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(12) **United States Patent**
Imai et al.

(10) **Patent No.: US 8,659,726 B2**
(45) **Date of Patent: Feb. 25, 2014**

(54) **LIQUID CRYSTAL DISPLAY AND METHOD OF MANUFACTURING LIQUID CRYSTAL DISPLAY**

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(73) Assignee: **Sharp Kabushiki Kaisha**, Osaka (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1169 days.

(21) Appl. No.: **12/595,782**

(22) PCT Filed: **Dec. 27, 2007**

(86) PCT No.: **PCT/JP2007/075147**

§ 371 (c)(1),
(2), (4) Date: **Oct. 13, 2009**

(87) PCT Pub. No.: **WO2008/129748**

PCT Pub. Date: **Oct. 30, 2008**

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(30) **Foreign Application Priority Data**

Apr. 13, 2007 (JP) 2007-105996

(51) **Int. Cl.**
G02F 1/1335 (2006.01)
G02F 1/136 (2006.01)

(52) **U.S. Cl.**
USPC **349/113**; 349/43; 349/114

(58) **Field of Classification Search**
USPC 349/38, 39, 113, 114, 129, 130
See application file for complete search history.

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Primary Examiner — Edward Glick
Assistant Examiner — David Chung
(74) *Attorney, Agent, or Firm* — Nixon & Vanderhye P.C.

(57) **ABSTRACT**

Transflective-type and reflection type liquid crystal display devices having a high image quality are provided with a good production efficiency.

A liquid crystal display device according to the present invention is a liquid crystal display device which includes; a first substrate and a second substrate between which liquid crystal is interposed; a first electrode and a second electrode formed on the first substrate for applying a voltage for controlling an orientation of the liquid crystal; a transistor having an electrode which is electrically connected to the first electrode; a metal layer being formed on the first substrate and including a protrusion, a recess, or an aperture; and a reflective layer formed above the metal layer on the first substrate for reflecting incident light toward a display surface. The metal layer is made of a same material as that of a gate electrode of the transistor. The reflective layer includes a protrusion, a recess, or a level difference which is formed in accordance with a protrusion, a recess, or an aperture of the metal layer.

11 Claims, 24 Drawing Sheets

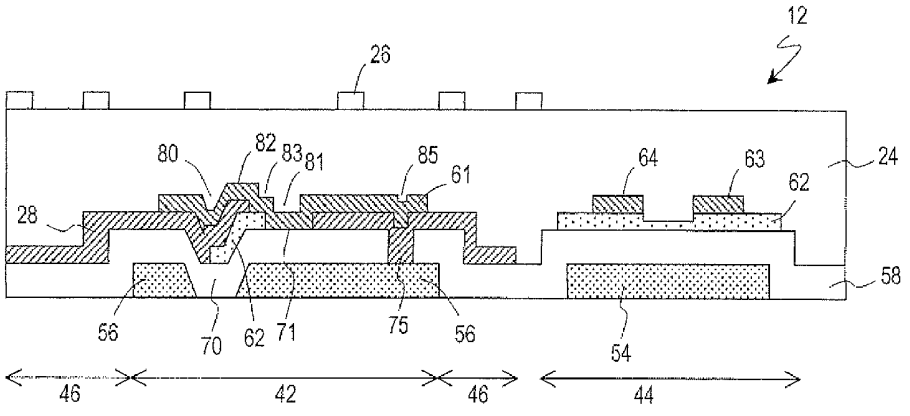

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FIG.1

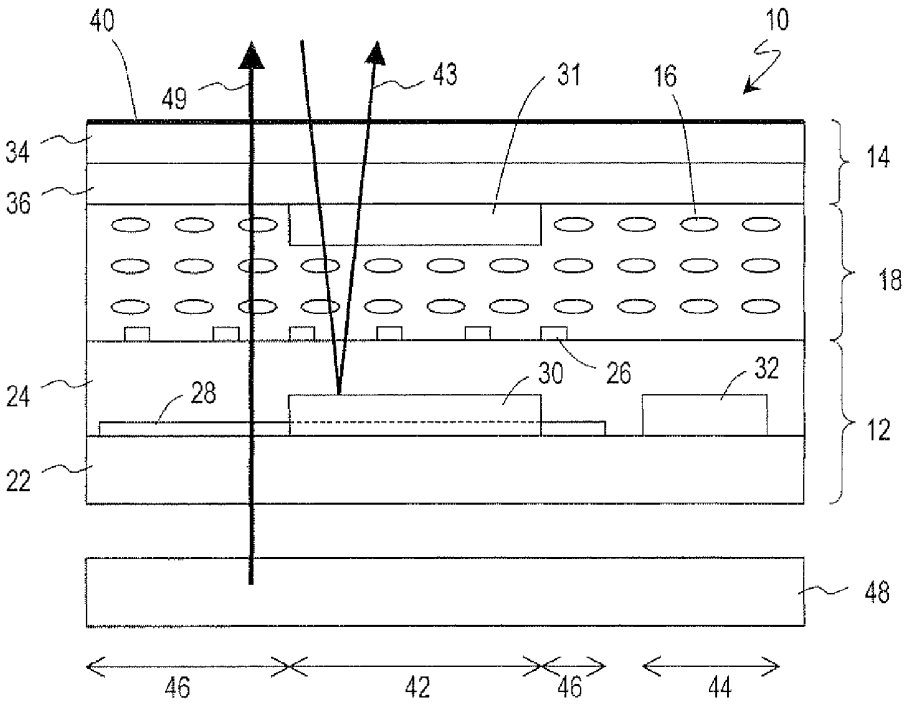
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FIG.2

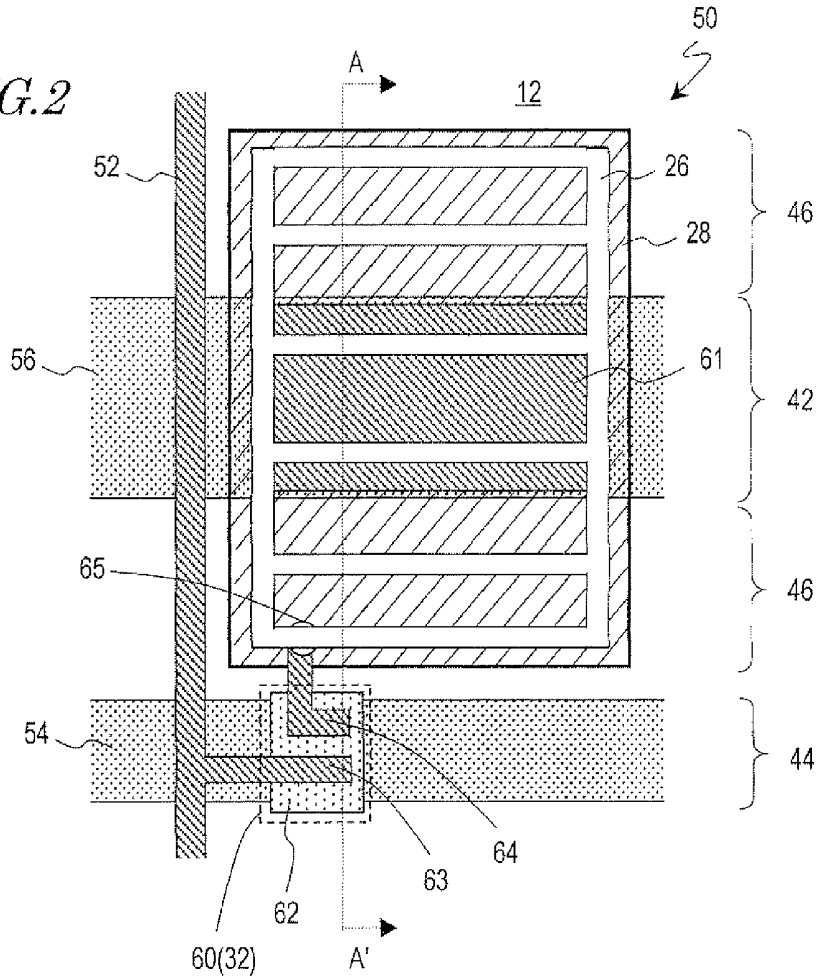
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FIG.3

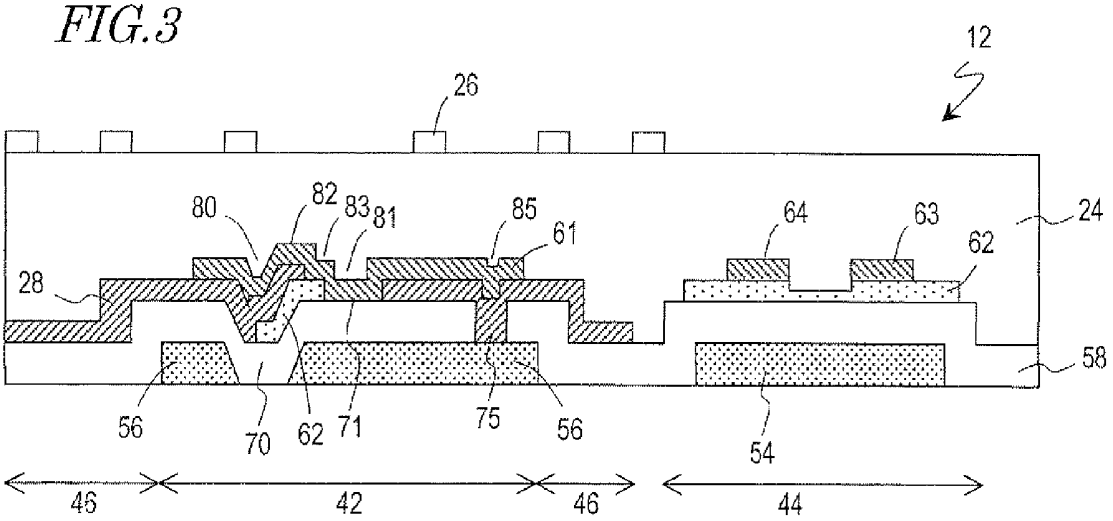
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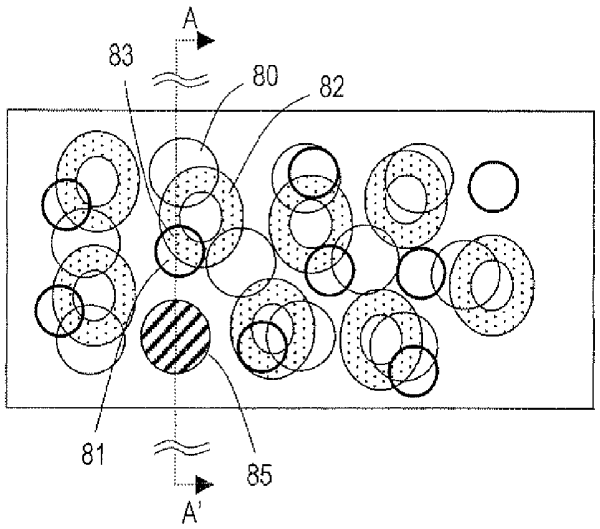
FIG.4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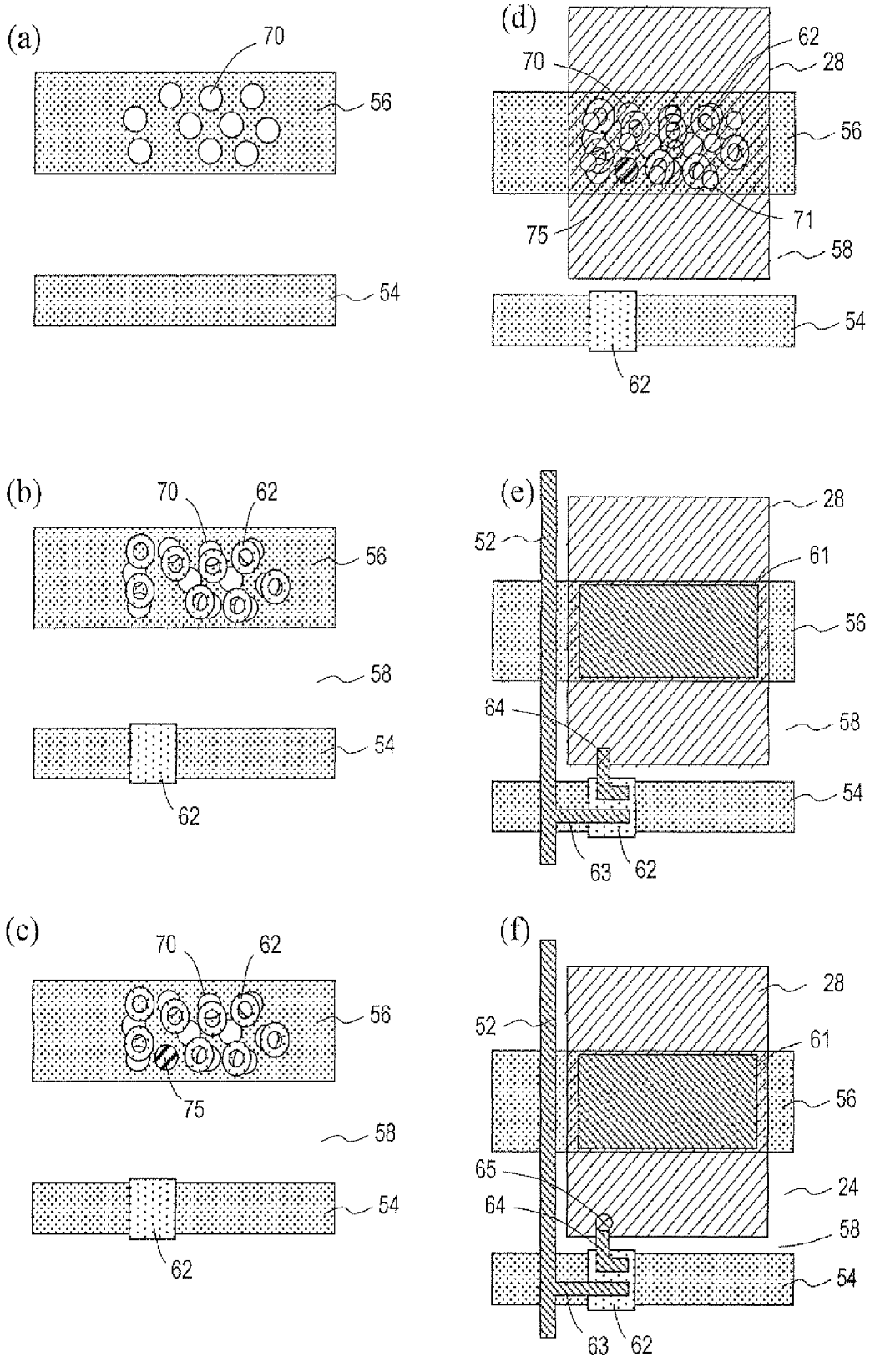
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FIG.6

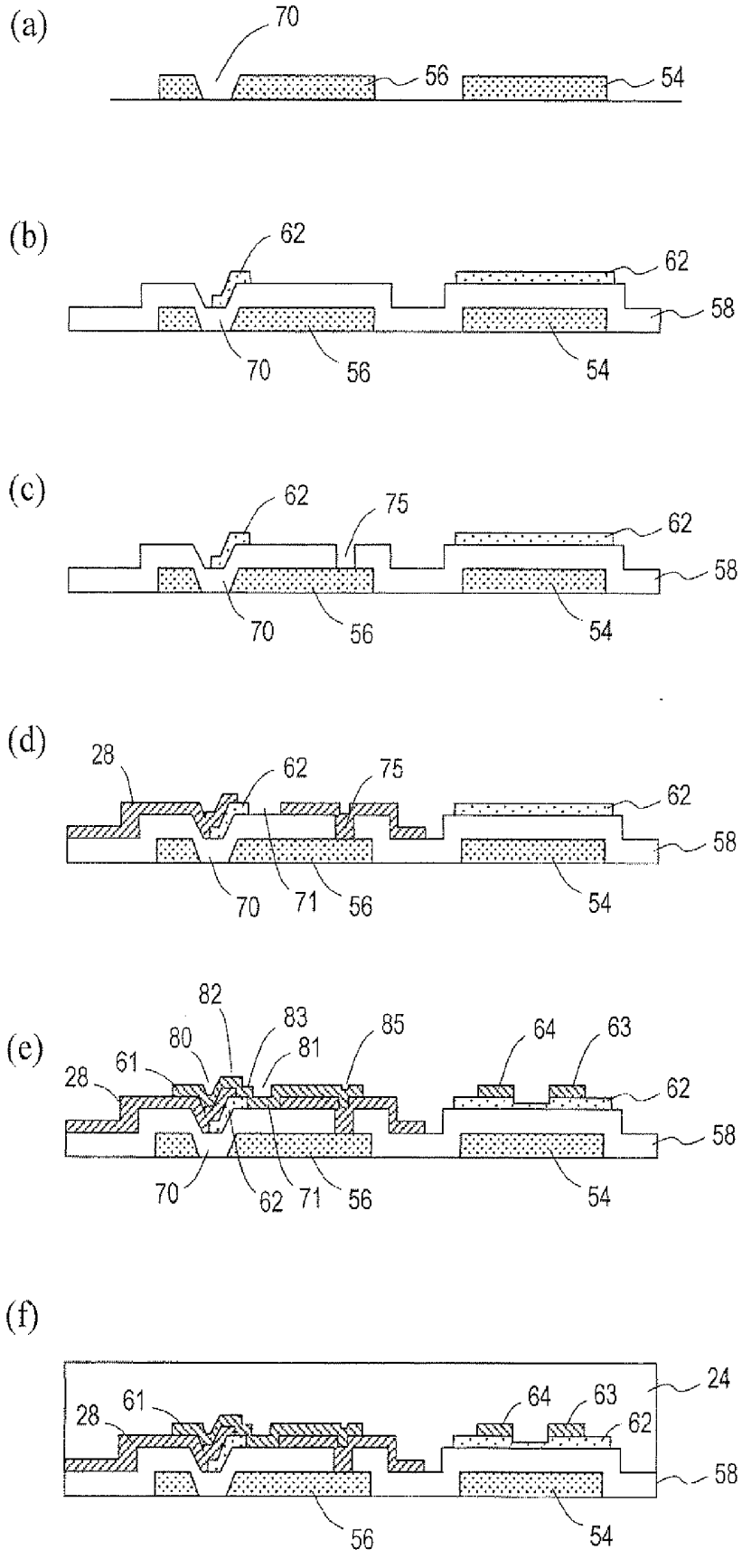
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FIG. 7

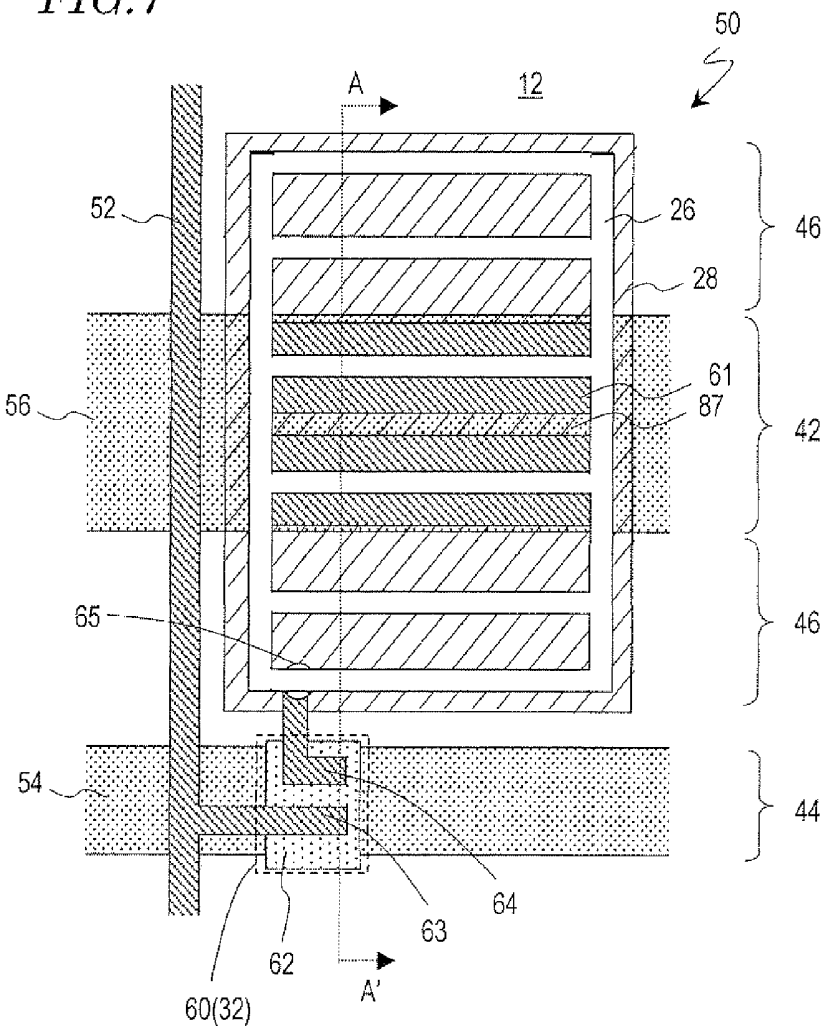
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FIG. 8

