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(54) PHOTOSENSOR, SEMICONDUCTOR DEVICE, AND LIQUID CRYSTAL PANEL

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(57) **ABSTRACT**

The light use efficiency of a thin film diode is improved even when the semiconductor layer of the diode has a small thickness, thereby improving the light detection sensitivity of the diode. A thin film diode (**130**) having a first semiconductor layer (**131**) including, at least, an n-type region (**131***n*) and a p-type region (**131***p*) is provided on one side of a substrate (**101**), and a light-blocking layer (**160**) is provided between the substrate and the first semiconductor layer. Asperities are provided on the side of the light-blocking layer facing the first semiconductor layer. The first semiconductor layer has a geometry of asperities conforming with the asperities on the light-blocking layer. Light incident on the light-blocking layer is diffusely reflected and enters the first semiconductor layer. Since the first semiconductor layer has a geometry of asperities conforming with the asperities on the light-blocking layer, light that was diffusely reflected travels a longer distance inside the first semiconductor layer. As a result, a larger amount of light is absorbed by the first semiconductor layer, thereby improving light detection sensitivity.

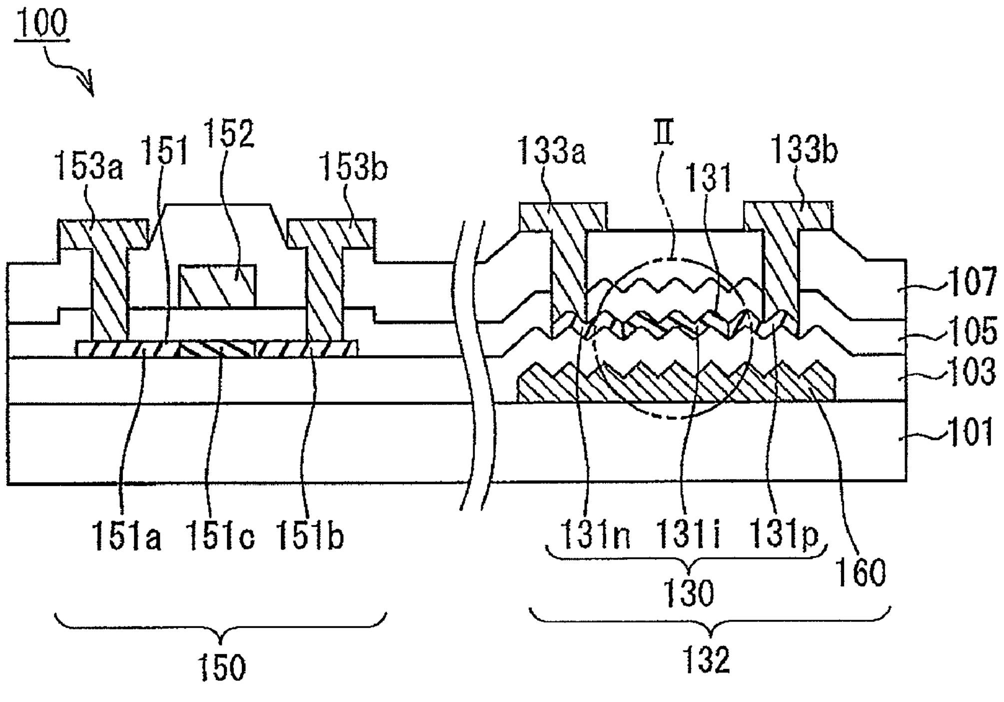
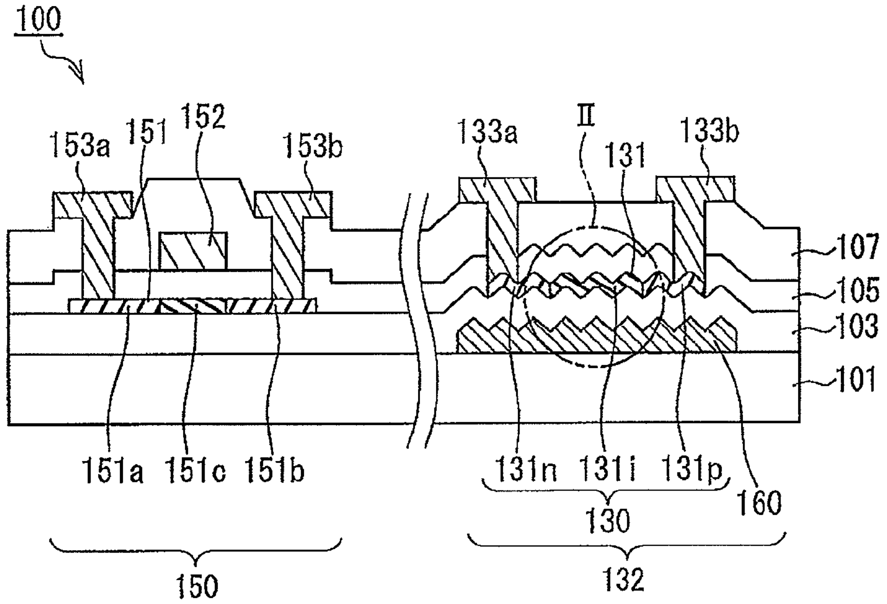


FIG. 1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153a
151
152
153b
133a
II
131
133b
107
105
103
101
151a
151c
151b
131n
131i
131p
160
130
150
132

