is turned on in response to a row scanning signal  $V_{read}$ , the row select transistor Tr3 passes on the signal appearing at the source electrode of the read transistor Tr2 to the vertical signal line 18. With regard to the row select transistor Tr3, it is also possible to provide a configuration in which the row select transistor Tr3 is connected between the drain electrode of the read transistor Tr2 and the power supply VDD whereas the source electrode of the read transistor Tr2 is connected directly to the vertical signal line 18.

[0074] The following description explains cross-sectional structures of each of the transistors Tr1, Tr2 and Tr3 which are each also referred to as the transistor 111B which is a generic technical term for the transistors Tr1, Tr2 and Tr3.

#### Detailed Configuration of the Transistor 111B

[0075] FIG. 4 is a cross-sectional diagram showing a typical configuration of the transistor 111B. The transistor 111B has the so-called dual-gate structure in which the two gate electrodes of the transistor 111B sandwich a semiconductor layer 126. To put it concretely, the transistor 111B has a gate electrode 120A in a selective area on a substrate 11 whereas a second gate insulation film 129 is provided to cover the gate electrode 120A. On the second gate insulation film 129, the semiconductor layer 126 is provided. The semiconductor layer 126 includes a channel layer 126a. The semiconductor layer 126 also includes an LDD (Lightly Doped Drain) layer 126b and an  $N^+$  layer 126c on each of the two edges of the channel layer 126a. A first gate insulation film 130 is provided to cover the semiconductor layer 126. In a selective area on the first gate insulation film 130, a gate electrode 120B is provided. The selective area on the first gate insulation film 130 is an area facing the gate electrode 120A.

[0076] On the gate electrode 120B, a first interlayer insulation film 131 is created. Holes H1 are provided in portions of the first interlayer insulation film 131 and the first gate insulation film 130. On the first interlayer insulation film 131, a pair of source and drain electrodes 128A and 128B are



provided on the first interlayer insulation film **131** to fill up such holes **H1** so that the source and drain electrodes **128A** and **128B** are electrically connected to the semiconductor layer **126**. A second interlayer insulation film **132** is provided on the source and drain electrodes **128A** and **128B**.

**[0077]** It is to be noted that the gate electrode **120B** according to this embodiment is a concrete example of the first gate electrode according to the embodiment of the present disclosure whereas the gate electrode **120A** according to this embodiment is a concrete example of the second gate electrode according to the embodiment of the present disclosure. In addition, the first gate insulation film **130** according to this embodiment is a concrete example of the first gate insulation film according to the embodiment of the present disclosure whereas the second gate insulation film **129** according to this embodiment is a concrete example of the insulation film according to the embodiment of the present disclosure. On top of that, the first interlayer insulation film **131** according to this embodiment is a concrete example of the first interlayer insulation film according to the embodiment of the present disclosure whereas the second interlayer insulation film **132** according to this embodiment is a concrete example of the second interlayer insulation film according to the embodiment of the present disclosure.

**[0078]** Each of the gate electrode **120A** and the gate electrode **120B** is a single-layer film or a multi-layer film and the film is made of a material such as titan (Ti), aluminum (Al), molybdenum (Mo), tungsten (W) or chrome (Cr). As described above, the second gate insulation film **129** is sandwiched between the gate electrode **120A** and the semiconductor layer **126** whereas the first gate insulation film **130** is sandwiched between the semiconductor layer **126** and the gate electrode **120B** which faces the gate electrode **120A**. In other words, the gate electrode **120A** and the gate electrode **120B** face each other in about the same area, sandwiching the channel layer **126a**. Such a gate electrode **120B** is subjected to a patterning process by making use of typically the same photo mask as the gate electrode **120A**. However, it is desirable to provide an ideal configuration in which the gate electrode **120B** is provided right above the gate electrode **120A**.

**[0079]** The thickness of each of the gate electrode **120A** and the gate electrode **120B** is in a range of 30 nm to 150 nm. For example, the thickness of the gate electrode **120A** is set at a typical value of 65 nm whereas the thickness of the gate electrode **120B** is set at a typical value of 90 nm.

**[0080]** Each of the second gate insulation film **129** and the first gate insulation film **130** is configured to include typically a silicon-oxide film. As the silicon-oxide film, it is possible to make use of a silicon compound film including oxygen. A typical example of the silicon compound film is a film made of silicon oxide (SiO<sub>2</sub>) or silicon oxynitride (SiON). To put it concretely, each of the second gate insulation film **129** and the first gate insulation film **130** is a laminated film created as a stack from a film made of silicon oxide (SiO<sub>2</sub>) and a film made of silicon nitride (SiN<sub>x</sub>). To be more specific, the second gate insulation film **129** is a laminated stack created by sequentially superposing a silicon-nitride film **129A** and a silicon-oxide film **129B** on the substrate **11** in the same order as the order in which the silicon-nitride film **129A** and the silicon-oxide film **129B** are enumerated in this sentence. By the same token, the first gate insulation film **130** is a laminated stack created by sequentially superposing a silicon-oxide film **130A**, a silicon-nitride film **130B** and a silicon-oxide film **130C** on the semiconductor layer **126** in the same order as the

order in which the silicon-oxide film **130A**, the silicon-nitride film **130B** and the silicon-oxide film **130C** are enumerated in this sentence. That is to say, it is desirable to provide a configuration in which the silicon-oxide film **129B** and the silicon-oxide film **130A** are created in the vicinity of the semiconductor layer **126** and at locations sandwiching the semiconductor layer **126**. Such a configuration is provided in order to eliminate a threshold-voltage shift caused by the effect of a boundary-surface level on the semiconductor layer **126**.

**[0081]** The semiconductor layer **126** can be made of typically polysilicon, low-temperature polysilicon, microcrystal silicon or a non-crystal silicon. However, it is desirable to make the semiconductor layer **126** of low-temperature polysilicon. As an alternative, the semiconductor layer **126** can also be made of a semiconductor oxide such as indium-gallium-zinc oxide (IGZO). On each edge side of the channel layer **126a** in the semiconductor layer **126**, the N' layer **126c** is provided to serve as an area of connection with the source or drain electrode **128A** or **128B**. The edge sides of the channel layer **126a** are edges on the source and drain sides. In addition, the LDD layer **126b** is created between the channel layer **126a** and the N' layer **126c** for the purpose of reducing the magnitude of a leak current.

#### Source/Drain Electrodes and Shield Electrode Layer

**[0082]** Each of the source and drain electrodes **128A** and **128B** is capable of functioning as a source or drain electrode, making it possible to swap the functions of the source and drain electrodes with each other between the source and drain electrodes **128A** and **128B**. In addition, while any one of the source and drain electrodes **128A** and **128B** is functioning as a source electrode, the other of the source and drain electrodes **128A** and **128B** is functioning as a drain electrode. Each of the source and drain electrodes **128A** and **128B** is a single-layer film or a multi-layer film and the film is made of a material such as titan (Ti), aluminum (Al), molybdenum (Mo), tungsten (W) or chrome (Cr). The source and drain electrodes **128A** and **128B** are connected to wires for reading out signals. In order to make each of the source and drain electrodes **128A** and **128B** capable of functioning as a source or drain electrode and make it possible to swap the functions of the source and drain electrodes with each other between the source and drain electrodes **128A** and **128B** in this embodiment as described above, the transistor **111B** is designed into a configuration in which the LDD layer **126b** is provided on each of the two sides of the channel layer **126a**.

**[0083]** In this embodiment, each of the source and drain electrodes **128A** and **128B** is provided by being extended to an area facing an edge **e2** of the gate electrode **120B**. In other words, each of the source and drain electrodes **128A** and **128B** is provided to overlap (or, strictly speaking, partially overlap) an area facing the edge **e2** of the gate electrode **120B**. The portions facing the edges **e2** correspond to the shield electrode layers **128a1** and **128b1** respectively. That is to say, the portions facing the edges **e2** function also as the shield electrode layers **128a1** and **128b1** respectively. As described above, the gate electrode **120B** is provided to face the gate electrode **120A**. Since the channel layer **126a** is created in an area corresponding to the gate electrode **120A** in the semiconductor layer **126**, however, the source and drain electrodes **128A** and **128B** are provided to face channels edges **e1**. It is to be noted that, as described above, the LDD layer **126b** is provided on each of the two sides of the channel layer **126a**

and, in this case, the shield electrode layers **128a1** and **128b1** are superposed also on the LDD layer **126b**.

**[0084]** It is to be noted that, in this embodiment, the gate electrode **120B** has a taper portion on each of the side surfaces thereof. These taper portions are created inevitably in an etching process. If the gate electrode **120B** has such taper portions, the edges **e2** of the gate electrode **120B** are the bottom edges of the taper portions as shown in an enlarged diagram provided on the right bottom corner of FIG. 4.

**[0085]** The shield electrode layers **128a1** and **128b1** function as electrical shields for reducing the effect of positive electric charge accumulated in the silicon-oxide film on the semiconductor layer **126** (or, particularly the channel layer **126a**). At least, portions of the shield electrode layers **128a1** and **128b1** are provided to face the edges **e2** of the gate electrode **120B**. It is desirable to provide the shield electrode layers **128a1** and **128b1** in such a way that the distance **d** between the shield electrode layers **128a1** and **128b1** is smaller than the gate length **L** of the gate electrode **120B**. It is even more desirable to provide the shield electrode layers **128a1** and **128b1** in such a way that the shield electrode layers **128a1** and **128b1** cover all the taper portions of the gate electrode **120B**. In this case, as explained before, it is ideal to provide the gate electrode **120B** at the same position as the gate electrode **120A**. In actuality, however, the position of the gate electrode **120B** may be shifted from the position of the gate electrode **120A** in some cases. The shift of the position of the gate electrode **120B** from the position of the gate electrode **120A** is referred to as an adjustment shift. If the shield electrode layers **128a1** and **128b1** cover the taper portions of the gate electrode **120B**, the effect of holes serving as positive electric charge on the channel layer **126a** can be reduced even in the case of such an adjustment shift. It is to be noted that the lower limit of the distance **d** between the shield electrode layers **128a1** and **128b1** is not limited to any value in particular. If the shield electrode layers **128a1** and **128b1** are too close to each other, however, problems such as a short circuit are raised. It is thus nice to set the position of an edge **e3** by taking these problems into consideration. In this embodiment, the shield electrode layers **128a1** and **128b1** are provided on the first interlayer insulation film **131** as portions of the source and drain electrodes **128A** and **128B** as described above.

