US012389745B2

(12) United States Patent
Yamazaki et al.

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(45) Date of Patent: Aug. 12, 2025

(54) **LIGHT-EMITTING DEVICE CONFIGURED TO IMPROVE LIGHT-EXTRACTION EFFICIENCY INCLUDING REFLECTIVE STRUCTURE BODY BETWEEN FIRST ELECTRODE AND LIGHT-EMITTING MATERIAL, FUNCTIONAL PANEL, DISPLAY DEVICE, INPUT/OUTPUT DEVICE, AND DATA PROCESSING DEVICE**

(71) Applicant: **SEMICONDUCTOR ENERGY LABORATORY CO., LTD.**, Atsugi (JP)

(72) Inventors: **Shunpei Yamazaki**, Tokyo (JP); **Daiki Nakamura**, Kanagawa (JP); **Ryo Hatsumi**, Kanagawa (JP); **Rai Sato**, Tochigi (JP); **Shingo Eguchi**, Kanagawa (JP)

(73) Assignee: **Semiconductor Energy Laboratory Co., Ltd.**, Atsugi (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 765 days.

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§ 371 (c)(1),
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(30) **Foreign Application Priority Data**

Jul. 5, 2019 (JP) 2019-125822

(51) **Int. Cl.**
H10K 50/856 (2023.01)
H10K 59/121 (2023.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H10K 50/856*** (2023.02); ***H10K 59/1213*** (2023.02); ***H10K 59/60*** (2023.02); *H10K 59/878* (2023.02)

(58) **Field of Classification Search**
CPC H10K 50/856; H10K 59/1213; H10K 59/122; H10K 59/60; H10K 59/878
(Continued)

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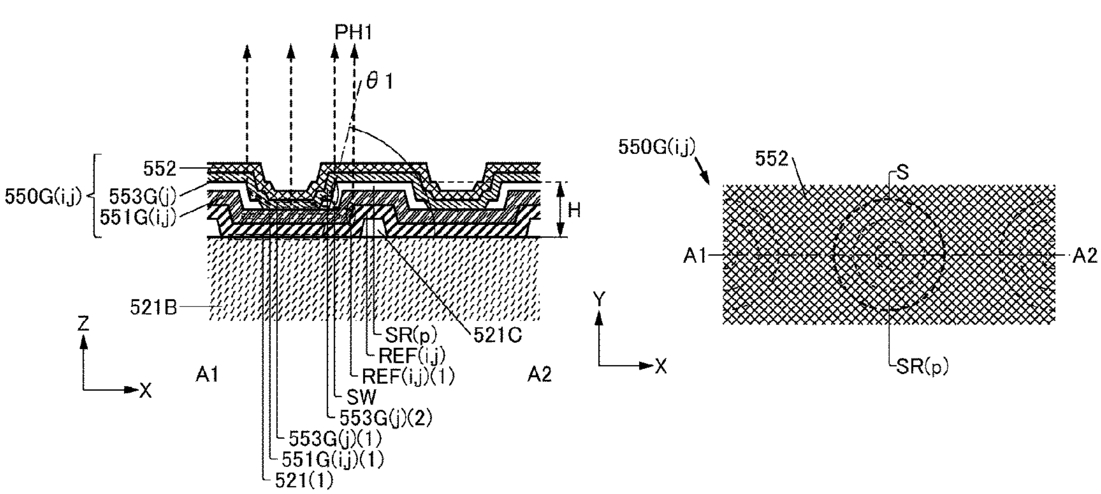
Primary Examiner — Matthew E. Gordon
(74) *Attorney, Agent, or Firm* — Fish & Richardson P.C.

(57) **ABSTRACT**

A novel light-emitting device that is highly convenient, useful, or reliable is provided. A novel functional panel that is highly convenient, useful, or reliable is provided. The light-emitting device includes an insulating film, a group of structure bodies, a layer containing a light-emitting material, a first electrode, and a second electrode. The group of structure bodies includes a structure body and a different
(Continued)



structure body, a first distance is provided between the different structure body and the structure body, the insulating film includes a first surface, the structure body includes a sidewall, the sidewall forms a first angle with the first surface, and the first angle is greater than 0° and less than or equal to 90°. The layer containing a light-emitting material includes a first region and a second region, the first region is interposed between the second electrode and the first electrode, light is emitted from the first region, the second region is interposed between the second electrode and the sidewall, and the sidewall reflects light. The first electrode includes a third region, and the third region is interposed between the first region and the first surface.

9 Claims, 25 Drawing Sheets

(51) **Int. Cl.**
H10K 59/60 (2023.01)
H10K 59/80 (2023.01)

(58) **Field of Classification Search**
USPC 257/40
See application file for complete search history.

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FIG. 1A

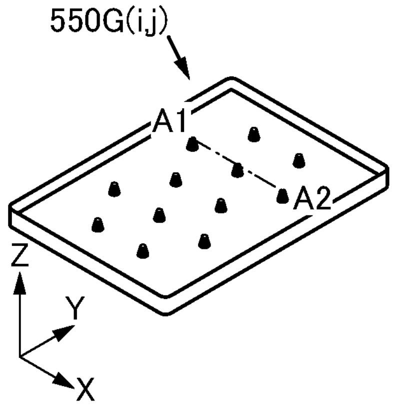


FIG. 1B

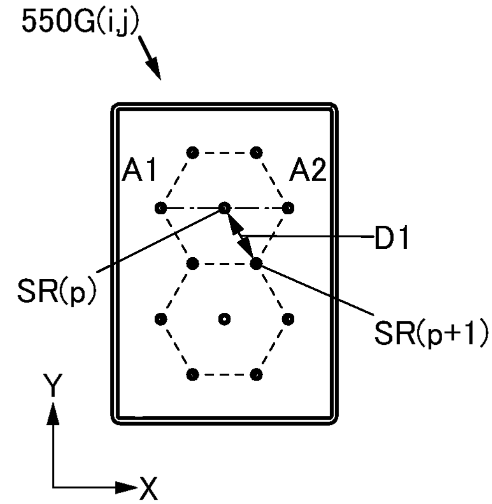


FIG. 1C

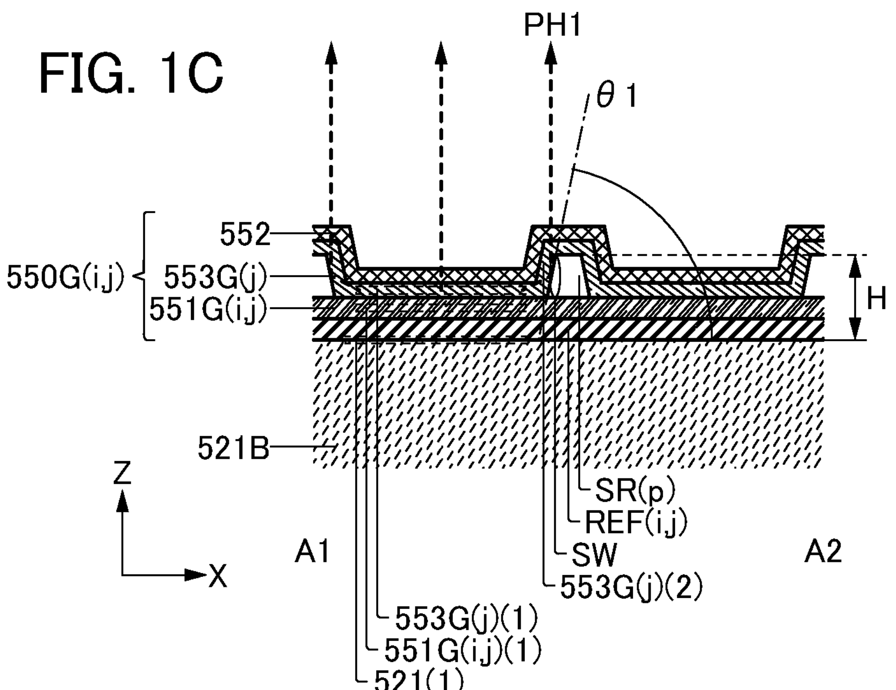


FIG. 1D

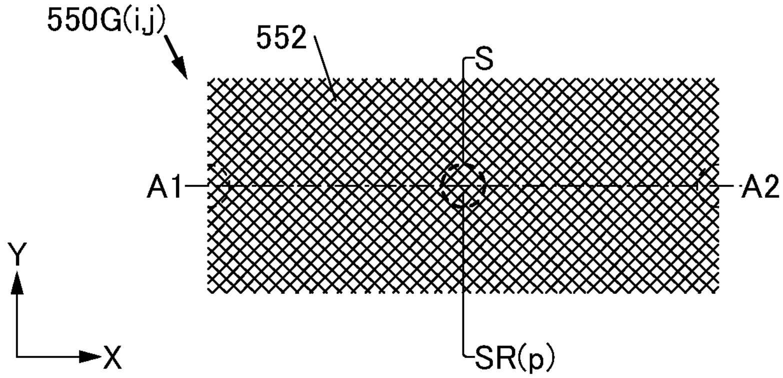


FIG. 2A

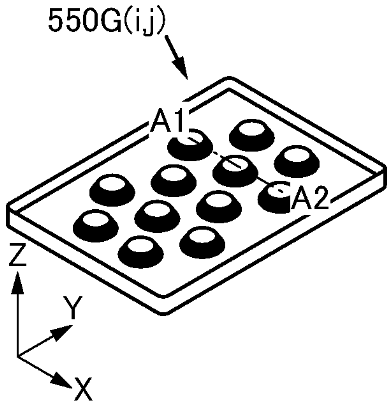


FIG. 2B

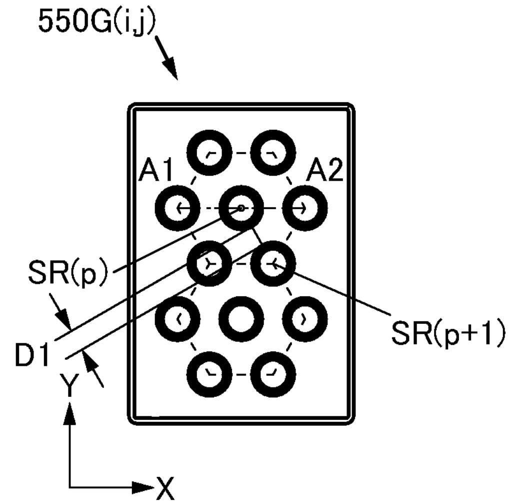


FIG. 2C

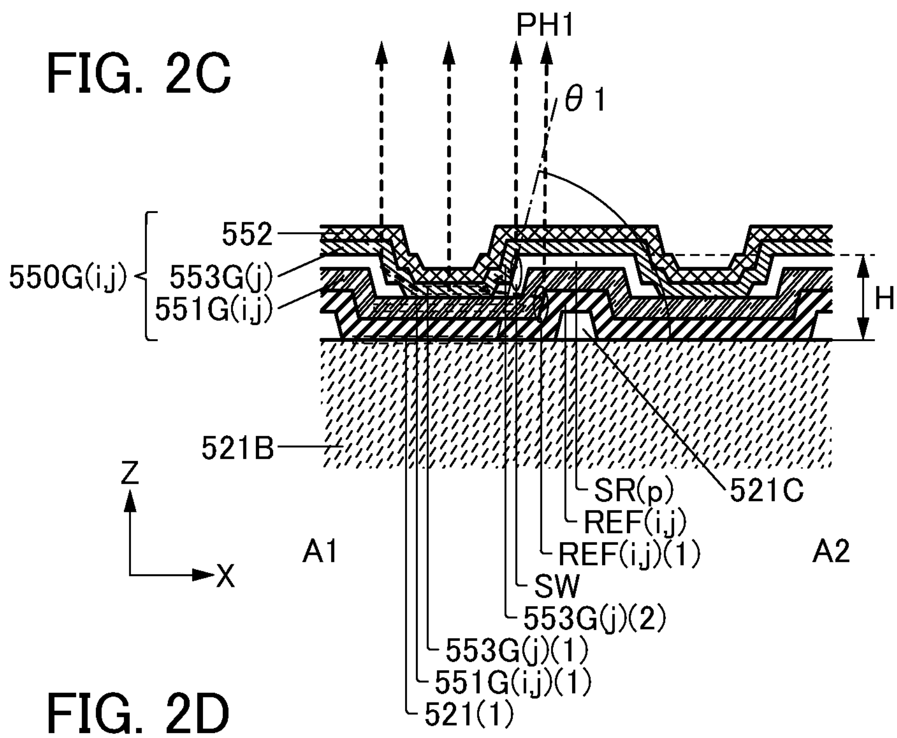


FIG. 2D

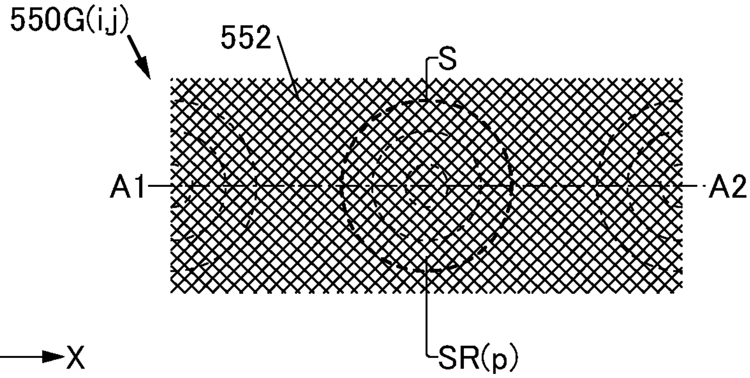


FIG. 3A

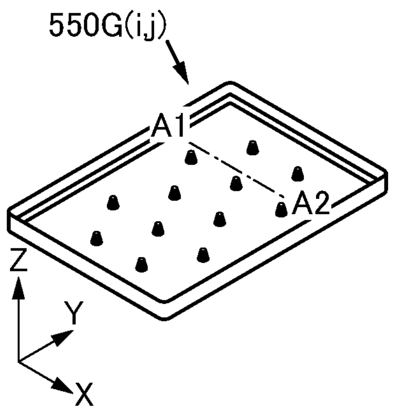


FIG. 3B

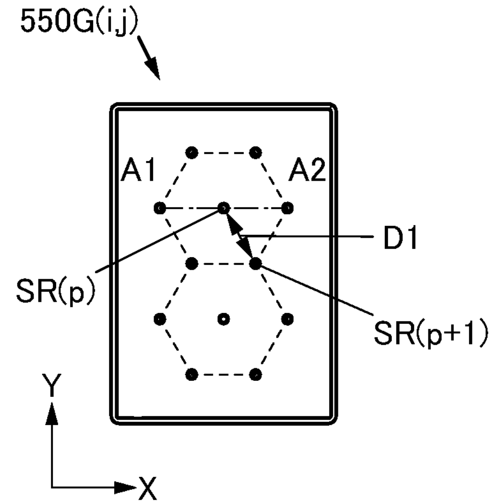


FIG. 3C

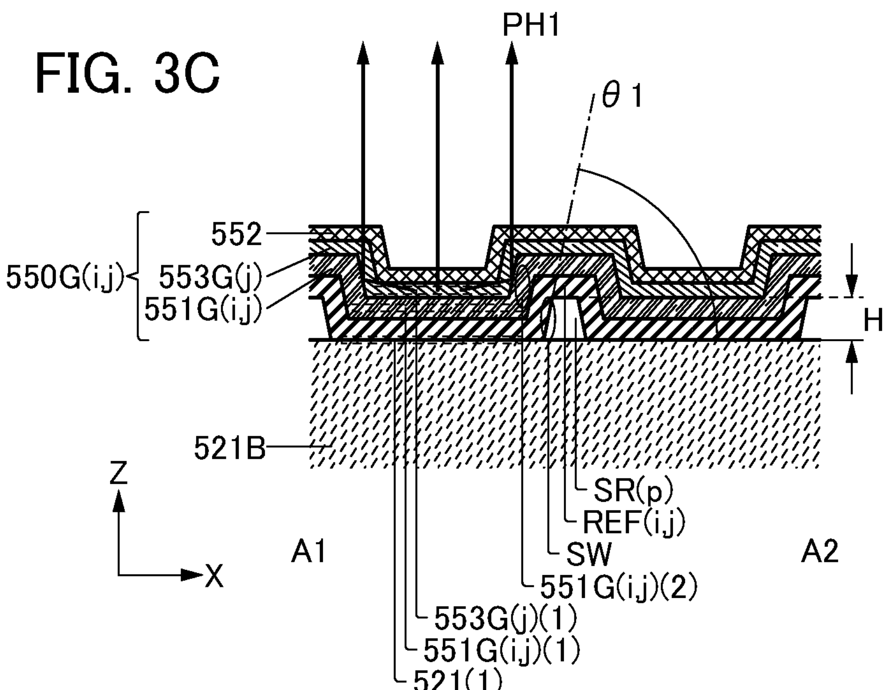


FIG. 3D

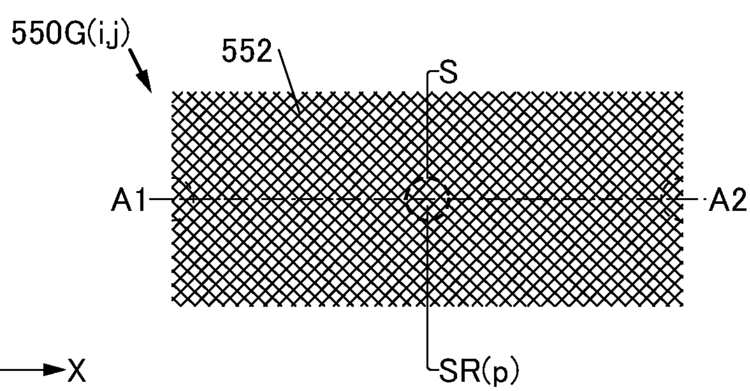


FIG. 4A

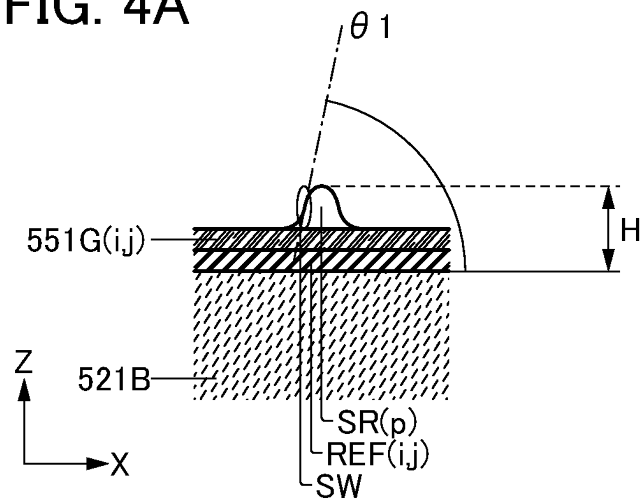


FIG. 4B

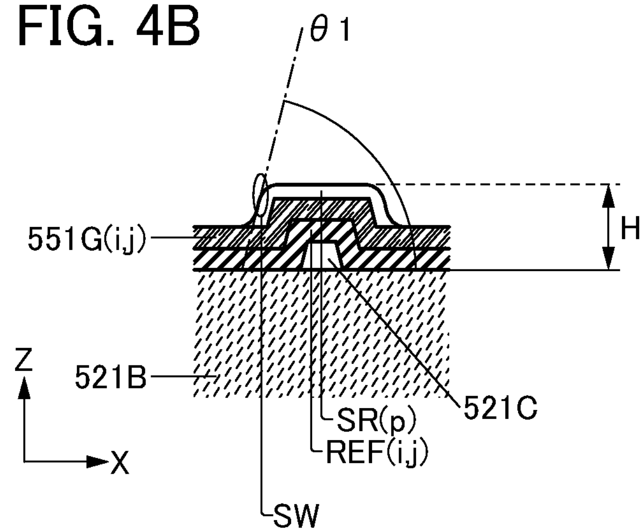


FIG. 4C

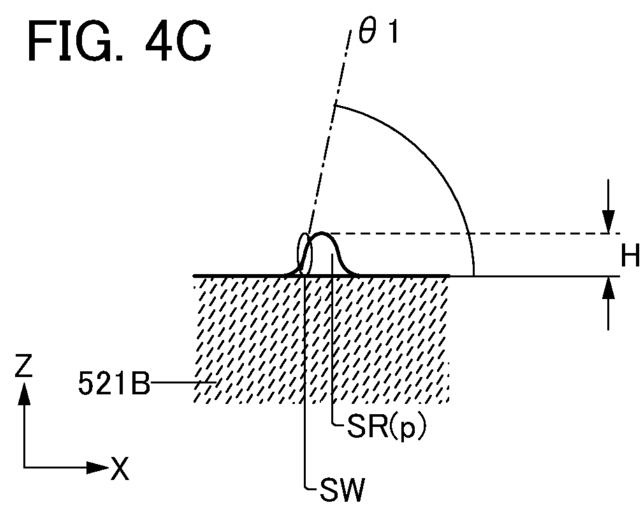


FIG. 5A

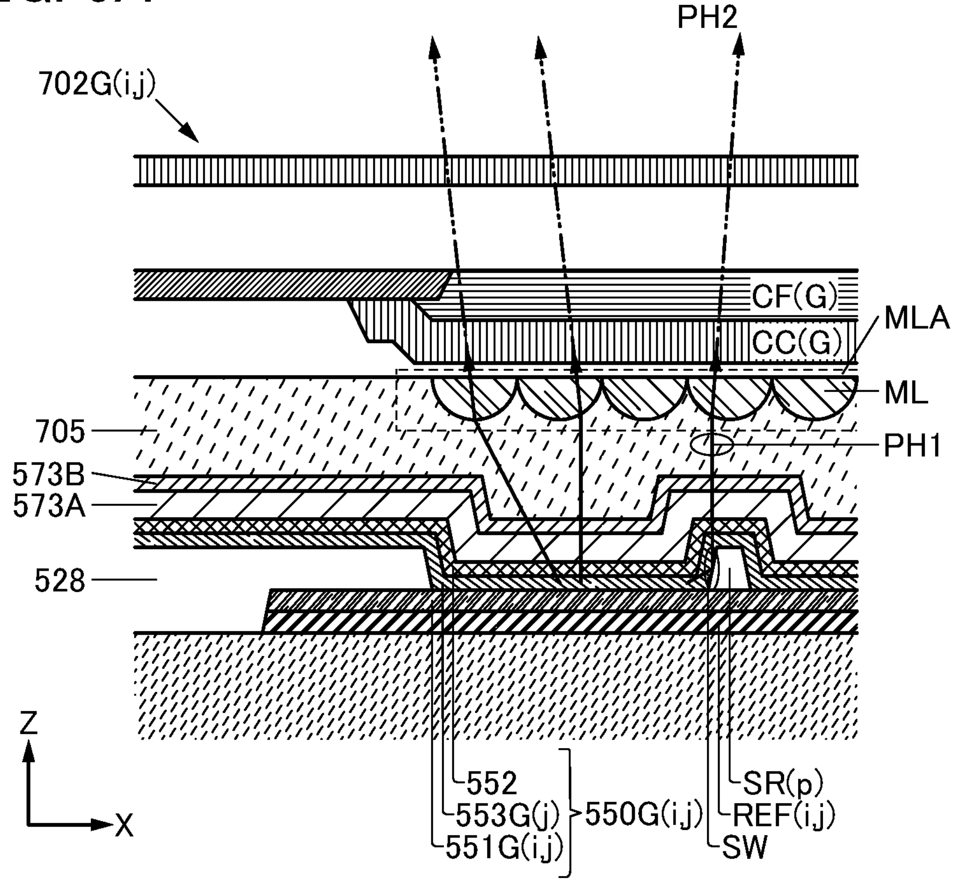


FIG. 5B

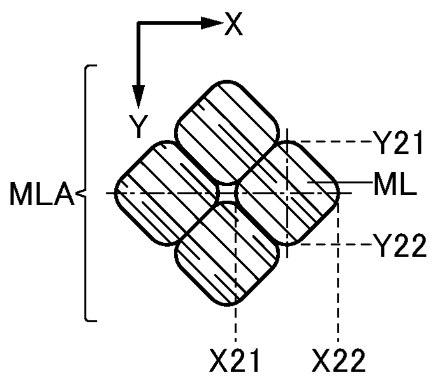


FIG. 5C

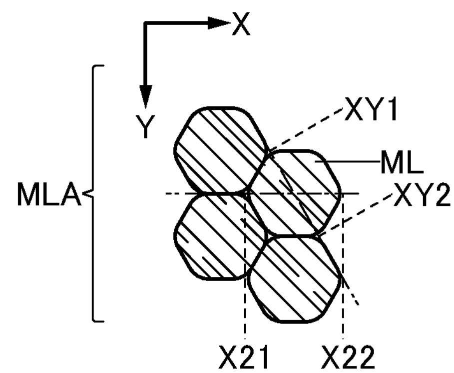


FIG. 5D

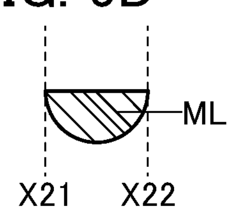


FIG. 5E

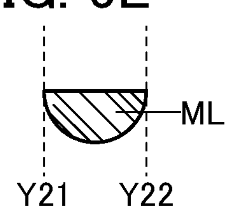


FIG. 5F

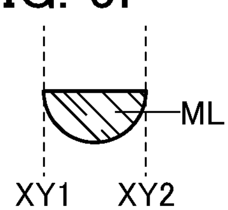


FIG. 6A

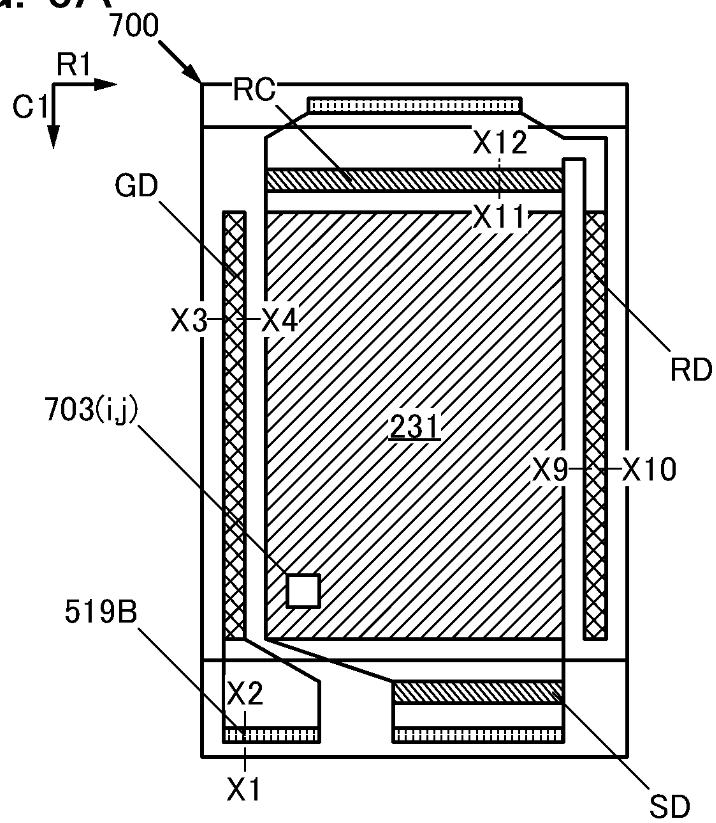

700
R1
C1
RC
X12
X11
GD
X3
X4
RD
703(i,j)
231
X9
X10
519B
X2
X1
SD

FIG. 6B

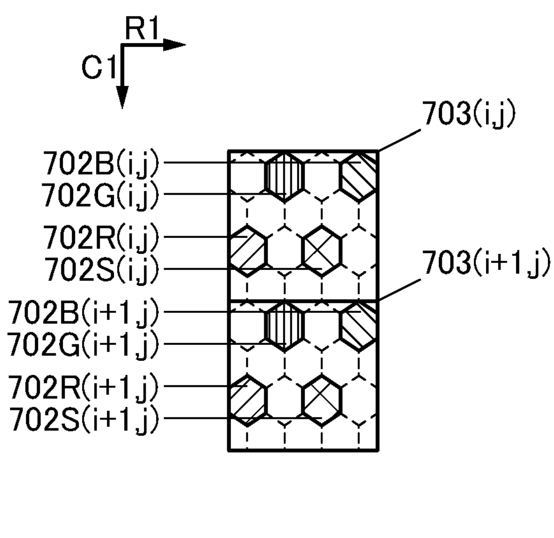

R1
C1
703(i,j)
702B(i,j)
702G(i,j)
702R(i,j)
702S(i,j)
703(i+1,j)
702B(i+1,j)
702G(i+1,j)
702R(i+1,j)
702S(i+1,j)