FIG. 2

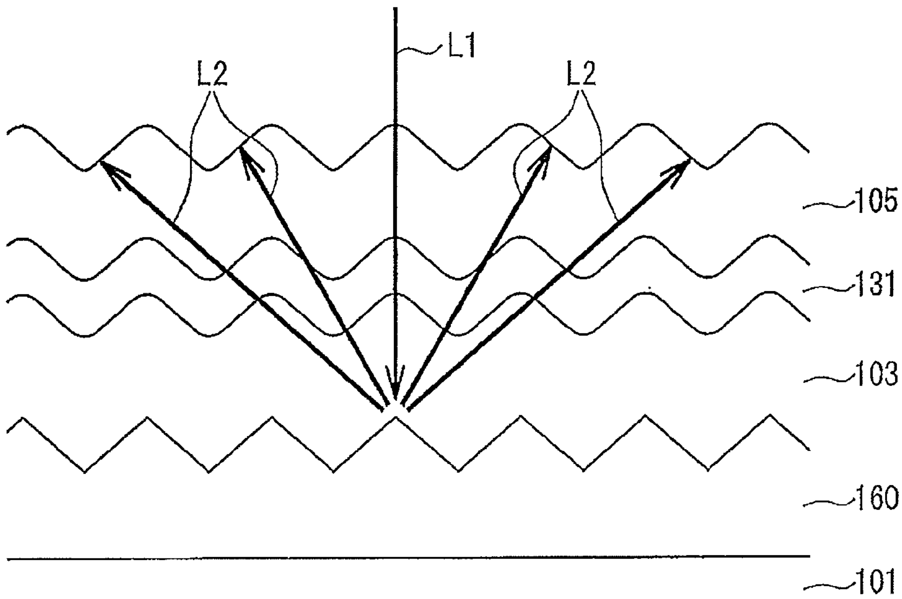

L1
L2
L2
105
131
103
160
101

FIG. 3A

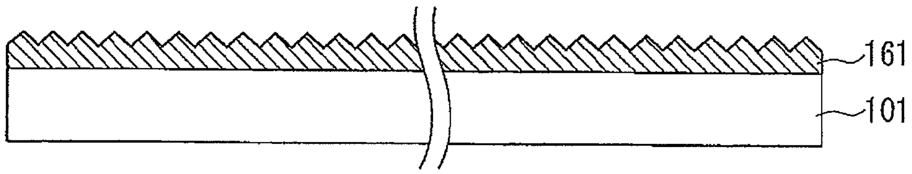


FIG. 3B

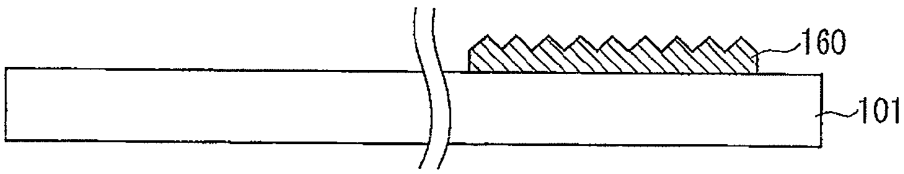


FIG. 3C

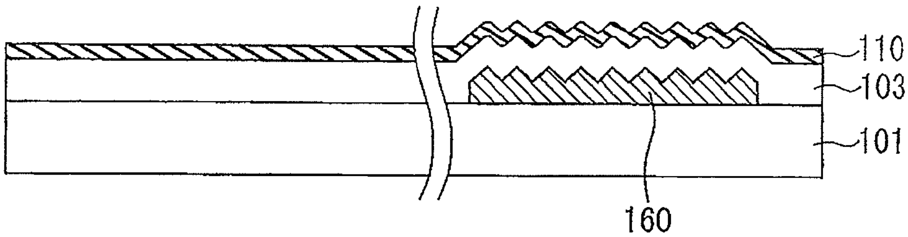


FIG. 3D

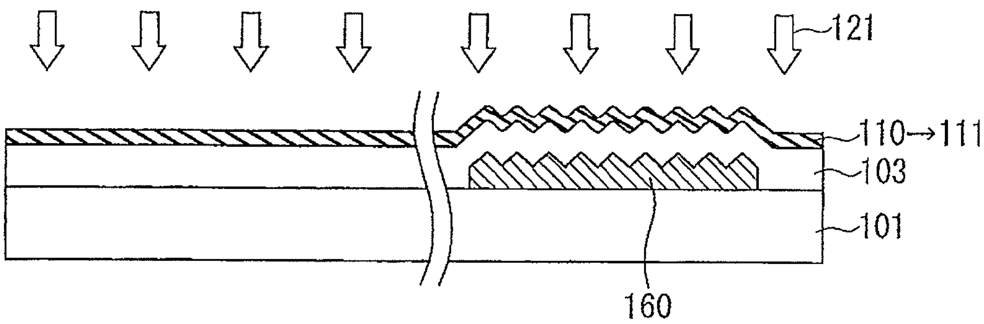


FIG. 3E

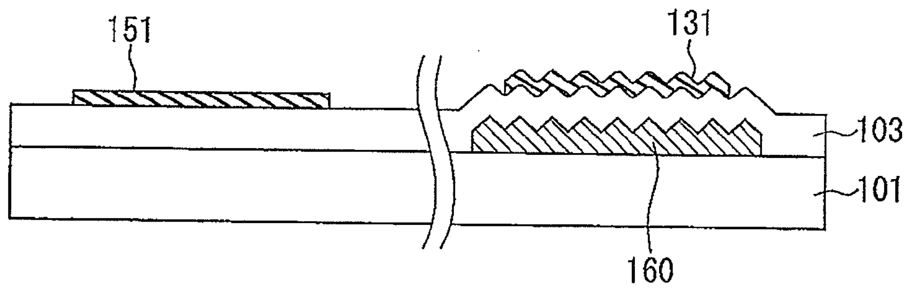


FIG. 3F

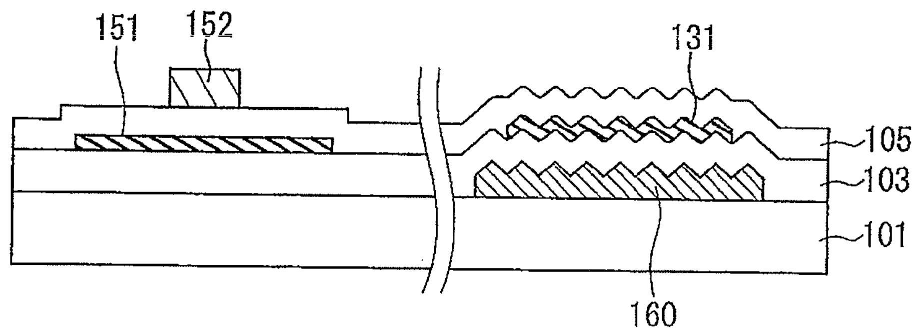


FIG. 3G

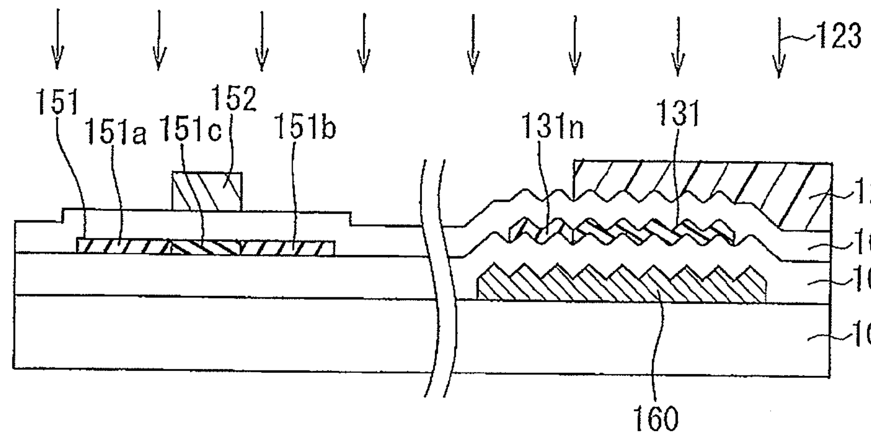


FIG. 3H

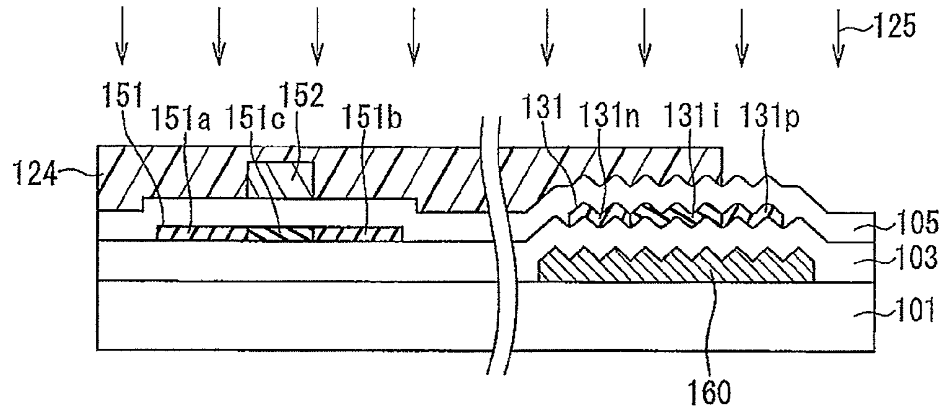


FIG. 3I

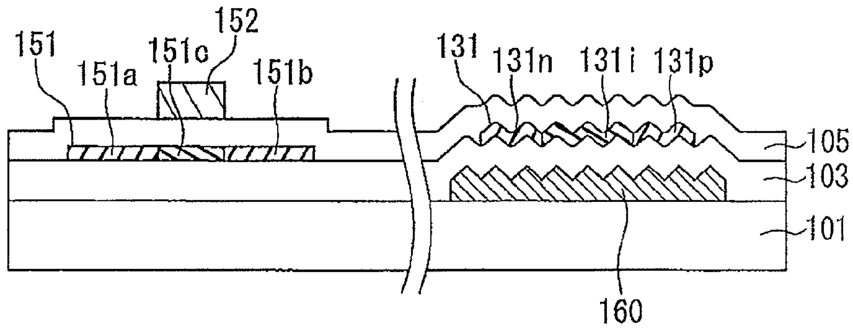
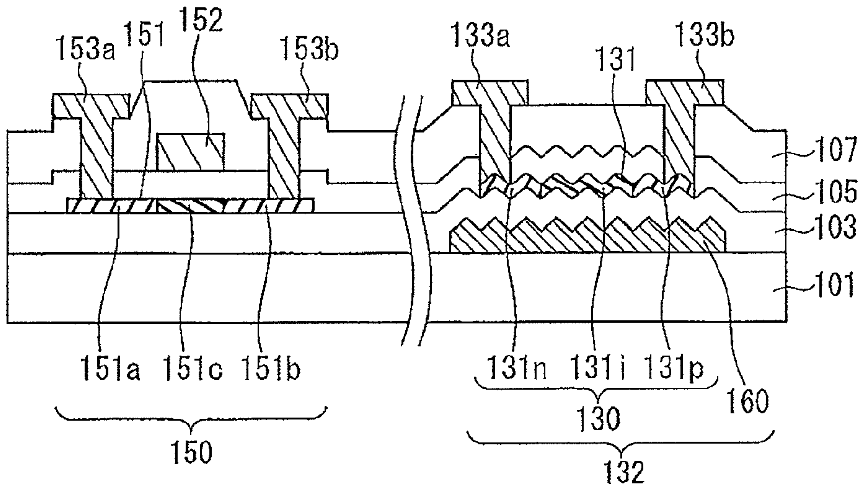
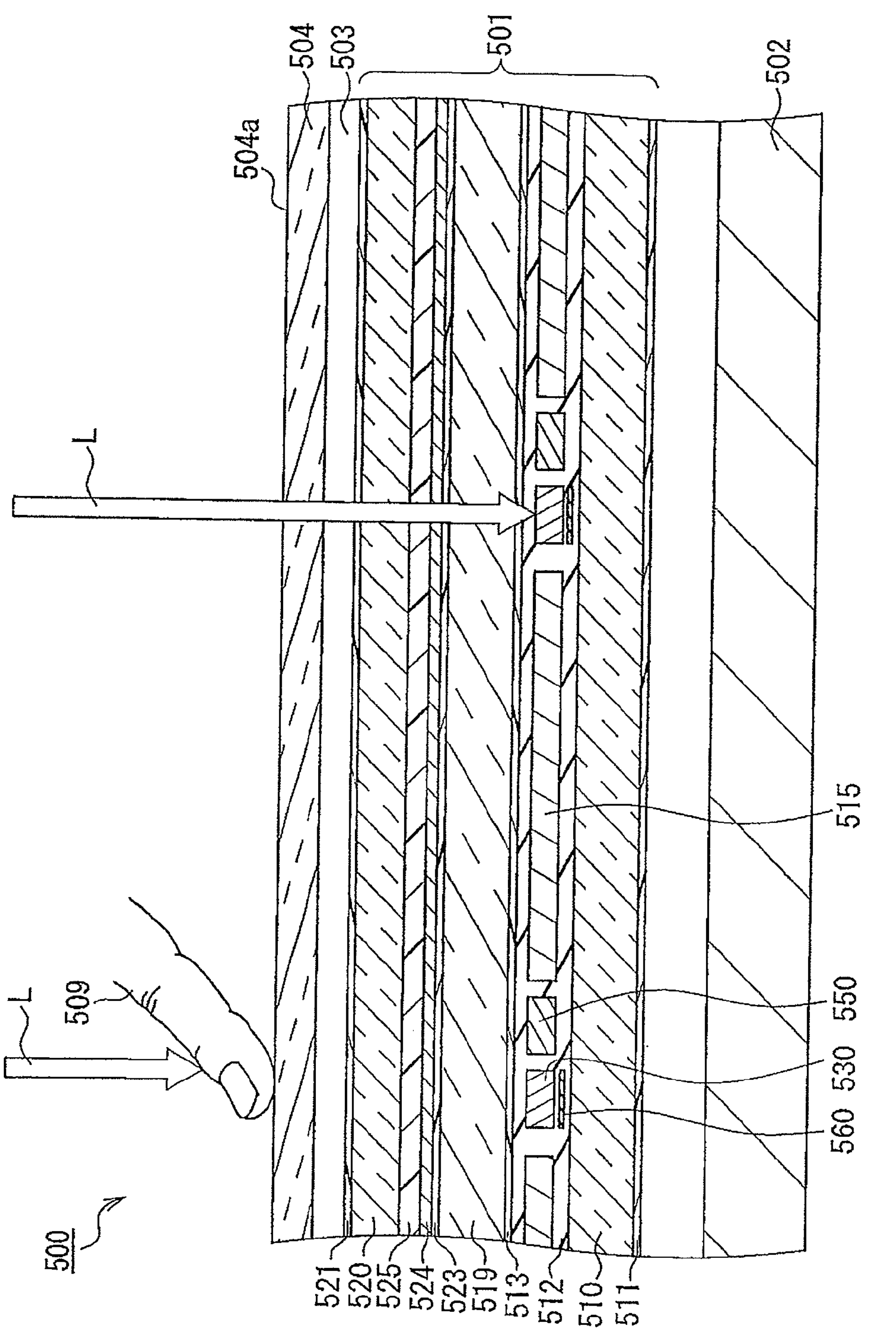