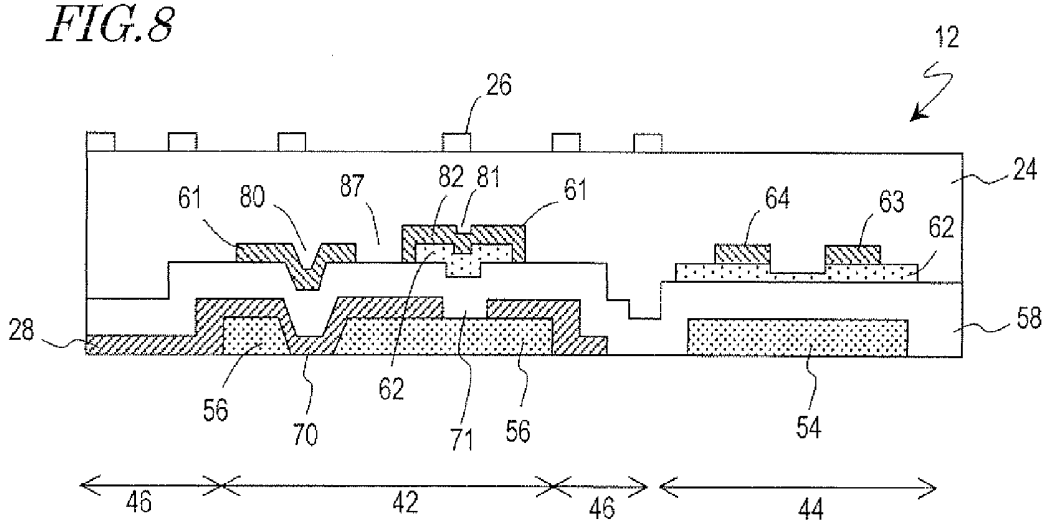
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FIG.9

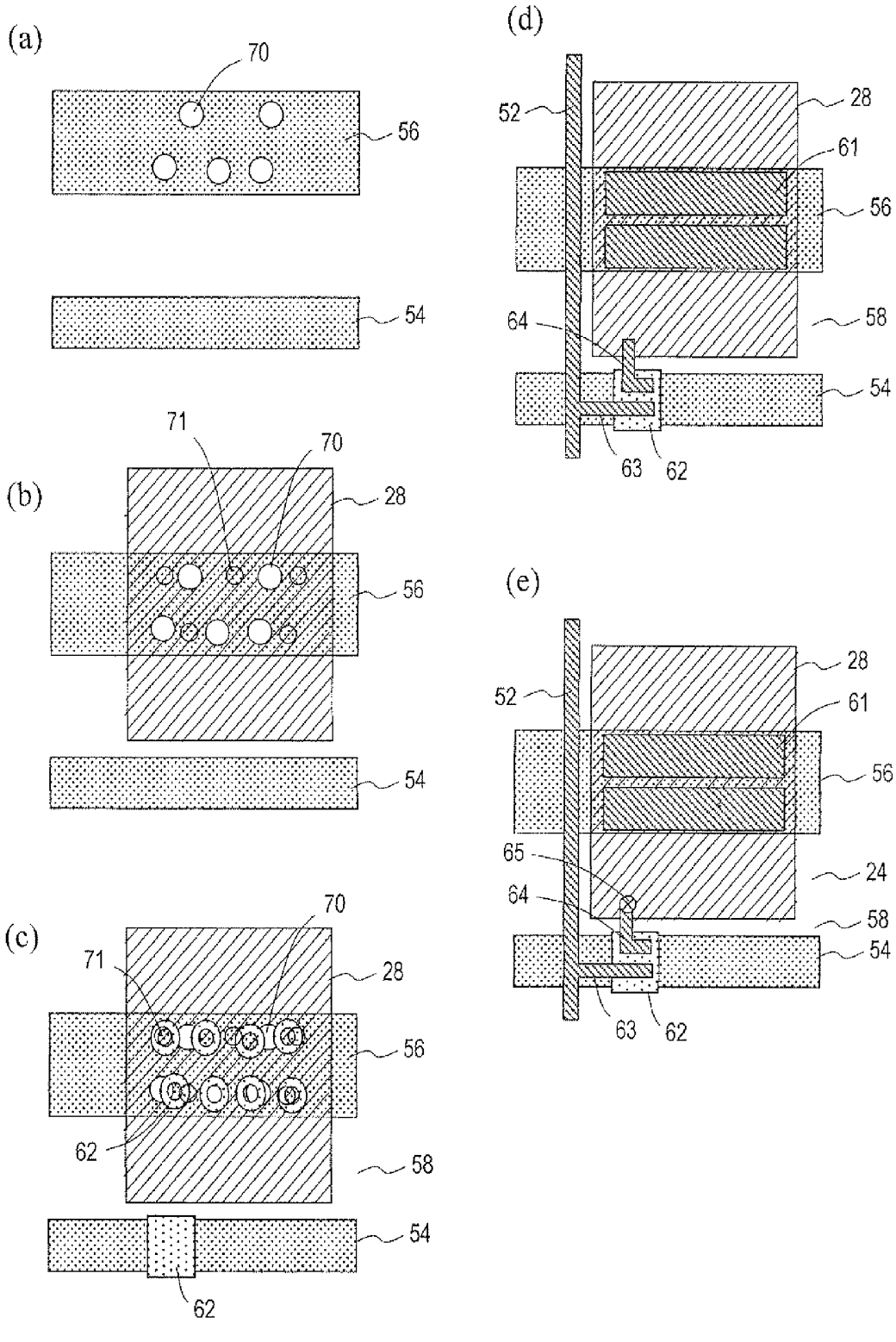
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FIG.10

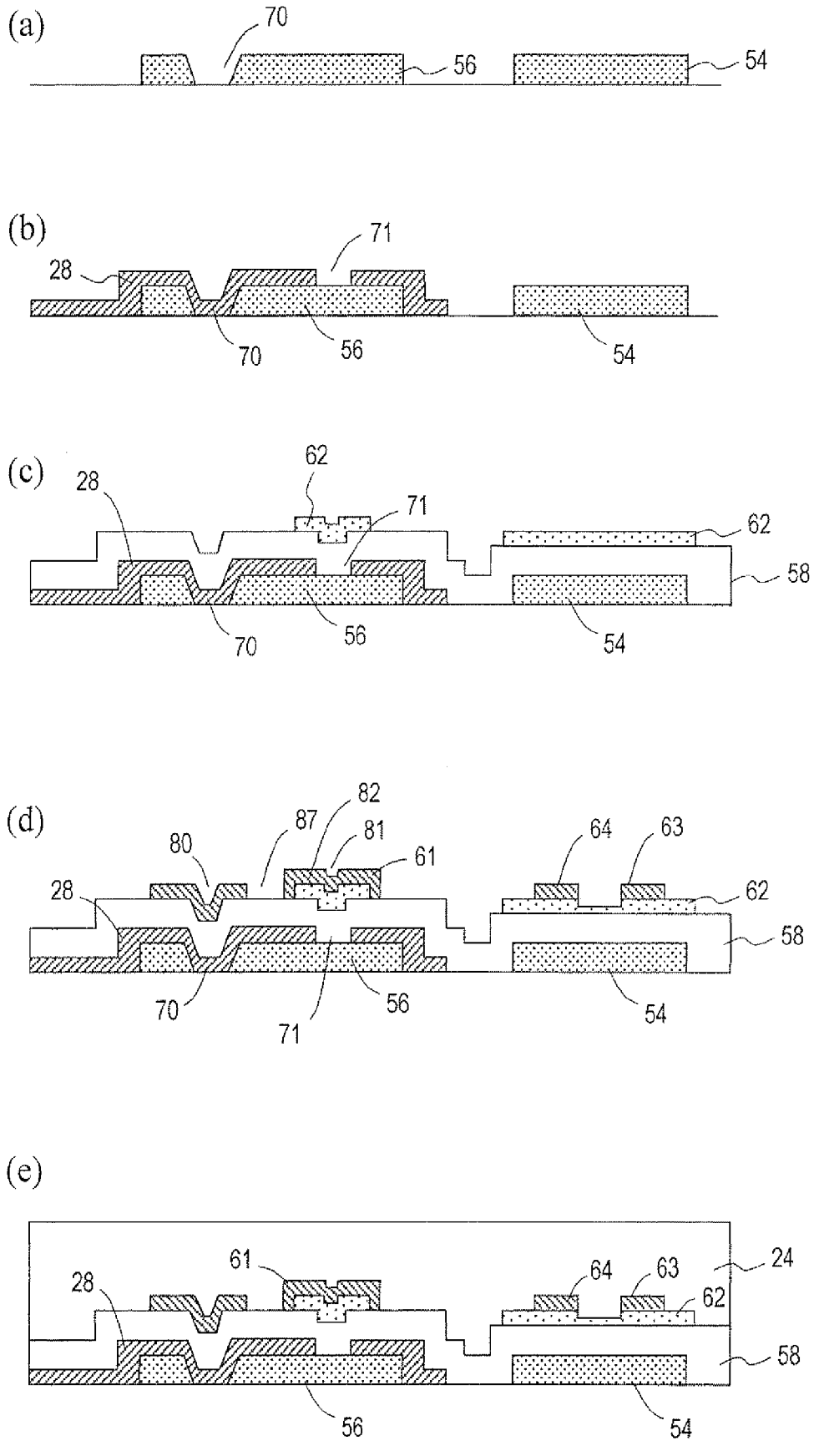
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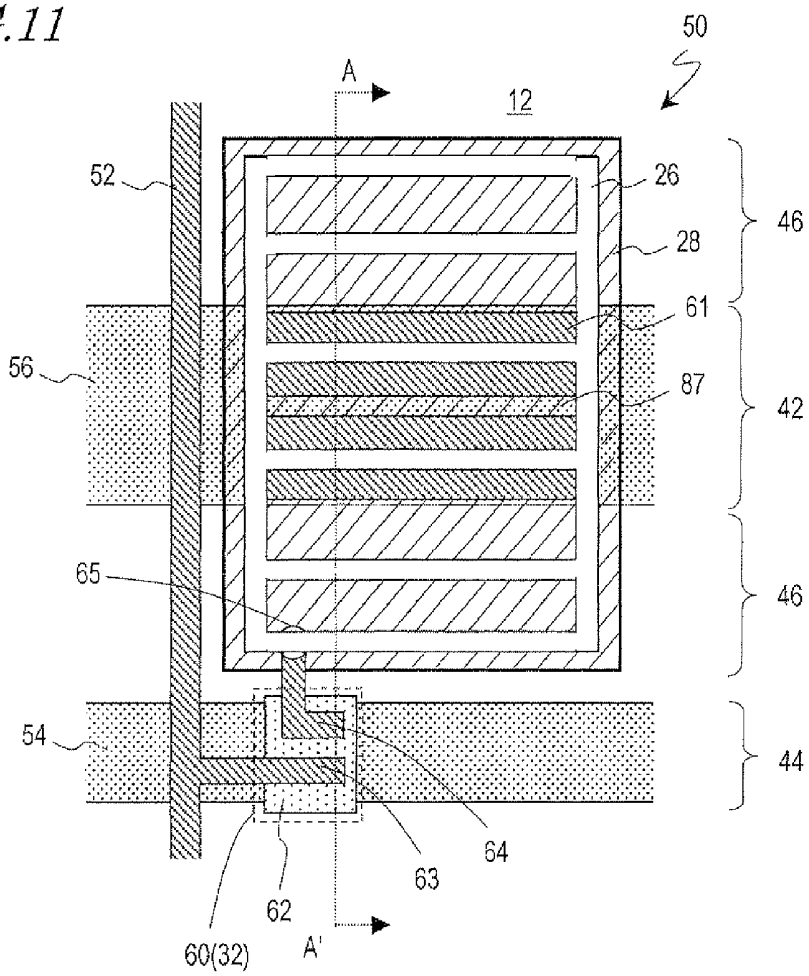
FIG. 11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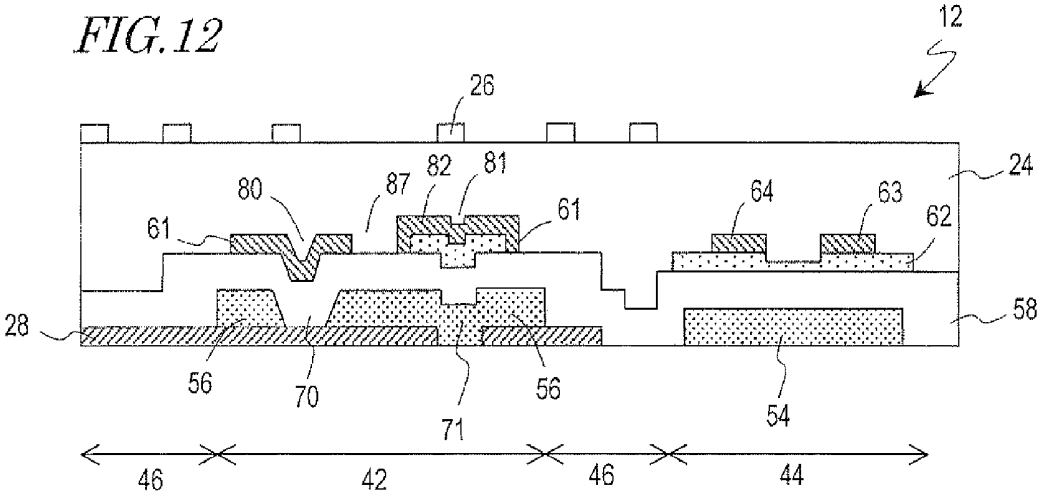
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FIG. 13

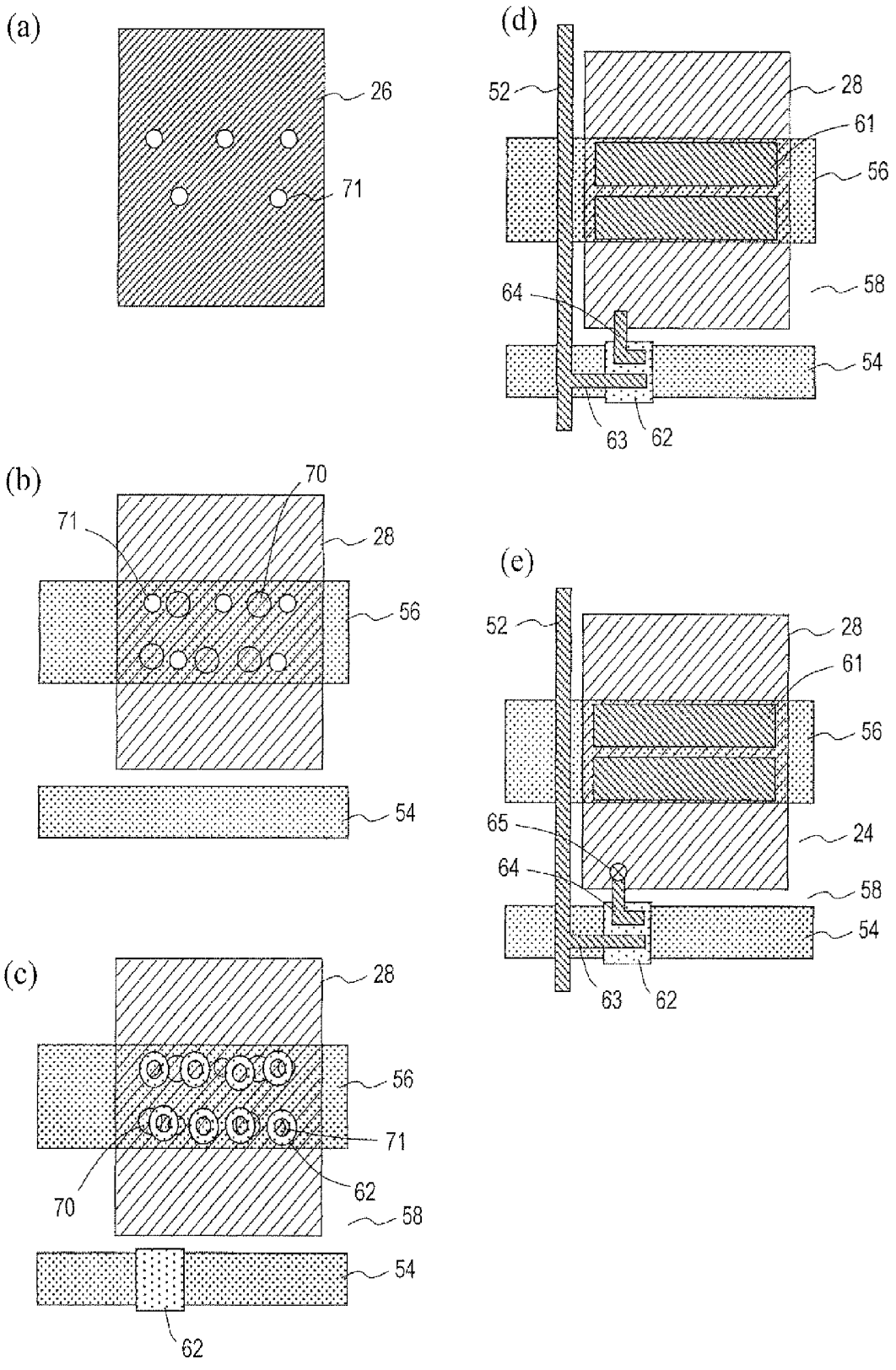
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FIG. 14

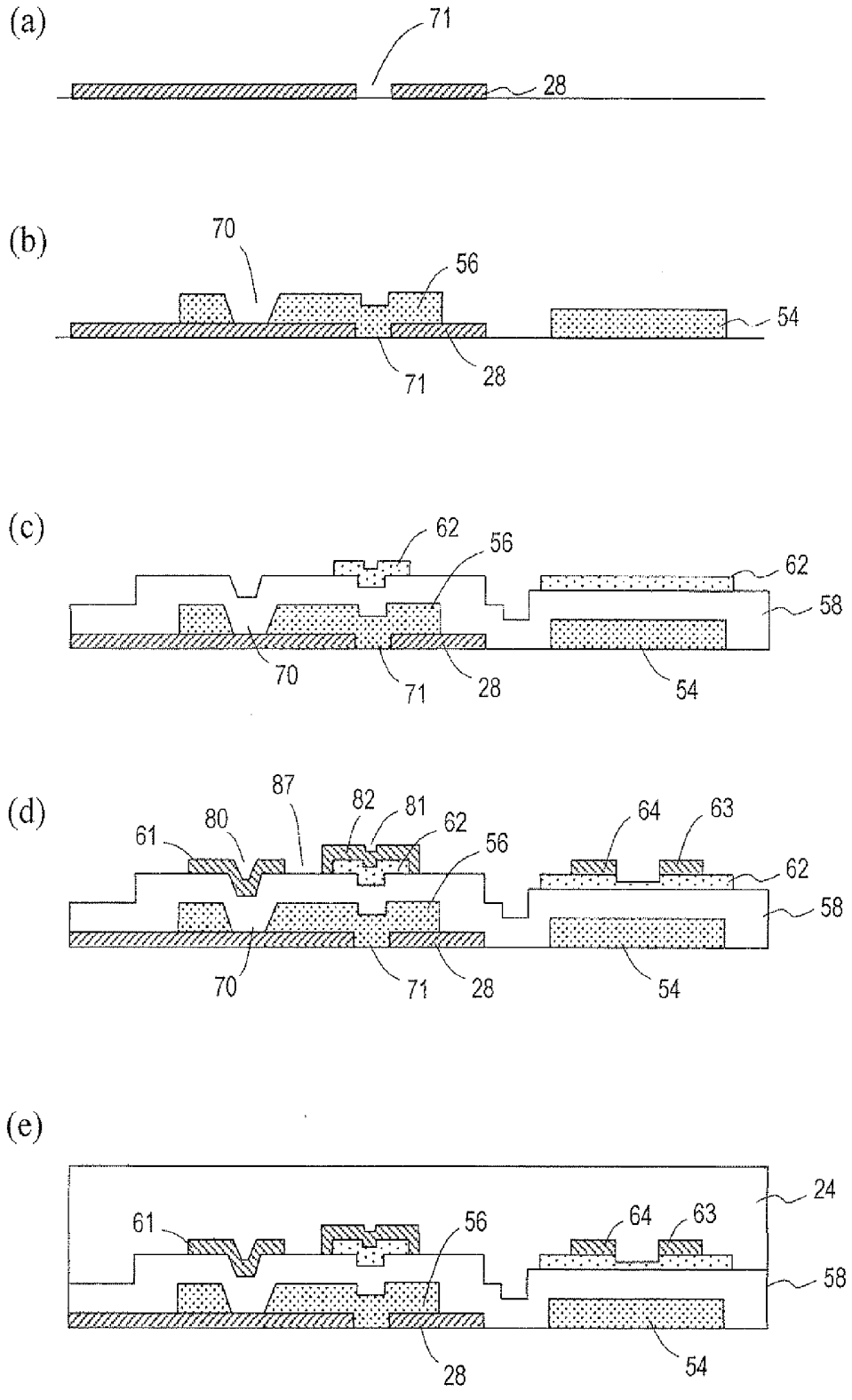
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FIG. 15

