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US 6,628,355 B1

(12) **United States Patent**
Takahara

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(45) **Date of Patent:** Sep. 30, 2003

(54) **LIQUID CRYSTAL DISPLAY PANEL INCLUDING A LIGHT SHIELDING FILM TO CONTROL INCIDENT LIGHT**

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(73) Assignee: **Matsushita Electric Industrial Co., Ltd.**, Osaka (JP)

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(21) Appl. No.: **09/697,991**

(22) Filed: **Oct. 27, 2000**

Related U.S. Application Data

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(30) **Foreign Application Priority Data**

Dec. 17, 1996	(JP)	 8-336777
Apr. 1, 1997	(JP)	 9-082595
Jul. 1, 1997	(JP)	 9-175744

(51) Int. Cl.^{7} **G02F 1/1335**; G02F 1/1333; G02F 1/136

(52) U.S. Cl. **349/106**; 349/86; 349/42; 349/113; 349/138

(58) Field of Search 349/86, 96, 106, 349/107, 108, 109, 110, 111, 113, 138

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Primary Examiner—Tarifur R. Chowdhury
(74) *Attorney, Agent, or Firm*—RatnerPrestia

(57) **ABSTRACT**

An array substrate 12 is formed with pixel electrodes 14 in the form of a matrix. The pixel electrode 14 is connected to a thin film transistor 155. The thin film transistor 155 is formed with a light shielding film 152 consisting of resin for preventing an entry of light into the thin film transistor 155. A polymer dispersion liquid crystal layer 21 is interposed between a counter electrode 25 and the pixel electrode 14. A substrate 11 is formed with a color filter 151 having red (R), green (G), and blue (B). The color filter 151 is formed from dielectric multilayer film or organic material. The counter electrode 25 is formed above the color filter 155, and the counter electrode 25 and the liquid crystal layer 21 are bonded together by an adhesive layer 371.

2 Claims, 220 Drawing Sheets
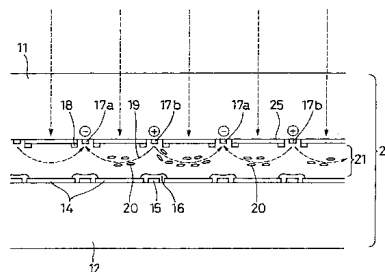
11 : COUNTER SUBSTRATE
12 : ARRAY SUBSTRATE
14 : PIXEL ELECTRODE
15 : SOURCE SIGNAL LINE
16 : LOW DIELECTRIC FILM
17 : TRANSVERSE ELECTRIC FIELD WIRE
18 : LIGHT SHIELDING FILM
19 : ELECTRIC FORCE LINE
20 : LIQUID CRYSTAL MOLECULE
21 : LIQUID CRYSTAL LAYER
22 : LIQUID CRYSTAL DISPLAY
25 : COUNTER ELECTRODE

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JP	09-080401			3/1997
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Fig. 1
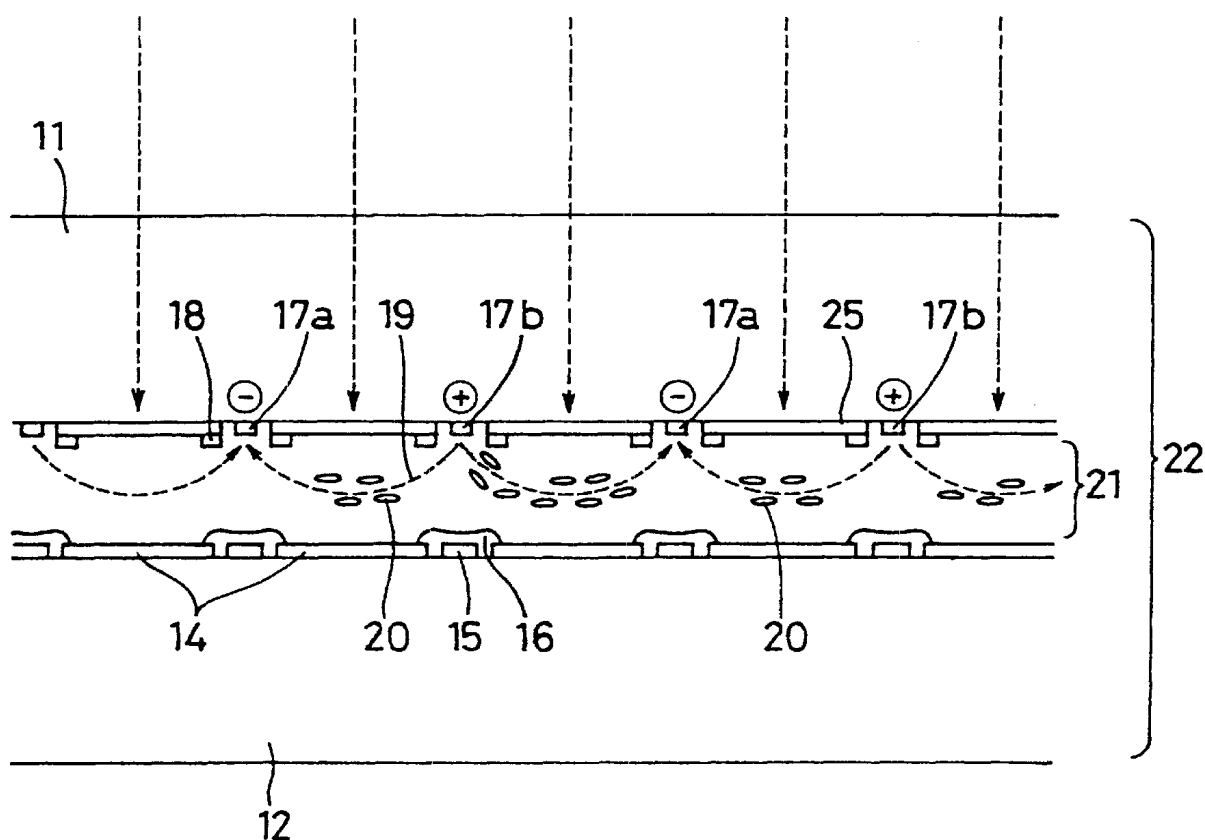
11 : COUNTER SUBSTRATE