FIG. 3J




504
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504a
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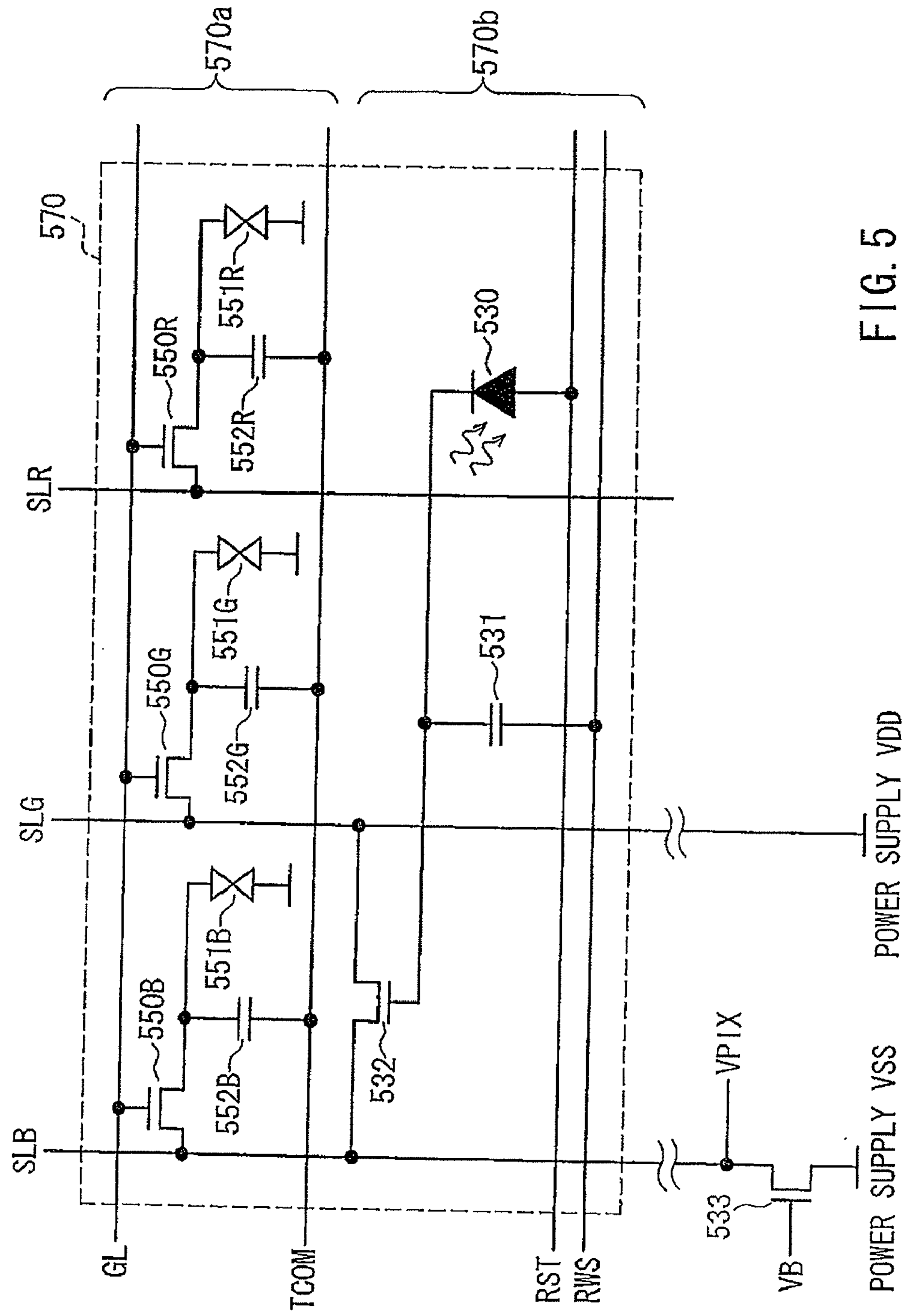
511

FIG. 4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570b
570
GL
TCOM
RST
RWS
SLB
SLG
SLR
550B
550G
550R
551B
551G
551R
552B
552G
552R
530
531
532
533
VPIX
VB
POWER SUPPLY VSS
POWER SUPPLY VDD

FIG. 5

FIG. 6

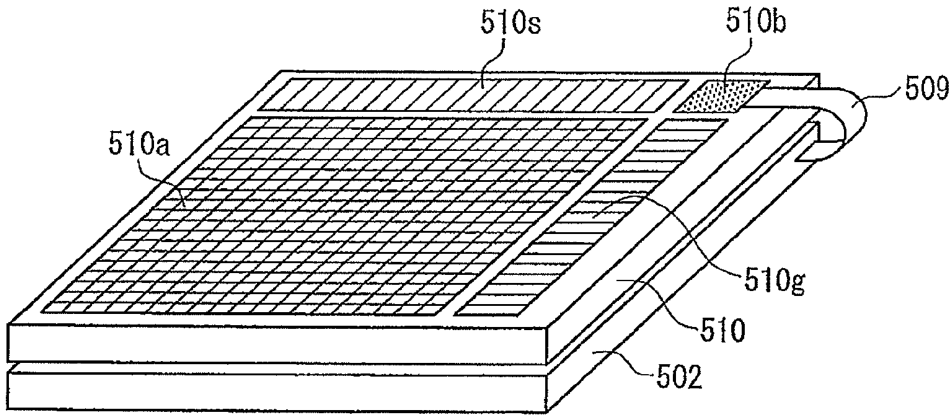
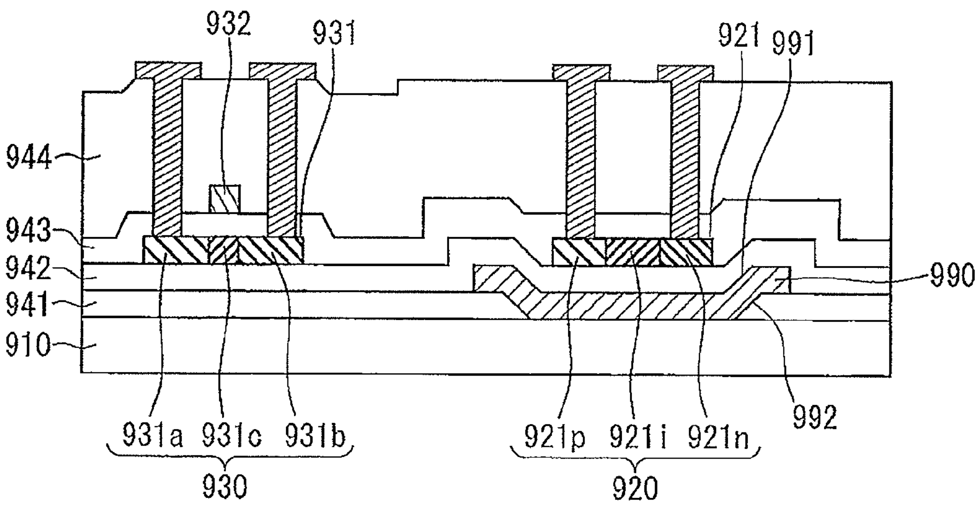

510s
510b
509
510a
510g
510
502

FIG. 7


932
931
921
991
944
943
942
941
910
990
992
931a 931c 931b
930
921p 921i 921n
920

PHOTOSENSOR, SEMICONDUCTOR DEVICE, AND LIQUID CRYSTAL PANEL

REFERENCE TO RELATED APPLICATIONS

[0001] This application is the national stage under 35 USC 371 of International Application No. PCT/JP2010/062338, filed Jul. 22, 2010, which claims priority from Japanese Patent Application No. 2009-189732, filed Aug. 19, 2009, the entire contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to a photosensor that includes a thin film diode (TFD) having a semiconductor layer including, at least, an n-type region and a p-type region. Further, the present invention relates to a semiconductor device including a thin film diode and a thin film transistor (TFT). Furthermore, the present invention relates to a liquid crystal panel including such a semiconductor device.

BACKGROUND OF THE INVENTION

[0003] Touch sensor functionality can be established by incorporating a photosensor including a thin film diode into a display device. In such a display device, information can be input as a finger or a touch pen touches the viewer's side (i.e. the display surface) of the display device and the resulting change in light entering the display surface is detected by a photosensor.

[0004] In such a display device, a change in light resulting from a finger touching the display surface may be small depending on the environment, such as the ambient brightness. As such, a change in light may not be detected by a photosensor.

[0005] JP2008-287061A discloses a technique for improving the light detection sensitivity of a photosensor in a semiconductor device used in a liquid crystal display device. The technique will now be described referring to FIG. **7**.