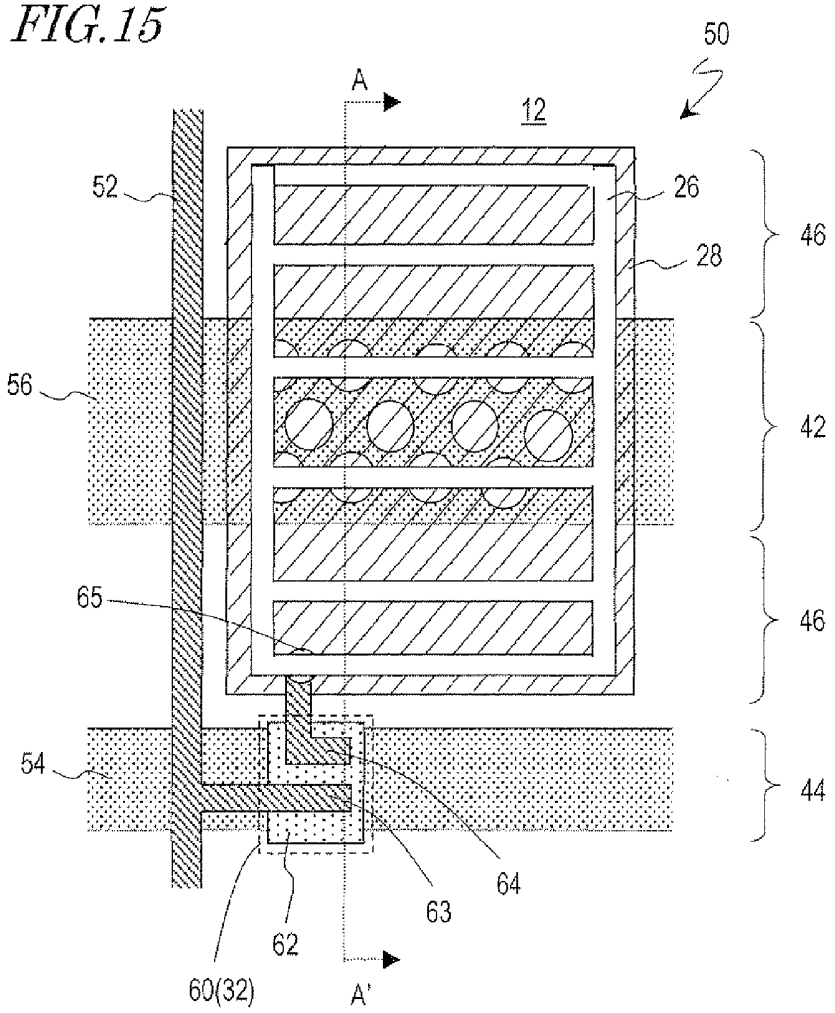
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FIG. 16

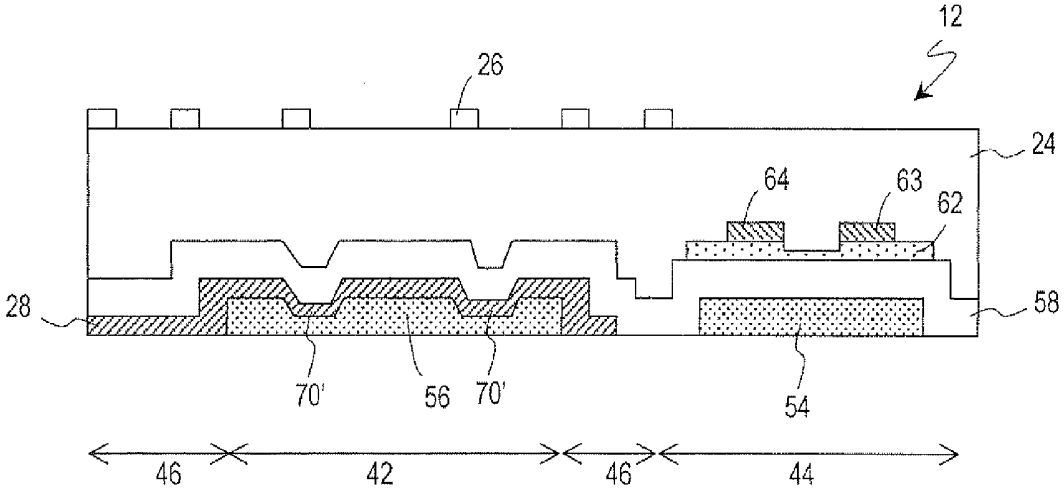
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FIG.17

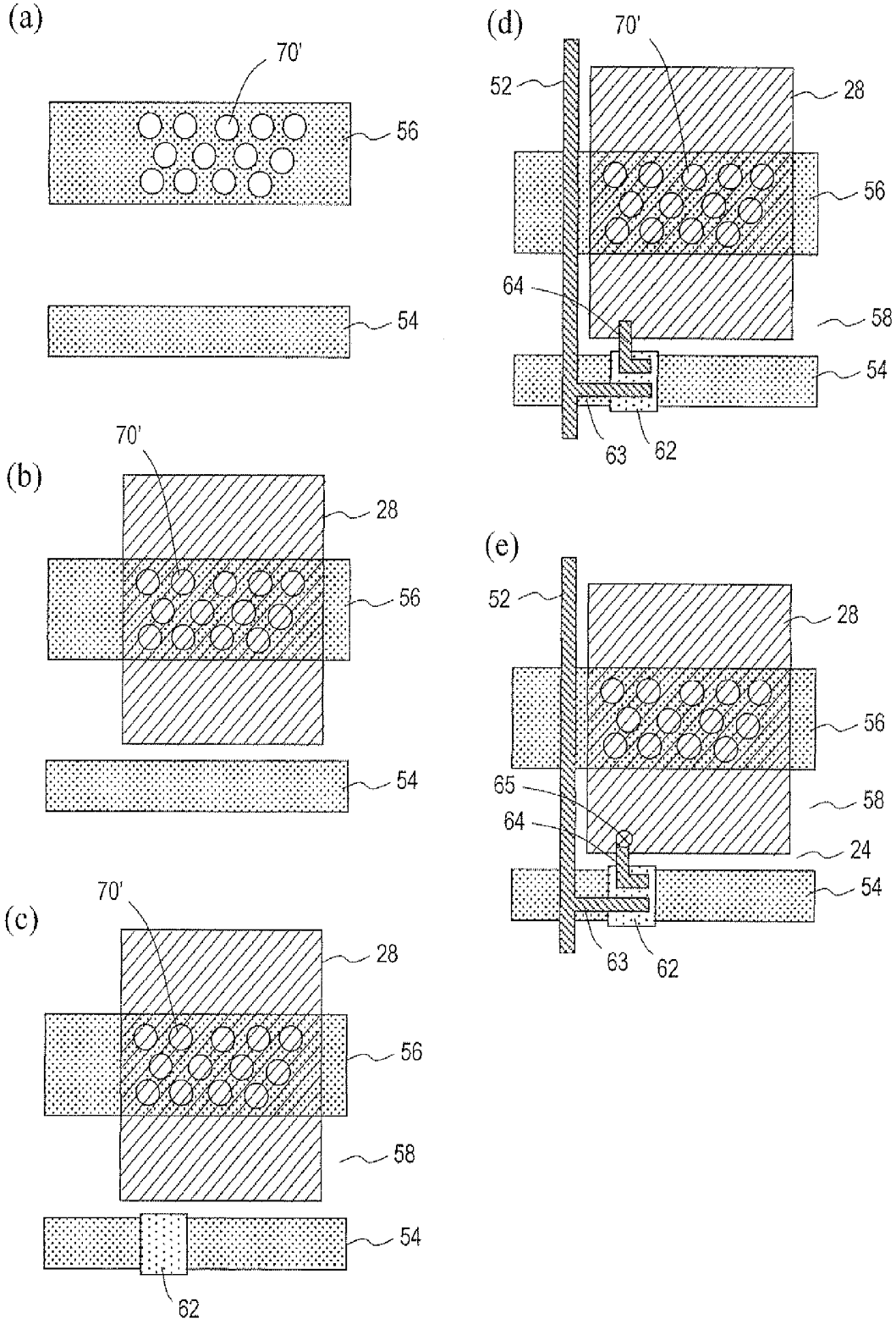
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FIG. 18

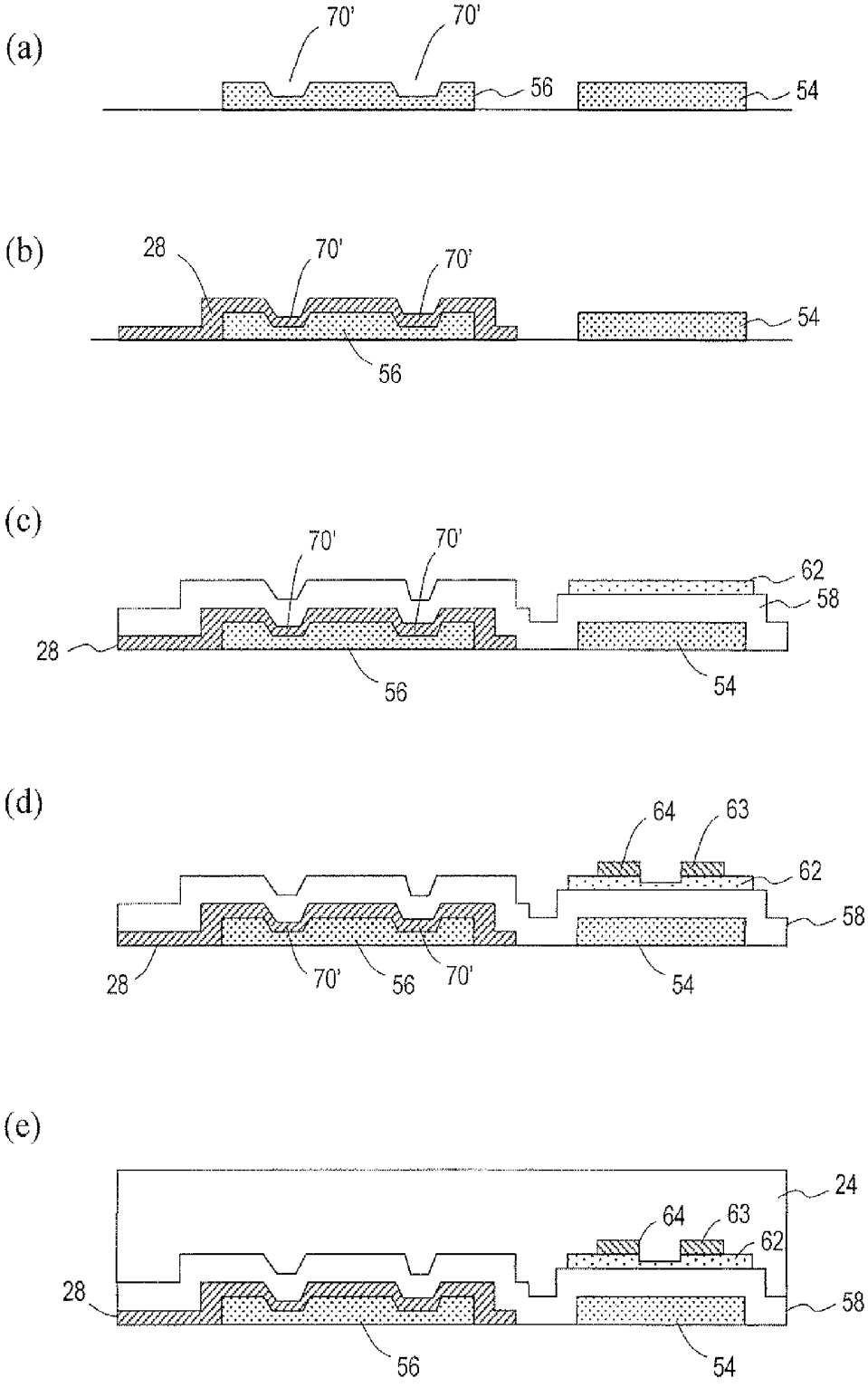
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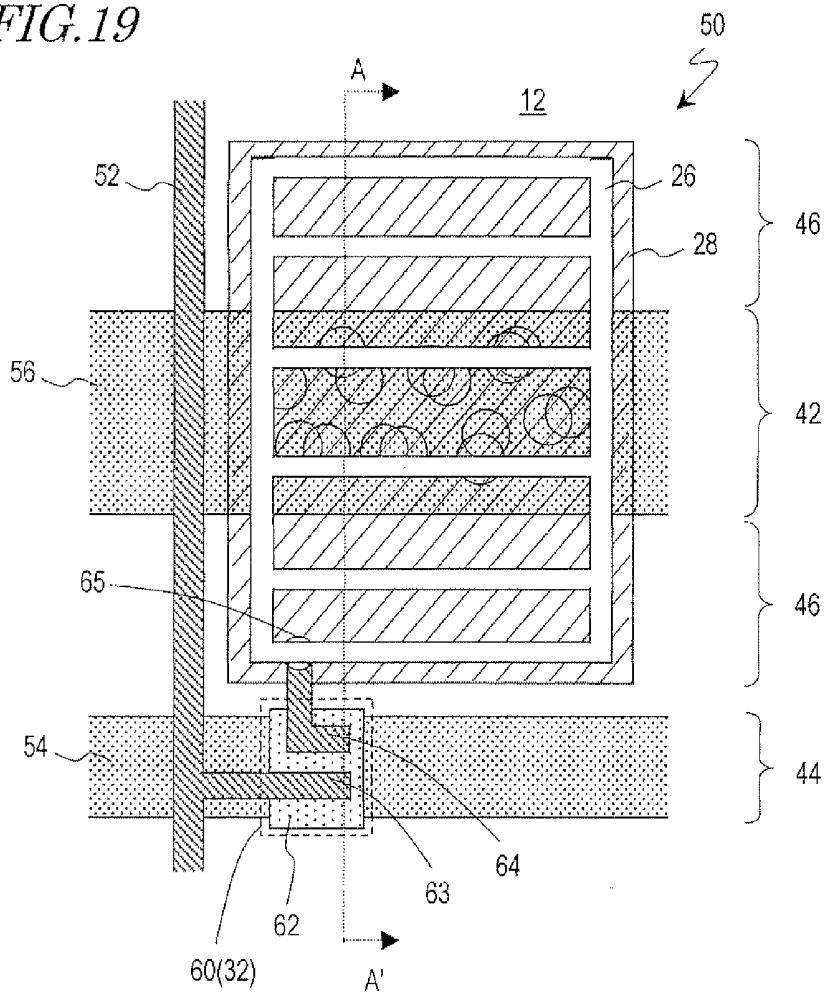
FIG.19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A
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60(32)
A'