**[0086]** In the same way as the second gate insulation film **129** and the first gate insulation film **130**, each of the first interlayer insulation film **131** and the second interlayer insulation film **132** is configured as a single-layer film or a multi-layer film and the film is typically a silicon-oxide film, a silicon-oxynitride film or a silicon-nitride film. In this case, the first interlayer insulation film **131** is a laminated stack including the silicon-oxide film **131a** and the silicon-nitride film **131b** which are sequentially created above the substrate **11** in the same order as the order in which the silicon-oxide film **131a** and the silicon-nitride film **131b** are enumerated in this sentence. On the other hand, the second interlayer insulation film **132** is a silicon-oxide film. It is to be noted that the layer of a portion of the transistor **111B** is common to the photodiode **111A** to be described later. That is to say, the layer of the portion of the transistor **111B** is created in the same thin-film process as the photodiode **111A**. Thus, as long as the second interlayer insulation film **132** in the photodiode **111A** is concerned, from the viewpoint of an etching select ratio used at the fabrication time, it is desirable to make use of a

silicon-oxide film rather than a silicon-nitride film as the second interlayer insulation film **132**.

#### Method for Manufacturing the Transistor **111B**

**[0087]** The transistor **111B** described above can be manufactured typically as follows. FIGS. **5A** to **5I** are explanatory cross-sectional model diagrams to be referred to in the following description of a process sequence according to a method for manufacturing the transistor **111B**.

**[0088]** First of all, as shown in FIG. **5A**, the gate electrode **120A** is created on the substrate **11**. To put it concretely, after a film made of a high-melting-point metal such as Mo has been created on the substrate **11** by adoption of typically a sputtering method, the film is subjected to a patterning process adopting typically a photolithography method to form an island shape.

**[0089]** Then, as shown in FIG. **5B**, the second gate insulation film **129** is created. To put it concretely, the silicon-nitride film **129A** and the silicon-oxide film **129B** are created sequentially and continuously to cover the gate electrode **120A** on the substrate **11** in the same order as the order in which the silicon-nitride film **129A** and the silicon-oxide film **129B** are enumerated in this sentence by adoption of typically the CVD method for creating the second gate insulation film **129** having a thickness determined in advance.

**[0090]** Subsequently, on the created second gate insulation film **129**, an amorphous silicon layer (that is, an  $\alpha$ -Si layer) **1260** to be used as the semiconductor layer **126** is created by adoption of typically the CVD method.

**[0091]** Then, as shown in FIG. **5C**, the created  $\alpha$ -Si layer **1260** is subjected to a multi-crystallization process in order to create the semiconductor layer **126**. To put it concretely, first of all, at a typical temperature in a range of 400 degrees Celsius to 450 degrees Celsius, the  $\alpha$ -Si layer **1260** is subjected to a dehydrogenation treatment (or an annealing process) in order to decrease the hydrogen content to a value not exceeding 1%. Then, by adoption of typically an ELA (Excimer Laser) method, a laser beam having a typical wavelength of 308 nm is radiated to the  $\alpha$ -Si layer **1260** in order to convert the  $\alpha$ -Si layer **1260** into a multi-crystal layer. Afterwards, the multi-crystal layer is doped with typically boron in order to adjust the threshold voltage **V<sub>th</sub>** so as to create the semiconductor layer **126**.

**[0092]** Subsequently, as shown in FIG. **5D**, ions are injected into predetermined areas of the semiconductor layer **126** obtained as a result of the multi-crystallization process in order to create the LDD layer **126b** and the N<sup>+</sup> layer **126c** in each of the predetermined areas.

**[0093]** Then, as shown in FIG. **5E**, the first gate insulation film **130** is created. To put it concretely, the silicon-oxide film **130A**, the silicon-nitride film **130B** and the silicon-oxide film **130C** are continuously created as films each having a predetermined thickness in the same order as the order in which the silicon-oxide film **130A**, the silicon-nitride film **130B** and the silicon-oxide film **130C** are enumerated in this sentence by adoption of typically the CVD method to form the first gate insulation film **130** covering the semiconductor layer **126**. It is to be noted that the thicknesses of the silicon-oxide film **130A**, the silicon-oxide film **130C** and the silicon-oxide film **129B** of the second gate insulation film **129** described above are set at such values that the sum of the thicknesses of the silicon-oxide film **130A**, the silicon-oxide film **130C** and the silicon-oxide film **129B** of the second gate insulation film **129** is not greater than 65 nm. It is also worth noting that, after the

first gate insulation film **130** has been created, contact holes are created in advance for electrically connecting the gate electrode **120A** to the gate electrode **120B** which is created in a process described below. However, the process of creating the contact holes is shown in none of the figures.

[0094] Then, as shown in FIG. 5F, the gate electrode **120B** is created on the first gate insulation film **130**. To put it concretely, after a film made of a high-melting-point metal such as Mo has been created on the substrate **11** by adoption of typically a sputtering method, the film is subjected to a patterning process adopting typically a photolithography method to form an island shape. At that time, the gate electrode **120B** is subjected to a patterning process by making use of typically the same photo mask as the gate electrode **120A**. However, it is desirable to adjust the position of the gate electrode **120B** in order to create the gate electrode **120B** ideally right above the gate electrode **120A**.

[0095] Then, as shown in FIG. 5G, the silicon-oxide film **131a** and the silicon-nitride film **131b** are continuously created by adoption of typically the sputtering method in the same order as the order in which the silicon-oxide film **131a** and the silicon-nitride film **131b** are enumerated in this sentence in order to create the first interlayer insulation film **131**.

[0096] Subsequently, as shown in FIG. 5H, the contact holes **H1** are created to penetrate the created first interlayer insulation film **131** and the created first gate insulation film **130** till the surface of the semiconductor layer **126** by carrying out typically an etching process.

[0097] Afterwards, as shown in FIG. 5I, the source and drain electrodes **128A** and **128B** are created to fill up the holes **H1** by adoption of typically the sputtering method and then subjected to a patterning process to form predetermined shapes of the source and drain electrodes **128A** and **128B**. In this process, a gap (or a separation groove) is created between the source and drain electrodes **128A** and **128B** so that a portion of each of the source and drain electrodes **128A** and **128B** overlaps the gate electrode **120B**. Thus, the source and drain electrodes **128A** and **128B** are created to function also as the shield electrode layers **128a1** and **128b1**. Finally, a silicon-oxide layer or the like is created to serve as the second interlayer insulation film **132** on the source and drain electrodes **128A** and **128B** as well as the first interlayer insulation film **131** by adoption of typically the CVD method. The creation of the second interlayer insulation film **132** completes the transistor **111B** shown in FIG. 4.

#### Configuration of the Photodiode **111A**

[0098] FIG. 6 is a model diagram showing a typical cross-sectional configuration of the photodiode **111A**. The photodiode **111A** is provided on the substrate **11** along with the transistor **111B**. A portion of the stack structure is common to the transistor **111B** and is created by carrying out the same thin-film process as the transistor **111B**. The detailed configuration of the photodiode **111A** is explained as follows.

[0099] The photodiode **111A** has a p-type semiconductor layer **122** in a selective area on a substrate **11**. The p-type semiconductor layer **122** and the selective area sandwich a gate insulation layer **121a**. A first interlayer insulation film **121b** having a contact hole **H2** is provided on the substrate **11** (or, strictly speaking, on the gate insulation layer **121a**) to face the p-type semiconductor layer **122**. An i-type semiconductor layer **123** is provided on the p-type semiconductor layer **122** and inside the contact hole **H2** of the first interlayer insulation film **121b**. On the i-type semiconductor layer **123**,

an n-type semiconductor layer **124** is created. In the n-type semiconductor layer **124**, a second interlayer insulation film **121c** having a contact hole **H3** is provided. The n-type semiconductor layer **124** is electrically connected to an upper electrode **125** through the contact hole **H3**.

[0100] In the typical structure described above, on the side close to the substrate **11** or the lower side, the p-type semiconductor layer **122** is provided and, on the upper side, the n-type semiconductor layer **124** is provided. It is to be noted, however, that the structure can also be made upside down. That is to say, on the lower side, the n-type layer is provided and, on the upper side, the p-type layer is provided. In addition, a portion or the whole or each of the gate insulation layer **121a**, the first interlayer insulation film **121b** and the second interlayer insulation film **121c** has the same layer structure as each layer of respectively the second gate insulation film **129**, the first gate insulation film **130** and the first interlayer insulation film **131** which are employed in the transistor **111B**. This photodiode **111A** can be manufactured by carrying out the same thin-film process as the transistor **111B**.

[0101] The p-type semiconductor layer **122** is a p+ area made of typically poly-crystal silicon (or polysilicon) doped with typically boron (B). The thickness of the p-type semiconductor layer **122** is typically in a range of 40 nm to 50 nm. The p-type semiconductor layer **122** functions also as typically a lower electrode for reading out signal electric charge. The p-type semiconductor layer **122** is connected to an accumulation node **N** described earlier by referring to FIG. 3. As an alternative, the p-type semiconductor layer **122** can also serve as the accumulation node **N** in which electric charge is accumulated.

[0102] The i-type semiconductor layer **123** is a semiconductor layer exhibiting intermediate conductivity between the p and n types. The i-type semiconductor layer **123** is typically an undoped pure semiconductor layer made of typically non-crystal silicon or amorphous silicon. The thickness of the i-type semiconductor layer **123** is typically in a range of 400 nm to 1,000 nm. The larger the thickness, the larger the optical sensitivity of the photodiode **111A**.

[0103] The n-type semiconductor layer **124** is made of typically non-crystal silicon or amorphous silicon, forming an n+ area. The thickness of the n+ area is typically in a range of 10 nm to 50 nm.

[0104] The upper electrode **125** is an electrode for supplying a reference level provided for photoelectric conversion. The n-type semiconductor layer **124** is typically a transparent conductive film made of ITO (Indium Tin Oxide) or the like. The upper electrode **125** is connected to a power-supply wire **127** for applying a voltage to the upper electrode **125**. The power-supply wire **127** is made of typically a material having a resistance lower than that of the upper electrode **125**. Typical examples of the material are Ti, Al, Mo, W and Cr.