FIG. 7A

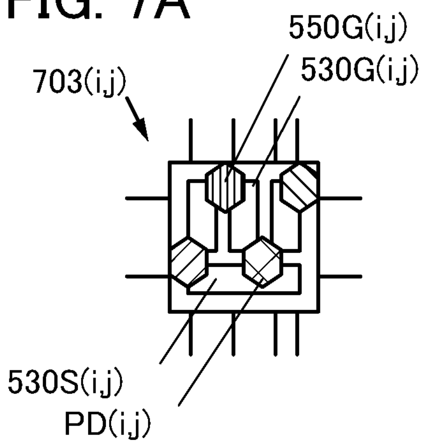


FIG. 7B

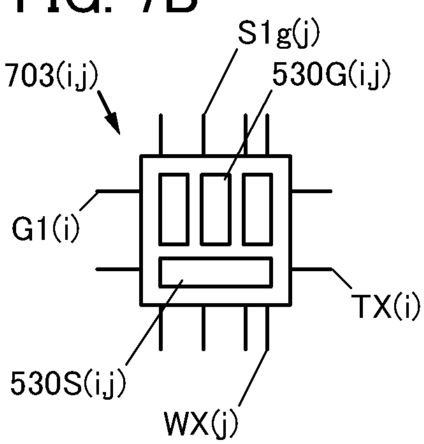


FIG. 7C

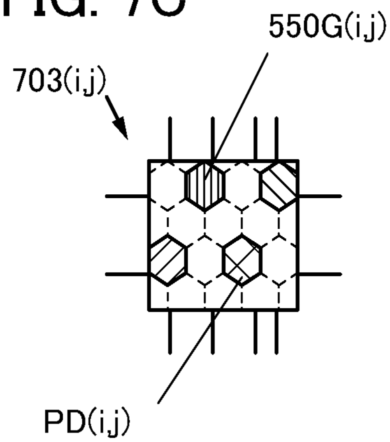
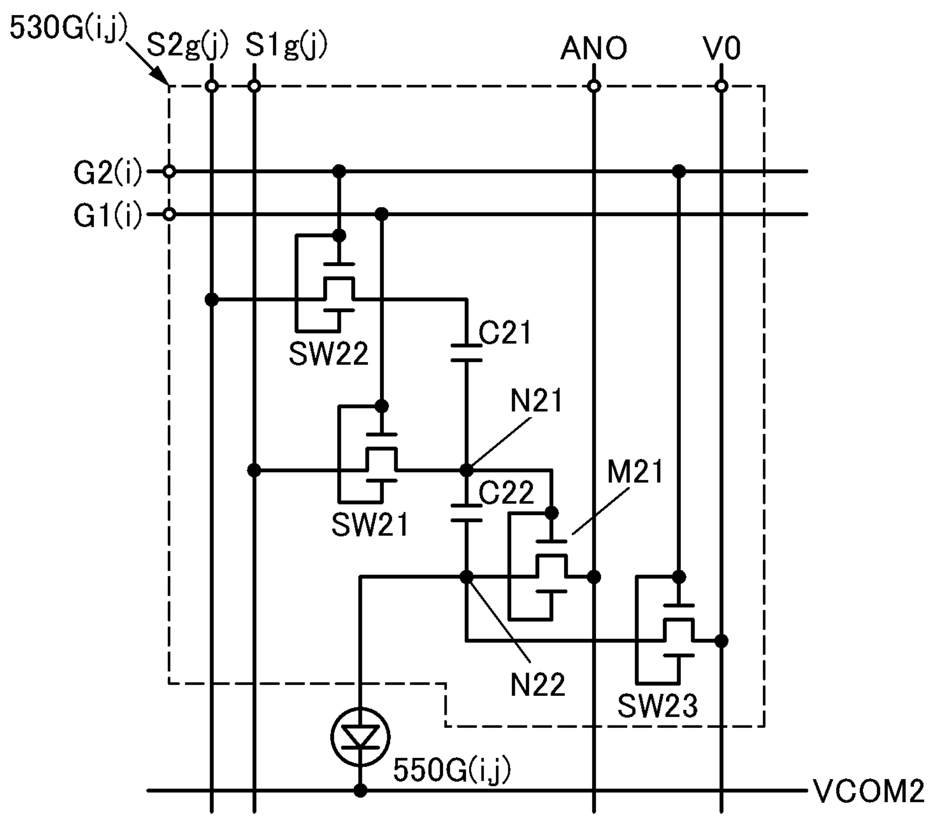


FIG. 8



530G(i,j)
S2g(j)
S1g(j)
ANO
V0
G2(i)
G1(i)
SW22
C21
N21
SW21
C22
M21
N22
SW23
550G(i,j)
VCOM2

FIG. 9

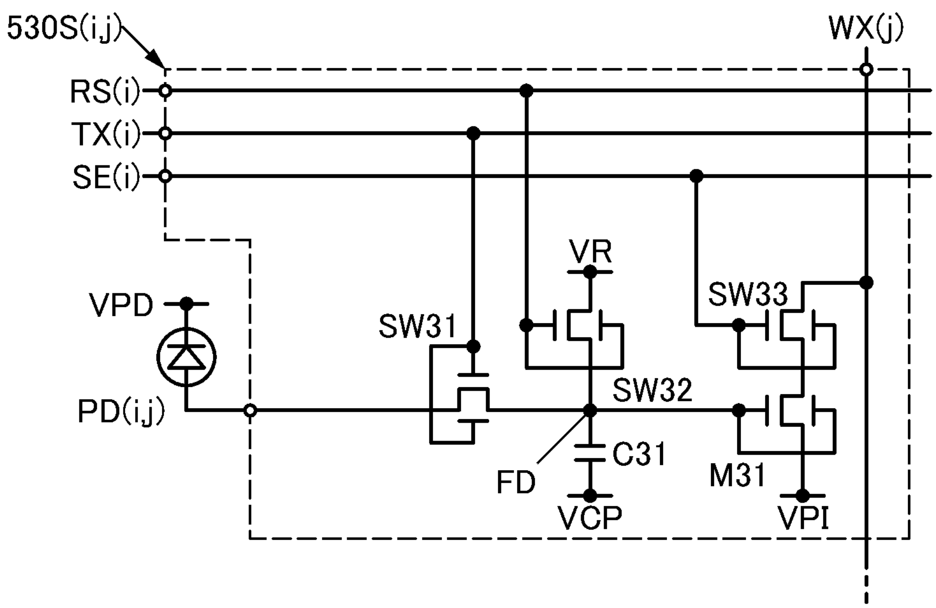

530S(i,j)
WX(j)
RS(i)
TX(i)
SE(i)
VR
SW33
VPD
SW31
SW32
PD(i,j)
C31
FD
M31
VCP
VPI

FIG. 10

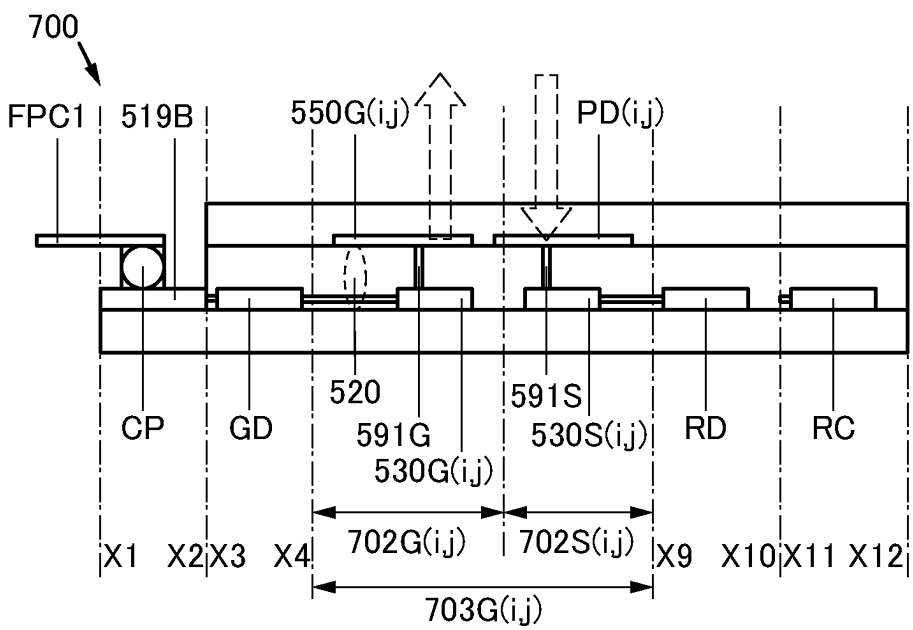

700
FPC1
519B
550G(i,j)
PD(i,j)
520
591S
CP
GD
591G
530S(i,j)
RD
RC
530G(i,j)
702G(i,j)
702S(i,j)
X1
X2
X3
X4
X9
X10
X11
X12
703G(i,j)

FIG. 11A

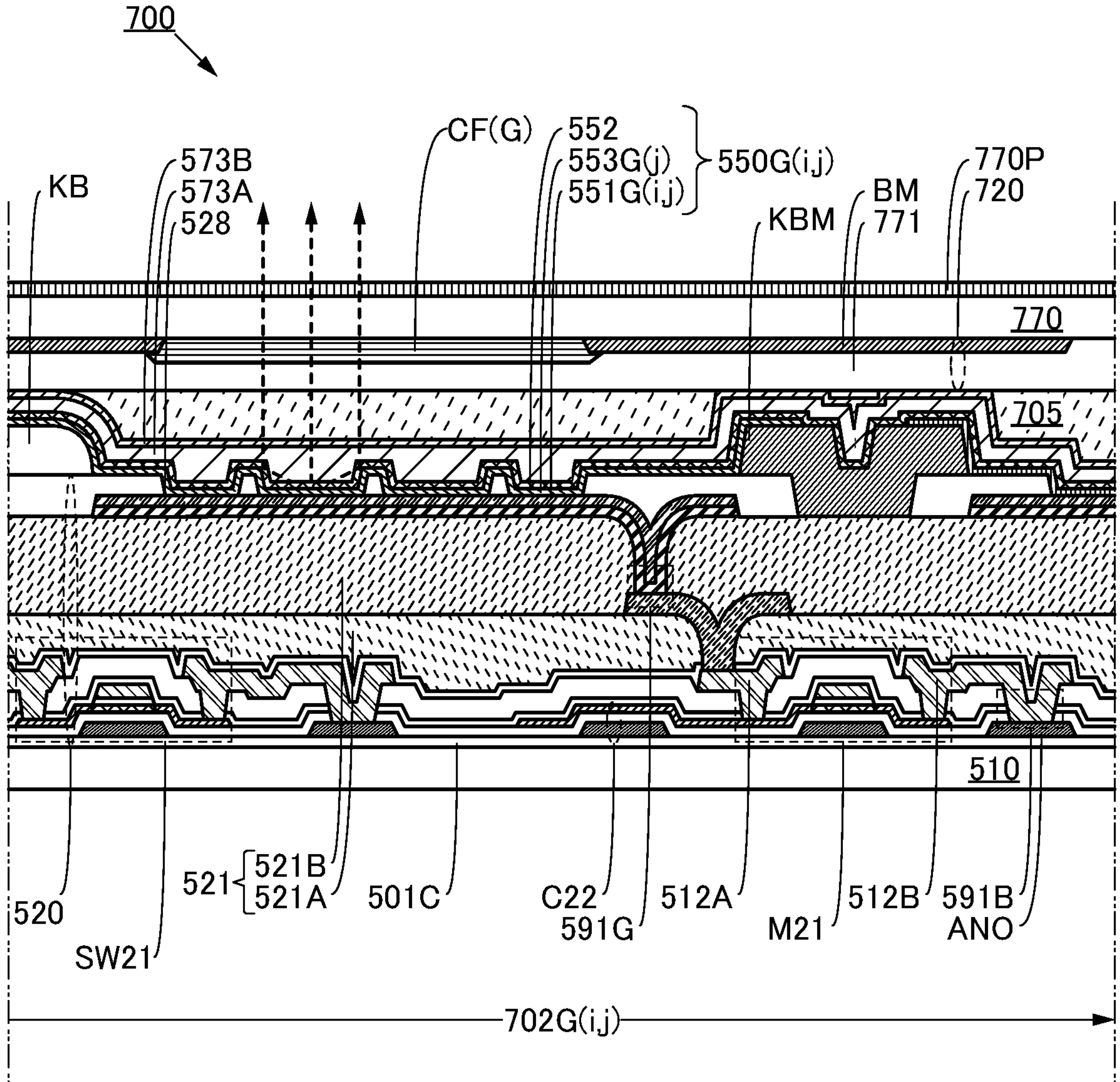


FIG. 11B

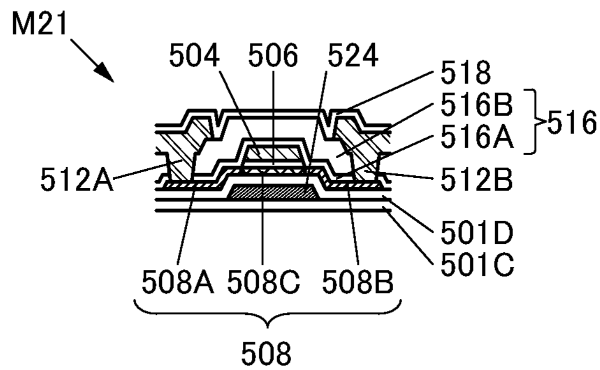


FIG. 12A

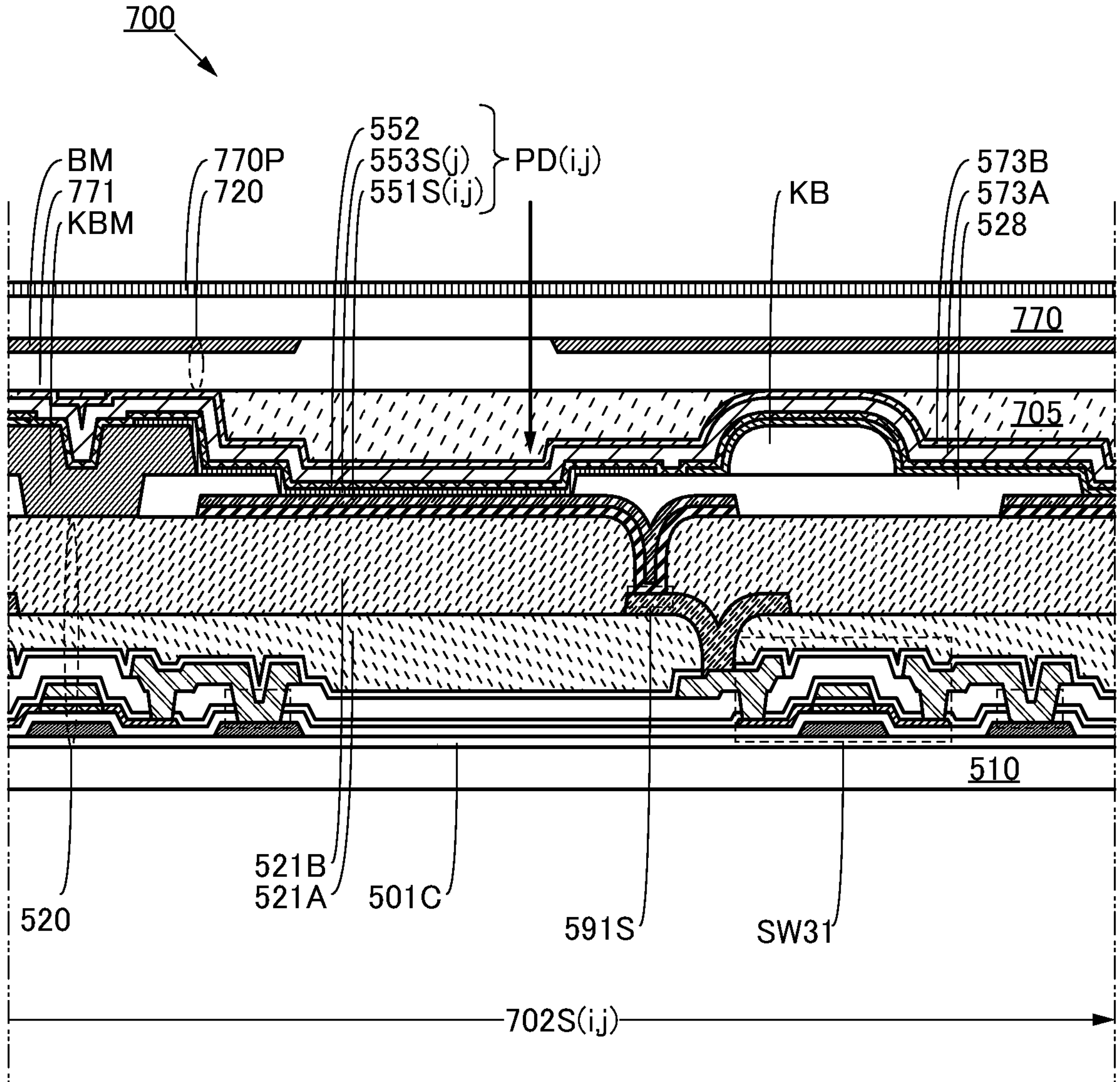


FIG. 12B

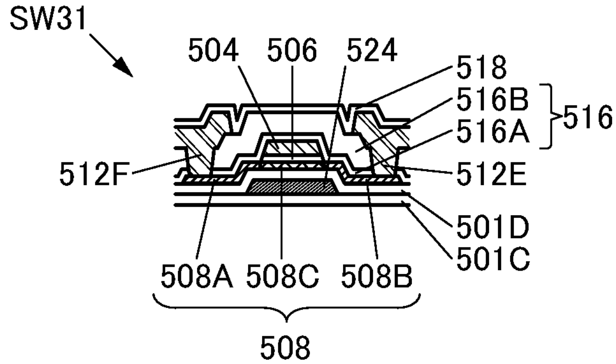


FIG. 13A

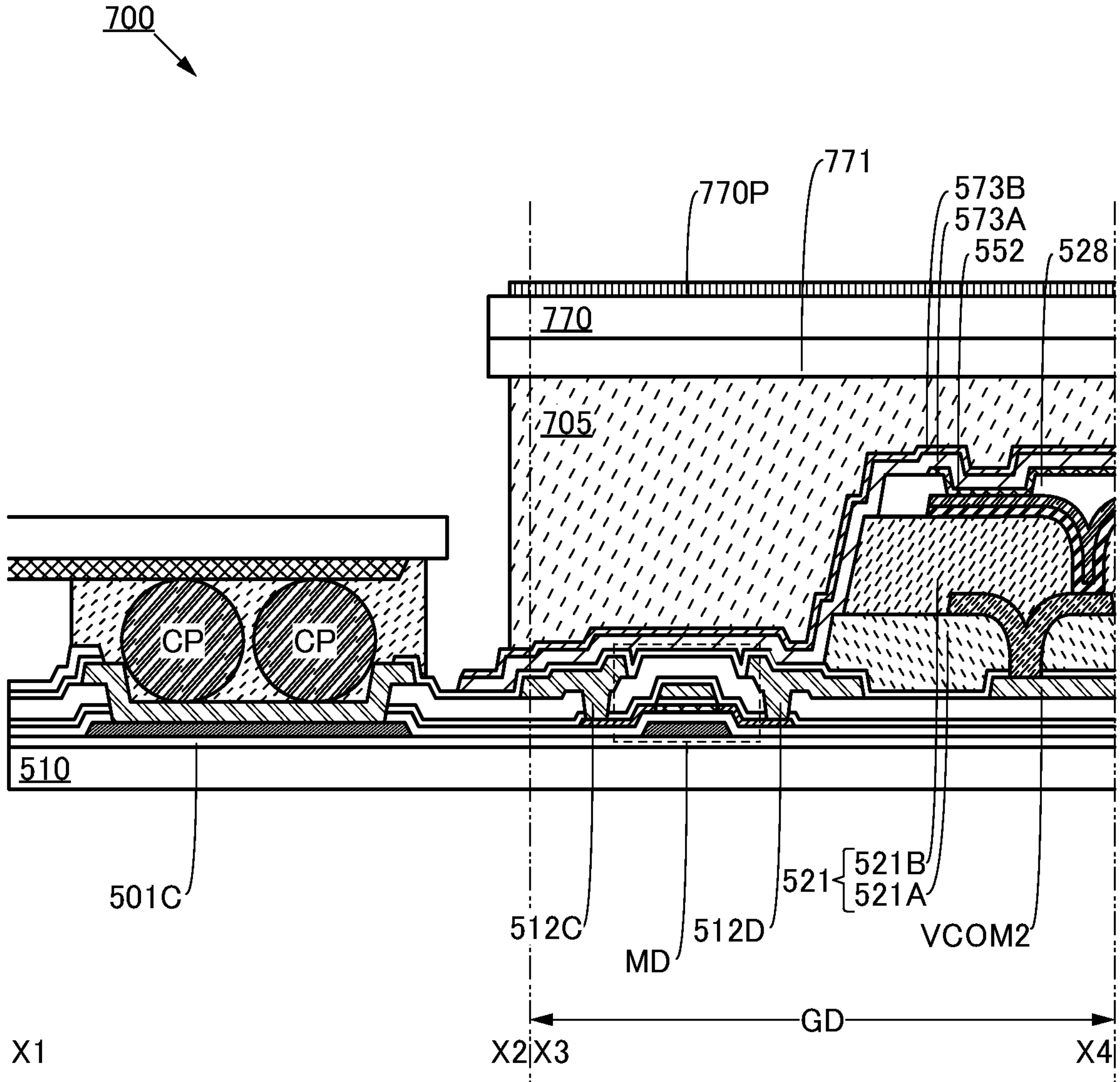


FIG. 13B

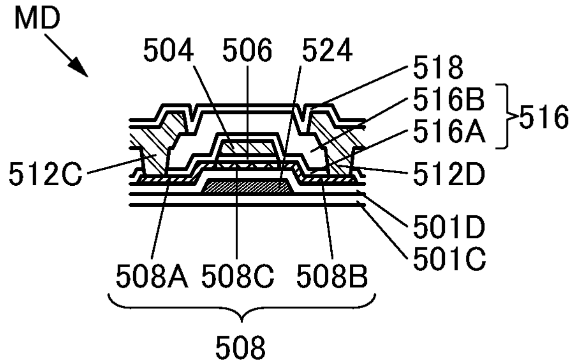


FIG. 14

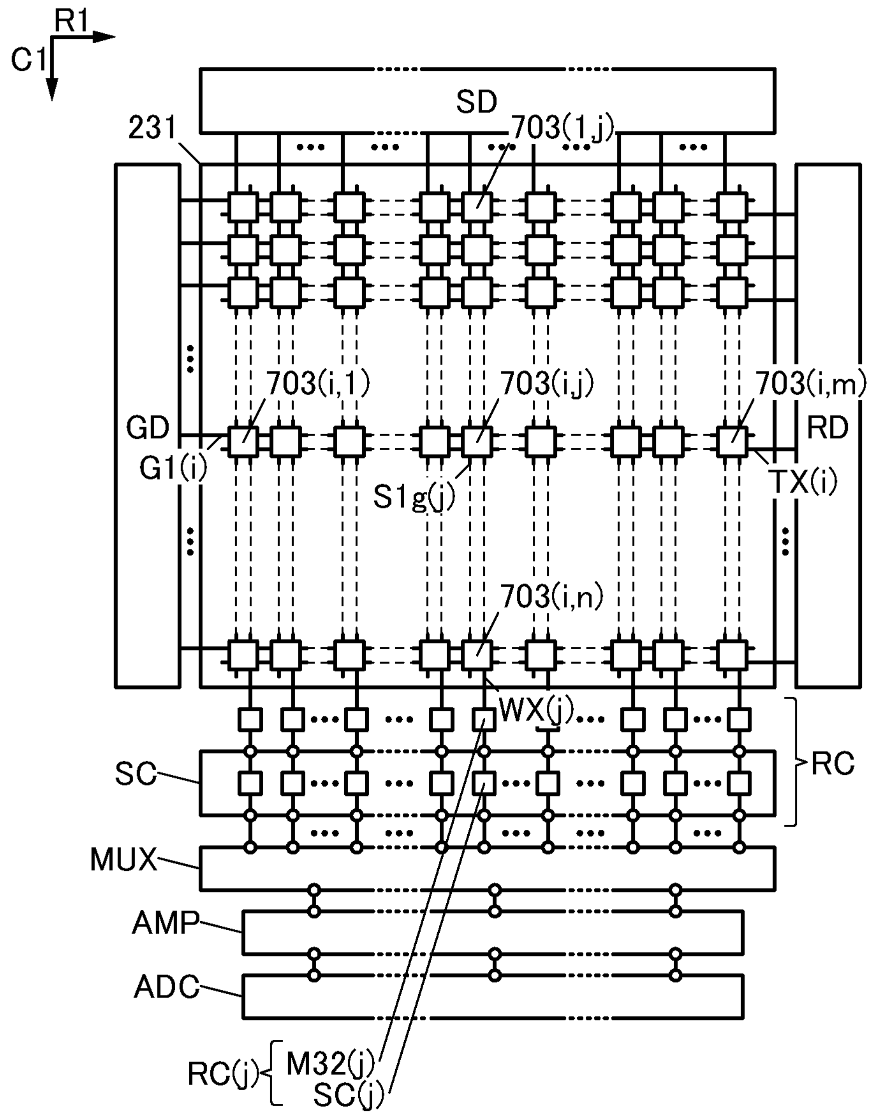

R1
C1
SD
231
703(1,j)
703(i,1)
703(i,j)
703(i,m)
GD
RD
G1(i)
S1g(j)
TX(i)
703(i,n)
WX(j)
RC
SC
MUX
AMP
ADC
RC(j)
M32(j)
SC(j)

FIG. 15A

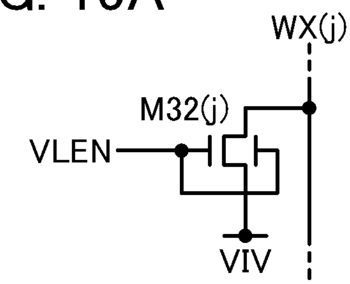


FIG. 15B

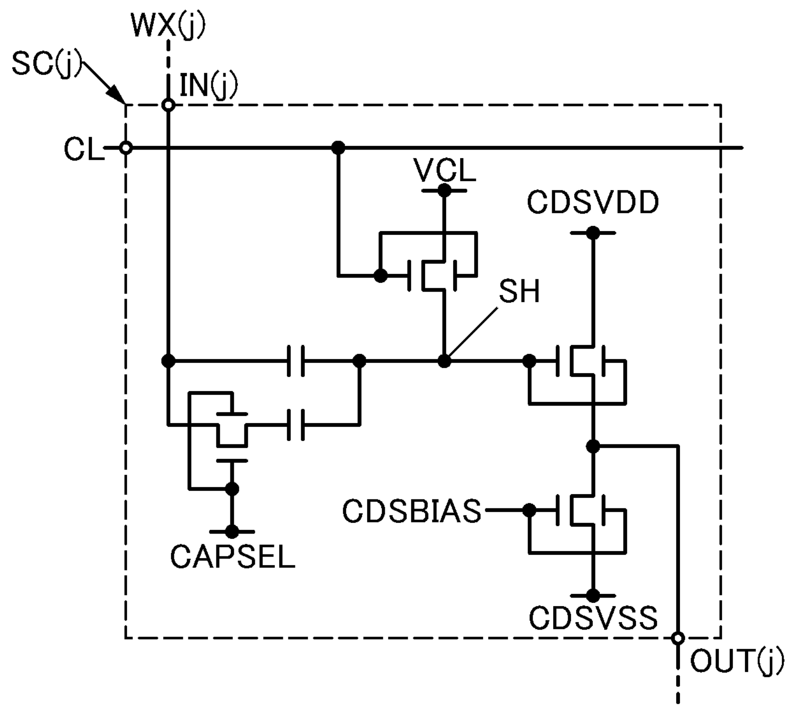
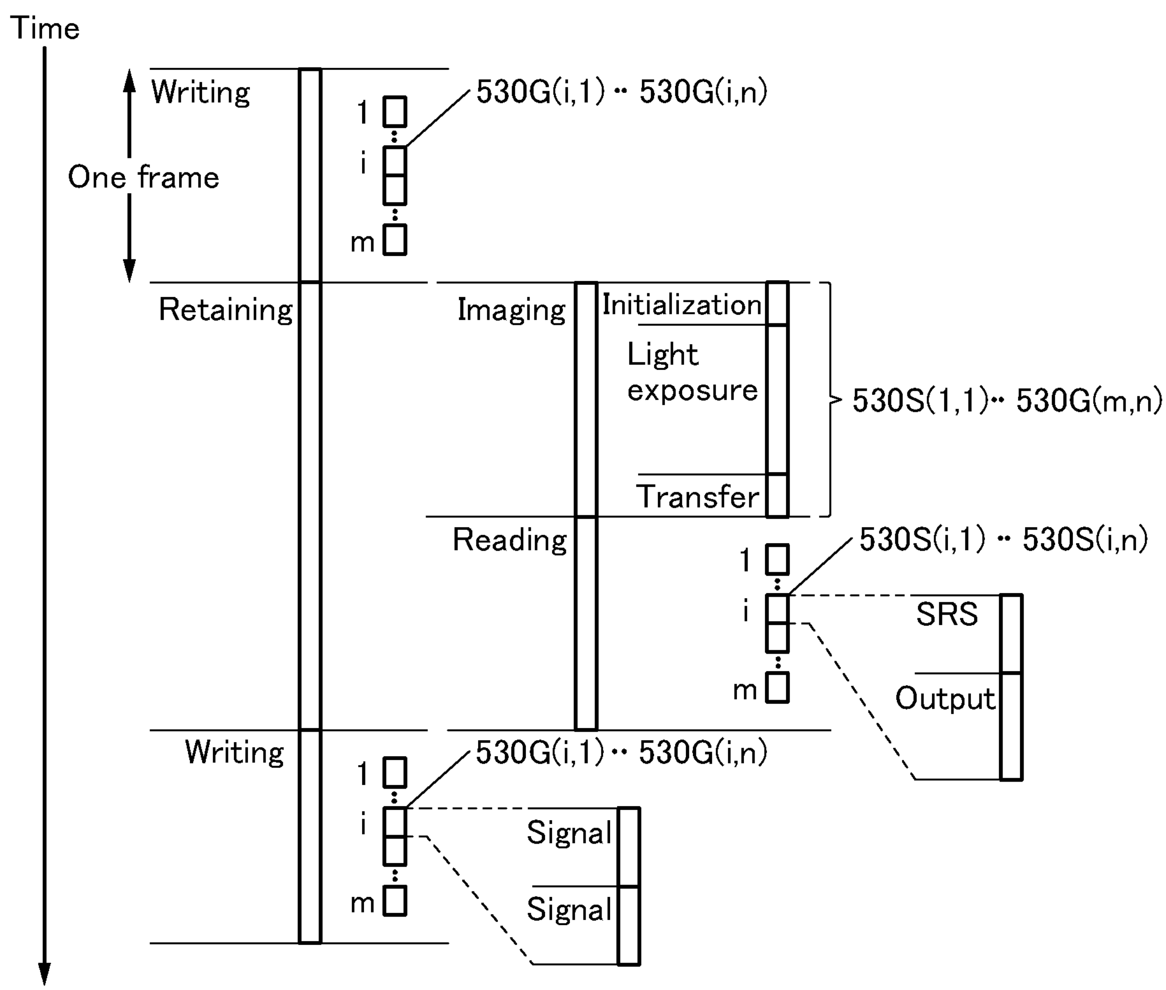