FIG.20

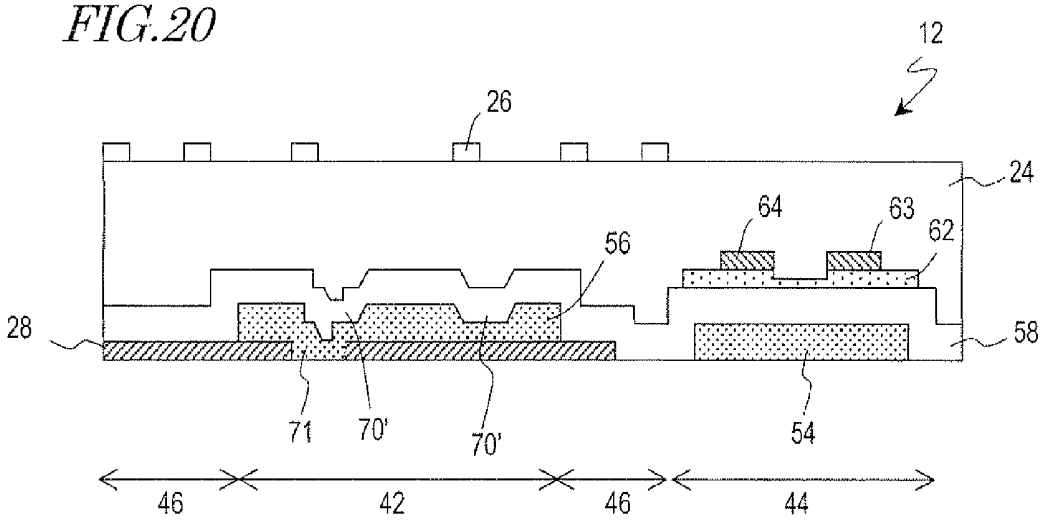
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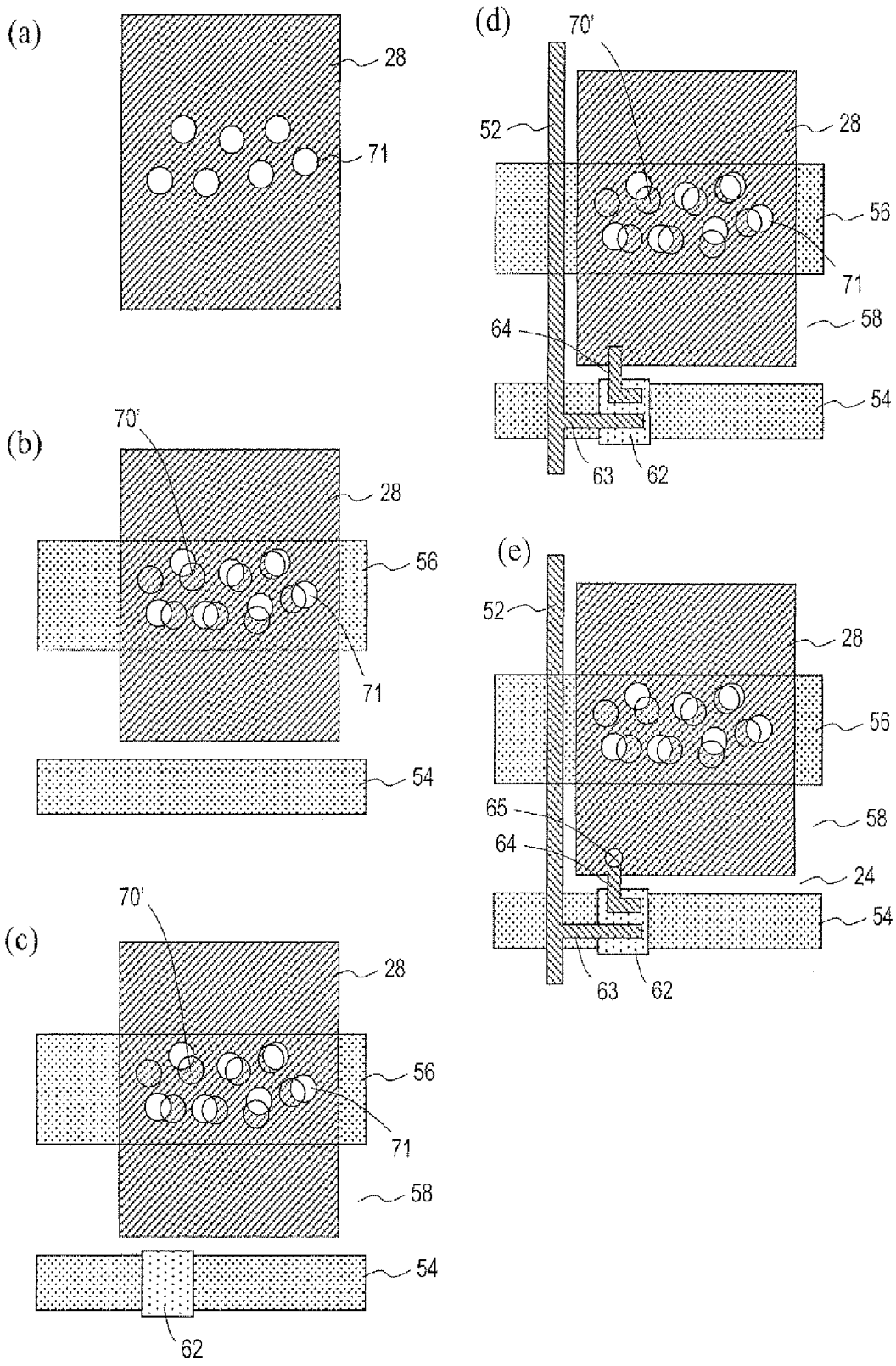
FIG.21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(d)
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28
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(e)
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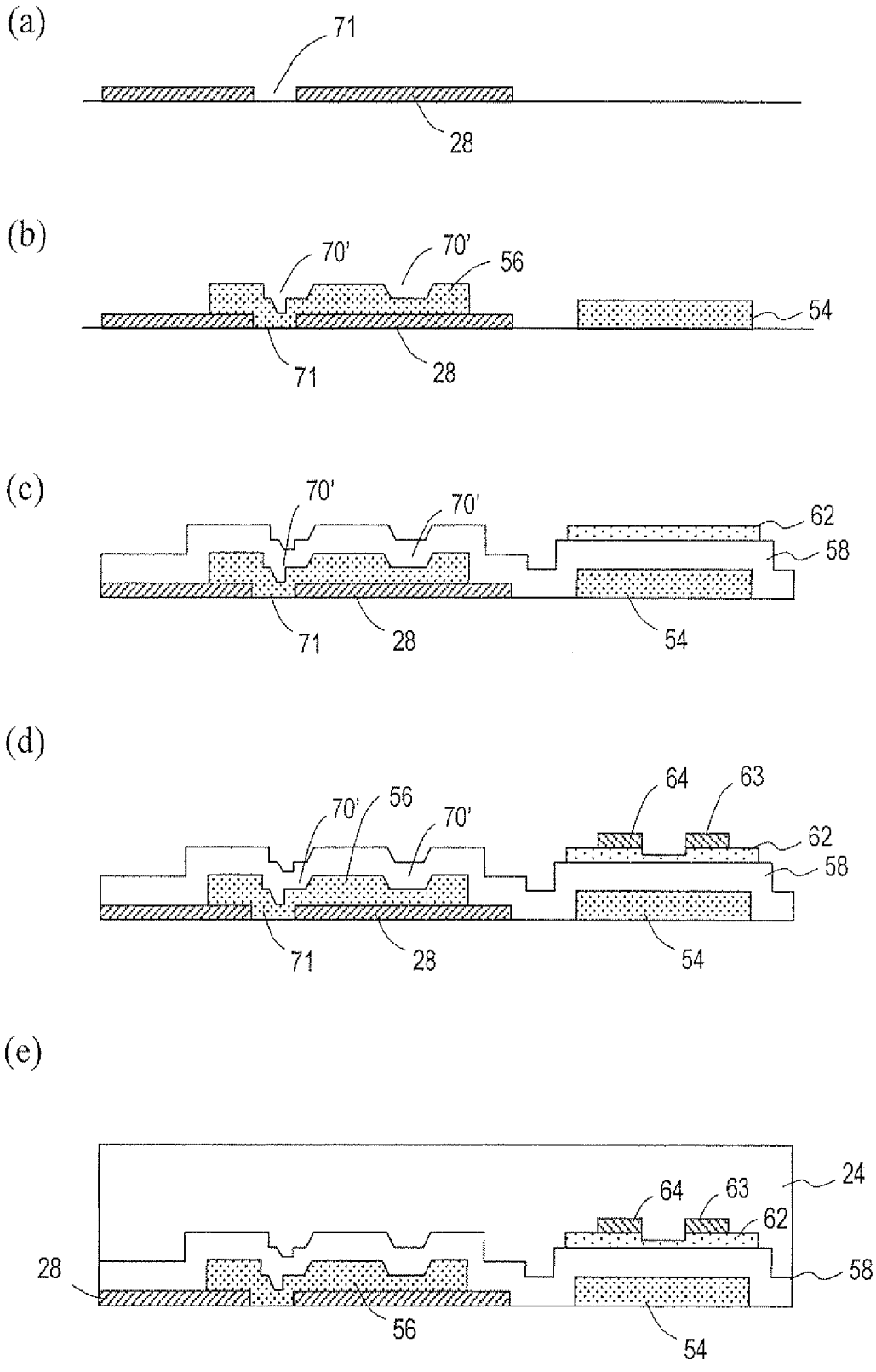
FIG.22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(d)
64
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70'
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(e)
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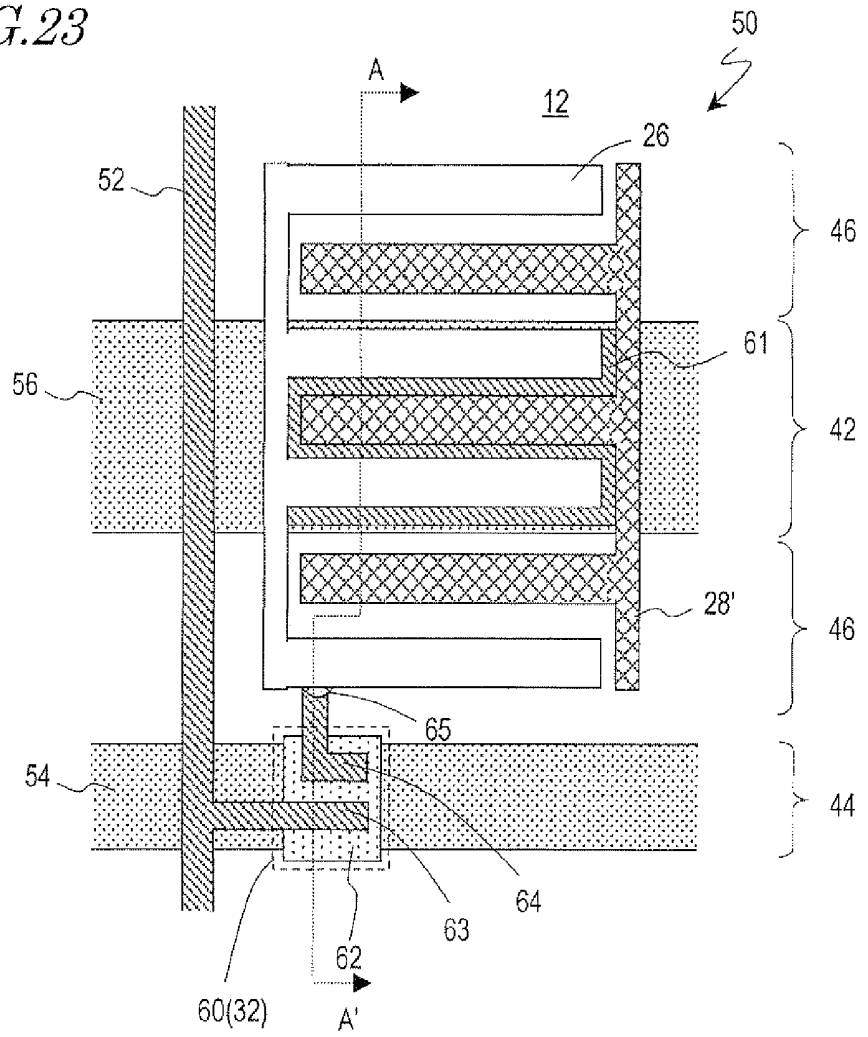
FIG.23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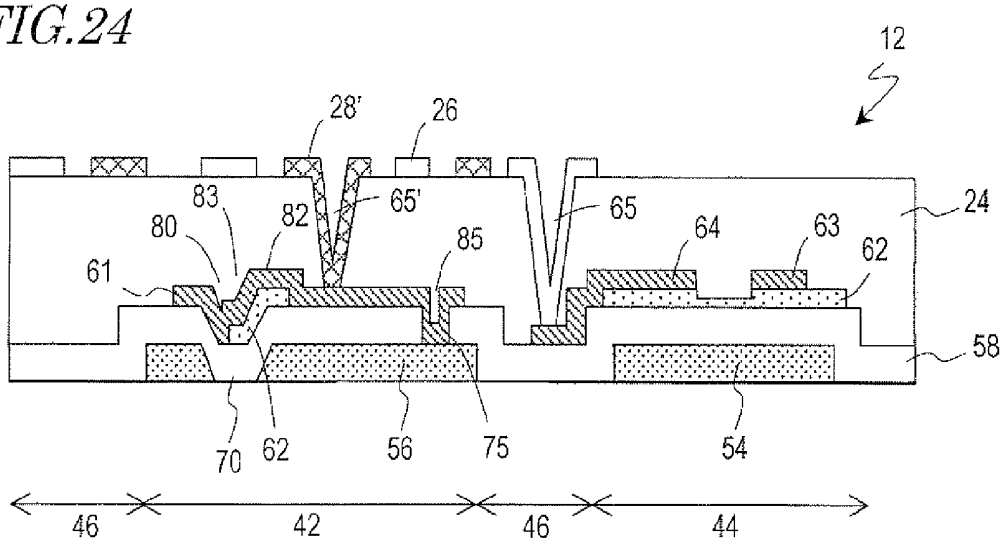
60(32)
A'

FIG.24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65'
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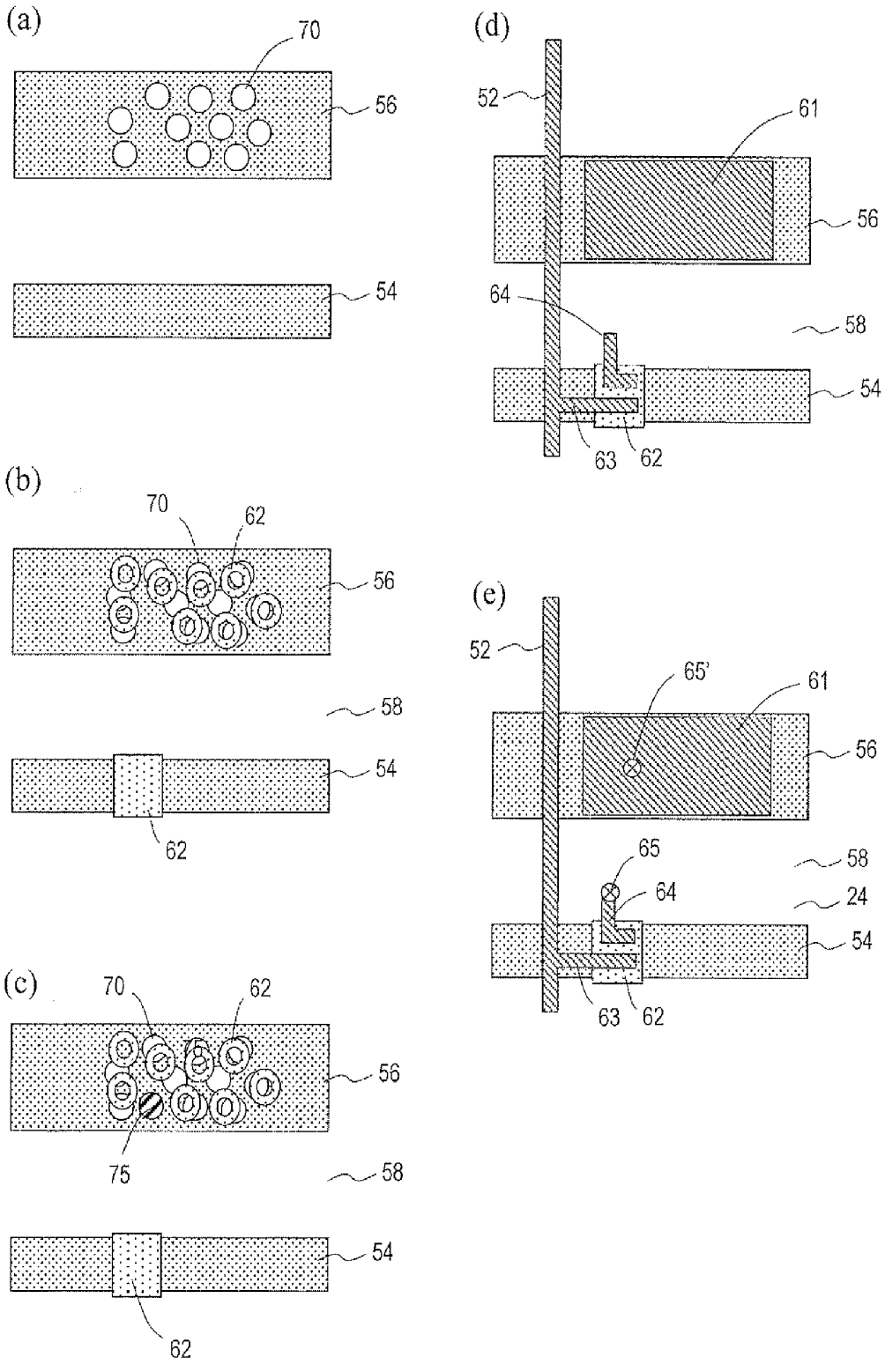
FIG.25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(e)
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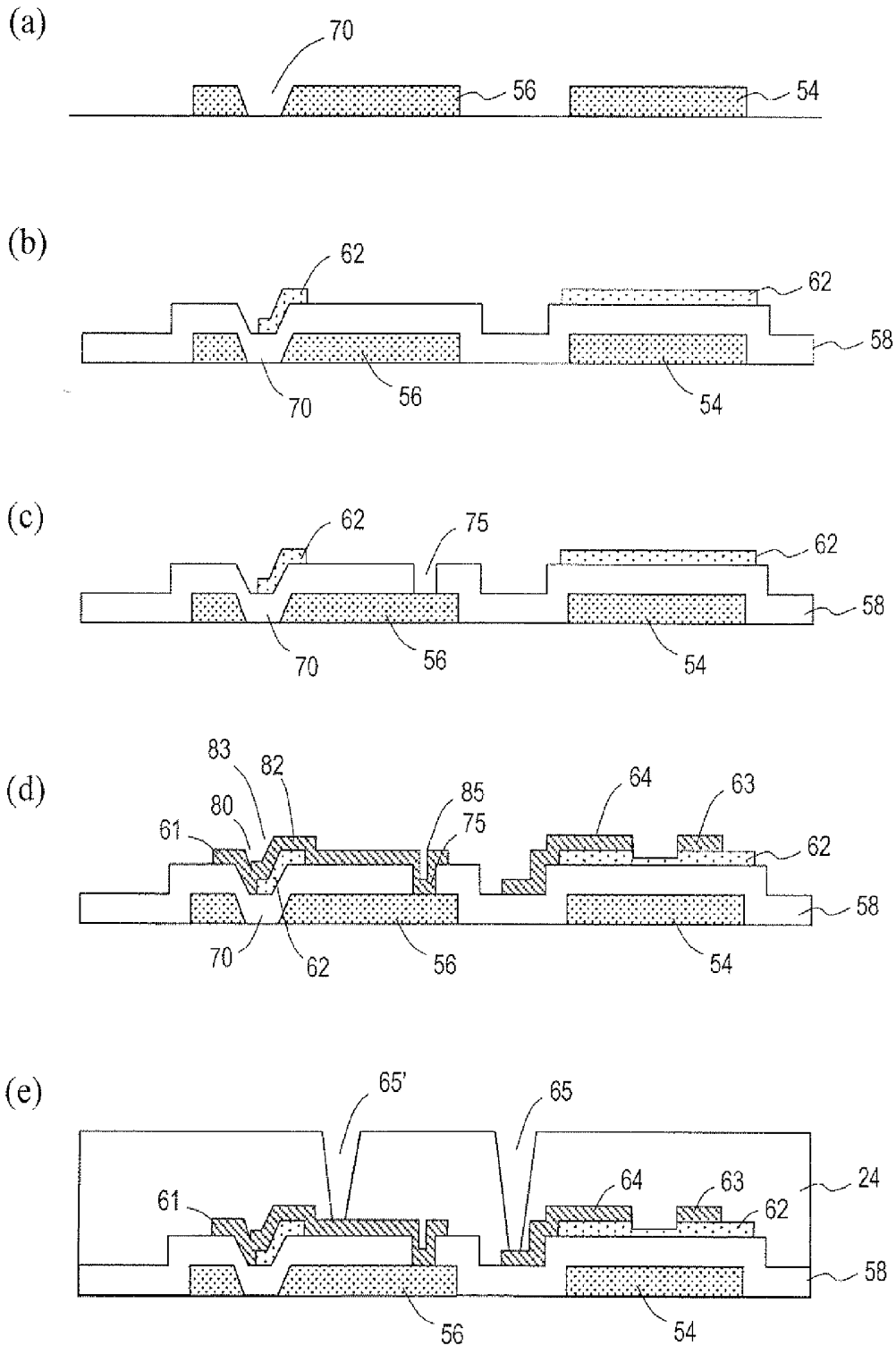
FIG.26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(d)
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(e)
65'
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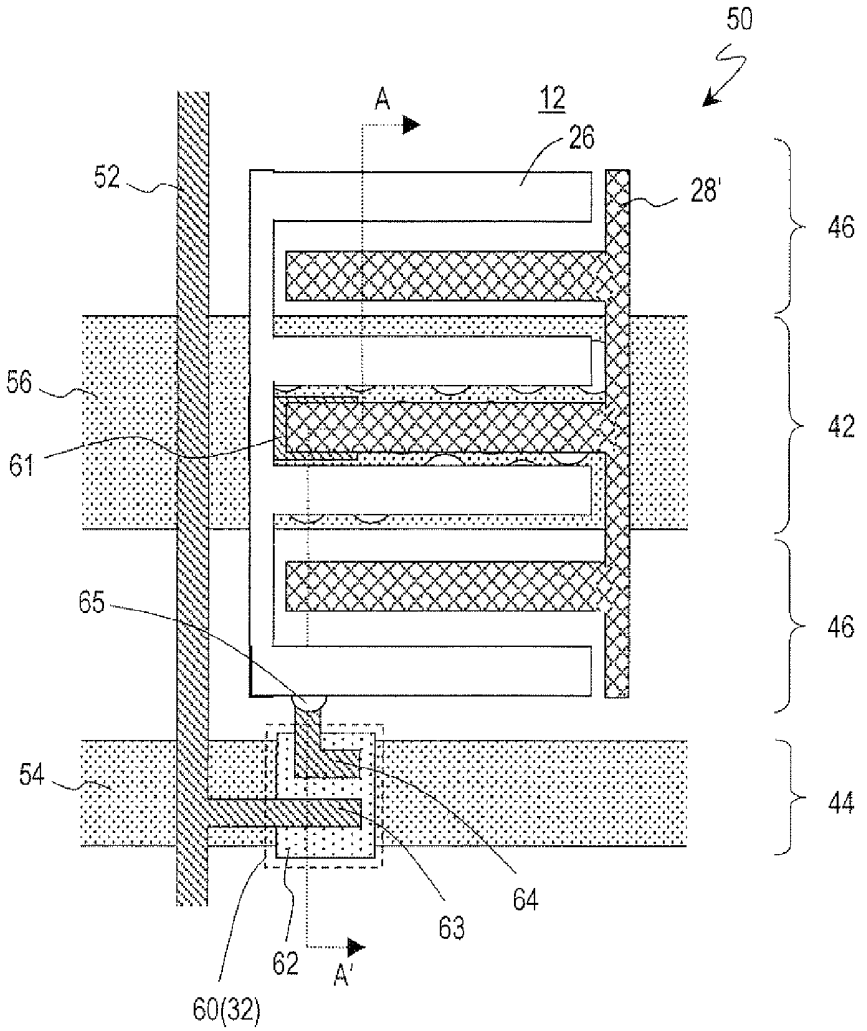
FIG.27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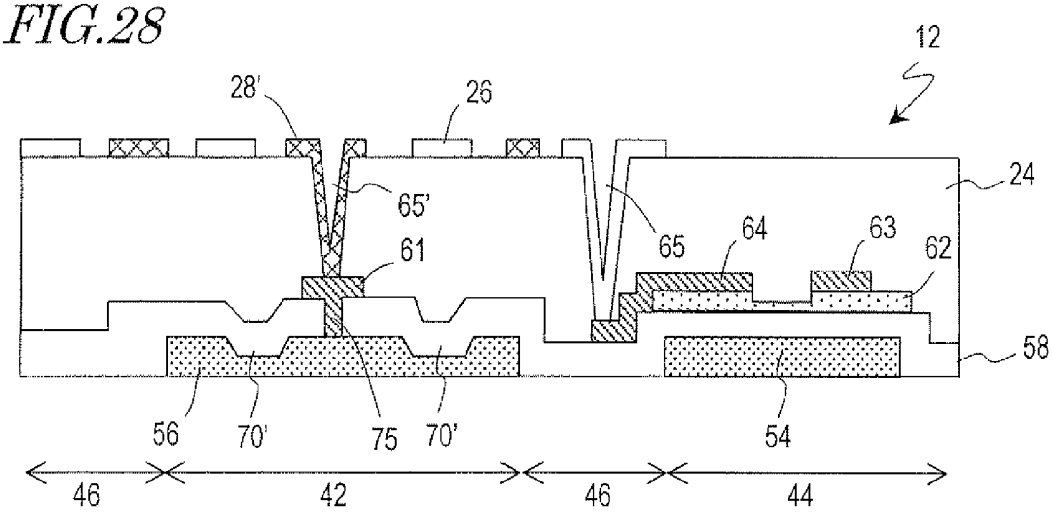
60(32)

