



US 20160109998A1

(19) **United States**(12) **Patent Application Publication**
Watanabe(10) **Pub. No.: US 2016/0109998 A1**(43) **Pub. Date: Apr. 21, 2016**(54) **TOUCH PANEL AND ELECTRONIC DEVICE**(71) Applicant: **Semiconductor Energy Laboratory Co., Ltd., Kanagawa-ken (JP)**(72) Inventor: **Kazunori Watanabe, Tokyo (JP)**(73) Assignee: **Semiconductor Energy Laboratory Co., Ltd., Kanagawa-ken (JP)**(21) Appl. No.: **14/881,660**(22) Filed: **Oct. 13, 2015**(30) **Foreign Application Priority Data**

Oct. 15, 2014 (JP) 2014-210943

Publication Classification(51) **Int. Cl.****G06F 3/041** (2006.01)**G02F 1/1335** (2006.01)**G02F 1/1333** (2006.01)**H01L 27/32** (2006.01)**H01L 51/00** (2006.01)(52) **U.S. Cl.**CPC **G06F 3/0412** (2013.01); **H01L 27/323** (2013.01); **H01L 27/3272** (2013.01); **H01L 27/322** (2013.01); **H01L 51/0097** (2013.01); **G02F 1/13338** (2013.01); **G02F 1/133512** (2013.01); **G02F 1/133514** (2013.01); **G02F 1/133345** (2013.01); **G02F 1/133305** (2013.01); **H01L 2251/5338** (2013.01); **G06F 2203/04103** (2013.01); **G06F 2203/04111** (2013.01); **G06F 2203/04112** (2013.01)

(57)

ABSTRACT

Provided is a touch panel or the like including a touch sensor that can perform high-speed detection and have high detection accuracy. The touch panel includes a data input device and a display panel. The data input device overlaps with the display panel and includes a light-blocking layer, first to third conductive layers, an insulating layer, and a coloring layer. The light-blocking layer overlaps with the first to third conductive layers. The first conductive layer overlaps with the third conductive layer. The second conductive layer overlaps with the third conductive layer. The second conductive layer is electrically connected to the third conductive layer. The widths of the first to third conductive layers are smaller than the width of the light-blocking layer. The first to third conductive layers are arranged to have a mesh pattern when seen from the top, and to surround pixels in the display panel.

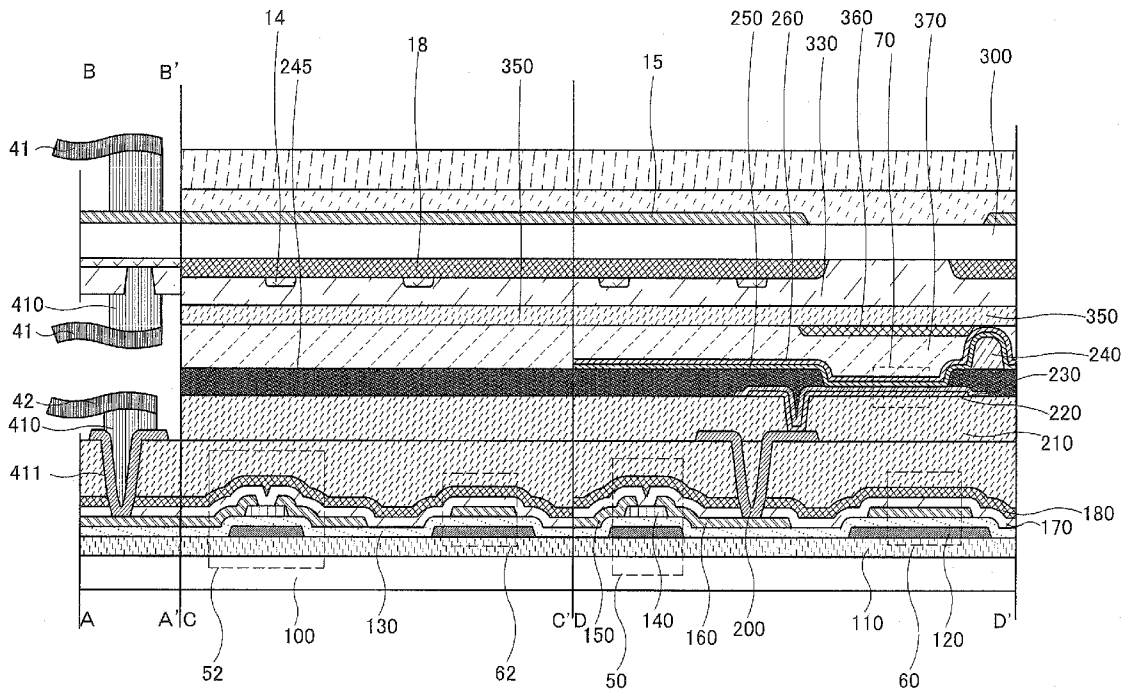


FIG. 1A

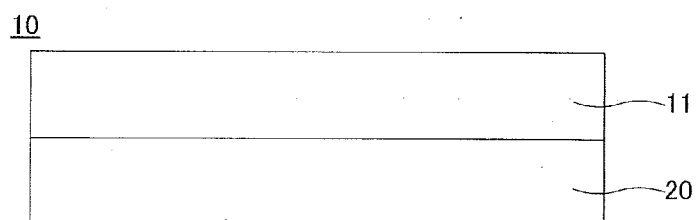


FIG. 1B

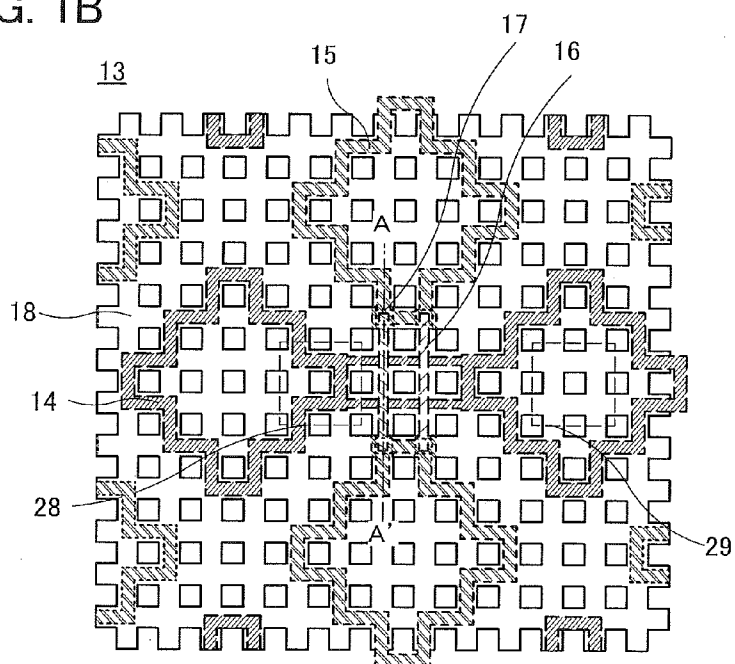


FIG. 2A

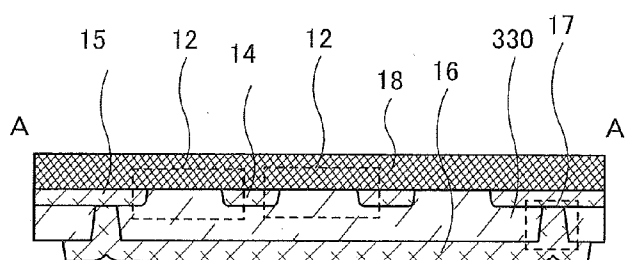


FIG. 2B

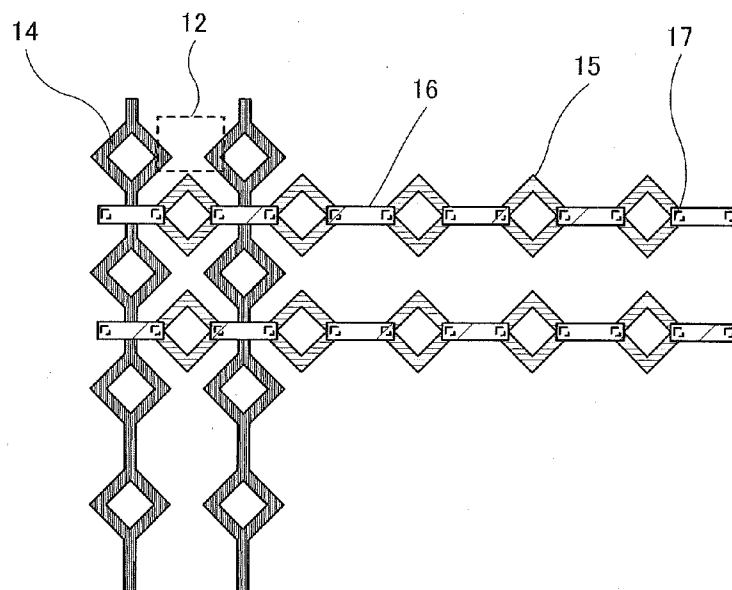


FIG. 3A

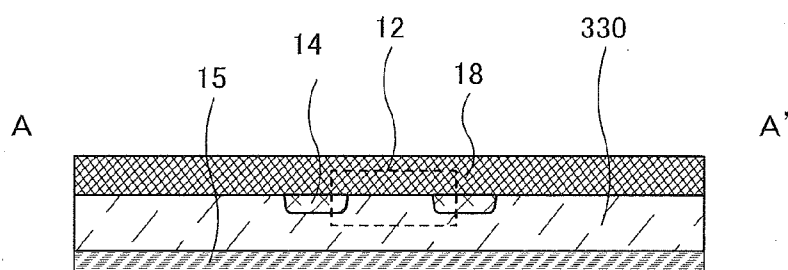


FIG. 3B

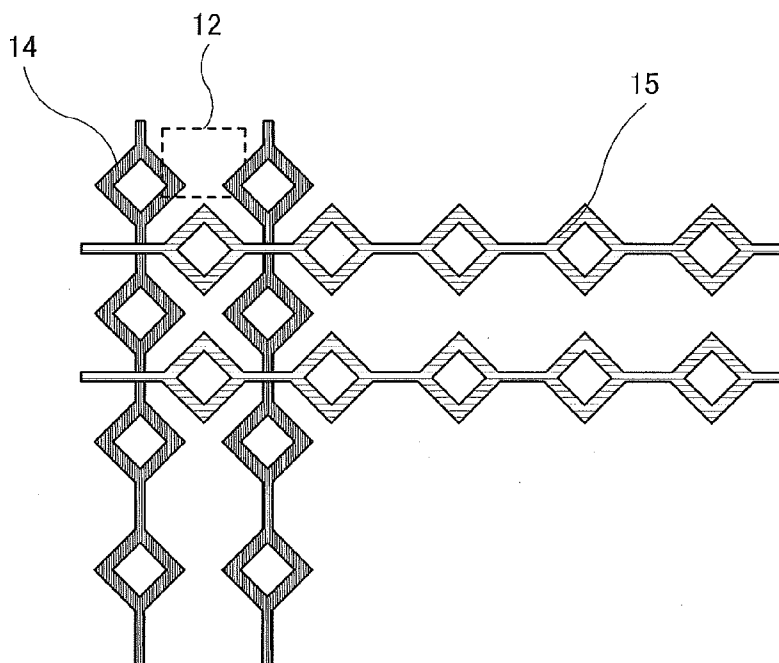


FIG. 4A

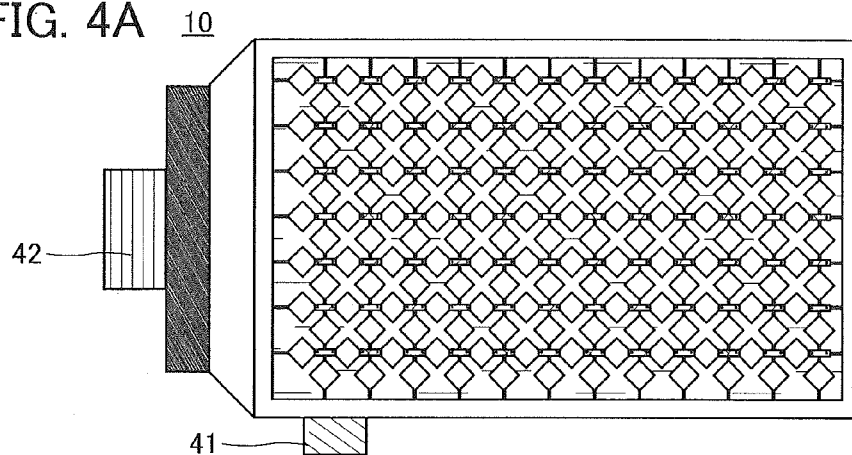


FIG. 4B

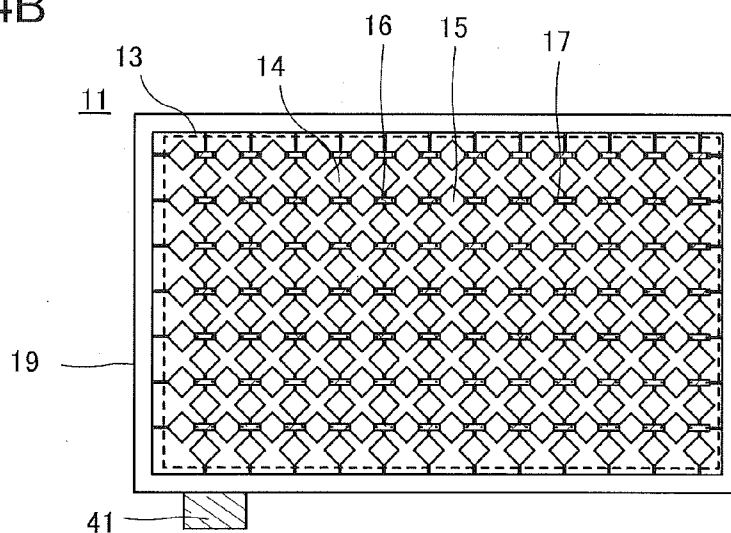


FIG. 4C

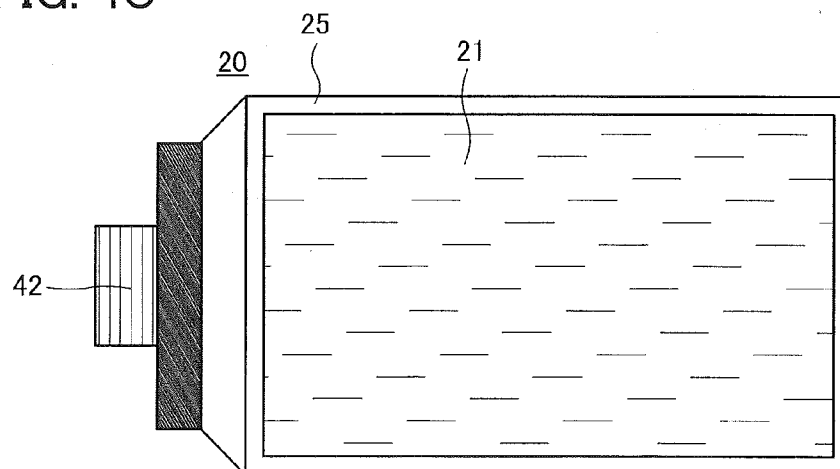


FIG. 5A

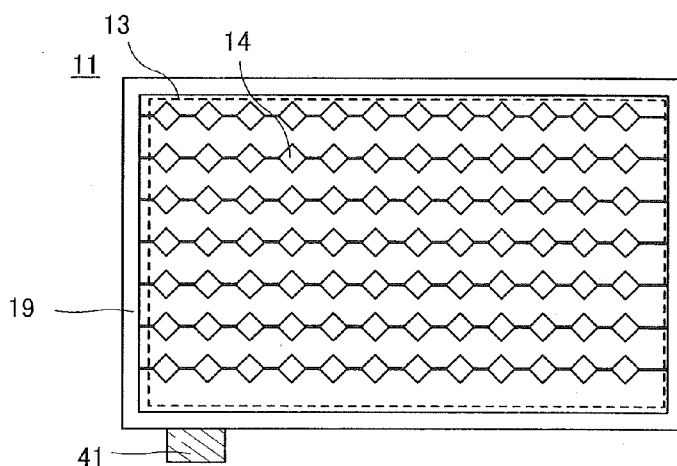


FIG. 5B

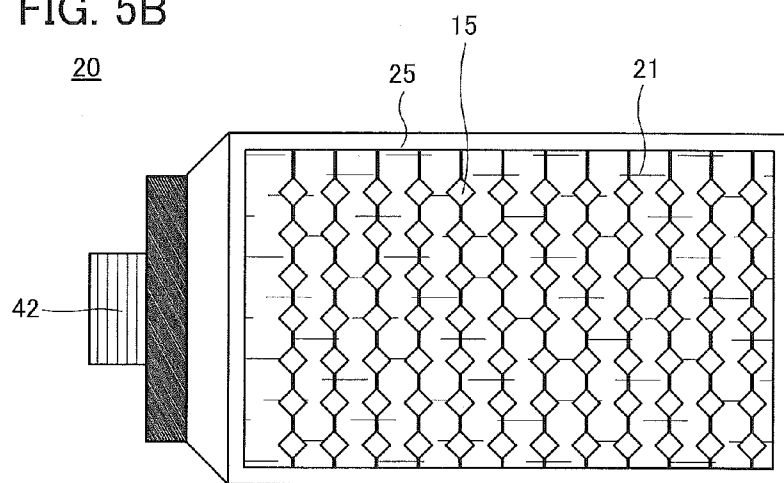


FIG. 6A

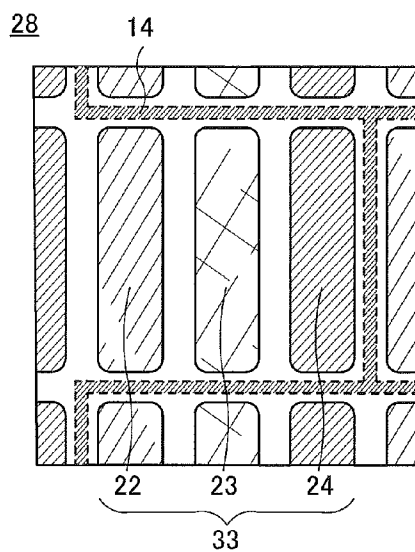
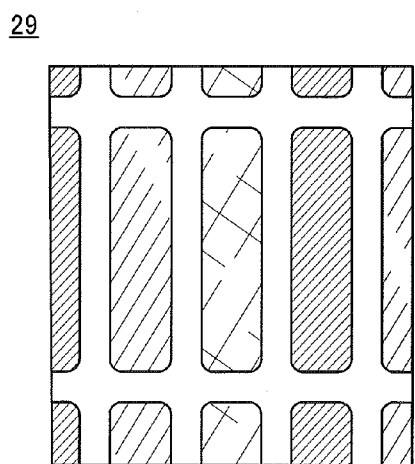


FIG. 6B



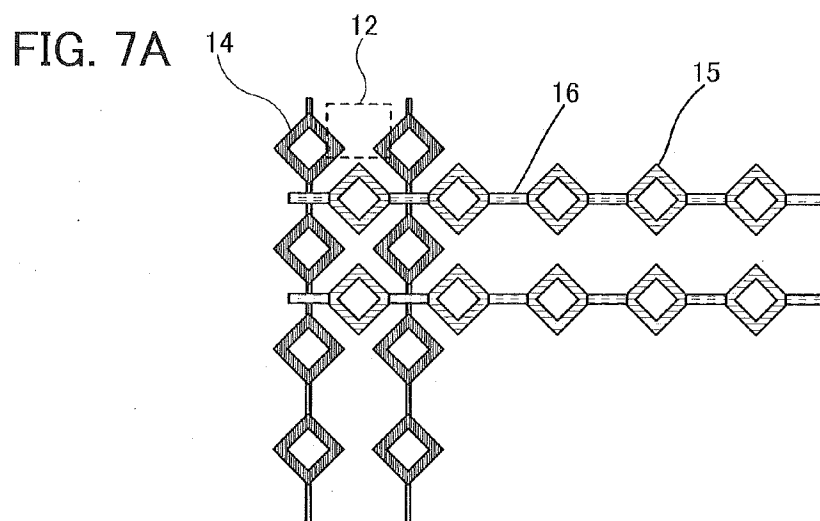
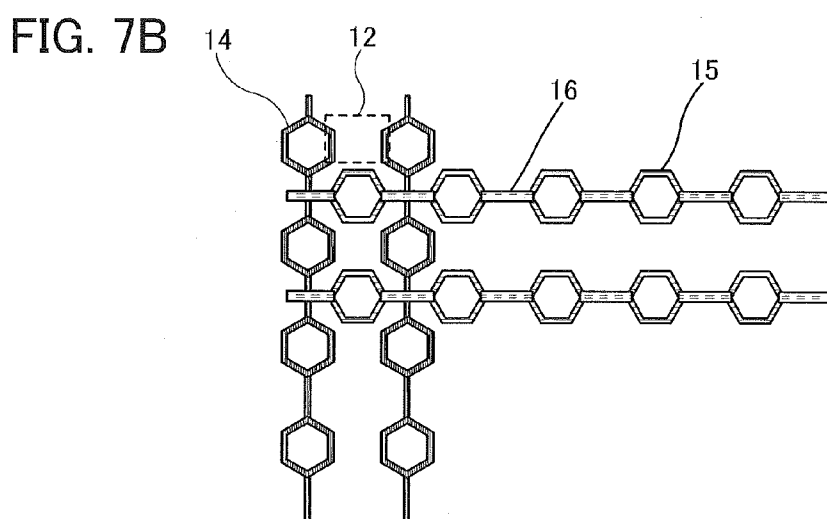
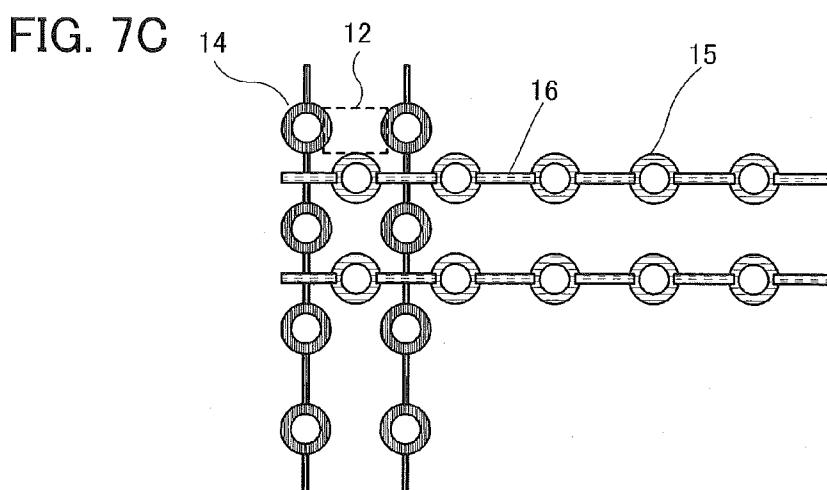