#### Effects of the Embodiment

[0105] Effects of this embodiment are explained by referring to FIGS. 1 to 4 and FIGS. 7 to 11 as follows. A radiation source shown in none of the figures radiates a radioactive ray such as an X ray to the radioactive-ray imaging apparatus **1**. When the radioactive ray enters the radioactive-ray imaging apparatus **1** after passing through a detected body serving as the imaging object, the incident radioactive ray is subjected to a photoelectric conversion process following a wavelength conversion process in order to generate an electrical signal representing an image of the imaging object. To put it in

detail, first of all, the radioactive ray incident to the radioactive-ray imaging apparatus **1** is subjected to the wavelength conversion process carried out by the scintillator layer **114** provided on the pixel section **12** in order to change the wavelength of the radioactive ray to a wavelength in the sensitive region (or the visible region in this case) of the photodiode **111A**. Thus, the scintillator layer **114** emits visible light. The visible light emitted by the scintillator layer **114** in this way is supplied to the pixel section **12**.

[0106] When an electric potential determined in advance is applied to the photodiode **111A** from a power-supply line shown in none of the figures through the upper electrode **125**, incident light is supplied to the pixel section **12** from the side close to the upper electrode **125** and the pixel section **12** carries out the photoelectric conversion process to convert the incident light into signal electric charge having an amount according to the quantity of the incident light. The signal electric charge generated as a result of the photoelectric conversion process is read out from the side close to the p-type semiconductor layer **122** as an optical current.

[0107] To put it in detail, electric charge generated as a result of the photoelectric conversion process carried out by the photodiode **111A** is collected in the p-type semiconductor layer **122** (or the accumulation node N) serving as an accumulation layer and read out from the accumulation layer as a current which is supplied to the gate electrode of the transistor Tr2 functioning as a read transistor. Receiving the current read out from the accumulation layer, the read transistor Tr2 outputs a signal voltage according to the signal electric charge represented by the current. When the row select transistor Tr3 is turned on in response to the row scanning signal Vread, the signal voltage output by the read transistor Tr2 is asserted on the vertical signal line **18**, that is the signal voltage output by the read transistor Tr2 is read out onto the vertical signal line **18**. The signal voltage asserted on the vertical signal line **18** is output to the horizontal select section **14** through the vertical signal line **18** for each pixel column.

[0108] As described above, in this embodiment, an incident radioactive ray such as an X ray is subjected to a waveform conversion process and a photoelectric conversion process in order to obtain an electrical signal representing image information. However, some radioactive rays pass through the scintillator layer **114** as they are without experiencing the waveform conversion process carried out in the scintillator layer **114**. If such radioactive rays hit the pixel section **12**, in particular, a problem like one described as follows is raised in a transistor **111B**. The transistor **111B** has silicon-oxide films each containing oxygen in the second gate insulation film **129**, the first gate insulation film **130**, the first interlayer insulation film **131** and the second interlayer insulation film **132**. If a radioactive ray hits an silicon-oxide film containing oxygen, electrons in the film are excited due to, among others, the so-called photoelectric effect, the Compton scattering phenomenon or the electron-pair generation phenomenon. As a result, residual holes are trapped on a boundary surface and a defect. That is to say, the boundary surface and the defect are electrically charged with residual holes.

#### Typical Comparison Transistor

[0109] FIG. 7 is an explanatory cross-sectional diagram referred to in the following description of an effect given by positive electric charge in a typical comparison transistor **100** serving as a typical transistor provided for the purpose of comparison with the transistor **111B** provided by the present

disclosure. The comparison transistor **100** is also a transistor having a dual-gate structure. As shown in the figure, the comparison transistor **100** includes a gate electrode **102A**, a first gate insulation film **103**, a semiconductor layer **104**, a second gate insulation film **105**, a gate electrode **102B** and a first interlayer insulation film **107** which are sequentially created on a substrate **101** in the same order as the order in which the gate electrode **102A**, the first gate insulation film **103**, the semiconductor layer **104**, the second gate insulation film **105**, the gate electrode **102B** and the first interlayer insulation film **107** are enumerated in this sentence. The semiconductor layer **104** includes a channel layer **104a**, an LDD layer **104b** and an N<sup>+</sup> layer **104c**. In the first interlayer insulation film **107** and the second gate insulation film **105**, contact holes are provided. Source and drain electrodes **106** are connected to the semiconductor layer **104** through these contact holes. A second interlayer insulation film **108** is created on the source and drain electrodes **106** as well as on the first interlayer insulation film **107**. In such a configuration, the first gate insulation film **103** is a laminated stack provided above the substrate **101** as a stack including a silicon-nitride film **103A** and a silicon-oxide film **103B** which are created above the substrate **101** sequentially in the same order as the order in which the silicon-nitride film **103A** and the silicon-oxide film **103B** are enumerated in this sentence. By the same token, the second gate insulation film **105** is a laminated stack provided above the substrate **101** as a stack including a silicon-oxide film **105A**, a silicon-nitride film **105b** and a silicon-oxide film **105C** which are created above the substrate **101** sequentially in the same order as the order in which the silicon-nitride film **103A**, the silicon-nitride film **105b** and the silicon-oxide film **105C** are enumerated in this sentence. In the same way, the first interlayer insulation film **107** is a laminated stack provided above the substrate **101** as a stack including a silicon-oxide film **107A** and a silicon-nitride film **107B** which are created above the substrate **101** sequentially in the same order as the order in which the silicon-oxide film **107A** and the silicon-nitride film **107B** are enumerated in this sentence.

[0110] In the transistor **100** serving as a typical comparison transistor, the silicon-oxide film **103B**, the silicon-oxide film **105A**, the silicon-oxide film **105C**, the silicon-oxide film **107A** and the second interlayer insulation film **108** which is also a silicon-oxide film are electrically charged with positive electric charge due to the reason described before. Among the silicon-oxide film **103B**, the silicon-oxide film **105A**, the silicon-oxide film **105C**, the silicon-oxide film **107A** and the second interlayer insulation film **108**, for example, the positive electric charge in the second interlayer insulation film **108** has a worst effect on the semiconductor layer **104** as indicated by a model shown in FIG. 7. To be more specific, the positive electric charge accumulated in the second interlayer insulation film **108** has a very bad effect on a channel edge e1 as indicated by dashed-line arrows in the model shown in the same figure. Since the comparison transistor **100** has a dual-gate structure in this case, the positive electric charge accumulated in portions right above the gate electrode **102B** is shielded by the gate electrode **102B** so that the effect of this positive electric charge on the semiconductor layer **104** is reduced. In an area on an outer side outside an edge e2 of the gate electrode **102B**, however, such a shielding effect cannot be obtained sufficiently. For example, in a gap between the gate electrode **102B** and the drain and source electrodes **106**, such a shielding effect cannot be obtained sufficiently. In addition, even though it is ideal to provide the gate electrode

**102B** at a position right above the gate electrode **102A**, in actuality, it is difficult to adjust the position of the gate electrode **102B** to the position of the gate electrode **102A** with a high degree of precision. Thus, variations of the position of the gate electrode **102B** are generated with ease. The variations of the position of the gate electrode **102B** are each referred to as a position shift. If such a position shift exists, it is particularly difficult to sufficiently obtain the shielding effect for the channel edge **e1**.

[0111] For the reasons described above, the channel layer **126a** or, in particular, the channel edge **e1** is affected by positive electric charge with ease. Thus, the threshold voltage  $V_{th}$  is undesirably shifted to the negative side. In addition, if the semiconductor layer **104** is made of low-temperature polysilicon in particular, it is desirable to sandwich the semiconductor layer **104** between silicon-oxide films. Thus, in comparison with a configuration using amorphous silicon for example, the threshold voltage  $V_{th}$  cited above is shifted with ease. In addition, if the threshold voltage  $V_{th}$  is shifted, typically, the off current and the on current change, raising problems. To put it concretely, the off current increases, causing a current leak whereas the on current decreases, making it impossible to read out the signal electric charge. That is to say, it is difficult to sustain the reliability of the transistor **100**.

[0112] In the case of this embodiment, on the other hand, the shield electrode layers **128a1** and **128b1** are provided on the first interlayer insulation film **131**. The shield electrode layers **128a1** and **128b1** are provided on the first interlayer insulation film **131** in such a way that portions of the shield electrode layers **128a1** and **128b1** face the edges **e2** of the gate electrode **120B**. That is to say, the shield electrode layers **128a1** and **128b1** are provided on the first interlayer insulation film **131** in such a way that the portions of the shield electrode layers **128a1** and **128b1** overlap the gate electrode **120B**. Thus, as shown in the model of FIG. 8, in the first place, the shielding effect of the gate electrode **120B** typically reduces the effect of positive electric charge accumulated in the second interlayer insulation film **132** made of silicon oxide on the channel layer **126a**. In the second place, in this embodiment, the shielding effect of the shield electrode layers **128a1** and **128b1** represses the effect of positive electric charge on the channel edges **e1**.

[0113] FIG. 9 is a diagram showing the effect of an X-ray radiation quantity of on the current-voltage characteristic of the transistor **111B** including the semiconductor layer **126** made of low-temperature polysilicon for a case in which an X-ray is radiated to the transistor **111B**. The current-voltage characteristic of the transistor **111B** is a relation between the gate voltage  $V_g$  and the drain current  $I_{ds}$ . The current-voltage characteristic has been obtained for a source-drain voltage of 6.1 V, a width  $W$  of 20.5 microns and a length  $L$  of 6 microns. In addition, FIG. 10 is a characteristic diagram showing a relation between the X-ray radiation quantity and the shift quantity ( $\Delta V_{shift}$ ) of a reference voltage which is a voltage  $V_g$  with the drain current  $I_{ds}$  of 1.0 e-11A taken as a reference. On the other hand, FIG. 11 is a characteristic diagram showing also a relation between the X-ray radiation quantity and the  $S$  value (or the threshold value).

[0114] It is to be noted that the curves shown in FIGS. 9, 10 and 11 are curves obtained for an X-ray tube voltage of 90 kV and X-ray radiation quantities of 0 Gy, 70 Gy, 110 Gy and 200 Gy. In addition, instead of measuring the shift quantity of the voltage  $V_g$  (that is, the threshold voltage  $V_{th}$ ) with the drain current  $I_{ds}$  of 5.0 e-7A taken as a reference, the shift quantity

( $\Delta V_{shift}$ ) of the voltage  $V_g$  with the drain current  $I_{ds}$  of 1.0 e-11A taken as a reference is measured in order to show this shift quantity in a more easily understood way.

[0115] As is obvious from the curves, if an X-ray is radiated to the transistor **111B**, as the radiation quantity of the X-ray is increased from 0 Gy to 200 Gy through 70 Gy and 110 Gy, the shift  $\Delta V_{th}$  of the threshold voltage  $V_{th}$  of the transistor **111B** shows a gradually rising trend. However, the curves represent good characteristics.