FIG. 16



Time
Writing
One frame
1
i
m
530G(i,1) ·· 530G(i,n)
Retaining
Imaging
Initialization
Light exposure
Transfer
530S(1,1)·· 530G(m,n)
Reading
530S(i,1) ·· 530S(i,n)
SRS
Output
Writing
530G(i,1) ·· 530G(i,n)
Signal
Signal

FIG. 17A

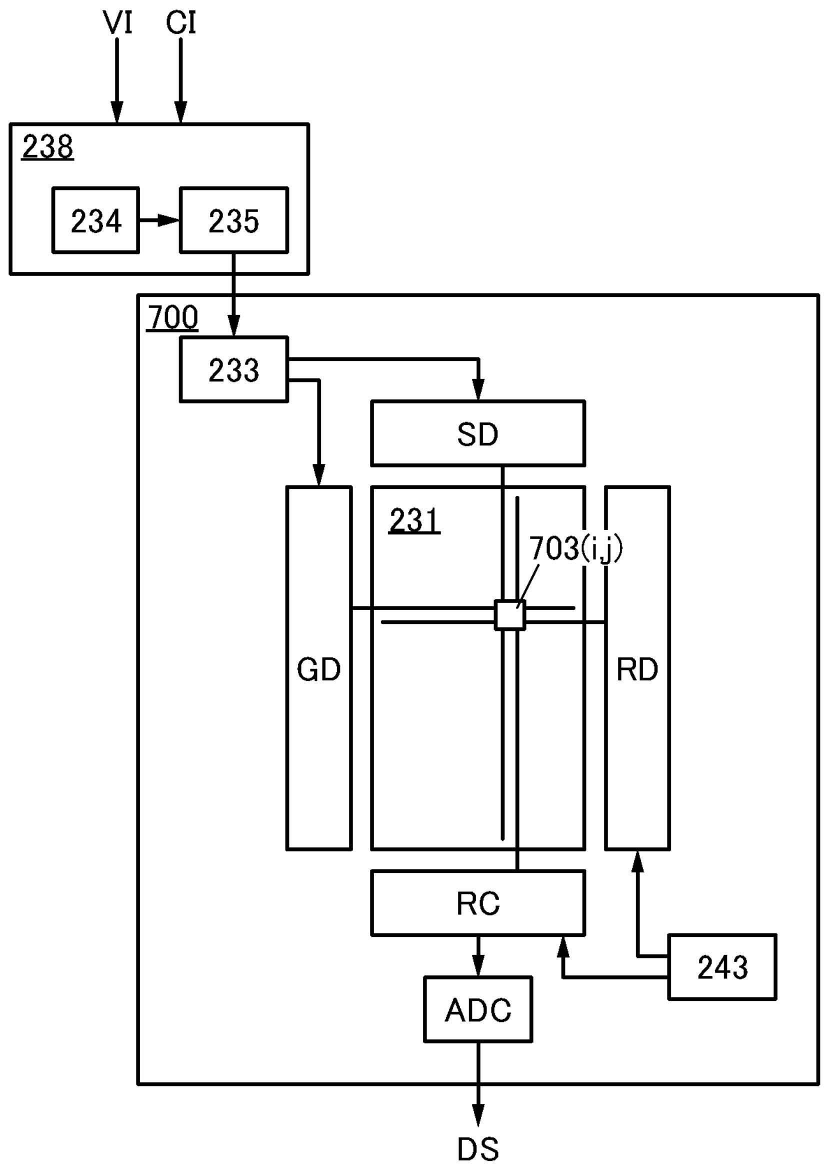


FIG. 17B

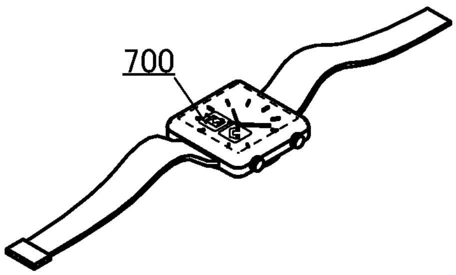


FIG. 17C

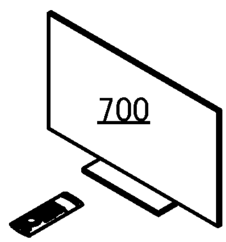


FIG. 17D

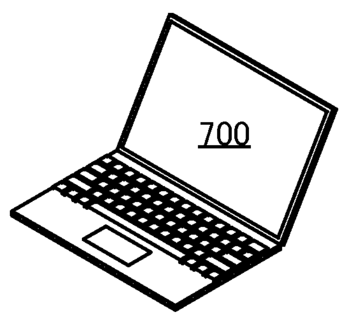
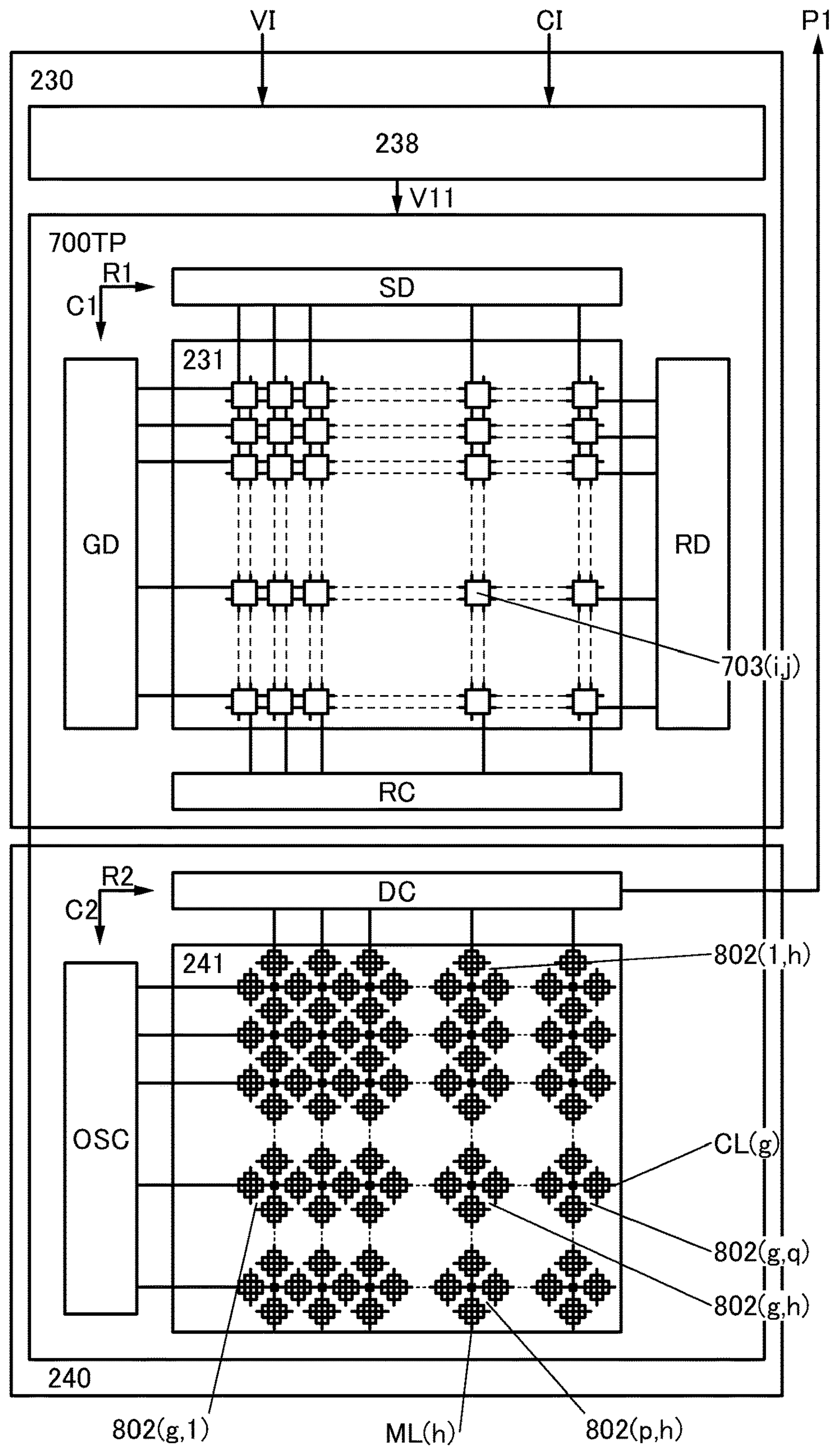


FIG. 18



VI
CI
P1
230
238
V11
700TP
R1
C1
SD
231
GD
RD
703(i,j)
RC
R2
C2
DC
241
802(1,h)
OSC
CL(g)
802(g,q)
802(g,h)
240
802(g,1)
ML(h)
802(p,h)