[0006] This semiconductor device includes, on a substrate (active matrix substrate) **910**, insulating layers **941**, **942**, **943** and **944** formed in this order, a thin film diode **920** and a thin film transistor **930**. The thin film diode **920** is a PIN diode having a semiconductor layer **921** composed of an n-type region **921***n*, a p-type region **921***p* and a low resistance region **921***i*. The thin film transistor **930** includes a semiconductor layer **931** composed of a channel region **931***c*, an n-type region **931***a* as the source region, and an n-type region **931***b* as the drain region. A gate electrode **932** is provided above the channel region **931***c* with an insulating layer **943** interposed therebetween. The n-type region **931***b* is connected with a pixel electrode (not shown).

[0007] The thin film diode **920** receives light entering the display surface (the top of paper in FIG. **7**). A light-blocking layer **990** is provided between the thin film diode **920** and the substrate **910** to prevent light from the backlight (not shown) on the side of the substrate **910** opposite the display surface (the bottom of paper in FIG. **7**) from entering the thin film diode **920**. The light-blocking layer **990** extends along the surface of a recess **992**, which is formed by removing a portion of the insulating layer **941**. The recess **992** is tapered, becoming wider toward the top, to form a slope **991** of the light-blocking layer **990** extending along the slope of the recess **992**.

[0008] The light-blocking layer **990** also serves as a reflective layer. Accordingly, light traveling through the display surface that did not enter the thin film diode **920** but entered the area between the thin film diode **920** and the light-blocking layer **990** is reflected from the light-blocking layer **990** and enters the thin film diode **920**. The slope **991** of the light-blocking layer **990** reflects light incident on the slope **991** back to the thin film diode **920**.

[0009] In the semiconductor device shown in FIG. **7**, the light blocking layer **990** described above causes more light that entered the display surface to enter the thin film diode **920**. Thus, light detection sensitivity is improved.

SUMMARY OF THE INVENTION

[0010] However, even the semiconductor device shown in FIG. **7** does not provide sufficient light detection sensitivity. The reasons will be discussed below.

[0011] The semiconductor layer **921** of the thin film diode **920** is formed at the same time as the semiconductor layer **931** of the thin film transistor **930**. Thus, the semiconductor layer **921** has a very small thickness. Consequently, part of light that entered the semiconductor layer **921** is not absorbed by the semiconductor layer **921** and passes through. As such, even though light entering the area between the thin film diode **920** and the light-blocking layer **990** is reflected from the slope **991** back toward the semiconductor layer **921**, part of light reflected toward the semiconductor layer **921** may not be absorbed by the semiconductor layer **921** and may pass through the semiconductor layer **921**. Moreover, the slope **991** is only provided near the edge of the light-blocking layer **990**. Thus, most of the light reflected from the slope **991** enters the periphery of the thin film diode **920**. As a result, only a small amount of light enters the low resistance region **921***i*, which constitutes the light receiving region.

[0012] An object of the present invention is to solve this problem with the conventional art by improving light use efficiency and thus improving the light detection sensitivity of the thin film diode even when the semiconductor layer of the thin film diode has a small thickness.

[0013] The photosensor of the present invention includes: a substrate; a thin film diode provided close to one side of the substrate and having a first semiconductor layer including, at least, an n-type region and a p-type region; and a light-blocking layer provided between the substrate and the first semiconductor layer. Asperities are formed on a side of the light-blocking layer facing the first semiconductor layer. The first semiconductor layer has a geometry generally consistent with the asperities of the light-blocking layer.

[0014] According to the present invention, asperities are formed on the light-blocking layer. Thus, light incident on the light-blocking layer is diffusely reflected from the asperities on the light-blocking layer and enters the first semiconductor layer. The first semiconductor layer has a geometry substantially consistent with the asperities on the light-blocking layer. Thus, light that entered the first semiconductor layer travels a longer distance inside the first semiconductor layer. As a result, a larger amount of light is absorbed in the first semiconductor layer. Accordingly, light use efficiency is improved even when the first semiconductor layer has a small thickness, thereby improving light detection sensitivity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. **1** is a schematic cross sectional view of a semiconductor device according to Embodiment 1 of the present invention.

[0016] FIG. 2 is an enlarged cross sectional view of section II of FIG. 1 for explaining how the light detection sensitivity of the thin film diode is improved in the semiconductor device according to Embodiment 1 of the present invention.

[0017] FIG. 3A is a cross sectional view of the semiconductor device according to Embodiment 1 of the present invention, illustrating one manufacturing step thereof.

[0018] FIG. 3B is a cross sectional view of the semiconductor device according to Embodiment 1 of the present invention, illustrating one manufacturing step thereof.

[0019] FIG. 3C is a cross sectional view of the semiconductor device according to Embodiment 1 of the present invention, illustrating one manufacturing step thereof.

[0020] FIG. 3D is a cross sectional view of the semiconductor device according to Embodiment 1 of the present invention, illustrating one manufacturing step thereof.

[0021] FIG. 3E is a cross sectional view of the semiconductor device according to Embodiment 1 of the present invention, illustrating one manufacturing step thereof.

[0022] FIG. 3F is a cross sectional view of the semiconductor device according to Embodiment 1 of the present invention, illustrating one manufacturing step thereof.

[0023] FIG. 3G is a cross sectional view of the semiconductor device according to Embodiment 1 of the present invention, illustrating one manufacturing step thereof.

[0024] FIG. 3H is a cross sectional view of the semiconductor device according to Embodiment 1 of the present invention, illustrating one manufacturing step thereof.

[0025] FIG. 3I is a cross sectional view of the semiconductor device according to Embodiment 1 of the present invention, illustrating one manufacturing step thereof.

[0026] FIG. 3J is a cross sectional view of the semiconductor device according to Embodiment 1 of the present invention, illustrating one manufacturing step thereof.

[0027] FIG. 4 is a schematic cross sectional view of a liquid crystal display device including a liquid crystal panel according to Embodiment 2 of the present invention.

[0028] FIG. 5 is an equivalent circuit of one pixel of the liquid crystal panel according to Embodiment 2 of the present invention.

[0029] FIG. 6 is a perspective view of major parts of another liquid crystal display device according to Embodiment 2 of the present invention.

[0030] FIG. 7 is a cross sectional view of a conventional semiconductor device including a thin film diode and a thin film transistor.

DETAILED DESCRIPTION OF THE INVENTION

[0031] A photosensor according to an embodiment of the present invention includes: a substrate; a thin film diode provided close to one side of the substrate and having a first semiconductor layer including, at least, an n-type region and a p-type region; and a light-blocking layer provided between the substrate and the first semiconductor layer, wherein asperities are formed on a side of the light-blocking layer facing the first semiconductor layer, and the first semiconductor layer has a geometry of asperities conforming with the asperities of the light-blocking layer (first arrangement).

[0032] In the first arrangement, asperities are formed on the side of the light-blocking layer facing the first semiconductor layer. Thus, light incident on the side of the light-blocking layer facing the first semiconductor layer may be diffusely reflected. Preferably, the asperities are irregular and random ones. Since light can be reflected in different directions, the incident angle dependence of light detection sensitivity of the thin film diode may be reduced.

[0033] The first semiconductor layer has a geometry of asperities conforming with the asperities formed on the light-blocking layer. It may be easily determined whether the first semiconductor layer has a geometry of asperities conforming with the asperities on the light-blocking layer by observing a cross section of the layer in the thickness direction using SEM (hereinafter referred to as "cross section SEM observation"), for example. That the first semiconductor layer has a geometry of asperities conforming with the asperities on the light-blocking layer means that, in a cross section SEM observation, for example, the first semiconductor layer is displaced upward at a position where the side of the light-blocking layer facing the first semiconductor layer forms an upward apex, and the first semiconductor layer is displaced downward at a position where it forms a downward concave. As a result, the lower side (i.e. the side facing the light-blocking layer) and the upper side (i.e. the side opposite the side thereof facing the light-blocking layer) of the first semiconductor layer with a substantially uniform thickness has a geometry of asperities conforming with the asperities formed on the side of the light-blocking layer facing the first semiconductor layer.

[0034] Since the first semiconductor layer has a geometry of asperities conforming with the asperities on the light-blocking layer, light diffusely reflected from the light-blocking layer may travel a longer distance inside the first semiconductor layer.

[0035] In the first arrangement, it is preferable that the first semiconductor layer has a thickness smaller than a difference in height between an apex and a bottom of the asperities formed on a side of the first semiconductor layer facing the light-blocking layer (second arrangement). Preferably, the thickness of the first semiconductor layer is smaller than the difference in height between an apex and a bottom of the asperities formed on the side of the light-blocking layer facing the first semiconductor layer. As the first semiconductor layer has such a small thickness, the first semiconductor layer may be formed in the same process as the second semiconductor layer constituting a thin film transistor. As a result, the manufacturing process may be made simpler. The thickness of the first semiconductor layer and the difference in height between an apex and a bottom of asperities on the first semiconductor layer and the light-blocking layer may be measured in a cross section SEM observation. The lower limit of thickness of the first semiconductor layer is not limited to a particular value; however, it is preferably equal to or larger than, for example, a half of the difference in height in the asperities formed on the side of the first semiconductor layer facing the light-blocking layer and the difference in height in the asperities formed on the side of the light-blocking layer facing the first semiconductor layer. If the intended thickness of the first semiconductor layer is too small, it is difficult to form a continuous film that is to be a thin first semiconductor layer without pin holes.

[0036] In the first or second arrangement, it is preferable that a difference in height between an apex and a bottom of the asperities formed on the side of the light-blocking layer facing the first semiconductor layer is in a range of 50 to 100 nanometers (third arrangement). If the difference in height in the asperities on the light-blocking layer is smaller than this range of number, light incident on the light-blocking layer may not be diffusely reflected; further, the asperities on the upper and lower sides of the first semiconductor layer are relatively small and almost flat; thus, light reflected from the light-blocking layer travels a short distance in the first semiconductor layer; as a result, it is difficult to improve light detection sensitivity. If, on the other hand, the difference in height in the asperities on the light-blocking layer is larger than that range of number, it is difficult to form a continuous film that is to be a thin first semiconductor layer without pinholes.