[0116] In the embodiment described above, in any of the silicon-oxide films included in the second gate insulation film **129**, the first gate insulation film **130**, the first interlayer insulation film **131** and the second interlayer insulation film **132** which are employed in the transistor **111B**, holes are generated by radiation of a radioactive ray so that positive electric charge is accumulated in the second gate insulation film **129**, the first gate insulation film **130**, the first interlayer insulation film **131** and the second interlayer insulation film **132**. However, the shield electrode layers **128a1** and **128b1** are provided on the first interlayer insulation film **131** in such a way that portions of the shield electrode layers **128a1** and **128b1** face the edges **e2** of the gate electrode **120B**. Thus, particularly in the vicinity of the channel edge **e1** of the semiconductor layer, for example, the effect of the positive electric charge accumulated in the second interlayer insulation film **132** is reduced so that the shift  $\Delta V_{th}$  of the threshold voltage  $V_{th}$  can be repressed. As a result, it is possible to repress characteristic deteriorations attributed to the radiation of the radioactive ray and, therefore, improve the reliability of the transistor **111B**.

[0117] In addition, in this embodiment, the source and drain electrodes **128A** and **128B** function also as the shield electrode layers **128a1** and **128b1** so that, in the process of patterning the source and drain electrodes **128A** and **128B**, the shield electrode layers **128a1** and **128b1** can be created with ease.

#### First Typical Modification

[0118] The first embodiment described so far has a structure in which the two shield electrode layers **128a1** and **128b1** are provided on both the sides of the channel by making use of portions of both the source and drain electrodes **128A** and **128B**. As shown in FIGS. 12A and 12B, however, a shield electrode layer can also be provided only on one side of the channel. FIGS. 12A and 12B are cross-sectional diagrams showing a rough configuration of a transistor **111C** according to first typical modification which is typical modification of the first embodiment described above. Much like the transistor **111B** according to the first embodiment described above, the transistor **111C** also referred to hereafter as a first modified version is a transistor having a dual-gate structure having the semiconductor layer **126** between the two gate electrodes **120A** and **120B**. In addition, the second gate insulation film **129**, the first gate insulation film **130**, the first interlayer insulation film **131** and the second interlayer insulation film **132** each include a silicon-oxide film. It is to be noted that, in the transistor **111C** described below, each configuration element identical with its counterpart employed in the first embodiment described above is denoted by the same reference numeral as the counterpart and the explanation of the identical configuration element is properly omitted.

[0119] In this first modified version, however, a drain electrode **128C** functioning only as the drain electrode and a source electrode **128D** functioning only as the source elec-

trode are connected electrically to the semiconductor layer **126** on the first interlayer insulation film **131**. In addition, among the channel layer **126a**, the LDD layer **126b** and the N<sup>+</sup> layer **126c** which are included in the semiconductor layer **126**, the LDD layer **126b** is provided only on the side close to the drain electrode **128C**. This is because, since the functions of the source and drain electrodes are not swapped with each other between the drain electrode **128C** and the source electrode **128D** in the transistor **111C** for example, it is nice to provide the LDD layer **126b** only on the side close to the drain electrode **128C**, the voltage supplied to which is relatively high. Since the source electrode **128D** is sustained at the electric potential of the ground in some cases, the LDD layer **126b** does not have to be provided on the side close to the source electrode **128D**.

[0120] In such a configuration, a portion of the drain electrode **128C** functions also as a shield electrode layer **128c1** and a portion of the shield electrode layer **128c1** is provided to face the edge **e2** of the gate electrode **120B**. Even if positive electric charge is accumulated in, for example, the second interlayer insulation film **132** due to the reasons explained before, the shielding effect of the shield electrode layer **128c1** reduces the effect of the positive electric charge on the channel layer **126a** provided on the drain side of the semiconductor layer **126**. In particular, the shielding effect of the shield electrode layer **128c1** reduces the effect of the positive electric charge on the channel edge **e2**. On the source side of the semiconductor layer **126**, on the other hand, the current is not so large as the current on the drain side of the semiconductor layer **126**. Thus, the LDD layer is not required on the source side of the semiconductor layer **126**. In addition, even if the shield electrode layer does not exist, there is hardly an effect, which is as large as that on the drain side of the semiconductor layer **126**, on the threshold voltage  $V_{th}$ . It is thus possible to provide a configuration in which the shield electrode layer **128c1** is provided only on one side of the channel, that is, only on the drain side in particular. In such a configuration, the shield electrode layer **128c1** can be provided efficiently on a portion which can easily have an effect on the characteristic.

[0121] The first modified version described above has a configuration in which the shield electrode layer **128c1** is provided only on the drain side. It is to be noted, however, that the shield electrode layer **128c1** can also be provided only on the source side. In this case, the shielding effect of the shield electrode layer **128c1** is small in comparison with the configuration in which the shield electrode layer **128c1** is provided on the drain side. In comparison with the structure of the typical comparison transistor in which the shield electrode layer is not provided at all, nevertheless, it is possible to reduce the effect of the positive electric charge on the channel edge **e1** and, thus, repress the shift of the threshold voltage  $V_{th}$ .

[0122] In addition, in the first modified version, the LDD layer **126b** is provided only on the drain side of the channel layer **126a**. However, the LDD layer **126b** can be provided also on the source side. In the case of such a structure, the shield electrode layer **128c1** can be provided only on either the drain side or the source side.

[0123] In addition, as shown in FIG. 12B, the drain electrode **128C** is created by being extended to positions covering both edges of the gate electrode **120B** so that a portion of the drain electrode **128C** also functions as the shield electrode layer **128c2**.

#### Second Embodiment

##### Configuration

[0124] FIG. 13 is a cross-sectional diagram showing a rough configuration of a transistor **111D** according to a sec-

ond embodiment of the present disclosure. It is to be noted that, in the transistor **111C** described below, each configuration element identical with its counterpart employed in the first embodiment described above is denoted by the same reference numeral as the counterpart and the explanation of the identical configuration element is properly omitted. In addition, in the same way as the transistor **111B** according to the first embodiment, the transistor **111D** according to the second embodiment is included in the pixel circuit **12a** of the pixel section **12** employed in the radioactive-ray imaging apparatus explained in the description of the first embodiment along with the photodiode **111A**.

[0125] Much like the transistor **111B** according to the first embodiment described above, the transistor **111D** is a transistor having a dual-gate structure including the semiconductor layer **126** between the two gate electrodes **120A** and **120B**. In addition, the second gate insulation film **129**, the first gate insulation film **130**, the first interlayer insulation film **131** and the second interlayer insulation film **132** each include a silicon-oxide film. On top of that, a pair of source and drain electrodes **128E** connected electrically to the semiconductor layer **126** are provided on the first interlayer insulation film **131**.

[0126] In the case of this embodiment, however, a shield electrode layer **128F** is electrically separated from the source and drain electrodes **128E** and also provided on the first interlayer insulation film **131**. In the same way as the source and drain electrodes **128A** and **128B** employed in the first embodiment, the source and drain electrodes **128E** are capable of swapping the functions the source and drain electrodes with each other. In addition, the source and drain electrodes **128E** are made of the same material as the source and drain electrodes **128A** and **128B**.

[0127] In the same way as the shield electrode layers **128a1** and **128b1** employed in the first embodiment, the shield electrode layer **128F** functions as an electrical shield for repressing the effect of positive electric charge accumulated in a silicon-oxide film on the semiconductor layer **126**. In addition, the shield electrode layer **128F** is provided in such a way that at least a portion of the shield electrode layer **128F** faces the edge **e2** of the gate electrode **120B**. To put it concretely, the shield electrode layer **128F** is provided in such a way that the shield electrode layer **128F** faces the gate electrode **120B** and a portion of the shield electrode layer **128F** overlaps the edge **e2** of the gate electrode **120B**. It is to be noted that the positions of the edges **e4** of the shield electrode layer **128F** are not limited to specific positions in particular as described above. However, it is nice to provide a desirable structure in which the shield electrode layer **128F** is provided to cover the entire taper portions of the gate electrode **120B** in the same way as the first embodiment described above.

[0128] The shield electrode layer **128F** can be made of typically the same material as the source and drain electrodes **128A** and **128B** employed in the first embodiment. In addition, the material used for making the shield electrode layer **128F** can be the same as that for the source and drain electrodes **128E** or different from that for the source and drain electrodes **128E**. If the material used for making the shield electrode layer **128F** is the same as that for the source and drain electrodes **128E**, the shield electrode layer **128F** and the source and drain electrodes **128E** can be created in the same process at the same time.

[0129] Such a shield electrode layer **128F** can be electrically connected to typically the gate electrode **120A** and/or

the gate electrode **120B** by making use of typically wiring layers not shown in the figure so that the electric potential appearing at the shield electrode layer **128F** can be sustained at the same level as the electric potential appearing at the gate electrode **120A** and/or the gate electrode **120B**. As an alternative, the shield electrode layer **128F** can be electrically disconnected from the gate electrode **120A** and the gate electrode **120B** so that the electric potential appearing at the shield electrode layer **128F** can be sustained at an arbitrary level set differently from the electric potentials appearing at the gate electrode **120A** and the gate electrode **120B**. As another alternative, the shield electrode layer **128F** can be sustained at the electric potential of the ground or can be put in a state of being floated.

#### Effects of the Second Embodiment

**[0130]** In the radioactive-ray imaging apparatus employing the transistors **111D** according to this embodiment as described above, electrical signals conveying information are obtained on the basis of radioactive rays which are typically X rays. However, radioactive rays directly incident to the transistors **111D** exist. In each of the transistors **111D**, the second gate insulation film **129**, the first gate insulation film **130**, the first interlayer insulation film **131** and the second interlayer insulation film **132** each has a silicon-oxide film. If a radioactive ray hits the silicon-oxide film containing such oxygen, positive electric charge is accumulated in the silicon-oxide film due to the reasons explained earlier and the electric charge undesirably shifts the threshold voltage  $V_{th}$  to the negative side.

**[0131]** In order to solve the problem described above, in this embodiment, the shield electrode layer **128F** is provided on the first interlayer insulation film **131** in such a way that a portion of the shield electrode layer **128F** faces or overlaps the edge **e2** of the gate electrode **120B**. Thus, as shown by a model in FIG. **14**, in the first place, the shielding effect of the gate electrode **120B** represses the effect of the positive electric charge accumulated typically in the second interlayer insulation film **132** including a silicon-oxide film on the channel layer **126a**. In the second place, in the case of this embodiment, the shielding effect of the shield electrode layer **128F** represses the effect of the positive electric charge on the channel layer **126a** or, in particular, on the channel edge **e1** in comparison with the typical comparison structure shown in FIG. **7**.