FIG. 19A

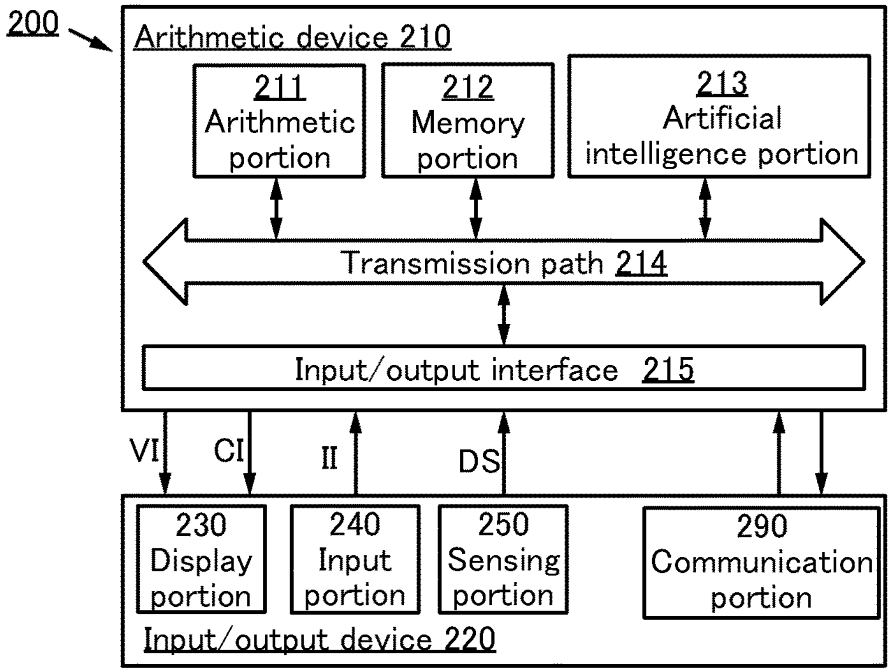


FIG. 19B

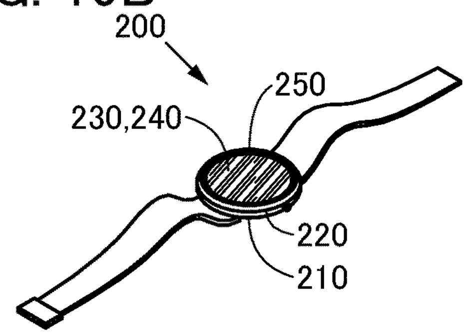


FIG. 19C

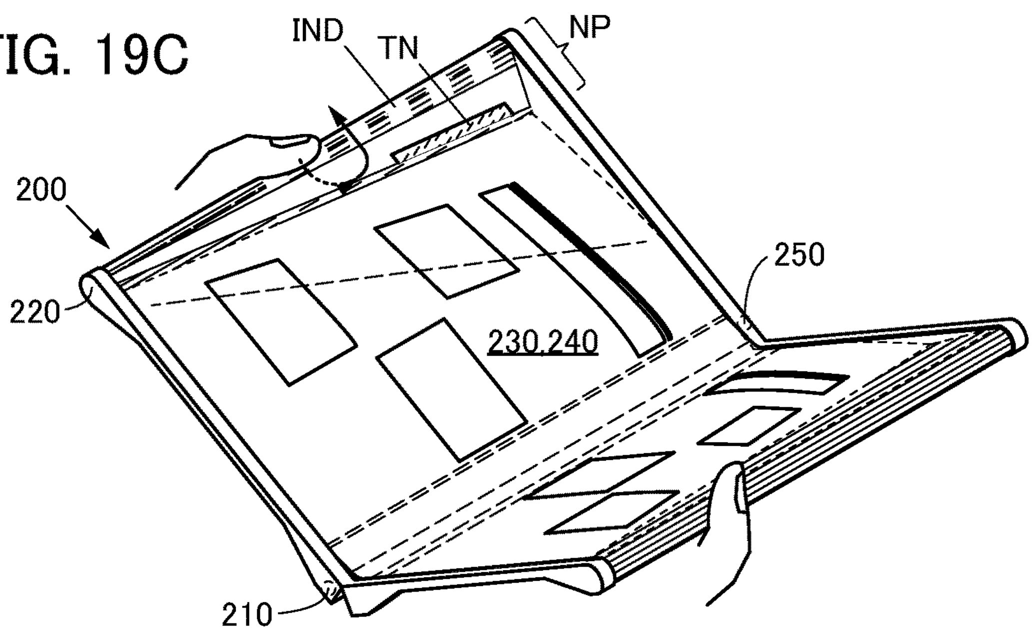


FIG. 20A

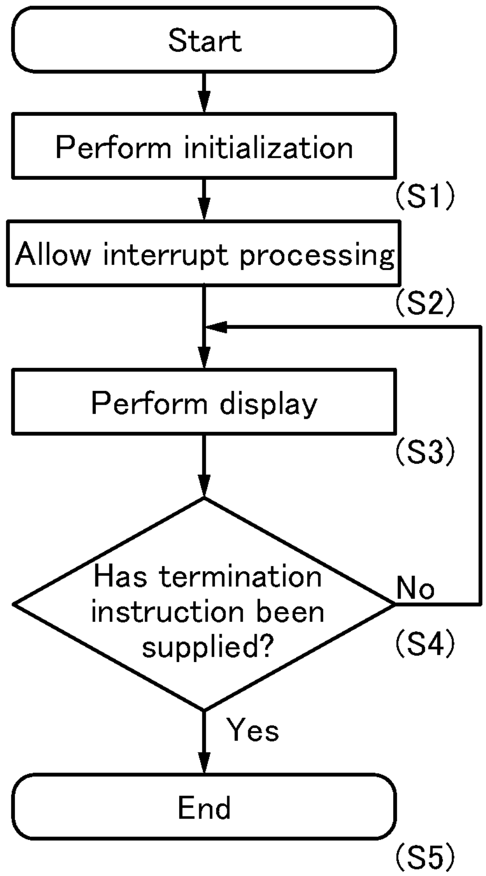


FIG. 20B

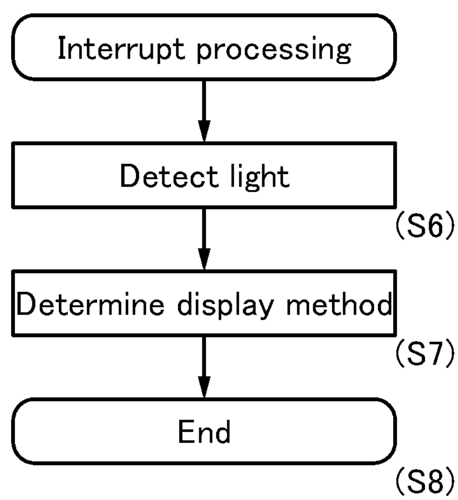


FIG. 21A

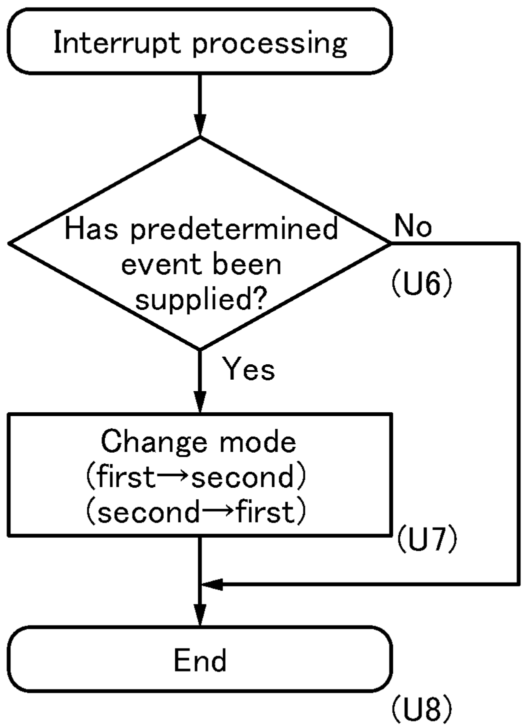


FIG. 21B

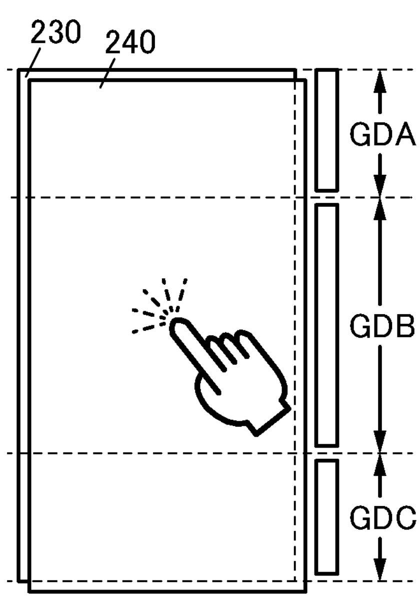


FIG. 21C

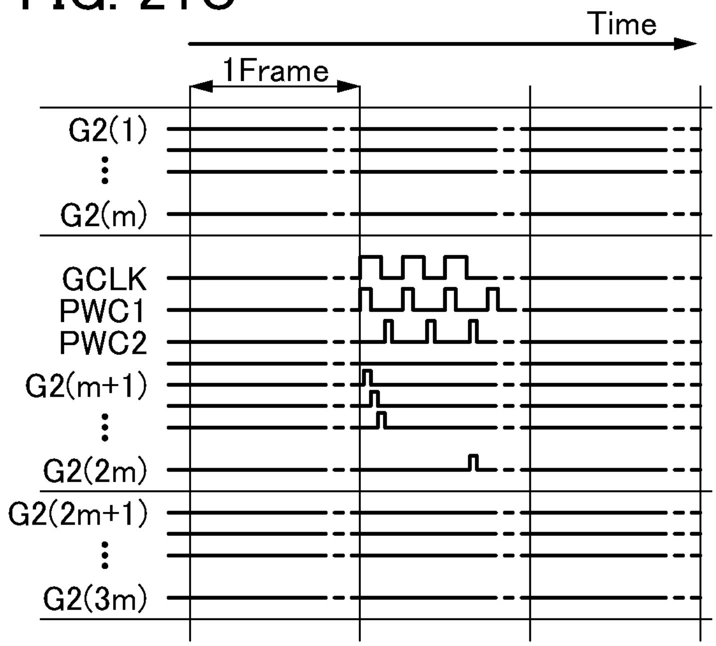


FIG. 22A

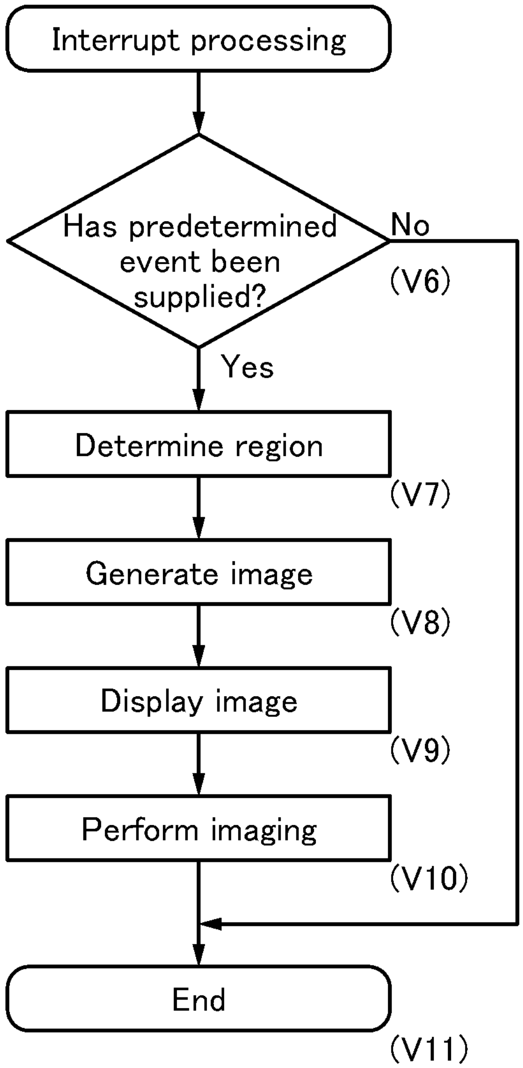


FIG. 22B

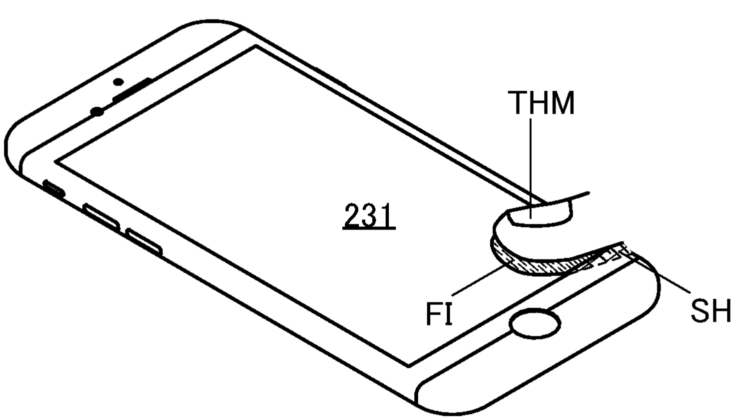


FIG. 22C

FIG. 23A

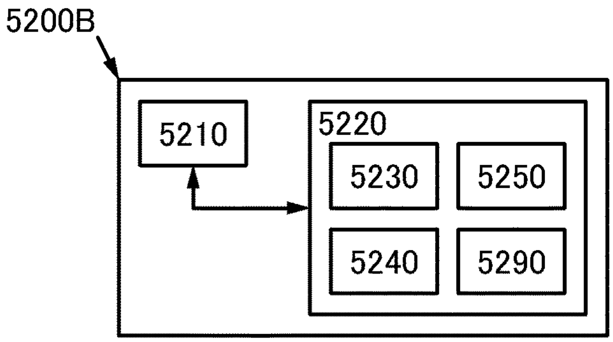


FIG. 23B

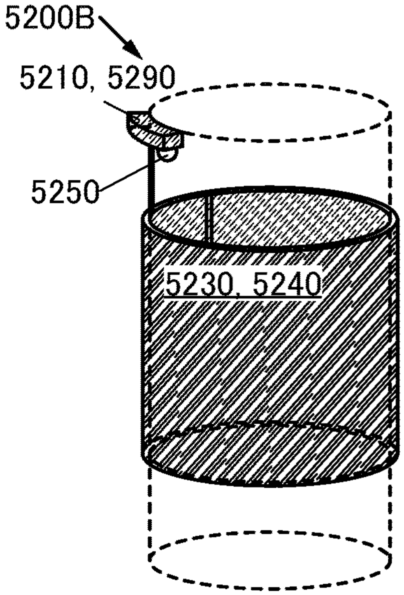


FIG. 23C

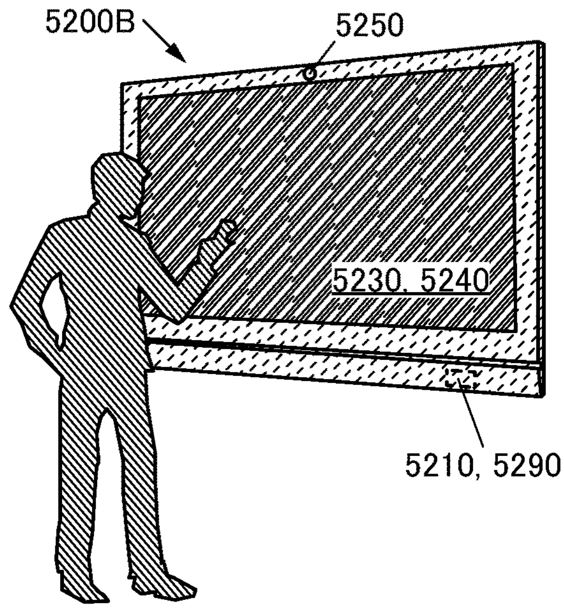


FIG. 23D

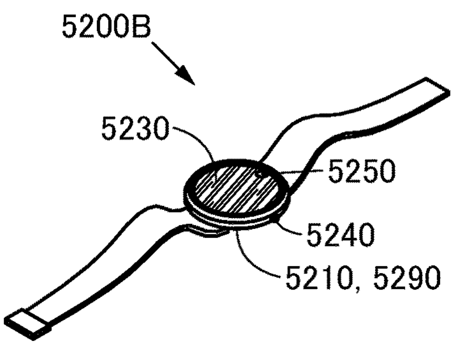


FIG. 23E

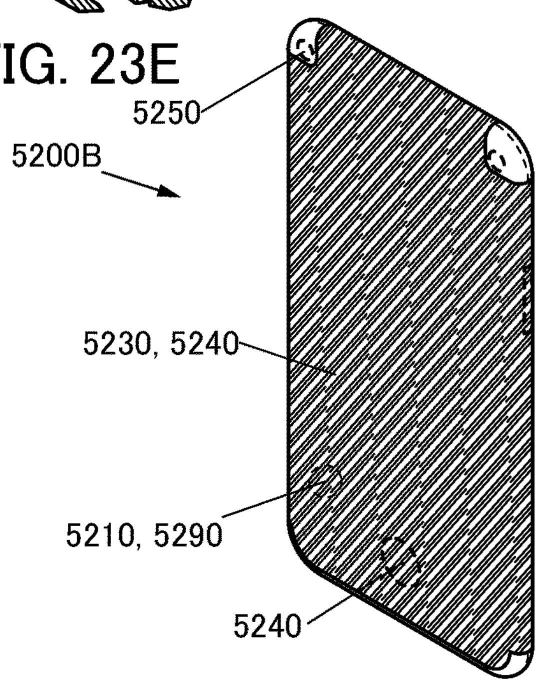


FIG. 24A

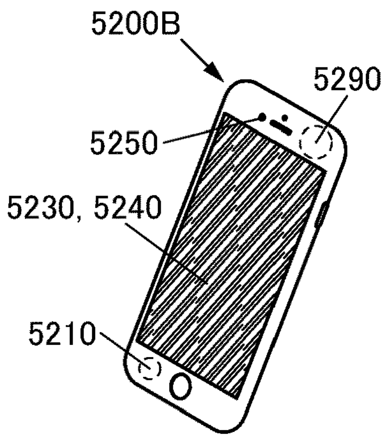


FIG. 24B

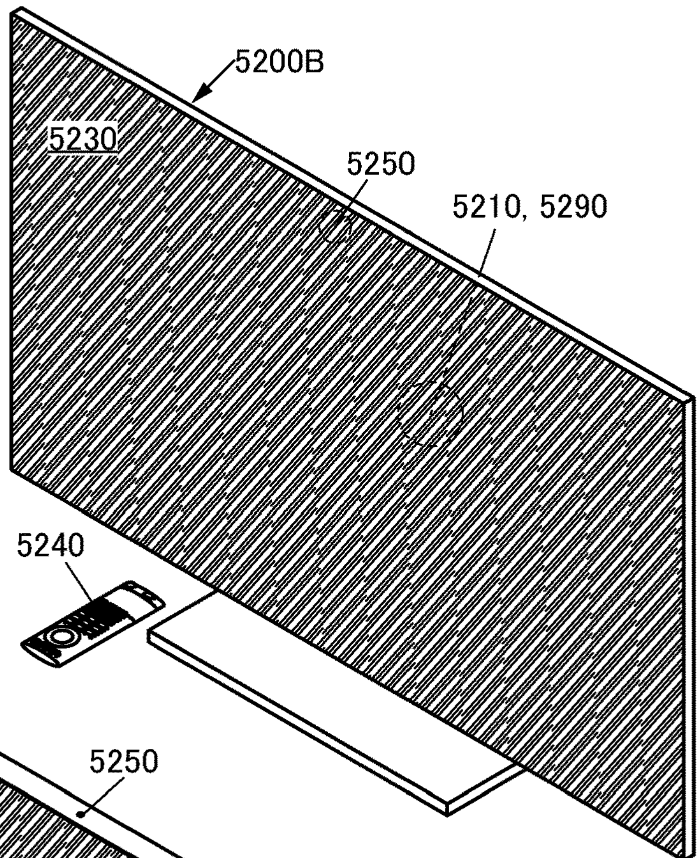


FIG. 24C

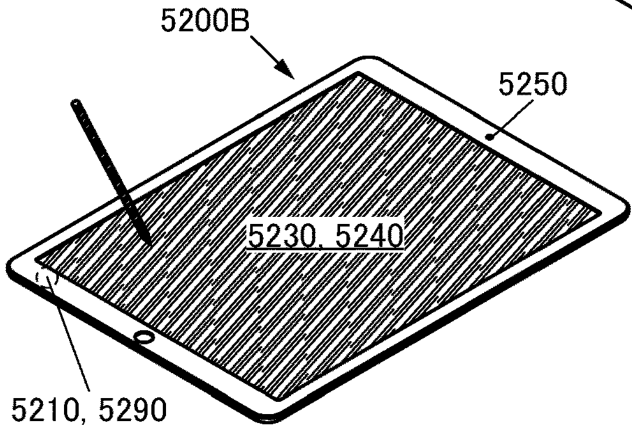


FIG. 24D

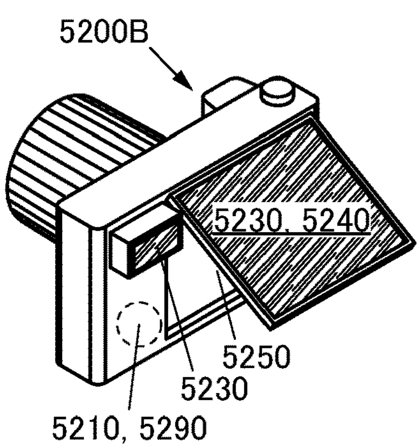


FIG. 24E

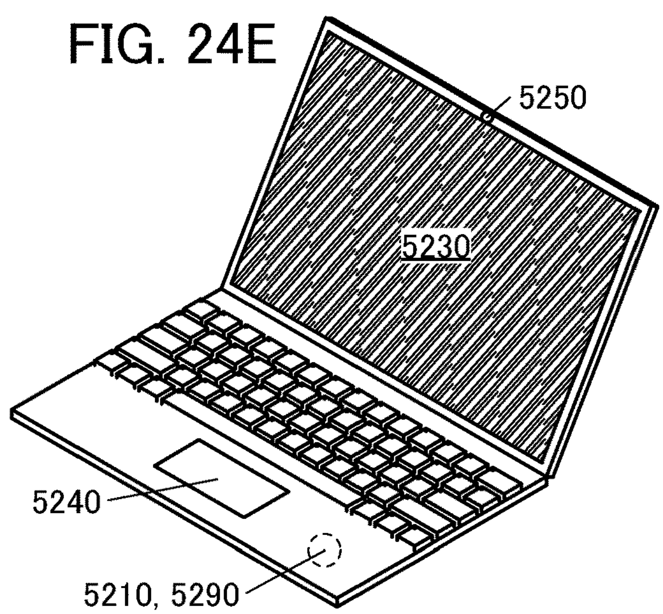


FIG. 25A

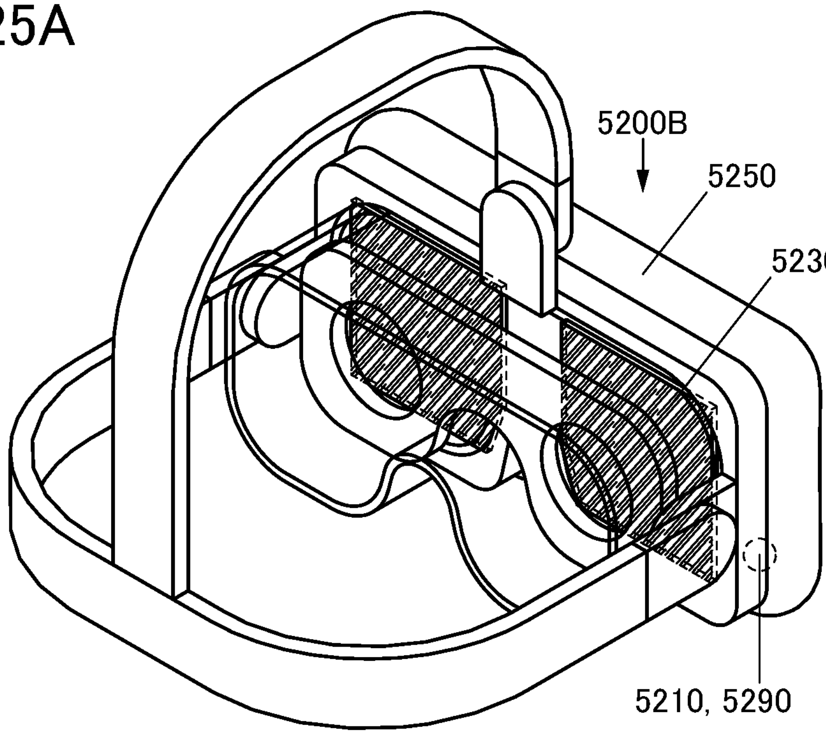
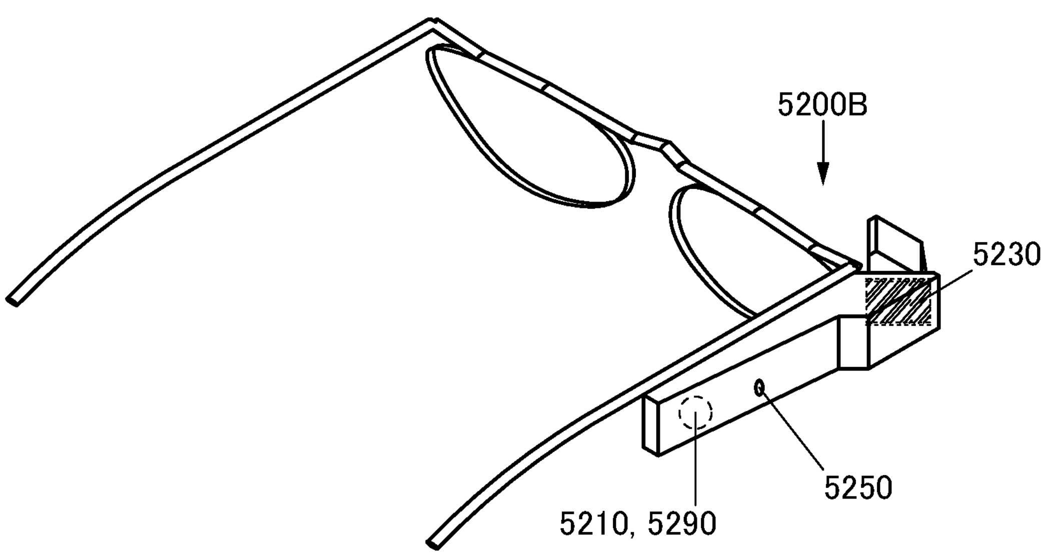


FIG. 25B



LIGHT-EMITTING DEVICE CONFIGURED TO IMPROVE LIGHT-EXTRACTION EFFICIENCY INCLUDING REFLECTIVE STRUCTURE BODY BETWEEN FIRST ELECTRODE AND LIGHT-EMITTING MATERIAL, FUNCTIONAL PANEL, DISPLAY DEVICE, INPUT/OUTPUT DEVICE, AND DATA PROCESSING DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a U.S. National Phase Application under 35 U.S.C. § 371 of International Application PCT/IB2020/055939, filed on Jun. 24, 2020, which is incorporated by reference and claims the benefit of a foreign priority application filed in Japan on Jul. 5, 2019, as Application No. 2019-125822.

TECHNICAL FIELD

One embodiment of the present invention relates to a light-emitting device, a functional panel, a display device, an input/output device, a data processing device, or a semiconductor device.

Note that one embodiment of the present invention is not limited to the above technical field. The technical field of one embodiment of the invention disclosed in this specification and the like relates to an object, a method, or a manufacturing method. One embodiment of the present invention relates to a process, a machine, manufacture, or a composition of matter. Thus, more specifically, examples of the technical field of one embodiment of the present invention disclosed in this specification include a semiconductor device, a display device, a light-emitting apparatus, a power storage device, a memory device, a driving method thereof, and a manufacturing method thereof.

BACKGROUND ART

A light-emitting device having a structure in which a first electrode has a four-layer structure containing materials of Ti/TiN/Al (or Al—Ti)/Ti (or TiN) to improve the light extraction efficiency is known (Patent Document 1).

A high-efficiency organic EL microdisplay that focuses on the increase in out-coupling efficiency using a microlens array and has an efficiency three times that of a conventional organic light-emitting diode is known (Non-Patent Document 1).

There is known a technique for increasing the current efficiency of a red organic light-emitting diode by 1.57 times using a nanolens array formed by a vacuum evaporation process (Non-Patent Document 2).

There is also known a technique for increasing the efficiency of extracting light from an organic light-emitting diode with the use of a concave structure that is formed by filling the inner side of a bank with a high-index filler (Non-Patent Document 3).

REFERENCES

Patent Document

[Patent Document 1] Japanese Published Patent Application No. 2004-214010

Non-Patent Documents

[Non-Patent Document 1] Yosuke Motoyama et al., Journal of the Society for Information Display, 2019, pp. 1-7.

[Non-Patent Document 2] Young-Sam Park et al., "SID Symposium Digest of Technical Papers", 2019, volume 50, issue 1, pp. 149-152.

[Non-Patent Document 3] Chung-China Chen et al., "SID Symposium Digest of Technical Papers", 2019, volume 50, issue 1, pp. 145-148.

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

An object of one embodiment of the present invention is to provide a novel light-emitting device that is highly convenient, useful, or reliable. Another object is to provide a novel functional panel that is highly convenient, useful, or reliable. Another object is to provide a novel display device that is highly convenient, useful, or reliable. Another object is to provide a novel input/output device that is highly convenient, useful, or reliable. Another object is to provide a novel data processing device that is highly convenient, useful, or reliable. Another object is to provide a novel functional panel, a novel display device, a novel input/output device, a novel data processing device, or a novel semiconductor device.

Note that the descriptions of these objects do not preclude the existence of other objects. One embodiment of the present invention does not have to achieve all these objects. Other objects will be apparent from the descriptions of the specification, the drawings, the claims, and the like, and other objects can be derived from the descriptions of the specification, the drawings, the claims, and the like.

Means for Solving the Problems

(1) One embodiment of the present invention is a light-emitting device including an insulating film, a group of structure bodies, a layer containing a light-emitting material, a first electrode, and a second electrode.

The insulating film includes a first surface, the group of structure bodies includes a structure body and a different structure body, a first distance is provided between the different structure body and the structure body, the structure body includes a sidewall, the sidewall forms a first angle with the first surface, and the first angle is greater than 0 and less than or equal to 90°.

The layer containing a light-emitting material includes a first region and a second region, the first region is interposed between the second electrode and the first electrode, and light is emitted from the first region.

The first electrode includes a third region, and the third region is interposed between the first region and the first surface.

Thus, in light emitted from the first region, components propagating along the layer containing a light-emitting material, for example, can be extracted efficiently. High luminance can be obtained with low electric energy. Thus, a novel light-emitting device that is highly convenient, useful, or reliable can be provided.

(2) Another embodiment of the present invention is the light-emitting device including a reflective film.

The reflective film includes a fourth region, the sidewall is interposed between the fourth region and the layer containing a light-emitting material, and the light is reflected in the fourth region.

Thus, not only components of light at the surface of the structure body but also those passing through the structure body can be reflected. Thus, a novel light-emitting device that is highly convenient, useful, or reliable can be provided.

(3) Another embodiment of the present invention is a light-emitting device including an insulating film, a group of structure bodies, a layer containing a light-emitting material, a first electrode, and a second electrode.

The insulating film includes a first surface, the group of structure bodies includes a structure body and a different structure body, a first distance is provided between the different structure body and the structure body, the structure body includes a sidewall, the sidewall forms a first angle with the first surface, and the first angle is greater than 0 and less than or equal to 90°.

The layer containing a light-emitting material includes a first region, the first region is interposed between the second electrode and the first electrode, and light is emitted from the first region.

The first electrode includes a third region and a fifth region, and the third region is interposed between the first region and the first surface. The fifth region is interposed between the layer containing a light-emitting material and the sidewall, and the light is reflected in the fifth region.

Thus, in light emitted from the first region, components propagating along the layer containing a light-emitting material, for example, can be extracted efficiently. High luminance can be obtained with low electric energy. Thus, a novel light-emitting device that is highly convenient, useful, or reliable can be provided.

(4) Another embodiment of the present invention is the light-emitting device in which the structure body has a first height from the insulating film and the structure body has a first projection area with respect to the insulating film. Note that the first height is greater than or equal to 0.1 μm and less than or equal to 5 μm, preferably greater than or equal to 1.5 μm and less than or equal to 3 μm. The first projection area is greater than or equal to 0.01 μm^2 and less than or equal to 100 μm^2, preferably greater than or equal to 3 μm^2 and less than or equal to 9 μm^2.

(5) Another embodiment of the present invention is the light-emitting device in which the first distance is greater than or equal to 0.1 μm and less than or equal to 5 μm, preferably 0.1 μm and less than or equal to 2.5 μm.

Thus, in light emitted from the second region, components propagating along the layer containing a light-emitting material, for example, can be extracted efficiently. Thus, a novel light-emitting device that is highly convenient, useful, or reliable can be provided.

(6) Another embodiment of the present invention is a functional panel including a set of pixels. The set of pixels includes a pixel and a different pixel.

The pixel includes a first pixel circuit and the light-emitting device, and the light-emitting device is electrically connected to the first pixel circuit.

The different pixel includes a second pixel circuit and a photoelectric conversion element, and the photoelectric conversion element is electrically connected to the second pixel circuit.

(7) Another embodiment of the present invention is the functional panel including a functional layer.

The functional layer includes the first pixel circuit, the first pixel circuit includes a first transistor, the functional layer includes the second pixel circuit, and the second pixel circuit includes a second transistor. The functional layer includes a driver circuit, and the driver circuit includes a third transistor.

The first transistor includes a semiconductor film, the second transistor includes a semiconductor film that can be formed in a step of forming the semiconductor film, and the third transistor includes a semiconductor film that can be formed in the step of forming the semiconductor film.

Thus, the first pixel circuit can be formed in the functional layer. The second pixel circuit can be formed in the functional layer. The semiconductor film used in the second pixel circuit can be formed in the step of forming the semiconductor film used in the first pixel circuit, for example. The manufacturing process of the functional panel can be simplified. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

(8) Another embodiment of the present invention is a display device including the functional panel and a control portion.

The control portion is supplied with image data and control data, the control portion generates data on the basis of the image data, and the control portion generates a control signal on the basis of the control data. The control portion supplies the data and the control signal.

The functional panel is supplied with the data and the control signal, and the pixel emits light in response to the data.

Thus, the image data can be displayed using the light-emitting device. Thus, a novel display device that is highly convenient, useful, or reliable can be provided.

(9) Another embodiment of the present invention is an input/output device including an input portion and a display portion.

The display portion includes the display panel, the input portion includes a sensing region, and the input portion senses an object approaching the sensing region **241**. The sensing region includes a region overlapping with the pixel.

Thus, the object approaching the region overlapping with the display portion can be sensed while image data is displayed using the display portion. A finger or the like approaching the display portion can be used as a pointer to input position data. Position data can be associated with image data displayed on the display portion. Thus, a novel input/output device that is highly convenient or reliable can be provided.

(10) Another embodiment of the present invention is a data processing device including one or more of a keyboard, a hardware button, a pointing device, a touch sensor, an illuminance sensor, an imaging device, an audio input device, an eye-gaze input device, and an attitude detection device, and the above display panel.

Thus, the arithmetic device can generate the image data or the control data on the basis of the data supplied using a variety of input devices. Thus, a novel data processing device that is highly convenient or reliable can be provided.

Note that in the drawings attached to this specification, the block diagram in which components are classified according to their functions and shown as independent blocks is illustrated; however, it is difficult to separate actual components completely according to their functions, and it is possible for one component to relate to a plurality of functions.

In this specification, the names of a source and a drain of a transistor interchange with each other depending on the polarity of the transistor and the levels of potentials applied to the terminals. In general, in an n-channel transistor, a terminal to which a lower potential is applied is called a source, and a terminal to which a higher potential is applied is called a drain. In a p-channel transistor, a terminal to which a lower potential is applied is called a drain, and a terminal to which a higher potential is applied is called a source. In this specification, for the sake of convenience, the connection relationship of a transistor is sometimes described assuming that the source and the drain are fixed; in reality, the source and the drain interchange with each other according to the above relationship of the potentials.

In this specification, a source of a transistor means a source region that is part of a semiconductor film functioning as an active layer or a source electrode connected to the semiconductor film. Similarly, a drain of a transistor means a drain region that is part of the semiconductor film or a drain electrode connected to the semiconductor film. Moreover, a gate means a gate electrode.

In this specification, a state in which transistors are connected in series means, for example, a state in which only one of a source and a drain of a first transistor is connected to only one of a source and a drain of a second transistor. In addition, a state in which transistors are connected in parallel means a state in which one of a source and a drain of a first transistor is connected to one of a source and a drain of a second transistor and the other of the source and the drain of the first transistor is connected to the other of the source and the drain of the second transistor.

In this specification, connection means electrical connection and corresponds to a state in which a current, a voltage, or a potential can be supplied or transmitted. Accordingly, a state of being connected does not necessarily mean a state of being directly connected and also includes, in its category, a state of being indirectly connected through a circuit element such as a wiring, a resistor, a diode, or a transistor that allows a current, a voltage, or a potential to be supplied or transmitted.

In this specification, even when independent components are connected to each other in a circuit diagram, there is actually a case where one conductive film has functions of a plurality of components, such as a case where part of a wiring functions as an electrode, for example. Connection in this specification also includes such a case where one conductive film has functions of a plurality of components, in its category.

Furthermore, in this specification, one of a first electrode and a second electrode of a transistor refers to a source electrode and the other refers to a drain electrode.

Effect of the Invention

According to one embodiment of the present invention, a novel light-emitting device that is highly convenient, useful, or reliable can be provided. A novel functional panel that is highly convenient, useful, or reliable can be provided. A novel display device that is highly convenient, useful, or reliable can be provided. A novel input/output device that is highly convenient, useful, or reliable can be provided. A novel data processing device that is highly convenient, useful, or reliable can be provided. A novel functional panel, a novel display device, a novel input/output device, a novel data processing device, or a novel semiconductor device can be provided.

Note that the descriptions of these effects do not preclude the existence of other effects. One embodiment of the present invention does not have to have all of these effects. Other effects will be apparent from the descriptions of the specification, the drawings, the claims, and the like and other effects can be derived from the descriptions of the specification, the drawings, the claims, and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A to FIG. **1**D are diagrams illustrating a structure of a light-emitting device of an embodiment.

FIG. **2**A to FIG. **2**D are diagrams illustrating a structure of a light-emitting device of an embodiment.

FIG. **3**A to FIG. **3**D are diagrams illustrating a structure of a light-emitting device of an embodiment.

FIG. **4**A to FIG. **4**C are diagrams each illustrating a structure of a light-emitting device of an embodiment.

FIG. **5**A to FIG. **5**F are diagrams illustrating structures of a light-emitting device of an embodiment.

FIG. **6**A and FIG. **6**B are diagrams illustrating a structure of a functional panel of an embodiment.

FIG. **7**A to FIG. **7**C are diagrams illustrating a structure of a functional panel of an embodiment.

FIG. **8** is a circuit diagram illustrating a structure of a functional panel of an embodiment.

FIG. **9** is a circuit diagram illustrating a structure of a functional panel of an embodiment.

FIG. **10** is a cross-sectional view illustrating a structure of a functional panel of an embodiment.

FIG. **11**A and FIG. **11**B are cross-sectional views illustrating a structure of a functional panel of an embodiment.

FIG. **12**A and FIG. **12**B are cross-sectional views illustrating a structure of a functional panel of an embodiment.

FIG. **13**A and FIG. **13**B are cross-sectional views illustrating a structure of a functional panel of an embodiment.

FIG. **14** is a diagram illustrating a structure of a functional panel of an embodiment.

FIG. **15**A and FIG. **15**B are circuit diagrams illustrating a structure of a functional panel of an embodiment.

FIG. **16** is a diagram showing an operation of a functional panel of an embodiment.

FIG. **17**A to FIG. **17**D are diagrams illustrating structures of a display device of an embodiment.

FIG. **18** is a block diagram illustrating a structure of an input/output device of an embodiment.

FIG. **19**A to FIG. **19**C are a block diagram and projection views each illustrating a structure of a data processing device of an embodiment.

FIG. **20**A and FIG. **20**B are flow charts showing a method for driving a data processing device of an embodiment.

FIG. **21**A to FIG. **21**C are diagrams showing a method for driving a data processing device of an embodiment.

FIG. **22**A to FIG. **22**C are diagrams showing a method for driving a data processing device of an embodiment.

FIG. **23**A to FIG. **23**E are diagrams illustrating structures of a data processing device of an embodiment.

FIG. **24**A to FIG. **24**E are diagrams illustrating structures of a data processing device of an embodiment.

FIG. **25**A and FIG. **25**B are diagrams illustrating structures of a data processing device of an embodiment.

MODE FOR CARRYING OUT THE INVENTION

A light-emitting device of one embodiment of the present invention includes an insulating film, a group of structure bodies, a layer containing a light-emitting material, a first electrode, and a second electrode. The insulating film includes a first surface, the group of structure bodies includes a structure body and a different structure body, a first distance is provided between the different structure body and the structure body, the structure body includes a sidewall, the sidewall forms a first angle with the first surface, and the first angle is greater than 0 and less than or equal to 90°. The layer containing a light-emitting material includes a first region and a second region, the first region is interposed between the second electrode and the first electrode, light is emitted from the first region, the second region is interposed between the second electrode and the sidewall, and the sidewall reflects light. The first electrode includes a third region, and the third region is interposed between the first region and the first surface.

Thus, in light emitted from the first region, components propagating along the layer containing a light-emitting material, for example, can be extracted efficiently. High luminance can be obtained with low electric energy. Thus, a novel light-emitting device that is highly convenient, useful, or reliable can be provided

Embodiments are described in detail with reference to the drawings. Note that the present invention is not limited to the following description, and it will be readily appreciated by those skilled in the art that modes and details of the present invention can be modified in various ways without departing from the spirit and scope of the present invention. Thus, the present invention should not be construed as being limited to the description in the following embodiments. Note that in structures of the invention described below, the same portions or portions having similar functions are denoted by the same reference numerals in different drawings, and a description thereof is not repeated.

Embodiment 1

In this embodiment, structures of a functional panel of one embodiment of the present invention will be described with reference to FIG. **1** to FIG. **4**.

FIG. **1** illustrates a structure of a light-emitting device of one embodiment of the present invention. FIG. **1**A is a perspective view of the light-emitting device of one embodiment of the present invention, and FIG. **1**B is a top view of the light-emitting device of one embodiment of the present invention. FIG. **1**C is a cross-sectional view taken along a cutting line A**1**-A**2** in FIG. **1**B, and FIG. **1**D is atop view.

FIG. **2** illustrates a structure of a light-emitting device of one embodiment of the present invention. FIG. **2**A is a perspective view of the light-emitting device of one embodiment of the present invention, and FIG. **2**B is a top view of the light-emitting device of one embodiment of the present invention. FIG. **2**C is a cross-sectional view taken along a cutting line A**1**-A**2** in FIG. **2**B, and FIG. **2**D is a top view.

FIG. **3** illustrates a structure of a light-emitting device of one embodiment of the present invention. FIG. **3**A is a perspective view of the light-emitting device of one embodiment of the present invention, and FIG. **3**B is a top view of the light-emitting device of one embodiment of the present invention. FIG. **3**C is a cross-sectional view taken along a cutting line A**1**-A**2** in FIG. **3**B, and FIG. **3**D is a top view.

FIG. **4** illustrates structures of the light-emitting devices of one embodiment of the present invention. FIG. **4**A is a cross-sectional view illustrating part of the light-emitting device of one embodiment of the present invention illustrated in FIG. **1**C, FIG. **4**B is a cross-sectional view illustrating part of the light-emitting device of one embodiment of the present invention illustrated in FIG. **2**C, and FIG. **4**C is a cross-sectional view illustrating part of the light-emitting device of one embodiment of the present invention illustrated in FIG. **3**C.

Note that in this specification, an integer variable of 1 or more is sometimes used in reference numerals. For example, (p) where p is an integer variable of 1 or more is sometimes used in part of a reference numeral that specifies any of p components at a maximum. As another example, (m,n) where m and n are each an integer variable of 1 or more is sometimes used in part of a reference numeral that specifies any of m×n components at a maximum.

Structure Example 1 of Light-Emitting Device **550**G(i,j)

A light-emitting device **550**G(i,j) described in this embodiment includes an insulating film **521**B, a structure body SR(p), a layer **553**G(j) containing a light-emitting material, an electrode **551**G(i,j), and an electrode **552** (see FIG. **1**C). Note that the insulating film **521**B includes a surface **521**(**1**). Note that in this specification, a light-emitting element can be referred to as a light-emitting device, and a photoelectric conversion element can be referred to as a photoelectric conversion device.

Structure Example 1 of Structure Body SR(p)

The structure body SR(p) includes a sidewall SW. The sidewall SW forms an angle θ**1** with the surface **521**(**1**), and the angle θ**1** is greater than 0 and less than or equal to 90°.

For example, a frustum shape can be used for the structure body SR(p) (see FIG. **1**A). Alternatively, a shape in which the angle θ**1** continuously changes can be used for the structure body SR(p) (see FIG. **4**A). Specifically, a shape with an S-shaped cross-section can be used for the structure body SR(p). In this case, a short circuit between the electrode **552** and the electrode **551**G(i,j) in the vicinity of a bottom surface of the structure body SR(p) can be prevented.

The structure body SR(p) includes a region interposed between the layer **553**G(j) containing a light-emitting material and the electrode **551**G(i,j).

A material having high reflectance with respect to light PH**1** can be used for the structure body SR(p).

Structure Example 1 of Layer **553**G(j) Containing Light-Emitting Material

The layer **553**G(j) containing a light-emitting material includes a region **553**G(j)(**1**) and a region **553**G(j)(**2**) (see FIG. **1**C).

The region **553**G(j)(**1**) is interposed between the electrode **552** and the electrode **551**G(i,j), and the region **553**G(j)(**1**) emits the light PH**1**.

The region **553**G(j)(**2**) is interposed between the electrode **552** and the sidewall SW, and the sidewall SW reflects the light PH**1**.

Structure Example 1 of Electrode **551**G(i,j)

The electrode **551**G(i,j) includes a region **551**G(i,j)(**1**). The region **551**G(i,j)(**1**) is interposed between the region **553**G(j)(**1**) and the surface **521**(**1**).

Thus, in light emitted from the region **553**G(j)(**1**), components propagating along the layer **553**G(j) containing a light-emitting material, for example, can be extracted efficiently. High luminance can be obtained with low electric energy. Thus, a novel light-emitting device that is highly convenient, useful, or reliable can be provided.

Structure Example 2 of Light-Emitting Device **550**G(i,j)

The light-emitting device **550**G(i,j) described in this embodiment includes a reflective film REF(i,j) (see FIG. **2**C).

The reflective film REF(i,j) includes a region REF(i,j)(**1**). The sidewall SW is interposed between the region REF(i,j)(**1**) and the layer **553**G(j) containing a light-emitting material, and the light PH**1** is reflected in the region REF(i,j)(**1**).

A conductive film having a light transmitting property can be used for the electrode **551**G(i,j), and a metal film can be used as the reflective film REF(i,j), for example. Thus, the optical path length can be adjusted using the thickness of the electrode **551**G(i,j). The reflective film REF(i,j) can be used as an auxiliary wiring. A metal film may be used as the electrode **551**G(i,j) to give the function of the reflective film REF(i,j) to the electrode **551**G(i,j).

A structure may be employed in which the reflective film REF(i,j) is interposed between the electrode **551**G(i,j) and the insulating film **521**B. For example, REF(i,j) includes a region interposed between the region **551**G(i,j)(**1**) and the surface **521**(**1**) (see FIG. **2**C).

Structure Example 2 of Structure Body SR(p)

The shape of the structure body SR(p) can be controlled using a stacked-layer structure, for example. Specifically, the shape of the structure body SR(p) can be controlled using a stacked-layer structure of an insulating film **521**C, the reflective film REF(i,j), and the electrode **551**G(i,j) that are formed to have a frustum shape (see FIG. **4**B). A shape in which the angle θ**1** continuously changes can be used for the structure body SR(p). Specifically, a shape with an S-shaped cross-section can be used for the structure body SR(p). In this case, a short circuit between the electrode **552** and the electrode **551**G(i,j) in the vicinity of the bottom surface of the structure body SR(p) can be prevented.