FIG.28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54
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42
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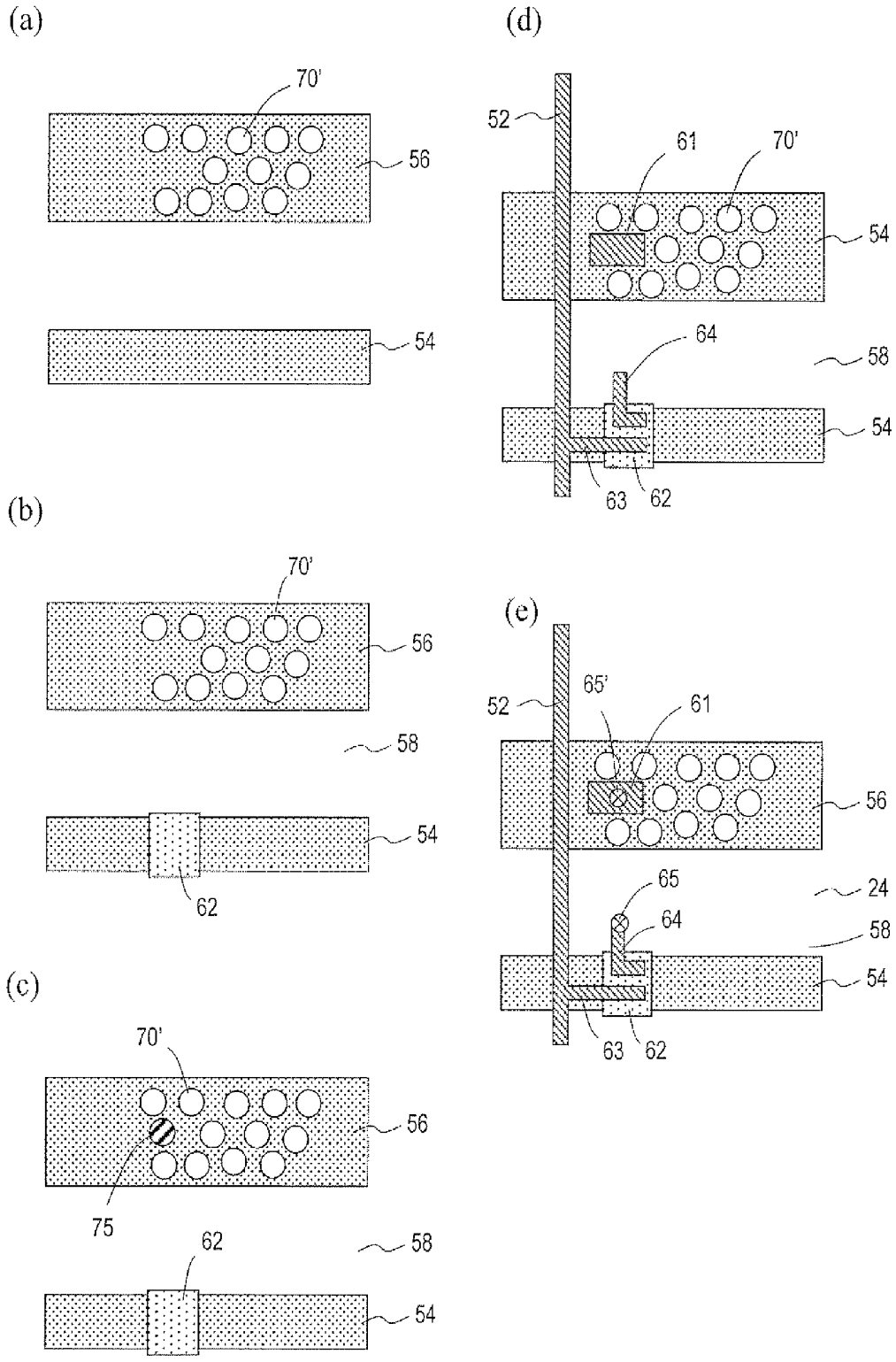
44

FIG.29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(b)
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70'
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(e)
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65'
61
56
65
24
64
58
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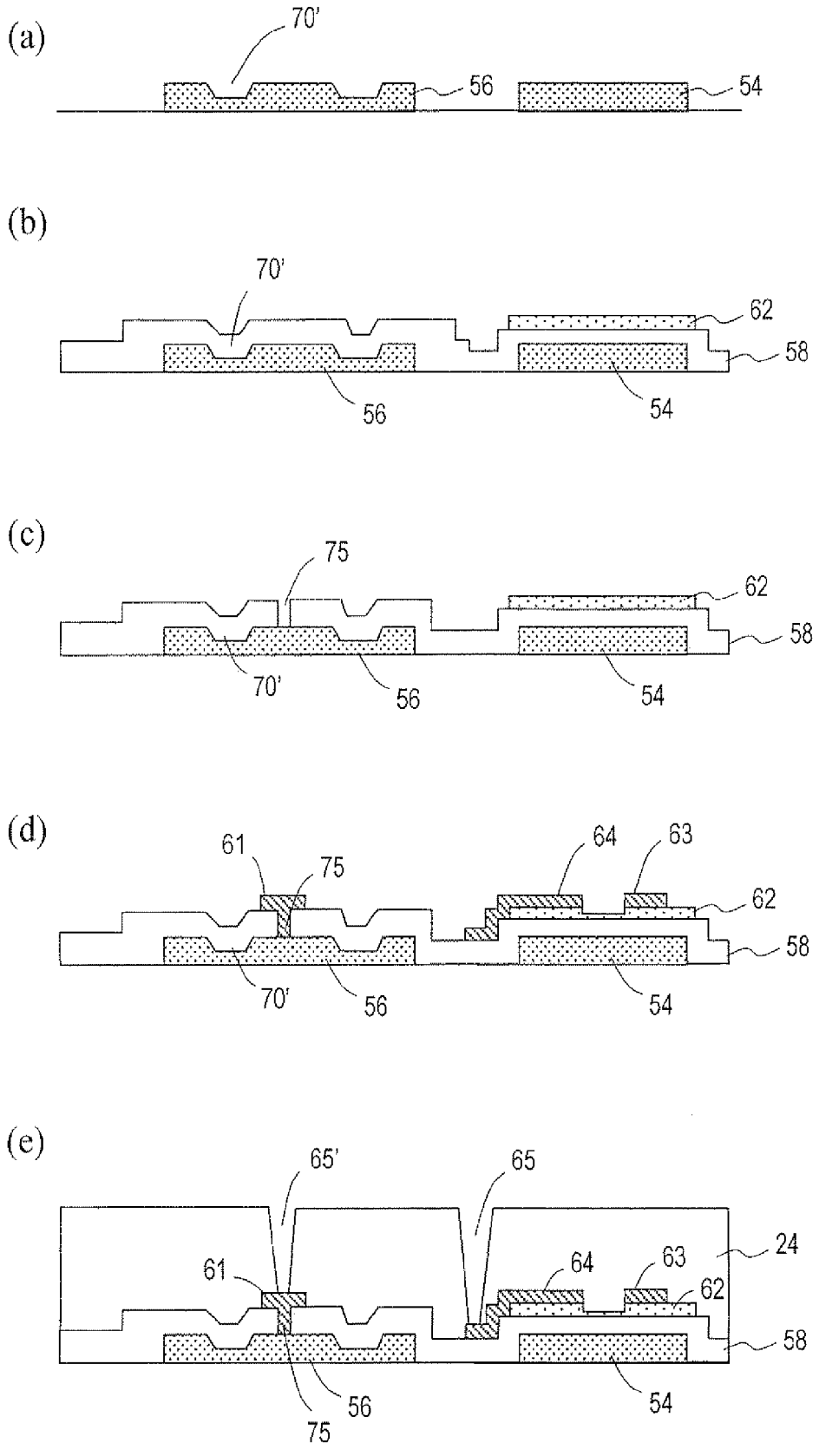
63
62

FIG.30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(e)
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FIG.31

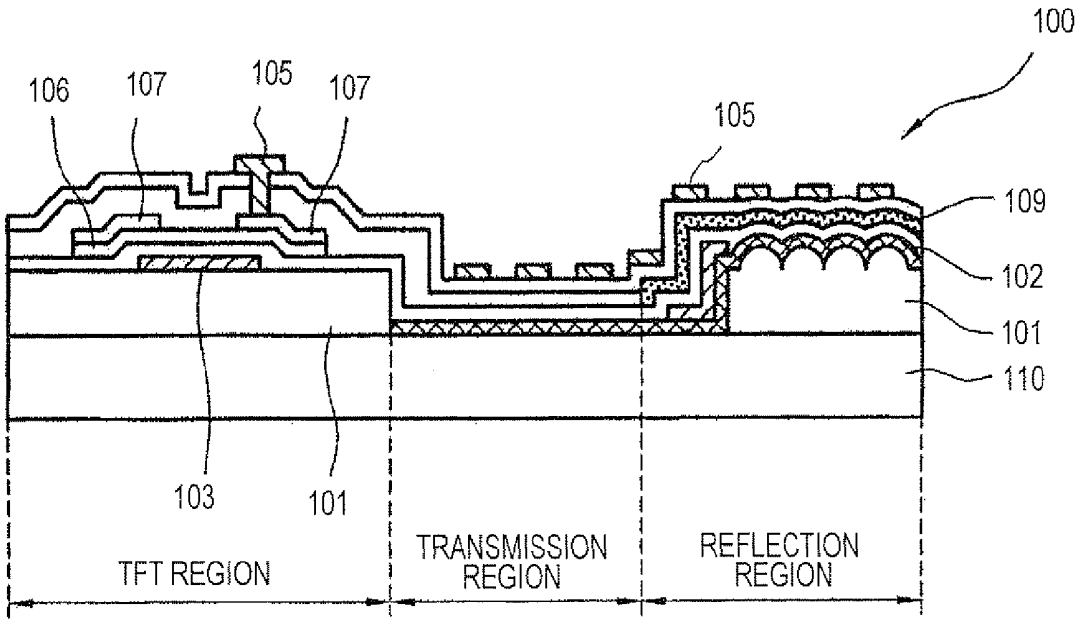
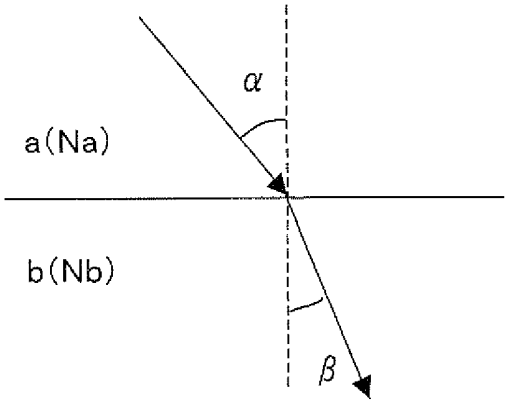
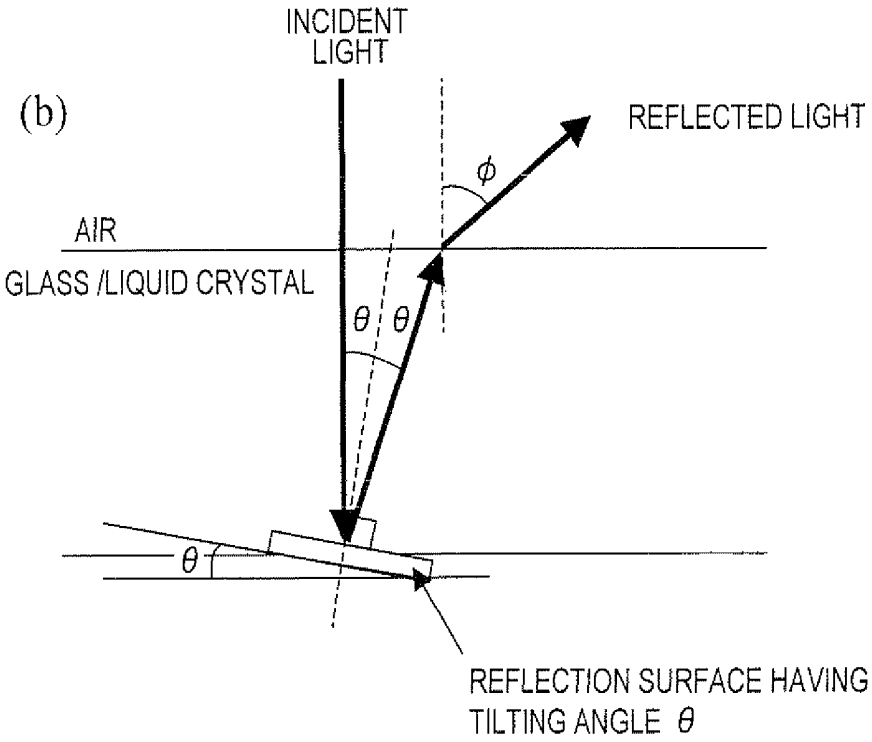

100
106
107
105
107
105
109
102
101
110
103
101
TFT REGION
TRANSMISSION REGION
REFLECTION REGION

FIG. 32

(a)


α
a(Na)
b(Nb)
β

(b)


INCIDENT LIGHT
REFLECTED LIGHT
φ
AIR
GLASS /LIQUID CRYSTAL
θ
θ
θ
REFLECTION SURFACE HAVING TILTING ANGLE θ

LIQUID CRYSTAL DISPLAY AND METHOD OF MANUFACTURING LIQUID CRYSTAL DISPLAY

This application is the U.S. national phase of International Application No. PCT/P2007/075147, filed 27 Dec. 2007, which designated the U.S. and claims priority to Japanese Patent Application No. 2007-105996, filed 13 Apr. 2007, the entire contents of each of which are hereby incorporated by reference.

TECHNICAL FIELD

The present invention relates to a reflection-type or transflective-type liquid crystal display device capable of performing display by utilizing reflected light.

BACKGROUND ART

Liquid crystal display devices (LCDs) include: the TN (Twisted Nematic) mode liquid crystal display device, in which a pixel electrode (picture element electrode) is provided on one of a pair of substrates (an upper substrate and a lower substrate) between which a liquid crystal layer is interposed, and a counter electrode on the other, such that displaying is performed by controlling the orientation of liquid crystal within a plane which is perpendicular to the substrate plane in accordance with an electric field occurring between both electrodes; and the FFS (Fringe-Field Switching) mode liquid crystal display device and the IPS (In-Plane Switching) mode liquid crystal display device, in which a pixel electrode and a counter electrode (lower electrode) are provided on one of a pair of opposing substrates, such that displaying is performed by controlling the orientation of liquid crystal within a plane which is substantially parallel to the substrate plane.

Moreover, liquid crystal display devices include: the transmission-type liquid crystal display device which utilizes backlight from behind the display panel as a light source for displaying; the reflection-type liquid crystal display device which utilizes reflected light of external light; and the transflective-type liquid crystal display device (reflection/transmission-type liquid crystal display device) which utilizes both reflected light of external light and backlight. The reflection-type liquid crystal display device and the transflective-type liquid crystal display device are characterized in that they have smaller power consumptions than that of the transmission-type liquid crystal display device, and their displayed images are easy to see in a bright place. The transflective-type liquid crystal display device is characterized in that its screen is easier to see than that of the reflection-type liquid crystal display device, even in a dark place.

FIG. **31** is a cross-sectional view showing the construction of a lower substrate **100** of a conventional FFS mode transflective-type liquid crystal display device which is described in Patent Document 1.

As shown in FIG. **31**, the lower substrate **100** includes a TFT region, a transmission region, and a reflection region. In the TFT region, a gate electrode **103**, an active layer **106**, a source/drain electrode **107**, and the like are formed on an organic resin film **101**. In the transmission region and the reflection region, a counter electrode **102**, a pixel electrode **105**, and the like are formed. A plurality of slits are formed in the pixel electrode **105**, such that the orientation of liquid crystal (not shown) which is disposed on the lower substrate **100** is controlled in accordance with a voltage or an electric field which is applied between electrode portions interposed between slits and the counter electrode **102**.

Between the counter electrode **102** and the pixel electrode **105** in the reflection region, a reflector **109** for reflecting incident light is provided. In the transmission region, the counter electrode **102** is provided in contact with the substrate **110**; however, in the reflection region, the counter electrode **102** is formed on the organic resin film **101** disposed on the substrate **110**. An emboss pattern is formed by etching on an upper face of the organic resin film **101** in the reflection region, and a plurality of protrusions (or recesses) are formed on the counter electrode **102** so as to conform to the shape of this upper face.

[Patent Document 1] Japanese Laid-Open Patent Publication No. 2006-317905

DISCLOSURE OF INVENTION

Problems to be Solved by the Invention

In the reflection-type liquid crystal display device or the transflective-type liquid crystal display device, in order to perform bright displaying by utilizing reflected light, it is necessary to allow incident light entering at various azimuths to be more uniformly and efficiently reflected by the reflection surface of the reflective layer across the entire display surface. For this purpose, it is better if the reflection surface has moderate ruggednesses rather than being a complete plane.

FIG. **32** is a diagram showing a relationship between the tilt of a reflection surface and reflected light. FIG. **32**(*a*) shows a relationship between an incident angle α and an outgoing angle β when light enters a medium b having a refractive index Nb from a medium a having a refractive index Na. In this case, according to Snell's Law, the following relationship holds true.

$$Na*\sin\alpha = Nb*\sin\beta$$

FIG. **32**(*b*) is a diagram showing a relationship between incident light and reflected light when incident light perpendicularly entering the display surface of a liquid crystal display device is reflected from a reflection surface which is tilted by θ with respect to the display surface (or the substrate). As shown in the figure, the incident light perpendicularly entering the display surface is reflected from the reflection surface which is tilted by angle θ with respect to the display surface, and goes out in a direction of an outgoing angle ϕ.

Results of calculating the outgoing angle ϕ according to Snell's Law with respect to each angle θ of the reflection surface are shown in Table 1.

TABLE 1

θ	ϕ	$90-\phi$
0	0	90
2	6.006121	83.99388
4	12.04967	77.95033
6	18.17181	71.82819
8	24.42212	65.57788
10	30.86588	59.13412
12	37.59709	52.40291
14	44.76554	45.23446
16	52.64382	37.35618
18	61.84543	28.15457
20	74.61857	15.38143
20.5	79.76542	10.23458
20.6	81.12757	8.872432
20.7	82.73315	7.266848
20.8	84.80311	5.19888
20.9	88.85036	1.149637
20.905	89.79914	0.200856

The values in this Table are calculated by assuming that air has a refractive index of 1.0 and the glass substrate and the liquid crystal layer have a refractive index of 1.5. As shown in Table 1, when the angle θ of the reflection surface exceeds 20

degrees, the outgoing angle ϕ becomes very large (i.e., 90-ϕ becomes very small), so that most of the outgoing light does not reach the user. Therefore, even if ruggednesses are provided on the reflection surface of the reflective layer, in order to effectively utilize reflected light, it must be ensured in more portions of the reflection surface that the angle θ is 20 degrees or less.

In FIG. **31**, it is described that, in the reflection region of the lower substrate **100**, ruggednesses are formed on the counter electrode **102** in accordance with the emboss pattern which is provided on the surface of the organic resin film **101**, but no consideration is given as to adjusting the tilting angle of the reflector **109** in order to efficiently utilize reflected light, or ensuring that the tilt of the surface of the reflector **109** is 20 degrees or less.

In order to impart a desired tilting angle to the reflection surface, as described above, it might be conceivable to form an emboss pattern on the surface of the organic resin film **101**, and form desired ruggednesses on the reflection surface so as to conform to that emboss pattern. However, in this case, a step of forming the organic resin film **101**, a step of forming a mask on the organic resin film **101**, a step of performing an etching treatment for the organic resin film **101** via the mask, a step of removing the mask, and the like are needed, thus resulting in a problem in that the amount of the materials and the number of steps are increased.

The present invention has been made in view of the above problems, and an objective thereof is to provide with a good production efficiency a reflection-type liquid crystal display device and a transflective-type liquid crystal display device having a high image quality and being capable of efficiently utilizing reflected light.

Means for Solving the Problems

A liquid crystal display device according to the present invention is a liquid crystal display device comprising: a first substrate and a second substrate between which liquid crystal is interposed; a first electrode and a second electrode formed on the first substrate for applying a voltage for controlling an orientation of the liquid crystal; a transistor having an electrode which is electrically connected to the first electrode; a metal layer formed on the first substrate, the metal layer including a protrusion, a recess, or an aperture; and a reflective layer formed above the metal layer in the first substrate, the reflective layer reflecting incident light toward a display surface, wherein, the metal layer is made of a same material as that of a gate electrode of the transistor; and the reflective layer includes a protrusion, a recess, or a level difference which is formed in accordance with the protrusion, recess, or aperture of the metal layer.