**[0132]** FIG. **15** is a diagram showing the effect of the X-ray radiation quantity on the current-voltage characteristic of the transistor **111D** including the semiconductor layer **126** made of low-temperature polysilicon for a case in which an X ray is radiated to the transistor **111D**. The current-voltage characteristic of the transistor **111D** is a relation between the gate voltage  $V_g$  and the drain current  $I_{ds}$ .

**[0133]** FIG. **16** is a characteristic diagram showing a relation between the X-ray radiation quantity and the shift quantity ( $\Delta V_{shift}$ ) of a reference voltage which is a voltage  $V_g$  with the drain current  $I_{ds}$  of 1.0 e-11A taken as a reference. On the other hand, FIG. **17** is a characteristic diagram showing a relation between the X-ray radiation quantity and the S value (or the threshold value) in the current-voltage characteristic for each of the transistors **111B** and **111D** according to the first and second embodiments respectively.

**[0134]** It is to be noted that the curves shown in FIGS. **15**, **16** and **17** are curves obtained for an X-ray tube voltage of 90 kV and X-ray radiation quantities of 0 Gy, 70 Gy, 110 Gy and

200 Gy. In addition, in the case of FIGS. **16** and **17**, every solid line represents measurement results for the transistor **111B** according to the first embodiment whereas each dashed-line represents measurement results for the transistor **111D** according to the second embodiment. As is obvious from the curves for the transistors **111B** and **111D** according to the first and second embodiments respectively, if an X ray is radiated to the transistor **111D**, as the radiation quantity of the X ray is increased from 0 Gy to 200 Gy through 70 Gy and 110 Gy, the shift  $\Delta V_{th}$  of the threshold voltage  $V_{th}$  of the transistor **111D** shows a gradually rising trend. However, the curves represent good characteristics.

**[0135]** In the second embodiment described above, in any of the silicon-oxide films included in the second gate insulation film **129**, the first gate insulation film **130**, the first interlayer insulation film **131** and the second interlayer insulation film **132** which are employed in the transistor **111D**, holes are generated by radiation of a radioactive ray so that positive electric charge is accumulated in the second gate insulation film **129**, the first gate insulation film **130**, the first interlayer insulation film **131** and the second interlayer insulation film **132**. However, the shield electrode layer **128F** is provided on the first interlayer insulation film **131** in such a way that portions of the shield electrode layers **128F** face the edges **e2** of the gate electrode **120B**. Thus, particularly in the vicinity of the channel edge **e1** of the semiconductor layer, for example, the effect of the positive electric charge accumulated in the second interlayer insulation film **132** is reduced so that the shift  $\Delta V_{th}$  of the threshold voltage  $V_{th}$  can be repressed. As a result, it is possible to obtain the same effects as the first embodiment.

#### Second Typical Modification

**[0136]** In the case of the configuration adopted by the second embodiment described above, the shield electrode layer **128F** is provided by electrically separating the shield electrode layer **128F** from the source and drain electrodes **128E** so that the shield electrode layer **128F** can be held at the gate or ground electric potential. In accordance with second typical modification, however, the shield electrode layer **128F** can also be held at a negative electric potential as well. In this case, as shown by a model in FIG. **18**, positive electric charge is accumulated in the silicon-oxide films of the second gate insulation film **129**, the first gate insulation film **130**, the first interlayer insulation film **131** and the second interlayer insulation film **132** due to radiation of radioactive rays to the second gate insulation film **129**, the first gate insulation film **130**, the first interlayer insulation film **131** and the second interlayer insulation film **132** respectively. Since the shield electrode layer **128F** is held at a negative electric potential in the case of a second modified version according to the second typical modification, however, the positive electric charge accumulated in the silicon-oxide films of the second gate insulation film **129**, the first gate insulation film **130**, the first interlayer insulation film **131** and the second interlayer insulation film **132** is attracted to the shield electrode layer **128F** so that the effect of the positive electric charge on the channel layer **126a** is reduced. As a result, it is possible to obtain the same effects as the second embodiment.

**[0137]** As described above, in the second modified version of the second embodiment, the shield electrode layer **128F** is provided between the first interlayer insulation film **131** and the second interlayer insulation film **132**. It is to be noted, however, that the location of the shield electrode layer **128F** is



by no means limited to a position between the first interlayer insulation film 131 and the second interlayer insulation film 132. For example, the shield electrode layer 128F can also be inserted into a position between the silicon-oxide film 131a and the silicon-nitride film 131b which are included in the first interlayer insulation film 131.

[0138] The following description explains third to fifth typical modifications which are modifications of the first and second embodiments. It is to be noted that, in the description of the third to fifth typical modifications described below, each configuration element identical with its counterpart employed in the first and/or embodiments described above is denoted by the same reference numeral as the counterpart and the explanation of the identical configuration element is properly omitted.

#### Third Modification

[0139] FIG. 19 is a cross-sectional diagram showing a rough configuration of a third modified version which is a transistor 111E according to third typical modification. In the same way as the transistor 111B according to the first embodiment, the transistor 111E is included in the pixel circuit 12a of the pixel section 12 employed in the radioactive-ray imaging apparatus along with the photodiode 111A. In addition, the transistor 111E also has a dual-gate structure having the semiconductor layer 126 between two gate electrodes. On top of that, each of the second gate insulation film 129, the first gate insulation film 130, the first interlayer insulation film 131 and the second interlayer insulation film 132 includes a silicon-oxide film. Furthermore, a pair of source and drain electrodes 128A and 128B electrically connected to the semiconductor layer 126 are provided on the first interlayer insulation film 131.

[0140] In this third modified version, however, two laminated structures each having the dual-gate structure described above are provided in parallel to each other in one transistor 111E. To put it concretely, the transistor 111E has two gate electrodes in selective areas on the substrate 11. The two electrodes are gate electrodes 120A1 and 120A2. The second gate insulation film 129 is provided to cover the gate electrodes 120A1 and 120A2. On the second gate insulation film 129, the semiconductor layer 126 is provided. The semiconductor layer 126 includes the channel layer 126a, the LDD layer 126b and the N<sup>+</sup> layer 126c for every pair of gate electrodes 120A1 and 120A2. The first gate insulation film 130 is created to cover the semiconductor layer 126. In selective areas on the first gate insulation film 130, gate electrodes 120B1 and 120B2 are provided. The selective areas on the first gate insulation film 130 are areas facing the gate electrodes 120A1 and 120A2 respectively. The first interlayer insulation film 131 is created to cover the gate electrodes 120B1 and 120B2. Contact holes H1 are each provided in portions of the first interlayer insulation film 131 and the first gate insulation film 130. In the same way as the transistor 111B according to the first embodiment, a pair of source and drain electrodes 128A and 128B are provided on the first interlayer insulation film 131 to fill up the contact holes H1 in a state of being electrically connected to the semiconductor layer 126. The second interlayer insulation film 132 is provided on the source and drain electrodes 128A and 128B. It is to be noted that, by providing the gate electrodes 120A1 and 120A2 as well as the gate electrodes 120B1 and 120B2 within one transistor in parallel to each other as is the case with this

modified version, it is possible to decrease the magnitude of an off leak current which is a leak current at  $V_g=0$  V.

[0141] It is to be noted that, in this embodiment, the gate electrodes 120B1 and 120B2 are concrete examples of the first gate electrode according to the embodiment of the present disclosure whereas the gate electrodes 120A1 and 120A2 are concrete examples of the second gate electrode according to the embodiment of the present disclosure.

[0142] In the same way as the transistor 111B, in the transistor 111E having such two dual-gate structures in accordance with this typical modification, portions of the source and drain electrodes 128A and 128B function also as the shield electrode layers 128a1 and 128b1. In this configuration, typically, the shield electrode layer 128a1 is provided in such a way that at least a portion of the shield electrode layer 128a1 faces the edge e2 of the gate electrode 120B1 whereas the shield electrode layer 128b1 is provided in such a way that at least a portion of the shield electrode layer 128b1 faces the edge e2 of the gate electrode 120B2. Even though the positions of the edges e3 of the shield electrode layers 128a1 and 128b1 are not limited to specific positions in particular as described above, it is nice to provide a desirable structure in which the shield electrode layers 128a1 and 128b1 are provided to cover the taper portions of the gate electrodes 120B1 and 120B2.

[0143] As described above, also in the transistor 111E having such two dual-gate structures provided in parallel to each other, the shielding effect of the shield electrode layers 128a1 and 128b1 allows the same effects as the first embodiment to be obtained.

[0144] In the third modified version described above, the shield electrode layers 128a1 and 128b1 are provided on both sides of the source and drain electrodes 128A and 128B. It is to be noted, however, that the shield electrode layer can also be provided only on either the source electrode or the drain electrode as explained before in the description of the first modified version. In addition, FIG. 19 shows a case in which the shield electrode layers 128a1 and 128b1 are provided to face only the edges e2 on one sides of the gate electrodes 120B1 and 120B2. However, the following configuration can also be provided. For example, as shown in FIG. 20, the shield electrode layers 128a1 and 128b1 can also be provided by extending the shield electrode layers 128a1 and 128b1 so that the shield electrode layers 128a1 and 128b1 face the edges e2 on both sides of the gate electrodes 120B1 and 120B2.

#### Fourth Typical Modification

[0145] FIG. 21 is a cross-sectional diagram showing a rough configuration of a transistor 111F provided in accordance with fourth typical modification to serve as a fourth modified version. In the same way as the transistor 111B according to the first embodiment, the transistor 111F is included in the pixel circuit 12a of the pixel section 12 employed in the radioactive-ray imaging apparatus along with the photodiode 111A. In addition, the transistor 111F also has a dual-gate structure having the semiconductor layer 126 between two gate electrodes. On top of that, each of the second gate insulation film 129, the first gate insulation film 130, the first interlayer insulation film 131 and the second interlayer insulation film 132 includes a silicon-oxide film. Furthermore, a pair of source and drain electrodes 128A and 128B electrically connected to the semiconductor layer 126 are provided on the first interlayer insulation film 131.



[0146] Also in the transistor 111F having two dual-gate structures in accordance with the fourth typical modification in the same way as the third modified version, portions of the source and drain electrodes 128A and 128B function also as the shield electrode layers 128a1 and 128b1.