Thus, not only components of light at the surface of the structure body SR(p) but also those passing through the structure body SR(p) can be reflected. Thus, a novel light-emitting device that is highly convenient, useful, or reliable can be provided.

Structure Example 3 of Light-Emitting Device 550G(i,j)

The light-emitting device **550**G(i,j) described in this embodiment includes the insulating film **521**B, the structure body SR(p), the layer **553**G(j) containing a light-emitting material, the electrode **551**G(i,j), and the electrode **552** (see FIG. **3**C). Note that the insulating film **521**B includes the surface **521**(**1**).

Structure Example 3 of Structure Body SR(p)

The structure body SR(p) includes the sidewall SW. The sidewall SW forms the angle θ**1** with the surface **521**(**1**), and the angle θ**1** is greater than 0 and less than or equal to 90°.

For example, a frustum shape can be used for the structure body SR(p) (see FIG. **3**A). Alternatively, a shape in which the angle θ**1** continuously changes can be used for the structure body SR(p) (see FIG. **4**C). Specifically, a shape with an S-shaped cross-section can be used for the structure body SR(p). In this case, a short circuit between the electrode **552** and the electrode **551**G(i,j) in the vicinity of the bottom surface of the structure body SR(p) can be prevented.

The structure body SR(p) includes a region interposed between the electrode **551**G(i,j) and the insulating film **521**B.

Structure Example 2 of Layer 553G(j) Containing Light-Emitting Material

The layer **553**G(j) containing a light-emitting material includes the region **553**G(j)(**1**). The region **553**G(j)(**1**) is interposed between the electrode **552** and the electrode **551**G(i,j), and the light PH**1** is emitted from the region **553**G(j)(**1**).

Structure Example 2 of Electrode 551G(i,j)

The electrode **551**G(i,j) includes the region **551**G(i,j)(**1**) and a region **551**G(i,j)(**2**).

The region **551**G(i,j)(**1**) is interposed between the region **553**G(j)(**1**) and the surface **521**(**1**).

The region **551**G(i,j)(**2**) is interposed between the sidewall SW and the layer **553**G(j) containing a light-emitting material. The light PH**1** is emitted from the region **551**G(i,j)(**2**).

Thus, in light emitted from the region **553**G(j)(**1**), components propagating along the layer **553**G(j) containing a light-emitting material, for example, can be extracted efficiently. High luminance can be obtained with low electric energy. Thus, a novel light-emitting device that is highly convenient, useful, or reliable can be provided.

Structure Example 4 of Structure Body SR(p)

The structure body SR(p) has a height H from the insulating film **521**B (see FIG. **1**C, FIG. **2**C, and FIG. **3**C). The structure body SR(p) has a projection area S with respect to the insulating film **521**B (see FIG. **1**D, FIG. **2**D, and FIG. **3**D).

The height H is greater than or equal to 0.1 μm and less than or equal to 5 μm, preferably greater than or equal to 1.5 μm and less than or equal to 3 μm, and the projection area is larger than or equal to 0.01 μm^2 and smaller than or equal to 100 μm^2, preferably larger than or equal to 3 μm^2 and smaller than or equal to 9 μm^2.

For the structure body SR(p), a shape with which a circular or polygonal shape is projected on the insulating film **521**B can be used.

Structure Example 4 of Light-Emitting Device 550G(i,j)

The light-emitting device **550**G(i,j) described in this embodiment includes a group of structure bodies (see FIG. **1**B, FIG. **2**B, and FIG. **3**B). The group of structure bodies can be arranged in a staggered manner, for example.

The group of structure bodies includes the structure body SR(p) and a different structure body SR(p+1). A distance D**1** is provided between the different structure body SR(p+1) and the structure body SR(p). The distance D**1** is greater than or equal to 0.1 μm and less than or equal to 5 μm, preferably greater than or equal to 0.1 μm and less than or equal to 2.5 μm. The distance D**1** is an interval between an outer surface of the structure body SR(p) and an outer surface of the different structure body SR(p+1).

Thus, in light emitted from the region **553**G(j)(**1**), components propagating along the layer **553**G(j) containing a light-emitting material, for example, can be extracted efficiently at a plurality of portions. Thus, a novel light-emitting device that is highly convenient, useful, or reliable can be provided.

Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 2

In this embodiment, structures of a functional panel of one embodiment of the present invention will be described with reference to FIG. **5**.

FIG. **5** illustrates structures of the functional panel of one embodiment of the present invention. FIG. **5**A is a cross-sectional view illustrating part of a pixel **702**G(i,j) in the functional panel of one embodiment of the present invention, FIG. **5**B is a plan view illustrating components of the part of the pixel, and FIG. **5**C is a plan view illustrating components of the part of the pixel having a structure different from that of FIG. **5**B. FIG. **5**D is a cross-sectional view taken along a cutting line X**21**-X**22** in FIG. **5**B, FIG. **5**E is a cross-sectional view taken along a cutting line Y**21**-Y**22** in FIG. **5**B, and FIG. **5**F is a cross-sectional view taken along a cutting line XY**1**-XY**2** in FIG. **5**C.

Structure Example 1 of Functional Panel **700**

The functional panel described in this embodiment includes the pixel **702**G(i,j).

Structure Example 1 of Pixel **702**G(i,j)

The pixel **702**G(i,j) includes a microlens array MLA and the light-emitting device **550**G(i,j) (see FIG. **5**A).

The light-emitting device **550**G(i,j) emits the light PH**1**. The light-emitting device **550**G(i,j) described in Embodiment 1 can be used, for example.

Structure Example 1 of Microlens Array MLA

The microlens array MLA condenses the light PH**1**. The microlens array MLA includes a plurality of microlenses ML (see FIG. **5**B).

The microlenses ML has a cross-sectional shape that allows arrangement with a filling rate higher than that of a circle on a plane (e.g., a plane XY) parallel to the light-emitting device **550**G(i,j).

The microlens ML has a curved surface on a plane orthogonal to the plane XY (e.g., a plane XZ or a plane YZ) (see FIG. **5**D to FIG. **5**F). The convex side of the curved surface faces the light-emitting device **550**G(i,j) (see FIG. **5**A). For example, a spherical surface or an aspherical surface can be used as the curved surface. In the case where a sealant **705**, for example, is provided between the microlens ML and the light-emitting device **550**G(i,j), the microlens ML has a refractive index different from that of the sealant **705**. Specifically, a material having a higher refractive index than the sealant **705** can be used for the microlens.

Accordingly, the thickness of the microlens ML can be made small compared with a structure in which one microlens is used to condense light, without a reduction in the light-receiving area. The microlenses ML can be placed close to the light-emitting device **550**G(i,j). The thickness of the functional panel can be made small. A plurality of microlenses can be arranged densely. The area can be effectively utilized. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Structure Example 2 of Pixel **702**G(i,j)

The pixel **702**G(i,j) includes the microlens ML and the light-emitting device **550**G(i,j).

The light-emitting device **550**G(i,j) emits the light PH**1**.

Structure Example 1 of Microlens ML

The microlens ML collects the light PH**1**, and the convex portion of the microlens ML faces the light-emitting device **550**G(i,j). The microlens ML is a Fresnel lens.

Accordingly, the thickness of the microlens ML can be made small compared with a structure in which one microlens is used to condense light, without a reduction in the light-receiving area. The microlenses ML can be placed closer to the light-emitting device **550**G(i,j). The thickness of the functional panel can be made small. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Structure Example 3 of Pixel **702**G(i,j)

The pixel **702**G(i,j) includes a color conversion layer CC(G) (see FIG. **5**A).

The microlens ML is interposed between the light-emitting device **550**G(i,j) and the color conversion layer CC(G), and the microlens ML condenses the light PH**1** on the color conversion layer CC(G).

Structure Example 1 of Color Conversion Layer CC(G)

The color conversion layer CC(G) converts the light PH**1** into light PH**2**, and the intensity of long-wavelength light in a spectrum of the light PH**2** is higher than that in a spectrum of the light PH**1**.

For example, a material that emits light with a wavelength longer than a wavelength of incident light can be used for the color conversion layer CC(G). For example, a material that absorbs blue light or ultraviolet rays, converts it into green light, and emits the green light, a material that absorbs blue light or ultraviolet rays, converts it into red light, and emits the red light, or a material that absorbs ultraviolet rays, converts it into blue light, and emits the blue light can be used for the color conversion layer. Specifically, a quantum dot with a diameter of several nanometers can be used for the color conversion layer. Thus, light having a spectrum with a narrow half width can be emitted. Light with high saturation can be emitted.

Accordingly, the light PH**1** emitted from the light-emitting device **550**G(i,j) can be condensed on the color conversion layer CC(G). The light PH**1** emitted from the light-emitting device **550**G(i,j) can be condensed and then converted into the light PH**2**. The light PH**1** emitted from the light-emitting device **550**G(i,j) can be efficiently condensed because of its higher directivity than that of light emitted through the color conversion layer CC(G). The light PH**1** emitted from the light-emitting device **550**G(i,j) can be used more efficiently than in the case of condensing light emitted through the color conversion layer CC(G). Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Structure Example 2 of Functional Panel **700**

The functional panel described in this embodiment includes an insulating film **528**.

<<Insulating Film **528**>>

The insulating film **528** has an opening portion, and the opening portion overlaps with the light-emitting device **550**G(i,j) (see FIG. **5**A). Note that the insulating film **528** has a function of separating a plurality of adjacent pixels and thus can be referred to as a bank.

Structure Example of Structure Body SR(p)

A material having high reflectance with respect to the light PH**1** can be used for the structure body SR(p).

Accordingly, the light PH**1** emitted from the light-emitting device **550**G(i,j) can be condensed on the microlens ML. The light PH**1** emitted from the light-emitting device **550**G(i,j) can be effectively used. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Structure Example 2 of Color Conversion Layer CC(G)

The color conversion layer CC(G) includes quantum dots and a light-transmitting resin. For example, the quantum dots can be covered with a film that has a light-transmitting property and is less likely to generate or transmit a gas. Alternatively, a resin polymerized with quantum dots can be used. Alternatively, a photosensitive polymer that covers quantum dots can be used. With the use of a photosensitive polymer, a fine color conversion layer CC(G) can be formed.

Thus, the spectral width of the light PH**2** can be narrowed. Light with a narrow half width of a spectrum can be used. A color with high saturation can be displayed. Aggregation of quantum dots can be prevented. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Structure Example 3 of Functional Panel **700**

The functional panel of one embodiment of the present invention includes a light-blocking layer BM. In addition, a coloring layer CF(G) is included.

<<Light-Blocking Layer BM>>

The light-blocking layer BM has an opening portion, and the opening portion overlaps with the light-emitting device **550**G(i,j).

<<Coloring Layer CF(G)>>

The transmittance of the coloring layer CF(G) with respect to the light PH**1** is lower than the transmittance with respect to the light PH**2**.

Accordingly, the amount of external light that reaches the color conversion layer CC(G) can be reduced. Unintentional conversion of external light by the color conversion layer CC(G) can be inhibited. A reduction in contrast due to external light can be inhibited. The display quality can be improved. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 3

In this embodiment, structures of a functional panel of one embodiment of the present invention will be described with reference to FIG. **6** to FIG. **9**.

FIG. **6** illustrates a structure of the functional panel of one embodiment of the present invention. FIG. **6**A is a top view illustrating the structure of the functional panel of one embodiment of the present invention, and FIG. **6**B is a diagram illustrating part of FIG. **6**A.

FIG. **7**A is a diagram illustrating part of FIG. **6**A, FIG. **7**B is a diagram illustrating part of FIG. **7**A, and FIG. **7**C is a diagram illustrating another part of FIG. **7**A.

FIG. **8** is a diagram illustrating a structure of the functional panel of one embodiment of the present invention. FIG. **8** is a circuit diagram illustrating a structure example of a pixel circuit.

FIG. **9** is a diagram illustrating a structure of the functional panel of one embodiment of the present invention. FIG. **9** is a circuit diagram illustrating a structure of a pixel circuit.

Structure Example 1 of Functional Panel **700**

The functional panel **700** includes a set of pixels **703**(*i,j*) (see FIG. **6**A).

Structure Example 1 of Pixel **703**(*i,j*)

The set of pixels **703**(*i,j*) includes the pixel **702**G(i,j) (see FIG. **6**B). The pixel **702**G(i,j) includes a pixel circuit **530**G(i,j) and the light-emitting device **550**G(i,j), and the light-emitting device **550**G(i,j) is electrically connected to the pixel circuit **530**G(i,j) (see FIG. **7**A). The light-emitting device **550**G(i,j) described in Embodiment 1 can be used, for example.

Structure Example 1 of Pixel Circuit **530**G(i,j)

The pixel circuit **530**G(i,j) includes a switch SW**21**, a switch SW**22**, a transistor M**21**, a capacitor C**21**, and a node N**21** (see FIG. **8**).

The transistor M**21** includes a gate electrode electrically connected to the node N**21**, a first electrode electrically connected to the light-emitting device **550**G(i,j), and a second electrode electrically connected to a conductive film ANO.

The switch SW**21** includes a first terminal electrically connected to the node N**21** and a second terminal electrically connected to a conductive film S**1***g*(*j*), and has a function of controlling the conduction state or the non-conduction state on the basis of a potential of a conductive film G**1**(*i*).

The switch SW**22** includes a first terminal electrically connected to a conductive film S**2***g*(*j*), and has a function of controlling the conduction state or the non-conduction state on the basis of a potential of a conductive film G**2**(*i*).

The capacitor C**21** includes a conductive film electrically connected to the node N**21** and a conductive film electrically connected to a second electrode of the switch SW**22**.

Thus, an image signal can be stored in the node N**21**. A potential of the node N**21** can be changed using the switch SW**22**. The intensity of light emitted from the light-emitting device **550**G(i,j) can be controlled with the potential of the node N**21**. Thus, a novel functional panel that is highly convenient or reliable can be provided.

Structure Example 1 of Light-Emitting Device **550**G(i,j)

For example, an organic electroluminescence element, an inorganic electroluminescence element, a light-emitting diode, a QDLED (Quantum Dot LED), or the like can be used as the light-emitting device **550**G(i,j).

Structure Example 2 of Pixel **703**(*i,j*)

The pixel **70301**) includes a pixel **702**S(i,j) (see FIG. **6**B). The pixel **702**S(i,j) includes a pixel circuit **530**S(i,j) and a photoelectric conversion element PD(i,j), and the photoelectric conversion element PD(i,j) is electrically connected to the pixel circuit **530**S(i,j) (see FIG. **7**A).

Structure Example 1 of Pixel Circuit **530**S(i,j)

The pixel circuit **530**S(i,j) includes a switch SW**31**, a switch SW**32**, a switch SW**33**, a transistor M**31**, a capacitor C**31**, and a node FD) (see FIG. **9**A).

The switch SW**31** includes a first terminal electrically connected to the photoelectric conversion element PD(i,j) and a second terminal electrically connected to the node FD, and has a function of controlling the conduction state or the non-conduction state on the basis of a potential of a conductive film TX(i).

The switch SW**32** includes a first terminal electrically connected to the node FD and a second terminal electrically connected to a conductive film VR, and has a function of controlling the conduction state or the non-conduction state on the basis of a potential of a conductive film RS(i).

The capacitor C**31** includes a conductive film electrically connected to the node FD and a conductive film electrically connected to a conductive film VCP.

The transistor M**31** includes a gate electrode electrically connected to the node FD and a first electrode electrically connected to a conductive film VPI.

The switch SW**33** includes a first terminal electrically connected to a second electrode of the transistor M**31** and a second terminal electrically connected to a conductive film WX(j), and has a function of controlling the conduction state or the non-conduction state on the basis of a potential of a conductive film SE(i).

Thus, an imaging signal generated by the photoelectric conversion element PD(i,j) can be transferred to the node FD using the switch SW**31**. The imaging signal generated by the photoelectric conversion element PD(i,j) can be stored in the node FD using the switch SW**31**. Electrical continuity between the pixel circuit **530**S(i,j) and the photoelectric conversion element PD(i,j) can be broken by the switch SW**31**. A correlated double sampling method can be used. Noise included in the imaging signal can be reduced. Thus, a novel functional panel that is highly convenient or reliable can be provided.

Structure Example 1 of Photoelectric Conversion Element PD(i,j)

For example, a heterojunction photoelectric conversion element, a bulk heterojunction photoelectric conversion element, or the like can be used as the photoelectric conversion element PD(i,j).

Structure Example 3 of Pixel **703**(*i,j*)

A plurality of pixels can be used in the pixel **703**(*i,j*). For example, a plurality of pixels capable of displaying colors with different hues can be used. Note that a plurality of pixels can be referred to as subpixels. A set of subpixels can be rephrased as a pixel.

This enables additive mixture or subtractive mixture of colors displayed by the plurality of pixels. It is possible to display a color of a hue that an individual pixel cannot display.

Specifically, a pixel **702**B(i,j) displaying blue, the pixel **702**G(i,j) displaying green, and a pixel **702**R(i,j) displaying red can be used in the pixel **703**(*i,j*). The pixel **702**B(i,j), the pixel **702**G(i,j), and the pixel **702**R(i,j) can each be referred to as a subpixel (see FIG. **6**B).

A pixel displaying white or the like can be used in addition to the above set in the pixel **703**(*i,j*), for example. A pixel displaying cyan, a pixel displaying magenta, and a pixel displaying yellow can be used in the pixel **703**(*i,j*).

A pixel emitting infrared rays can be used in addition to the above set in the pixel **703**(*i,j*), for example. Specifically, a pixel that emits light including light with a wavelength of greater than or equal to 650 nm and less than or equal to 1000 nm can be used in the pixel **703**(*i,j*).

Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 4

In this embodiment, structures of a functional panel of one embodiment of the present invention will be described with reference to FIG. **10** to FIG. **13**.

FIG. **10** is a diagram illustrating the structure of the functional panel of one embodiment of the present invention. FIG. **10** is a cross-sectional view taken along cutting lines X**1**-X**2**, X**3**-X**4**, X**9**-X**10**, and X**11**-X**12** in FIG. **6**A and in a pixel.

FIG. **11** illustrates the structure of the functional panel of one embodiment of the present invention. FIG. **11**A is a cross-sectional view of the pixel **702**G(i,j) illustrated in FIG. **6**B, and FIG. **11**B is a cross-sectional view illustrating part of FIG. **11**A.

FIG. **12** illustrates the structure of the functional panel of one embodiment of the present invention. FIG. **12**A is a cross-sectional view of the pixel **702**S(i,j) illustrated in FIG. **6**B, and FIG. **12**B is a cross-sectional view illustrating part of FIG. **12**A.

FIG. **13** illustrates the structure of the functional panel of one embodiment of the present invention. FIG. **13**A is a cross-sectional view taken along the cutting line X**1**-X**2** and the cutting line X**3**-X**4** in FIG. **6**A, and FIG. **13**B is a diagram illustrating part of FIG. **13**A.

Structure Example 1 of Functional Panel **700**

The functional panel of one embodiment of the present invention includes a functional layer **520** (see FIG. **10**).

Structure Example 1 of Functional Layer **520**

The functional layer **520** includes the pixel circuit **530**G(i,j) (see FIG. **10**). The functional layer **520** includes, for example, the transistor M**21** used in the pixel circuit **530**G(i,j) (see FIG. **8** and FIG. **11**A).

The functional layer **520** has an opening portion **591**G. The pixel circuit **530**G(i,j) is electrically connected to the light-emitting device **550**G(i,j) through the opening portion **591**G (see FIG. **10** and FIG. **11**). The functional layer **520** has an opening portion **591**B.

Structure Example 2 of Functional Layer **520**

The functional layer **520** includes the pixel circuit **530**S(i,j) (see FIG. **10**). The functional layer **520** includes a transistor used as the switch SW**31** in the pixel circuit **530**S(i,j) (see FIG. **10** and FIG. **12**A). The transistor includes a semiconductor film **508**, a conductive film **504**, a conductive film **512**E, and a conductive film **512**F.

The functional layer **520** has an opening portion **591**S, and the pixel circuit **530**S(i,j) is electrically connected to the photoelectric conversion element PD(i,j) through the opening portion **591**S (see FIG. **10** and FIG. **12**A).

Thus, the pixel circuit **530**G(i,j) can be formed in the functional layer **520**. The pixel circuit **530**S(i,j) can be formed in the functional layer **520**. The semiconductor film used in the pixel circuit **530**S(i,j) can be formed in a step of forming a semiconductor film used in the pixel circuit **530**G(i,j), for example. The manufacturing process of the functional panel can be simplified. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Structure Example 3 of Functional Layer **520**

The functional layer **520** includes a driver circuit GD (see FIG. **6**A and FIG. **10**). The functional layer **520** includes, for example, a transistor MD used in the driver circuit GD (see FIG. **10** and FIG. **13**A). The transistor MD includes the semiconductor film **508**, the conductive film **504**, a conductive film **512**C, and a conductive film **512**D.

The functional layer **520** includes a driver circuit RD and a read circuit RC (see FIG. **10**).

Thus, the semiconductor film used in the driver circuit GD can be formed in the step of forming the semiconductor film used in the pixel circuit **530**G(i,j). Semiconductor films used in the driver circuit RD and the reading circuit RC can be formed in the step of forming the semiconductor film used in the pixel circuit **530**G(i,j). The manufacturing process of the functional panel can be simplified. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Structure Example of Transistor

A bottom-gate transistor, a top-gate transistor, or the like can be used in the functional layer **520**. Specifically, a transistor can be used as a switch.

The transistor includes the semiconductor film **508**, the conductive film **504**, a conductive film **512**A, and a conductive film **512**B (see FIG. **11**B).

The semiconductor film **508** includes a region **508**A electrically connected to the conductive film **512**A and a region **508**B electrically connected to the conductive film **512**B. The semiconductor film **508** includes a region **508**C between the region **508**A and the region **508**B.

The conductive film **504** includes a region overlapping with the region **508**C, and the conductive film **504** has a function of a gate electrode.

An insulating film **506** includes a region interposed between the semiconductor film **508** and the conductive film **504**. The insulating film **506** has a function of a gate insulating film.

The conductive film **512**A has one of a function of a source electrode and a function of a drain electrode, and the conductive film **512**B has the other of the function of the source electrode and the function of the drain electrode.

A conductive film **524** can be used for the transistor. The semiconductor film **508** is interposed between a region of the conductive film **524** and the conductive film **504**. The conductive film **524** has a function of a second gate electrode.

Note that the semiconductor film used in the transistor of the driver circuit can be formed in the step of forming the semiconductor film used in the transistor of the pixel circuit.

Structure Example 1 of Semiconductor Film **508**

A semiconductor containing a Group 14 element can be used for the semiconductor film **508**, for example. Specifically, a semiconductor containing silicon can be used for the semiconductor film **508**.

[Hydrogenated Amorphous Silicon]

For example, hydrogenated amorphous silicon can be used for the semiconductor film **508**. Alternatively, microcrystalline silicon or the like can be used for the semiconductor film **508**. Thus, a functional panel having less display unevenness than a functional panel using polysilicon for the semiconductor film **508**, for example, can be provided. The size of the functional panel can be easily increased.

[Polysilicon]

For example, polysilicon can be used for the semiconductor film **508**. In this case, the field-effect mobility of the transistor can be higher than that of a transistor using hydrogenated amorphous silicon for the semiconductor film **508**, for example. The driving capability can be higher than that of a transistor using hydrogenated amorphous silicon for the semiconductor film **508**, for example. The aperture ratio of the pixel can be higher than that in the case of using a transistor that uses hydrogenated amorphous silicon for the semiconductor film **508**, for example.

The reliability of the transistor can be higher than that of a transistor using hydrogenated amorphous silicon for the semiconductor film **508**, for example.

The temperature required for fabrication of the transistor can be lower than that required for a transistor using single crystal silicon, for example.

The semiconductor film used in the transistor of the driver circuit can be formed in the same step as the semiconductor film used in the transistor of the pixel circuit. The driver circuit can be formed over the same substrate where the pixel circuit is formed. The number of components included in an electronic device can be reduced.

[Single Crystal Silicon]

For example, single crystal silicon can be used for the semiconductor film **508**. In this case, a functional panel with higher resolution than a functional panel using hydrogenated amorphous silicon for the semiconductor film **508**, for example, can be provided. A functional panel having less display unevenness than a functional panel using polysilicon for the semiconductor film **508**, for example, can be provided. Smart glasses or a head-mounted display can be provided, for example.

Structure Example 2 of Semiconductor Film **508**

For example, a metal oxide can be used for the semiconductor film **508**. In this case, the pixel circuit can hold an image signal for a longer time than a pixel circuit utilizing a transistor using amorphous silicon for a semiconductor film. Specifically, a selection signal can be supplied at a frequency of lower than 30 Hz, preferably lower than 1 Hz, further preferably less than once per minute with the suppressed occurrence of flickers. Consequently, fatigue accumulation in a user of a data processing device can be reduced. Moreover, power consumption for driving can be reduced.

The pixel circuit can hold the imaging signal for a longer time than a pixel circuit utilizing a transistor using amorphous silicon for a semiconductor film. Specifically, a second selection signal can be supplied at a frequency lower than 30 Hz, preferably lower than 1 Hz, further preferably less than once per minute. Accordingly, an image can be taken by a global shutter method. An image of a moving object can be taken while distortion is inhibited.

A transistor using an oxide semiconductor can be used, for example. Specifically, an oxide semiconductor containing indium or an oxide semiconductor containing indium, gallium, and zinc can be used for the semiconductor film.

A transistor having a lower leakage current in an off state than a transistor using amorphous silicon for a semiconductor film can be used, for example. Specifically, a transistor using an oxide semiconductor for a semiconductor film can be used as a switch or the like. In that case, a potential of a floating node can be held for a longer time than in a circuit in which a transistor using amorphous silicon is used as a switch.

A 25-nm-thick film containing indium, gallium, and zinc can be used as the semiconductor film **508**, for example.

A conductive film in which a 10-nm-thick film containing tantalum and nitrogen and a 300-nm-thick film containing copper are stacked can be used as the conductive film **504**, for example. Note that the film containing tantalum and nitrogen is interposed between a region of the film containing copper and the insulating film **506**.

A stacked film in which a 400-nm-thick film containing silicon and nitrogen and a 200-nm-thick film containing silicon, oxygen, and nitrogen are stacked can be used as the insulating film **506**, for example. Note that the film containing silicon, oxygen, and nitrogen is interposed between a region of the film containing silicon and nitrogen and the semiconductor film **508**.

A conductive film in which a 50-nm-thick film containing tungsten, a 400-nm-thick film containing aluminum, and a 100-nm-thick film containing titanium are stacked in this order can be used as the conductive film **512**A or the conductive film **512**B, for example. Note that the film containing tungsten includes a region in contact with the semiconductor film **508**.

A manufacturing line for a bottom-gate transistor using amorphous silicon for a semiconductor can be easily remodeled into a manufacturing line for a bottom-gate transistor using an oxide semiconductor for a semiconductor, for example. Furthermore, a manufacturing line for a top-gate transistor using polysilicon for a semiconductor can be easily remodeled into a manufacturing line for a top-gate transistor using an oxide semiconductor for a semiconductor, for example. In either remodeling, an existing manufacturing line can be effectively utilized.

Accordingly, flickering of a display can be inhibited. Power consumption can be reduced. A moving image with quick movements can be smoothly displayed. A photograph and the like can be displayed with a wide range of grayscale. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Structure Example 3 of Semiconductor Film 508

For example, a compound semiconductor can be used for the semiconductor of the transistor. Specifically, a semiconductor containing gallium arsenide can be used.

For example, an organic semiconductor can be used for the semiconductor of the transistor. Specifically, an organic semiconductor containing any of polyacenes or graphene can be used for the semiconductor film.

Structure Example of Capacitor

A capacitor includes one conductive film, a different conductive film, and an insulating film. The insulating film includes a region interposed between the one conductive film and the different conductive film.

For example, a conductive film used as the source electrode or the drain electrode of the transistor, a conductive film used as the gate electrode, and an insulating film used as the gate insulating film can be used for the capacitor.

Structure Example 2 of Functional Layer 520

The functional layer **520** includes an insulating film **521**, an insulating film **518**, an insulating film **516**, the insulating film **506**, an insulating film **501**C, and the like (see FIG. **11**A and FIG. **11**B). The insulating film **521** includes an insulating film **521**A and the insulating film **521**B, and the insulating film **516** includes an insulating film **516**A and an insulating film **516**B.

The insulating film **521** includes a region interposed between the pixel circuit **530**G(i,j) and the light-emitting device **550**G(i,j).

The insulating film **518** includes a region interposed between the insulating film **521** and the insulating film **501**C.

The insulating film **516** includes a region interposed between the insulating film **518** and the insulating film **501**C.

The insulating film **506** includes a region interposed between the insulating film **516** and the insulating film **501**C.

[Insulating Film **521**]

An insulating inorganic material, an insulating organic material, or an insulating composite material containing an inorganic material and an organic material, for example, can be used for the insulating film **521**.

Specifically, an inorganic oxide film, an inorganic nitride film, an inorganic oxynitride film, or the like, or a stacked-layer material in which a plurality of films selected from these films are stacked can be used as the insulating film **521**.