[0037] In any one of the first to third arrangements, it is preferable that the asperities are formed on an entire surface of the side of the light-blocking layer facing the first semiconductor layer (fourth arrangement). Thus, light incident on the light-blocking layer is diffusely reflected irrespective of the incident position. As a result, the light detection sensitivity of the photosensor (thin film diode) is further improved. In addition, the process of forming asperities may be made simpler than in an implementation where asperities are formed in a limited area.

[0038] A semiconductor device according to an embodiment of the present invention includes: the photosensor according to an embodiment of the present invention as described above; and a thin film transistor provided close to the same side of the substrate as the thin film diode, wherein the thin film transistor includes: a second semiconductor layer including a channel region, a source region and a drain region; a gate electrode that controls a conductivity of the channel region; and a gate insulating film provided between the second semiconductor layer and the gate electrode (fifth arrangement). A thin film diode and a thin film transistor are provided on a common substrate.

[0039] Thus, the semiconductor device according to an embodiment of the present invention can be employed in various applications where light detection functionality is required.

[0040] In the fifth arrangement, it is preferable that the first semiconductor layer and the second semiconductor layer are formed on a single insulating layer (sixth arrangement). Thus, the first and second semiconductor layers may be formed concurrently in a single process. As a result, the manufacturing process may be simplified.

[0041] In the fifth or sixth arrangement above, it is preferable that a side of the second semiconductor layer facing the substrate is flat (seventh arrangement). Thus, the light detection sensitivity of the thin film diode may be improved without adversely affecting the gate capability or the like of the thin film transistor. The side of the second semiconductor layer facing the substrate does not have to be completely flat but, suitably, it is substantially flat.

[0042] In any of the fifth to seventh arrangements, it is preferable that the first semiconductor layer has a thickness that is identical with that of the second semiconductor layer (eighth arrangement). Thus, the first and second semiconductor layers may be formed concurrently in a single process. As a result, the manufacturing process may be simplified. The first semiconductor layer and the second semiconductor layer do not have to be completely identical in thickness but, suitably, they are substantially identical.

[0043] A liquid crystal panel according to an embodiment of the present invention includes: the semiconductor device above; a counter substrate facing the side of the substrate where the thin film diode and the thin film transistor are provided; and a liquid crystal layer enclosed between the substrate and the counter substrate (ninth arrangement). Thus, a liquid crystal panel with touch sensor functionality or ambient sensor functionality for measuring the ambient brightness may be realized.

[0044] Now, the present invention will be described in detail based on several preferred embodiments. Of course, the present invention is not limited to the embodiments below. For purposes of explanation, the drawings referred to in the following description only show, in a simplified form, those components of the embodiments of the present invention that are relevant to the description of the present invention. Accordingly, the present invention may include any desired component(s) not shown in the drawings. Further, the sizes of the components in the drawings do not exactly reflect the sizes of the actual components and the size ratios of the components.

Embodiment 1

[0045] FIG. **1** is a schematic cross sectional view of a semiconductor device **100** according to Embodiment 1 of the present invention. The semiconductor device **100** includes: a photosensor **132** having a substrate **101**, a thin film diode **130** formed above the substrate **101** with interposed base layer **103** therebetween as an insulating layer, and a light-blocking layer **160** provided between the substrate **101** and the thin film diode **130**; and a thin film transistor **150**. The substrate **101** is preferably translucent. To simplify the drawing, FIG. **1** only shows a single photosensor **132** and a single thin film transistor **150**; however, a plurality of photosensors **132** and a plurality of thin film transistors **150** may be formed on a common substrate **101**. Further, to facilitate understanding, FIG. **1** shows a cross section of the photosensor **132** and that of the thin film transistor **150** in the same drawing; however, these cross sections do not have to be on a single common plane.

[0046] The thin film diode **130** has a semiconductor layer (first semiconductor layer) **131** including, at least, an n-type region **131***n* and a p-type region **131***p*. In the present embodiment, an intrinsic region **131***i* is provided between the n-type region **131***n* and the p-type region **131***p* in the semiconductor layer **131**. Electrodes **133***a* and **133***b* are connected with the n-type region **131***n* and the p-type region **131***p*, respectively.

[0047] The thin film transistor **150** includes: a semiconductor layer (second semiconductor layer) **151** including a channel region **151***c*, a source region **151***a* and a drain region **151***b*; a gate electrode **152** for controlling the conductivity of the channel region **151***c*; and a gate insulating film **105** provided between the semiconductor layer **151** and the gate electrode **152**. Electrodes **153***a* and **153***b* are connected with the source region **151***a* and the drain region **151***b*, respectively. The gate insulating film **105** expands over the semiconductor layer **131**, too.

[0048] The semiconductor layer **131** of the thin film diode **130** and the semiconductor layer **151** of the thin film transistor **150** may have different crystallinities or the same crystallinity. If the two layers have the same crystallinity, the crystal conditions of the semiconductor layers **131** and **151** do not have to be controlled separately. As a result, a reliable and high-performance semiconductor device **100** can be provided without complicating the manufacturing process.

[0049] An interlayer insulating film **107** is formed on the thin film diode **130** and the thin film transistor **150**.

[0050] A light-blocking layer **160** is provided between the substrate **101** and the thin film diode **130** facing the thin film diode **130**. This prevents light that entered the side of the substrate **101** opposite that with the thin film diode **130** and passed the substrate **101** from entering the semiconductor layer **131**. More particularly, the light-blocking layer **160** is located on the substrate **101** in a position that includes an area facing the semiconductor layer **131**.

[0051] Small and random asperities are provided on the side of the light-blocking layer **160** facing the thin film diode **130** (upper surface). The semiconductor layer **131** of the thin film diode **130** has a geometry of asperities conforming with the asperities on the light-blocking layer **160**. More specifically, the first semiconductor layer **131** having a substantially uniform thickness in a cross section taken in the thickness direction as shown in FIG. **1** is displaced upward and downward (i.e. is bent) with a substantially constant distance between itself and the asperities on the upper surface of the light-blocking layer **160**.

[0052] Effects of the asperities on the upper surface of the light-blocking layer **160** and the geometry of asperities of the semiconductor layer **131** constituting the thin film diode **130** will now be described. FIG. **2** is an enlarged cross sectional view of section II of FIG. **1** including the light-blocking layer **160** and the semiconductor layer **131**. Incident light, L**1**, traveling toward the thin film diode **130** from above enters the semiconductor layer **131** of the thin film diode **130** and is, ideally, absorbed by the semiconductor layer **131**. However, since the semiconductor layer **131** has a small thickness, a portion of the incident light L**1** passes through the semiconductor layer **131**. The portion of the light L**1** that has passed through the semiconductor layer **131** passes through the base layer **103** and reaches the upper surface of the light-blocking layer **160**. Random asperities are provided on the upper surface of the light-blocking layer **160'**. Thus, the light-blocking layer **160** diffusely reflects the incident light L**1**. The reflected light, L**2**, which has been diffusely reflected from the upper surface of the light-blocking layer **160**, travels in different directions, passes through the base layer **103** and enters the semiconductor layer **131**. Those reflected light L**2** beams that were reflected in relatively large reflection angles generally enter the semiconductor layer **131** in large incident angles. As a result, light tends to travel a long distance inside the semiconductor layer **131**. In addition, the semiconductor layer **131** substantially conforms with the asperities on the light-blocking layer **160**. Thus, even those incident light L**1** and reflected light L**2** beams that form relatively small angles with respect to the normal line of the substrate **101** tend to travel a longer distance inside the semiconductor layer **131** than in an implementation where the semiconductor layer **131** is flat. Thus, according to the present invention, the incident light L**1** and the reflected light L**2** travel a longer distance inside the semiconductor layer **131**. Consequently, more light is absorbed in the semiconductor layer **131**. As a result, light use efficiency is improved and thus the light detection sensitivity of the thin film diode **130** is improved. Further, the more random the asperities on the upper surface of the light-blocking layer **160** and the geometry of asperities of the semiconductor layer **131** are, the smaller incident angle dependence and thus the more stable improvement in light detection sensitivity can be achieved.

[0053] Preferably, the random asperities on the upper surface of the light-blocking layer **160** cover the entire upper surface of the light-blocking layer **160**. Thus, the light detection sensitivity of the thin film diode **130** is improved irrespective of the incident location of the incident light L**1** on the light-blocking layer **160**. Further, the area where asperities are formed is not limited. As a result, the step of forming asperities is simplified.

[0054] Suitably, the semiconductor layer **131** of the thin film diode **130** has a geometry of asperities conforming with the asperities on the upper surface of the light-blocking layer **160** in at least the intrinsic region **131***i;* however, it is preferable that this applies to the entire area including the n-type region **131***n* and the p-type region **131***p*.

[0055] The manufacturing process is thus simplified.

[0056] The present invention improves light detection sensitivity even if the semiconductor layer **131** is so thin that most of the incident light L**1** passes through the semiconductor layer **131**. For example, even if the semiconductor layer **131** has a thickness that is smaller than the difference in height between the apexes and bottoms of the asperities on the lower surface of the semiconductor layer **131**, the reflected light L**2** travels a longer distance inside the semiconductor layer **131**, as shown in FIG. **2**. As a result, the light detection sensitivity of the thin film diode **130** is improved. Accordingly, it is not necessary to increase the thickness of the semiconductor layer **131** to reduce the amount of light passing through the semiconductor layer **131**. As a result, the semiconductor layer **131** may be formed in the same process as the semiconductor layer **151** of the thin film transistor **150**, as will be discussed below.

[0057] One example of a method of manufacturing such a semiconductor device **100** according to the present embodiment will be described. However, methods of manufacturing a semiconductor device **100** are not limited to the example below.

[0058] First, as shown in FIG. **3**A, a thin film **161** that is to be a light-blocking layer **160** later is formed on a substrate **101**.