FIG. 8

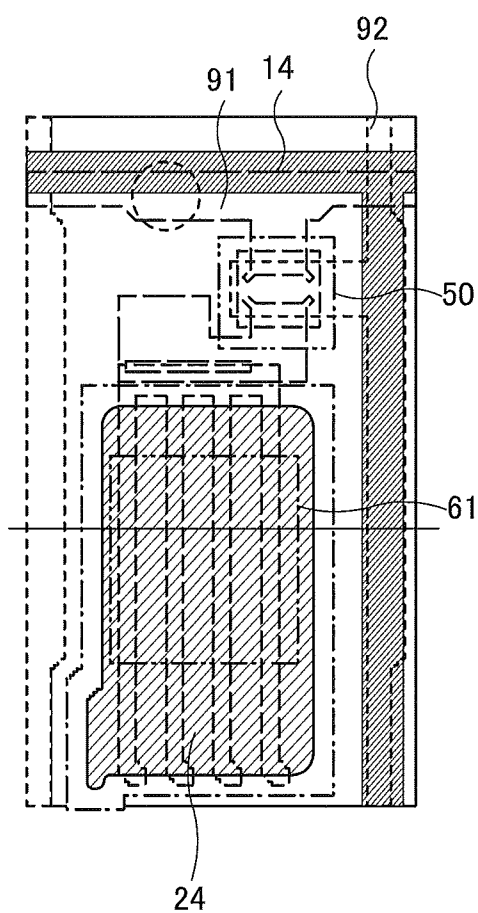


FIG. 9A

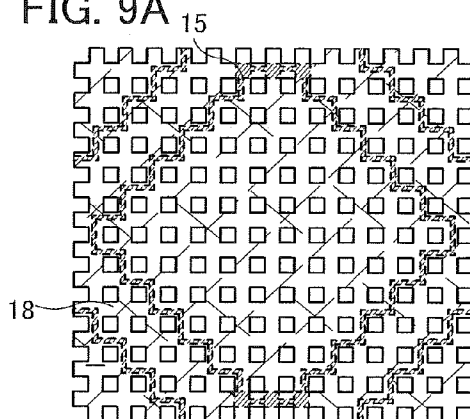


FIG. 9B

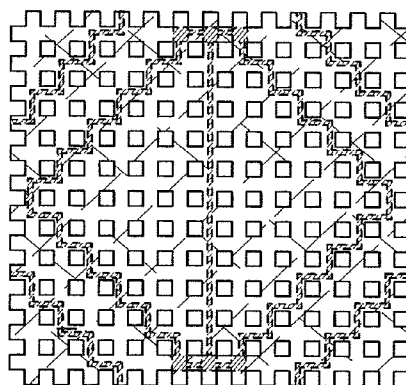


FIG. 9C

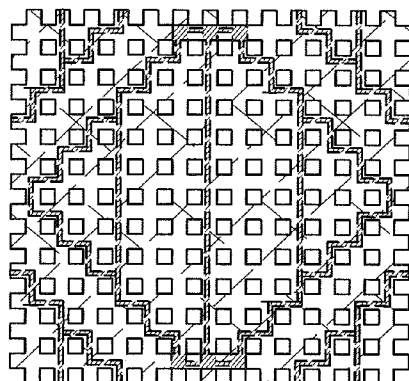


FIG. 9D

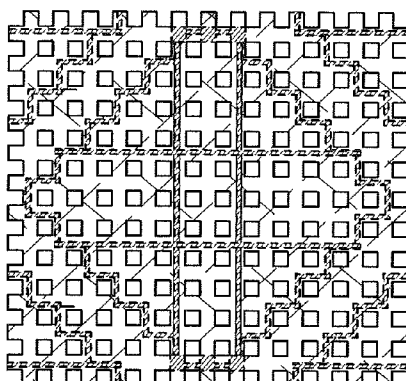


FIG. 9E

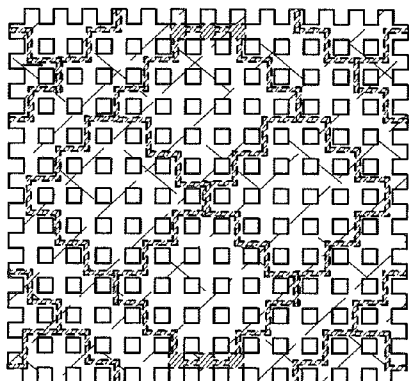


FIG. 9F

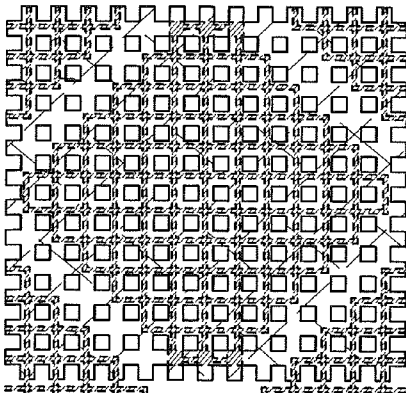


FIG. 10A

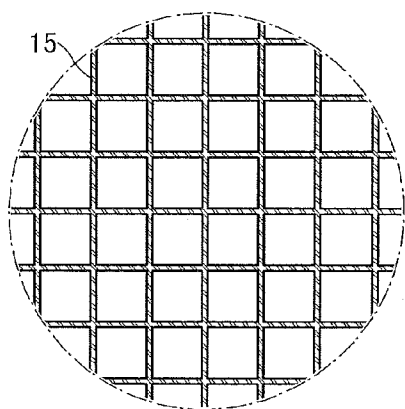


FIG. 10B

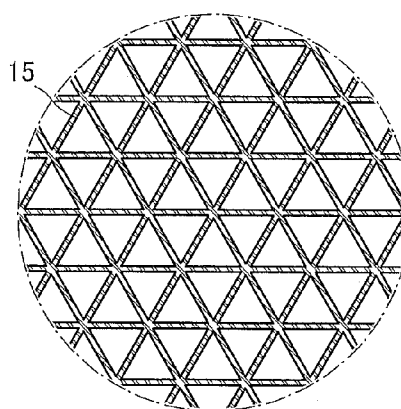


FIG. 10C

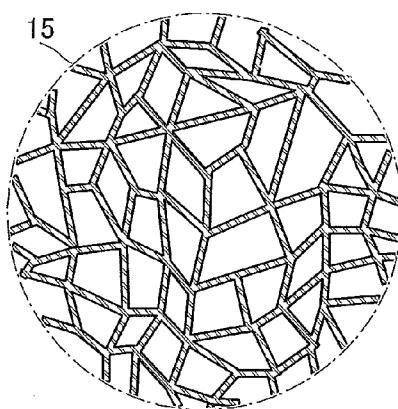


FIG. 10D

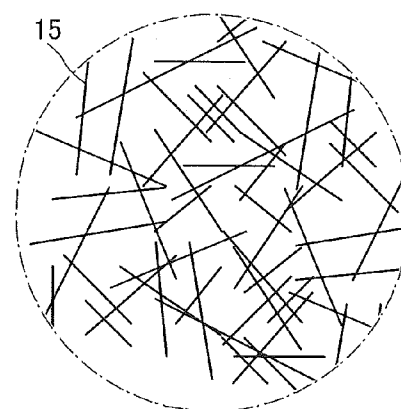


FIG. 11A

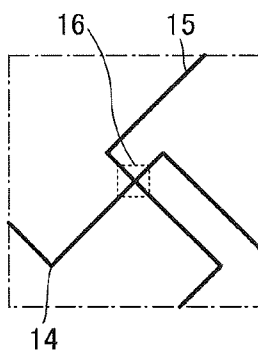


FIG. 11B

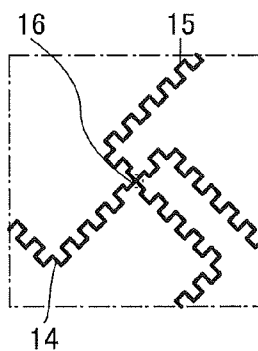


FIG. 11C

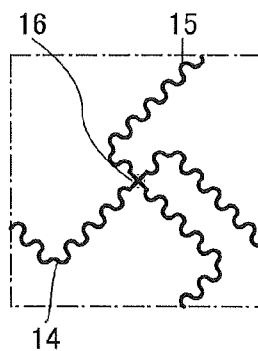


FIG. 11D

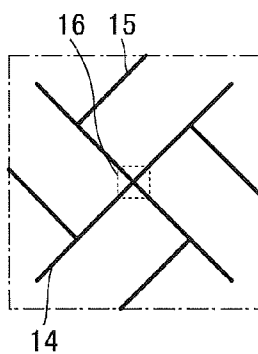


FIG. 11E

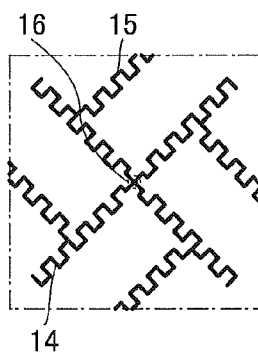


FIG. 11F

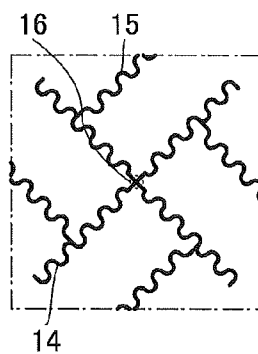


FIG. 12A

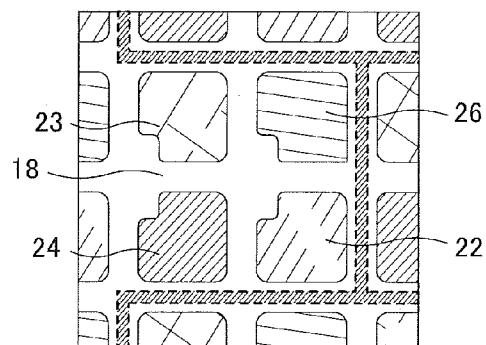


FIG. 12B

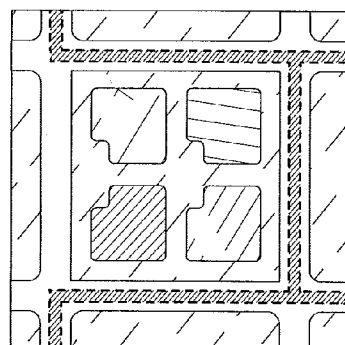


FIG. 12C

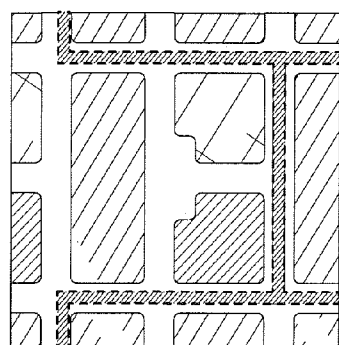


FIG. 12D

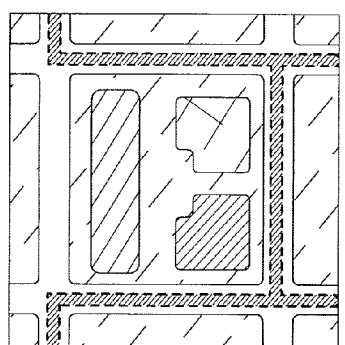


FIG. 12E

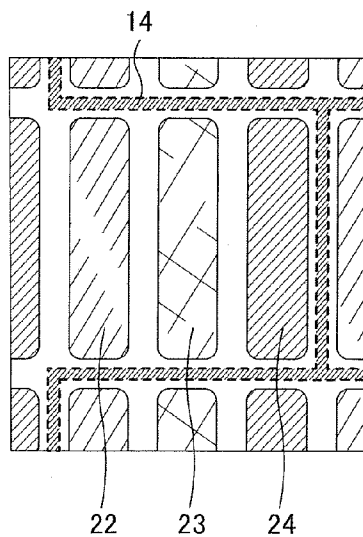


FIG. 12F

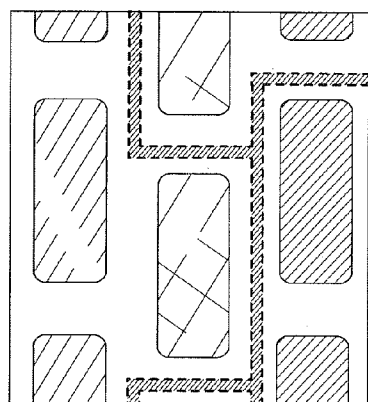


FIG. 13A

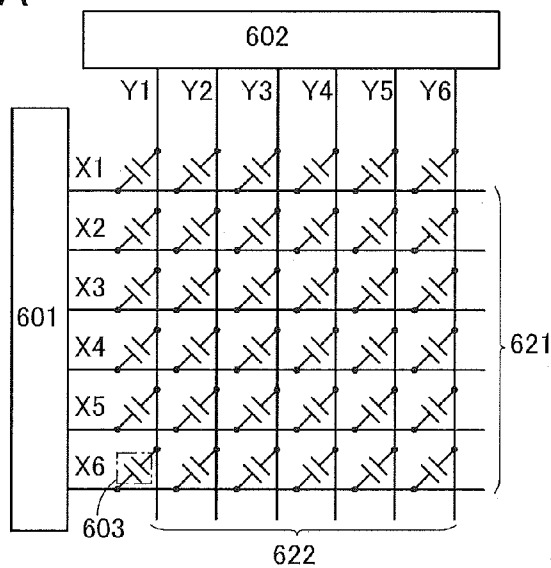


FIG. 13B

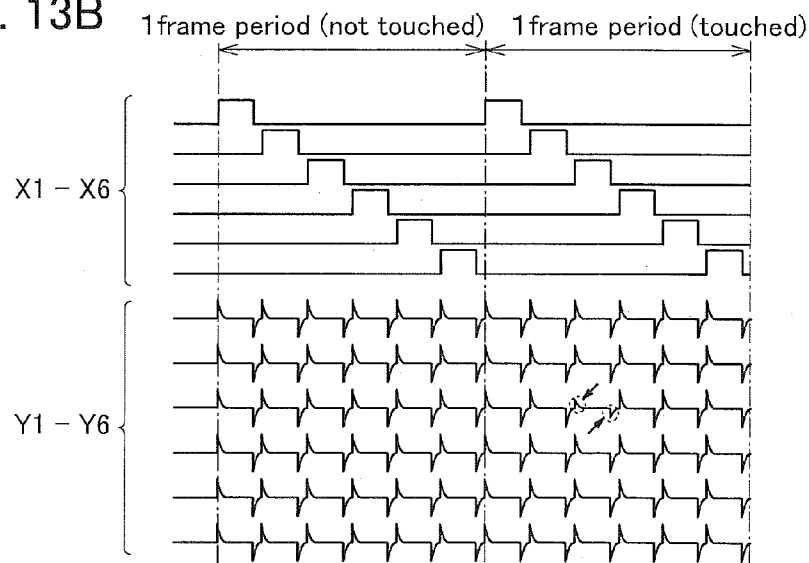
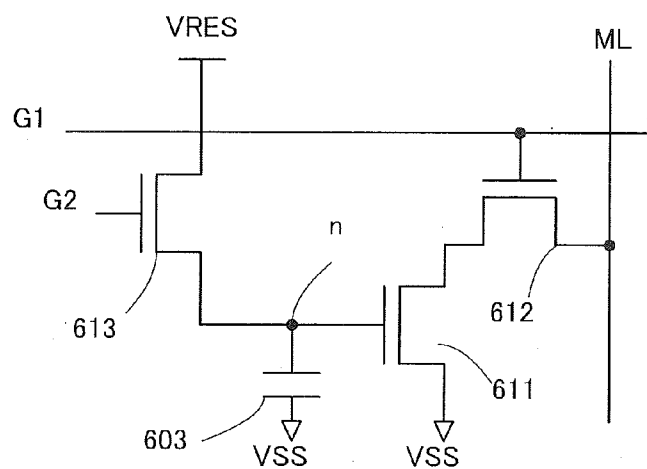
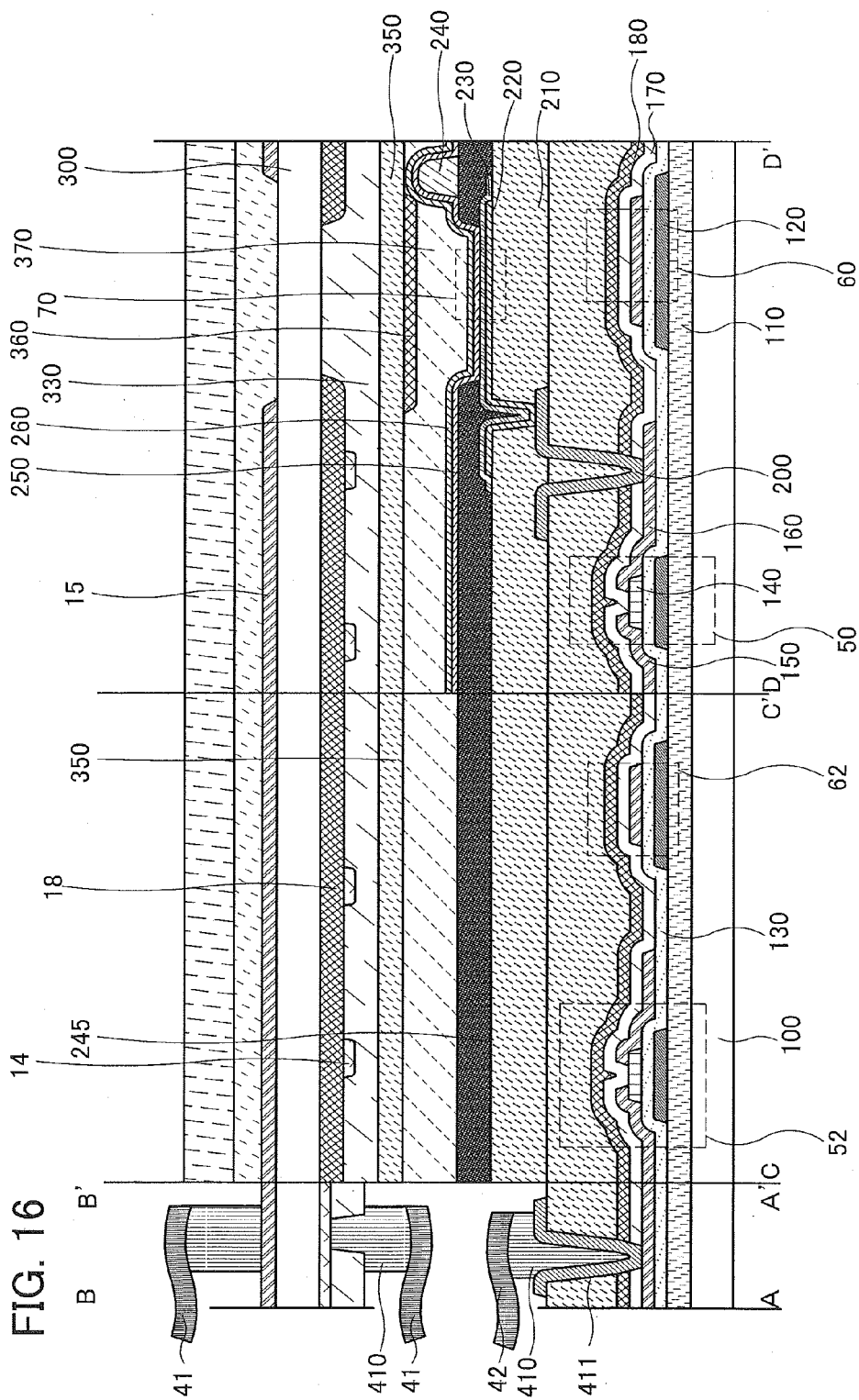


FIG. 14





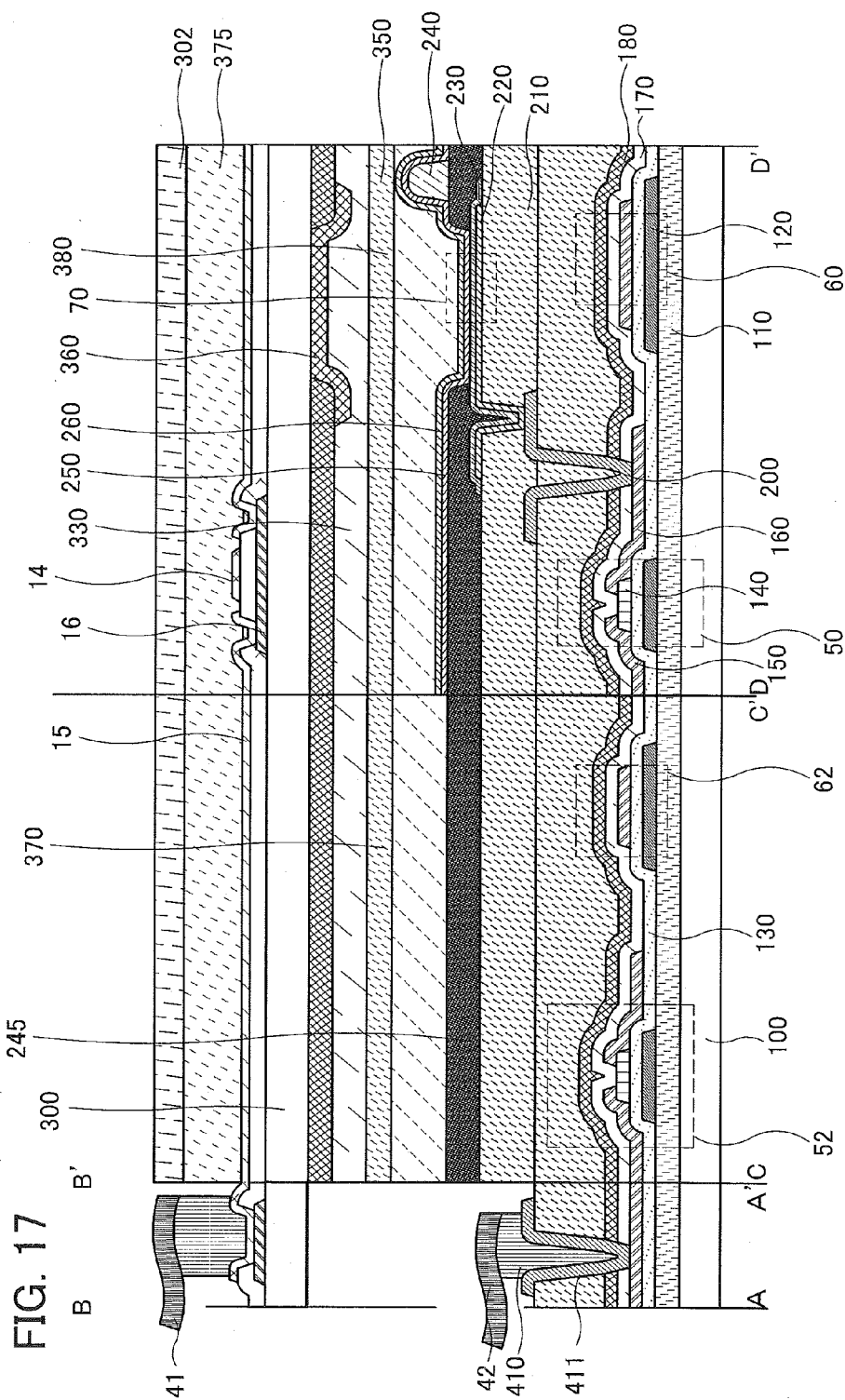
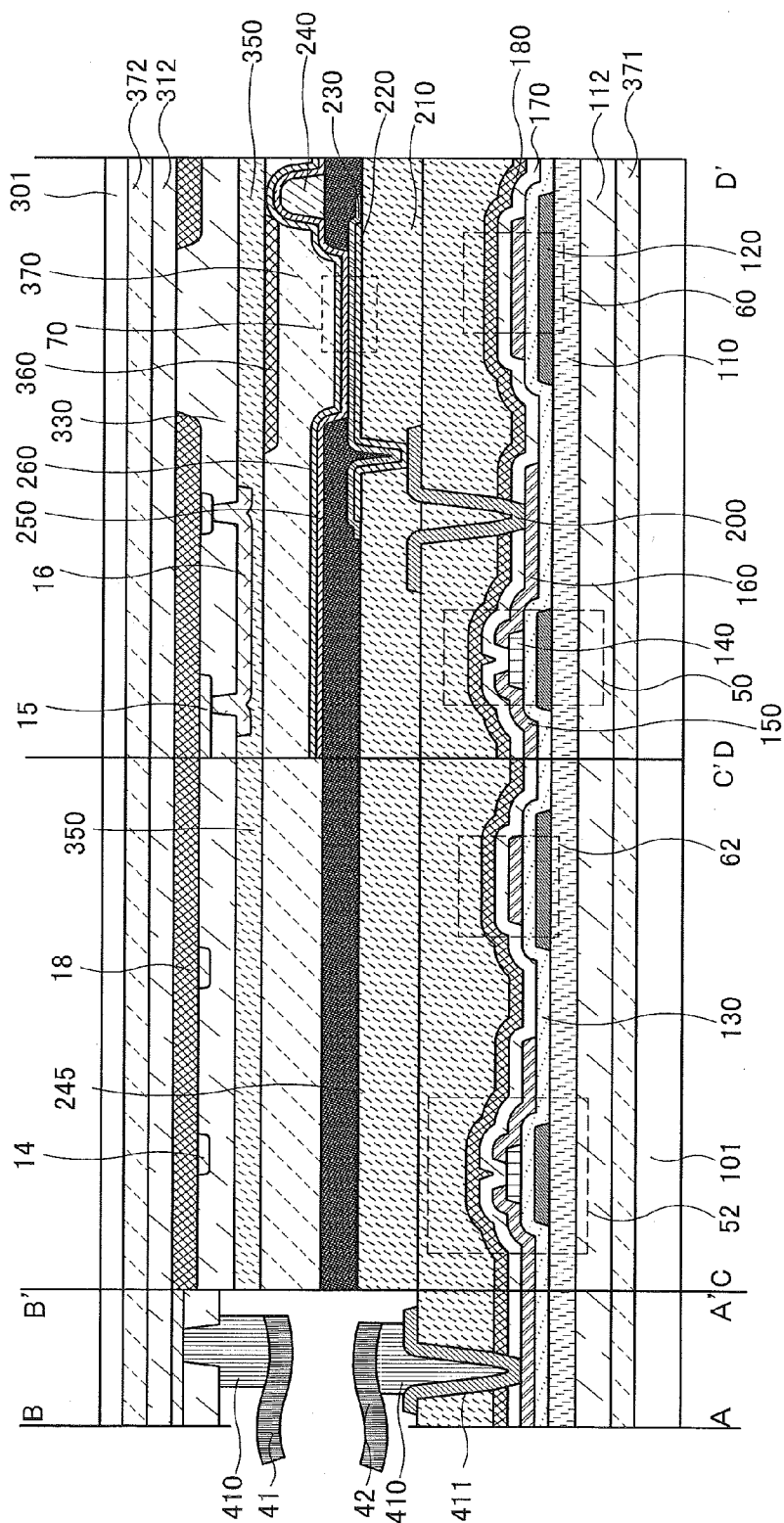
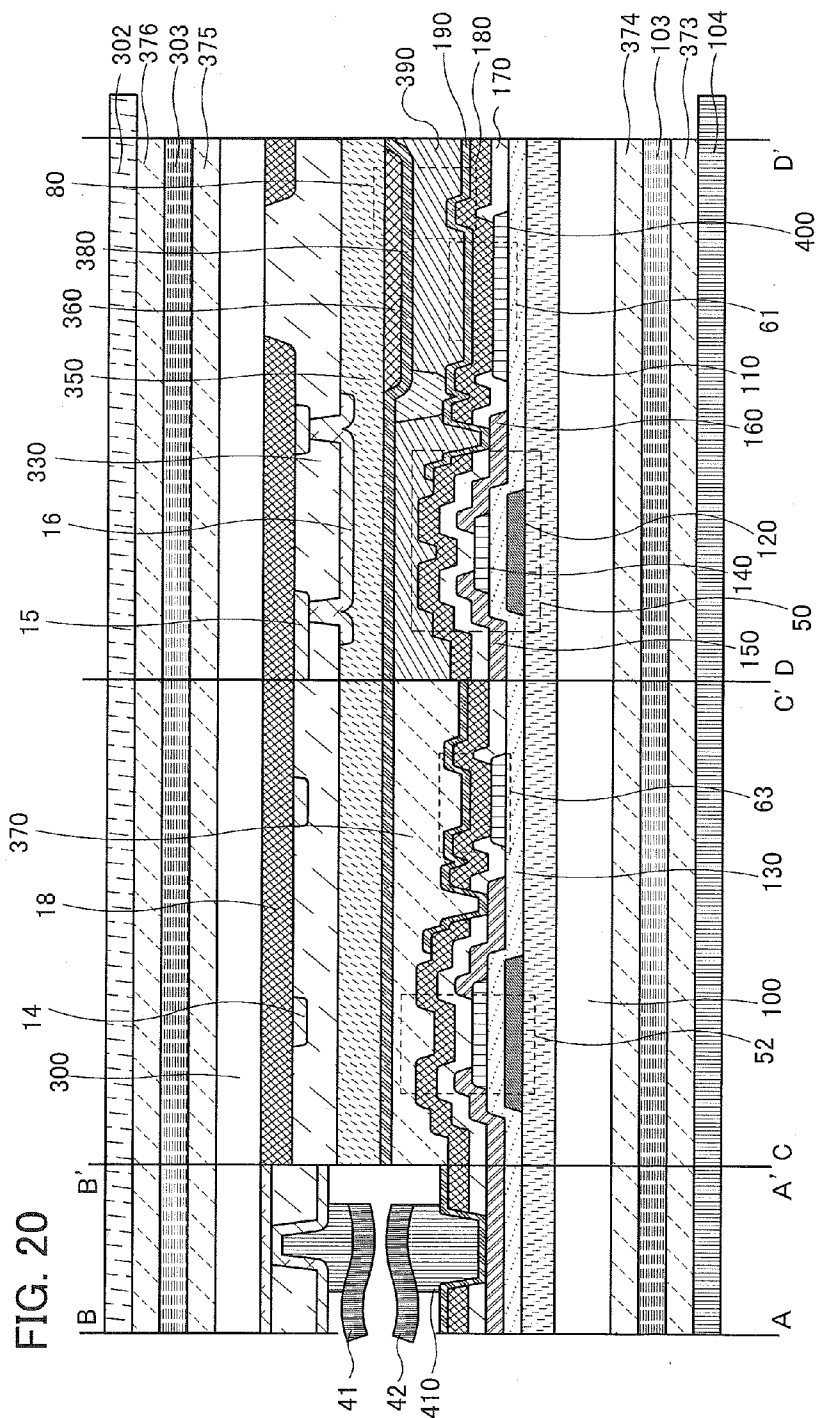