For example, a film including a silicon oxide film, a silicon nitride film, a silicon oxynitride film, an aluminum oxide film, or the like, or a film including a stacked-layer material in which a plurality of films selected from these films are stacked can be used as the insulating film **521**. Note that the silicon nitride film is a dense film and has an excellent function of inhibiting diffusion of impurities.

For example, for the insulating film **521**, polyester, polyolefin, polyamide, polyimide, polycarbonate, polysiloxane, an acrylic resin, or the like, or a stacked-layer material, a composite material, or the like of a plurality of resins selected from these resins can be used. Note that polyimide is excellent in thermal stability, insulating property, toughness, low dielectric constant, low coefficient of thermal expansion, chemical resistance, and other properties compared with other organic materials. Accordingly, in particular, polyimide can be suitably used for the insulating film **521** or the like.

The insulating film **521** may be formed using a photosensitive material. Specifically, a film formed using photosensitive polyimide, a photosensitive acrylic resin, or the like can be used as the insulating film **521**.

Thus, the insulating film **521** can eliminate a level difference due to various components overlapping with the insulating film **521**, for example.

[Insulating Film **518**]

The material that can be used for the insulating film **521**, for example, can be used for the insulating film **518**.

For example, a material having a function of inhibiting diffusion of oxygen, hydrogen, water, an alkali metal, an alkaline earth metal, and the like can be used for the insulating film **518**. Specifically, a nitride insulating film can be used as the insulating film **518**. For example, silicon nitride, silicon nitride oxide, aluminum nitride, aluminum nitride oxide, or the like can be used for the insulating film **518**. Thus, diffusion of impurities into the semiconductor film of the transistor can be inhibited.

[Insulating Film **516**]

The material that can be used for the insulating film **521**, for example, can be used for the insulating film **516**.

Specifically, a film formed by a fabrication method different from that of the insulating film **518** can be used as the insulating film **516**.

[Insulating Film **506**]

The material that can be used for the insulating film **521**, for example, can be used for the insulating film **506**.

Specifically, a film including a silicon oxide film, a silicon oxynitride film, a silicon nitride oxide film, a silicon nitride film, an aluminum oxide film, a hafnium oxide film, an yttrium oxide film, a zirconium oxide film, a gallium oxide film, a tantalum oxide film, a magnesium oxide film, a lanthanum oxide film, a cerium oxide film, or a neodymium oxide film can be used as the insulating film **506**.

[Insulating Film **501**D]

An insulating film **501**D includes a region interposed between the insulating film **501**C and the insulating film **516**.

The material that can be used for the insulating film **506**, for example, can be used for the insulating film **501**D.

[Insulating Film **501**C]

The material that can be used for the insulating film **521**, for example, can be used for the insulating film **501**C. Specifically, a material containing silicon and oxygen can be used for the insulating film **501**C. Thus, diffusion of impurities into the pixel circuit, the light-emitting element, the photoelectric conversion element, or the like can be inhibited.

Structure Example 3 of Functional Layer **520**

The functional layer **520** includes a conductive film, a wiring, and a terminal. A material having conductivity can be used for the wiring, an electrode, the terminal, the conductive film, and the like.

[Wiring and the Like]

For example, an inorganic conductive material, an organic conductive material, a metal, a conductive ceramic, or the like can be used for the wiring and the like.

Specifically, a metal element selected from aluminum, gold, platinum, silver, copper, chromium, tantalum, titanium, molybdenum, tungsten, nickel, iron, cobalt, palladium, and manganese, or the like can be used for the wiring and the like. Alternatively, an alloy containing the above-described metal element, or the like can be used for the wiring and the like. In particular, an alloy of copper and manganese is suitable for microfabrication using a wet etching method.

Specifically, a two-layer structure in which a titanium film is stacked over an aluminum film, a two-layer structure in which a titanium film is stacked over a titanium nitride film, a two-layer structure in which a tungsten film is stacked over a titanium nitride film, a two-layer structure in which a tungsten film is stacked over a tantalum nitride film or a tungsten nitride film, a three-layer structure of a titanium film, an aluminum film stacked over the titanium film, and a titanium film further formed thereover, or the like can be used for the wiring and the like.

Specifically, a conductive oxide such as indium oxide, indium tin oxide, indium zinc oxide, zinc oxide, or zinc oxide to which gallium is added can be used for the wiring and the like.

Specifically, a film containing graphene or graphite can be used for the wiring and the like.

For example, a film containing graphene oxide is formed and the film containing graphene oxide is reduced, so that a film containing graphene can be formed. As a reducing method, a method with application of heat, a method using a reducing agent, or the like can be given.

For example, a film including a metal nanowire can be used for the wiring and the like. Specifically, a nanowire containing silver can be used.

Specifically, a conductive polymer can be used for the wiring and the like.

Note that a terminal **519**B can be electrically connected to a flexible printed circuit FPC**1** using a conductive material, for example (see FIG. **10**). Specifically, the terminal **519**B can be electrically connected to the flexible printed circuit FPC**1** using a conductive material CP.

Structure Example 2 of Functional Panel **700**

The functional panel **700** includes a base material **510**, a base material **770**, and the sealant **705** (see FIG. **11**A). In addition, the functional panel **700** includes a structure body KB.

<<Base Material **510** and Base Material **770**>>

A material having a light-transmitting property can be used for the base material **510** or the base material **770**.

For example, a flexible material can be used for the base material **510** or the base material **770**. Thus, a flexible functional panel can be provided.

For example, a material with a thickness less than or equal to 0.7 mm and greater than or equal to 0.1 mm can be used. Specifically, a material polished to a thickness of approximately 0.1 mm can be used. Thus, the weight can be reduced.

A glass substrate of the 6th generation (1500 mm×1850 mm), the 7th generation (1870 mm×2200 mm), the 8th generation (2200 mm×2400 mm), the 9th generation (2400 mm×2800 mm), the 10th generation (2950 mm×3400 mm), or the like can be used as the base material **510** or the base material **770**. Thus, a large-sized display device can be fabricated.

For the base material **510** or the base material **770**, an organic material, an inorganic material, a composite material of an organic material and an inorganic material, or the like can be used.

For example, an inorganic material such as glass, ceramic, or a metal can be used. Specifically, non-alkali glass, soda-lime glass, potash glass, crystal glass, aluminosilicate glass, tempered glass, chemically tempered glass, quartz, sapphire, or the like can be used for the base material **510** or the base material **770**. Aluminosilicate glass, tempered glass, chemically tempered glass, sapphire, or the like can be suitably used for the base material **510** or the base material **770** that is provided on the side close to a user of the functional panel. Thus, the functional panel can be prevented from being broken or damaged by the use thereof.

Specifically, an inorganic oxide film, an inorganic nitride film, an inorganic oxynitride film, or the like can be used. For example, a silicon oxide film, a silicon nitride film, a silicon oxynitride film, an aluminum oxide film, or the like can be used. Stainless steel, aluminum, or the like can be used for the base material **510** or the base material **770**.

For example, a single crystal semiconductor substrate or a polycrystalline semiconductor substrate of silicon or silicon carbide, a compound semiconductor substrate of silicon germanium or the like, an SOI substrate, or the like can be used as the base material **510** or the base material **770**. Thus, a semiconductor element can be formed on the base material **510** or the base material **770**.

For example, an organic material such as a resin, a resin film, or plastic can be used for the base material **510** or the base material **770**. Specifically, a material containing polyester, polyolefin, polyamide (e.g., nylon or aramid), polyimide, polycarbonate, polyurethane, an acrylic resin, an epoxy resin, or a resin having a siloxane bond, such as silicone, can be used for the base material **510** or the base material **770**. For example, a resin film, a resin plate, a stacked-layer material, or the like containing any of these materials can be used. Thus, the weight can be reduced. The frequency of occurrence of breakage or the like due to dropping can be reduced, for example.

Specifically, polyethylene terephthalate (PET), polyethylene naphthalate (PEN), polyethersulfone (PES), a cycloolefin polymer (COP), a cycloolefin copolymer (COC), or the like can be used for the base material **510** or the base material **770**.

For example, a composite material formed by attaching a metal plate, a thin glass plate, or a film of an inorganic material or the like and a resin film or the like to each other can be used for the base material **510** or the base material **770**. For example, a composite material formed by dispersing a fibrous or particulate metal, glass, an inorganic material, or the like into a resin can be used for the base material **510** or the base material **770**. For example, a composite material formed by dispersing a fibrous or particulate resin, an organic material, or the like into an inorganic material can be used for the base material **510** or the base material **770**.

Furthermore, a single-layer material or a material in which a plurality of layers are stacked can be used for the base material **510** or the base material **770**. For example, a material in which insulating films and the like are stacked can be used. Specifically, a material in which one or a plurality of films selected from a silicon oxide layer, a silicon nitride layer, a silicon oxynitride layer, and the like are stacked can be used. Thus, diffusion of impurities contained in the base materials can be prevented, for example. Diffusion of impurities contained in glass or a resin can be prevented. Diffusion of impurities that pass through a resin can be prevented.

Furthermore, paper, wood, or the like can be used for the base material **510** or the base material **770**.

For example, a material having heat resistance high enough to withstand heat treatment in the fabricating process can be used for the base material **510** or the base material **770**. Specifically, a material having heat resistance to heat applied in the formation process of directly forming the transistor, the capacitor, or the like can be used for the base material **510** or the base material **770**.

For example, a method in which an insulating film, a transistor, a capacitor, or the like is formed on a process substrate having heat resistance to heat applied in the fabricating process, and the formed insulating film, transistor, capacitor, or the like is transferred to the base material **510** or the base material **770** can be used. Accordingly, an insulating film, a transistor, a capacitor, or the like can be formed on a flexible substrate, for example.

<<Sealant **705**>>

The sealant **705** includes a region interposed between the functional layer **520** and the base material **770** and has a function of bonding the functional layer **520** and the base material **770** together (see FIG. **11**A).

An inorganic material, an organic material, a composite material of an inorganic material and an organic material, or the like can be used for the sealant **705**.

For example, an organic material such as a thermally fusible resin or a curable resin can be used for the sealant **705**.

For example, an organic material such as a reactive curable adhesive, a photocurable adhesive, a thermosetting adhesive, and/or an anaerobic adhesive can be used for the sealant **705**.

Specifically, an adhesive containing an epoxy resin, an acrylic resin, a silicone resin, a phenol resin, a polyimide resin, an imide resin, a PVC (polyvinyl chloride) resin, a PVB (polyvinyl butyral) resin, an EVA (ethylene vinyl acetate) resin, or the like can be used for the sealant **705**.

<<Structure Body KB>>

The structure body KB includes a region interposed between the functional layer **520** and the base material **770**. The structure body KB has a function of providing a predetermined space between the functional layer **520** and the base material **770**.

Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 5

In this embodiment, structures of a functional panel of one embodiment of the present invention will be described with reference to FIG. **11** to FIG. **13**.

Structure Example 1 of Functional Panel **700**

The functional panel **700** includes the light-emitting device **550**G(i,j) (see FIG. **11**). The light-emitting device **550**G(i,j) described in Embodiment 1 can be used, for example.

Structure Example 2 of Light-Emitting Device **550**G(i,j)

The electrode **551**G(i,j), the electrode **552**, and the layer **553**G(j) containing a light-emitting material can be used in the light-emitting device **550**G(i,j). The layer **553**G(i) containing a light-emitting material includes a region interposed between the electrode **551**G(i,j) and the electrode **552**.

Structure Example 1 of Layer **553**G(j) Containing Light-Emitting Material

A stacked-layer material can be used for the layer **553**G(j) containing a light-emitting material, for example.

For example, a material emitting blue light, a material emitting green light, a material emitting red light, a material emitting infrared rays, or a material emitting ultraviolet rays can be used for the layer **553**G(j) containing a light-emitting material.

Structure Example 2 of Layer **553**G(j) Containing Light-Emitting Material

A stacked-layer material stacked to emit white light can be used for the layer **553**G(j) containing a light-emitting material, for example.

Specifically, a plurality of materials emitting light with different hues can be used for the layer **553**G(j) containing a light-emitting material.

For example, a stacked-layer material in which a layer containing a light-emitting material containing a fluorescent material that emits blue light and a layer containing materials that are other than fluorescent materials and emit green light and red light are stacked can be used for the layer **553**G(j) containing a light-emitting material. A stacked-layer material in which a layer containing a light-emitting material containing a fluorescent material that emits blue light and a layer containing a material that is other than a fluorescent material and emits yellow light are stacked can be used for the layer **553**G(j) containing a light-emitting material.

Note that the layer **553**G(j) containing a light-emitting material can be used with a coloring layer CF overlapping, for example. Thus, light of a predetermined hue can be extracted from white light.

Structure Example 3 of Layer 553G(j) Containing Light-Emitting Material

A stacked-layer material stacked to emit blue light or ultraviolet rays can be used for the layer **553**G(j) containing a light-emitting material, for example. A color conversion layer CC can be used to overlap with the layer **553**G(j) containing a light-emitting material, for example.

Structure Example 4 of Layer 553G(j) Containing Light-Emitting Material

The layer **553**G(j) containing a light-emitting material includes a light-emitting unit. The light-emitting unit includes one region where electrons injected from one side are recombined with holes injected from the other side. The light-emitting unit contains a light-emitting material, and the light-emitting material releases energy generated by recombination of electrons and holes as light. Note that a hole-transport layer and an electron-transport layer can be used in the light-emitting unit. The hole-transport layer is placed closer to the positive electrode than the electron-transport layer is, and has higher hole mobility than the electron-transport layer.

A plurality of light-emitting units and an intermediate layer can be used for the layer **553**G(j) containing a light-emitting material, for example. The intermediate layer includes a region interposed between two light-emitting units. The intermediate layer includes a charge-generation region, and the intermediate layer has functions of supplying holes to the light-emitting unit placed on the cathode side and supplying electrons to the light-emitting unit placed on the anode side. Furthermore, a structure including a plurality of light-emitting units and an intermediate layer is referred to as a tandem light-emitting element in some cases.

Accordingly, the current efficiency of light emission can be increased. The density of current flowing through the light-emitting element at the same luminance can be reduced. The reliability of the light-emitting element can be increased.

For example, a light-emitting unit containing a material emitting light with one hue and a light-emitting unit containing a material emitting light with a different hue can be stacked and used for the layer **553**G(j) containing a light-emitting material. A light-emitting unit containing a material emitting light with one hue and a light-emitting unit containing a material emitting light with the same hue can be stacked and used for the layer **553**G(j) containing a light-emitting material. Specifically, two light-emitting units each containing a material emitting blue light can be stacked and used.

For the layer **553**G(j) containing a light-emitting material, a high molecular compound (e.g., an oligomer, a dendrimer, or a polymer), a middle molecular compound (a compound between a low molecular compound and a high molecular compound with a molecular weight greater than or equal to 400 and less than or equal to 4000), or the like can be used.

[Electrode **551**G(i,j) and Electrode **552**]

The material that can be used for the wiring or the like, for example, can be used for the electrode **551**G(i,j) or the electrode **552**. Specifically, a material having a visible-light-transmitting property can be used for the electrode **551**G(i,j) or the electrode **552**.

For example, a conductive oxide, a conductive oxide containing indium, indium oxide, indium tin oxide, indium zinc oxide, zinc oxide, zinc oxide to which gallium is added, or the like can be used. Alternatively, a metal film thin enough to transmit light can be used. Alternatively, a material having a visible-light-transmitting property can be used.

For example, a metal film that transmits part of light and reflects another part of the light can be used for the electrode **551**G(i,j) or the electrode **552**. The distance between the electrode **551**G(i,j) and the electrode **552** is adjusted using the layer **553**G(j) containing a light-emitting material, for example.

Thus, a microcavity structure can be provided in the light-emitting device **550**G(i,j). Light of a predetermined wavelength can be extracted more efficiently than other light. Light with a narrow half width of a spectrum can be extracted. Light of a bright color can be extracted.

A film that efficiently reflects light, for example, can be used for the electrode **551**G(i,j) or the electrode **552**. Specifically, a material containing silver, palladium, and the like or a material containing silver, copper, and the like can be used for the metal film.

The electrode **551**G(i,j) is electrically connected to the pixel circuit **530**G(i,j) through the opening portion **591**G (see FIG. **12**A). For example, the electrode **551**G(i,j) overlaps with the opening portion formed in the insulating film **528**, and the insulating film **528** is at the periphery of the electrode **551**G(i,j).

Thus, a short circuit between the electrode **551**G(i,j) and the electrode **552** can be prevented.

Structure Example 2 of Photoelectric Conversion Element PD(i,j)

The photoelectric conversion element PD(i,j) includes an electrode **551**S(i,j), the electrode **552**, and a layer **553**S(**1**) containing a photoelectric conversion material (see FIG. **12**A).

For example, a heterojunction photoelectric conversion element, a bulk heterojunction photoelectric conversion element, or the like can be used as the photoelectric conversion element PD(i,j).

Structure Example 1 of Layer 553S(j) Containing Photoelectric Conversion Material

For example, a stacked-layer film in which a p-type semiconductor film and an n-type semiconductor film are stacked in contact with each other can be used as the layer **553**S(j) containing a photoelectric conversion material. Note that the photoelectric conversion element PD(i,j) in which a stacked-layer film with such a structure is used as the layer **553**S(j) containing a photoelectric conversion material can be referred to as a PN photodiode.

For example, a stacked-layer film in which a p-type semiconductor film, an i-type semiconductor film, and an n-type semiconductor film are stacked such that the i-type semiconductor film is interposed between the p-type semiconductor film and the n-type semiconductor film can be used as the layer **553**S(j) containing a photoelectric conversion material. Note that the photoelectric conversion element PD(i,j) in which a stacked-layer film with such a structure is used as the layer **553**S(j) containing a photoelectric conversion material can be referred to as a PIN photodiode.

For example, a stacked-layer film in which a p+-type semiconductor film, a p−-type semiconductor film, a p-type semiconductor film, and an n-type semiconductor film are stacked such that the p−-type semiconductor film is interposed between the p+-type semiconductor film and the n-type semiconductor film and the p-type semiconductor film is interposed between the p−-type semiconductor film and the n-type semiconductor film can be used as the layer **553**S(j) containing a photoelectric conversion material. Note that the photoelectric conversion element PD(i,j) in which a stacked-layer film with such a structure is used as the layer **553**S(j) containing a photoelectric conversion material can be referred to as an avalanche photodiode.

Structure Example 2 of Layer **553**S(j) Containing Photoelectric Conversion Material

For example, a semiconductor containing a Group 14 element can be used for the layer **553**S(j) containing a photoelectric conversion material. Specifically, a semiconductor containing silicon can be used for the layer **553**S(j) containing a photoelectric conversion material. For example, hydrogenated amorphous silicon, microcrystalline silicon, polysilicon, single crystal silicon, or the like can be used for the layer **553**S(j) containing a photoelectric conversion material.

For example, an organic semiconductor can be used for the layer **553**S(j) containing a photoelectric conversion material. Specifically, part of the layer used as the layer **553**G(j) containing a light-emitting material can be used as part of the layer **553**S(j) containing a photoelectric conversion material.

Specifically, a hole-transport layer used in the layer **553**G(j) containing a light-emitting material can be used in the layer **553**S(j) containing a photoelectric conversion material. An electron-transport layer used in the layer **553**G(j) containing a light-emitting material can be used in the layer **553**S(**1**) containing a photoelectric conversion material. The hole-transport layer and the electron-transport layer can be used in the layer **553**S(j) containing a photoelectric conversion material. Thus, in a step of forming the hole-transport layer used in the layer **553**G(j) containing a light-emitting material, the hole-transport layer used in the layer **553**S(j) containing a photoelectric conversion material can be formed. In a step of forming the electron-transport layer used in the layer **553**G(j) containing a light-emitting material, the electron-transport layer used in the layer **553**S(j) containing a photoelectric conversion material can be formed. The manufacturing process can be simplified.

For example, an electron-accepting organic semiconductor material such as fullerene (e.g., C_{60} or C_{70}) or the derivative thereof can be used for the n-type semiconductor film.

For example, an electron-donating organic semiconductor material such as copper(II) phthalocyanine (CuPc) or tetraphenyldibenzoperiflanthene (DBP) can be used for the p-type semiconductor film.

For example, a film obtained by co-evaporation of an electron-accepting semiconductor material and an electron-donating semiconductor material can be used as the i-type semiconductor film.

Structure Example 2 of Functional Panel **700**

The functional panel **700** includes the insulating film **528** and an insulating film **573** (see FIG. **11**A).

<<Insulating Film **528**>>

The insulating film **528** includes a region interposed between the functional layer **520** and the base material **770**, and the insulating film **528** has an opening portion in a region overlapping with the light-emitting device **550**G(i,j) (see FIG. **11**A).

The material that can be used for the insulating film **521**, for example, can be used for the insulating film **528**. Specifically, a silicon oxide film, a film containing an acrylic resin, a film containing polyimide, or the like can be used as the insulating film **528**.

<<Insulating Film **573**>>

The light-emitting device **550**G(i,j) is interposed between a region of the insulating film **573** and the functional layer **520** (see FIG. **11**A).

For example, a single film or a stacked film in which a plurality of films are stacked can be used as the insulating film **573**. Specifically, a stacked film, in which an insulating film **573**A which can be formed by a method that hardly damages the light-emitting device **550**G(i,j) and a dense insulating film **573**B with a few defects are stacked, can be used as the insulating film **573**.

Thus, diffusion of impurities into the light-emitting device **550**G(i,j) can be inhibited. The reliability of the light-emitting device **550**G(i,j) can be increased.

Structure Example 3 of Functional Panel **700**

The functional panel **700** includes a functional layer **720** (see FIG. **11**A).

<<Functional Layer **720**>>

The functional layer **720** includes a light-blocking layer BM, the coloring layer CF(G), and an insulating film **771**. The color conversion layer CC(G) can also be used.

<<Light-Blocking Layer BM>>

The light-blocking layer BM has an opening portion in a region overlapping with the pixel **702**G(i,j). The light-blocking layer BM has an opening portion in a region overlapping with the pixel **702**S(i,j).

A material of a dark color can be used for the light-blocking layer BM, for example. Thus, the display contrast can be increased.

<<Coloring Layer CF(G)>>

The coloring layer CF(G) includes a region interposed between the base material **770** and the light-emitting device **550**G(i,j). A material that selectively transmits light of a predetermined color, for example, can be used for the coloring layer CF(G). Specifically, a material that transmits red light, green light, or blue light can be used for the coloring layer CF(G).

Structure Example of Insulating Film **771**

The insulating film **771** includes a region interposed between the base material **770** and the light-emitting device **550**G(i,j).

The light-blocking layer BM and the coloring layer CF(G) are interposed between a region of the insulating film **771** and the base material **770**. Thus, unevenness due to the thicknesses of the light-blocking layer BM and the coloring layer CF(G) can be reduced.

Structure Example 4 of Functional Panel **700**

The functional panel **700** includes a light-blocking film KBM (see FIG. **13**A).

<<Light-Blocking Film KBM>>

The light-blocking film KBM has an opening portion in a region overlapping with the pixel **702**S(i,j). Moreover, the light-blocking film KBM includes a region interposed between the functional layer **520** and the base material **770**, and has a function of providing a predetermined space between the functional layer **520** and the base material **770**. A material of a dark color can be used for the light-blocking film KBM, for example. Thus, stray light that would enter the pixel **702**S(i,j) can be reduced.

Structure Example 5 of Functional Panel **700**

The functional panel **700** includes a functional film **770**P or the like (see FIG. **11**A).

<<Functional Film **770**P and the Like>>

The functional film **770**P includes a region overlapping with the light-emitting device **550**G(i,j).

An anti-reflection film, a polarizing film, a retardation film, a light diffusion film, a condensing film, or the like can be used as the functional film **770**P, for example.

For example, an anti-reflection film with a thickness less than or equal to 1 μm can be used as the functional film **770**P. Specifically, a stacked film in which three or more layers, preferably five or more layers, further preferably 15 or more layers of dielectrics are stacked can be used as the functional film **770**P. This allows the reflectance to be as low as 0.5% or less, preferably 0.08% or less.

For example, a circularly polarizing film can be used as the functional film **770**P.

Furthermore, an antistatic film inhibiting the attachment of a dust, a water repellent film inhibiting the attachment of a stain, an oil repellent film inhibiting the attachment of a stain, a non-glare film (anti-glare film), a hard coat film inhibiting generation of a scratch in use, a self-healing film that self-heals from generated scratches, or the like can be used as the functional film **770**P.

Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 6

In this embodiment, structures of the functional panel of one embodiment of the present invention will be described with reference to FIG. **14** to FIG. **16**.

FIG. **14** is a diagram illustrating a structure of the functional panel of one embodiment of the present invention.

FIG. **15** illustrates circuit diagrams of the functional panel of one embodiment of the present invention. FIG. **15**A is a circuit diagram illustrating part of an amplifier circuit that can be used in the functional panel of one embodiment of the present invention, and FIG. **15**B is a circuit diagram illustrating part of a sampling circuit that can be used in the functional panel of one embodiment of the present invention.

FIG. **16** is a diagram showing an operation of the functional panel of one embodiment of the present invention.

Structure Example 1 of Functional Panel **700**

The functional panel **700** described in this embodiment includes a region **231** (see FIG. **14**).

Structure Example 1 of Region **231**

The region **231** includes a group of pixels **703**(*i*,**1**) to **703**(*i*,*n*) and a different group of pixels **703**(**1**,*j*) to **703**(*m*,*j*). The region **231** also includes the conductive film G**1**(*i*), the conductive film TX(i), the conductive film S**1***g*(*j*), and the conductive film WX(j).

The group of pixels **703**(*i*,**1**) to **703**(*i*,*n*) is arranged in the row direction (the direction indicated by an arrow R**1** in the drawing), and the group of pixels **703**(*i*,**1**) to **703**(*i*,*n*) includes the pixel **703**(*i*,*j*).

The group of pixels **703**(*i*,**1**) to **703**(*i*,*n*) is electrically connected to the conductive film G**1**(*i*), and the group of pixels **703**(*i*,**1**) to **703**(*i*,*n*) is electrically connected to the conductive film TX(i).

The different group of pixels **703**(**1**,*j*) to **703**(*m*,*j*) is arranged in the column direction intersecting the row direction (the direction indicated by an arrow C**1** in the drawing), and the different group of pixels **703**(**1**,*j*) to **703**(*m*,*j*) includes the pixel **703**(*i*,*j*).

The different group of pixels **703**(**1**,*j*) to **703**(*m*,*j*) is electrically connected to the conductive film S**1***g*(*j*), and the different group of pixels **703**(**1**,*j*) to **703**(*m*,*j*) is electrically connected to the conductive film WX(j).

Thus, imaging data can be obtained from a plurality of pixels. In addition, image data can be supplied to a plurality of pixels. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Although not illustrated, the region **231** includes a conductive film VCOM**2** and the conductive film ANO.

Structure Example 2 of Functional Panel **700**

The functional panel described in this embodiment includes the driver circuit GD (see FIG. **14**).

Structure Example 1 of Driver Circuit GD

The driver circuit GD supplies a first selection signal.

Structure Example 1 of Pixel Circuit **530**G(i,j)

The pixel circuit **530**G(i,j) is supplied with the first selection signal, and the pixel circuit **530**G(i,j) obtains an image signal on the basis of the first selection signal. For example, the first selection signal can be supplied using the conductive film G**1**(*i*) (see FIG. **7**B). The image signal can be supplied using the conductive film S**1***g*(*j*). Note that the operation of supplying the first selection signal and making the pixel circuit **530**G(i,j) obtain the image signal can be referred to as "writing" (see FIG. **16**).

The light-emitting device **550**G(i,j) emits light in response to the image signal (see FIG. **7**B).

Note that the light-emitting device **550**G(i,j) includes the electrode **551**G(i,j) electrically connected to the pixel circuit **530**G(i,j), and the electrode **552** electrically connected to the conductive film VCOM**2** (see FIG. **8** and FIG. **11**A).

Structure Example 3 of Functional Panel **700**

The functional panel of one embodiment of the present invention includes the reading circuit RC(j), a conductive film VLEN, a conductive film VIV, and a conductive film CL (see FIG. **14**, FIG. **9**, FIG. **15**A, and FIG. **15**B). In addition, the functional panel includes a conductive film CAPSEL, a conductive film CDSVDD, a conductive film CDSVSS, and a conductive film VCL.

Structure Example of Reading Circuit RC(j)

The reading circuit RC(j) includes an amplifier circuit and a sampling circuit SC(j) (see FIG. **14**).

Structure Example of Amplifier Circuit

The amplifier circuit includes a transistor M**32**(*j*) (see FIG. **15**A).

The transistor M**32**(*j*) includes a gate electrode electrically connected to the conductive film VLEN, a first electrode electrically connected to the conductive film WX(j), and a second electrode electrically connected to the conductive film VIV.

Note that the conductive film WX(j) connects the transistor M**31**(*j*) and the transistor M**32**(*j*) when the switch SW**33** is in a conduction state (see FIG. **9** and FIG. **15**A). Thus, a source follower circuit can be configured with the transistor M**31**(*j*) and the transistor M**32**(*j*). The potential of the conductive film WX(j) can be changed on the basis of the potential of the node FD.

Structure Example of Sampling Circuit SC(j)

The sampling circuit SC(j) includes a first terminal IN(j), a second terminal, and a third terminal OUT(j) (see FIG. **15**B).