In one embodiment, the second electrode includes a protrusion, a recess, or an aperture; and the reflective layer includes a protrusion, a recess, or a level difference which is formed in accordance with the protrusion, recess, or aperture of the second electrode.

One embodiment comprises, under the reflective layer, a semiconductor layer made of a same material as a semiconductor portion of the transistor, the semiconductor layer including a protrusion, a recess, or an aperture, wherein, the reflective layer includes a protrusion, a recess, or a level difference which is formed in accordance with the protrusion, recess, or aperture of the semiconductor layer.

In one embodiment, the reflective layer is made of a same material as that of a source electrode or a drain electrode of the transistor.

In one embodiment, an insulating layer is formed between the metal layer and the second electrode; and a contact hole electrically connecting the metal layer and the second electrode is formed in the insulating layer.

In one embodiment, the reflective layer includes an aperture.

In one embodiment, the second electrode is formed over the metal layer, and includes a protrusion, a recess, or a level difference which is formed in accordance with the protrusion, recess, or aperture of the metal layer.

In one embodiment, the second electrode is formed under the metal layer, and includes a protrusion, a recess, or an aperture; and the metal layer includes a protrusion, a recess, or a level difference which is formed in accordance with the protrusion, recess, or aperture of the second electrode.

In one embodiment, the first electrode is a pixel electrode, and the second electrode is a counter electrode formed under the first electrode.

In one embodiment, the first electrode is a pixel electrode, and the second electrode is a counter electrode formed on a same plane as the first electrode.

Another liquid crystal display device according to the present invention is a liquid crystal display device comprising: a first substrate and a second substrate between which liquid crystal is interposed; a first electrode and a second electrode formed on the first substrate for applying a voltage for controlling an orientation of the liquid crystal; a transistor having an electrode which is electrically connected to the first electrode; a metal layer formed on the first substrate for reflecting incident light toward a display surface, the metal layer including a protrusion, a recess, or an aperture, wherein, the metal layer is made of a same material as that of a gate electrode of the transistor.

In one embodiment, the first electrode is a pixel electrode; and the second electrode is a counter electrode formed over the metal layer.

In one embodiment, the first electrode is a pixel electrode; the second electrode is a counter electrode being formed under the metal layer and including a protrusion, a recess, or an aperture; and the metal layer includes a protrusion, a recess, or a level difference which is formed in accordance with the protrusion, recess, or aperture of the second electrode.

In one embodiment, the first electrode is a pixel electrode, and the second electrode is a counter electrode formed on a same plane as the first electrode.

Another liquid crystal display device according to the present invention is a liquid crystal display device having: a reflection region including a reflective layer for reflecting incident light toward a display surface; and a TFT region, the liquid crystal display device comprising: a first substrate and a second substrate between which liquid crystal is interposed; a first electrode and a second electrode formed on the first substrate for applying a voltage for controlling an orientation of the liquid crystal; and a transistor being formed in the TFT region and having a gate layer, a semiconductor layer, a source electrode, and a drain electrode, wherein, in the reflection region, a layer is formed which is made of a same material as that of the gate layer, the semiconductor layer, the source electrode, or the drain electrode of the transistor, the layer including a protrusion, a recess, or an aperture.

In one embodiment, the reflective layer is made of a same material as that of the gate layer, the source electrode, or the drain electrode of the transistor, and includes a protrusion, a recess, an aperture, or a level difference.

A production method for a liquid crystal display device according to the present invention is a production method for

a liquid crystal display device including a first substrate and a second substrate between which liquid crystal is interposed and a first electrode and a second electrode for applying a voltage for controlling an orientation of the liquid crystal, the liquid crystal display device having: a reflection region including a reflective layer for reflecting incident light toward a display surface; and a TFT region, the production method comprising the steps of: (a) forming a gate layer in the TFT region; (b) forming a semiconductor layer above the gate layer in the TFT region; and (c) forming a source electrode and a drain electrode above the semiconductor layer in the TFT region, wherein, at step (a), a first metal layer including a protrusion, a recess, or an aperture is formed in the reflection region, from a same material as that of the gate layer of the TFT region, or at step (c), a second metal layer including a protrusion, a recess, or an aperture is formed in the reflection region, from a same material as that of the source electrode or drain electrode in the TFT region.

In one embodiment, the first metal layer or the second metal layer constitutes the reflective layer.

In one embodiment, at step (b), in the reflection region, a semiconductor layer including a protrusion, a recess, or an aperture is formed from a same material as that of the semiconductor layer in the TFT region.

In one embodiment, at step (c), in the second metal layer, a protrusion, a recess, or a level difference which is in accordance with the protrusion, recess, or aperture of the first metal layer is formed.

Effects of the Invention

According to the present invention, in a reflection region of a liquid crystal display device, a layer which is made of the same material as that of a layer composing a transistoror, or a layer which is stacked in the same step as that of a layer composing a transistor is formed, and in accordance with the shape of this layer, a protrusion, a recess, or a level difference is formed in a reflective layer (including any layer having the function as a reflective layer). Therefore, a reflection-type liquid crystal display device and a transflective-type liquid crystal display device having a high image quality and being capable of efficiently utilizing reflected light can be provided with a good production efficiency.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** A diagram schematically showing a cross-sectional shape of a liquid crystal display device of Embodiment 1.

FIG. **2** A plan view schematically showing the construction of a TFT substrate of the liquid crystal display device of Embodiment 1.

FIG. **3** A diagram schematically showing a cross-sectional structure of the TFT substrate of the liquid crystal display device of Embodiment 1.

FIG. **4** A plan view schematically showing the shape of a reflective layer of the TFT substrate of Embodiment 1.

FIG. **5** Plan views showing a production method for the TFT substrate of Embodiment 1.

FIG. **6** Cross-sectional views showing the production method for the TFT substrate of Embodiment 1.

FIG. **7** A plan view schematically showing the construction of a TFT substrate of a liquid crystal display device of Embodiment 2.

FIG. **8** A diagram schematically showing a cross-sectional structure of the TFT substrate of the liquid crystal display device of Embodiment 2.

FIG. **9** Plan views showing a production method for the TFT substrate of Embodiment 2.

FIG. **10** Cross-sectional views showing the product-on method for the TFT substrate of Embodiment 2.

FIG. **11** A plan view schematically showing the construction of a TFT substrate of a liquid crystal display device of Embodiment 3.

FIG. **12** A diagram schematically showing a cross-sectional structure of the TFT substrate of the liquid crystal display device of Embodiment 3.

FIG. **13** Plan views showing a production method for the TFT substrate of Embodiment 3.

FIG. **14** Cross-sectional views showing the production method for the TFT substrate of Embodiment 3.

FIG. **15** A plan view schematically showing the construction of a TFT substrate of a liquid crystal display device of Embodiment 4.

FIG. **16** A diagram schematically showing a cross-sectional structure of the TFT substrate of the liquid crystal display device of Embodiment 4.

FIG. **17** Plan views showing a production method for the TFT substrate of Embodiment 4.

FIG. **18** Cross-sectional views showing the production method for the TFT substrate of Embodiment 4.

FIG. **19** A plan view schematically showing the construction of a TFT substrate of a liquid crystal display device of Embodiment 5.

FIG. **20** A diagram schematically showing a cross-sectional structure of the TFT substrate of the liquid crystal display device of Embodiment 5.

FIG. **21** Plan views showing a production method for the TFT substrate of Embodiment 5.

FIG. **22** Cross-sectional views showing the production method for the TFT substrate of Embodiment 5.

FIG. **23** A plan view schematically showing the construction of a TFT substrate of a liquid crystal display device of Embodiment 6.

FIG. **24** A diagram schematically showing a cross sectional structure of the TFT substrate of the liquid crystal display device of Embodiment 6.

FIG. **25** Plan views showing a production method for the TFT substrate of Embodiment 6.

FIG. **26** Cross-sectional views showing the production method for the TFT substrate of Embodiment 6.

FIG. **27** A plan view schematically showing the construction of a TFT substrate of a liquid crystal display device of Embodiment 7.

FIG. **28** A diagram schematically showing a cross-sectional structure of the TFT substrate of the liquid crystal display device of Embodiment 7.

FIG. **29** Plan views showing a production method for the TFT substrate of Embodiment 7.

FIG. **30** Cross-sectional views showing the production method for the TFT substrate of Embodiment 7.

FIG. **31** A cross-sectional view showing the construction of a lower substrate of a conventional FFS mode transflective-type liquid crystal display device.

FIG. **32** A diagram showing a relationship between a tilt of a reflection surface and reflected light in a liquid crystal display device, where (a) shows a relationship between an incident angle α and an outgoing angle β when light enters a medium b having a refractive index Nb from a medium a having a refractive index Na, and (b) is a diagram showing a relationship between incident light and reflected light as well as the angle of the display surface of the LCD.

DESCRIPTION OF REFERENCE NUMERALS

10 quid crystal display device
12 TFT substrate

14 counter substrate
16 liquid crystal
18 liquid crystal layer
22 transparent substrate
24 interlayer insulating layer
26 pixel electrode
28, **28'** counter electrode
30 reflection section
31 adjustment layer
32 TFT section
34 transparent substrate
36 CF layer
40 display surface
42 reflection region
43 reflected light
44 TFT region
46 transmission region
48 light source
49 transmitted light
50 pixel
52 source line
54 gate line (gate electrode)
56 Cs line (Cs metal layer)
58 insulating layer
60 TFT
61 reflective layer
62 semiconductor layer
63 source electrode
64 drain electrode
65, **65'** contact hole
70, **71** aperture
70' recess
75 contact hole
80, **81** recess
82 protrusion
83 level difference
85 recess
87 aperture
100 lower substrate
101 organic resin film
102 counter electrode
103 gate electrode
105 pixel electrode
106 active layer
107 source/drain electrode
109 reflector
110 substrate

BEST MODE FOR CARRYING OUT THE INVENTION

Embodiment 1

Hereinafter, with reference to the drawings, a first embodiment of the liquid crystal display device according to the present invention will be described.

FIG. **1** is a diagram schematically showing a cross-sectional shape of a liquid crystal display device **10** of the present embodiment, which is a cross-sectional view showing the construction of one pixel among a plurality of pixels which are disposed in a matrix shape in the liquid crystal display device **10**.

The liquid crystal display device **10** of the present embodiment is an FFS mode transflective-type liquid crystal display device adopting an active matrix method. As shown in FIG. **1**, the liquid crystal display device **10** includes a TFT (Thin Film Transistor) substrate (first substrate) **12**, a counter substrate (second substrate) **14** including color filters (CEs) and the like, and a liquid crystal layer **18** containing liquid crystal **16** which is sealed between the TFT substrate **12** and the counter substrate **14**.

The TFT substrate **12** includes a transparent substrate **22**, an interlayer insulating layer (PAS) **24**, a pixel electrode (first electrode) **26**, and a counter electrode (common electrode or lower electrode) **28** disposed below the pixel electrode **26**, and has a reflection section **30** and a TFT section **32**. The pixel electrode **26** is electrically connected to a drain electrode of a TFT which is formed in the TFT section **32**, and as a voltage or electric field is applied to the liquid crystal **16** by the pixel electrode **26** and the counter electrode **28**, the orientation of the liquid crystal **16** is controlled with respect to each pixel, thereby performing display. Although not shown herein, gate lines (scanning lines), source Lines (signal lines), and Cs lines (storage capacitor electrode lines) are also provided on the TFT substrate **12**.

The counter substrate **14** includes a transparent substrate **34**, a CF layer (color filter layer) **36**, and the like. The upper face of the transparent substrate **34** serves as a display surface **40** of the liquid crystal display device. Although the TFT substrate **12** and the counter substrate **14** each include optical film layers such as an alignment film and a polarizer, those are omitted from illustration herein.

In the liquid crystal display device **10**, a region where the reflection section **30** is formed is referred to as a reflection region **42**, whereas a region where the TFT section **32** is formed is referred to as a TFT region **44**. In the reflection region **42**, light entering from the display surface **40** is reflected by the reflective layer in the reflection section **30**, and travels through the liquid crystal layer **18** and the counter substrate **14** so as to go out from the display surface **40** as reflected light **43**. Furthermore, the liquid crystal display device **10** has transmission regions **46** which are formed in regions other than the reflection regions **42** and the TFT regions **44**. In the transmission regions **46**, light which is emitted from a light source **48** in the liquid crystal display device **10** travels through the TFT substrate **12**, the liquid crystal layer **18**, and the counter substrate **14** so as to go out from the display surface **40** as transmitted light **49**.

Note that, by providing an adjustment layer **31** made of transmissive resin or the like on the lower face of the counter substrate **14** over the reflection section **30** as shown in FIG. **1**, it becomes possible to reduce the thickness of the liquid crystal layer **18** in the reflection region **42** to substantially a half of the thickness of the liquid crystal layer **18** in the transmission region **46**. As a result, the optical path lengths of the reflected light **43** and the transmitted light **49** in the liquid crystal layer **18** can be made equal.

Next, the construction of the TFT substrate **12** will be described in more detail with reference to FIG. **2** to FIG. **4**.

FIG. **2** is a plan view schematically showing the construction of the TFT substrate **12** in one pixel among the plurality of pixels which are disposed in a matrix shape in the liquid crystal display device **10**.

As shown in the figure, a pixel **50** includes the reflection region **42**, the TFT region **44**, and the transmission region **46** mentioned above. In the border of the pixel **50**, source lines **52** extend along the column direction (up-down direction in the figure) of the plurality of pixels disposed in a matrix shape, and gate lines (gate metal layers) **54** extend along the row direction (right-left direction in the figure). In the central portion of the pixel **50**, a Cs line (also referred to as a metal layer or a Cs metal layer) **56** extends along the row direction.

A TFT **60** is formed in the TFT section **32** of the TFT region **44**, whereas the counter electrode **28**, the pixel electrode **26**,

and the like are formed in the transmission region **46**. In the reflection region **42**, the Cs line **56**, the counter electrode **28**, the reflective layer **61**, the pixel electrode **26**, and the like, which are the elements of the reflection section **30** as shown in FIG. **1**, are formed.

FIG. **3** is a cross-sectional view schematically showing an A-A' cross section of the TFT substrate **12** shown in FIG. **2**.

As shown in FIG. **3**, in the TFT section **32** of the TFT substrate **12**, an insulating layer **58** is formed on the gate line (gate electrode) **54**, and a semiconductor layer **62** is formed on the insulating layer **58**. Note that a portion of the gate line **54** that is located in the TFT section **32** is referred to as the gate electrode **54** herein. The semiconductor layer **62** is composed of an intrinsic amorphous silicon layer (Si(i)layer) and an n^+ amorphous silicon layer (Si(n^+)layer) doped with phosphorus, for example. A source electrode **63** and a drain electrode **64** are formed on the semiconductor layer **62**, such that, as shown in FIG. **2**, the source electrode **63** is electrically connected to the source line **52**, whereas the drain electrode **64** is electrically connected to the pixel electrode **26** via a contact hole **65** formed in the interlayer insulating layer **24**.

In the reflection region **42**, the Cs metal layer (also referred to as metal layer or Cs line) **56** is formed from the same member as the gate line (gate electrode) **54**. On the Cs metal layer **56**, the insulating layer **58**, the counter electrode **28**, the semiconductor layer **62**, the reflective layer **61**, the interlayer insulating layer **24**, and the pixel electrode **26** are stacked. Note that the Cs metal layer **56** is formed concurrently with and from the same member as the gate electrode **54** of the TFT **60**; the semiconductor layer **62** as the semiconductor layer **62** of the TFT **60**; and the reflective layer **61** as the source electrode **63** and drain electrode **64** of the TFT **60**.

The Cs metal layer **56** has apertures **70**, the counter electrode **28** has apertures **71**, and the semiconductor layer **62** is formed in an island shape from above an aperture **70** to inside the aperture **71**. In the reflective layer **61**, recesses **80**, recesses **81**, and protrusions **82** are formed so as to conform to the shapes of the apertures **70**, the apertures **71**, and the semiconductor layer **62**, respectively. Because the semiconductor layer **62** is formed inside the apertures **71**, level differences **83** are formed in the reflective layer **61**. A contact hole **75** is formed in the insulating layer **58**, such that the counter electrode **28** is electrically connected to the Cs metal layer **56** via the contact hole **75**.

Note that, instead of the apertures **70** or in addition to the apertures **70**, protrusions or recesses (dents) may be formed on or in the Cs metal layer **56**, and the Cs metal layer **56** may be formed in island shapes (it is assumed that each island portion of the Cs metal layer **56** also qualifies as "a protrusion of the Cs metal layer **56**"). Moreover, instead of the apertures **71** or in addition to the apertures **71**, protrusions or recesses (dents) may be formed on or in the counter electrode **28**, and the counter electrode **28** may be formed in island shapes (it is assumed that each island portion of the counter electrode **28** qualifies as a "protrusion of the counter electrode **28**"). Furthermore, the semiconductor layer **62** may be formed as a layer having apertures, protrusions, or recesses. In either case, protrusions, recesses, or level differences are formed on or in the reflective layer **61** in accordance with the protrusions, recesses, and apertures of the Cs metal layer **56**, the counter electrode **28**, and the semiconductor layer **62**.

FIG. **4** is a diagram schematically showing the shape of the reflective layer **61** as viewed from the display surface **40** side.

As shown in the figure, the recesses **80** which are formed in accordance with the apertures **70** in the Cs metal layer **56**, the recesses **81** which are formed in accordance with the apertures **71** in the counter electrode **28**, the protrusions **82** which are formed in accordance with the protrusions of the semiconductor layer **62** (island shapes of the semiconductor layer **62**), and the recesse **85** which is formed in accordance with the contact hole **75** in the insulating layer **58** are formed in the reflective layer **61**. Moreover, a level difference **83** is formed at each portion where a recess **81** and a protrusion **82** overlap.

Although about eight to ten each of the recesses **80**, recesses **81**, and protrusions **82** are illustrated for ease of understanding the construction, the numbers of the recesses **80**, recesses **81**, and protrusions **82** are not limited to the illustrated numbers; more of them may be formed.

According to the present invention, a plurality of recesses, protrusions, or level differences (hereinafter also referred to as recesses or the like) as mentioned above are formed in or on the reflective layer **61**. Since the corner portions and slopes of such recesses or the like include many faces whose angles with respect to the substrate are 20 degrees or less (effective reflection surfaces), reflected light can be effectively utilized. Moreover, since a multitude of faces having respectively different tilting angles are formed in the corner portions of the recesses or the like, reflected light is prevented from heading only in a fixed direction. Therefore, by forming more recesses or the like, it becomes possible to obtain reflected light which expands in a broader range.

Moreover, since the reflective layer **61** is formed so as to conform to the shapes of the plurality of layers which are located below the reflective layer **61**, more recesses or the like can be easily formed in the reflective layer **61**, and shapes can be easily formed in which a plurality of recesses or the like overlap. Therefore, more effective reflection surfaces can be easily formed on the surface of the reflective layer **61**.

Furthermore, according to the present invention, since the reflective layer **61** is formed so as to conform to the shapes of a layer which are formed concurrently with and from the same material of a layer composing the TFT **60**, there is no need to separately add a stacking step, a photolithography step, or the like in order to form the recesses or the like. Therefore, it is possible to provide a liquid crystal display device having a good reflection efficiency with a good production efficiency and at low cost. Moreover, since the shapes, depths, and slope tilting angles of the recesses or the like can be easily adjusted when shaping the respective layers composing the TFT **60**, more effective reflection surfaces can be easily formed on the surface of the reflective layer **61**.

Next, with reference to FIG. **5** and FIG. **6**, a production method for the TFT substrate **12** of Embodiment 1 will be described.

FIG. **5** is plan views showing a production method for the TFT substrate **12**, schematically showing the production steps of the portion illustrated in FIG. **2**. FIG. **6** is cross-sectional views for describing the production method for the TFT substrate **12**, schematically showing the production steps of the portion illustrated in FIG. **3**.

As shown in FIG. **5**(*a*) and FIG. **6**(*a*), first, by a method such as sputtering, a thin metal film of Ta (tantalum) is formed on the transparent substrate having been cleaned. Other than Ta, this thin metal film may be formed by using Al (aluminum), Ti (titanium), Cr (chromium), Mo (molybdenum), W (tungsten), or an alloy thereof, etc., or formed from a multilayer body of a layer of such materials and a nitride film.

Thereafter, a resist film is formed on the thin metal film, and after forming a resist pattern through an exposure-development step, a dry etching is performed to form the gate electrode **54** and the Cs metal layer (first metal layer) **56**. The thickness of the gate electrode **54** is 50 to 1000 nm, for example. Note that wet etching may be employed as the etching. At this time, a plurality of apertures **70** are formed in

the Cs metal layer **56**. In the case of forming the apertures **70**, it is possible to adjust the tilting angle of the side face of each aperture **70** by using halftone exposure. Moreover, recesses (dents) may be formed instead of the apertures **70**. In this step, the gate line **54** and the Cs line **56** shown in FIG. **2** are also formed concurrently from the same metal.