[0147] In this fourth modified version, however, a shield electrode layer 128G is further provided on the first interlayer insulation film 131. For example, the shield electrode layer 128G is provided in an area between the source and drain electrodes 128A and 128B on the first interlayer insulation film 131, being separated electrically from the source and drain electrodes 128A and 128B.

[0148] In the same way as the shield electrode layers 128a1 and 128b1 employed in the first embodiment, the shield electrode layer 128G functions as an electrical shield for repressing the effect of positive electric charge accumulated in a silicon-oxide film on the semiconductor layer 126. In addition, the shield electrode layer 128G is provided in such a way that at least a portion of the shield electrode layer 128F faces the edges e2 of the gate electrodes 120B1 and 120B2. It is to be noted that the positions of the edges e5 of the shield electrode layer 128G are not limited to specific positions in particular as described above. However, it is nice to provide a desirable structure in which the shield electrode layer 128G is provided to cover the entire taper portions of the gate electrodes 120B1 and 120B2.

[0149] The shield electrode layer 128G can be made of typically the same material as the source and drain electrodes 128A and 128B employed in the first embodiment. In addition, the material used for making the shield electrode layer 128G can be the same as that for the source and drain electrodes 128A and 128B or different from that for the source and drain electrodes 128A and 128B.

[0150] It is to be noted that, for example, the shield electrode layer 128G can be electrically connected by making use of typically a wiring layer not shown in the figure to at least one of typically the gate electrodes 120A1 and 120A2 and the gate electrodes 120B1 and 120B2 in order to sustain the shield electrode layer 128G at the same electric potential as the gate electrodes 120A1 and 120A2 and the gate electrodes 120B1 and 120B2. As an alternative, the shield electrode layer 128G can be electrically disconnected from the gate electrodes 120A1 and 120A2 as well as from the gate electrodes 120B1 and 120B2 so that the electric potential appearing at the shield electrode layer 128G can be sustained at an arbitrary level set differently from the electric potentials appearing at the gate electrodes 120A1 and 120A2 as well as the gate electrodes 120B1 and 120B2. As another alternative, the shield electrode layer 128G can be sustained at the electric potential of the ground or can be put in a state of being floated.

[0151] As described above, also in the transistor 111F having such two dual-gate structures provided in parallel to each other, the shielding effect of the shield electrode layers 128a1 and 128b1 allows the same effects as the first embodiment to be obtained. In addition, in this transistor 111F, the shield electrode layer 128G is further provided between the source and drain electrodes 128A and 128B so that it is possible to improve the shielding effect to a level higher than the third modified version and, thus, further reduce the effect of holes on the semiconductor layer 126.

#### Fifth Typical Modification

[0152] FIG. 22 is a cross-sectional diagram showing a rough configuration of a transistor 111G provided in accordance

with fifth typical modification to serve as a fifth modified version. In the same way as the transistor 111B according to the first embodiment, the transistor 111G is included in the pixel circuit 12a of the pixel section 12 employed in the radioactive-ray imaging apparatus along with the photodiode 111A. In addition, the transistor 111G also has a dual-gate structure having the semiconductor layer 126 between two gate electrodes. On top of that, each of the second gate insulation film 129, the first gate insulation film 130, the first interlayer insulation film 131 and the second interlayer insulation film 132 includes a silicon-oxide film. Furthermore, a pair of source and drain electrodes 128E electrically connected to the semiconductor layer 126 are provided on the first interlayer insulation film 131.

[0153] Much like the third and fourth modified versions, the fifth modified version also has two dual-gate structures.

[0154] In the structure according to this typical modification, much like the second embodiment, shield electrode layers 128F electrically disconnected from the source and drain electrodes 128E are provided on the first interlayer insulation film 131. In this structure, however, the shield electrode layers 128F are provided to face their respective gate electrodes 120B1 and 120B2. It is to be noted that the positions of the edges e4 of the two shield electrode layers 128F are not limited to specific positions in particular as described above. However, it is nice to provide a desirable structure in which the shield electrode layers 128F are provided to cover the entire taper portions of the gate electrodes 120B1 and 120B2.

[0155] It is to be noted that, for example, the two shield electrode layers 128F can be electrically connected by making use of typically a wiring layer not shown in the figure to at least one of typically the gate electrodes 120A1 and 120A2 and the gate electrodes 120B1 and 120B2 in order to sustain the shield electrode layers 128F at the same electric potential as the gate electrodes 120A1 and 120A2 and the gate electrodes 120B1 and 120B2. As an alternative, the two shield electrode layers 128F can also be electrically disconnected from the gate electrodes 120A1 and 120A2 and the gate electrodes 120B1 and 120B2 so that the electric potential appearing at the two shield electrode layers 128F can be sustained at an arbitrary level set differently from the electric potentials appearing at the gate electrodes 120A1 and 120A2 and the gate electrodes 120B1 and 120B2. As another alternative, the two shield electrode layers 128F can also be sustained at the electric potential of the ground or can be put in a state of being floated.

[0156] As described above, also in the transistor 111G having such two dual-gate structures provided in parallel to each other, the shielding effect of the two shield electrode layers 128F allows the same effects as the second embodiment to be obtained.

[0157] Each of the third to fifth modified versions described above has a configuration in which the shield electrode layers are provided at locations horizontally symmetrical with respect to the two gate electrodes 120B1 and 120B2 laid out in parallel to each other. It is to be noted, however, that the locations of the shield electrode layers do not have to be horizontally symmetrical. For example, in a specific half of the transistor or for a specific one of the gate electrodes 120B1 and 120B2, a shield electrode layer is created by making use of a portion of the source and drain electrodes. In the other half of the transistor or for the other one of the gate electrodes 120B1 and 120B2, on the other hand, a shield electrode layer electrically disconnected from the source and drain elec-

trodes is created separately. In addition, the widths (or the creation areas) of the shield electrode layers on the left and right sides may be different from each other. On top of that, the number of gate electrodes laid out in parallel to each other on the substrate or the number of second gate electrodes laid out in parallel to each other on the second gate insulation film is by no means limited to 1 or 2 as described above, but can be 3 or an integer greater than 3.

#### Sixth Typical Modification

**[0158]** FIG. 23 is a diagram showing a cross-sectional structure of a transistor provided in accordance with sixth modification to serve as a transistor 111J according to a sixth modified version. In the same way as the transistor 111B according to the first embodiment, the transistor 111J is employed in the pixel circuit 12a of the pixel section 12, which is included in the radioactive-ray imaging apparatus, along with the photodiode 111A. In addition, each of the second gate insulation film 129, the first gate insulation film 130, the first interlayer insulation film 131 and the second interlayer insulation film 132 includes a silicon-oxide film. On top of that, a pair of source and drain electrodes 128A and 128B electrically connected to the semiconductor layer 126 are provided on the first interlayer insulation film 131.

**[0159]** However, the transistor 111J according to the sixth modified version has the so-called top gate structure. The transistor 111B according to this embodiment has a structure including only the gate electrode 120B which is one of the gate electrodes. In the same way as the transistor 111B, in the transistor 111J having such a gate electrode 120B, portions of the source and drain electrodes 128A and 128B also function as the shield electrode layers 128a1 and 128b1. Also in the case of the transistor 111J having such a top gate structure, the shield effects of the shield electrode layers 128a1 and 128b1 can be obtained.

**[0160]** It is to be noted that the gate electrode 120B in this modified version is a concrete example of the first gate electrode provided by the embodiment of the present disclosure.

**[0161]** In addition, in the same way as the first modified version, as shown in FIG. 24A, a transistor having the top gate structure can also be configured into a structure in which only a portion of the drain electrode 128c is provided to face one edge e2 of the gate electrode 120B so that the portion also functions as the shield electrode layer 128c1. On top of that, as shown in FIG. 24B, a transistor having the top gate structure can also be configured into a structure in which the drain electrode 128c is created by being further extended to positions covering both edges of the gate electrode 120B so that a portion of the drain electrode 128c also functions as the shield electrode layer 128c2. As an alternative shown in none of the figures, it is also possible to provide a structure in which, instead of a portion of the drain electrode 128c, a portion of the source electrode 128D also functions as a shield electrode layer.

**[0162]** In addition, in the same way as the second embodiment, as shown in FIG. 25, it is also possible to provide a structure in which a shield electrode layer 128F electrically separated from the source/drain electrode 128E is provided on the first interlayer isolation film 131.

#### Seventh Typical Modification

**[0163]** FIG. 26 is a diagram showing a cross-sectional structure of a transistor provided in accordance with seventh

modification to serve as a transistor 111K according to a seventh modified version. In the same way as the transistor 111B according to the first embodiment, the transistor 111K is employed in the pixel circuit 12a of the pixel section 12, which is included in the radioactive-ray imaging apparatus, along with the photodiode 111A. In addition, each of the second gate insulation film 129, the first gate insulation film 130, the first interlayer insulation film 131 and the second interlayer insulation film 132 includes a silicon-oxide film. On top of that, a pair of source and drain electrodes 128A and 128B electrically connected to the semiconductor layer 126 are provided on the first interlayer insulation film 131.

**[0164]** However, the transistor 111K according to the seventh modified version has the so-called bottom gate structure. The transistor 111B according to this embodiment has a structure including only the gate electrode 120A which is one of the gate electrodes. In the same way as the transistor 111B, in the transistor 111K having such a gate electrode 120A, portions of the source and drain electrodes 128A and 128B also function as the shield electrode layers 128a1 and 128b1. Also in the case of the transistor 111K having such a bottom gate structure, the shield effects of the shield electrode layers 128a1 and 128b1 can be obtained.

**[0165]** It is to be noted that the gate electrode 120A in this modified version is a concrete example of the first gate electrode provided by the embodiment of the present disclosure.

**[0166]** In addition, in the same way as the first modified version, as shown in FIG. 27A, a transistor having the bottom gate structure can also be configured into a structure in which only a portion of the drain electrode 128c is provided to face one edge e1 of the gate electrode 120A so that the portion also functions as the shield electrode layer 128c1. On top of that, as shown in FIG. 27B, the transistor having the bottom gate structure can also be configured into a structure in which the drain electrode 128c is created by being further extended to positions covering both edges of the gate electrode 120A so that a portion of the drain electrode 128c also functions as the shield electrode layer 128c2.

**[0167]** In addition, in the same way as the second embodiment, as shown in FIG. 28, it is also possible to provide a structure in which a shield electrode layer 128F electrically separated from the source/drain electrode 128E is provided on the first interlayer isolation film 131.