The first terminal is electrically connected to the conductive film WX(j), the second terminal is electrically connected to the conductive film CL, and the third terminal OUT(j) has a function of supplying a signal that changes on the basis of the potential of the first terminal IN(j).

Accordingly, an imaging signal can be obtained from the pixel circuit **530**S(i,j). A correlated double sampling method can be employed, for example. The sampling circuit SC(j) can be provided for each conductive film WX(j). A differential signal of the pixel circuit **530**S(i,j) can be obtained by the corresponding conductive film WX(j). The operating frequency of the sampling circuit SC(j) can be low. Noise can be reduced. Thus, a novel functional panel that is highly convenient or reliable can be provided.

Structure Example 4 of Functional Panel **700**

The functional panel **700** includes the driver circuit RD (see FIG. **14**).

Structure Example 1 of Driver Circuit RD

The driver circuit RD supplies a second selection signal and a third selection signal.

Structure Example 1 of Pixel Circuit **530**S(i,j)

The pixel circuit **530**S(i,j) is supplied with the second selection signal and the third selection signal in a period during which the first selection signal is not supplied (see FIG. **16**). In addition, the pixel circuit **530**S(i,j) obtains an imaging signal on the basis of the second selection signal, and supplies the imaging signal on the basis of the third selection signal. For example, the second selection signal can be supplied using the conductive film TX(i), and the third selection signal can be supplied using the conductive film SE(i) (see FIG. **9**).

Note that the operation of supplying the second selection signal and making the pixel circuit **530**S(i,j) obtain an imaging signal can be referred to as "imaging" (see FIG. **16**). The operation of reading an imaging signal from the pixel circuit **530**S(i,j) can be referred to as "reading". The operation of supplying a predetermined voltage to the photoelectric conversion element PD(i,j) can be referred to as "initialization", the operation of exposing the initialized photoelectric conversion element PD(i,j) to light in a predetermined period as "light exposure", and the operation of reflecting a voltage that has been changed along with the light exposure on the pixel circuit **530**S(i,j) as "transfer". Moreover, in the figure, SRS corresponds to the operation of supplying a reference signal used in a correlated double sampling method, and "output" corresponds to the operation of supplying an imaging signal.

For example, image data of one frame can be written in 16.7 msec. Specifically, the operation can be performed at a frame rate of 60 Hz. Note that an image signal can be written to the pixel circuit **530**G(i,j) in 15.2 μsec.

For example, image data of one frame can be held in a period corresponding to 16 frames. Imaging data of one frame can be imaged and read in a period corresponding to 16 frames.

Specifically, it is possible to perform the initialization in 15 μsec, the light exposure in a period from 1 msec to 5 msec, and the transfer in 150 μsec. Moreover, the reading can be performed in 250 msec.

The photoelectric conversion element PD(i,j) includes the electrode **551**S(i,j) electrically connected to the pixel circuit **530**S(i,j), and the electrode **552** electrically connected to a conductive film VPD (see FIG. **9** and FIG. **12**A). The electrode **552** used in the light-emitting device **550**G(i,j) can be used in the photoelectric conversion element PD(i,j). Thus, the structure and the manufacturing process of the functional panel can be simplified.

Accordingly, imaging can be performed in a period during which the first selection signal is not supplied. Noise in imaging can be inhibited. An imaging signal can be read in the period during which the first selection signal is not supplied. Noise in reading can be inhibited. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Structure Example 3 of Pixel **703**(*i,j*)

The pixel **703**(*i,j*) is supplied with the second selection signal in a period during which the pixel **703**(*i,j*) holds one image signal. For example, in a period during which the pixel circuit **530**G(i,j) holds one image signal, the pixel **703**(*i,j*) can emit light using the light-emitting device **550**G (i,j) on the basis of the image signal (see FIG. **16**). The pixel circuit **530**S(i,j) is supplied with the second selection signal after the pixel circuit **530**G(i,j) obtains one image signal on the basis of the first selection signal by the time when the pixel circuit **530**G(i,j) is supplied with the first selection signal again.

Accordingly, the intensity of light emitted from the light-emitting device **550**G(i,j) can be controlled using the image signal. Light having a controlled intensity can be emitted to an object. The object can be imaged using the photoelectric conversion element PD(i,j). The object can be imaged using the photoelectric conversion element PD(i,j) while the intensity of emitted light is controlled. The influence of a change from one image signal to another image signal held in the pixel circuit **530**G(i,j) on an imaging signal can be eliminated. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Structure Example 5 of Functional Panel **700**

The functional panel **700** of one embodiment of the present invention includes a multiplexer MUX, an amplifier circuit AMP, and an analog-digital converter circuit ADC (see FIG. **14**).

Structure Example of Multiplexer MUX

The multiplexer MUX has a function of obtaining an imaging signal from one selected from the plurality of sampling circuits SC(j) and supplying the imaging signal to the amplifier circuit AMP, for example.

For example, the multiplexer MUX is electrically connected to the third terminal OUT(j) of the sampling circuit SC (see FIG. **15**B). Specifically, the multiplexer MUX, which is electrically connected to a sampling circuit SC(**1**) to a sampling circuit SC(**9**), can obtain an imaging signal from a predetermined sampling circuit and supply the imaging signal to the amplifier circuit AMP.

Thus, imaging data can be obtained by selecting a predetermined pixel from a plurality of pixels arranged in the row direction. The number of imaging signals obtained at the same time can be limited to a predetermined number. It is possible to use the analog-digital converter circuit ADC in which the number of input channels is smaller than the number of pixels arranged in the row direction. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Structure Example of Amplifier Circuit AMP

The amplifier circuit AMP can amplify the imaging signal and supply the amplified signal to the analog-digital converter circuit ADC.

Note that the functional layer **520** includes the multiplexer MUX and the amplifier circuit AMP.

Accordingly, for example, in the step of forming the semiconductor film used in the pixel circuit **530**G(i,j), semiconductor films used in the multiplexer MUX and the amplifier circuit AMP can be formed. The manufacturing process of the functional panel can be simplified. Thus, a novel functional panel that is highly convenient, useful, or reliable can be provided.

Structure Example of Analog-Digital Converter Circuit ADC

The analog-digital converter circuit ADC has a function of converting an analog imaging signal to a digital signal. This can suppress deterioration of an imaging signal due to transmission.

Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 7

In this embodiment, a structure of a display device of one embodiment of the present invention will be described with reference to FIG. **17**.

FIG. **17** is a diagram illustrating the structure of the display device of one embodiment of the present invention. FIG. **17**A is a block diagram of the display device of one embodiment of the present invention, and FIG. **17**B to FIG. **17**D are projection views each illustrating the appearance of the display device of one embodiment of the present invention.

Structure Example of Display Device

The display device described in this embodiment includes the functional panel **700** and a control portion **238** (see FIG. **17**A). In addition, the display device includes a control portion **243**.

Structure Example 1 of Control Portion **238**

The control portion **238** is supplied with image data VI and control data CI. For example, a clock signal, a timing signal, or the like can be used as the control data CI.

The control portion **238** generates data V**11** on the basis of the image data VI and generates a control signal on the basis of the control data CI. Furthermore, the control portion **238** supplies the data V**11** and the control signal.

The data V**11** includes a grayscale of 8 bits or more, preferably 12 bits or more, for example. In addition, a clock signal, a start pulse, or the like of a shift register used for a driver circuit can be used as the control signal, for example.

Structure Example 2 of Control Portion **238**

For example, a decompression circuit **234** and an image processing circuit **235** can be used in the control portion **238**.

<<Decompression Circuit **234**>>

The decompression circuit **234** has a function of decompressing the image data VI supplied in a compressed state. The decompression circuit **234** includes a memory portion. The memory portion has a function of storing decompressed image data, for example.

<<Image Processing Circuit **235**>>

The image processing circuit **235** includes a memory region, for example. The memory region has a function of storing data included in the image data VI, for example.

The image processing circuit **235** has a function of generating the data V**11** by correcting the image data VI on the basis of a predetermined characteristic curve and a function of supplying the data V**11**, for example.

Structure Example 1 of Functional Panel

The functional panel **700** is supplied with the data V**11** and the control signal. For example, the functional panel **700** described in any one of Embodiment 2 to Embodiment 6 can be used.

Structure Example 5 of Pixel **703**(i,j)

The pixel **703**(i,j) performs display on the basis of the data V**11**.

Thus, the image data can be displayed using the display element. Thus, a novel display device that is highly convenient or reliable can be provided. For example, an information terminal (see FIG. **17**B), a video display system (see FIG. **17**C), a computer (see FIG. **17**D), or the like can be provided.

Structure Example 2 of Functional Panel

The functional panel **700** includes a driver circuit and a control circuit, for example (see FIG. **17**A).

<<Driver Circuit>>

The driver circuit operates on the basis of the control signal. Using the control signal enables a synchronized operation of a plurality of driver circuits.

For example, the driver circuit GD can be used in the functional panel **700**. The driver circuit GD is supplied with the control signal and has a function of supplying the first selection signal.

For example, a driver circuit SD can be used in the functional panel **700**. The driver circuit SD is supplied with the control signal and the data V**11** and can supply an image signal.

For example, the driver circuit RD can be used in the functional panel **700**. The driver circuit RD is supplied with the control signal and can supply a second selection signal.

For example, the reading circuit RC can be used in the functional panel **700**. The reading circuit RC is supplied with the control signal, and can read an imaging signal by a correlated double sampling method, for example.

<<Control Circuit>>

The control circuit has a function of generating and supplying the control signal. For example, a clock signal or a timing signal can be used as the control signal.

Specifically, the control circuit formed over a rigid substrate can be used in the functional panel. The control circuit formed over the rigid substrate and the control portion **238** can be electrically connected to each other using a flexible printed circuit.

<<Control Circuit **233**>>

A timing controller can be used as a control circuit **233**, for example.

Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 8

In this embodiment, a structure of an input/output device of one embodiment of the present invention will be described with reference to FIG. **18**.

FIG. **18** is a block diagram illustrating the structure of the input/output device of one embodiment of the present invention.

Structure Example 1 of Input/Output Device

The input/output device described in this embodiment includes an input portion **240** and a display portion **230** (see FIG. **18**).

<<Display Portion **230**>>

The display portion **230** includes a display panel. For example, the functional panel **700** described in any one of Embodiment 2 to Embodiment 6 can be used for the display portion **230**. Note that a panel including the input portion **240** and the display portion **230** can be referred to as an input/output panel **700**TP.

Structure Example 1 of Input Portion **240**

The input portion **240** includes a sensing region **241**. The input portion **240** has a function of sensing an object approaching the sensing region **241**.

The sensing region **241** includes a region overlapping with the pixel **703**(*i,j*).

Thus, the object approaching the region overlapping with the display portion can be sensed while image data is displayed using the display portion. A finger or the like approaching the display portion can be used as a pointer to input position data. Position data can be associated with image data displayed on the display portion. Thus, a novel input/output device that is highly convenient or reliable can be provided.

Structure Example 1 of Sensing Region **241**

The sensing region **241** includes one or a plurality of sensors, for example.

The sensing region **241** includes a group of sensors **802**(*g*,**1**) to **802**(*g,q*) and a different group of sensors **802**(**1**,*h*) to **802**(*p,h*). Note that g is an integer greater than or equal to 1 and less than or equal to p, h is an integer greater than or equal to 1 and less than or equal to q, and p and q are each an integer greater than or equal to 1.

The group of sensors **802**(*g*,**1**) to **802**(*g,q*) includes a sensor **802**(*g,h*) and is arranged in the row direction (the direction indicated by an arrow R**2** in the drawing). Note that the direction indicated by the arrow R**2** may be the same as or different from the direction indicated by the arrow R**1**.

The different group of sensors **802**(**1**,*h*) to **802**(*p,h*) includes the sensor **802**(*g,h*) and is arranged in the column direction intersecting the row direction (the direction indicated by an arrow C**2** in the drawing).

<<Sensor>>

The sensor has a function of sensing an approaching pointer. For example, a finger or a stylus pen can be used as the pointer. For example, a piece of metal or a coil can be used for the stylus pen.

Specifically, a capacitive proximity sensor, an electromagnetic inductive proximity sensor, an optical proximity sensor, a resistive proximity sensor, or the like can be used as the sensor.

A plurality of types of sensors can be used in combination. For example, a sensor that senses a finger and a senor that senses a stylus pen can be used in combination.

This allows determination of the kind of a pointer. Different instructions can be associated with sensing data depending on the kind of a pointer that has been determined. Specifically, in the case where it is determined that a finger is used as a pointer, sensing data can be associated with a gesture. In the case where it is determined that a stylus pen is used as a pointer, sensing data can be associated with drawing processing.

Specifically, a finger can be sensed using a capacitive, pressure-sensitive, or optical proximity sensor. A stylus pen can be sensed using an electromagnetic inductive or optical proximity sensor.

Structure Example 2 of Input Portion **240**

The input portion **240** includes an oscillation circuit OSC and a sensing circuit DC (see FIG. **18**).

The oscillation circuit OSC supplies a search signal to the sensor **802**(*g,h*). For example, a rectangular wave, a sawtooth wave, a triangular wave, or a sine wave can be used as the search signal.

The sensor **802**(*g,h*) generates and supplies a sensing signal that changes in accordance with the search signal and the distance to a pointer approaching the sensor **802**(*g,h*).

The sensing circuit DC supplies input data in response to the sensing signal.

Accordingly, the distance from an approaching pointer to the sensing region **241** can be sensed. The position in the sensing region **241** where the pointer comes the closest can be sensed.

Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 9

In this embodiment, a structure of a data processing device of one embodiment of the present invention will be described with reference to FIG. **19** to FIG. **21**.

FIG. **19**A is a block diagram illustrating the structure of the data processing device of one embodiment of the present invention. FIG. **19**B and FIG. **19**C are projection views each illustrating an example of the appearance of the data processing device.

FIG. **20** shows flow charts showing a program of one embodiment of the present invention. FIG. **20**A is a flow chart showing main processing of the program of one embodiment of the present invention, and FIG. **20**B is a flow chart showing interrupt processing.

FIG. **21** shows the program of one embodiment of the present invention. FIG. **21**A is a flow chart showing interrupt processing of the program of one embodiment of the present invention. FIG. **21**B is a schematic view illustrating handling of the data processing device, and FIG. **21**C is a timing chart showing the operation of the data processing device of one embodiment of the present invention.

Structure Example 1 of Data Processing Device

The data processing device described in this embodiment includes an arithmetic device **210** and an input/output device **220** (see FIG. **19**A). Note that the input/output device **220** is electrically connected to the arithmetic device **210**. A data processing device **200** can include a housing (see FIG. **19**B and FIG. **19**C).

Structure Example 1 of Arithmetic Device **210**

The arithmetic device **210** is supplied with input data II or sensing data DS. The arithmetic device **210** generates the control data CI and the image data VI on the basis of the input data II or the sensing data DS, and supplies the control data CI and the image data VI.

The arithmetic device **210** includes an arithmetic portion **211** and a memory portion **212**. The arithmetic device **210** also includes a transmission path **214** and an input/output interface **215**.

The transmission path **214** is electrically connected to the arithmetic portion **211**, the memory portion **212**, and the input/output interface **215**.

<<Arithmetic Portion **211**>>

The arithmetic portion **211** has a function of executing a program, for example.

<<Memory Portion **212**>>

The memory portion **212** has a function of storing, for example, the program executed by the arithmetic portion **211**, initial data, setting data, an image, or the like.

Specifically, a hard disk, a flash memory, a memory using a transistor including an oxide semiconductor, or the like can be used.

<<Input/Output Interface **215** and Transmission Path **214**>>

The input/output interface **215** includes a terminal or a wiring and has a function of supplying data and being supplied with data. The input/output interface **215** can be electrically connected to the transmission path **214**, for example. The input/output interface **215** can also be electrically connected to the input/output device **220**.

The transmission path **214** includes a wiring and has a function of supplying data and being supplied with data. The transmission path **214** can be electrically connected to the input/output interface **215**, for example. The transmission path **214** can also be electrically connected to the arithmetic portion **211**, the memory portion **212**, or the input/output interface **215**.

Structure Example of Input/Output Device **220**

The input/output device **220** supplies the input data II and the sensing data DS. The input/output device **220** is supplied with the control data CI and the image data VI (see FIG. **19**A).

As the input data II, for example, a scan code of a keyboard, position data, data on button handling, sound data, or image data can be used. As the sensing data DS, for example, illuminance data, attitude data, acceleration data, bearing data, pressure data, temperature data, humidity data, or the like of the environment where the data processing device **200** is used, or the like can be used.

As the control data CI, for example, a signal controlling the luminance of display of the image data VI, a signal controlling the color saturation, or a signal controlling the hue can be used. A signal that changes display of part of the image data VI can be used as the control data CI.

The input/output device **220** includes the display portion **230**, the input portion **240**, and a sensor portion **250**. For example, the input/output device described in Embodiment D can be used as the input/output device **220**. The input/output device **220** can include a communication portion **290**.

Structure Example of Display Portion **230**

The display portion **230** displays the image data VI on the basis of the control data CI.

The display portion **230** includes the control portion **238**, the driver circuit GD, the driver circuit SD, and the functional panel **700** (see FIG. **17**). For example, the display device described in Embodiment 7 can be used for the display portion **230**.

Structure Example of Input Portion **240**

The input portion **240** generates the input data II. For example, the input portion **240** has a function of supplying position data P**1**.

For example, a human interface or the like can be used as the input portion **240** (see FIG. **19**A). Specifically, a keyboard, a mouse, a touch sensor, a microphone, a camera, or the like can be used as the input portion **240**.

A touch sensor including a region overlapping with the display portion **230** can be used. Note that an input/output device including the display portion **230** and a touch sensor including a region overlapping with the display portion **230** can be referred to as a touch panel or a touch screen.

A user can make various gestures (tap, drag, swipe, pinch in, and the like) using his/her finger touching the touch panel as a pointer, for example.

The arithmetic device **210**, for example, analyzes data on the position, path, or the like of a finger in contact with the touch panel and can determine that a predetermined gesture is supplied when the analysis results meet predetermined conditions. Thus, the user can supply a predetermined operation instruction associated with a predetermined gesture in advance by using the gesture.

For instance, the user can supply a "scroll instruction" for changing the display position of image data by using a gesture of moving a finger in contact with the touch panel along the touch panel.

The user can supply a "dragging instruction" for pulling out and displaying a navigation panel NP at an edge portion of the region **231** by using a gesture of moving a finger in contact with the edge portion of the region **231** (see FIG. **19**C). Moreover, the user can supply a "leafing through instruction" for displaying index images IND, some parts of other pages, or thumbnail images TN of other pages in a predetermined order on the navigation panel NP so that the user can flip through these images, by using a gesture of moving the position where a finger presses hard. The instruction can be supplied by using the finger press pressure. Consequently, the user can turn the pages of an e-book reader terminal like flipping through the pages of a paper book. The user can search a certain page with the aid of the thumbnail images TN or the index images IND.

Structure Example of Sensor Portion **250**

The sensor portion **250** generates the sensing data DS. The sensor portion **250** has a function of sensing the illuminance of the environment where the data processing device **200** is used and a function of supplying illuminance data, for example.

The sensor portion **250** has a function of sensing the ambient conditions and supplying the sensing data. Specifically, illuminance data, attitude data, acceleration data, bearing data, pressure data, temperature data, humidity data, or the like can be supplied.

For example, a photosensor, an attitude sensor, an acceleration sensor, a direction sensor, a GPS (Global positioning system) signal receiving circuit, a pressure-sensitive switch, a pressure sensor, a temperature sensor, a humidity sensor, a camera, or the like can be used as the sensor portion **250**.

<<Communication Portion **290**>>

The communication portion **290** has a function of supplying data to a network and obtaining data from the network.

<<Housing>>

Note that the housing has a function of storing the input/output device **220** or the arithmetic device **210**. The housing has a function of supporting the display portion **230** or the arithmetic device **210**.

Thus, the control data can be generated on the basis of the input data or the sensing data. The image data can be displayed on the basis of the input data or the sensing data. The data processing device is capable of operating with knowledge of the intensity of light that the housing of the data processing device receives in the environment where the data processing device is used. The user of the data processing device can select a display method. Thus, a novel data processing device that is highly convenient or reliable can be provided.

Note that in some cases, these components cannot be clearly distinguished from each other and one component may also serve as another component or may include part of another component. For example, a touch panel in which a touch sensor overlaps with a display panel is an input portion as well as a display portion.

Structure Example 2 of Arithmetic Device **210**

The arithmetic device **210** includes an artificial intelligence portion **213** (see FIG. **19**A).

The artificial intelligence portion **213** is supplied with the input data II or the sensing data DS, and the artificial intelligence portion **213** infers the control data CI on the basis of the input data II or the sensing data DS. Moreover, the artificial intelligence portion **213** supplies the control data CI.

In this manner, the control data CI for display that can be felt suitable can be generated. Display that can be felt suitable is possible. The control data CI for display that can be felt comfortable can be generated. Display that can be felt comfortable is possible. Thus, a novel data processing device that is highly convenient or reliable can be provided.

[Natural Language Processing on Input Data II]

Specifically, the artificial intelligence portion **213** can perform natural language processing on the input data II to extract one feature from the whole input data II. For example, the artificial intelligence portion **213** can infer emotion or the like put in the input data II, which can be a feature. The artificial intelligence portion **213** can infer the color, design, font, or the like empirically felt suitable for the feature. The artificial intelligence portion **213** can generate data specifying the color, design, or font of a letter or data specifying the color or design of the background, and the data can be used as the control data CI.

Specifically, the artificial intelligence portion **213** can perform natural language processing on the input data II to extract some words included in the input data II. For example, the artificial intelligence portion **213** can extract expressions including a grammatical error, a factual error, emotion, and the like. The artificial intelligence portion **213** can generate the control data CI for displaying extracted part in the color, design, font, or the like different from those of another part, and the data can be used as the control data CI.

[Image Processing on Input Data II]

Specifically, the artificial intelligence portion **213** can perform image processing on the input data II to extract one feature from the input data II. For example, the artificial intelligence portion **213** can infer the age where an image of the input data II is taken, whether the image is taken indoors or outdoors, whether the image is taken in the daytime or at night, or the like, which can be a feature. The artificial intelligence portion **213** can infer the color tone empirically felt suitable for the feature and generate the control data CI for use of the color tone for display. Specifically, data specifying color (e.g., full color, monochrome, or sepia) used for expression of a gradation can be used as the control data CI.

Specifically, the artificial intelligence portion **213** can perform image processing on the input data II to extract some images included in the input data II. For example, the artificial intelligence portion **213** can generate the control data CI for displaying a boundary between extracted part of the image and another part. Specifically, the artificial intelligence portion **213** can generate the control data CI for displaying a rectangle surrounding the extracted part of the image.

[Inference Using Sensing Data DS]

Specifically, the artificial intelligence portion **213** can generate an inference using the sensing data DS. The artificial intelligence portion **213** can generate the control data CI on the basis of the inference so that the user of the data processing device **200** can feel comfortable.

Specifically, the artificial intelligence portion **213** can generate the control data CI for adjustment of display brightness on the basis of the ambient illuminance or the like so that the display brightness can be felt comfortable. The artificial intelligence portion **213** can generate the control data CI for adjustment of volume on the basis of the ambient noise or the like so that the volume can be felt comfortable.

As the control data CI, a clock signal, a timing signal, or the like that is supplied to the control portion **238** included in the display portion **230** can be used. A clock signal, a timing signal, or the like that is supplied to a control portion included in the input portion **240** can be used as the control data CI.

Structure Example 2 of Data Processing Device

Another structure of the data processing device of one embodiment of the present invention will be described with reference to FIG. **20**A and FIG. **20**B.

<<Program>>

A program of one embodiment of the present invention has the following steps (see FIG. **20**A).

[First Step]

In a first step, setting is initialized (see (S**1**) in FIG. **20**A).

For example, predetermined image data that is to be displayed on start-up, a predetermined mode for displaying the image data, and data for determining a predetermined display method for displaying the image data are acquired from the memory portion **212**. Specifically, one still image data or another moving image data can be used as the predetermined image data. Furthermore, a first mode or a second mode can be used as the predetermined mode.

[Second Step]

In a second step, interrupt processing is allowed (see (S**2**) in FIG. **20**A). Note that an arithmetic device allowed to execute the interrupt processing can perform the interrupt processing in parallel with the main processing. The arithmetic device that has returned from the interrupt processing to the main processing can reflect the results obtained through the interrupt processing in the main processing.

The arithmetic device may execute the interrupt processing when a counter has an initial value, and the counter may be set at a value other than the initial value when the arithmetic device returns from the interrupt processing. Thus, the interrupt processing can be executed any time after the program is started up.

[Third Step]

In a third step, image data is displayed by a predetermined mode or a predetermined display method selected in the first step or the interrupt processing (see (S**3**) in FIG. **20**A). Note that the predetermined mode determines a mode for displaying the data, and the predetermined display method determines a method for displaying the image data. For example, the image data VI can be used as data to be displayed.

One method for displaying the image data VI can be associated with the first mode, for example. Another method for displaying the image data VI can be associated with the second mode. Thus, a display method can be selected on the basis of the selected mode.

<<First Mode>>

Specifically, a method for supplying selection signals to a scan line at a frequency of 30 Hz or higher, preferably 60 Hz or higher, to perform display in response to the selection signals can be associated with the first mode.

For example, when selection signals are supplied at a frequency of 30 Hz or higher, preferably 60 Hz or higher, the movement of a displayed moving image can be smooth. For example, when an image is refreshed at a frequency of 30 Hz or higher, preferably 60 Hz or higher, an image that changes so as to smoothly follow the user's operation can be displayed on the data processing device **200** which is being operated by the user.

<<Second Mode>>

Specifically, a method for supplying selection signals to a scan line at a frequency lower than 30 Hz, preferably lower than 1 Hz, further preferably less than once a minute, to perform display in response to the selection signals can be associated with the second mode.

The supply of selection signals at a frequency lower than 30 Hz, preferably lower than 1 Hz, further preferably less than once a minute enables display with a flicker or flickering suppressed. Furthermore, the power consumption can be reduced.

For example, in the case where the data processing device **200** is used for a clock, the display can be refreshed at a frequency of once a second, once a minute, or the like.

In the case where a light-emitting element is used as a display element, for example, the light-emitting element can be made to emit light in a pulsed manner so that the image data is displayed. Specifically, an organic EL element can be made to emit light in a pulsed manner, and its afterglow can be used for display. The organic EL element has excellent frequency characteristics; thus, time for driving the light-emitting element can be shortened and the power consumption can be reduced in some cases. Heat generation is inhibited; thus, the deterioration of the light-emitting element can be suppressed in some cases.

[Fourth Step]

In a fourth step, selection is performed such that the program proceeds to a fifth step when an end instruction has been supplied, whereas the program proceeds to the third step when the end instruction has not been supplied (see (S**4**) in FIG. **20**A).

For example, the end instruction supplied in the interrupt processing may be used for the determination.

[Fifth Step]

In the fifth step, the program ends (see (S**5**) in FIG. **20**A).

<<Interrupt Processing>>

The interrupt processing includes a sixth step to an eighth step described below (see FIG. **20**B).

[Sixth Step]

In the sixth step, the illuminance of the environment where the data processing device **200** is used is sensed using the sensor portion **250**, for example (see (S**6**) in FIG. **20**B). Note that color temperature or chromaticity of ambient light may be sensed instead of the illuminance of the environment.

[Seventh Step]

In the seventh step, a display method is determined on the basis of the sensed illuminance data (see (S**7**) in FIG. **20**B). For example, a display method is determined such that the brightness of display is not too dark or too bright.

Note that in the case where the color temperature of the ambient light or the chromaticity of the ambient light is sensed in the sixth step, the color of display may be adjusted.

[Eighth Step]

In the eighth step, the interrupt processing ends (see (S**8**) in FIG. **20**B).

Structure Example 3 of Data Processing Device

Another structure of the data processing device of one embodiment of the present invention is described with reference to FIG. **21**.

FIG. **21**A is a flow chart showing a program of one embodiment of the present invention. FIG. **21**A is a flow chart showing interrupt processing different from the interrupt processing shown in FIG. **20**B.

Note that the structure example 3 of the data processing device is different from the interrupt processing described with reference to FIG. **20**B in that the interrupt processing includes a step of changing a mode on the basis of a supplied predetermined event. Different portions will be described in detail here, and the above description is referred to for portions that can use similar structures.

<<Interrupt Processing>>

The interrupt processing includes a sixth step to an eighth step described below (see FIG. **21**A).

[Sixth Step]

In the sixth step, the program proceeds to the seventh step when a predetermined event has been supplied, whereas the program proceeds to the eighth step when the predetermined event has not been supplied (see (U**6**) in FIG. **21**A). For example, whether the predetermined event is supplied in a predetermined period or not can be used as a condition. Specifically, the predetermined period can be longer than 0 seconds, and shorter than or equal to 5 seconds, shorter than or equal to 1 second, or shorter than or equal to 0.5 seconds, preferably shorter than or equal to 0.1 seconds.

[Seventh Step]

In the seventh step, the mode is changed (see (U**7**) in FIG. **21**A). Specifically, the second mode is selected in the case where the first mode has been selected, and the first mode is selected in the case where the second mode has been selected.