Next, as shown in FIG. **5**(*b*) and FIG. **6**(*b*), by using a P-CVD technique and a gaseous mixture of SiH_4, NH_3, and N_2, the insulating layer **58** composed of SiN (silicon nitride) is formed on the entire substrate surface. The insulating layer **58** may also be composed of SiO_2 (silicon oxide), Ta_2O_5 (tantalum oxide), Al_2O_3 (aluminum oxide), or the like. The thickness of the insulating layer **58** is 100 to 600 nm, for example.

Next, on the insulating layer **58**, an intrinsic amorphous silicon (a-Si) film (Si(i) film) and an n^+ a-Si film ($Si(n^+)$ film) obtained by doping amorphous silicon with phosphorus (P) are formed. The thickness of the a-Si film is 20 to 300 nm, for example, and the thickness of the n^+ a-Si film is 20 to 100 nm, for example. Thereafter, these films are shaped by photolithography technique, whereby the semiconductor layer **62** is formed. Here, above the Cs metal layer **56**, a plurality of annular shapes of semiconductor layer **62** are formed in island shapes, at positions overlapping the apertures **70** in the Cs metal layer **56**.

Next, as shown in FIG. **5**(*c*) and FIG. **6**(*c*), the contact hole **75** reaching the Cs metal layer **56** is formed in the insulating layer **58** by photolithography technique.

Next, as shown in FIG. **5**(*d*) and FIG. **6**(*d*), a transparent electrode film of ITO, IZO, or the like is formed on the insulating layer **58** and the semiconductor layer **62** by sputtering technique or the like, and the resultant transparent electrode film is pattern-shaped by photolithography technique, whereby the counter electrode **28** is formed in the reflection region **42** and the transmission region **46**. At this time, a plurality of apertures **71** are formed in the counter electrode **28**. At least some of the plurality of apertures **71** are formed in positions overlapping the apertures **70** in the Cs metal layer **56** and the semiconductor layer **62**, whereby recesses, protrusions, and level differences are formed on the surface of the counter electrode **28**. A recess in accordance with the contact hole **75** is also formed in the counter electrode **28**.

Next, as shown in FIG. **5**(*e*) and FIG. **6**(*e*), a thin metal film of Al or the like is formed on the entire substrate surface by sputtering technique or the like, and a photolithography technique is employed to form the source electrode **63**, the source line **52**, the drain electrode **64**, and the reflective layer (second metal layer) **61**. At this time, in the reflective layer **61**, the recesses **80**, the recesses **81**, the protrusions **82**, the level differences **83**, and the recess **85** are formed, which conform to the shapes of the apertures **70** in the Cs metal layer **56**, the semiconductor layer **62**, the contact holes **75** in the insulating layer **58**, and the apertures **71** in the counter electrode **28**. Note that, as the thin metal film, the materials listed above as the materials for the gate electrode **54** can be used. The thickness of the reflective layer **61** is 30 to 1000 nm, for example.

Next, as shown in FIG. **5**(*f*) and FIG. **6**(*f*), a photosensitive acrylic resin is applied onto the substrate by spin-coating, whereby the interlayer insulating layer **24** is formed. The thickness of the interlayer insulating layer **24** is 0.3 to 5 μm, for example. Although omitted from illustration herein, the contact hole **65** is formed in the interlayer insulating layer **24** over the drain electrode **64**. Although a thin film of SiN_x, SiO_2, or the like may be formed by P-CVD technique as a protection layer under the interlayer insulating layer **24**, such is omitted from illustration herein. The thickness of the protection film is 50 to 1000 nm, for example.

Finally, the pixel electrode **26** is formed on the interlayer insulating layer **24**, whereby the TFT substrate **12** shown in FIG. **2** and FIG. **3** is completed. The pixel electrode **26** is obtained by stacking a transparent electrode film of ITO, IZO, or the like by sputtering technique or the like, and pattern-shaping the stacked transparent electrode film by photolithography technique. The pixel electrode **26** and the drain electrode **64** are electrically connected via the contact hole **65**.

Preferably, as many recesses **80**, recesses **81**, protrusions **82**, level differences **83**, and recesses **85** as possible are formed. Therefore, it is preferable that as many apertures **70** in the Cs metal layer **56**, island shapes of semiconductor layer **62**, and apertures **71** in the counter electrode **28** as possible are formed on the reflection surface, within the limitations of the masks and photoexposure during the production steps. The preferable sizes of the apertures **70**, the apertures **71**, and the island shapes of semiconductor layer **62**, are defined by diameters of 2 to 10 μm.

Embodiment 2

Next, with reference to FIGS. **7** to **10**, a second embodiment of the liquid crystal display device according to the present invention will be described. The liquid crystal display device of the present embodiment differs from the Embodiment 1 only with respect to a portion of the construction of the TFT substrate **12**, and is identical to Embodiment 1 including the production method, effects, and the like, except for what is described below. Constituent elements which are identical to those of Embodiment 1 will be denoted by like reference numerals, and detailed descriptions thereof will be omitted.

FIG. **7** is a plan view schematically showing the construction of the TFT substrate **12** corresponding to one pixel **50** of the liquid crystal display device **10** shown in FIG. **1**. FIG. **8** is a cross-sectional view schematically showing an A-A' cross section of the TFT substrate **12** shown in FIG. **7**.

As shown in FIG. **7** and FIG. **8**, in the reflection region **42** of the TFT substrate **12** of Embodiment 2, the counter electrode **28** is stacked on the Cs metal layer **56** so as to be in contact with the Cs metal layer **56**. On the counter electrode **28**, the insulating layer **58**, the semiconductor layer **62**, and the reflective layer **61** are stacked in this order. An aperture (gap or slit) **87** is formed in the reflective Layer **61**, such that the reflective layer **61** is divided into two portions because of the aperture **87**.

As shown in FIG. **8**, recesses **80** conforming to the apertures **70** in the Cs metal layer **56**, recesses **81** conforming to the apertures **71** in the counter electrode **28**, and protrusions **82** conforming to the island shapes of semiconductor layer **62** are formed in the reflective layer **61**. The aperture **87** is formed also in the reflective layer **61** itself. This makes it possible to form a multitude of corner portions on the surface of the reflective layer **61**. Note that a recess or protrusion may be formed instead of the aperture **87** in the reflective layer **61**.

Next, with reference to FIG. **9** and FIG. **10**, a production method for the TFT substrate **12** of Embodiment 2 will be described.

FIG. **9** is plan views for describing a production method for the TFT substrate **12**, schematically showing production steps for the portion shown in FIG. **7**. FIG. **10** is cross-sectional views for describing a production method for the TFT substrate **12**, schematically showing production steps for the portion shown in FIG. **8**.

As shown in FIG. **9**(*a*) and FIG. **10**(*a*), first, by a method such as sputtering, a thin metal film of Ta (tantalum) or the like is formed on a transparent substrate having been cleaned. Thereafter, the Cs metal layer **56** having the gate electrode **54** and the apertures **70** is formed by photolithography technique. In this step, the gate line **54** and the Cs line **56** shown in FIG. **7** are also formed concurrently from the same metal.

Next, as shown in FIG. **9**(*b*) and FIG. **10**(*b*), a transparent electrode film of ITO, IZO, or the like is formed on the substrate including the gate electrode **54** and the Cs metal layer **56** by sputtering technique or the like, and the transparent electrode film having been stacked is pattern-shaped by photolithography technique, whereby the counter electrode **28** is formed. At this time, a plurality of apertures **71** are formed in the counter electrode **28**.

Next, as shown in FIG. **9**(*c*) and FIG. **10**(*c*), after the insulating layer **58** is stacked on the entire substrate surface, a semiconductor film is stacked on the insulating layer **58**, and the stacked semiconductor film is shaped by photolithography technique, thereby forming the semiconductor layer **62**.

Next, as shown in FIG. **9**(*d*) and FIG. **10**(*d*), a thin metal film of Al or the like is formed on the entire substrate surface by sputtering technique or the like, and a photolithography technique is employed to form the source electrode **63**, the source line **52**, the drain electrode **64**, and the reflective layer **61**. At this time, in the reflective layer **61**, the recess **80**, the recess **81**, and the protrusion **82** are formed so as to conform to the shapes of the apertures **70** in the Cs metal layer **56**, the apertures **71** in the counter electrode **28**, and the semiconductor layer **62**. The aperture **87** is formed also in the reflective layer **61** itself.

Next, as shown in FIG. **9**(*e*) and FIG. **10**(*e*), a photosensitive acrylic resin is applied onto the substrate by spin-coating, whereby the interlayer insulating layer **24** is formed. The contact hole **65** is formed in the interlayer insulating layer **24** over the drain electrode **64**.

Finally, the pixel electrode **26** is formed on the interlayer insulating layer **24**, whereby the TFT substrate **12** shown in FIG. **7** and FIG. **8** is completed.

Embodiment 3

Next, with reference to FIGS. **11** to **14**, a third embodiment of the liquid crystal display device according to the present invention will be described. The liquid crystal display device of the present embodiment differs from the Embodiment 1 only with respect to a portion of the construction of the TFT substrate **12**, and is identical to Embodiment 1 including the production method, effects, and the like, except for what is described below. Constituent elements which are identical to those of Embodiment 1 will be denoted by like reference numerals, and detailed descriptions thereof will be omitted.

FIG. **11** is a plan view schematically showing the construction of the TFT substrate **12** corresponding to one pixel **50** of the liquid crystal display device **10** shown in FIG. **1**. FIG. **12** is a cross-sectional view schematically showing an A-A' cross section of the TFT substrate **12** shown in FIG. **11**.

As shown in FIG. **11** and FIG. **12**, in the reflection region **42** of the TFT substrate **12** of Embodiment 3, the Cs metal layer **56** is stacked on the counter electrode **28** so as to be in contact with the counter electrode **28**, the insulating layer **58** is stacked on the Cs metal layer **56**, and the semiconductor layer **62** and the reflective layer **61** are stacked on the insulating layer **58**. An aperture (gap or slit) **87** is formed in the reflective layer **61**, such that the reflective layer **61** is divided into two portions because of the aperture **87**.

As shown in FIG. **12**, recesses **80** conforming to the apertures **70** in the Cs metal layer **56**, recess **81** conforming to the apertures **71** in the counter electrode **28**, and protrusions **82** conforming to the island shapes of semiconductor layer **62** are formed in the reflective layer **61**. The aperture **87** is formed also in the reflective layer **61** itself. This makes it possible to form a multitude of corner portions on the surface of the reflective layer **61**. Note that a recess or protrusion may be formed instead of the aperture **87** in the reflective layer **61**.

Next, with reference to FIG. **13** and FIG. **14**, a production method for the TFT substrate **12** of Embodiment 3 will be described.

FIG. **13** is plan views for describing a production method for the TFT substrate **12**, schematically showing production steps for the portion shown in FIG. **11**. FIG. **14** is cross-sectional views for describing a production method for the TFT substrate **12**, schematically showing production steps for the portion shown in FIG. **12**.

As shown in FIG. **13**(*a*) and FIG. **14**(*a*), first, a transparent electrode film of ITO, IZO, or the like is stacked on a transparent substrate by sputtering technique or the like, and the transparent electrode film having been stacked is pattern-shaped by photolithography technique, whereby the counter electrode **28** is formed. At this time, a plurality of apertures **71** are formed in the counter electrode **28**.

Next, as shown in FIG. **13**(*b*) and FIG. **14**(*b*), a thin metal film of Ta (tantalum) or the like is formed by a method such as sputtering, and the Cs metal layer **56** having the gate electrode **54** and the apertures **70** is formed by photolithography technique. At this time, recesses conforming to the apertures **71** in the counter electrode **28** are formed in the Cs metal layer **56**. Note that, In this step, the gate line **54** and the Cs line **56** shown in FIG. **11** are also formed concurrently from the same metal.

Next, as shown in FIG. **13**(*c*) and FIG. **14**(*c*), the insulating layer **58** is stacked on the entire substrate surface, and after a semiconductor film is stacked thereupon, the stacked semiconductor film is shaped by photolithography technique, thereby forming the semiconductor layer **62**.

Next, as shown in FIG. **13**(*d*) and FIG. **14**(*d*), a thin metal film of Al or the like is formed on the entire substrate surface by sputtering technique or the like, and a photolithography technique is employed to form the source electrode **63**, the source line **52**, the drain electrode **64**, and the reflective layer **61**. At this time, in the reflective layer **61**, the recesses **80**, the recesses **81**, and the protrusions **82** are formed so as to conform to the shapes of the apertures **70** in the Cs metal layer **56**, the apertures **71** in the counter electrode **28**, and the semiconductor layer **62**. Moreover, the aperture **87** is formed also in the reflective layer **61** itself.

Next, as shown in FIG. **13**(*e*) and FIG. **14**(*e*), a photosensitive acrylic resin is applied onto the substrate by spin-coating, whereby the interlayer insulating layer **24** is formed. The contact hole **65** is formed in the interlayer insulating layer **24** over the drain electrode **64**.

Finally, the pixel electrode **26** is formed on the interlayer insulating layer **24**, whereby the TFT substrate **12** shown in FIG. **11** and FIG. **12** is completed.

Embodiment 4

Next, with reference to FIGS. **15** to **18**, a fourth embodiment of the liquid crystal display device according to the present invention will be described. The liquid crystal display device of the present embodiment differs from the Embodiment 1 only with respect to a portion of the construction of the TFT substrate **12**, and is identical to Embodiment 1 including

the production method, effects, and the like, except for what is described below. Constituent elements which are identical to those of Embodiment 1 will be denoted by like reference numerals, and detailed descriptions thereof will be omitted.

FIG. **15** is a plan view schematically showing the construction of the TFT substrate **12** corresponding to one pixel **50** of the liquid crystal display device **10** shown in FIG. **1**. FIG. **16** is a cross-sectional view schematically showing an A-A' cross section of the TFT substrate **12** shown in FIG. **15**.

As shown in FIG. **15** and FIG. **16**, in the reflection region **42** of the TFT substrate **12** of Embodiment 4, the counter electrode **28** is stacked on the Cs metal layer **56** so as to be in contact with the Cs metal layer **56**, and the insulating layer **58** is stacked on the counter electrode **28**, but the semiconductor layer **62** and the reflective layer **61** are not stacked here (in the TFT region **44**, similarly to Embodiment 1, the semiconductor layer **62**, the source electrode **63** and the drain electrode **64** are formed).

In the reflection region **42** of Embodiment 4, the Cs metal layer **56** functions as a reflective layer. Therefore, rather than apertures **70**, recesses **701** are formed in the Cs metal layer **56**, whereby a plurality of corner portions and slopes are formed in the surface of the Cs metal layer **56**, thus improving the efficiency of utility of reflected light.

Next, with reference to FIG. **17** and FIG. **18**, a production method for the TFT substrate **12** of the Embodiment 4 will be described.

FIG. **17** is plan views for describing a production method for the TFT substrate **12**, schematically showing production steps for the portion shown in FIG. **15**. FIG. **18** is cross-sectional views for describing a production method for the TFT substrate **12**, schematically showing production steps for the portion shown in FIG. **16**.

As shown in FIG. **17**(*a*) and FIG. **18**(*a*), first, by a method such as sputtering, a thin metal film of Ta (tantalum) or the like is formed, and the Cs metal layer **56** having the gate electrode **54** and the recesses **701** is formed by photolithography technique. In this step, the gate line **54** and the Cs line **56** shown in FIG. **15** are also formed concurrently from the same metal.

Next, as shown in FIG. **17**(*b*) and FIG. **18**(*b*), a transparent electrode film of ITO, IZO, or the like is stacked by sputtering technique or the like, and the transparent electrode film having been stacked is pattern-shaped by photolithography technique, whereby the counter electrode **28** is formed. At this time, recesses conforming to the recesses **70'** are formed in the counter electrode **28**.

Next, as shown in FIG. **17**(*c*) and FIG. **18**(*c*), the insulating layer **58** is stacked on the entire substrate surface, and a semiconductor film is stacked thereupon. Thereafter, the stacked semiconductor film is shaped by photolithography technique to form the semiconductor layer **62**. However, herein, the semiconductor layer **62** is only formed in the TFT region **44**.

Next, with reference to FIG. **17**(*d*) and FIG. **18**(*d*), a thin metal film of Al or the like is stacked on the entire substrate surface by sputtering technique or the like, and a photolithography technique is employed to form the source electrode **63**, the drain electrode **64**, and the source line **52**. At this time, any thin metal film that has been stacked on the reflection region **42** and the transmission region **46** is removed.

Next, as shown in FIG. **17**(*e*) and FIG. **18**(*e*), a photosensitive acrylic resin is applied onto the substrate by spin-coating, whereby the interlayer insulating layer **24** is formed. The contact hole **65** is formed in the interlayer insulating layer **24** over the drain electrode **64**.

Finally, the pixel electrode **26** is formed on the interlayer insulating layer **24**, whereby the TFT substrate **12** shown in FIG. **15** and FIG. **16** is completed.

Embodiment 5

Next, with reference to FIGS. **19** to **22**, a fifth embodiment of the liquid crystal display device according to the present invention will be described. The liquid crystal display device of the present embodiment differs from the Embodiment 1 only with respect to a portion of the construction of the TFT substrate **12**, and is identical to Embodiment 1 including the production method, effects, and the like, except for what is described below. Constituent elements which are identical to those of Embodiment 1 will be denoted by like reference numerals, and detailed descriptions thereof will be omitted.

FIG. **19** is a plan view schematically showing the construction of the TFT substrate **12** corresponding to one pixel **50** of the liquid crystal display device **10** shown in FIG. **1**. FIG. **20** is a cross-sectional view schematically showing an A-A' cross section of the TFT substrate **12** shown in FIG. **19**.

As shown in FIG. **19** and FIG. **20**, in the reflection region **42** of the TFT substrate **12** of Embodiment 5, the Cs metal layer **56** is stacked on the counter electrode **28** so as to in contact with the counter electrode **28**, and the insulating layer **58** is stacked on the Cs metal layer **56**, but the semiconductor layer **62** and the reflective layer **61** are not stacked here (in the TFT region **44**, similarly to Embodiment 1, the semiconductor layer **62**, the source electrode **63**, and the drain electrode **64** are formed).

In the reflection region **42** of Embodiment 5, the Cs metal layer **56** functions as a reflective layer. Therefore, rather than apertures **70**, recesses **70'** are formed in the Cs metal layer **56**. Moreover, apertures **71** are formed in the counter electrode **28**. Therefore, recesses conforming to the apertures **71** are formed in addition to the recesses **701**, so that a plurality of corner portions and slopes are formed on the surface of the Cs metal layer **56**, thus improving the efficiency of utility of reflected light. Note that, herein, the Cs metal layer **56** also has the function of a counter electrode because the Cs metal layer **56** is in electrical contact with the counter electrode **28**.

Next, with reference to FIG. **21** and FIG. **22**, a production method for the TFT substrate **12** of Embodiment 5 will be described.

FIG. **21** is plan views for describing a production method for the TFT substrate **12**, schematically showing production steps for the portion shown in FIG. **19**. FIG. **22** is cross-sectional views for describing a production method for the TFT substrate **12**, schematically showing production steps for the portion shown in FIG. **20**.

As shown in FIG. **21**(*a*) and FIG. **22**(*a*), first, a transparent electrode film of ITO, IZO, or the like is stacked by sputtering technique or the like, and the transparent electrode film having been stacked is pattern-shaped by photolithography technique, whereby the counter electrode **28** is formed. At this time, the apertures **71** are formed in the counter electrode **28**.

Next, as shown in FIG. **21**(*b*) and FIG. **22**(*b*), a thin metal film of Ta (tantalum) or the like is formed by a method such as sputtering, and the gate electrode **54** and the Cs metal layer **56** are formed by photolithography technique. At this time, the recesses **70'** are formed in the Cs metal layer **56**. Moreover, recesses conforming to the apertures **71** in the counter electrode **28** are also formed in the Cs metal layer **56**. Note that, in this step, the gate line **54** and the Cs line **56** shown in FIG. **19** are also formed concurrently from the same metal.

Next, as shown in FIG. **21**(*c*) and FIG. **22**(*c*), the insulating layer **58** is stacked on the entire substrate surface, and a

semiconductor film is stacked thereupon. Thereafter, the stacked semiconductor film is shaped by photolithography technique to form the semiconductor layer **62**. However, herein, the semiconductor layer **62** is only formed in the TFT region **44**.