**[0168]** The following description explains eighth and ninth typical modifications which are each a modification implementing a modified version of the radioactive-ray imaging apparatus according to the embodiments of the present disclosure. It is to be noted that, in the description of the eighth and ninth typical modifications described below, each configuration element identical with its counterpart employed in the first and/or second embodiments described above is denoted by the same reference numeral as the counterpart and the explanation of the identical configuration element is properly omitted.

#### Eighth Typical Modification

**[0169]** In the first embodiment, the pixel circuit provided in every pixel P is the pixel circuit 12a which adopts the active driving method. However, the pixel circuit provided in every pixel P can also be a pixel circuit 12b like one shown in FIG. 29 to serve as a pixel circuit which adopts the passive driving method. In a sixth modified version according to eighth typical modification, the unit pixel P is configured to include the photodiode 111A, a capacitor 138 and a transistor Tr which

corresponds to the read transistor Tr3. The transistor Tr is connected between the accumulation node N and the vertical signal line 18. When the transistor Tr is turned on in response to the row scanning signal Vread, signal electric charge accumulated in the accumulation node N in accordance with the quantity of light incident to the photodiode 111A is output to the vertical signal line 18. It is to be noted that the transistor Tr (or Tr3) is any one of the transistors 111A to 111D which are provided by the embodiments described above and the modified versions also explained so far. As described above, the method for driving the pixel P is not limited to the active driving method adopted by the embodiments described above. That is to say, the method for driving the pixel P can also be the passive driving method as is the case with this sixth modified version.

#### Ninth Typical Modification

[0170] In the embodiments described above, an indirect-conversion-type FPD having the scintillator layer 114 provided on the pixel section 12 is taken as a typical radioactive-ray imaging apparatus. However, the radioactive-ray imaging apparatus according to the embodiments of the present disclosure can also be applied to an FPD of the direct conversion type. The FPD of the direct conversion type does not employ the scintillator layer 114 for carrying out a wavelength conversion process of converting a radioactive ray into a visible ray and the protection layer 115. Instead, the pixel section 12 is provided with a function for directly converting a radioactive ray into an electrical signal.

[0171] FIG. 30 is an explanatory model diagram referred to in the following description of a radioactive-ray imaging apparatus provided in accordance with seventh modification to serve as a seventh modified version which is a radioactive-ray imaging apparatus having a direct conversion type. The seventh modified version includes a typical pixel section 12 making use of a pixel circuit 12b according to the sixth modified version adopting the passive driving method. In this seventh modified version, the pixel section 12 is configured to include a photoelectrical conversion device 111H, a capacitor 141 and a transistor Tr which corresponds to the read transistor Tr3. The photoelectrical conversion device 111H is a section for converting a radioactive ray into an electrical signal. The photoelectrical conversion device 111H has a direct conversion layer 140 provided typically between an upper electrode 139A and a pixel electrode 139B. The direct conversion layer 140 is made of typically an amorphous selenium semiconductor (an a-Se semiconductor) or a cadmium tellurium semiconductor (a CdTe semiconductor). It is to be noted that the transistor Tr (or Tr3) is any one of the transistors 111B to 111D which are provided by the embodiments described above and the modified versions also explained so far.

[0172] As described above, the transistors provided by the present disclosure can be applied to not only an FPD of the indirect conversion type, but also an FPD of the direct conversion type. In the case of the direct conversion type particularly, an incident radioactive ray directly hits the pixel section 12. Thus, the transistor is exposed more easily than the transistors according to the embodiments described above and the modified versions also explained so far. As a result, the effect to repress the shift of the threshold voltage  $V_{th}$  is also effective

for the seventh modified version serving as a radioactive-ray imaging apparatus of the direct conversion type.

#### Typical Application

[0173] The transistors and the radioactive-ray imaging apparatus which are provided by the first and second embodiments as well as the first to fourth modified versions can be applied to a radioactive-ray imaging display system 2 like one shown in FIG. 31. As shown in the figure, the radioactive-ray imaging display system 2 includes the radioactive-ray imaging apparatus 1, an image processing section 25 and a display apparatus 28. In the radioactive-ray imaging display system 2 with such a configuration, on the basis of a radioactive ray radiated by a radioactive-ray source 26 to an imaging object 27, the radioactive-ray imaging apparatus 1 acquires image data Dout of the imaging object 27 and supplies the image data Dout to the image processing section 25. The image processing section 25 carries out predetermined image processing on the image data Dout received from the radioactive-ray imaging apparatus 1 and outputs image data (or display data) D1 obtained as a result of the image processing to the display apparatus 28. The display apparatus 28 has a monitor screen 28a for displaying an image based on the display data D1 received from the image processing section 25.

[0174] As described above, the radioactive-ray imaging apparatus 1 employed in the radioactive-ray imaging display system 2 is capable of acquiring an image of the imaging object 27 as an electrical signal. Thus, by supplying the acquired electrical signal to the display apparatus 28, the image of the imaging object 27 can be displayed. That is to say, the image of the imaging object 27 can be observed without making use of a radioactive-ray photograph film. In addition, it is also possible to cope with moving-picture imaging operations and moving-picture displaying operations.

[0175] The embodiments and the modified versions have been explained so far. However, the scope of the present disclosure is by no means limited to the embodiments and the modified versions. That is to say, a variety of changes can be further made to the embodiments and the modified versions. For example, the wavelength conversion material used for making the scintillator layer 114 employed in the embodiments and the modified versions is by no means limited those explained in the above descriptions. In other words, a variety of other fluorescent materials can also be used for making the scintillator layer 114.

[0176] In addition, each of the embodiments and the modified versions has a configuration in which the shield electrode layer as well as the source and drain electrodes are provided on the same layer. However, the shield electrode layer as well as the source and drain electrodes may be provided not necessarily on the same layer. That is to say, the shield electrode layer as well as the source and drain electrodes may also be provided on different layers.

[0177] On top of that, in the embodiments and the modified versions, each of the second gate insulation film 129, the first gate insulation film 130, the first interlayer insulation film 131 and the second interlayer insulation film 132 includes a silicon-oxide film. If at least one of the second gate insulation film 129, the first gate insulation film 130, the first interlayer insulation film 131 and the second interlayer insulation film 132 include a silicon-oxide film, however, it is possible to obtain the same effects as the disclosed present disclosure.

[0178] In addition, each of the embodiments and the modified versions has a configuration in which the second inter-

layer insulation film 132 made of silicon oxide is provided on the source and drain electrodes. However, the second interlayer insulation film 132 is not necessarily required. As an alternative, the second interlayer insulation film 132 can also be made of a material not including oxygen. A typical example of the material not including oxygen is silicon nitride. As explained earlier in the description of the first embodiment, from the viewpoint of the manufacturability of the photodiode 111A, however, it is desirable to provide a silicon-oxide film to serve as the second interlayer insulation film 132. In addition, the effect of the provided shield electrode layer is particularly effective for a silicon-oxide film provided above the shield electrode layer. A typical example of the silicon-oxide film provided above the shield electrode layer is the second interlayer insulation film 132.

[0179] On top of that, in each of the embodiments and the modified versions, a gate electrode having a taper portion on each of the side surfaces thereof is taken as a typical example of the second gate electrode according to the embodiments of the present disclosure. However, the second gate electrode is not necessarily required to have a taper portion on each of the side surfaces thereof. As shown in FIG. 32 for example, a second gate electrode 130B3 can also have side surfaces each forming a shape perpendicular to the surface of the substrate. In this case, the entire side surfaces of the second gate electrode 130B3 are each an edge of the second gate electrode 130B3.

[0180] In addition, in each of the embodiments and the modified versions, a film made of silicon oxide ( $\text{SiO}_2$ ) is taken as a typical example of a silicon-oxide film according to the embodiments of the present disclosure. However, the silicon-oxide film can be any other film as far as the other film is a silicon compound film containing oxygen. For example, the silicon-oxide film can also be a film made of silicon oxynitride ( $\text{SiON}$ ).

[0181] On top of that, in each of the embodiments and the modified versions, an N-type transistor made of N-MOS is taken as a typical example of the transistor according to the embodiments of the present disclosure. However, the transistor according to the embodiments of the present disclosure is by no means limited to the N-type transistor. For example, the transistor according to the embodiments of the present disclosure can also be a P-type transistor made of P-MOS.

[0182] In addition, in each of the embodiments and the modified versions, the photodiode 111A has a laminated structure built by creating a p-type semiconductor layer, an i-type semiconductor layer and an n-type semiconductor layer above the substrate in the same order as the order in which the p-type semiconductor layer, the i-type semiconductor layer and the n-type semiconductor layer are enumerated in this sentence. However, the photodiode 111A can also have a laminated structure built by creating an n-type semiconductor layer, an i-type semiconductor layer and a p-type semiconductor layer above the substrate in the same order as the order in which the n-type semiconductor layer, the i-type semiconductor layer and the p-type semiconductor layer are enumerated in this sentence.

[0183] On top of that, it is not necessary to employ all the configuration elements explained in the descriptions of each embodiment and each modified version which are provided by the present disclosure. Conversely, another layer can be added to each of the embodiments and the modified versions. For example, a protection film made of SiN or the like can also be created on the upper electrode 125.

[0184] It is to be noted that the present disclosure can be applied to transistors having configurations described in implementations 1 to 11 given below, a radioactive-ray imaging apparatus employing any of the transistors and a radioactive-ray imaging display system employing the radioactive-ray imaging apparatus.

1: A transistor including:

[0185] a semiconductor layer;

[0186] a first gate insulation film and a first interlayer insulation film which are provided on a specific surface side of the semiconductor layer;

[0187] a first gate electrode provided at a location between the first gate insulation film and the first interlayer insulation film;

[0188] an insulation film provided on the other surface side of the semiconductor layer;

[0189] source and drain electrodes provided by being electrically connected to the semiconductor layer; and

[0190] a shield electrode layer provided in such a way that at least portions of the shield electrode layer face edges of the first gate electrode,

[0191] wherein at least one of the first gate insulation film, the first interlayer insulation film and the insulation film include a silicon-oxide film.

2: The transistor according to implementation 1 further including a second gate electrode facing the first gate electrode through the semiconductor layer, wherein

[0192] the second gate electrode, the insulation film, the semiconductor layer, the first gate insulation film, the first gate electrode and the first interlayer insulation film are sequentially created on a substrate in the same order as an order in which the second gate electrode, the insulation film, the semiconductor layer, the first gate insulation film, the first gate electrode and the first interlayer insulation film are enumerated in this sentence.

3: The transistor according to implementation 1 or 2 wherein the shield electrode layer is provided on the first interlayer insulation film.