For example, it is possible to change the display mode of a region that is part of the display portion **230**. Specifically, the display mode of a region where one driver circuit in the display portion **230** including a driver circuit GDA, a driver circuit GDB, and a driver circuit GDC supplies a selection signal can be changed (see FIG. **21**B).

For example, the display mode of the region where a selection signal is supplied from the driver circuit GDB can be changed when a predetermined event is supplied to the input portion **240** in a region overlapping with the region where a selection signal is supplied from the driver circuit GDB (see FIG. **21**B and FIG. **21**C). Specifically, the frequency of supply of the selection signal from the driver circuit GDB can be changed in accordance with a "tap" event supplied to a touch panel with a finger or the like.

A signal GCLK is a clock signal controlling the operation of the driver circuit GDB, and a signal PWC**1** and a signal PWC**2** are pulse width control signals controlling the operation of the driver circuit GDB. The driver circuit GDB supplies selection signals to a conductive film G**2**(m+1) to a conductive film G**2**(**2**m) on the basis of the signal GCLK, the signal PWC**1**, the signal PWC**2**, and the like.

Thus, for example, the driver circuit GDB can supply a selection signal without supply of selection signals from the driver circuit GDA and the driver circuit GDC. The display of the region where a selection signal is supplied from the driver circuit GDB can be refreshed without any change in the display of regions where selection signals are supplied from the driver circuit GDA and the driver circuit GDC. Power consumed by the driver circuits can be reduced.

[Eighth Step]

In the eighth step, the interrupt processing ends (see (U**8**) in FIG. **21**A). Note that in a period during which the main processing is executed, the interrupt processing may be repeatedly executed.

<<Predetermined Event>>

For example, it is possible to use events supplied using a pointing device such as a mouse, such as "click" and "drag", and events supplied to a touch panel with a finger or the like used as a pointer, such as "tap", "drag", and "swipe".

For example, the position of a slide bar pointed by a pointer, the swipe speed, and the drag speed can be used to assign arguments to an instruction associated with a predetermined event.

For example, data sensed by the sensor portion **250** is compared with a predetermined threshold value, and the compared results can be used for the event.

Specifically, a pressure sensor or the like in contact with a button or the like that is arranged so as to be pushed in a housing can be used for the sensor portion **250**.

<<Instruction Associated with Predetermined Event>>

For example, the end instruction can be associated with a predetermined event.

For example, "page-turning instruction" for switching display from one displayed image data to another image data can be associated with a predetermined event. Note that an argument determining the page-turning speed or the like, which is used when the "page-turning instruction" is executed, can be supplied using the predetermined event.

For example, "scroll instruction" for moving the display position of displayed part of image data and displaying another part continuing from that part, or the like can be associated with a predetermined event. Note that an argument determining the moving speed of display, or the like, which is used when the "scroll instruction" is executed, can be supplied using the predetermined event.

For example, an instruction for setting the display method, an instruction for generating image data, or the like can be associated with a predetermined event. Note that an argument determining the brightness of a generated image can be associated with a predetermined event. An argument determining the brightness of a generated image may be determined on the basis of ambient brightness sensed by the sensor portion **250**.

For example, an instruction for acquiring data distributed via a push service using the communication portion **290** or the like can be associated with a predetermined event.

Note that position data sensed by the sensor portion **250** may be used for the determination of the presence or absence of a qualification for acquiring data. Specifically, it may be determined that there is a qualification for acquiring data in the case of presence in a predetermined class room, school, conference room, company, building, or the like or in a predetermined region. Thus, for example, educational materials distributed in a classroom of a school, a university, or the like can be received, so that the data processing device **200** can be used as a schoolbook or the like (see FIG. **19**C). Materials distributed in a conference room in, for example, a company can be received and used for a conference material.

Structure Example 4 of Data Processing Device

Another structure of the data processing device of one embodiment of the present invention is described with reference to FIG. **22**.

FIG. **22**A is a flow chart showing a program of one embodiment of the present invention. FIG. **22**A is a flow chart showing interrupt processing different from the interrupt processing shown in FIG. **20**B. FIG. **22**B is a schematic view illustrating operation of the program shown in FIG. **22**A. FIG. **22**C is a schematic view of an imaged fingerprint.

Note that the structure example 4 of the data processing device described with reference to FIG. **22**A is different from the structure example described with reference to FIG. **20**B in the interrupt processing. Specifically, the interrupt processing includes the step of determining a region, the step of generating an image, the step of displaying the image, and the step of imaging on the basis of a supplied predetermined event. Different portions will be described in detail here, and the above description is referred to for portions that can use similar structures.

<<Interrupt Processing>>

The interrupt processing includes a sixth step to an eleventh step (see FIG. **22**A).

[Sixth Step]

In the sixth step, the program proceeds to the seventh step when a predetermined event has been supplied, whereas the program proceeds to the eleventh step when the predetermined event has not been supplied (see (V**6**) in FIG. **22**A).

The predetermined event can be supplied using the sensor portion **250**, for example. Specifically, a motion such as lifting of the data processing device can be used as the predetermined event. For example, a motion of the data processing device can be sensed using an angular sensor or an acceleration sensor. Touch or approach of an object such as a finger can be sensed using a touch sensor.

[Seventh Step]

In the seventh step, a first region SH is determined (see (V**7**) in FIG. **22**A).

For example, a region where an object such as a finger touches or approaches the input/output device **220** of one embodiment of the present invention can be the first region SH. A region that is set in advance by the user or the like can be used as the first region SH.

Specifically, an image of a finger THM or the like that touches or approaches the functional panel of one embodiment of the present invention is taken using the pixel **703**(*i,j*) and subjected to image processing, whereby the first region SH can be determined (see FIG. **22**B).

For example, an image of a shadow caused when external light is blocked by touch or approach of an object such as the finger THM is taken using the pixel **703**(*i,j*) in the functional panel of one embodiment of the present invention and subjected to image processing, whereby the first region SH can be determined.

With the use of the pixel **703**(*i,j*) in the functional panel of one embodiment of the present invention, an object such as the finger THM that touches or approaches the functional panel is irradiated with light, and an image of light reflected by the object is taken using the pixel **703**(*i,j*) and subjected to image processing, whereby the first region SH can be determined.

A region where an object such as the finger THM touches can be determined as the first region SH by a touch sensor.

[Eighth Step]

In the eighth step, an image FI including a second region and a third region is generated on the basis of the first region SH (see (V**8**) in FIG. **22**A and FIG. **22**B). For example, the shape of the first region SH is used as the shape of the second region, and a region excluding the first region SH is used as the third region.

[Ninth Step]

In the ninth step, the image FI is displayed such that the second region overlaps with the first region SH (see (V**9**) in FIG. **22**A and FIG. **22**B).

For example, an image signal is generated from the image FI and supplied to the region **231**, and light is emitted from the pixel **703**(*i,j*). In a period during which the first selection signal is supplied to the conductive film G**1**(*i*), the generated image signal is supplied to the conductive film S**1***g*(*j*), and the image signal can be written to the pixel **703**(*i,j*). The generated image signal is supplied to the conductive film S**1***g*(*j*) and the conductive film S**2***g*(*j*), and an enhanced image signal can be written to the pixel **703**(*i,j*). The use of an enhanced image signal enables display with higher luminance.

Thus, the image FI can be displayed to overlap with the first region SH that is a region where the object such as a finger touches or approaches the region **231**. The region where the object such as a finger touches can be irradiated with light using the pixel **703**(*i,j*). The touching or approaching object such as the finger THM can be illuminated with a light. The object such as a finger can be led to touch or approach the region that is determined in advance by the user or the like.

[Tenth Step]

In the tenth step, the object that touches or approaches the first region SH is imaged while the image FI is displayed (see (V**10**) in FIG. **22**A and FIG. **22**B).

For example, an image of the finger THM or the like approaching the region **231** is taken while the finger or the like is irradiated with light. Specifically, an image of a fingerprint FP of the finger THM touching the region **231** can be taken (see FIG. **22**C).

For example, the supply of the first selection signal can be stopped while an image is displayed with the pixel **703**(*i,j*). For example, imaging can be performed using the pixel **703**(*i,j*) while the supply of the selection signal to the pixel circuit **530**G(i,j) is stopped.

Accordingly, the touching or approaching object such as a finger can be imaged while the object is illuminated. Imaging can be performed in a period during which the first selection signal is not supplied. Noise in imaging can be inhibited. A clear image of a fingerprint can be obtained. An image that can be used for the authentication of the user can be obtained. In any area of the region **231**, an image of the fingerprint of the finger touching the region **231** can be taken clearly. Thus, a novel data processing device that is highly convenient or reliable can be provided.

[Eleventh Step]

In the eleventh step, the interrupt processing ends (see (V**11**) in FIG. **22**A).

Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 10

In this embodiment, structures of a data processing device of one embodiment of the present invention will be described with reference to FIG. **23** to FIG. **25**.

FIG. **23** to FIG. **25** are diagrams illustrating structures of the data processing device of one embodiment of the present invention. FIG. **23**A is a block diagram of the data processing device, and FIG. **23**B to FIG. **23**E are perspective views illustrating structures of the data processing device. In addition, FIG. **24**A to FIG. **24**E are perspective views illustrating structures of the data processing device. FIG. **25**A and FIG. **25**B are perspective views illustrating structures of the data processing device.

<Data Processing Device>

A data processing device **5200**B described in this embodiment includes an arithmetic device **5210** and an input/output device **5220** (see FIG. **23**A).

The arithmetic device **5210** has a function of being supplied with operation data and has a function of supplying image data on the basis of the operation data.

The input/output device **5220** includes a display portion **5230**, an input portion **5240**, a sensor portion **5250**, and a communication portion **5290** and has a function of supplying operation data and a function of being supplied with image data. The input/output device **5220** also has a function of supplying sensing data, a function of supplying communication data, and a function of being supplied with communication data.

The input portion **5240** has a function of supplying operation data. For example, the input portion **5240** supplies operation data on the basis of operation by a user of the data processing device **5200**B.

Specifically, a keyboard, a hardware button, a pointing device, a touch sensor, an illuminance sensor, an imaging device, an audio input device, an eye-gaze input device, an attitude detection device, or the like can be used as the input portion **5240**.

The display portion **5230** includes a display panel and has a function of displaying image data. For example, the display panel described in any one of Embodiment 2 to Embodiment 6 can be used for the display portion **5230**.

The sensor portion **5250** has a function of supplying sensing data. For example, the sensor portion **5250** has a function of sensing a surrounding environment where the data processing device is used and supplying sensing data.

Specifically, an illuminance sensor, an imaging device, an attitude detection device, a pressure sensor, a human motion sensor, or the like can be used as the sensor portion **5250**.

The communication portion **5290** has a function of being supplied with communication data and a function of supplying communication data. For example, the communication portion **5290** has a function of being connected to another electronic device or a communication network through wireless communication or wired communication. Specifically, the communication portion **5290** has a function of wireless local area network communication, telephone communication, near field communication, or the like.

Structure Example 1 of Data Processing Device

For example, the display portion **5230** can have an outer shape along a cylindrical column or the like (see FIG. **23**B). In addition, the data processing device has a function of changing its display method in accordance with the illuminance of a usage environment. Furthermore, the data processing device has a function of changing displayed content in response to sensed existence of a person. This allows the data processing device to be provided on a column of a building, for example. The data processing device can display advertising, guidance, or the like. The data processing device can be used for digital signage or the like.

Structure Example 2 of Data Processing Device

For example, the data processing device has a function of generating image data on the basis of the path of a pointer used by a user (see FIG. **23**C). Specifically, the display panel with a diagonal size of 20 inches or longer, preferably 40 inches or longer, further preferably 55 inches or longer can be used. Alternatively, a plurality of display panels can be arranged and used as one display region. Alternatively, a plurality of display panels can be arranged and used as a multiscreen. Thus, the data processing device can be used for an electronic blackboard, an electronic bulletin board, digital signage, or the like.

Structure Example 3 of Data Processing Device

The data processing device can receive data from another device and display the data on the display portion **5230** (see FIG. **23**D). Several options can be displayed. The user can choose some from the options and send a reply to a transmitter of the data. For example, the data processing device has a function of changing its display method in accordance with the illuminance of a usage environment. Thus, the power consumption of a smartwatch can be reduced, for example. A smartwatch can display an image to be suitably used even in an environment under strong external light, e.g., outdoors in fine weather, for example.

Structure Example 4 of Data Processing Device

For example, the display portion **5230** has a surface gently curved along a side surface of a housing (see FIG. **23**E). The display portion **5230** includes a display panel, and the display panel has a function of performing display on the front surface, the side surfaces, the top surface, and the rear surface, for example. Thus, for example, a mobile phone can display data not only on its front surface but also on its side surfaces, its top surface, and its rear surface.

Structure Example 5 of Data Processing Device

For example, the data processing device can receive data via the Internet and display the data on the display portion **5230** (see FIG. **24**A). A created message can be checked on the display portion **5230**. The created message can be sent to another device. The data processing device has a function of changing its display method in accordance with the illuminance of a usage environment, for example. Thus, the power consumption of a smartphone can be reduced. A smartphone can display an image to be suitably used even in an environment under strong external light, e.g., outdoors in fine weather, for example.

Structure Example 6 of Data Processing Device

A remote controller can be used as the input portion **5240** (see FIG. **24**B). For example, the data processing device can receive data from a broadcast station or via the Internet and display the data on the display portion **5230**. An image of a user can be taken using the sensor portion **5250**. The image of the user can be transmitted. The data processing device can acquire a viewing history of the user and provide it to a cloud service. The data processing device can acquire recommendation data from a cloud service and display the data on the display portion **5230**. A program or a moving image can be displayed on the basis of the recommendation data. The data processing device has a function of changing its display method in accordance with the illuminance of a usage environment, for example. Accordingly, for example, a television system can display an image to be suitably used even when irradiated with strong external light that enters a room in fine weather.

Structure Example 7 of Data Processing Device

For example, the data processing device can receive educational materials via the Internet and display them on the display portion **5230** (see FIG. **24**C). An assignment can be input with the input portion **5240** and sent via the Internet. A corrected assignment or the evaluation of the assignment can be obtained from a cloud service and displayed on the display portion **5230**. Suitable educational materials can be selected on the basis of the evaluation and displayed.

For example, the display portion **5230** can perform display using an image signal received from another data processing device. When the data processing device is placed on a stand or the like, the display portion **5230** can be used as a sub-display. Thus, for example, a tablet computer can display an image to be suitably used even in an environment under strong external light, e.g., outdoors in fine weather.

Structure Example 8 of Data Processing Device

The data processing device includes, for example, a plurality of display portions **5230** (see FIG. **24**D). For example, the display portion **5230** can display an image that the sensor portion **5250** is capturing. A captured image can be displayed on the sensor portion. A captured image can be decorated using the input portion **5240**. A message can be attached to a captured image. A captured image can be transmitted via the Internet. The data processing device has a function of changing its shooting conditions in accordance with the illuminance of a usage environment. Accordingly, for example, a digital camera can display an object in such a manner that an image is favorably viewed even in an environment under strong external light, e.g., outdoors in fine weather.

Structure Example 9 of Data Processing Device

For example, the data processing device of this embodiment is used as a master and another data processing device is used as a slave, whereby the other data processing device can be controlled (see FIG. **24**E). As another example, part of image data can be displayed on the display portion **5230** and another part of the image data can be displayed on a display portion of another data processing device. With the communication portion **5290**, data to be written can be obtained from an input portion of another data processing device. Thus, a large display region can be utilized by using a portable personal computer, for example.

Structure Example 10 of Data Processing Device

The data processing device includes, for example, the sensor portion **5250** that senses an acceleration or a direction (see FIG. **25**A). The sensor portion **5250** can supply data on the position of the user or the direction in which the user faces. The data processing device can generate image data for the right eye and image data for the left eye in accordance with the position of the user or the direction in which the user faces. The display portion **5230** includes a display region for the right eye and a display region for the left eye. Thus, a virtual reality image that gives the user a sense of immersion can be displayed on a goggles-type data processing device, for example.

Structure Example 11 of Data Processing Device

The data processing device includes, for example, an imaging device and the sensor portion **5250** that senses an acceleration or a direction (see FIG. **25**B). The sensor portion **5250** can supply data on the position of the user or the direction in which the user faces. The data processing device can generate image data in accordance with the position of the user or the direction in which the user faces. Accordingly, the data can be shown together with a real-world scene, for example. An augmented reality image can be displayed on a glasses-type data processing device.

Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

In the case where there is an explicit description, X and Y are connected, in this specification and the like, for example, the case where X and Y are electrically connected, the case where X and Y are functionally connected, and the case where X and Y are directly connected are disclosed in this specification and the like. Accordingly, without being limited to a predetermined connection relationship, for example, a connection relationship shown in drawings or texts, a connection relationship other than one shown in drawings or texts is regarded as being disclosed in the drawings or the texts.

Here, X and Y each denote an object (e.g., a device, an element, a circuit, a wiring, an electrode, a terminal, a conductive film, or a layer).

Examples of the case where X and Y are directly connected include the case where an element that allows an electrical connection between X and Y (e.g., a switch, a transistor, a capacitor, an inductor, a resistor, a diode, a display element, a light-emitting element, and a load) is not connected between X and Y, and the case where X and Y are connected without the element that allows the electrical connection between X and Y (e.g., a switch, a transistor, a capacitor, an inductor, a resistor, a diode, a display element, a light-emitting element, and a load).

For example, in the case where X and Y are electrically connected, one or more elements that allow an electrical connection between X and Y (e.g., a switch, a transistor, a capacitor, an inductor, a resistor, a diode, a display element, a light-emitting element, and a load) can be connected between X and Y. Note that a switch has a function of being controlled to be turned on or off. That is, a switch has a function of being in a conduction state (on state) or a non-conduction state (off state) to control whether or not current flows. Alternatively, the switch has a function of selecting and changing a current path. Note that the case where X and Y are electrically connected includes the case where X and Y are directly connected.

An example of the case where X and Y are functionally connected is the case where one or more circuits that allow functional connection between X and Y (for example, a logic circuit (an inverter, a NAND circuit, a NOR circuit, or the like), a signal converter circuit (a DA converter circuit, an AD converter circuit, a gamma correction circuit, or the like), a potential level converter circuit (a power supply circuit (for example, a step-up circuit, a step-down circuit, or the like), a level shifter circuit for changing the potential level of a signal, or the like), a voltage source, a current source, a switching circuit, an amplifier circuit (a circuit capable of increasing signal amplitude, the amount of current, or the like, an operational amplifier, a differential amplifier circuit, a source follower circuit, a buffer circuit, or the like), a signal generator circuit, a memory circuit, a control circuit, or the like) can be connected between X and Y. For example, even when another circuit is interposed between X and Y, X and Y are functionally connected when a signal output from X is transmitted to Y. Note that the case where X and Y are functionally connected includes the case where X and Y are directly connected and the case where X and Y are electrically connected.

Note that in the case where there is an explicit description, X and Y are electrically connected, the case where X and Y are electrically connected (i.e., the case where X and Y are connected with another element or another circuit provided therebetween), the case where X and Y are functionally connected (i.e., the case where X and Y are functionally connected with another circuit provided therebetween), and the case where X and Y are directly connected (i.e., the case where X and Y are connected without another element or another circuit provided therebetween) are disclosed in this specification and the like. That is, in the case where there is an explicit description, being electrically connected, the same contents as the case where there is only an explicit description, being connected, are disclosed in this specification and the like.

Note that, for example, the case where a source (or a first terminal or the like) of a transistor is electrically connected to X through (or not through) Z1 and a drain (or a second terminal or the like) of the transistor is electrically connected to Y through (or not through) Z2, or the case where a source (or a first terminal or the like) of a transistor is directly connected to one part of Z1 and another part of Z1 is directly connected to X while a drain (or a second terminal or the like) of the transistor is directly connected to one part of Z2 and another part of Z2 is directly connected to Y can be expressed as follows.

It can be expressed as, for example, "X, Y, a source (or a first terminal or the like) of a transistor, and a drain (or a second terminal or the like) of the transistor are electrically connected to each other, and X, the source (or the first terminal or the like) of the transistor, the drain (or the second terminal or the like) of the transistor, and Y are electrically connected to each other in this order". Alternatively, it can be expressed as "a source (or a first terminal or the like) of a transistor is electrically connected to X, a drain (or a second terminal or the like) of the transistor is electrically connected to Y, and X, the source (or the first terminal or the like) of the transistor, the drain (or the second terminal or the like) of the transistor, and Y are electrically connected to each other in this order". Alternatively, it can be expressed as "X is electrically connected to Y through a source (or a first terminal or the like) and a drain (or a second terminal or the like) of a transistor, and X, the source (or the first terminal or the like) of the transistor, the drain (or the second terminal or the like) of the transistor, and Y are provided in this connection order". When the connection order in a circuit configuration is defined by an expression similar to the above examples, a source (or a first terminal or the like) and a drain (or a second terminal or the like) of a transistor can be distinguished from each other to specify the technical scope.

As another expression, it can be expressed as "a source (or a first terminal or the like) of a transistor is electrically connected to X through at least a first connection path, the first connection path does not include a second connection path, the second connection path is a path through the transistor and between the source (or the first terminal or the like) of the transistor and a drain (or a second terminal or the like) of the transistor, the first connection path is a path through Z1, the drain (or the second terminal or the like) of the transistor is electrically connected to Y through at least a third connection path, the third connection path does not include the second connection path, and the third connection path is a path through Z2". Alternatively, it can be expressed as "a source (or a first terminal or the like) of a transistor is electrically connected to X through Z1 by at least a first connection path, the first connection path does not include a second connection path, the second connection path includes a connection path through the transistor, a drain (or a second terminal or the like) of the transistor is electrically connected to Y through Z2 by at least a third connection path, and the third connection path does not include the second connection path". Alternatively, it can be expressed as "a source (or a first terminal or the like) of a transistor is electrically connected to X by at least a first electrical path through Z1, the first electrical path does not include a second electrical path, the second electrical path is an electrical path from the source (or the first terminal or the like) of the transistor to a drain (or a second terminal or the like) of the transistor, the drain (or the second terminal or the like) of the transistor is electrically connected to Y by at least a third electrical path through Z2, the third electrical path does not include a fourth electrical path, and the fourth electrical path is an electrical path from the drain (or the second terminal or the like) of the transistor to the source (or the first terminal or the like) of the transistor". When the connection path in a circuit configuration is defined by an expression similar to the above examples, a source (or a first terminal or the like) and a drain (or a second terminal or the like) of a transistor can be distinguished from each other to specify the technical scope.

Note that these expressions are examples and the expression is not limited to these expressions. Here, X, Y, Z1, and Z2 denote an object (e.g., a device, an element, a circuit, a wiring, an electrode, a terminal, a conductive film, and a layer).

Even when independent components are electrically connected to each other in a circuit diagram, one component has functions of a plurality of components in some cases. For example, when part of a wiring also functions as an electrode, one conductive film has functions of both components: a function of the wiring and a function of the electrode. Thus, "electrical connection" in this specification includes in its category such a case where one conductive film has functions of a plurality of components.

REFERENCE NUMERALS

ANO: conductive film, C**21**: capacitor, C**31**: capacitor, CI: control data, CL: conductive film, CP: conductive material, DS: sensing data, FD: node, G**1**: conductive film, G**2**: conductive film, GCLK: signal, II: input data, IN: terminal, MD: transistor, M**21**: transistor, M**31**: transistor, M**32**: transistor, N**21**: node, OUT: terminal, P**1**: positional data, PWC**1**: signal, PWC**2**: signal, REF(i,j)(**1**): region, REF: reflective film, RS: conductive film, S**1***g*: conductive film, S**2***g*: conductive film, SE: conductive film, SH: region, SP: control signal, SW**1**: switch, SW**21**: switch, SW**22**: switch, SW**31**: switch, SW**32**: switch, SW**33**: switch, TX: conductive film, V**11**: data, VCOM**2**: conductive film, VCP: conductive film, VI: image data, VIV: conductive film, VLEN: conductive film, VPD: conductive film, VPI: conductive film, VR: conductive film, WX: conductive film, FPC**1**: flexible printed circuit board, **200**: data processing device, **210**: arithmetic device, **211**: arithmetic portion, **212**: memory portion, **213**: artificial intelligence portion, **214**: transmission path, **215**: input/output interface, **220**: input/output device, **230**: display portion, **231**: region, **233**: control circuit, **234**: decompression circuit, **235**: image processing circuit, **238**: control portion, **240**: input portion, **241**: sensing region, **250**: sensor portion, **290**: communication portion, **501**C: insulating film, **501**D: insulating film, **504**: conductive film, **506**: insulating film, **508**: semiconductor film, **508**A: region, **508**B: region, **508**C: region, **510**: base material, **512**A: conductive film, **512**B: conductive film, **516**: insulating film, **518**: insulating film, **519**B: terminal, **520**: functional layer, **521**: insulating film, **521**(**1**): surface, **521**B: insulating film, **521**C: insulating film, **524**: conductive film, **528**: insulating film, **530**G: pixel circuit, **530**S: pixel circuit, **550**G: light-emitting device, **551**G(i,j)(**1**): region, **551**G(i,j)(**2**): region, **551**G: electrode, **551**S: electrode, **552**: electrode, **553**G(j)(**1**): region, **553**G(j)(**2**): region, **553**G: layer containing light-emitting material, **553**S: layer containing photoelectric conversion material, **573**: insulating film, **573**A: insulating film, **573**B: insulating film, **591**G: opening portion, **591**S: opening portion, **700**:

functional panel, **700**TP: input/output panel, **702**B: pixel, **702**G: pixel, **702**R: pixel, **702**S: pixel, **703**: pixel, **705**: sealant, **720**: functional layer, **770**: base material, **770**P: functional film, **771**: insulating film, **802**: sensor, **5200**B: data processing device, **5210**: arithmetic device, **5220**: input/output device, **5230**: display portion, **5240**: input portion, **5250**: sensor portion, **5290**: communication portion

The invention claimed is:

1. A light-emitting device comprising:
an insulating film;
a first structure body and a second structure body;
a layer comprising a light-emitting material;
a first electrode; and
a second electrode, wherein the insulating film comprises a first surface,
wherein an entirety of the first structure body overlaps the first electrode in plan view,
wherein an entirety of the second structure body overlaps the first electrode in plan view,
wherein the first structure body and the second structure body are apart from each other with a first distance therebetween,
wherein the first structure body comprises a sidewall,
wherein the sidewall forms a first angle with the first surface,
wherein the first angle is greater than 0° and less than or equal to 90°,
wherein the layer comprising the light-emitting material comprises a first region and a second region,
wherein the first region is interposed between the second electrode and the first electrode,
wherein light is emitted from the first region,
wherein the second region is interposed between the second electrode and the sidewall,
wherein the sidewall is configured to reflect the light,
wherein the first electrode comprises a third region, and
wherein the third region is interposed between the first region and the first surface.

2. The light-emitting device according to claim **1**,
further comprising a reflective film,
wherein the reflective film comprises a fourth region,
wherein the sidewall is interposed between the fourth region and the layer comprising the light-emitting material, and
wherein the light is configured to be reflected in the fourth region.

3. The light-emitting device according to claim **1**,
wherein the first structure body has a first height from the insulating film,
wherein the first structure body has a first projection area with respect to the insulating film,
wherein the first height is greater than or equal to 0.1 μm and less than or equal to 5 μm, and
wherein the first projection area is greater than or equal to 0.01 μm^2 and less than or equal to 100 μm^2.

4. The light-emitting device according to claim **1**, wherein the first distance is greater than or equal to 0.1 μm and less than or equal to 5 μm.

5. A functional panel comprising a set of pixels,
wherein the set of pixels comprises a first pixel and a second pixel,
wherein the first pixel comprises a first pixel circuit and the light-emitting device according to claim **1**,
wherein the light-emitting device is electrically connected to the first pixel circuit,
wherein the second pixel comprises a second pixel circuit and a photoelectric conversion element, and
wherein the photoelectric conversion element is electrically connected to the second pixel circuit.

6. The functional panel according to claim **5**,
further comprising a functional layer,
wherein the functional layer comprises the first pixel circuit,
wherein the first pixel circuit comprises a first transistor,
wherein the functional layer comprises the second pixel circuit,
wherein the second pixel circuit comprises a second transistor,
wherein the functional layer comprises a driver circuit,
wherein the driver circuit comprises a third transistor,
wherein the first transistor comprises a first semiconductor film,
wherein the second transistor comprises a second semiconductor film that is formed in a step of forming the first semiconductor film, and
wherein the third transistor comprises a third semiconductor film that is formed in the step of forming the first semiconductor film.

7. A display device comprising:
the functional panel according to claim **5**; and
a control portion,
wherein the control portion is supplied with image data and control data,
wherein the control portion generates data on the basis of the image data,
wherein the control portion generates a control signal on the basis of the control data,
wherein the control portion supplies the data and the control signal,
wherein the functional panel is supplied with the data and the control signal, and
wherein the first pixel emits light in response to the data.

8. An input/output device comprising:
an input portion and a display portion,
wherein the display portion comprises the functional panel according to claim **5**,
wherein the input portion comprises a sensing region,
wherein the input portion senses an object approaching the sensing region, and
wherein the sensing region comprises a region overlapping with the first pixel.

9. A data processing device comprising at least one of a keyboard, a hardware button, a pointing device, a touch sensor, an illuminance sensor, an imaging device, an audio input device, an eye-gaze input device, and an attitude detection device, and the functional panel according to claim **5**.

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