Next, as shown in FIG. **21**(*d*) and FIG. **22**(*d*), a thin metal film of Al or the like is stacked on the entire substrate surface by sputtering technique or the like, and a photolithography technique is employed to form the source electrode **63**, the drain electrode **64**, and the source line **52**. At this time, any thin metal film that has been stacked on the reflection region **42** and the transmission region **46** is removed.

Next, as shown in FIG. **21**(*e*) and FIG. **22**(*e*), a photosensitive acrylic resin is applied onto the substrate by spin-coating, whereby the interlayer insulating layer **24** is formed. The contact hole **65** is formed in the interlayer insulating layer **24** over the drain electrode **64**.

Finally, the pixel electrode **26** is formed on the interlayer insulating layer **24**, whereby the TFT substrate **12** shown in FIG. **19** and FIG. **20** is completed.

Embodiment 6

Next, with reference to FIGS. **23** to **26**, a sixth embodiment of the liquid crystal display device according to the present invention will be described.

The liquid crystal display device of the present embodiment is an IPS mode transflective-type liquid crystal display device, whose overall construction is basically the same as that shown in FIG. **1**. However, it is different from the liquid crystal display device of Embodiment 1 in terms of the construction of the TFT substrate **12**. Therefore, those constituents of the TFT substrate **12** which are different from of Embodiment 1 will be mainly described below, and the descriptions of any portion that is identical to Embodiment 1 will be omitted, including the production method, effects, and the like. Moreover, constituent elements which are identical to those of Embodiment 1 will be denoted by like reference numerals, and descriptions thereof will be omitted.

FIG. **23** is a plan view schematically showing the construction of the TFT substrate **12** corresponding to one pixel **50** of the liquid crystal display device of the present embodiment. FIG. **24** is a cross-sectional view schematically showing an A-A' cross section of the TFT substrate **12** shown in FIG. **23**.

As shown in FIG. **23** and FIG. **24**, on the upper face of the TFT substrate **12** in Embodiment 6 (the upper face of the interlayer insulating layer **24**), a pixel electrode **26** and a counter electrode **28'** in interdigitated shapes each having a plurality of projections are formed, and orientation control of the liquid crystal is performed in accordance with a voltage which is applied between the projections of the pixel electrode **26** and the projections of the counter electrode **28'**.

The pixel electrode **26** is electrically connected to the drain electrode **64** of the TFT **60** via the contact hole **65** formed in the interlayer insulating layer **24**, whereas the counter electrode **28'** is electrically connected to the reflective layer **61** formed in the reflection region **42** via a contact hole **651** which is formed in the interlayer insulating layer **24**. Under the reflective layer **61**, the Cs metal layer **56** having the apertures **70**, the insulating layer **58**, and the island shapes of semiconductor layer **62** are formed in this order from the bottom. The reflective layer **61** is electrically connected to the Cs metal layer **56** via the contact hole **75** which is formed in the insulating layer **58**.

The reflective layer **61** has recesses **80** which are formed in accordance with the apertures **70** in the Cs metal layer **56**, protrusions **82** which are formed in accordance with the island shapes of semiconductor layer **62**, level differences **83** which are formed in accordance with the apertures **70** and the semiconductor layer **62**, and a recess **85** which is formed in accordance with the contact hole **75** in the interlayer insulating layer **24**. Thus, a plurality of corner portions and slopes are formed on the surface of the reflective layer **61**, thus improving the efficiency of utility of reflected light.

Next, with reference to FIG. **25** and FIG. **26**, a production method for the TFT substrate **12** of Embodiment 6 will be described.

FIG. **25** is plan views for describing a production method for the TFT substrate **12**, schematically showing production steps for the portion shown in FIG. **23**. FIG. **26** is cross-sectional views for describing a production method for the TFT substrate **12**, schematically showing production steps for the portion shown in FIG. **24**.

As shown in FIG. **25**(*a*) and FIG. **26**(*a*), first, by a method such as sputtering, a thin metal film of Ta (tantalum) or the like is formed, and the gate electrode **54** and the Cs metal layer **56** are formed by photolithography technique. At this time, the apertures **70** are formed in the Cs metal layer **56**. Note that, in this step, the gate line **54** and the Cs line **56** shown in FIG. **23** are also formed concurrently from the same metal.

Next, as shown in FIG. **25**(*b*) and FIG. **26**(*b*), the insulating layer **58** is stacked on the entire substrate surface, and a semiconductor film is stacked thereupon. Thereafter, the stacked semiconductor film is shaped by photolithography technique to form the semiconductor layer **62**. Herein, a plurality of island shapes of semiconductor layer **62** are formed in the reflection region **42**, at least some of which overlap the apertures **70**.

Next, as shown in FIG. **25**(*c*) and FIG. **26**(*c*), the contact hole **75** is formed in the insulating layer **58** by photolithography technique or the like.

Next, as shown in FIG. **25**(*d*) and FIG. **26**(*d*), a thin metal film of Al or the like is stacked on the entire substrate surface by sputtering technique or the like, and a photolithography technique is employed to form the source electrode **63**, the drain electrode **64**, the reflective layer **61**, and the source line **52**. At this time, in the reflective layer **61**, the recesses **80** conforming to the shapes of the apertures **70** in the Cs metal layer **56**, the protrusions **82** conforming to the shapes of the island shapes of semiconductor layer **62**, the level differences **83** conforming to the shapes of the apertures **70** and the semiconductor layer **62**, and the recess **85** conforming to the shapes of the contact hole **75** in the interlayer insulating layer **24** are formed.

Next, as shown in FIG. **25**(*e*) and FIG. **26**(*e*), a photosensitive acrylic resin is applied onto the substrate by spin-coating, whereby the interlayer insulating layer **24** is formed. In the interlayer Insulating layer **24**, by photolithography technique or the like, the contact hole **65** is formed over the drain electrode **64**, and the contact hole **65'** is formed over the reflective layer **61**.

Finally, after stacking a transparent electrode film of ITO, IZO, or the like on the interlayer insulating layer **24** by sputtering technique or the like, the transparent electrode film is pattern-shaped by photolithography technique to form the pixel electrode **26** and the counter electrode **281**, whereby the TFT substrate **12** shown in FIG. **23** and FIG. **24** is completed.

Embodiment 7

Next, with reference to FIGS. **27** to **30**, a seventh embodiment of the liquid crystal display device according to the present invention will be described.

Similarly to Embodiment 6, the liquid crystal display device of the present embodiment is an IPS mode transflective-type liquid crystal display device, and its construction is basically the same as that shown in FIG. **1**, except for the TFT substrate **12**. Therefore, the construction of the TFT substrate **12** will be mainly described below, and the descriptions of any portion that is identical to Embodiment 1 will be omitted, including the production method, effects, and the like. Moreover, constituent elements which are identical to those of Embodiment 1 will be denoted by like reference numerals, and descriptions thereof will be omitted.

FIG. **27** is a plan view schematically showing the construction of the TFT substrate **12** corresponding to one pixel **50** of the liquid crystal display device of the present embodiment. FIG. **28** is a cross-sectional view schematically showing an A-A' cross section of the TFT substrate **12** shown in FIG. **27**.

As shown in FIG. **27** and FIG. **28**, on the upper face of the TFT substrate **12** in Embodiment 7 (the upper face of the interlayer insulating layer **24**), a pixel electrode **26** and a counter electrode **28'** in interdigitated shapes each having a plurality of projections are formed, and orientation control of the liquid crystal is performed in accordance with a voltage which is applied between the projections of the pixel electrode **26** and the projections of the counter electrode **281**.

The pixel electrode **26** is electrically connected to the drain electrode **64** of the TFT **60** via a contact hole **65** which is formed in the interlayer insulating layer **24**, whereas the counter electrode **28'** is electrically connected to the reflective layer **61** formed in the reflection region **42** via a contact hole **65'** which is formed in the interlayer insulating layer **24**. However, since the reflective layer **61** is formed only under a portion of the counter electrode **28** in Embodiment 7, a reflective layer's function of reflecting incident light toward the display surface pertains to the Cs metal layer **56** herein.

In the portion of the reflection region **42** that is under the reflective layer **61**, the Cs metal layer **56** and the insulating layer **58** are formed in this order from the bottom. The semiconductor layer **62** is not formed in the reflection region **42**. The reflective layer **61** is electrically connected to the Cs metal layer **56** via a contact hole **75** which is formed in the insulating layer **58**. Therefore, the counter electrode **28'** is electrically connected to the Cs metal layer **56** via the contact hole **651**, the reflective layer **61**, and the contact hole **75**.

Since the Cs metal layer **56** has a function as a reflective layer, recesses **70'** are formed in the Cs metal layer **56**, rather than apertures. Since the recesses **70'** are formed, a plurality of corner portion and slopes are formed on the surface of the reflective layer **61**, thus improving the efficiency of utility of reflected light.

Next, with reference to FIG. **29** and FIG. **30**, a production method for the TFT substrate **12** of the Embodiment 7 will be described.

FIG. **29** is plan views for describing a production method for the TFT substrate **12**, schematically showing production steps for the portion shown in FIG. **27**. FIG. **30** is cross-sectional views for describing a production method for the TFT substrate **12**, schematically showing production steps for the portion shown in FIG. **28**.

As shown in FIG. **29**(*a*) and FIG. **30**(*a*), first, by a method such as sputtering, a thin metal film of Ta (tantalum) or the like is formed, and the gate electrode **54** and the Cs metal layer **56** are formed by photolithography technique. At this time, the recesses **701** are formed in the Cs metal layer **56**. Note that, in this step, the gate line **54** and the Cs line **56** shown in FIG. **27** are also formed concurrently from the same metal.

Next, as shown in FIG. **29**(*b*) and FIG. **30**(*b*), the insulating layer **58** is stacked on the entire substrate surface, and a semiconductor film is stacked thereupon. Thereafter, the stacked semiconductor film is shaped by photolithography technique to form the semiconductor layer **62**. Herein, any semiconductor film that has been stacked in the reflection region **42** is removed, and no semiconductor layer **62** is formed in the reflection region **42**.

Next, as shown in FIG. **29**(*c*) and FIG. **30**(*c*), the contact hole **75** is formed in the insulating layer **58** by photolithography technique or the like.

Next, as shown in FIG. **29**(*d*) and FIG. **30**(*d*), a thin metal film of Al or the like is stacked on the entire substrate surface by sputtering technique or the like, and a photolithography technique is employed to form the source electrode **63**, the drain electrode **64**, the reflective layer **61**, and the source line **52**. At this time, in the reflection region **42**, the reflective layer **61** is formed only over the contact hole **75** so as to cover the contact hole **75**.

Next, as shown in FIG. **29**(*e*) and FIG. **30**(*e*), a photosensitive acrylic resin is applied onto the substrate by spin-coating, whereby the interlayer insulating layer **24** is formed. In the interlayer insulating layer **24**, by photolithography technique or the like, the contact hole **65** is formed over the drain electrode **64**, and the contact hole **651** is formed over the reflective layer **61**.

Finally, after stacking a transparent electrode film of ITO, IZO, or the like on the interlayer insulating layer **24** by sputtering technique or the like, the transparent electrode film is pattern-shaped by photolithography technique to form the pixel electrode **26** and the counter electrode **28'**, whereby the TFT substrate **12** shown in FIG. **27** and the FIG. **28** is completed.

Although the above Embodiments illustrate that the plurality of apertures and recesses that are formed in the Cs metal layer **56** in the reflection region **42** are all circular as viewed perpendicularly to the substrate, some or all of these apertures and recesses may be formed in other shapes, e.g., ellipses or rectangles. Although it has been illustrated that a plurality of circular-island shapes of semiconductor layer **62** are formed in the reflection region **42**, some or all of these may be formed in other shapes, e.g., ellipses or rectangles.

When forming the contact hole **75** in the insulating layer **58** under the reflective layer **61**, recesses may be formed in the insulating layer **58** concurrently with the formation of the contact hole **75**. As a result, more recesses and level differences can be formed in the reflective layer **61**, thus improving the efficiency of utility of reflected light.

In the case where the Cs metal layer **56**, the insulating layer **58**, and the semiconductor layer **62** are located under the reflective layer **61** in the reflection region **42**, apertures, recesses, protrusion, and the like may be formed by employing halftone exposure during the shaping of these layers. By employing halftone exposure, it becomes possible to easily adjust the tilting angles of the side faces of the apertures and the like to desired angles, and it becomes easy to provide more level differences inside the apertures and the like. As a result, slopes having more corner portions and desired tilting angles are formed in the reflective layer **61**, thus improving the efficiency of utility of reflected light.

Moreover, when viewed from the substrate normal direction, the apertures and the like to be formed in the respective layers may be disposed in a manner of overlapping concentric circles, but more preferably, they may be disposed so that the edges of the apertures and the like overlap. In the case where the edges of the apertures and the like overlap, more complicated rugged structures are formed on the surface of the

reflective layer **61**, thus allowing the reflected light to be uniformly reflected in a broader range.

It is preferable that as many recesses, protrusions, and level differences as possible are formed in the reflective layer **61**. For this purpose, sizes and shapes of the recesses or the like are not limited to those described above, but they may be formed into various shapes such as polygons other than rectangles, recesses or the like with sawtoothed edges, or combines thereof.

As has been illustrated by the above Embodiments, a liquid crystal display device according to the present invention includes a large number of level differences and corner portions on the surface of a reflective layer, as well as a multitude of slopes with a tilting angle of 20 degrees or less, and therefore acquires reflection regions with broad effective reflection surfaces and excellent scattering characteristics. Moreover, since the level differences and corner portions on the reflection surface are formed based on layers which are shaped concurrently with the shaping of a gate layer of TFTs, a semiconductor layer, a source electrode, or a drain electrode, a reflection region having excellent reflection characteristics can be easily obtained without increasing the production steps. Therefore, a liquid crystal display device that is capable of uniform and high-brightness displaying can be inexpensively provided with a good production efficiency.

Since the liquid crystal display device according to the present invention is formed by the above-described production method, it can be produced with the substantially the same material and steps as those of a transmission-type liquid crystal display device. Therefore, a liquid crystal display device with an excellent reflection efficiency can be provided at low cost.

The liquid crystal display device according to the present invention encompasses display apparatuses, television sets, mobile phones, etc., in which a liquid crystal panel is utilized. Although the present embodiments employ transflective-type liquid crystal display devices as examples, a reflection-type liquid crystal display device or the like having a configuration similar to the aforementioned reflection section is also encompassed as an embodiment of the present invention.

INDUSTRIAL APPLICABILITY

According to the present invention, a transflective-type liquid crystal display device and a reflection-type liquid crystal display device of the FFS mode and the IPS mode having a high image quality can be provided at low cost. Liquid crystal display devices according to the present invention are suitably used for various liquid crystal display devices, and are suitably used for transflective-type liquid crystal display devices and reflection-type liquid crystal display devices which perform display by utilizing reflected light, e.g., mobile phones, onboard display devices such as car navigation systems, display devices of ATMs and vending machines, etc., portable display devices, laptop PCs, and the like.

The invention claimed is:

1. A liquid crystal display device comprising:
- a first substrate and a second substrate between which liquid crystal is interposed;
- a first electrode and a second electrode formed on the first substrate for applying a voltage for controlling an orientation of the liquid crystal;
- a transistor having an electrode which is electrically connected to the first electrode;
- a metal layer formed on the first substrate, the metal layer including a protrusion, a recess, or an aperture;
- a reflective layer formed above the metal layer in the first substrate, the reflective layer reflecting incident light toward a display surface, wherein,
- the metal layer is made of a same material as that of a gate electrode of the transistor; and
- the reflective layer includes a protrusion, a recess, or a level difference which is formed in accordance with the protrusion, recess, or aperture of the metal layer; and
- under the reflective layer, a semiconductor layer made of a same material as a semiconductor portion of the transistor, the semiconductor layer including a protrusion, a recess, or an aperture, wherein, the reflective layer includes a protrusion, a recess, or a level difference which is formed in accordance with the protrusion, recess, or aperture of the semiconductor layer.

2. The liquid crystal display device of claim **1**, wherein,
- the second electrode includes a protrusion, a recess, or an aperture; and
- the reflective layer includes a protrusion, a recess, or a level difference which is formed in accordance with the protrusion, recess, or aperture of the second electrode.

3. The liquid crystal display device of claim **1**, wherein the reflective layer is made of a same material as that of a source electrode or a drain electrode of the transistor.

4. The liquid crystal display device of claim **1**, wherein,
- an insulating layer is formed between the metal layer and the second electrode; and
- a contact hole electrically connecting the metal layer and the second electrode is formed in the insulating layer.

5. A liquid crystal display device comprising:
- a first substrate and a second substrate between which liquid crystal is interposed;
- a first electrode and a second electrode formed on the first substrate for applying a voltage for controlling an orientation of the liquid crystal;
- a transistor having an electrode which is electrically connected to the first electrode;
- a metal layer formed on the first substrate, the metal layer including a protrusion, a recess, or an aperture;
- a reflective layer formed above the metal layer in the first substrate, the reflective layer reflecting incident light toward a display surface, wherein,
- the metal layer is made of a same material as that of a gate electrode of the transistor; and
- the reflective layer includes a protrusion, a recess, or a level difference which is formed in accordance with the protrusion, recess, or aperture of the metal layer; and
- wherein the reflective layer includes an aperture.

6. The liquid crystal display device of claim **1**, wherein,
- the second electrode is formed under the metal layer, and includes a protrusion, a recess, or an aperture; and
- the metal layer includes a protrusion, a recess, or a level difference which is formed in accordance with the protrusion, recess, or aperture of the second electrode.

7. The liquid crystal display device of claim **1**, wherein the first electrode is a pixel electrode, and the second electrode is a counter electrode formed under the first electrode.

8. The liquid crystal display device of claim **1**, wherein the first electrode is a pixel electrode, and the second electrode is a counter electrode formed on a same plane as the first electrode.

9. A production method for a liquid crystal display device including a first substrate and a second substrate between which liquid crystal is interposed and a first electrode and a second electrode for applying a voltage for controlling an orientation of the liquid crystal, the liquid crystal display device having: a reflection region including a reflective layer

for reflecting incident light toward a display surface; and a TFT region, the production method comprising the steps of:

(a) forming a gate layer in the TFT region;

(b) forming a semiconductor layer above the gate layer in the TFT region;

wherein, at step (b), in the reflection region a semiconductor layer including a protrusion, a recess, and/or an aperture is formed from a same material as that of the semiconductor layer in the TFT region; and

(c) forming a source electrode and a drain electrode above the semiconductor layer in the TFT region, wherein,

at step (a), a first metal layer including a protrusion, a recess, or an aperture is formed in the reflection region, from a same material as that of the gate layer of the TFT region, or

at step (c), a second metal layer including a protrusion, a recess, or an aperture is formed in the reflection region, from a same material as that of the source electrode or drain electrode in the TFT region.

10. The production method for a liquid crystal display device of claim **9**, wherein the first metal layer or the second metal layer constitutes the reflective layer.

11. The production method of claim **9**, wherein, at step (c), in the second metal layer, a protrusion, a recess, or a level difference which is in accordance with the protrusion, recess, or aperture of the first metal layer is formed.

* * * * *

专利名称(译)	液晶显示器和制造液晶显示器的方法		
公开(公告)号	US8659726	公开(公告)日	2014-02-25
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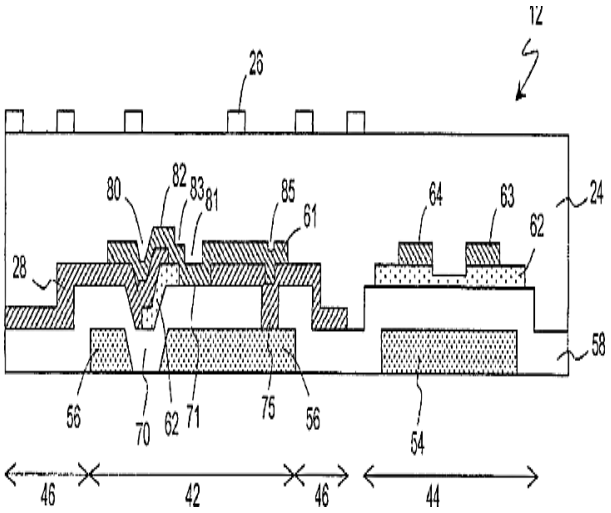
摘要(译)

具有高图像质量的半透射型和反射型液晶显示装置具有良好的生产效率。 根据本发明的液晶显示装置是一种液晶显示装置，其包括：第一基板和第二基板，在它们之间插入液晶;第一电极和第二电极，形成在第一基板上，用于施加用于控制液晶取向的电压;晶

体管，具有与第一电极电连接的电极;金属层形成在第一基板上并包括突起，凹槽或孔;以及在第一基板上的金属层上方形成的反射层，用于将入射光朝向显示表面反射。金属层由与晶体管的栅电极相同的材料制成。反射层包括突起，凹槽或高度差，其根据金属层的突起，凹槽或孔形成。