FIG. 19





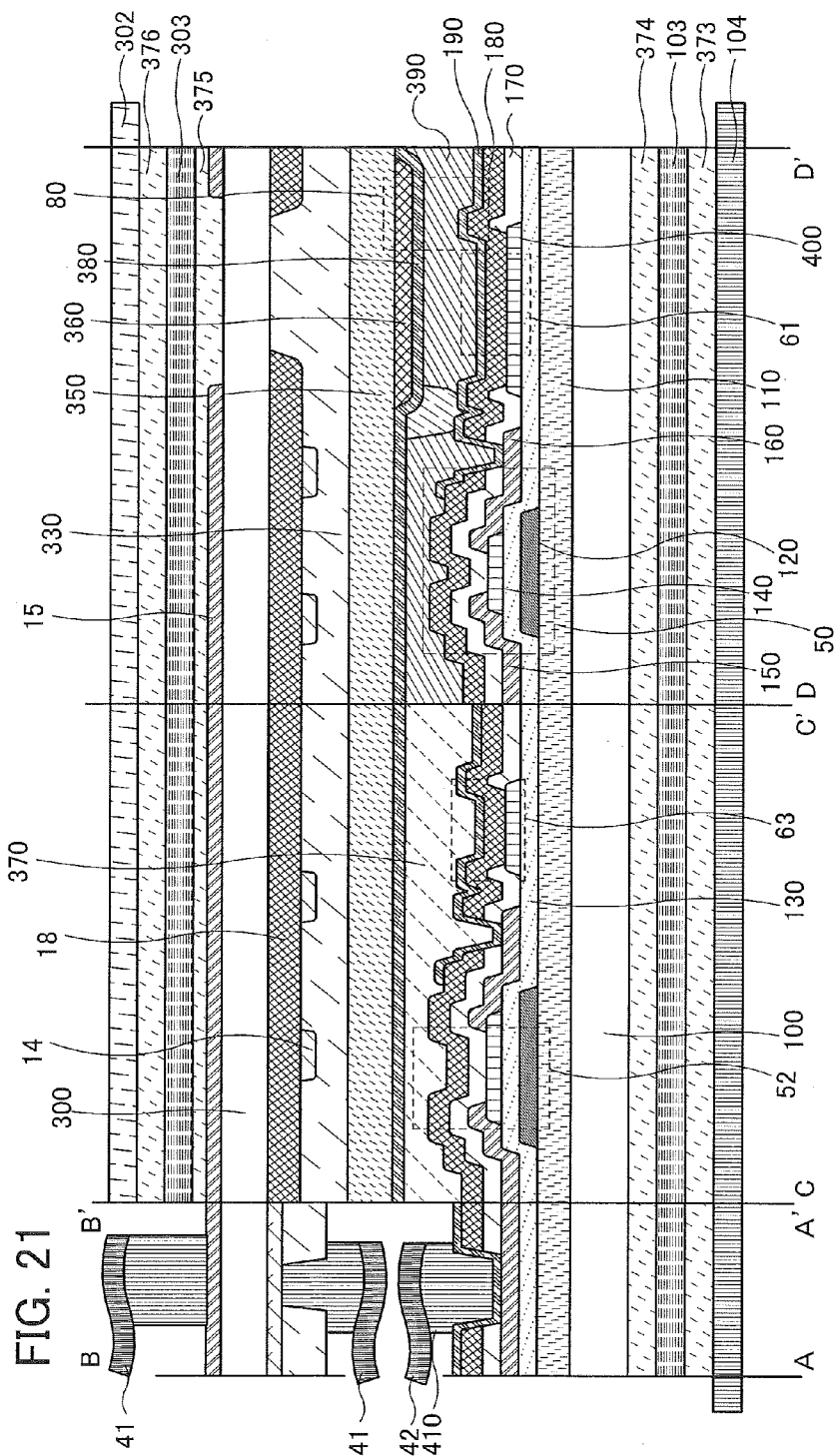
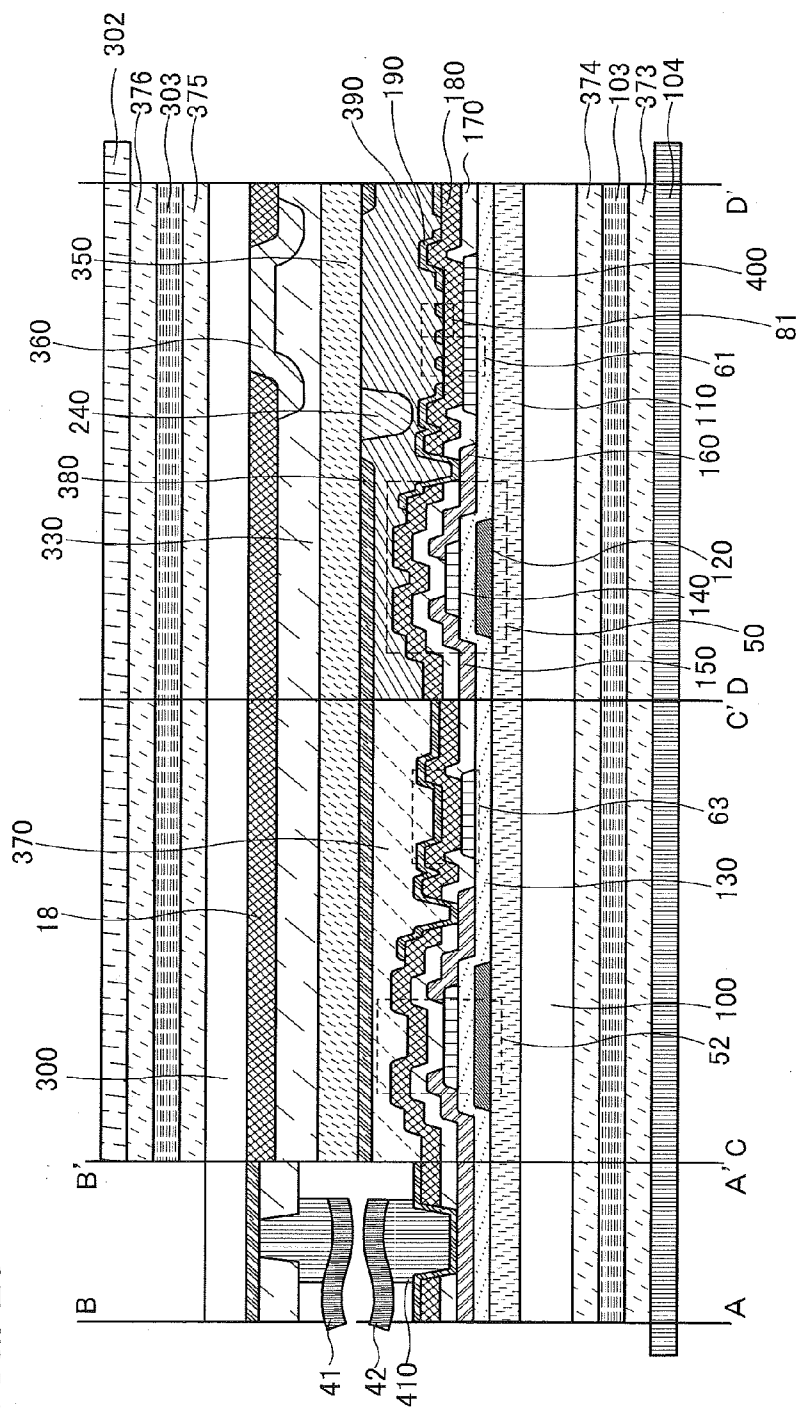