4: The transistor according to implementation 3 wherein:

[0193] one or both of the source electrode and the drain electrode are provided on the first interlayer insulation film by being extended to areas facing the edges of the first gate electrode; and

[0194] portions included in the source electrode and the drain electrode to serve as portions facing the edges of the first gate electrode also function as the shield electrode layer.

5: The transistor according to implementation 3 wherein:

[0195] only the drain electrode is selected from the source electrode and the drain electrode to serve as an electrode to be provided on the first interlayer insulation film by being extended to an area facing the edge of the first gate electrode; and

[0196] a portion included in the drain electrode to serve as a portion facing the edge of the first gate electrode also functions as the shield electrode layer.

6: The transistor according to any of implementations 3 to 5, the transistor further having a second interlayer insulation film provided on the source electrode and the drain electrode, [0197] wherein the second interlayer insulation film includes a silicon-oxide film.

7: The transistor according to any of implementations 3 to 5 wherein the source electrode, the drain electrode and the

shield electrode layer are provided on the first interlayer insulation film by being electrically disconnected from each other.

8: The transistor according to implementation 7, the transistor further including a second interlayer insulation film provided on the source electrode, the drain electrode and the shield electrode layer,

**[0198]** wherein the second interlayer insulation film includes a silicon-oxide film.

9: The transistor according to implementation 7 or 8 wherein the shield electrode layer is held at a negative electric potential.

10: The transistor according to any of implementations 2 to 9 wherein a plurality of sets each consisting of the first and second gate electrodes are provided for a pair of the source and drain electrodes.

11: The transistor according to any of implementations 1 to 10 wherein the first gate electrode, the first gate insulation film, the semiconductor layer, the insulation film and the first interlayer insulation film are sequentially created on a substrate in the same order as an order in which the first gate electrode, the first gate insulation film, the semiconductor layer, the insulation film and the first interlayer insulation film are enumerated in this sentence.

12: The transistor according to any of implementations 1 to 11 wherein the insulation film, the semiconductor layer, the first gate insulation film, the first gate electrode and the first interlayer insulation film are sequentially created on a substrate in the same order as an order in which the insulation film, the semiconductor layer, the first gate insulation film, the first gate electrode and the first interlayer insulation film are enumerated in this sentence.

13: The transistor according to any of implementations 1 to 12 wherein the semiconductor layer is made of polysilicon.

14: The transistor according to any of implementations 1 to 13 wherein the silicon-oxide film is made of silicon oxide ( $\text{SiO}_2$ ).

15: A radioactive-ray imaging apparatus including a pixel section having a transistor and a photoelectric conversion device, the transistor including:

**[0199]** a semiconductor layer;

**[0200]** a first gate insulation film and a first interlayer insulation film which are provided on a specific surface side of the semiconductor layer;

**[0201]** a first gate electrode provided at a location between the first gate insulation film and the first interlayer insulation film;

**[0202]** an insulation film provided on the other surface side of the semiconductor layer;

**[0203]** source and drain electrodes provided by being electrically connected to the semiconductor layer; and

**[0204]** a shield electrode layer provided in such a way that at least portions of the shield electrode layer face edges of the first gate electrode, wherein

**[0205]** at least one of the first gate insulation film, the first interlayer insulation film and the insulation film include a silicon-oxide film.

16: The radioactive-ray imaging apparatus according to implementation 15

**[0206]** wherein a wavelength conversion layer is provided on the pixel section to serve as a layer for changing the wavelength of an incident radioactive ray to a wavelength in a sensitive region of the photoelectric conversion device.

17: The radioactive-ray imaging apparatus according to implementation 15

**[0207]** wherein the photoelectric conversion device has a function for absorbing a radioactive ray and converting the radioactive ray into an electrical signal.

18: The radioactive-ray imaging display system employing a radioactive-ray imaging apparatus for acquiring an image based on radioactive rays and a display apparatus for displaying the image acquired by the radioactive-ray imaging apparatus wherein

**[0208]** the radioactive-ray imaging apparatus includes a pixel section having a transistor and a photoelectric conversion device, the transistor including:

**[0209]** a semiconductor layer;

**[0210]** a first gate insulation film and a first interlayer insulation film which are provided on a specific surface side of the semiconductor layer;

**[0211]** a first gate electrode provided at a location between the first gate insulation film and the first interlayer insulation film;

**[0212]** an insulation film provided on the other surface side of the semiconductor layer;

**[0213]** source and drain electrodes provided by being electrically connected to the semiconductor layer; and

**[0214]** a shield electrode layer provided in such a way that at least portions of the shield electrode layer face edges of the first gate electrode, and

**[0215]** at least one of the first gate insulation film, the first interlayer insulation film and the insulation film include a silicon-oxide film.

**[0216]** The present disclosure contains subject matter related to that disclosed in Japanese Priority Patent Application JP 2011-127598 filed in the Japan Patent Office on Jun. 7, 2011, and Japanese Priority Patent Application JP 2012-000956 filed in the Japan Patent Office on Jan. 6, 2012 the entire content of which is hereby incorporated by reference.

**[0217]** It should be understood by those skilled in the art that various modifications, combinations, sub-combinations and alterations may occur depending on design requirements and other factors in so far as they are within the scope of the appended claims or the equivalents thereof.

What is claimed is:

1. A transistor comprising:

a semiconductor layer;

a first gate insulation film and a first interlayer insulation film which are provided on a specific surface side of said semiconductor layer;

a first gate electrode provided at a location between said first gate insulation film and said first interlayer insulation film;

an insulation film provided on the other surface side of said semiconductor layer;

source and drain electrodes provided by being electrically connected to said semiconductor layer; and

a shield electrode layer provided in such a way that at least portions of said shield electrode layer face edges of said first gate electrode,

wherein at least one of said first gate insulation film, said first interlayer insulation film and said insulation film include a silicon-oxide film.

2. The transistor according to claim 1 further including a second gate electrode facing said first gate electrode through said semiconductor layer, wherein

said second gate electrode, said insulation film, said semiconductor layer, said first gate insulation film, said first gate electrode and said first interlayer insulation film are sequentially created on a substrate in the same order as an order in which said second gate electrode, said insulation film, said semiconductor layer, said first gate insulation film, said first gate electrode and said first interlayer insulation film are enumerated in this sentence.

3. The transistor according to claim 1 wherein said shield electrode layer is provided on said first interlayer insulation film.

4. The transistor according to claim 3 wherein: one or both of said source electrode and said drain electrode are provided on said first interlayer insulation film by being extended to areas facing said edges of said first gate electrode; and portions included in said source electrode and said drain electrode to serve as portions facing said edges of said first gate electrode also function as said shield electrode layer.

5. The transistor according to claim 3 wherein: only said drain electrode is selected from said source electrode and said drain electrode to serve as an electrode to be provided on said first interlayer insulation film by being extended to an area facing said edge of said first gate electrode; and a portion included in said drain electrode to serve as a portion facing said edge of said first gate electrode also functions as said shield electrode layer.

6. The transistor according to claim 3, said transistor further having a second interlayer insulation film provided on said source electrode and said drain electrode, wherein said second interlayer insulation film includes a silicon-oxide film.

7. The transistor according to claim 3 wherein said source electrode, said drain electrode and said shield electrode layer are provided on said first interlayer insulation film by being electrically disconnected from each other.

8. The transistor according to claim 7, said transistor further comprising a second interlayer insulation film provided on said source electrode, said drain electrode and said shield electrode layer, wherein said second interlayer insulation film includes a silicon-oxide film.

9. The transistor according to claim 7 wherein said shield electrode layer is held at a negative electric potential.

10. The transistor according to claim 2 wherein a plurality of sets each consisting of said first and second gate electrodes are provided for a pair of said source and drain electrodes.

11. The transistor according to claim 1 wherein said first gate electrode, said first gate insulation film, said semiconductor layer, said insulation film and said first interlayer insulation film are sequentially created on a substrate in the same order as an order in which said first gate electrode, said first gate insulation film, said semiconductor layer, said insulation film and said first interlayer insulation film are enumerated in this sentence.

12. The transistor according to claim 1 wherein said insulation film, said semiconductor layer, said first gate insulation film, said first gate electrode and said first interlayer insulation film are sequentially created on a

substrate in the same order as an order in which said insulation film, said semiconductor layer, said first gate insulation film, said first gate electrode and said first interlayer insulation film are enumerated in this sentence.

13. The transistor according to claim 1 wherein said semiconductor layer is made of polysilicon.

14. The transistor according to claim 1 wherein said silicon-oxide film is made of silicon oxide (SiO<sub>2</sub>).

15. A radioactive-ray imaging apparatus comprising a pixel section having a transistor and a photoelectric conversion device, said transistor including:

- a semiconductor layer;
- a first gate insulation film and a first interlayer insulation film which are provided on a specific surface side of said semiconductor layer;
- a first gate electrode provided at a location between said first gate insulation film and said first interlayer insulation film;
- an insulation film provided on the other surface side of said semiconductor layer;
- source and drain electrodes provided by being electrically connected to said semiconductor layer; and
- a shield electrode layer provided in such a way that at least portions of said shield electrode layer face edges of said first gate electrode, wherein at least one of said first gate insulation film, said first interlayer insulation film and said insulation film include a silicon-oxide film.

16. The radioactive-ray imaging apparatus according to claim 15 wherein

- a wavelength conversion layer is provided on said pixel section to serve as a layer for changing the wavelength of an incident radioactive ray to a wavelength in a sensitive region of said photoelectric conversion device.

17. The radioactive-ray imaging apparatus according to claim 15 wherein

- said photoelectric conversion device has a function for absorbing a radioactive ray and converting said radioactive ray into an electrical signal.

18. A radioactive-ray imaging display system employing a radioactive-ray imaging apparatus for acquiring an image based on radioactive rays and a display apparatus for displaying said image acquired by said radioactive-ray imaging apparatus wherein

- said radioactive-ray imaging apparatus includes a pixel section having a transistor and a photoelectric conversion device, said transistor comprising:
  - a semiconductor layer;
  - a first gate insulation film and a first interlayer insulation film which are provided on a specific surface side of said semiconductor layer;
  - a first gate electrode provided at a location between said first gate insulation film and said first interlayer insulation film;
  - an insulation film provided on the other surface side of said semiconductor layer;
  - source and drain electrodes provided by being electrically connected to said semiconductor layer; and
  - a shield electrode layer provided in such a way that at least portions of said shield electrode layer face edges of said first gate electrode, and
  - at least one of said first gate insulation film, said first interlayer insulation film and said insulation film include a silicon-oxide film.