[0059] The substrate **101** is not limited to a particular type and can be selected as appropriate according to the application of the semiconductor device **100** or other conditions. For example, a translucent glass substrate (such as a low-alkali glass substrate) or quartz substrate may be used. If the substrate **101** is a low-alkali glass substrate, the substrate **101** may be thermally treated in advance at a temperature about 10 to 20° C. lower than the glass strain point.

[0060] The thin film **161** may be made of a metal material, for example. Particularly, high-melting-point metals such as tantalum (Ta), tungsten (W) and molybdenum (Mo) are preferable when thermal treatments in later manufacturing steps are taken into consideration. A film of such a metal material is formed over the substrate **101** using sputtering. The thickness of the film **161** is preferably in the range of about 200 to 300 nanometers. Sputtering may be used such that columnar crystals of the metal material extending in the thickness direction (i.e. the vertical direction on paper in FIG. **3**A) are formed in the formed film **161**. Next, the film **161** undergoes anisotropic etching, such as reactive ion etching, in the thickness direction. The etching depth is preferably in the range of about 100 to 150 nanometers. Since columnar crystals are formed in the film **161**, the surface of the film **161** is selectively etched. As a result, random asperities are formed on the surface of the film **161**. The degree of asperities, i.e. the difference in height between an apex and a bottom of the asperities (i.e. the distance in the thickness direction), is preferably in the range of about 50 to 100 nanometers.

[0061] Next, a pattern of a desired light-blocking layer **160** is formed on the upper surface of the film **161** using a resist.

Then, unnecessary portions of the film **161** are removed using wet etching. The portions of the film **161** where a thin film diode **130** is to be formed later are left out. The portions of the film **161** outside the area for the thin film diode **130**, including the area(s) where a thin film transistor **150** is to be formed later, are removed. As a result, a patterned light-blocking layer **160** is provided, as shown in FIG. 3B.

[0062] Next, as shown in FIG. 3C, a base layer **103** is formed to cover the substrate **101** and the light-blocking layer **160**, before an amorphous semiconductor film **110** is formed.

[0063] The base layer **103** is provided to prevent impurities from diffusing from the substrate **101**. The base layer **103** may be made of, for example, a simple layer made of silicon oxide, a multiple layer made of a silicon nitride film and a silicon oxide film in this order from the substrate **101**, or other known compositions. Such a base layer **103** may be formed using plasma

[0064] CVD, for example. The thickness of the base layer **103** is preferably in the range of 100 to 600 nanometers, more preferably in the range of 150 to 450 nanometers.

[0065] Preferable semiconductors that may constitute the amorphous semiconductor film **110** include silicon. Other semiconductors such as Ge, SiGe, compound semiconductors, or chalcogenide may also be used. The following description uses silicon. The amorphous silicon film **110** is formed using a known technique, such as plasma CVD or sputtering. Preferably, the thickness of the amorphous silicon film **110** is in the range of 25 to 100 nanometers, which allows high-quality polycrystalline silicon to be obtained during the following crystallization process by laser illumination. For example, an amorphous silicon film **110** with a thickness of 50 nanometers may be formed using plasma CVD. If the base layer **103** and the amorphous silicon film **110** are formed using the same film-formation method, these two layers may be formed consecutively. Surface contamination of the base layer **103** is prevented, as the base layer **103** is not exposed to the atmosphere after it is formed. As a result, variations in properties or variations in threshold voltage of the fabricated thin film transistor **150** and the thin film diode **130** are reduced.

[0066] As shown in FIG. 3C, in the area where the light-blocking layer **160** was formed, asperities conforming with the asperities on the upper surface of the light-blocking layer **160** are formed on the upper surface of the base layer **103** and the upper surface of the amorphous silicon film **110**.

[0067] Next, as shown in FIG. 3D, the amorphous silicon film **110** is crystallized by illuminating the amorphous silicon film **110** with a laser beam **121** from above. The laser beam **121** may be an XeCl excimer laser beam (with a wavelength of 308 nanometers and a pulse width of 10 to 150 nanoseconds, for example **40** nanoseconds) or a KrF excimer laser beam (with a wavelength of 248 nanometers and a pulse width of 10 to 150 nanoseconds). The laser beam **121** is adjusted to illuminate an area of an elongated shape on the surface of the substrate **101**. The entire surface of the amorphous silicon film **110** is crystallized by scanning it with the laser beam **121** sequentially in a direction perpendicular to the elongation of the area of the surface of the substrate **101** illuminated by the laser **121**. Preferably, scanning with the laser beam **121** is performed such that some portions of two consecutive illuminated areas lie over each other at a given moment. Thus, any given point on the amorphous silicon film **110** is illuminated with a laser multiple times. As a result, the homogeneity of crystal conditions of the polycrystalline silicon film **111** is improved. When illuminated with the laser beam **121**, the amorphous silicon film **110** melts for a moment and then solidifies, during which process the film is crystallized to become a polycrystalline silicon film **111**.

[0068] Next, as shown in FIG. 3E, the unnecessary portions of the polycrystalline silicon film **111** are removed to separate the devices from each other. The devices may be separated from each other using photolithography, that is, by removing the unnecessary portions of the polycrystalline silicon film **111** using dry etching after a resist of a predetermined pattern is formed. Thus, the semiconductor layer **131** which is to be an active region (i.e. an n-type region **131***n*, a p-type region **131***p* and an intrinsic region **131***i*) of a thin film diode **130** later and the semiconductor layer **151** which is to be an active region (i.e. a source region **151***a*, a drain region **151***b* and a channel region **151***c*) of a thin film transistor **150** later are formed separate from each other. Thus, these semiconductor layers **131** and **151** are formed like islands.

[0069] Next, as shown in FIG. 3F, after a gate insulating film **105** covering these island-like semiconductor layers **131** and **151** are formed, a gate electrode **152** of the thin film transistor **150** is formed on the gate insulating film **105**.

[0070] Preferably, the gate insulating film **105** is a silicon oxide film. The thickness of the gate insulating film **105** is preferably in the range of 20 to 150 nanometers (for example, 100 nanometers). As shown in FIG. 3F, in the area where the light-blocking layer **160** was formed, asperities conforming with the asperities on the upper surface of the light-blocking layer **160** are formed on the upper surface of the gate insulating film **105**.

[0071] The gate electrode **152** is formed by depositing a conductive film over the gate insulating film **105** using sputtering or CVD and patterning this conductive film. It is desirable that the conductive film be made of a high-melting-point metal such as W, Ta, Ti, Mo or an alloy thereof. Further, the thickness of the conductive film is preferably in the range of 300 to 600 nanometers.

[0072] Next, as shown in FIG. 3G, a mask **122** made of a resist is formed on the gate insulating film **105**, covering an area including the portion of the semiconductor layer **131** that is to be an active region of the thin film diode **130** later. Then, the entire surface of the substrate **101** is ion-doped with n-type impurities (such as phosphorus) **123** from above the substrate **101**. The n-type impurities **123** pass through the gate insulating film **105** and are injected into the semiconductor layers **151** and **131**. This step injects n-type impurities **123** into the regions of the semiconductor layer **131** of the thin film diode **130** not covered with the mask **122** and the regions of the semiconductor layer **151** of the thin film transistor **150** not covered with the gate electrode **152**. The regions covered with the mask **122** or the gate electrode **152** are not doped with n-type impurities **123**. Thus, the region of the semiconductor layer **131** of the thin film diode **130** into which n-type impurities **123** are injected is to be the n-type region **131***n* of the thin film diode **130** later. The regions of the semiconductor layer **151** of the thin film transistor **150** into which n-type impurities **123** are injected are to become the source region **151***a* and the drain region **151***b* of the thin film transistor **150** later. The region of the semiconductor layer **151** that is covered with the gate electrode **152** and into which no n-type impurities **123** are injected is to become the channel region **151***c* of the thin film transistor **150** later.

[0073] Next, after the mask **122** is removed, as shown in FIG. 3H, a mask **124** made of a resist is formed on the gate insulating film **105**, covering an area including the portion of the semiconductor layer **131** that is to be an active region of the thin film diode **130** later, and the entire semiconductor layer **151**, which is to be an active region of the thin film transistor **150** later. Then, the entire surface of the substrate **101** is ion-doped with p-type impurities (such as boron) **125** from above the substrate **101**. The p-type impurities **125** pass through the gate insulating film **105** and are injected into the semiconductor layer **131**. This step injects p-type impurities **125** into the region of the semiconductor layer **131** of the thin film diode **130** not covered with the mask **124**. The regions covered with the mask **124** are not doped with p-type impurities **125**. Thus, the region of the semiconductor layer **131** of the thin film diode **130** into which p-type impurities **125** are injected is to become the p-type region **131***p* of the thin film diode **130** later. Further, the regions of the semiconductor layer **131** into which no p-type impurities and no n-type impurities are injected are to become the intrinsic region **131***i* later.

[0074] Next, as shown in FIG. **31**, after the mask **124** is removed, thermal treatment is performed in an inert atmosphere, such as a nitrogen atmosphere. This thermal treatment removes doping damage, such as crystal deficiencies produced during doping, in the n-type region **131***n* and the p-type region **131***p* of the thin film diode **130**, as well as in the source region **151***a* and the drain region **151***b* of the thin film transistor **150**, and phosphorus and boron injected therein are activated. This thermal treatment may be performed using a typical heating furnace; however, it is preferably performed using RTA (rapid thermal annealing). Methods in which hot inert gases are blown onto the surface of the substrate **101** and temperature is rapidly increased and decreased are particularly suitable.