FIG. 23



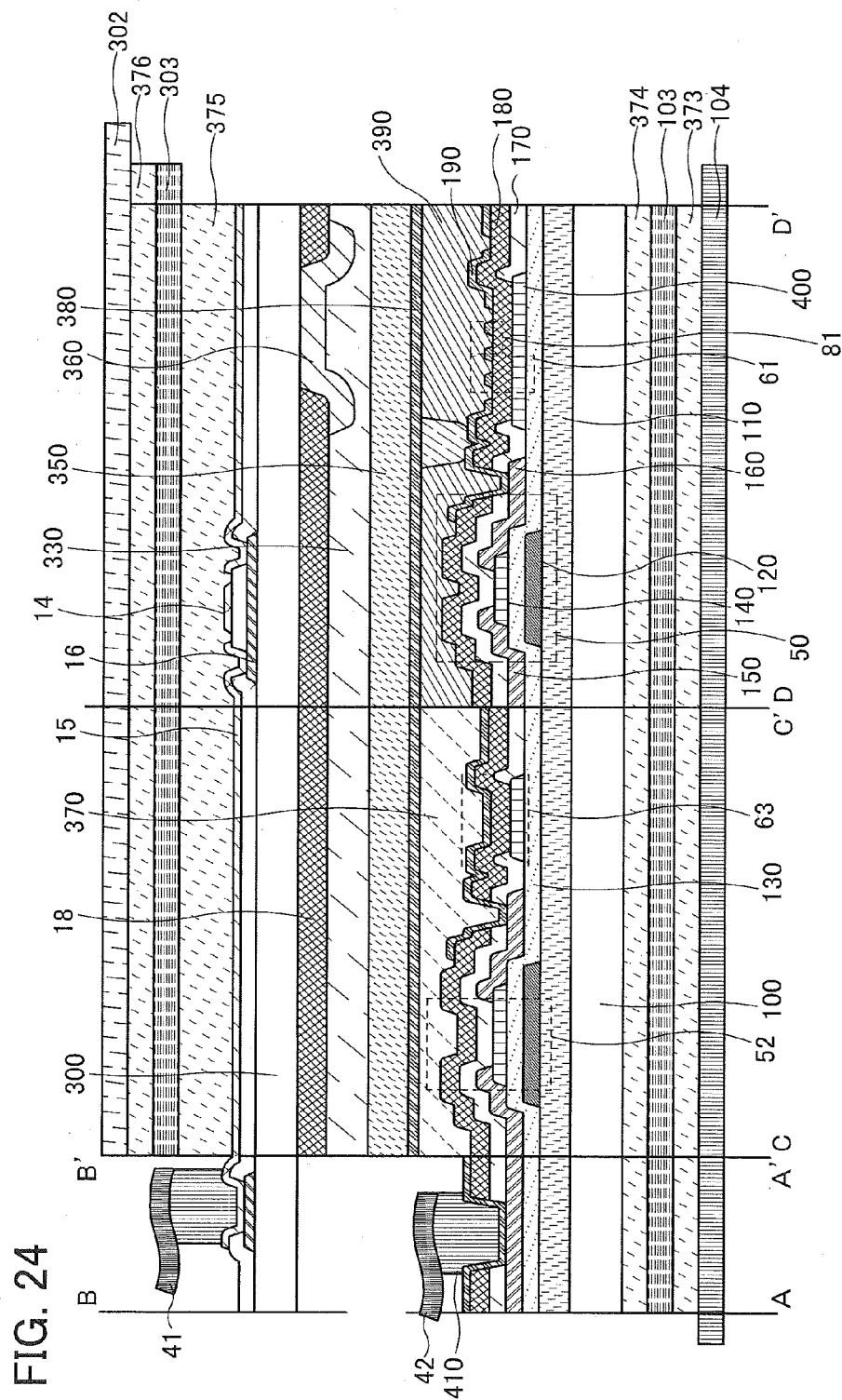


FIG. 25

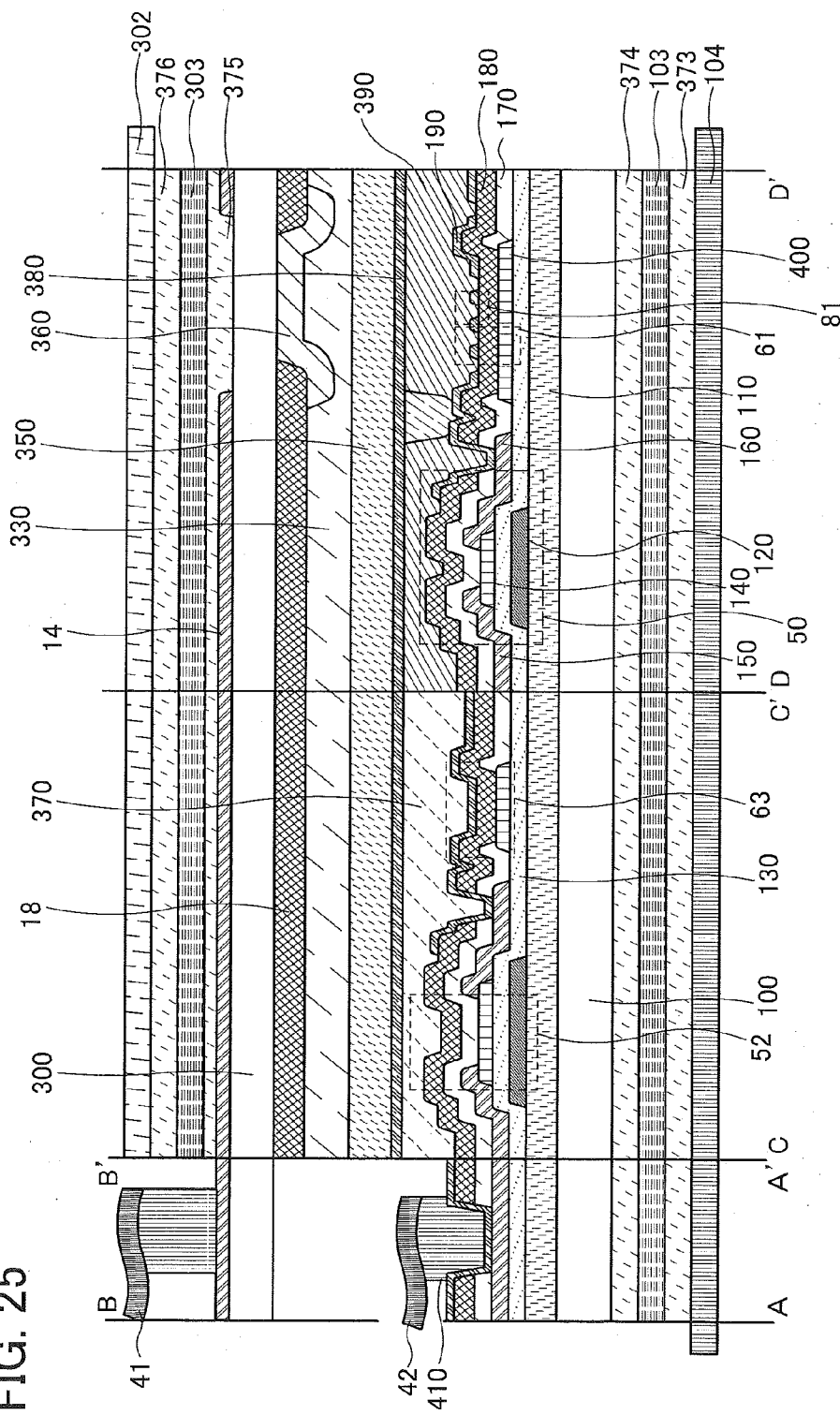


FIG. 26A

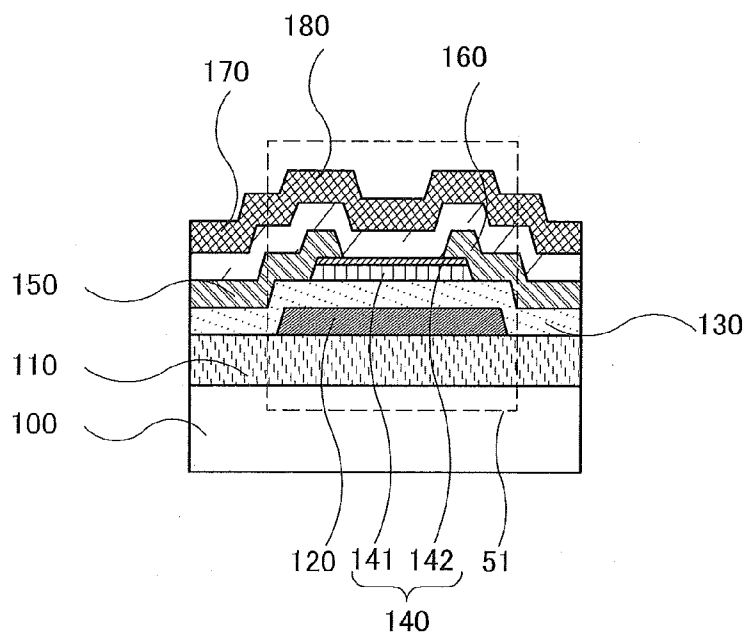


FIG. 26B

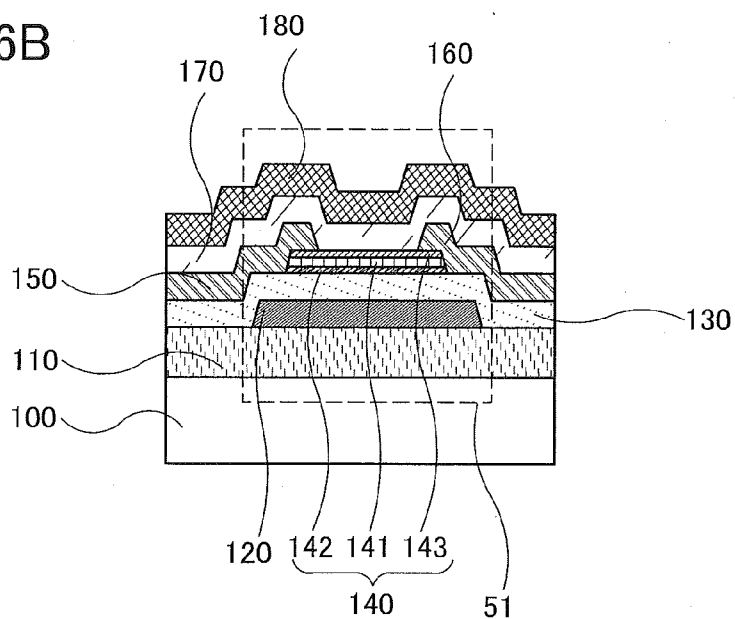


FIG. 27A

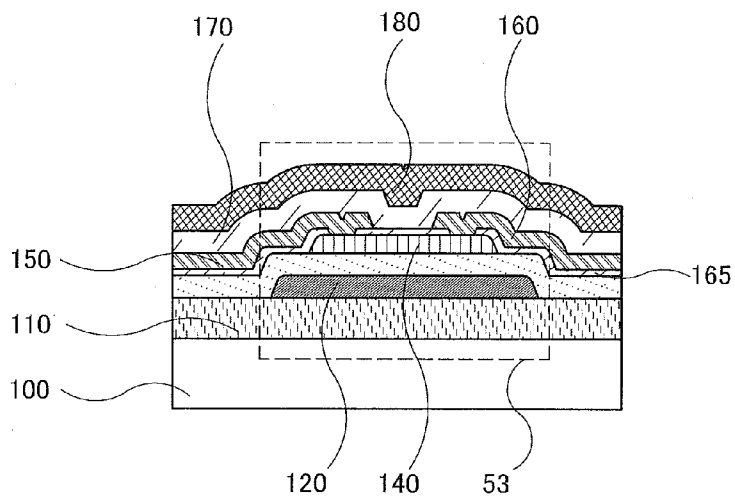


FIG. 27B

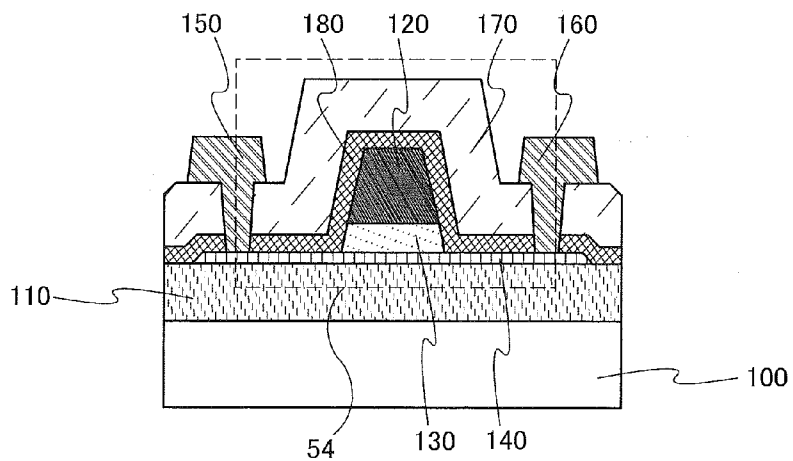


FIG. 28A

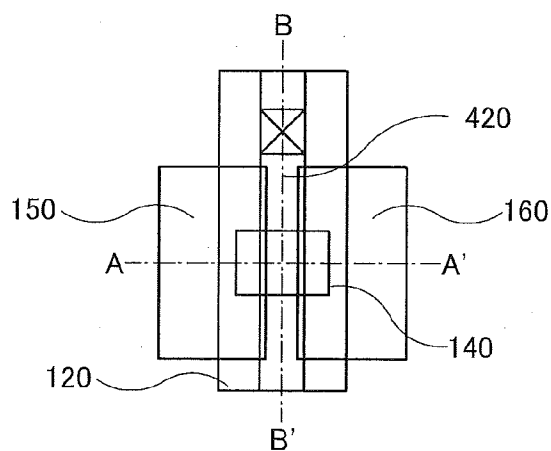


FIG. 28B

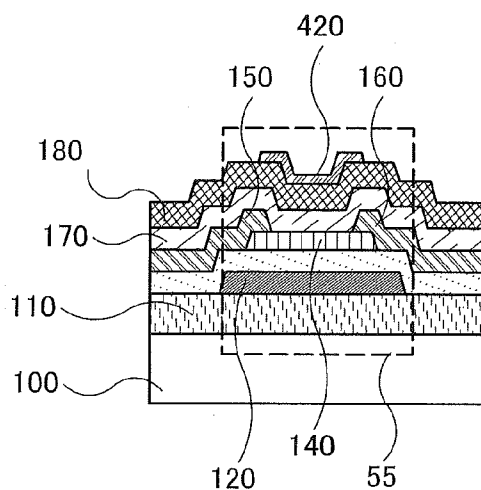


FIG. 28C

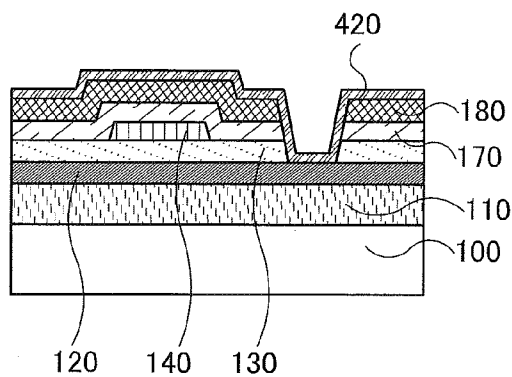


FIG. 29A

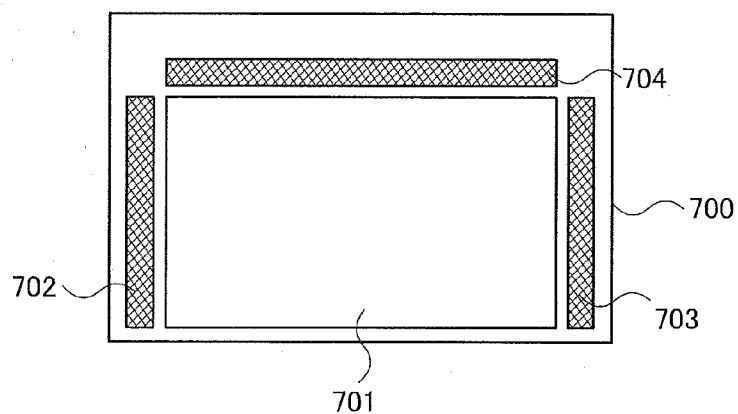


FIG. 29B

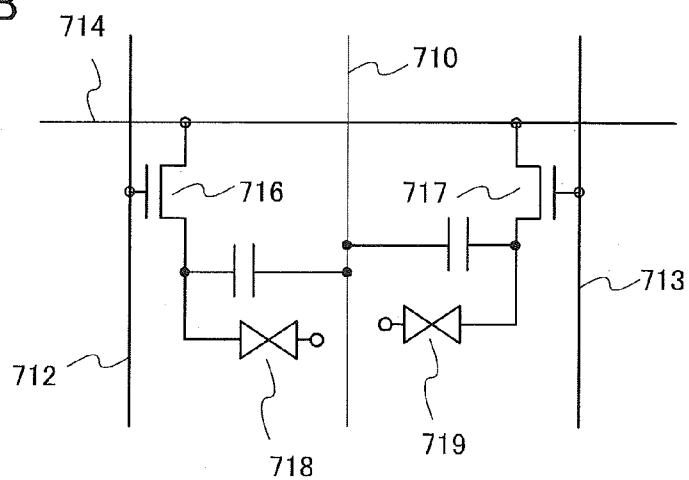


FIG. 29C

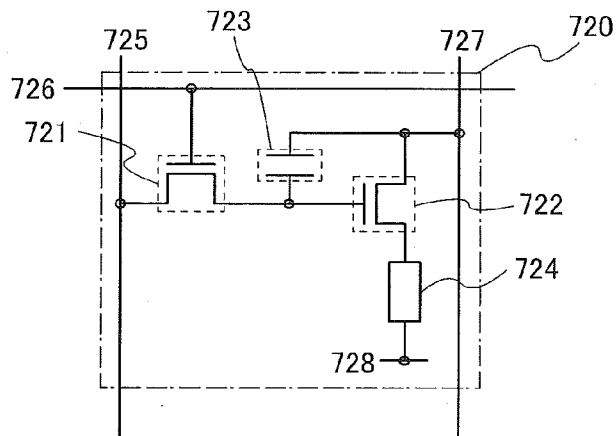


FIG. 30A

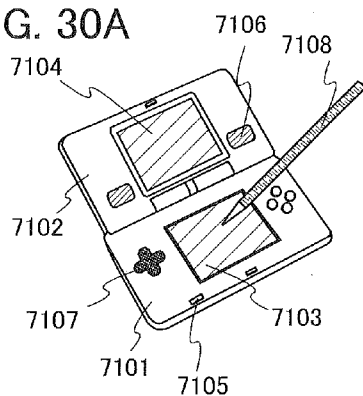


FIG. 30B

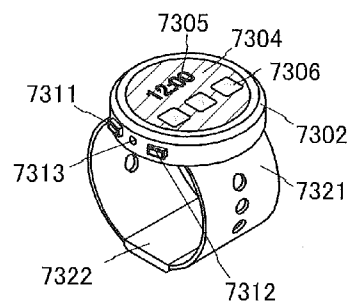


FIG. 30D

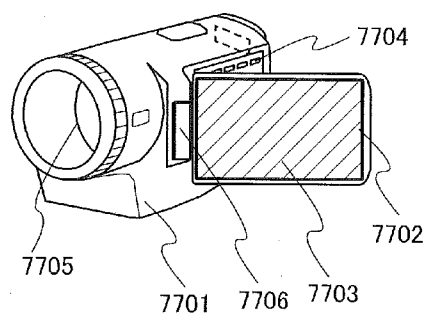


FIG. 30C

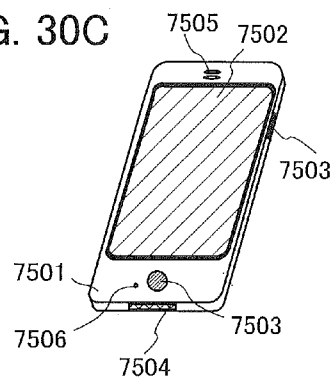


FIG. 30E

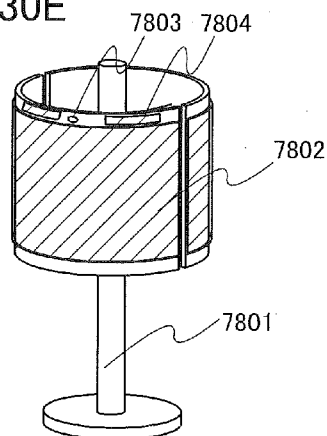


FIG. 30F

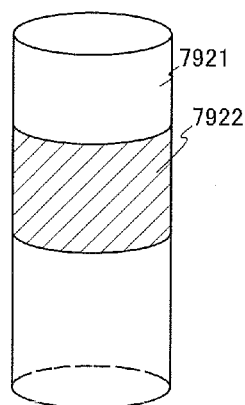


FIG. 31A

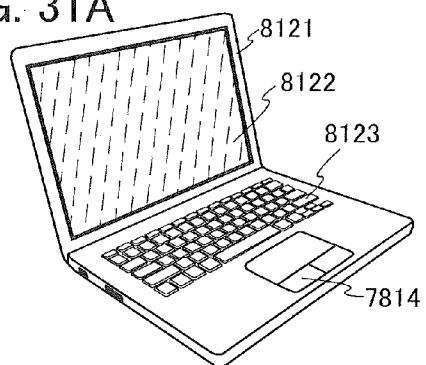


FIG. 31B

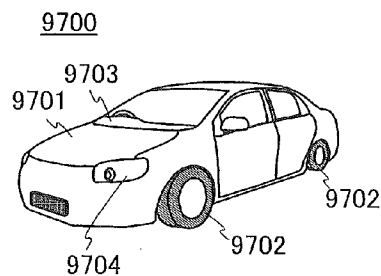


FIG. 31C

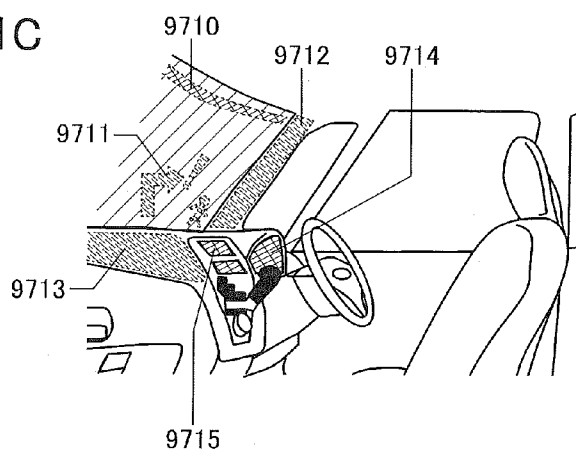
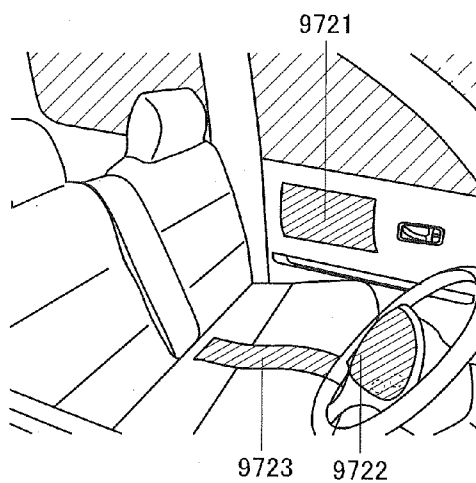


FIG. 31D



TOUCH PANEL AND ELECTRONIC DEVICE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] One embodiment of the present invention relates to a touch panel.

[0003] Note that one embodiment of the present invention is not limited to the above technical field. The technical field of the invention disclosed in this specification and the like relates to an object, a method, or a manufacturing method. In addition, one embodiment of the present invention relates to a process, a machine, manufacture, or a composition of matter. 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 device, a power storage device, a memory device, an input device, an input/output device, a method for driving any of them, and a method for manufacturing any of them.

[0004] In this specification and the like, a semiconductor device generally means a device that can function by utilizing semiconductor characteristics. A semiconductor element such as a transistor, a semiconductor circuit, an arithmetic device, and a memory device are each an embodiment of a semiconductor device. An imaging device, a display device, a liquid crystal display device, a light-emitting device, an electro-optical device, a power generation device (including a thin film solar cell, an organic thin film solar cell, and the like), and an electronic device may each include a semiconductor device.

[0005] 2. Description of the Related Art

[0006] Touch panels in which data input devices including touch sensors are combined with display panels are widely spread all over the world. Touch panels are extremely important especially in portable information terminals, and have been developed globally to achieve further progress of the information society (see Patent Document 1).

[0007] Patent Document 2 discloses a flexible active matrix light-emitting device in which a light-emitting element and a transistor serving as a switching element are provided over a film substrate. Such light-emitting devices with flexibility have also been developed.

REFERENCE

Patent Documents

[0008] [Patent Document 1] Japanese Published Patent Application No. 2012-256819

[0009] [Patent Document 2] Japanese Published Patent Application No. 2003-174153

SUMMARY OF THE INVENTION

[0010] Many electronic devices include touch panels as user interfaces in which data can be input to display panels when a finger, a stylus, or the like touches screens.

[0011] An electronic device including an input/output device such as a touch panel is required to respond instantly when touched; thus, a touch panel that can respond quickly is demanded.

[0012] It is also required that an electronic device including a touch panel be reduced in thickness and weight. Thus, a touch panel itself is required to reduce its thickness and weight.

[0013] A touch panel can be provided with a data input device including a touch sensor on the viewer side (display surface side) of a display panel.

[0014] Note that in the case of a touch panel provided with a data input device including a capacitive touch sensor, parasitic capacitance is increased when the distance between wirings included in the touch sensor is reduced, which might cause a reduction in the response speed or the touch sensitivity of the touch sensor.

[0015] An object of one embodiment of the present invention is to provide a touch panel including a touch sensor that performs high-speed detection.

[0016] Another object of one embodiment of the present invention is to provide a touch panel including a touch sensor with high detection accuracy.

[0017] Another object of one embodiment of the present invention is to provide a light touch panel.

[0018] Another object of one embodiment of the present invention is to provide a touch panel including a high-resolution display panel.

[0019] Another object of one embodiment of the present invention is to provide a highly reliable touch panel.

[0020] Another object of one embodiment of the present invention is to provide a low-power touch panel.

[0021] Another object of one embodiment of the present invention is to provide a novel display device or the like.

[0022] Note that the description of these objects does not preclude the existence of other objects. In one embodiment of the present invention, there is no need to achieve all the objects. Other objects will be apparent from and can be derived from the description of the specification, the drawings, the claims, and the like.

[0023] One embodiment of the present invention is a touch panel including a data input device and a display panel. The data input device overlaps with the display panel. The data input device includes a light-blocking layer, a first conductive layer, a second conductive layer, a third conductive layer, an insulating layer, and a coloring layer. The light-blocking layer overlaps with the first conductive layer. The light-blocking layer overlaps with the second conductive layer. The light-blocking layer overlaps with the third conductive layer. The first conductive layer overlaps with the third conductive layer. The second conductive layer overlaps with the third conductive layer. The second conductive layer is electrically connected to the third conductive layer. The widths of the first conductive layer, the second conductive layer, and the third conductive layer are each smaller than the width of the light-blocking layer. The first conductive layer, the second conductive layer, and the third conductive layer are arranged to have a mesh pattern when seen from the top, and to surround pixels in the display panel.

[0024] Another embodiment of the present invention is a touch panel including a data input device and a display panel. The data input device includes a first substrate. The display panel includes a second substrate. The first substrate and the second substrate are flexible. The data input device overlaps with the display panel. The data input device includes a light-blocking layer, a first conductive layer, a second conductive layer, a third conductive layer, an insulating layer, and a coloring layer. The light-blocking layer overlaps with the first conductive layer. The light-blocking layer overlaps with the second conductive layer. The light-blocking layer overlaps with the third conductive layer. The first conductive layer overlaps with the third conductive layer. The second conductive layer overlaps with the third conductive layer. The second conductive layer is electrically connected to the third conductive layer. The widths of the first conductive layer, the second conductive layer, and the third conductive layer are each smaller than the width of the light-blocking layer. The first conductive layer, the second conductive layer, and the third conductive layer are arranged to have a mesh pattern when seen from the top, and to surround pixels in the display panel.

tive layer overlaps with the third conductive layer. The second conductive layer is electrically connected to the third conductive layer. The widths of the first conductive layer, the second conductive layer, and the third conductive layer are each smaller than the width of the light-blocking layer. The first conductive layer, the second conductive layer, and the third conductive layer are arranged to have a mesh pattern when seen from the top, and to surround pixels in the display panel.

[0025] The display panel can be provided with an organic EL element.

[0026] The display panel can be provided with a liquid crystal element.

[0027] The first conductive layer, the second conductive layer, and the third conductive layer are preferably arranged such that the distance between adjacent portions of the first conductive layer, the distance between adjacent portions of the second conductive layer, and the distance between adjacent third conductive layers are each larger than the width of one pixel.

[0028] The first conductive layer, the second conductive layer, and the third conductive layer are preferably formed using a metal element selected from aluminum, silver, copper, palladium, chromium, tantalum, titanium, molybdenum, nickel, iron, cobalt, tungsten, manganese, and zirconium; an alloy containing any of the metal elements; or an alloy containing two or more of the metal elements.

[0029] One embodiment of the present invention is an electronic device including the touch panel, a microphone, and a speaker.

[0030] Note that other embodiments of the present invention will be shown below in the description of Embodiments and the drawings.

[0031] One embodiment of the present invention can provide a touch panel including a touch sensor that performs high-speed detection.

[0032] Another embodiment of the present invention can provide a touch panel including a touch sensor with high detection accuracy.

[0033] Another embodiment of the present invention can provide a touch panel including a high-resolution display panel.

[0034] Another embodiment of the present invention can provide a light touch panel.

[0035] Another embodiment of the present invention can provide a highly reliable touch panel.

[0036] Another embodiment of the present invention can provide a low-power touch panel.

[0037] Another embodiment of the present invention can provide a novel display device or the like.

[0038] Note that the description of these effects does not preclude the existence of other effects. One embodiment of the present invention does not necessarily have all the effects listed above. Other effects will be apparent from and can be derived from the description of the specification, the drawings, the claims, and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] FIGS. 1A and 1B are a side view and a top view illustrating a touch panel of one embodiment of the present invention.

[0040] FIGS. 2A and 2B are a cross-sectional view and a top view illustrating a data input device of one embodiment of the present invention.

[0041] FIGS. 3A and 3B are a cross-sectional view and a top view illustrating a data input device of one embodiment of the present invention.

[0042] FIGS. 4A to 4C are top views illustrating a touch panel of one embodiment of the present invention.

[0043] FIGS. 5A and 5B are top views illustrating a touch panel of one embodiment of the present invention.

[0044] FIGS. 6A and 6B are top views illustrating a touch panel of one embodiment of the present invention.

[0045] FIGS. 7A to 7C are top views each illustrating a data input device of one embodiment of the present invention.

[0046] FIG. 8 is a top view illustrating a touch panel of one embodiment of the present invention.

[0047] FIGS. 9A to 9F are top views each illustrating a data input device of one embodiment of the present invention.

[0048] FIGS. 10A to 10D are top views each illustrating a data input device of one embodiment of the present invention.

[0049] FIGS. 11A to 11F are top views each illustrating a data input device of one embodiment of the present invention.

[0050] FIGS. 12A to 12F are top views each illustrating a touch panel of one embodiment of the present invention.

[0051] FIGS. 13A and 13B are a block diagram and a timing chart for describing an embodiment of a circuit of one embodiment of the present invention.

[0052] FIG. 14 is a circuit diagram illustrating an embodiment of a circuit of one embodiment of the present invention.

[0053] FIGS. 15A and 15B are a top view and a cross-sectional view illustrating a touch panel of one embodiment of the present invention.

[0054] FIG. 16 is a cross-sectional view illustrating a touch panel of one embodiment of the present invention.

[0055] FIG. 17 is a cross-sectional view illustrating a touch panel of one embodiment of the present invention.

[0056] FIG. 18 is a cross-sectional view illustrating a touch panel of one embodiment of the present invention.

[0057] FIG. 19 is a cross-sectional view illustrating a touch panel of one embodiment of the present invention.

[0058] FIG. 20 is a cross-sectional view illustrating a touch panel of one embodiment of the present invention.

[0059] FIG. 21 is a cross-sectional view illustrating a touch panel of one embodiment of the present invention.

[0060] FIG. 22 is a cross-sectional view illustrating a touch panel of one embodiment of the present invention.

[0061] FIG. 23 is a cross-sectional view illustrating a touch panel of one embodiment of the present invention.

[0062] FIG. 24 is a cross-sectional view illustrating a touch panel of one embodiment of the present invention.

[0063] FIG. 25 is a cross-sectional view illustrating a touch panel of one embodiment of the present invention.

[0064] FIGS. 26A and 26B are cross-sectional views each illustrating a transistor of one embodiment of the present invention.

[0065] FIGS. 27A and 27B are cross-sectional views each illustrating a transistor of one embodiment of the present invention.

[0066] FIGS. 28A to 28C are a top view and cross-sectional views illustrating a transistor of one embodiment of the present invention.

[0067] FIGS. 29A to 29C are a top view and circuit diagrams each illustrating a display device of one embodiment of the present invention.

[0068] FIGS. 30A to 30F illustrate electronic devices of one embodiment of the present invention.

[0069] FIGS. 31A to 31D illustrate electronic devices of one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0070] Embodiments will be described in detail with reference to drawings. Note that the present invention is not limited to the description below, and it is easily understood by those skilled in the art that various changes and modifications can be made without departing from the spirit and scope of the present invention. Accordingly, the present invention should not be interpreted as being limited to the content of the embodiments below. Note that in the 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 the description of such portions is not repeated.

[0071] In this specification and the like, a structure in which a flexible printed circuit (FPC), a tape carrier package (TCP), or the like is attached to a substrate of a touch panel, or a structure in which an integrated circuit (IC) is directly mounted on a substrate by a chip on glass (COG) method is referred to as a touch panel module or simply referred to as a touch panel in some cases.

[0072] Note that the terms “film” and “layer” can be interchanged with each other depending on the case or circumstances. For example, the term “conductive layer” can be changed into the term “conductive film” in some cases. In addition, the term “insulating film” can be changed into the term “insulating layer” in some cases.

[0073] In this specification and the like, a transistor is an element having at least three terminals: a gate, a drain, and a source. The transistor has a channel region between the drain (a drain terminal, a drain region, or a drain electrode) and the source (a source terminal, a source region, or a source electrode), and current can flow through the drain, the channel region, and the source.

[0074] Since the source and the drain of the transistor change depending on the structure, operating conditions, and the like of the transistor, it is difficult to define which is a source or a drain. Thus, a portion that functions as a source or a portion is not referred to as a source or a drain in some cases. In that case, one of the source and the drain might be referred to as a first electrode, and the other of the source and the drain might be referred to as a second electrode.

[0075] In this specification, ordinal numbers such as first, second, and third are used to avoid confusion among components, and thus do not limit the number of the components.

[0076] In this specification, the expression “A and B are connected” means the case where A and B are electrically connected to each other in addition to the case where A and B are directly connected to each other. Here, the expression “A and B are electrically connected” means the case where electric signals can be transmitted and received between A and B when an object having any electric action exists between A and B.

[0077] In this specification, terms for explaining arrangement, such as “over” and “under”, are used for convenience to describe the positional relationship between components with reference to drawings. The positional relationship between components is changed as appropriate in accordance with a direction in which each component is described. Thus, the positional relationship is not limited to that described with a term used in this specification and can be explained with another term as appropriate depending on the situation.

[0078] In this specification, the term “parallel” indicates that the angle formed between two straight lines is greater than or equal to -10° and less than or equal to 10° , and accordingly also includes the case where the angle is greater than or equal to -5° and less than or equal to 5° . The term “substantially parallel” indicates that the angle formed between two straight lines is greater than or equal to -30° and less than or equal to 30° . The term “perpendicular” indicates that the angle formed between two straight lines is greater than or equal to 80° and less than or equal to 100° , and accordingly includes the case where the angle is greater than or equal to 85° and less than or equal to 95° . The term “substantially perpendicular” indicates that the angle formed between two straight lines is greater than or equal to 60° and less than or equal to 120° .

[0079] In this specification, trigonal and rhombohedral crystal systems are included in a hexagonal crystal system.

Embodiment 1

[0080] In this embodiment, a structure example of a touch panel of one embodiment of the present invention will be described.

[0081] FIG. 1A is a side view of a touch panel 10. Note that in this specification and the like, the touch panel 10 includes a display panel 20 and a data input device 11 overlapping with each other. The display panel 20 has a function of displaying or outputting an image or the like on or to a display surface. The data input device 11 includes a touch sensor capable of sensing contact or proximity of an object such as a finger or a stylus on or to the display surface. Thus, the touch panel is one embodiment of an input/output device.

[0082] Note that the data input device does not need to have all data input functions. The display panel may have some of the data input functions, in which case the combination of the data input device and the display panel can have all data input functions.

<<Structure of Metal-Mesh Wiring>>

[0083] FIG. 1B is an enlarged view of a touch sensor 13 included in the data input device 11. FIG. 2A is a cross-sectional view taken along dashed-dotted line A-A' in FIG. 1B. FIG. 2B illustrates an example of a top view for clearly illustrating the positional relationship between conductive layers included in the touch sensor 13. Note that some components are not illustrated for simplification.

[0084] A conductive layer 14 functions as an electrode in one of the X direction and the Y direction, and conductive layers 15 collectively function as an electrode in the other of the X direction and the Y direction.

[0085] The conductive layer 14 and the conductive layer 15 are formed on the same surface. A conductive layer 16 is formed over an insulating layer 330 provided over the conductive layer 14 and the conductive layer 15. The conductive layer 14, the conductive layer 15, and the conductive layer 16 may be formed using the same material. The conductive layer 15 and the conductive layer 16 can be connected to each other through an opening 17. The conductive layer 16 electrically connecting the conductive layers 15 is provided at the intersection of the electrode in the X direction and the electrode in the Y direction. The conductive layers 14, 15, and 16 overlap with a light-blocking layer 18. In addition, the widths of the conductive layers 14, 15, and 16 are each smaller than the width of the light-blocking layer 18. Thus, in the case where

the light-blocking layer **18** is provided over the conductive layers **14**, **15**, and **16**, the conductive layers **14**, **15**, and **16** are hidden behind the light-blocking layer **18** and are hardly visually recognized from the top. Accordingly, a low-resistance material as well as a transparent material can be used for the conductive layers **14**, **15**, and **16**.

[0086] For the conductive layers **14**, **15**, and **16**, a visible-light transmitting material containing one or more of indium (In), zinc (Zn), and tin (Sn) is preferably used, for example. Alternatively, a metal element selected from aluminum, silver, copper, palladium, chromium, tantalum, titanium, molybdenum, nickel, iron, cobalt, and tungsten; an alloy containing any of these metal elements as a component; an alloy containing any of these metal elements in combination; or the like may be used. Further, one or more metal elements selected from manganese and zirconium may be used. The conductive layers **14**, **15**, and **16** may each have a single-layer structure or a layered structure of two or more layers. For example, any of the following can be used: a single-layer structure of an aluminum film containing silicon; a single-layer structure of a copper film containing manganese; 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 two-layer structure in which a copper film is stacked over a copper film containing manganese; a three-layer structure in which a titanium film, an aluminum film, and a titanium film are stacked in this order; a three-layer structure in which a copper film containing manganese, a copper film, and a copper film containing manganese are stacked in this order; and the like. Alternatively, an alloy film or a nitride film which contains aluminum and one or more elements selected from titanium, tantalum, tungsten, molybdenum, chromium, neodymium, and scandium may be used.

[0087] A metal nanowire including a plurality of conductors with extremely small widths (for example, a diameter of several nanometers) may be used. Examples of such a metal nanowire include an Ag nanowire, a Cu nanowire, and an Al nanowire. In the case of using an Ag nanowire, light transmittance can be 89% or more and a sheet resistance can be 40 ohm/square or more and 100 ohm/square or less. Note that because such a metal nanowire provides high transmittance, the metal nanowire may be used for an electrode of a display element, such as a pixel electrode or a common electrode. In that case, the conductive layers **14**, **15**, and **16** are not necessarily provided so as to be hidden behind the light-blocking layer, and can be provided over the light-blocking layer.

[0088] With the use of a low-resistance material for the conductive layers **14**, **15**, and **16**, data obtained by the touch sensor **13** can be sent instantly; thus, the data input device can respond quickly.

[0089] As illustrated in FIG. 2B, the conductive layers **14** along the Y direction are arranged in the X direction, for example. Furthermore, the conductive layers **15** are arranged in the X and Y directions such that each of the conductive layers **15** are provided between two adjacent conductive layers **14**. The conductive layers **15** arranged in the X direction are electrically connected to each other through the conductive layers **16** for each column. The conductive layer **14** can serve as an electrode in the X direction and the conductive

layers **15** and the conductive layers **16** can collectively serve as an electrode in the Y direction, for example.

[0090] FIGS. 3A and 3B are a cross-sectional view and a top view illustrating another structure example of the touch sensor **13**. The touch sensor **13** may have the conductive layers **14** and **15** on different surfaces, as illustrated in FIGS. 3A and 3B. In that case, the conductive layer **16** is unnecessary. The conductive layer **15** extends in the X direction, and the insulating layer is provided between the conductive layer **14** and the conductive layer **15**. Part of each of the conductive layers **14** and **15** serves as an electrode of a capacitor **12**.

[0091] In the description below, a capacitive touch sensor is used as a touch sensor included in the data input device in the touch panel.

[0092] A capacitive touch sensor that can be used for one embodiment of the present invention includes the capacitor **12**. In the capacitor **12**, for example, the insulating layer **330** is provided between two conductive layers **14**. In that case, the conductive layers **14** function as electrodes of the capacitor **12**. Similarly, the insulating layer **330** is provided between two conductive layers **15**, and the capacitor **12** is formed. Part of the conductive layer **14** and part of the conductive layer **15** may each function as a wiring. The capacitor **12** may also be formed using the conductive layer **14** and the conductive layer **15**.

[0093] There is a region where the conductive layer **14** and the conductive layer **16** overlap with each other. The insulating layer **330** serving as a dielectric is positioned between the conductive layer **14** and the conductive layer **16**, and the insulating layer **330** and the conductive layers **14** and **16** form the capacitor **12**. Thus, the conductive layer **14** and the conductive layer **16** can partly function as a pair of electrodes of the capacitor **12**.

[0094] Examples of the capacitive touch sensor include a surface capacitive touch sensor and a projected capacitive touch sensor. Examples of the projected capacitive touch sensor include a self-capacitive touch sensor, a mutual capacitive touch sensor, and the like, which differ mainly in the driving method. A mutual capacitive touch sensor is preferably used because multiple points can be sensed simultaneously.

(Top View of Touch Panel)

[0095] FIGS. 4A, 4B, and 4C are top views of the touch panel **10**, the data input device **11**, and the display panel **20**, respectively, of one embodiment of the present invention. In the touch panel **10**, the data input device **11** including the touch sensor **13** illustrated in FIG. 1B overlaps with the display panel **20**.

[0096] In the data input device **11**, an FPC **41** is provided over a substrate, and the touch sensor **13** is provided on a surface on the display panel **20** side. The touch sensor **13** includes the conductive layer **14**, the conductive layer **15**, the conductive layer **16**, and the opening **17**. The touch sensor **13** also includes a wiring **19** which electrically connects the conductive layers to the FPC **41**. The FPC **41** has a function of supplying a signal from the outside to the touch sensor **13**. Alternatively, the FPC **41** has a function of outputting a signal from the touch sensor **13** to the outside.

[0097] In the display panel **20**, a display portion **21** is provided over a substrate. The display portion **21** includes a plurality of pixels arranged in a matrix. Each pixel preferably includes a plurality of subpixels. Each subpixel includes a display element. A peripheral circuit **25** electrically con-

nected to the pixels is preferably provided over the substrate. A circuit functioning as a gate driver circuit can be used as the peripheral circuit **25**, for example. An FPC **42** has a function of supplying a signal from the outside to at least one of the display portion **21** and the peripheral circuit **25**. An IC functioning as a source driver circuit is preferably mounted on the substrate or the FPC **42**. The IC can be mounted on the substrate by a COG method or a COF method. Alternatively, the FPC **42**, a TCP, or the like on which an IC is mounted can be attached to the substrate. Note that a device in which an IC, an FPC, or the like is mounted on the display panel **20** can be referred to as a display device.

[0098] Since the conductive layers **14** and **15** can be formed of a low-resistance material, each of the conductive layers can have an extremely small line width. That is, the area of each of the conductive layers **14** and **15** when seen from the display surface side (in a plan view) can be reduced. As a result, the influence of noise caused by driving a pixel is suppressed and detection sensitivity is increased. Furthermore, even when the capacitor included in the touch sensor and the display element included in the pixel are provided close to each other and between the two substrates, a reduction in detection sensitivity can be suppressed. Thus, the thickness of the touch panel can be reduced. In particular, in the case where a flexible material is used for the pair of substrates, a flexible touch panel that is thin and lightweight can be obtained.

[0099] The touch panel **10** of one embodiment of the present invention can output positional information based on the change in capacitance by the touch sensor **13** at the time of a touch motion. Furthermore, the display portion **21** can display an image.

[0100] FIGS. **5A** and **5B** are top views of a structure example, which is different from that illustrated in FIGS. **4A** to **4C**. The data input device **11** does not necessarily include all wirings (or electrodes) necessary for the touch sensor. For example, when a wiring along the X direction (e.g., the conductive layer **14**) is provided in the data input device **11**, a wiring along the Y direction (e.g., the conductive layer **15**) can be provided in the display panel **20**. In this manner, the combination of the data input device **11** and the display panel **20** can function as a touch sensor.

(Arrangement of Conductive Layers in Pixel Portion)

[0101] FIGS. **6A** and **6B** are enlarged views of a region **28** and a region **29** in FIG. **1B**. As illustrated in FIG. **6A**, the conductive layer **14** overlapping with the light-blocking layer **18** can be provided so as to surround one pixel **33**, which is a combination of a red subpixel (R) **22**, a green subpixel (G) **23**, and a blue subpixel (B) **24**, for example. The distance between adjacent portions of the conductive layer **14** is desirably larger than the width of one pixel. There may be a region having no conductive layer **14** around a pixel as illustrated in FIG. **6B**. The conductive layer **14** can be provided to have a mesh pattern. Note that the conductive layer **14** provided to have a mesh pattern is provided like a net. FIGS. **7A** to **7C** each illustrate an example of a mesh pattern. Part of the conductive layer **14** may form a square as in FIG. **7A**, a hexagon as in FIG. **7B**, a circle as in FIG. **7C**, or another complex polygonal shape. The conductive layer **15** may form a similar shape.

[0102] FIG. **8** is a top view illustrating the positional relationship between the pixel, a transistor, and wirings of the touch sensor. The conductive layer **14**, which is an electrode of the touch sensor, can be provided so as to overlap with a

source line **91** or a gate line **92**, or can be provided parallel to the source line **91** or the gate line **92** so as not to overlap with each other, for example. The conductive layer **14**, which is an electrode of the touch sensor, may overlap with a transistor **50** and a capacitor **61** unlike in the example illustrated in FIG. **8**. The conductive layers **15** and **16** can be arranged in a similar manner.

(Arrangement Pattern of Conductive Layers)

[0103] When the width of the pixel is 30 μm , for example, the distance between adjacent portions of the conductive layer **14** is desirably larger than 30 p.m. When the width of the pixel is 5 μm , for example, the distance between adjacent portions of the conductive layer **14** is desirably larger than 5 μm . Accordingly, the parasitic capacitance generated between wirings or between electrodes can be reduced. The distance between adjacent portions of the conductive layer **15** and the distance between adjacent conductive layers **16** can be determined in a similar manner.

[0104] The conductive layers **15** can be arranged in various patterns as illustrated in FIGS. **9A** to **9F** and FIGS. **10A** to **10D** and desirably arranged according to the areas of the subpixel (R) **22**, the subpixel (G) **23**, and the subpixel (B) **24** or the area of an object in contact with the conductive layers **15**, for example. The conductive layers **14** can be arranged in a similar manner. Alternatively, the conductive layers **14**, **15**, and **16** may be arranged as illustrated in FIGS. **11A** to **11F**.

(Arrangement Pattern of Conductive Layers in Pixel Portion)

[0105] Pixels can be arranged in various patterns as illustrated in FIGS. **12A** to **12F**. The number of subpixels in one pixel is not limited to three; for example, the subpixel (R) **22**, the subpixel (G) **23**, the subpixel (B) **24**, a yellow subpixel (Y) **26**, and the like may be used, or a white subpixel (W) may be used instead of the subpixel (Y) **26**. The pixels may be not aligned as illustrated in FIG. **12F**. In any case, the conductive layers **14**, **15**, and **16** are desirably arranged so as to surround the pixels.

[0106] In this manner, the use of one embodiment of the present invention can reduce the influence of detection signal delay or the like and improve the detection accuracy of the data input device.

[0107] Note that such a structure can be applied to large-sized display devices such as televisions as well as portable devices.

Embodiment 2

Sensing Method

[0108] In this embodiment, an example of a method for operating a touch panel that can be used in an electronic device of one embodiment of the present invention will be described with reference to drawings.

[Example of Sensing Method of Sensor]

[0109] FIG. **13A** is a block diagram illustrating the structure of a mutual capacitive touch sensor. FIG. **13A** illustrates a pulse voltage output circuit **601** and a current detection circuit **602**. Note that in FIG. **13A**, six wirings X1 to X6 represent electrodes **621** to which a pulse voltage is applied, and six wirings Y1 to Y6 represent electrodes **622** that sense changes in current. FIG. **13A** also illustrates a capacitor **603** that is formed where the electrodes **621** and **622** overlap with

each other. Note that functional replacement between the electrodes **621** and **622** is possible.

[0110] The pulse voltage output circuit **601** is a circuit for sequentially applying a pulse voltage to the wirings **X1** to **X6**. By application of the pulse voltage to the wirings **X1** to **X6**, an electric field is generated between the electrodes **621** and **622** of the capacitor **603**. When the electric field between the electrodes is shielded, for example, mutual capacitance of the capacitor **603** changes. The approach or contact of an object can be detected by utilizing this change.

[0111] The current detection circuit **602** is a circuit for detecting changes in current flowing through the wirings **Y1** to **Y6** that are caused by the change in mutual capacitance in the capacitor **603**. No change in current value is detected in the wirings **Y1** to **Y6** when there is no approach or contact of an object, whereas a decrease in current value is detected when mutual capacitance is decreased because of the approach or contact of an object. Note that an integrator circuit or the like is used for detection of current values.

[0112] FIG. **13B** is a timing chart showing input and output waveforms in the mutual capacitive touch sensor illustrated in FIG. **13A**. In FIG. **13B**, detection of an object is performed in all the rows and columns in one frame period. FIG. **13B** shows a period when an object is not detected (not touched) and a period when an object is detected (touched). Detected current values of the wirings **Y1** to **Y6** are shown as the waveforms of voltage values.

[0113] A pulse voltage is sequentially applied to the wirings **X1** to **X6**, and the waveforms of the wirings **Y1** to **Y6** change in accordance with the pulse voltage. At the point where there is no approach or contact of an object, the waveforms of the wirings **Y1** to **Y6** change uniformly in accordance with changes in the voltages of the wirings **X1** to **X6**. In contrast, the current value is decreased at the point of approach or contact of an object and accordingly the waveform of the voltage value changes.

[0114] By detecting a change in mutual capacitance in this manner, the approach or contact of an object can be sensed.

[0115] It is preferable that the pulse voltage output circuit **601** and the current detection circuit **602** be mounted on a substrate in a housing of an electronic device or on the touch panel in the form of an IC. In the case where the touch panel has flexibility, parasitic capacitance might be increased in a bent portion of the touch panel, and the influence of noise might be increased. In view of this, it is preferable to use an IC to which a driving method less influenced by noise is applied. For example, it is preferable to use an IC to which a driving method capable of increasing a signal-noise ratio (S/N ratio) is applied.

<<Active Matrix Touch Sensor>>

[0116] Although the touch sensor in FIG. **13A** is a passive matrix touch sensor in which only the capacitor **603** is provided at the intersection of wirings, an active matrix touch sensor including a transistor and a capacitor may be used. FIG. **14** is a sensor circuit included in an active matrix touch sensor.

[0117] The sensor circuit includes the capacitor **603** and transistors **611**, **612**, and **613**. A signal **G2** is input to a gate of the transistor **613**. A voltage **VRES** is applied to one of a source and a drain of the transistor **613**, and one electrode of the capacitor **603** and a gate of the transistor **611** are electrically connected to the other of the source and the drain of the transistor **613**. One of a source and a drain of the transistor

611 is electrically connected to one of a source and a drain of the transistor **612**, and a voltage **VSS** is applied to the other of the source and the drain of the transistor **611**. A signal **G1** is input to a gate of the transistor **612**, and a wiring **ML** is electrically connected to the other of the source and the drain of the transistor **612**. The voltage **VSS** is applied to the other electrode of the capacitor **603**.

[0118] Next, the operation of the sensor circuit will be described. First, a potential for turning on the transistor **613** is supplied as the signal **G2**, and a potential with respect to the voltage **VRES** is thus applied to the node **n** connected to the gate of the transistor **611**. Then, a potential for turning off the transistor **613** is applied as the signal **G2**, whereby the potential of the node **n** is maintained.

[0119] Then, mutual capacitance of the capacitor **603** changes owing to the approach or contact of an object such as a finger, and accordingly the potential of the node **n** is changed from **VRES**.

[0120] In reading operation, a potential for turning on the transistor **612** is supplied as the signal **G1**. A current flowing through the transistor **611**, that is, a current flowing through the wiring **ML** is changed in accordance with the potential of the node **n**. By detecting this current, the approach or contact of an object can be detected.

[0121] It is preferred that the transistors **611**, **612**, and **613** each include an oxide semiconductor in a semiconductor layer where a channel is formed. In particular, by using an oxide semiconductor in a semiconductor layer where a channel of the transistor **613** is formed, the potential of the node **n** can be held for a long time and the frequency of operation (refresh operation) of resupplying **VRES** to the node **n** can be reduced.

[0122] At least part of this embodiment can be implemented in combination with any of the embodiments described in this specification as appropriate.

Embodiment 3

[0123] In this embodiment, the details of the touch panel described in Embodiments 1 and 2 will be described with reference to drawings.

[0124] FIGS. **15A** and **15B** are examples of a top view and a cross-sectional view of the touch panel **10**. Note that FIG. **15A** illustrates a typical structure including the data input device **11**, the display panel **20**, the peripheral circuit **25**, the FPC **41**, and the FPC **42**.

[0125] FIG. **15B** is a cross-sectional view taken along dashed-dotted lines A-A', B-B', C-C', and D-D' in FIG. **15A**. The data input device **11** and the display panel **20** are bonded to each other with an adhesive layer **370**.

<<Organic EL Panel>>

[0126] In FIG. **15B**, an organic EL panel is used as the display panel **20**.

<<Substrate 100>>

[0127] There is no particular limitation on a material and the like of a substrate **100** as long as the material has heat resistance high enough to withstand at least heat treatment performed later. The material desirably has a high light-transmitting property.

[0128] For the substrate **100**, 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, a ceramic, or a metal can be used for the substrate **100**.

[0129] Specifically, non-alkali glass, soda-lime glass, pot-ash glass, crystal glass, or the like can be used for the substrate **100**. An inorganic oxide film, an inorganic nitride film, an inorganic oxynitride film, or the like can also be used for the substrate **100**. Silicon oxide, silicon nitride, silicon oxynitride, alumina, stainless steel, aluminum, or the like can be used for the substrate **100**.

[0130] A single-layer material or a stacked-layer material in which a plurality of layers are stacked can be used for the substrate **100**. For example, a stacked-layer material in which a base, an insulating film that prevents diffusion of impurities contained in the base, and the like are stacked can be used for the substrate **100**. Specifically, a stacked-layer material in which glass and one or a plurality of films that prevent diffusion of impurities contained in the glass and that are selected from a silicon oxide layer, a silicon nitride layer, a silicon oxynitride layer, and the like are stacked can be used for the substrate **100**. Alternatively, a stacked-layer material in which a resin and a film for preventing diffusion of impurities that penetrate the resin, such as a silicon oxide film, a silicon nitride film, and a silicon oxynitride film are stacked can be used for the substrate **100**.

[0131] The above-described materials that can be used as the substrate **100** can be used as the substrate **300** as well.

<<Transistor **50**, **52**>>

[0132] The transistor **50** can be formed using a conductive layer **120**, an insulating layer **130**, a semiconductor layer **140**, a conductive layer **150**, a conductive layer **160**, an insulating layer **170**, and an insulating layer **180**. A transistor **52** can include similar components.

<<Insulating Layer **110**>>

[0133] The insulating layer **110** that functions as a base film is formed using silicon oxide, silicon oxynitride, silicon nitride, silicon nitride oxide, gallium oxide, hafnium oxide, yttrium oxide, aluminum oxide, aluminum oxynitride, or the like. Note that when silicon nitride, gallium oxide, hafnium oxide, yttrium oxide, aluminum oxide, or the like is used as a material for the insulating layer **110**, it is possible to suppress diffusion of impurities such as alkali metal, water, and hydrogen into the semiconductor layer **140** from the substrate **100**. The insulating layer **110** is formed over the substrate **100**. The insulating layer **110** is not necessarily provided.

<<Conductive Layer **120**>>

[0134] The conductive layer **120** that functions as a gate electrode is formed using a metal element selected from aluminum, chromium, copper, tantalum, titanium, molybdenum, nickel, iron, cobalt, and tungsten; an alloy containing any of these metal elements as a component; an alloy containing any of these metal elements in combination; or the like. Furthermore, one or more metal elements selected from manganese and zirconium may be used. The conductive layer **120** may have a single-layer structure or a layered structure of two or more layers. For example, any of the following can be used: a single-layer structure of an aluminum film containing silicon; a single-layer structure of a copper film containing manganese; 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 two-layer structure in which a copper film is stacked over a copper film containing manganese; a three-layer structure in which a titanium film, an aluminum film, and a titanium film are stacked in this order; a three-layer structure in which a copper film containing manganese, a copper film, and a copper film containing manganese are stacked in this order; and the like. Alternatively, an alloy film or a nitride film which contains aluminum and one or more elements selected from titanium, tantalum, tungsten, molybdenum, chromium, neodymium, and scandium may be used.

<<Insulating Layer **130**>>

[0135] The insulating layer **130** functions as a gate insulating film. The insulating layer **130** can be formed using, for example, an insulating film containing at least one of aluminum oxide, magnesium oxide, silicon oxide, silicon oxynitride, silicon nitride oxide, silicon nitride, gallium oxide, germanium oxide, yttrium oxide, zirconium oxide, lanthanum oxide, neodymium oxide, hafnium oxide, and tantalum oxide. The insulating layer **130** may be a stack of any of the above materials. The insulating layer **130** may contain lanthanum, nitrogen, or zirconium as an impurity.

<<Semiconductor Layer **140**>>

[0136] The semiconductor layer **140** is formed using a metal oxide containing at least In or Zn. The area of a top surface of the semiconductor layer **140** is preferably the same as or smaller than the area of a top surface of the conductive layer **120**.

<<Oxide Semiconductor>>

[0137] As an oxide semiconductor used for the aforementioned semiconductor layer **140**, any of the following can be used, for example: an In—Ga—Zn-based oxide, an In—Al—Zn-based oxide, an In—Sn—Zn-based oxide, an In—Hf—Zn-based oxide, an In—La—Zn-based oxide, an In—Ce—Zn-based oxide, an In—Pr—Zn-based oxide, an In—Nd—Zn-based oxide, an In—Sm—Zn-based oxide, an In—Eu—Zn-based oxide, an In—Gd—Zn-based oxide, an In—Tb—Zn-based oxide, an In—Dy—Zn-based oxide, an In—Ho—Zn-based oxide, an In—Er—Zn-based oxide, an In—Tm—Zn-based oxide, an In—Yb—Zn-based oxide, an In—Lu—Zn-based oxide, an In—Sn—Ga—Zn-based oxide, an In—Hf—Ga—Zn-based oxide, an In—Al—Ga—Zn-based oxide, an In—Sn—Al—Zn-based oxide, an In—Sn—Hf—Zn-based oxide, an In—Hf—Al—Zn-based oxide, and an In—Ga-based oxide.

[0138] Note that here, an “In—Ga—Zn-based oxide” means an oxide containing In, Ga, and Zn as its main components and there is no limitation on the ratio of In:Ga:Zn. The In—Ga—Zn-based oxide may contain another metal element in addition to In, Ga, and Zn.

[0139] When the semiconductor layer **140** is formed using an In—M—Zn oxide, the atomic ratio of In to M when the summation of In and M is assumed to be 100 atomic % is preferably as follows: the proportion of In is higher than 25 atomic % and the proportion of M is lower than 75 atomic %; further preferably, the proportion of In is higher than 34 atomic % and the proportion of M is lower than 66 atomic %.

[0140] The energy gap of the semiconductor layer 140 is 2 eV or more, preferably 2.5 eV or more, and further preferably 3 eV or more. With the use of an oxide semiconductor having such a wide energy gap, the off-state current of the transistor 50 can be reduced.

[0141] The thickness of the semiconductor layer 140 desirably ranges from 3 nm to 200 nm, preferably from 3 nm to 100 nm, and further preferably from 3 nm to 50 nm.

[0142] In the case where the semiconductor layer 140 is formed using an In-M-Zn oxide (M is Al, Ga, Y, Zr, La, Ce, or Nd), it is preferable that the atomic ratio of metal elements of a sputtering target used for forming the In-M-Zn oxide satisfy $\text{In} \geq \text{M}$ and $\text{Zn} \geq \text{M}$. As the atomic ratio of metal elements of such a sputtering target, $\text{In:M:Zn}=1:1:1$, $\text{In:M:Zn}=1:1:1.2$, $\text{In:M:Zn}=3:1:2$, and $\text{In:M:Zn}=4:1:4.1$ are preferable. Note that the atomic ratio of metal elements in the formed semiconductor layer 140 varies from the above atomic ratio of metal elements of the sputtering target within a range of $\pm 40\%$ as an error. Note that a c-axis aligned crystalline oxide semiconductor (CAAC-OS) film and a microcrystalline oxide semiconductor film that are described later can be formed using a target including an In—Ga—Zn oxide, preferably a polycrystalline target including an In—Ga—Zn oxide.

[0143] Hydrogen contained in the semiconductor layer 140 reacts with oxygen bonded to a metal atom to be water, and also causes oxygen vacancies in a lattice from which oxygen is released (or a portion from which oxygen is released). Due to entry of hydrogen into the oxygen vacancies, an electron serving as a carrier is generated. Further, in some cases, bonding of part of hydrogen to oxygen bonded to a metal atom causes generation of an electron serving as a carrier. Thus, a transistor including an oxide semiconductor which contains hydrogen is likely to be normally on.

[0144] Accordingly, it is preferable that hydrogen as well as the oxygen vacancies in the semiconductor layer 140 be reduced as much as possible. Specifically, in the semiconductor layer 140, the concentration of hydrogen which is measured by secondary ion mass spectrometry (SIMS) is set to lower than or equal to 5×10^{19} atoms/cm³, preferably lower than or equal to 1×10^{19} atoms/cm³, further preferably lower than or equal to 5×10^{18} atoms/cm³, still further preferably lower than or equal to 1×10^{18} atoms/cm³, yet still further preferably lower than or equal to 5×10^{17} atoms/cm³, and still more preferably lower than or equal to 1×10^{16} atoms/cm³. As a result, the transistor 50 has a positive threshold voltage (also referred to as normally-off characteristics).

[0145] When silicon or carbon which is one of the elements belonging to Group 14 is contained in the semiconductor layer 140, oxygen vacancies are increased in the semiconductor layer 140, and the semiconductor layer 140 has n-type conductivity. Thus, the concentration of silicon or carbon (the concentration is measured by SIMS) in the semiconductor layer 140 is lower than or equal to 2×10^{18} atoms/cm³, preferably lower than or equal to 2×10^{17} atoms/cm³. As a result, the transistor 50 has a positive threshold voltage (also referred to as normally-off characteristics).

[0146] Furthermore, the concentration of alkali metal or alkaline earth metal in the semiconductor layer 140, which is measured by SIMS, is lower than or equal to 1×10^{18} atoms/cm³, preferably lower than or equal to 2×10^{16} atoms/cm³. Alkali metal and alkaline earth metal might generate carriers when bonded to an oxide semiconductor, in which case the off-state current of the transistor might be increased. There-

fore, it is preferable to reduce the concentration of alkali metal or alkaline earth metal in the semiconductor layer 140. As a result, the transistor 50 has a positive threshold voltage (also referred to as normally-off characteristics).

[0147] Furthermore, when nitrogen is contained in the semiconductor layer 140, electrons serving as carriers are generated to increase the carrier density, so that the semiconductor layer 140 easily has n-type conductivity. Thus, the transistor tends to have normally-on characteristics. For this reason, nitrogen in the semiconductor layer 140 is preferably reduced as much as possible; for example, the concentration of nitrogen which is measured by SIMS is preferably set to lower than or equal to 5×10^{18} atoms/cm³.

[0148] When impurities in the semiconductor layer 140 are reduced, the carrier density of the semiconductor layer 140 can be lowered. The semiconductor layer 140 preferably has a carrier density of 1×10^{17} /cm³ or less, further preferably 1×10^{15} /cm³ or less, still further preferably 1×10^{13} /cm³ or less, and yet still further preferably 1×10^{11} /cm³ or less.

[0149] When an oxide semiconductor having a low impurity concentration and a low density of defect states is used for the semiconductor layer 140, the transistor can have more excellent electrical characteristics. Here, the state in which impurity concentration is low and the density of defect states is low (the amount of oxygen vacancies is small) is referred to as “highly purified intrinsic” or “substantially highly purified intrinsic.” A highly purified intrinsic or substantially highly purified intrinsic oxide semiconductor has few carrier generation sources, and thus has a low carrier density in some cases. Thus, the transistor whose channel region is formed in the semiconductor layer 140 including the oxide semiconductor is likely to have a positive threshold voltage (also referred to as normally-off characteristics). A highly purified intrinsic or substantially highly purified intrinsic oxide semiconductor has a low density of defect states and accordingly has a low density of trap states in some cases. The transistor including the semiconductor layer 140 containing the highly purified intrinsic or substantially highly purified intrinsic oxide semiconductor has an extremely low off-state current; the off-state current can be less than or equal to the measurement limit of a semiconductor parameter analyzer, i.e., less than or equal to 1×10^{-13} A, at a voltage (drain voltage) between a source electrode and a drain electrode of from 1 V to 10 V. In addition, variation in characteristics can be prevented.