[0075] Next, as shown in FIG. **3**J, an interlayer insulating film **107** is formed. The interlayer insulating film **107** is not limited to a particular structure, and any known compositions may be used. For example, a double structure in which a silicon nitride film and a silicon oxide film are formed in this order may be used. Thermal treatment for hydrogenating the semiconductor layers **151** and **131**, such as annealing at 350 to 450° C. in a nitrogen atmosphere or hydrogen mixture atmosphere at 1 atmosphere, for example, may be performed where necessary. After the interlayer insulating film **107** is formed, contact holes are formed in the interlayer insulating film **107**. Next, a film made of a metal material (for example, a double film of titanium nitride and aluminum) is formed on the interlayer insulating film **107** and inside the contact holes, and the film is patterned. Thus, electrodes **133***a* and **133***b* of the thin film diode **130** and electrodes **153***a* and **153***b* of the thin film transistor **150** are formed. Thus, a thin film diode **130** connected with the electrodes **133***a* and **133***b* and a thin film transistor **150** connected with the electrodes **153***a* and **153***b* are provided. A protection film made of, for example, a silicon nitride film (not shown) may be provided on the interlayer insulating film **107** in order to protect the electrodes **133***a* and **133***b* connected with the thin film diode **130** and the electrodes **153***a* and **153***b* connected with the thin film transistor **150**.

[0076] According to the above method, the semiconductor layer **131** of the thin film diode **130** and the semiconductor layer **151** of the thin film transistor **150** may be formed concurrently. As a result, a thin film diode **130** and a thin film transistor **150** may be fabricated efficiently on a common substrate **101**.

[0077] This manufacturing method necessarily produces a semiconductor layer **131** of a thin film diode **130** with a thickness equal to that of the semiconductor layer **151** of the thin film transistor **150**. As such, the thickness of the semiconductor layer **131** of the thin film diode **130** cannot be increased to improve light detection sensitivity. However, as discussed above, in a semiconductor device **100** according to an embodiment of the present invention, the light detection sensitivity of the light sensor **132** (thin film diode **130**) is improved even if the thickness of the semiconductor layer **131** cannot be increased.

[0078] Further, according to the above manufacturing method, forming asperities on the upper surface of the light-blocking layer **160** causes the semiconductor layer **131** of the thin film diode **130** formed thereafter to be in a geometry substantially consistent with the asperities on the upper surface of the light-blocking layer **160**.

[0079] Thus, according to the above manufacturing method, a semiconductor device **100** may be fabricated in a simple manner and at low cost without significantly altering the conventional manufacturing process of semiconductor devices.

[0080] As shown in FIG. **3**B, the portions of the film **161** where a thin film transistor **150** is to be formed are removed. Thus, the upper and lower surfaces of the semiconductor layer **151** constituting the thin film transistor **150** are substantially flat. Thus, the light detection sensitivity of the photosensor **132** (thin film diode **130**) is improved without adversely affecting properties (for example, decreasing the gate capability) of the thin film transistor **150**.

[0081] The thin film transistor **150** is not limited to the structure described above. For example, a dual-gate thin film transistor, an LDD or GOLD thin film transistor, a p-channel thin film transistor or the like may be used. Moreover, several types of thin film transistors with different structures may be combined.

[0082] The above embodiment has illustrated a semiconductor device **100** including a photosensor **132** and a thin film transistor **150**. However, the present invention is not limited thereto. For example, only a photosensor **132** may be made. Further, the semiconductor layers **131** and **151** may be formed of amorphous silicon.

Embodiment 2

[0083] Embodiment 2 illustrates a liquid crystal panel including a semiconductor device having light detection functionality illustrated in Embodiment 1.

[0084] FIG. **4** is a schematic cross sectional view of a liquid crystal display device **500** including a liquid crystal panel **501** according to Embodiment 2.

[0085] The liquid crystal display device **500** includes a liquid crystal panel **501**, an illuminating device **502** that illuminates the backside of the liquid crystal panel **501**, and a translucent protection panel **504** disposed above the liquid crystal panel **501** with an air gap **503** interposed therebetween.

[0086] The liquid crystal panel **501** includes a TFT array substrate **510** and a counter substrate **520**, both of which are translucent plates, and a liquid crystal layer **519** enclosed between the TFT array substrate **510** and the counter substrate **520**. The TFT array substrate **510** and the counter substrate **520** are not limited to any particular material. The same materials that are used in conventionally known liquid crystal panels, such as glass or an acrylic resin, may be used.

[0087] A polarizer **511** that passes or absorbs specific polarization components is provided on the side of the TFT array substrate **510** facing the illuminating device **502**. An insulating layer **512** and an oriented film **513** are deposited in this order on the side of the TFT array substrate **510** opposite the polarizer **511**. The oriented film **513** is a layer in which liquid crystals are oriented, and is formed of an organic film such as polyimide. Inside the insulating layer **512** are formed: a pixel electrode **515** composed of a transparent and conductive film, such as ITO; a thin film transistor (TFT) **550** connected with the pixel electrode **515** for working as a switching device for driving liquid crystal; and a thin film diode **530** having light detection functionality. A light-blocking layer **560** is formed on the side of the thin film diode **530** facing the illuminating device **502**.

[0088] A polarizer **521** that passes or absorbs specific polarization components is provided on the side of the counter substrate **520** opposite the liquid crystal layer **519**. On the side of the counter substrate **520** facing the liquid crystal layer **519** are formed, starting from the liquid crystal layer **519**, an oriented film **523**, a common electrode **524** and a color filter **525** in this order. Similar to the oriented film **513** on the TFT array substrate **510**, the oriented film **523** is a layer in which liquid crystals are oriented and is formed of an organic film, such as polyimide. The common electrode **524** is formed of a transparent and conductive film, such as ITO. The color filter layer **525** includes three types of resin films (color filters) that each selectively pass light in the wavelength range of one of the primary colors: red (R), green (G) and blue (B), and a black matrix as a light-blocking layer disposed between two adjacent color filters. Preferably, no color filter or black matrix is provided in the region corresponding to a thin film diode **530**.

[0089] In the liquid crystal panel **501** of the present embodiment, one pixel electrode **515** and one thin film transistor **550** are disposed for a color filter of one of the primary colors: red, green and blue, and all these together form a pixel of a primary color (subpixel). Three subpixels of red, green and blue form a color pixel (pixel). Such color pixels are arranged regularly in the vertical and horizontal directions.

[0090] The translucent protection panel **504** is made of a flat plate of glass or an acrylic resin, for example. The side of the translucent protection panel **504** opposite the liquid crystal panel **501** is a touch sensor side **504***a* that can be touched by a human finger **509**. Disposing a translucent protection panel **504** above the liquid crystal panel **501** with an air gap **503** interposed therebetween prevents a depressing force by the human finger **509** onto the translucent protection panel **504** from being transmitted to the liquid crystal panel **501**. This prevents an undesired waving pattern from being generated on the display screen by the depressing force by the finer **509**.

[0091] The illuminating device **502** is not limited to a particular type and any illuminating device known as an illuminating device for a liquid crystal panel may be used. For example, a direct-lighting or edge-light illuminating device may be used. An edge-light illuminating device is preferable since it is advantageous in realizing a thin liquid crystal display device. The light source is not limited to a particular type, either, and a cold/hot-cathode tube or an LED may be used, for example.

[0092] The liquid crystal display device **500** of the present embodiment is capable of displaying a color image by permitting light from the illuminating device **502** to pass through the liquid crystal panel **501** and the translucent protection panel **504**.

[0093] Meanwhile, external light, L, that entered the touch sensor side **504***a* enters the thin film diode **530**. When the finger **509** touches the touch sensor side **504***a*, part of the external light L is blocked. As a change in the external light L entering a thin film diode **530** is detected, it can be determined whether the finger **509** is in contact with the touch sensor side **504***a* and where it is in contact with it. The light-blocking layer **560** prevents light from the illuminating device **502** from entering the thin film diode **530**.

[0094] In the above arrangement, the thin film diode **530**, the thin film transistor **550**, the light-blocking layer **560** and the TFT array substrate **510** may be the thin film diode **130**, the thin film transistor **150**, the light-blocking layer **160** and the substrate **101** illustrated in Embodiment 1. The insulating layer **512** includes the base layer **103**, the gate insulating film **105**, the interlayer insulating film **107** and the planarizing film, illustrated in Embodiment 1.

[0095] FIG. **4** shows a transmissive liquid crystal display device as the liquid crystal display device; however, the present invention is not limited thereto and may be used in a semi-transmissive or reflective liquid crystal display device. No illuminating device **502** is required in a reflective liquid crystal display device.

[0096] FIG. **5** is an equivalent circuit of one pixel of the liquid crystal panel **501** shown in FIG. **4**. The pixel **570** of the liquid crystal panel **501** includes a display section **570***a*, constituting a color pixel, and a photosensor section **570***b*. A large number of such pixels **570** are arranged in a matrix in the horizontal and vertical directions in the pixel region of the liquid crystal panel **501**.

[0097] The display section **570***a* includes thin film transistors **550**R, **550**G and **550**B, liquid crystal elements **551**R, **551**G and **551**B, and electrostatic capacitances **552**R, **552**G and **552**B (the suffixes R, G and B indicate that the elements correspond to the red, green and blue subpixels constituting a pixel. The same applies to the following description). The source regions of the thin film transistors **550**R, **550**G and **550**B are connected with the source electrode lines (signal lines) SLR, SLG and SLB, respectively. The gate electrodes are connected with the gate electrode line (scan line) GL. Each of the drain regions is connected with the pixel electrode of the respective one of the liquid crystal elements **551**R, **551**G and **551**B (see the pixel electrode **515** of FIG. **4**) and one of the electrodes of the respective one of the electrostatic capacitances **552**R, **552**G and **552**B. The other one of the electrodes of each of the electrostatic capacitances **552**R, **552**G and **552**B is connected with the common electrode line TCOM.