[0150] In the case where the voltage between a source and a drain is set to about 0.1 V, 5 V, or 10 V, for example, the off-state current standardized on the channel width of the transistor 50 in which the semiconductor layer 140 is used for the semiconductor layer can be as low as several yoctoamperes per micrometer to several zeptoamperes per micrometer.

[0151] When a transistor with an extremely low off-state leakage current is used as the transistor 50 connected to a display element (e.g., a light-emitting element 70), the time for holding image signals can be extended. For example, images can be held even when the frequency of writing image signals is higher than or equal to 11.6 μHz (once a day) and less than 0.1 Hz (0.1 times a second), preferably higher than or equal to 0.28 mHz (once an hour) and less than 1 Hz (once a second). As a result, the frequency of writing image signals can be reduced, leading to a reduction in the power consumption of the display panel 20. Needless to say, the frequency of writing image signals can be higher than or equal to 1 Hz, preferably higher than or equal to 30 Hz (30 times a second),

further preferably higher than or equal to 60 Hz (60 times a second) and less than 960 Hz (960 times a second).

[0152] From the above reason, the use of a transistor containing an oxide semiconductor allows fabrication of a highly reliable display panel with low power consumption.

[0153] In the transistor containing an oxide semiconductor, the semiconductor layer **140** can be formed by a sputtering method, an MOCVD method, a PLD method, or the like. When a sputtering method is used, the transistor can be used in a large-area display device.

[0154] Note that instead of the semiconductor layer **140**, a semiconductor layer including silicon or silicon germanium may be used. The semiconductor layer including silicon or silicon germanium can have an amorphous structure, a polycrystalline structure, or a single crystal structure, as appropriate.

<<Conductive Layer **150**, **160**>>

[0155] The conductive layer **150** and the conductive layer **160** function as a source electrode layer and a drain electrode layer. The conductive layer **150** and the conductive layer **160** can be formed using a material similar to that of the conductive layer **120**.

<<Insulating Layer **170**>>

[0156] The insulating layer **170** has a function of protecting the channel region of the transistor. The insulating layer **170** is formed using an oxide insulating film such as silicon oxide, silicon oxynitride, aluminum oxide, aluminum oxynitride, gallium oxide, gallium oxynitride, yttrium oxide, yttrium oxynitride, hafnium oxide, or hafnium oxynitride, or a nitride insulating film such as silicon nitride or aluminum nitride. The insulating layer **170** can have a single-layer structure or a stacked-layer structure.

[0157] The insulating layer **170** is preferably formed using an oxide insulating film containing more oxygen than that in the stoichiometric composition. Part of oxygen is released by heating from the oxide insulating film containing more oxygen than that in the stoichiometric composition. The oxide insulating film containing more oxygen than that in the stoichiometric composition is an oxide insulating film of which the amount of released oxygen atoms is greater than or equal to 1.0×10^{18} atoms/cm³, preferably greater than or equal to 3.0×10^{20} atoms/cm³ in thermal desorption spectroscopy (TDS) analysis in which heat treatment is performed such that a temperature of a film surface is higher than or equal to 100° C. and lower than or equal to 700° C. or higher than or equal to 100° C. and lower than or equal to 500° C. By the heat treatment, oxygen contained in the insulating layer **170** can be transferred to the semiconductor layer **140**, so that the amount of oxygen vacancies in the semiconductor layer **140** can be reduced.

<<Insulating Layer **180**>>

[0158] When an insulating film having a blocking effect against oxygen, hydrogen, water, and the like is provided as the insulating layer **180**, it is possible to prevent outward diffusion of oxygen from the semiconductor layer **140** and entry of hydrogen, water, or the like into the semiconductor layer **140** from the outside. The insulating layer **180** can be formed using, for example, an insulating film containing at least one of aluminum oxide, magnesium oxide, silicon oxide, silicon oxynitride, silicon nitride oxide, silicon nitride,

gallium oxide, germanium oxide, yttrium oxide, zirconium oxide, lanthanum oxide, neodymium oxide, hafnium oxide, and tantalum oxide. The insulating layer **180** may be a stack of any of the above materials. The insulating layer **180** may contain lanthanum, nitrogen, or zirconium as an impurity.

<<Conductive Layer **200**>>

[0159] A conductive layer **200** is formed using a metal element selected from aluminum, chromium, copper, tantalum, titanium, molybdenum, nickel, iron, cobalt, and tungsten; an alloy containing any of these metal elements as a component; an alloy containing any of these metal elements in combination; or the like. Further, one or more metal elements selected from manganese and zirconium may be used. The conductive layer **200** may have a single-layer structure or a layered structure of two or more layers. For example, any of the following can be used: a single-layer structure of an aluminum film containing silicon; a single-layer structure of a copper film containing manganese; 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 two-layer structure in which a copper film is stacked over a copper film containing manganese; a three-layer structure in which a titanium film, an aluminum film, and a titanium film are stacked in this order; a three-layer structure in which a copper film containing manganese, a copper film, and a copper film containing manganese are stacked in this order; and the like. Alternatively, an alloy film or a nitride film which contains aluminum and one or more elements selected from titanium, tantalum, tungsten, molybdenum, chromium, neodymium, and scandium may be used.

<<Capacitor **60**, **62**>>

[0160] A capacitor **60** includes the conductive layer **120**, the insulating layer **130**, and the conductive layer **160**. The conductive layer **120** functions as one electrode of the capacitor **60**. The conductive layer **160** functions as the other electrode of the capacitor **60**. The insulating layer **130** is provided between the conductive layer **120** and the conductive layer **160**. A capacitor **62** can have a structure similar to that of the capacitor **60**.

<<Insulating Layer **210**>>

[0161] An insulating layer **210** functions as a planarization film. The insulating layer **210** is formed using a heat-resistant organic material, such as a polyimide resin, an acrylic resin, a polyimide amide resin, a benzocyclobutene resin, a polyamide resin, or an epoxy resin. Note that the insulating layer **210** may be formed by stacking a plurality of insulating films formed using any of these materials.

<<Insulating Layer **350**>>

[0162] An insulating layer **350** functions as a planarization film. The insulating layer **350** can be formed using a material similar to that of the insulating layer **210**. The insulating layer **350** is not necessarily formed.

<<Light-Blocking Layer 18>>

[0163] A light-blocking material can be used for the light-blocking layer 18. A resin in which a pigment is dispersed, a resin containing a dye, or an inorganic film such as a black chromium film can be used for the light-blocking layer 18. Carbon black, an inorganic oxide, a composite oxide containing a solid solution of a plurality of inorganic oxides, or the like can be used for the light-blocking layer 18.

<<Coloring Layer 360>>

[0164] A coloring layer 360 transmits light in a specific wavelength range. For example, a color filter that transmits light in a specific wavelength range, such as red, green, blue, or yellow light, can be used. Each coloring layer is formed in a desired position with any of various materials by a printing method, an inkjet method, an etching method using a photolithography method, or the like. In a white pixel, a resin such as a transparent resin or a white resin may overlap with the light-emitting element. The coloring layer 360 may be in contact with the light-blocking layer 18.

<<Partition 245>>

[0165] An insulating material can be used for a partition 245. For example, an inorganic material, an organic material, or a stacked-layer material of an inorganic material and an organic material can be used. Specifically, a film containing silicon oxide, silicon nitride, or the like, acrylic, polyimide, a photosensitive resin, or the like can be used.

<<Spacer 240>>

[0166] An insulating material can be used for a spacer 240. For example, an inorganic material, an organic material, or a stacked-layer material of an inorganic material and an organic material can be used. Specifically, a film containing silicon oxide, silicon nitride, or the like, acrylic, polyimide, a photosensitive resin, or the like can be used.

<<Light-Emitting Element 70>>

[0167] As the light-emitting element 70, a self-luminous element can be used, and an element whose luminance is controlled by current or voltage is included in the category of the light-emitting element. For example, a light-emitting diode (LED), an organic EL element, an inorganic EL element, or the like can be used. For example, an organic element which includes a lower electrode, an upper electrode, and a layer (also referred to as an EL layer 250) containing a light-emitting organic compound between the lower electrode and the upper electrode can be used as the light-emitting element 70.

[0168] The light-emitting element may be a top emission, bottom emission, or dual emission light-emitting element. A conductive film that transmits visible light is used as the electrode through which light is extracted. A conductive film that reflects visible light is preferably used as the electrode through which light is not extracted.

[0169] When a voltage higher than the threshold voltage of the light-emitting element is applied between a lower electrode including a conductive layer 220 and an upper electrode including a conductive layer 260, holes are injected to the EL layer 250 from the anode side and electrons are injected to the EL layer 250 from the cathode side. The injected electrons

and holes are recombined in the EL layer 250 and a light-emitting substance contained in the EL layer 250 emits light.

[0170] The EL layer 250 includes at least a light-emitting layer. In addition to the light-emitting layer, the EL layer 250 may further include one or more layers containing any of a substance with a high hole-injection property, a substance with a high hole-transport property, a hole-blocking material, a substance with a high electron-transport property, a substance with a high electron-injection property, a substance with a bipolar property (a substance with a high electron- and hole-transport property), and the like.

[0171] Either a low molecular compound or a high molecular compound can be used for the EL layer 250, and an inorganic compound may be used. Each of the layers included in the EL layer 250 can be formed by any of the following methods: an evaporation method (including a vacuum evaporation method), a transfer method, a printing method, an inkjet method, a coating method, and the like.

[0172] The light-emitting element may contain two or more kinds of light-emitting substances. Thus, for example, a light-emitting element that emits white light can be achieved. For example, light-emitting substances are selected so that two or more light-emitting substances emit complementary colors to obtain white light emission. A light-emitting substance that emits red (R) light, green (G) light, blue (B) light, yellow (Y) light, or orange (O) light or a light-emitting substance that emits light containing spectral components of two or more of R light, G light, and B light can be used, for example. A light-emitting substance that emits blue light and a light-emitting substance that emits yellow light may be used, for example. At this time, the emission spectrum of the light-emitting substance that emits yellow light preferably contains spectral components of G light and R light. The emission spectrum of the light-emitting element preferably has two or more peaks in the wavelength range in a visible region (e.g., greater than or equal to 350 nm and less than or equal to 750 nm or greater than or equal to 400 nm and less than or equal to 800 nm).

[0173] The EL layer 250 may include a plurality of light-emitting layers. In the EL layer 250, the plurality of light-emitting layers may be stacked in contact with one another or may be stacked with a separation layer provided therebetween. The separation layer may be provided between a fluorescent layer and a phosphorescent layer, for example.

[0174] The separation layer can be provided, for example, to prevent energy transfer by the Dexter mechanism (particularly triplet energy transfer) from a phosphorescent material or the like in an excited state which is generated in the phosphorescent layer to a fluorescent material or the like in the fluorescent layer. The thickness of the separation layer may be several nanometers. Specifically, the thickness of the separation layer may be greater than or equal to 0.1 nm and less than or equal to 20 nm, greater than or equal to 1 nm and less than or equal to 10 nm, or greater than or equal to 1 nm and less than or equal to 5 nm. The separation layer contains a single material (preferably, a bipolar substance) or a plurality of materials (preferably, a hole-transport material and an electron-transport material).

[0175] The separation layer may be formed using a material contained in a light-emitting layer in contact with the separation layer. This facilitates the manufacture of the light-emitting element and reduces the drive voltage. For example, in the case where the phosphorescent layer contains a host material, an assist material, and the phosphorescent material

(a guest material), the separation layer may contain the host material and the assist material. In other words, the separation layer includes a region not containing the phosphorescent material and the phosphorescent layer includes a region containing the phosphorescent material in the above structure. Accordingly, the separation layer and the phosphorescent layer can be evaporated separately depending on whether a phosphorescent material is used or not. With such a structure, the separation layer and the phosphorescent layer can be formed in the same chamber. Thus, the manufacturing cost can be reduced.

<<Microcavity>>

[0176] The light-emitting element **70** is an example of a light-emitting element having a microcavity structure. For example, the microcavity structure may be formed using the lower electrode and the upper electrode of the light-emitting element **70** so that light with a specific wavelength can be extracted from the light-emitting element efficiently.

[0177] Specifically, a reflective film which reflects visible light is used as the lower electrode, and a semi-transmissive and semi-reflective film which transmits part of visible light and reflects part of visible light is used as the upper electrode. The upper electrode and the lower electrode are arranged so that light with a specific wavelength can be extracted efficiently.

[0178] The lower electrode functions as, for example, a lower electrode or an anode of the light-emitting element. The lower electrode may include a layer **230** that adjusts the optical path length so that desired light emitted from light-emitting layers resonates and its wavelength can be amplified. The layer **230** that adjusts the optical path length can be formed using, for example, indium oxide, indium tin oxide (ITO), indium zinc oxide, zinc oxide (ZnO), or zinc oxide to which gallium is added.

<<Conductive Layer **260**>>

[0179] The conductive layer **260** that transmits visible light can be formed using, for example, indium oxide, indium tin oxide (ITO), indium zinc oxide, zinc oxide (ZnO), or zinc oxide to which gallium is added. Alternatively, a film of a metal material such as gold, silver, platinum, magnesium, nickel, tungsten, chromium, molybdenum, iron, cobalt, copper, palladium, or titanium; an alloy containing any of these metal materials; or a nitride of any of these metal materials (e.g., titanium nitride) can be formed thin so as to have a light-transmitting property. A stack of any of the above materials can be used as the conductive layer. For example, a stacked film of ITO and an alloy of silver and magnesium is preferably used, in which case conductivity can be increased. Further alternatively, graphene or the like may be used.

<<Conductive Layer **220**>>

[0180] For the conductive layer **220** that reflects visible light, for example, a metal material such as aluminum, gold, platinum, silver, nickel, tungsten, chromium, molybdenum, iron, cobalt, copper, or palladium or an alloy containing any of these metal materials can be used. Lanthanum, neodymium, germanium, or the like may be added to the metal material or the alloy. Furthermore, an alloy containing aluminum (an aluminum alloy) such as an alloy of aluminum and titanium, an alloy of aluminum and nickel, an alloy of aluminum and neodymium, or an alloy of aluminum, nickel, and

lanthanum (Al—Ni—La), or an alloy containing silver such as an alloy of silver and copper, an alloy of silver, palladium, and copper (Ag—Pd—Cu, also referred to as APC), or an alloy of silver and magnesium can be used for the conductive film. An alloy of silver and copper is preferable because of its high heat resistance. A metal film or a metal oxide film is stacked on an aluminum alloy film, whereby oxidation of the aluminum alloy film can be suppressed. Examples of a material for the metal film or the metal oxide film are titanium and titanium oxide. Alternatively, the conductive film having a property of transmitting visible light and a film containing any of the above metal materials may be stacked. For example, a stacked film of silver and ITO or a stacked film of an alloy of silver and magnesium and ITO can be used.

[0181] In the case of using the microcavity structure, a semi-transmissive and semi-reflective electrode can be used as the upper electrode (the conductive layer **260**) of the light-emitting element. The semi-transmissive semi-reflective electrode is formed using a reflective conductive material and a light-transmitting conductive material. As the conductive materials, a conductive material having a visible light reflectivity of higher than or equal to 20% and lower than or equal to 80%, preferably higher than or equal to 40% and lower than or equal to 70%, and a resistivity of lower than or equal to $1 \times 10^{-2} \Omega\text{-cm}$ can be used. The semi-transmissive semi-reflective electrode can be formed using one or more kinds of conductive metals, conductive alloys, conductive compounds, and the like. In particular, a material with a small work function (3.8 eV or less) is preferable. For example, aluminum, silver, an element belonging to Group 1 or 2 of the periodic table (e.g., an alkali metal such as lithium or cesium, an alkaline earth metal such as calcium or strontium, or magnesium), an alloy containing any of these elements (e.g., Ag—Mg or Al—Li), a rare earth metal such as europium or ytterbium, and an alloy containing any of these rare earth metals.

[0182] The conductive layers **220** and **260** can be formed by an evaporation method or a sputtering method. Alternatively, a discharging method such as an ink jet method, a printing method such as a screen printing method, or a plating method may be used.

[0183] Note that an organic EL can employ a structure other than a microcavity structure. For example, a separate coloring method by which different colors are emitted from light-emitting elements, or a white EL method in which a material emitting white light is used can be employed.

<<Adhesive Layer **370**>>

[0184] The adhesive layer **370** has a function of bonding the data input device **11** to the display panel **20**.

[0185] 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 adhesive layer **370**.

[0186] For example, an organic material such as a light curable adhesive, a reactive curable adhesive, a thermosetting adhesive, and/or an anaerobic adhesive can be used for the adhesive layer **370**. Note that each of the adhesives can be used alone or in combination.

[0187] The light curable adhesive refers to, for example, an adhesive that is cured by ultraviolet rays, an electron beam, visible light, infrared light, or the like.

[0188] Specifically, an adhesive containing an epoxy resin, an acrylic resin, a silicone resin, a phenol resin, a polyimide resin, an imide resin, a polyvinyl chloride (PVC) resin, a

polyvinyl butyral (PVB) resin, an ethylene vinyl acetate (EVA) resin, silica, or the like can be used for the adhesive layer 370.

[0189] The material is cured rapidly particularly when a light curable adhesive is used, leading to shortening of the process time. In addition, involuntary curing of the adhesive due to environment can be prevented because curing starts with light irradiation. In addition, involuntary curing of the adhesive due to environment can be prevented because curing starts with light irradiation. Furthermore, curing can be performed at low temperatures to facilitate the control of process environment. From the above reasons, the use of a light curable adhesive shortens the process time and reduces processing costs.

<<Conductive Layer 14, 15, 16>>

[0190] For the conductive layers 14, 15, and 16, a visible-light transmitting material containing one or more of indium (In), zinc (Zn), and tin (Sn) is preferably used. Alternatively, a metal element selected from aluminum, silver, copper, palladium, chromium, tantalum, titanium, molybdenum, nickel, iron, cobalt, and tungsten; an alloy containing any of these metal elements as a component; an alloy containing any of these metal elements in combination; or the like may be used. Further, one or more metal elements selected from manganese and zirconium may be used. The conductive layers 14, 15, and 16 may each have a single-layer structure or a layered structure of two or more layers. For example, any of the following can be used: a single-layer structure of an aluminum film containing silicon; a single-layer structure of a copper film containing manganese; 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 two-layer structure in which a copper film is stacked over a copper film containing manganese; a three-layer structure in which a titanium film, an aluminum film, and a titanium film are stacked in this order; a three-layer structure in which a copper film containing manganese, a copper film, and a copper film containing manganese are stacked in this order; and the like. Alternatively, an alloy film or a nitride film which contains aluminum and one or more elements selected from titanium, tantalum, tungsten, molybdenum, chromium, neodymium, and scandium may be used.

<<Insulating Layer 330>>

[0191] The insulating layer 330 has a function of making a flat surface. An inorganic material or an organic material can be used for the insulating layer 330. For example, an oxide insulating film of silicon oxide, silicon oxynitride, aluminum oxide, aluminum oxynitride, gallium oxide, gallium oxynitride, yttrium oxide, yttrium oxynitride, hafnium oxide, hafnium oxynitride, or the like; a nitride insulating film of silicon nitride, aluminum nitride, or the like; or a heat-resistant organic material such as a polyimide resin, an acrylic resin, a polyimide amide resin, a benzocyclobutene resin, a polyamide resin, or an epoxy resin can be used.

<<FPC 41, 42>>

[0192] The FPC 42 is electrically connected to a conductive layer 411 through an anisotropic conductive film 410.

conductive layer 411 can be formed in a step of forming electrode layers of the transistor 50 and the like. An image signal and the like can be supplied from the FPC 42 to the driver circuit including the transistor 52, the capacitor 62, and the like. Furthermore, the FPC 41 is electrically connected to the conductive layers 14 and 15 through the anisotropic conductive film 410.

[0193] FIG. 16 and FIG. 17 each illustrate a variation of the cross-sectional view illustrated in FIG. 15B. A metal nanowire including a plurality of conductors with an extremely small width (for example, a diameter of several nanometers) may be used for the conductive layer 15. Examples of such a metal nanowire include an Ag nanowire, a Cu nanowire, and an Al nanowire. In the case of using an Ag nanowire, light transmittance of 89% or more and a sheet resistance of 40 ohm/square or more and 100 ohm/square or less can be achieved. Note that because such a metal nanowire provides high transmittance, the metal nanowire may be used for an electrode of the display element, e.g., a pixel electrode or a common electrode. In that case, the conductive layers 14, 15, and 16 do not need to be provided so as to be hidden behind the light-blocking layer, and can be provided over the light-blocking layer.

<<Organic EL Panel Using Separate Coloring Method>>

[0194] An organic EL element can be formed using a separate coloring method as illustrated in FIG. 18. FIG. 18 is different from FIG. 15B in that a separate coloring method is used for the EL layer 250 over the conductive layer 220.

<<Flexible Touch Panel>>

[0195] The touch panel may be formed over a flexible substrate 101 or a flexible substrate 301 as illustrated in FIG. 19.

[0196] The flexible substrate and the touch panel can be bonded to each other with the adhesive layer 370. In this manner, a flexible touch panel that can be folded or a touch panel having a curved surface can be fabricated. Moreover, the thickness of the substrate can be small, leading to a reduction in weight of the touch panel.

[Manufacturing Method Example of Flexible Touch Panel]

[0197] Here, a method for manufacturing a flexible touch panel will be described.

[0198] For convenience, a structure including a pixel and a circuit, a structure including an optical member such as a color filter, or a structure including a touch sensor is referred to as an element layer. An element layer includes a display element, for example, and may include a wiring electrically connected to the display element or an element such as a transistor used in a pixel or a circuit in addition to the display element.

[0199] Here, a support body (e.g., the substrate 101 or the substrate 301) with an insulating surface where an element layer is formed is referred to as a base material.

[0200] As a method for forming an element layer over a flexible base material provided with an insulating surface, there are a method in which an element layer is formed directly over a base material, and a method in which an element layer is formed over a supporting base material that has stiffness and then the element layer is separated from the supporting base material and transferred to the base material.

[0201] In the case where a material of the base material can withstand heating temperature in a process for forming the

element layer, it is preferable that the element layer be formed directly over the base material, in which case a manufacturing process can be simplified. At this time, the element layer is preferably formed in a state where the base material is fixed to the supporting base material, in which case transfer thereof in an apparatus and between apparatuses can be easy.

[0202] In the case of employing the method in which the element layer is formed over the supporting base material and then transferred to the base material, first, a separation layer and an insulating layer are stacked over the supporting base material, and then the element layer is formed over the insulating layer. Next, the element layer is separated from the supporting base material and then transferred to the base material. At this time, a material is selected that would cause separation at an interface between the supporting base material and the separation layer, at an interface between the separation layer and the insulating layer, or in the separation layer.

[0203] For example, it is preferable that a stacked layer of a layer including a high-melting-point metal material, such as tungsten, and a layer including an oxide of the metal material be used as the separation layer, and a stacked layer of a plurality of layers, such as a silicon nitride layer and a silicon oxynitride layer be used over the separation layer. The use of the high-melting-point metal material is preferable because the degree of freedom of the process for forming the element layer can be increased.

[0204] The separation may be performed by application of mechanical power, by etching of the separation layer, by dripping of a liquid into part of the separation interface to penetrate the entire separation interface, or the like. Alternatively, separation may be performed by heating the separation interface by utilizing a difference in thermal expansion coefficient.

[0205] The separation layer is unnecessary in the case where separation can occur at an interface between the supporting base material and the insulating layer. For example, glass is used as the supporting base material and an organic resin such as polyimide is used as the insulating layer, a separation trigger is formed by locally heating part of the organic resin by laser light or the like, and separation is performed at an interface between the glass and the insulating layer. Alternatively, a metal layer may be provided between the supporting base material and the insulating layer formed of an organic resin, and separation may be performed at the interface between the metal layer and the insulating layer by heating the metal layer by feeding a current to the metal layer. In that case, the insulating layer formed of an organic resin can be used as a base material.

[0206] Examples of such a base material having flexibility include polyester resins such as polyethylene terephthalate (PET) and polyethylene naphthalate (PEN), a polyacrylonitrile resin, a polyimide resin, a polymethyl methacrylate resin, a polycarbonate (PC) resin, a polyethersulfone (PES) resin, a polyamide resin, a cycloolefin resin, a polystyrene resin, a polyamide imide resin, and a polyvinyl chloride resin. In particular, it is preferable to use a material with a low thermal expansion coefficient, and for example, a polyamide imide resin, a polyimide resin, PET, or the like with a thermal expansion coefficient lower than or equal to $30 \times 10^{-6}/K$ can be suitably used. A substrate in which a fibrous body is impregnated with a resin (also referred to as prepreg) or a

substrate whose thermal expansion coefficient is reduced by mixing an inorganic filler with an organic resin can also be used.

[0207] In the case where a fibrous body is included in the above material, a high-strength fiber of an organic compound or an inorganic compound is used as the fibrous body. The high-strength fiber is specifically a fiber with a high tensile elastic modulus or a fiber with a high Young's modulus. Typical examples thereof include a polyvinyl alcohol based fiber, a polyester based fiber, a polyamide based fiber, a polyethylene based fiber, an aramid based fiber, a polyparaphenylene benzobisoxazole fiber, a glass fiber, and a carbon fiber. As the glass fiber, glass fiber using E glass, S glass, D glass, Q glass, or the like can be used. These fibers may be used in a state of a woven fabric or a nonwoven fabric, and a structure body in which this fibrous body is impregnated with a resin and the resin is cured may be used as the flexible substrate. The structure body including the fibrous body and the resin is preferably used as the flexible substrate, in which case the reliability against bending or breaking due to local pressure can be increased.

[0208] Alternatively, glass, metal, or the like that is thin enough to have flexibility can be used as the base material. Alternatively, a composite material where glass and a resin material are attached to each other may be used.

[0209] In the structure shown in FIG. 19, for example, a first separation layer and an insulating layer 112 are formed in this order over a first supporting base material, and then components over the first separation layer and the insulating layer 112 are formed. Separately, a second separation layer and an insulating layer 312 are formed in this order over a second supporting base material, and then components over the second separation layer and the insulating layer 312 are formed. Next, the first supporting base material is bonded to the second supporting base material with the adhesive layer 370 so that the components face each other. After that, separation at an interface between the second separation layer and the insulating layer 312 is conducted so that the second supporting base material and the second separation layer are removed, and then the substrate 301 is bonded to the insulating layer 312 using an adhesive layer 372. Furthermore, separation at an interface between the first separation layer and the insulating layer 112 is conducted so that the first supporting base material and the first separation layer are removed, and then the substrate 101 is bonded to the insulating layer 112 using an adhesive layer 371. Note that either side may be subjected to separation and attachment first.

[0210] The above is the description of a manufacturing method of a flexible touch panel.

<<Liquid Crystal Panel>>

[0211] As illustrated in FIG. 20, a liquid crystal panel may be used as a display panel included in the touch panel. A touch panel illustrated in FIG. 20 includes a liquid crystal element 80 as a display element. The touch panel also includes a polarizing plate 103, a polarizing plate 303, and a backlight 104, which are bonded with adhesive layers 373, 374, and 375. Furthermore, a protective substrate 302 is provided on the side closer to a viewer than the polarizing plate 303 is, and is bonded with an adhesive layer 376.

<<Liquid Crystal Element 80>>

[0212] A liquid crystal layer 390 is sandwiched between a conductive layer 190 and a conductive layer 380. The align-

ment of liquid crystal molecules included in the liquid crystal layer 390 can be controlled by an electric field between the conductive layer 190 and the conductive layer 380; thus, the liquid crystal layer 390, the conductive layer 190, and the conductive layer 380 function as the liquid crystal element 80. [0213] Although not illustrated in FIG. 20, an alignment film may be provided on a side of the conductive layer 190 in contact with the liquid crystal layer 390 and on a side of the conductive layer 380 in contact with the liquid crystal layer 390.

[0214] Examples of a driving method of the display device include a twisted nematic (TN) mode, a super twisted nematic (STN) mode, a vertical alignment (VA) mode, an axially symmetric aligned micro-cell (ASM) mode, an optically compensated birefringence (OCB) mode, a ferroelectric liquid crystal (FLC) mode, an antiferroelectric liquid crystal (AFLC) mode, a multi-domain vertical alignment (MVA) mode, a patterned vertical alignment (PVA) mode, an in plane switching (IPS) mode, a fringe field switching (FFS) mode (described as a liquid crystal element 81 in FIG. 22, FIG. 23, FIG. 24, and FIG. 25), and a transverse bend alignment (TBA) mode. Other examples of the driving method of the display device include an electrically controlled birefringence (ECB) mode, a polymer dispersed liquid crystal (PDLC) mode, a polymer network liquid crystal (PNLC) mode, and a guest-host mode. Note that one embodiment of the present invention is not limited to the above, and various liquid crystal elements and driving methods can be employed.

[0215] The liquid crystal element 80 may be formed using a liquid crystal composition including a liquid crystal exhibiting a nematic phase and a chiral material. In that case, a cholesteric phase or a blue phase is exhibited. The liquid crystal exhibiting a blue phase has a short response time of 1 msec or less. Since the liquid crystal exhibiting a blue phase is optically isotropic, alignment treatment is not necessary and viewing angle dependence is small.

<<Capacitor 61, 63>>

[0216] The capacitor 61 includes the conductive layer 190, the insulating layer 180, and a conductive layer 400. The conductive layer 190 functions as one electrode of the capacitor 61. The conductive layer 400 functions as the other electrode of the capacitor 61. The insulating layer 180 is provided between the conductive layer 190 and the conductive layer 400. The conductive layer 190 is connected to the transistor 50. A capacitor 63 can have a structure similar to that of the capacitor 61.

[0217] The conductive layer 400 as well as the semiconductor layer 140 is formed over the insulating layer 130.

[0218] When the transistor 50 includes an oxide semiconductor in the semiconductor layer 140, the conductive layer 400 can be formed of the same material as the semiconductor layer 140 over the insulating layer 130. In that case, the conductive layer 400 is formed by processing a film formed at the same time as the semiconductor layer 140, and therefore contains elements similar to those in the semiconductor layer 140. The conductive layer 400 has a crystal structure similar to or different from that of the semiconductor layer 140. When the film formed at the same time as the semiconductor layer 140 includes impurities or oxygen vacancies, the film can have conductivity to be the conductive layer 400. Typical examples of the impurities contained in the conductive layer 400 are a rare gas, hydrogen, boron, nitrogen, fluorine, aluminum, and phosphorus. Typical examples of the rare gas

include helium, neon, argon, krypton, and xenon. Note that the conductive layer 400 has conductivity as an example; however, one embodiment of the present invention is not limited to this example and the conductive layer 400 does not need to have conductivity depending on the case or circumstances. In other words, the conductive layer 400 may have properties similar to those of the semiconductor layer 140.

[0219] Although the semiconductor layer 140 and the conductive layer 400 are formed over the insulating layer 130 as described above, they have different impurity concentrations. Specifically, the impurity concentration of the conductive layer 400 is higher than that of the semiconductor layer 140. For example, in the semiconductor layer 140, the hydrogen concentration measured by secondary ion mass spectrometry is lower than or equal to 5×10^{19} atoms/cm³, preferably lower than or equal to 5×10^{18} atoms/cm³, further preferably lower than or equal to 1×10^{18} atoms/cm³, still further preferably lower than or equal to 5×10^{17} atoms/cm³, and yet still further preferably lower than or equal to 1×10^{16} atoms/cm³. In contrast, the hydrogen concentration in the conductive layer 400 measured by secondary ion mass spectrometry is higher than or equal to 8×10^{19} atoms/cm³, preferably higher than or equal to 1×10^{20} atoms/cm³, and further preferably higher than or equal to 5×10^{20} atoms/cm³. In addition, the hydrogen concentration in the conductive layer 400 is greater than or equal to 2 times or greater than or equal to 10 times that in the semiconductor layer 140.

[0220] When the hydrogen concentration in the semiconductor layer 140 is set in the aforementioned range, generation of electrons serving as carriers in the semiconductor layer 140 can be suppressed.

[0221] When an oxide semiconductor film formed at the same time as the semiconductor layer 140 is exposed to plasma, the oxide semiconductor film is damaged and oxygen vacancies can be generated. For example, when a film is formed over the oxide semiconductor film by a plasma CVD method or a sputtering method, the oxide semiconductor film is exposed to plasma and oxygen vacancies are generated. Alternatively, when the oxide semiconductor film is exposed to plasma in etching treatment for formation of an opening in the insulating layer 170, oxygen vacancies are generated. Alternatively, when the oxide semiconductor film is exposed to plasma of a mixed gas of oxygen and hydrogen, hydrogen, a rare gas, ammonia, and the like, oxygen vacancies are generated. Alternatively, when impurities are added to the oxide semiconductor film, oxygen vacancies can be formed while the impurities are added to the oxide semiconductor film. The impurities can be added by an ion doping method, an ion implantation method, a plasma treatment method, and the like. In the plasma treatment method, plasma is generated in a gas atmosphere containing the impurities to be added, and ions of the impurities accelerated by plasma treatment are made to collide with the oxide semiconductor film, whereby oxygen vacancies can be formed in the oxide semiconductor film.

[0222] When an impurity, e.g., hydrogen is contained in the oxide semiconductor film in which oxygen vacancies are generated by addition of impurity elements, hydrogen enters an oxygen vacant site and forms a donor level in the vicinity of the conduction band. As a result, the oxide semiconductor film has increased conductivity to be a conductor. An oxide semiconductor film that has become a conductor can be referred to as an oxide conductor film. That is, it can be said that the semiconductor layer 140 is formed of an oxide semi-

conductor and the conductive layer 400 is formed of an oxide conductor film. It can also be said that the conductive layer 400 is formed of an oxide semiconductor film having high conductivity or a metal oxide film having high conductivity.

[0223] Note that the insulating layer 180 preferably contains hydrogen. Since the conductive layer 400 is in contact with the insulating layer 180, hydrogen contained in the insulating layer 180 can be diffused into the oxide semiconductor film formed at the same time as the semiconductor layer 140. As a result, impurities can be added to the oxide semiconductor film formed at the same time as the semiconductor layer 140.

[0224] Furthermore, the insulating layer 170 is preferably formed using an oxide insulating film containing more oxygen than that in the stoichiometric composition, and the insulating layer 180 is preferably formed using an insulating film containing hydrogen. When oxygen contained in the insulating layer 170 is transferred to the semiconductor layer 140 of the transistor 50, the amount of oxygen vacancies in the semiconductor layer 140 can be reduced and a change in the electrical characteristics of the transistor 50 can be reduced. In addition, hydrogen contained in the insulating layer 180 is transferred to the conductive layer 400 to increase the conductivity of the conductive layer 400.

[0225] In the above manner, the conductive layer 400 can be formed at the same time as the semiconductor layer 140, and conductivity is given to the conductive layer 400 after the formation. Such a structure results in a reduction in manufacturing costs.

[0226] Oxide semiconductor films generally have a visible light transmitting property because of their large energy gap. In contrast, an oxide conductor film is an oxide semiconductor film having a donor level in the vicinity of the conduction band. Thus, the influence of light absorption due to the donor level is small, so that an oxide conductor film has a visible light transmitting property comparable to that of an oxide semiconductor film.

<<Conductive Layer 190>>

[0227] The conductive layer 190 is formed using a conductive film that transmits visible light. For example, a material including one of indium (In), zinc (Zn), and tin (Sn) can be used for the conductive film that transmits visible light. Typical examples of the conductive film that transmits visible light include conductive oxides such as indium tin oxide, indium oxide containing tungsten oxide, indium zinc oxide containing tungsten oxide, indium oxide containing titanium oxide, indium tin oxide containing titanium oxide, indium zinc oxide, and indium tin oxide containing silicon oxide.

[0228] From the above, the conductive layer 190 and the conductive layer 400 have light-transmitting properties; as a result, the capacitor 61 can have a light-transmitting property as a whole.

<<Conductive Layer 380>>

[0229] The conductive layer 380 is formed using a conductive film that transmits visible light. For example, a material including one of indium (In), zinc (Zn), and tin (Sn) can be used for the conductive film that transmits visible light. Typical examples of the conductive film that transmits visible light include conductive oxides such as indium tin oxide, indium oxide containing tungsten oxide, indium zinc oxide containing tungsten oxide, indium oxide containing titanium oxide,

indium tin oxide containing titanium oxide, indium zinc oxide, and indium tin oxide containing silicon oxide.

[0230] FIG. 21, FIG. 22, FIG. 23, FIG. 24, and FIG. 25 illustrate modification examples of the cross-sectional view illustrated in FIG. 20. A metal nanowire including a plurality of conductors with an extremely small width (for example, a diameter of several nanometers) may be used for the conductive layer 15. Examples of such a metal nanowire include an Ag nanowire, a Cu nanowire, and an Al nanowire. In the case of using an Ag nanowire, light transmittance of 89% or more and a sheet resistance of 40 ohm/square or more and 100 ohm/square or less can be achieved. Note that because such a metal nanowire provides high transmittance, the metal nanowire may be used for an electrode of the display element, e.g., a pixel electrode or a common electrode. In that case, the conductive layers 14, 15, and 16 do not need to be provided so as to be hidden behind the light-blocking layer, and can be provided over the light-blocking layer. As illustrated in FIG. 23, the conductive layer 380 can be used as the conductive layer 14, for example. Further, as illustrated in FIG. 22, FIG. 23, and FIG. 25, a conductive layer formed on the display panel side (e.g., the conductive layer 190) can be used as the conductive layer 15.

[0231] Although an example of using a transistor including an oxide semiconductor is shown in this embodiment, one embodiment of the present invention is not limited to this example. Depending on the case or circumstances, a transistor including a semiconductor material that is not an oxide semiconductor may be used in one embodiment of the present invention.

[0232] For example, a transistor in which a Group 14 element, a compound semiconductor, an oxide semiconductor, or the like is used for the semiconductor layer can be used. Specifically, a transistor that includes a semiconductor containing silicon, a semiconductor containing gallium arsenide, an organic semiconductor, a semiconductor containing silicon carbide, a semiconductor containing germanium, a semiconductor containing silicon germanium, a carbon nanotube, or the like can be used.

[0233] For example, single crystal silicon, polysilicon, or amorphous silicon can be used for the semiconductor layer of the transistor.

[0234] Note that the structures, methods, and the like described in this embodiment can be used in appropriate combination with any of the structures, methods, and the like described in the other embodiments.

Embodiment 4

[0235] Described in this embodiment is a modification example of the structure of the transistor described in Embodiment 3.

<<Stacked Oxide Semiconductor>>

[0236] Note that in the semiconductor layer 140, a plurality of oxide semiconductor films that differ in the atomic ratio of metal elements may be stacked. For example, as in a transistor 51 in FIG. 26A, an oxide semiconductor layer 141 and an oxide semiconductor layer 142 may be stacked in this order over the insulating layer 130. Alternatively, as illustrated in FIG. 26B, the oxide semiconductor layer 142, the oxide semiconductor layer 141, and an oxide semiconductor layer 143 may be stacked in this order over the insulating layer 130. The

oxide semiconductor layers **142** and **143** differ from the oxide semiconductor layer **141** in the atomic ratio of metal elements.

<<Channel-Protective Transistor and Top-Gate Transistor>>

[0237] The transistor **50** and the like illustrated in FIG. **15B** are, but are not limited to, bottom-gate transistors. FIG. **27A** illustrates a transistor **53** and FIG. **27B** illustrates a transistor **54** as modification examples of the transistor **50**. Although the transistor **50** illustrated in FIG. **15B** is a channel-etched transistor, it may be the channel-protective transistor **53** including an insulating layer **165** as illustrated in the cross-sectional view of FIG. **27A** or may be the top-gate transistor **54** as illustrated in the cross-sectional view of FIG. **27B**.

<<Dual-Gate Transistor>>

[0238] A transistor **55**, which is a modification example of the transistor **50**, will be described with reference to FIGS. **28A** to **28C**. The transistor illustrated in FIGS. **28A** to **28C** has a dual-gate structure.

[0239] FIGS. **28A** to **28C** are a top view and cross-sectional views of the transistor **55**. FIG. **28A** is a top view of the transistor **55**, FIG. **28B** is a cross-sectional view taken along dashed-dotted line A-A' in FIG. **28A**, and FIG. **28C** is a cross-sectional view taken along dashed-dotted line B-B' in FIG. **28A**. Note that in FIG. **28A**, the substrate **100**, the insulating layer **110**, the insulating layer **130**, the insulating layer **170**, the insulating layer **180**, and the like are not illustrated for the sake of clarity.

[0240] The transistor **55** illustrated in FIGS. **28A** to **28C** includes the conductive layer **120** functioning as a gate electrode over the insulating layer **110**, the insulating layer **130** functioning as a gate insulating film over the conductive layer **120**, the semiconductor layer **140** overlapping with the conductive layer **120** with the insulating layer **130** provided therebetween, the conductive layers **150** and **160** in contact with the semiconductor layer **140**, the insulating layer **170** over the semiconductor layer **140** and the conductive layers **150** and **160**, the insulating layer **180** over the insulating layer **170**, and a conductive layer **420** functioning as a back gate electrode over the insulating layer **180**. The conductive layer **120** is connected to the conductive layer **420** in an opening in the insulating layers **130**, **170**, and **180**.

<<Conductive Layer 420>>

[0241] The conductive layer **420** is formed using a conductive film that transmits visible light or a conductive film that reflects visible light. For example, a material including one of indium (In), zinc (Zn), and tin (Sn) can be used for the conductive film that transmits visible light. Typical examples of the conductive film that transmits visible light include conductive oxides such as indium tin oxide, indium oxide containing tungsten oxide, indium zinc oxide containing tungsten oxide, indium oxide containing titanium oxide, indium tin oxide containing titanium oxide, indium zinc oxide, and indium tin oxide containing silicon oxide. For the conductive film that reflects visible light, a material containing aluminum or silver can be used, for example.

[0242] Note that when a side surface of the semiconductor layer **140** faces the conductive layer **420** in the channel width direction as shown in FIG. **28C**, carriers flow not only at the interface between the insulating layer **170** and the semiconductor layer **140** and at the interface between the insulating

layer **130** and the semiconductor layer **140** but also in the semiconductor layer **140**. Therefore, the amount of transfer of carriers in the transistor **55** is increased. As a result, the on-state current and field-effect mobility of the transistor **55** are increased. The electric field of the conductive layer **420** affects the side surface or an end portion including the side surface and its vicinity of the semiconductor layer **140**; thus, generation of a parasitic channel at the side surface or the end portion of the semiconductor layer **140** can be suppressed.

[0243] By providing the transistor illustrated in FIGS. **28A** to **28C** in a pixel portion, signal delay in wirings can be reduced and display defects such as display unevenness can be suppressed even though the number of wirings is increased in a large-sized display device or a high-resolution display device.

[0244] Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 5

[0245] In this embodiment, a structure example of the display panel of one embodiment of the present invention will be described with reference to FIGS. **29A** to **29C**.

[Structure Example]

[0246] FIG. **29A** is a top view of the display device of one embodiment of the present invention. FIG. **29B** is a circuit diagram illustrating a pixel circuit that can be used in the case where a liquid crystal element is used in a pixel in the display device of one embodiment of the present invention. FIG. **29C** is a circuit diagram illustrating a pixel circuit that can be used in the case where an organic EL element is used in a pixel in the display device of one embodiment of the present invention.

[0247] The transistor in the pixel portion can be formed in accordance with the other embodiments. The transistor can be easily formed as an n-channel transistor, and thus part of a driver circuit that can be formed using an n-channel transistor is formed over the same substrate as the transistor of the pixel portion. With the use of any of the transistors described in the above embodiments for the pixel portion or the driver circuit in this manner, a highly reliable display device can be provided.

[0248] FIG. **29A** illustrates an example of a top view of an active matrix display device. A pixel portion **701**, a scan line driver circuit **702**, a scan line driver circuit **703**, and a signal line driver circuit **704** are formed over a substrate **700** of the display device. In the pixel portion **701**, a plurality of signal lines extended from the signal line driver circuit **704** are arranged and a plurality of scan lines extended from the scan line driver circuit **702** and the scan line driver circuit **703** are arranged. Note that pixels which include display elements are provided in a matrix in respective regions where the scan lines and the signal lines intersect with each other. The substrate **700** of the display device is connected to a timing control circuit (also referred to as a controller or a controller IC) through a connection portion such as a flexible printed circuit (FPC).

[0249] In FIG. **29A**, the scan line driver circuit **702**, the scan line driver circuit **703**, and the signal line driver circuit **704** are formed over the substrate **700** where the pixel portion **701** is formed. Accordingly, the number of components which are provided outside, such as a driver circuit, can be reduced, so

that a reduction in cost can be achieved. Furthermore, if the driver circuit is provided outside the substrate **700**, wirings would need to be extended and the number of wiring connections would increase. When the driver circuit is provided over the substrate **700**, the number of wiring connections can be reduced. Consequently, an improvement in reliability or yield can be achieved.

[Liquid Crystal Display Device]

[0250] FIG. **29B** illustrates an example of a circuit configuration of the pixel. Here, a pixel circuit which is applicable to a pixel of a VA liquid crystal display device is illustrated as an example.

[0251] This pixel circuit can be applied to a structure in which one pixel includes a plurality of pixel electrode layers. The pixel electrode layers are connected to different transistors, and the transistors can be driven with different gate signals. Accordingly, signals applied to individual pixel electrode layers in a multi-domain pixel can be controlled independently.

[0252] A gate wiring **712** of a transistor **716** and a gate wiring **713** of a transistor **717** are separated so that different gate signals can be supplied thereto. In contrast, a data line **714** is shared by the transistors **716** and **717**. The transistor described in any of the above embodiments can be used as appropriate as each of the transistors **716** and **717**. Thus, a highly reliable liquid crystal display device can be provided.

[0253] A first pixel electrode layer is electrically connected to the transistor **716** and a second pixel electrode is electrically connected to the transistor **717**. The first pixel electrode and the second pixel electrode are separated. There is no particular limitation on the shapes of the first pixel electrode and the second pixel electrode. For example, the first pixel electrode may have a V-like shape.

[0254] A gate electrode of the transistor **716** is connected to the gate wiring **712**, and a gate electrode of the transistor **717** is connected to the gate wiring **713**. When different gate signals are supplied to the gate wiring **712** and the gate wiring **713**, operation timings of the transistor **716** and the transistor **717** can be varied. As a result, alignment of liquid crystals can be controlled.

[0255] Furthermore, storage capacitors may be formed using a capacitor wiring **710**, gate insulating films functioning as dielectrics, and capacitor electrodes electrically connected to the first pixel electrode layer and the second pixel electrode layer.

[0256] The multi-domain pixel includes a first liquid crystal element **718** and a second liquid crystal element **719**. The first liquid crystal element **718** includes the first pixel electrode layer, a counter electrode layer, and a liquid crystal layer therebetween. The second liquid crystal element **719** includes the second pixel electrode layer, a counter electrode layer, and a liquid crystal layer therebetween.

[0257] Note that a pixel circuit of the present invention is not limited to that shown in FIG. **29B**. For example, a switch, a resistor, a capacitor, a transistor, a sensor, a logic circuit, or the like may be added to the pixel circuit illustrated in FIG. **29B**.

[Organic EL Display Device]

[0258] FIG. **29C** illustrates another example of a circuit configuration of the pixel. Here, a pixel structure of a display device using an organic EL element is shown.

[0259] In an organic EL element, by application of voltage to a light-emitting element, electrons are injected from one of a pair of electrodes and holes are injected from the other of the pair of electrodes, into a layer containing a light-emitting organic compound; thus, current flows. The electrons and holes are recombined, and thus, the light-emitting organic compound is excited. The light-emitting organic compound returns to a ground state from the excited state, thereby emitting light. Owing to such a mechanism, this light-emitting element is referred to as a current-excitation light-emitting element.

[0260] FIG. **29C** illustrates an applicable example of a pixel circuit. Here, one pixel includes two n-channel transistors. Note that a metal oxide film can be used for a channel formation region of the n-channel transistor. Further, digital time grayscale driving can be employed for the pixel circuit.

[0261] The configuration of the applicable pixel circuit and operation of a pixel employing digital time grayscale driving will be described.

[0262] A pixel **720** includes a switching transistor **721**, a driver transistor **722**, a light-emitting element **724**, and a capacitor **723**. A gate electrode layer of the switching transistor **721** is connected to a scan line **726**, a first electrode (one of a source electrode layer and a drain electrode layer) of the switching transistor **721** is connected to a signal line **725**, and a second electrode (the other of the source electrode layer and the drain electrode layer) of the switching transistor **721** is connected to a gate electrode layer of the driver transistor **722**. The gate electrode layer of the driver transistor **722** is connected to a power supply line **727** through the capacitor **723**, a first electrode of the driver transistor **722** is connected to the power supply line **727**, and a second electrode of the driver transistor **722** is connected to a first electrode (a pixel electrode) of the light-emitting element **724**. A second electrode of the light-emitting element **724** corresponds to a common electrode **728**. The common electrode **728** is electrically connected to a common potential line formed over the same substrate as the common electrode **728**.

[0263] As the switching transistor **721** and the driver transistor **722**, any of the transistors described in other embodiments can be used as appropriate. In this manner, a highly reliable organic EL display device can be provided.

[0264] The potential of the second electrode (the common electrode **728**) of the light-emitting element **724** is set to be a low power supply potential. Note that the low power supply potential is lower than a high power supply potential supplied to the power supply line **727**. For example, the low power supply potential can be GND, 0 V, or the like. The high power supply potential and the low power supply potential are set to be higher than or equal to the forward threshold voltage of the light-emitting element **724**, and the difference between the potentials is applied to the light-emitting element **724**, whereby current is supplied to the light-emitting element **724**, leading to light emission. The forward voltage of the light-emitting element **724** refers to a voltage at which a desired luminance is obtained, and includes at least a forward threshold voltage.

[0265] Note that the gate capacitance of the driver transistor **722** may be used as a substitute for the capacitor **723**, so that the capacitor **723** can be omitted. The gate capacitance of the driver transistor **722** may be formed between the channel formation region and the gate electrode layer.

[0266] Next, a signal input to the driver transistor **722** will be described. In the case of a voltage-input voltage driving

method, a video signal for sufficiently turning on or off the driver transistor 722 is input to the driver transistor 722. In order for the driver transistor 722 to operate in a linear region, voltage higher than the voltage of the power supply line 727 is applied to the gate electrode layer of the driver transistor 722. Note that voltage higher than or equal to voltage which is the sum of power supply line voltage and the threshold voltage V_{th} of the driver transistor 722 is applied to the signal line 725.

[0267] In the case of performing analog grayscale driving, a voltage higher than or equal to a voltage which is the sum of the forward voltage of the light-emitting element 724 and the threshold voltage V_{th} of the driver transistor 722 is applied to the gate electrode layer of the driver transistor 722. A video signal by which the driver transistor 722 is operated in a saturation region is input, so that current is supplied to the light-emitting element 724. In order for the driver transistor 722 to operate in a saturation region, the potential of the power supply line 727 is set higher than the gate potential of the driver transistor 722. When an analog video signal is used, it is possible to supply current to the light-emitting element 724 in accordance with the video signal and perform analog grayscale driving.