[0098] When a positive pulse is applied to the gate electrode line GL, the thin film transistors **550**R, **550**G and **550**B are turned on. Thus, a signal voltage applied to the source electrode lines SLR, SLG and SLB is transmitted from the source electrodes of the thin film transistors **550**R, **550**G and **550**B, respectively, via the respective drain electrodes to the liquid crystal elements **551**R, **551**G and **551**B, respectively, and the electrostatic capacitances **552**R, **552**G and **552**B, respectively. As a result, a voltage is applied to the liquid crystal layer **519** (see FIG. **4**) by means of the pixel electrodes **515** of the liquid crystal elements **551**R, **551**G and **551**B (see FIG. **4**) and the common electrode **524** (see FIG. **4**) to change the orientation of liquid crystal molecules in the liquid crystal layer **519** to achieve a desired color display.

[0099] The photosensor section **570***b* includes a thin film diode **530**, a storage capacitance **531**, and a thin film transistor **532**. The p^+-type region of the thin film diode **530** is connected with the reset signal line RST. The n^+-type region of the thin film diode **530** is connected with one electrode of the storage capacitance **531** and the gate electrode of the thin film transistor **532**. The other electrode of the storage capacitance **531** is connected with the read-out signal line RWS. The drain electrode of the thin film transistor **532** is connected with the source electrode line SLG. The source electrode of the thin film transistor **532** is connected with the source electrode line SLB. The source electrode line SLG is connected with a rated voltage VDD. The source electrode line SLB is connected with the drain electrode of a bias transistor **533**. The source electrode of the bias transistor **533** is connected with a rated voltage VSS.

[0100] In the photosensor section **570***b* of this configuration, an output voltage VPIX corresponding to the amount of light received by the thin film diode **530** is obtained in the following manner.

[0101] First, a high-level reset signal is supplied to the reset signal line RST. Thus, the thin film diode **530** is forward biased. At this point, the potential of the gate electrode of the thin film transistor **532** is lower than the threshold voltage of the thin film transistor **532**. Consequently, the thin film transistor **532** is non-conductive.

[0102] Next, the potential of the reset signal line RST is lowered to low level. Thus, an integration period of photocurrent begins. During this integration period, the amount of photocurrent proportional to the amount of light entering the thin film diode **530** flows out of the storage capacitance **531**, discharging the storage capacitance **531**. Even during the integration period, the potential of the gate electrode of the thin film transistor **532** is lower than the threshold voltage of the thin film transistor **532**. Consequently, the thin film transistor **532** remains non-conductive.

[0103] Next, a high-level read-out signal is supplied to the read-out signal line RWS. Thus, the integration period ends and a read-out period begins. As a read-out signal is supplied, electric charge is injected into the storage capacitance **531**, such that the potential of the gate electrode of the thin film transistor **532** becomes higher than the threshold voltage of the thin film transistor **532**. As a result, the thin film transistor **532** becomes conductive and works together with the bias transistor **533** to function as a source follower amplifier. The output voltage VPIX obtained from the thin film transistor **532** is proportional to the value of integral of photocurrent of the thin film diode **530** during the integration period.

[0104] Next, the potential of the read-out signal line RWS is lowered to low level and the read-out period ends.

[0105] These operations are repeated for each of the pixels **570** arranged in the pixel region of the liquid crystal panel **501** to provide touch sensor functionality in the pixel region of the liquid crystal panel **501**.

[0106] Using the thin film diode **130** illustrated in Embodiment 1 as the thin film diode **530** will realize a liquid crystal display device **500** having touch sensor functionality with excellent light detection sensitivity.

[0107] In FIG. **5**, one photosensor section **570***b* is provided for one display section **570***a* constituting a color pixel; however, the present invention is not limited to such an arrangement. For example, one photosensor section **570***b* may be provided for a plurality of display sections **570***a*. Alternatively, one photosensor section **570***b* may be provided for each of the subpixels for red, blue and green within one display section **570***a*. Further, while FIG. **5** shows an implementation where the present invention is employed in a liquid crystal panel for color display, the present invention may also be employed in a liquid crystal panel for monochrome display.

[0108] FIGS. **4** and **5** illustrate an implementation where the thin film transistor **150** of Embodiment 1 is the thin film transistor **550** (**550**R, **550**G and **550**B) provided in each of the subpixels; however, the present invention is not limited thereto. The thin film transistor **150** may be a thin film transistor shown in FIG. **5** other than the thin film transistors **550** (**550**R, **550**G and **550**B) provided in the subpixels. Alternatively, the thin film transistor **150** may be a thin film transistor for a driver circuit (the gate driver **510***g* or source driver **510***s* described below), for example.

[0109] In FIGS. **4** and **5**, the photosensor of the present invention having light detection functionality is provided in the pixel region of a TFT array substrate **510**, in which a large number of thin film transistors **550** for driving liquid crystal are disposed in a matrix. However, the present invention is not limited to such an arrangement. For example, the photosensor may be provided outside the pixel region of the TFT array substrate **510**. An implementation where the photosensor is provided outside the pixel region of the TFT array substrate **510** will be described referring to FIG. **6**. Out of the components of a liquid crystal display device, FIG. **6** only shows the TFT array substrate **510** and the illuminating device **502** that illuminates the backside of the TFT array substrate **510**. The TFT array substrate **510** includes a pixel region **510***a* in which a large number of thin film transistors for driving liquid crystal are arranged in a matrix, and a gate driver **510***g*, a source driver **510***s* and a light detection unit **510***b* are provided in a frame-shaped area around the pixel region **510***a*. The photosensor **132** illustrated in Embodiment 1 (the thin film diode **130** and the light-blocking layer **160**) is formed in the light detection unit **510***b*. The thin film diode **130** in the light detection unit **510***b* generates an illuminance signal corresponding to the brightness of the environment. The illuminance signal is input to a control circuit (not shown) of the illuminating device **502** via a line **509** of a flexible substrate, for example. The control circuit controls the illuminance of the illuminating device **502** in accordance with the illuminance signal. As a result, a liquid crystal display device where the brightness of the display screen is automatically regulated in accordance with the brightness of the environment is provided. Thus, the photosensor **132** according to an embodiment of the present invention (the thin film diode **130** and the light-blocking layer **160**) may be disposed in the frame-shaped area of the TFT array substrate **510** and be used as an ambient sensor that measures the brightness of the environment. Since the thin film diode **130** constituting the photosensor **132** according to an embodiment of the present invention has excellent light detection sensitivity, it provides a liquid crystal display device where the brightness of the display screen is optimized in accordance with the brightness of the environment. Further, a larger thin film diode **130** can be provided than in an implementation where a thin film diode **130** is formed inside the pixel region, thereby increasing the light receiving area to further improve light detection sensitivity in a simple manner.

[0110] Embodiment 2 has illustrated an implementation where the semiconductor device of the present invention illustrated in Embodiment 1 is used in a liquid crystal panel; however, the semiconductor device of the present invention is not limited to such an application. The semiconductor device of the invention may be used as a display element, such as an EL panel, a plasma panel or the like.

[0111] Alternatively, the semiconductor device of the invention may be used in various equipment including light detection functionality other than a display element.

[0112] While the present invention is not limited to any particular application field, it may be used widely in various equipment in which a photosensor with improved light detection sensitivity is required. Particularly, it may be suitably used in various display elements as a touch sensor or an ambient sensor that measures the brightness of the environment.

1. A photosensor comprising:

a substrate;

a thin film diode provided close to one side of the substrate and having a first semiconductor layer including, at least, an n-type region and a p-type region; and

a light-blocking layer provided between the substrate and the first semiconductor layer,

wherein asperities are formed on a side of the light-blocking layer facing the first semiconductor layer, and

the first semiconductor layer has a geometry of asperities conforming with the asperities of the light-blocking layer.

2. The photosensor according to claim **1**, wherein the first semiconductor layer has a thickness smaller than a difference in height between an apex and a bottom of the asperities formed on a side of the first semiconductor layer facing the light-blocking layer.

3. The photosensor according to claim **1**, wherein a difference in height between an apex and a bottom of the asperities formed on the side of the light-blocking layer facing the first semiconductor layer is in a range of 50 to 100 nanometers.

4. The photosensor according to claim **1**, wherein the asperities are formed on an entire surface of the side of the light-blocking layer facing the first semiconductor layer.

5. A semiconductor device comprising:

the photosensor according to claims **1**; and

a thin film transistor provided close to the same side of the substrate as the thin film diode,

wherein the thin film transistor includes: a second semiconductor layer including a channel region, a source region and a drain region; a gate electrode that controls a conductivity of the channel region; and a gate insulating film provided between the second semiconductor layer and the gate electrode.

6. The semiconductor device according to claim **5**, wherein the first semiconductor layer and the second semiconductor layer are formed on a single insulating layer.

7. The semiconductor device according to claim **5**, wherein a side of the second semiconductor layer facing the substrate is flat.

8. The semiconductor device according to claim **5**, wherein the first semiconductor layer has a thickness that is identical with that of the second semiconductor layer.

9. A liquid crystal panel comprising: the semiconductor device according to claim **5**; a counter substrate facing the side of the substrate where the thin film diode and the thin film transistor are provided; and a liquid crystal layer enclosed between the substrate and the counter substrate.

* * * * *

专利名称(译)	光传感器，半导体器件和液晶面板		
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摘要(译)

即使当二极管的半导体层具有小的厚度时，薄膜二极管的光利用效率也得到改善，从而提高了二极管的光检测灵敏度。具有至少包括n型区域（131n）和p型区域（131p）的第一半导体层（131）的薄膜二极管（130）设置在基板（101）的一侧上，并且在基板和第一半导体层之间提供光阻层（160）。在光阻挡层的面向第一半导体层的一侧提供凹凸不平。第一半导体层具有与光阻挡层上的粗糙度一致的粗糙度的几何形状。入射在光阻挡层上的光被漫反射并进入第一半导体层。由于第一半导体层具有与光阻挡层上的凹凸不平的凹凸几何形状，因此漫反射的光在第一半导体层内行进更长的距离。结果，更大量的光被第一半导体层吸收，从而提高了光检测灵敏度。