[0268] Note that the configuration of the pixel circuit of the present invention is not limited to that shown in FIG. 29C. For example, a switch, a resistor, a capacitor, a sensor, a transistor, a logic circuit, or the like may be added to the pixel circuit illustrated in FIG. 29C.

[0269] In the case where, the transistor described in any of the above embodiments is used for the circuit illustrated in FIGS. 29A to 29C, the source electrode (the first electrode) can be electrically connected to the low potential side and the drain electrode (the second electrode) can be electrically connected to the high potential side. The following structure can also be employed: the potential of a first gate electrode is controlled by a control circuit or the like, and a potential lower than a potential applied to a source electrode is input to a second gate electrode through a wiring that is not illustrated.

[0270] For example, in this specification and the like, for example, a display element, a display device which is a device including a display element, a light-emitting element, and a light-emitting device which is a device including a light-emitting element can employ a variety of modes or can include a variety of elements. The display element, the display device, the light-emitting element, or the light-emitting device includes at least one of an electroluminescence (EL) element (e.g., an EL element including organic and inorganic materials, an organic EL element, or an inorganic EL element), an LED (e.g., a white LED, a red LED, a green LED, or a blue LED), a transistor (a transistor that emits light depending on current), an electron emitter, a liquid crystal element, electronic ink, an electrophoretic element, a grating light valve (GLV), a plasma display panel (PDP), a display element using micro electro mechanical systems (MEMS), a digital micromirror device (DMD), a digital micro shutter (DMS), MIRASOL (registered trademark), an interferometric modulator display (IMOD) element, a MEMS shutter display element, an optical-interference-type MEMS display element, an electrowetting element, a piezoelectric ceramic display, a display element including a carbon nanotube, and the like. Other than the above, a display medium whose contrast, luminance, reflectance, transmittance, or the like is changed by an electrical or magnetic effect may be included. Note that examples of a display device including an EL ele-

ment include an EL display. Examples of a display device including an electron emitter include a field emission display (FED) and an SED-type flat panel display (SED: surface-conduction electron-emitter display). Examples of a display device including a liquid crystal element include a liquid crystal display (e.g., a transmissive liquid crystal display, a transmissive liquid crystal display, a reflective liquid crystal display, a direct-view liquid crystal display, or a projection liquid crystal display). Examples of a display device including electronic ink, Electronic Liquid Powder (registered trademark), or an electrophoretic element include electronic paper. In the case of a transmissive liquid crystal display or a reflective liquid crystal display, some or all of pixel electrodes function as reflective electrodes. For example, some or all of pixel electrodes are formed to contain aluminum, silver, or the like. In such a case, a memory circuit such as an SRAM can be provided under the reflective electrodes, leading to lower power consumption. Note that in the case of using an LED, graphene or graphite may be provided under an electrode or a nitride semiconductor of the LED. Graphene or graphite may be a multilayer film in which a plurality of layers are stacked. As described above, provision of graphene or graphite enables easy formation of a nitride semiconductor thereover, such as an n-type GaN semiconductor layer including crystals. Furthermore, a p-type GaN semiconductor layer including crystals or the like can be provided thereover, and thus the LED can be formed. Note that an AlN layer may be provided between the n-type GaN semiconductor layer including crystals and graphene or graphite. The GaN semiconductor layers included in the LED may be formed by MOCVD. Note that when the graphene is provided, the GaN semiconductor layers included in the LED can also be formed by a sputtering method.

[0271] Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 6

[0272] A structure of the oxide semiconductor film will be described below.

<<Structure of Oxide Semiconductor>>

[0273] An oxide semiconductor film is classified into a non-single-crystal oxide semiconductor film and a single crystal oxide semiconductor film. Alternatively, an oxide semiconductor is classified into, for example, a crystalline oxide semiconductor and an amorphous oxide semiconductor.

[0274] Examples of a non-single-crystal oxide semiconductor include a CAAC-OS, a polycrystalline oxide semiconductor, a microcrystalline oxide semiconductor, and an amorphous oxide semiconductor. In addition, examples of a crystalline oxide semiconductor include a single crystal oxide semiconductor, a CAAC-OS, a polycrystalline oxide semiconductor, and a microcrystalline oxide semiconductor.

[0275] First, a CAAC-OS film is described.

[0276] The CAAC-OS film is one of oxide semiconductor films having a plurality of c-axis aligned crystal parts.

[0277] With a transmission electron microscope (TEM), a combined analysis image (also referred to as a high-resolution TEM image) of a bright-field image and a diffraction pattern of the CAAC-OS film is observed. Consequently, a plurality of crystal parts are observed clearly. However, in the

high-resolution TEM image, a boundary between crystal parts, i.e., a grain boundary is not observed clearly. Thus, in the CAAC-OS film, a reduction in electron mobility due to the grain boundary is less likely to occur.

[0278] According to the high-resolution cross-sectional TEM image of the CAAC-OS film observed in a direction substantially parallel to a sample surface, metal atoms are arranged in a layered manner in the crystal parts. Each metal atom layer has a morphology that reflects a surface over which the CAAC-OS film is formed (also referred to as a formation surface) or a top surface of the CAAC-OS film, and is provided parallel to the formation surface or the top surface of the CAAC-OS film.

[0279] On the other hand, according to the high-resolution planar TEM image of the CAAC-OS film observed in a direction substantially perpendicular to the sample surface, metal atoms are arranged in a triangular or hexagonal configuration in the crystal parts. However, there is no regularity of arrangement of metal atoms between different crystal parts.

[0280] The CAAC-OS film is subjected to structural analysis with an X-ray diffraction (XRD) apparatus. For example, when the CAAC-OS film including an InGaZnO_4 crystal is analyzed by an out-of-plane method, a peak appears frequently when the diffraction angle (2θ) is around 31° . This peak is derived from the (009) plane of the InGaZnO_4 crystal, which indicates that crystals in the CAAC-OS film have c-axis alignment, and that the c-axes are aligned in a direction substantially perpendicular to the formation surface or the top surface of the CAAC-OS film.

[0281] Note that when the CAAC-OS film with an InGaZnO_4 crystal is analyzed by an out-of-plane method, a peak of 2θ may also be observed at around 36° , in addition to the peak of 2θ at around 31° . The peak of 2θ at around 36° indicates that a crystal having no c-axis alignment is included in part of the CAAC-OS film. It is preferable that in the CAAC-OS film, a peak of 2θ appear at around 31° and a peak of 2θ not appear at around 36° .

[0282] The CAAC-OS film is an oxide semiconductor film having low impurity concentration. The impurity is an element other than the main components of the oxide semiconductor film, such as hydrogen, carbon, silicon, or a transition metal element. In particular, an element that has higher bonding strength to oxygen than a metal element included in the oxide semiconductor film, such as silicon, disturbs the atomic order of the oxide semiconductor film by depriving the oxide semiconductor film of oxygen and causes a decrease in crystallinity. Furthermore, a heavy metal such as iron or nickel, argon, carbon dioxide, or the like has a large atomic radius (molecular radius), and thus disturbs the atomic order of the oxide semiconductor film and causes a decrease in crystallinity when it is contained in the oxide semiconductor film. Note that the impurity contained in the oxide semiconductor film might serve as a carrier trap or a carrier generation source.

[0283] The CAAC-OS film is an oxide semiconductor film having low density of defect states. In some cases, oxygen vacancies in the oxide semiconductor film serve as carrier traps or serve as carrier generation sources when hydrogen is captured therein.

[0284] The state in which impurity concentration is low and density of defect states is low (the number of oxygen vacancies is small) is referred to as "highly purified intrinsic" or "substantially highly purified intrinsic." A highly purified intrinsic or substantially highly purified intrinsic oxide semiconductor film has few carrier generation sources, and thus

can have low carrier density. Thus, a transistor including the oxide semiconductor film rarely has negative threshold voltage (is rarely normally on). The highly purified intrinsic or substantially highly purified intrinsic oxide semiconductor film has few carrier traps. Accordingly, the transistor including the oxide semiconductor film has few variations in electrical characteristics and high reliability. Charge trapped by the carrier traps in the oxide semiconductor film takes a long time to be released and may behave like fixed charge. Thus, the transistor that includes the oxide semiconductor film having high impurity concentration and high density of defect states has unstable electrical characteristics in some cases.

[0285] In a transistor including the CAAC-OS film, changes in electrical characteristics of the transistor due to irradiation with visible light or ultraviolet light are small.

[0286] Next, a microcrystalline oxide semiconductor film is described.

[0287] A microcrystalline oxide semiconductor film has a region where a crystal part is observed in a high-resolution TEM image and a region where a crystal part is not clearly observed in a high-resolution TEM image. In most cases, a crystal part in the microcrystalline oxide semiconductor film is greater than or equal to 1 nm and less than or equal to 100 nm, or greater than or equal to 1 nm and less than or equal to 10 nm. A microcrystal with a size greater than or equal to 1 nm and less than or equal to 10 nm, or a size greater than or equal to 1 nm and less than or equal to 3 nm is specifically referred to as nanocrystal (nc). An oxide semiconductor film including nanocrystal is referred to as a nanocrystalline oxide semiconductor (nc-OS) film. In a high-resolution TEM image for example, a grain boundary cannot be found clearly in the nc-OS film in some cases.

[0288] In the nc-OS film, a microscopic region (e.g., a region with a size greater than or equal to 1 nm and less than or equal to 10 nm, in particular, a region with a size greater than or equal to 1 nm and less than or equal to 3 nm) has periodic atomic order. There is no regularity of crystal orientation between different crystal parts in the nc-OS film. Thus, the orientation of the whole film is not observed. Accordingly, in some cases, the nc-OS film cannot be distinguished from an amorphous oxide semiconductor film depending on an analysis method. For example, when the nc-OS film is subjected to structural analysis by an out-of-plane method with an XRD apparatus using an X-ray having a diameter larger than that of a crystal part, a peak that shows a crystal plane does not appear. Furthermore, a halo pattern is shown in a selected-area electron diffraction pattern of the nc-OS film obtained by using an electron beam having a probe diameter larger than the diameter of a crystal part (e.g., larger than or equal to 50 nm). Meanwhile, spots are shown in a nanobeam electron diffraction pattern of the nc-OS film obtained by using an electron beam having a probe diameter close to or smaller than the diameter of a crystal part. Furthermore, in a nanobeam electron diffraction pattern of the nc-OS film, regions with high luminance in a circular (ring) pattern are observed in some cases. Also in a nanobeam electron diffraction pattern of the nc-OS film, a plurality of spots are shown in a ring-like region in some cases.

[0289] The nc-OS film is an oxide semiconductor film that has high regularity than an amorphous oxide semiconductor film. Thus, the nc-OS film has a lower density of defect states than the amorphous oxide semiconductor film. Note that there is no regularity of crystal orientation between different crystal

parts in the nc-OS film; thus, the nc-OS film has a higher density of defect states than the CAAC-OS film.

[0290] Next, an amorphous oxide semiconductor film is described.

[0291] The amorphous oxide semiconductor film has disordered atomic arrangement and no crystal part. For example, the amorphous oxide semiconductor film does not have a specific state as in quartz.

[0292] In a high-resolution TEM image of the amorphous oxide semiconductor film, crystal parts cannot be found.

[0293] When the amorphous oxide semiconductor film is subjected to structural analysis by an out-of-plane method with an XRD apparatus, a peak which shows a crystal plane does not appear. A halo pattern is shown in an electron diffraction pattern of the amorphous oxide semiconductor film. Furthermore, a halo pattern is shown but a spot is not shown in a nanobeam electron diffraction pattern of the amorphous oxide semiconductor film.

[0294] Note that an oxide semiconductor film may have a structure having physical properties between the nc-OS film and the amorphous oxide semiconductor film. The oxide semiconductor film having such a structure is specifically referred to as an amorphous-like oxide semiconductor (a-like OS) film.

[0295] In a high-resolution TEM image of the a-like OS film, a void may be seen. Furthermore, in the high-resolution TEM image, there are a region where a crystal part is clearly observed and a region where a crystal part is not observed. In the a-like OS film, crystallization by a slight amount of electron beam used for TEM observation occurs and growth of the crystal part is found sometimes. In contrast, crystallization by a slight amount of electron beam used for TEM observation is less observed in the nc-OS film having good quality.

[0296] Note that the crystal part size in the a-like OS film and the nc-OS film can be measured using high-resolution TEM images. For example, an InGaZnO₄ crystal has a layered structure in which two Ga—Zn—O layers are included between In—O layers. A unit cell of the InGaZnO₄ crystal has a structure in which nine layers of three In—O layers and six Ga—Zn—O layers are layered in the c-axis direction. Accordingly, the spacing between these adjacent layers is equivalent to the lattice spacing on the (009) plane (also referred to as a d value). The value is calculated to be 0.29 nm from crystal structure analysis. Thus, each of the lattice fringes in which the spacing therebetween is from 0.28 nm to 0.30 nm corresponds to the a-b plane of the InGaZnO₄ crystal, focusing on the lattice fringes in the high-resolution TEM image.

[0297] The density of an oxide semiconductor film might vary depending on its structure. For example, if the composition of an oxide semiconductor film is determined, the structure of the oxide semiconductor film can be estimated from a comparison between the density of the oxide semiconductor film and the density of a single-crystal oxide semiconductor film having the same composition as the oxide semiconductor film. For example, the density of an a-like OS film is higher than or equal to 78.6% and lower than 92.3% of that of the single-crystal oxide semiconductor film. In addition, for example, the density of an nc-OS film or a CAAC-OS film is higher than or equal to 92.3% and lower than 100% of that of the single-crystal oxide semiconductor film. Note that it is difficult to form an oxide semiconductor film whose density is lower than 78% of that of the single-crystal oxide semiconductor film.

[0298] Specific examples of the above are described. For example, in the case of an oxide semiconductor film with an atomic ratio of In:Ga:Zn=1:1:1, the density of single-crystal InGaZnO₄ with a rhombohedral crystal structure is 6.357 g/cm³. Thus, for example, in the case of the oxide semiconductor film with an atomic ratio of In:Ga:Zn=1:1:1, the density of an a-like OS film is higher than or equal to 5.0 g/cm³ and lower than 5.9 g/cm³. In addition, for example, in the case of the oxide semiconductor film with an atomic ratio of In:Ga:Zn=1:1:1, the density of an nc-OS film or a CAAC-OS film is higher than or equal to 5.9 g/cm³ and lower than 6.3 g/cm³.

[0299] Note that single crystals with the same composition do not exist in some cases. In such a case, by combining single crystals with different compositions at a given proportion, it is possible to calculate the density that corresponds to the density of a single crystal with a desired composition. The density of the single crystal with a desired composition may be calculated using weighted average with respect to the combination ratio of the single crystals with different compositions. Note that it is preferable to combine as few kinds of single crystals as possible for density calculation.

[0300] Note that an oxide semiconductor film may be a stacked film including, for example, two or more films of an amorphous oxide semiconductor film, an a-like OS film, a microcrystalline oxide semiconductor film, and a CAAC-OS film.

[0301] Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 7

Electronic Device

[0302] In this embodiment, examples of an electronic device to which the display device of one embodiment of the present invention can be applied will be described with reference to FIGS. 30A to 30F and FIGS. 31A to 31D.

[0303] Examples of an electronic device including the display device include television sets (also referred to as televisions or television receivers), monitors of computers or the like, cameras such as digital cameras or digital video cameras, digital photo frames, mobile phones (also referred to as cellular phones or mobile phone devices), portable game machines, portable information terminals, audio reproducing devices, and large game machines such as pachinko machines. Specific examples of these electronic devices are illustrated in FIGS. 30A to 30F and FIGS. 31A to 31D.

[0304] FIG. 30A illustrates a portable game machine including a housing 7101, a housing 7102, a display portion 7103, a display portion 7104, a microphone 7105, speakers 7106, an operation key 7107, a stylus 7108, and the like. The display device according to one embodiment of the present invention can be used for the display portion 7103 or the display portion 7104.

[0305] When the display device according to one embodiment of the present invention is used as the display portion 7103 or 7104, it is possible to provide a user-friendly portable game machine with quality that hardly deteriorates. Although the portable game machine illustrated in FIG. 30A includes two display portions, the display portion 7103 and the display portion 7104, the number of display portions included in the portable game machine is not limited to two.

[0306] FIG. 30B illustrates a smart watch, which includes a housing 7302, a display portion 7304, operation buttons 7311

and **7312**, a connection terminal **7313**, a band **7321**, a clasp **7322**, and the like. The display device, data input device, or touch panel of one embodiment of the present invention can be used for the display portion **7304**.

[0307] FIG. 30C illustrates a portable information terminal, which includes a display portion **7502** incorporated in a housing **7501**, operation buttons **7503**, an external connection port **7504**, a speaker **7505**, a microphone **7506**, and the like. The display device, data input device, or touch panel of one embodiment of the present invention can be used for the display portion **7502**.

[0308] FIG. 30D illustrates a video camera, which includes a first housing **7701**, a second housing **7702**, a display portion **7703**, operation keys **7704**, a lens **7705**, a joint **7706**, and the like. The operation keys **7704** and the lens **7705** are provided for the first housing **7701**, and the display portion **7703** is provided for the second housing **7702**. The first housing **7701** and the second housing **7702** are connected to each other with the joint **7706**, and the angle between the first housing **7701** and the second housing **7702** can be changed with the joint **7706**. Images displayed on the display portion **7703** may be switched in accordance with the angle at the joint **7706** between the first housing **7701** and the second housing **7702**. The imaging device in one embodiment of the present invention can be provided in a focus position of the lens **7705**. The display device, data input device, or touch panel of one embodiment of the present invention can be used for the image display portion **7703**.

[0309] FIG. 30E illustrates a curved display including a display portion **7802** incorporated in a housing **7801**, an operation button **7803**, a speaker **7804**, and the like. The display device, the data input device, or the touch panel of one embodiment of the present invention can be used for the display portion **7802**.

[0310] FIG. 30F illustrates a digital signage including a display portion **7922** provided on a utility pole **7921**. The display device, the data input device, or the touch panel of one embodiment of the present invention can be used for the display portion **7922**.

[0311] FIG. 31A illustrates a notebook personal computer, which includes a housing **8121**, a display portion **8122**, a keyboard **8123**, a pointing device **8124**, and the like. The display device, data input device, or touch panel of one embodiment of the present invention can be used for the display portion **8122**.

[0312] FIG. 31B is an external view of an automobile **9700**. FIG. 31C illustrates a driver's seat of the automobile **9700**. The automobile **9700** includes a car body **9701**, wheels **9702**, a dashboard **9703**, lights **9704**, and the like. The display device, input/output device, or touch panel of one embodiment of the present invention can be used in a display portion or the like of the automobile **9700**. For example, the display device, input/output device, or touch panel of one embodiment of the present invention can be used in display portions **9710** to **9715** illustrated in FIG. 31C.

[0313] The display portion **9710** and the display portion **9711** are each a display device or an input/output device provided in an automobile windshield. The display device or input/output device of one embodiment of the present invention can be a see-through display device or input/output device, through which the opposite side can be seen, using a light-transmitting conductive material for its electrodes. Such a see-through display device or input/output device does not hinder driver's vision during driving the automobile **9700**.

Thus, the display device or input/output device of one embodiment of the present invention can be provided in the windshield of the automobile **9700**. Note that in the case where a transistor or the like for driving the display device or input/output device is provided in the display device or input/output device, a transistor having a light-transmitting property, such as an organic transistor using an organic semiconductor material or a transistor using an oxide semiconductor, is preferably used.

[0314] The display portion **9712** is a display device or input/output device provided on a pillar portion. For example, an image taken by an imaging unit provided in the car body is displayed on the display portion **9712**, whereby the view hindered by the pillar portion can be compensated. The display portion **9713** is a display device or input/output device provided on the dashboard. For example, an image taken by an imaging unit provided in the car body is displayed on the display portion **9713**, whereby the view hindered by the dashboard can be compensated. That is, by displaying an image taken by an imaging unit provided on the outside of the automobile, blind areas can be eliminated and safety can be increased. Displaying an image to compensate for the area which a driver cannot see, makes it possible for the driver to confirm safety easily and comfortably.

[0315] FIG. 31D illustrates the inside of a car in which bench seats are used for a driver seat and a front passenger seat. A display portion **9721** is a display device or input/output device provided in a door portion. For example, an image taken by an imaging unit provided in the car body is displayed on the display portion **9721**, whereby the view hindered by the door can be compensated. A display portion **9722** is a display device or input/output device provided in a steering wheel. A display portion **9723** is a display device or input/output device provided in the middle of a seating face of the bench seat. Note that the display device or input/output device can be used as a seat heater by providing the display device or input/output device on the seating face or backrest and by using heat generation of the display device or input/output device as a heat source.

[0316] The display portion **9714**, the display portion **9715**, and the display portion **9722** can provide a variety of kinds of information such as navigation data, a speedometer, a tachometer, a mileage, a fuel meter, a gearshift indicator, and air-condition setting. The content, layout, or the like of the display on the display portions can be changed freely by a user as appropriate. The information listed above can also be displayed on the display portions **9710** to **9713**, **9721**, and **9723**. The display portions **9710** to **9715** and **9721** to **9723** can also be used as lighting devices. The display portions **9710** to **9715** and **9721** to **9723** can also be used as heating devices.

[0317] A display portion including the display device or the input/output device of one embodiment of the present invention can be flat, in which case the display device or the input/output device does not necessarily have a curved surface or flexibility.

[0318] Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

[0319] This application is based on Japanese Patent Application serial no. 2014-210943 filed with Japan Patent Office on Oct. 15, 2014, the entire contents of which are hereby incorporated by reference.

What is claimed is:

1. A touch panel comprising:
a data input device; and
a display panel,
wherein the data input device overlaps with the display panel,
wherein the data input device comprises a light-blocking layer, a first conductive layer, a second conductive layer, a third conductive layer, and an insulating layer,
wherein the light-blocking layer overlaps with the first conductive layer, the second conductive layer, and the third conductive layer,
wherein the first conductive layer, the second conductive layer, and the insulating layer form a capacitor,
wherein the second conductive layer is electrically connected to the third conductive layer,
wherein widths of the first conductive layer, the second conductive layer, and the third conductive layer are each smaller than a width of the light-blocking layer,
wherein the first conductive layer, the second conductive layer, and the third conductive layer are arranged to have a mesh pattern in a plan view of the touch panel, and
wherein the first conductive layer, the second conductive layer, and the third conductive layer are arranged to surround pixels in the display panel.
2. The touch panel according to claim 1, wherein the data input device further comprises a coloring layer in contact with the light-blocking layer.
3. The touch panel according to claim 1, wherein the second conductive layer is electrically connected to the third conductive layer in an opening in the insulating layer.
4. The touch panel according to claim 1,
wherein the first conductive layer along an X direction and the second conductive layer along a Y direction are on a same surface, and
wherein the third conductive layer is at an intersection of the first conductive layer and the second conductive layer.
5. The touch panel according to claim 1, wherein the display panel comprises an organic EL element.
6. The touch panel according to claim 1, wherein the display panel comprises a liquid crystal element.
7. The touch panel according to claim 1, wherein a distance between adjacent portions of the first conductive layer, a distance between adjacent portions of the second conductive layer, and a distance between adjacent third conductive layers are each larger than a width of one pixel.
8. The touch panel according to claim 1, wherein the first conductive layer, the second conductive layer, and the third conductive layer contain a metal element selected from aluminum, silver, copper, palladium, chromium, tantalum, titanium, molybdenum, nickel, iron, cobalt, tungsten, manganese, and zirconium.
9. An electronic device comprising:
the touch panel according to claim 1;
a microphone; and
a speaker.
10. A touch panel comprising:
a data input device; and
a display panel,
wherein the data input device comprises a first substrate,
wherein the display panel comprises a second substrate,
wherein the first substrate and the second substrate are flexible,
wherein the data input device overlaps with the display panel,
wherein the data input device comprises a light-blocking layer, a first conductive layer, a second conductive layer, a third conductive layer, and an insulating layer,
wherein the light-blocking layer overlaps with the first conductive layer, the second conductive layer, and the third conductive layer,
wherein the first conductive layer, the second conductive layer, and the insulating layer form a capacitor,
wherein the second conductive layer is electrically connected to the third conductive layer,
wherein widths of the first conductive layer, the second conductive layer, and the third conductive layer are each smaller than a width of the light-blocking layer,
wherein the first conductive layer, the second conductive layer, and the third conductive layer are arranged to have a mesh pattern in a plan view of the touch panel, and
wherein the first conductive layer, the second conductive layer, and the third conductive layer are arranged to surround pixels in the display panel.
11. The touch panel according to claim 10, wherein the data input device further comprises a coloring layer in contact with the light-blocking layer.
12. The touch panel according to claim 10, wherein the second conductive layer is electrically connected to the third conductive layer in an opening in the insulating layer.
13. The touch panel according to claim 10,
wherein the first conductive layer along an X direction and the second conductive layer along a Y direction are on a same surface, and
wherein the third conductive layer is at an intersection of the first conductive layer and the second conductive layer.
14. The touch panel according to claim 10, wherein the display panel comprises an organic EL element.
15. The touch panel according to claim 10, wherein the display panel comprises a liquid crystal element.
16. The touch panel according to claim 10, wherein a distance between adjacent portions of the first conductive layer, a distance between adjacent portions of the second conductive layer, and a distance between adjacent third conductive layers are each larger than a width of one pixel.
17. The touch panel according to claim 10, wherein the first conductive layer, the second conductive layer, and the third conductive layer contain a metal element selected from aluminum, silver, copper, palladium, chromium, tantalum, titanium, molybdenum, nickel, iron, cobalt, tungsten, manganese, and zirconium.
18. An electronic device comprising:
the touch panel according to claim 10;
a microphone; and
a speaker.

* * * * *