12 : ARRAY SUBSTRATE

14 : PIXEL ELECTRODE

15 : SOURCE SIGNAL LINE

16 : LOW DIELECTRIC FILM

17 : TRANSVERSE ELECTRIC FIELD WIRE

18 : LIGHT SHIELDING FILM

19 : ELECTRIC FORCE LINE

20 : LIQUID CRYSTAL MOLECULE

21 : LIQUID CRYSTAL LAYER

22 : LIQUID CRYSTAL DISPLAY

25 : COUNTER ELECTRODE

Fig. 2 (a)

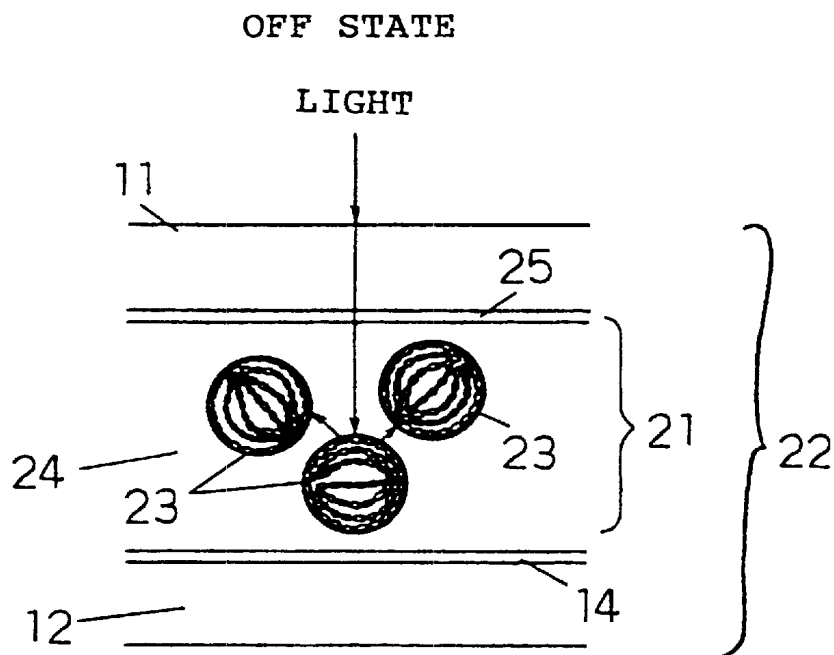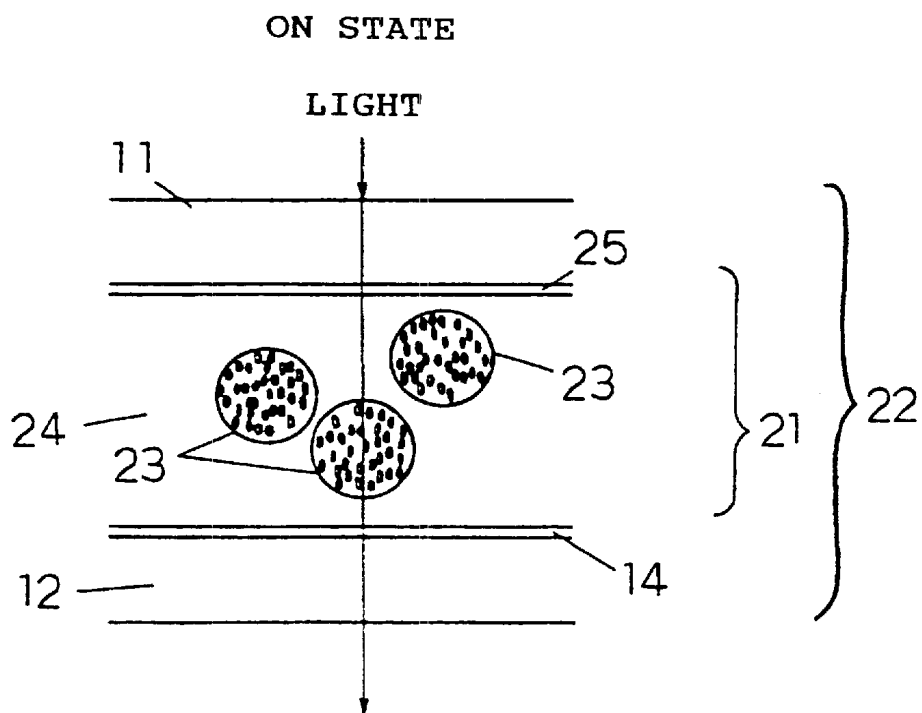23 : WATERDROP-LIKE LIQUID CRYSTAL

24 : POLYMER

OFF STATE

LIGHT
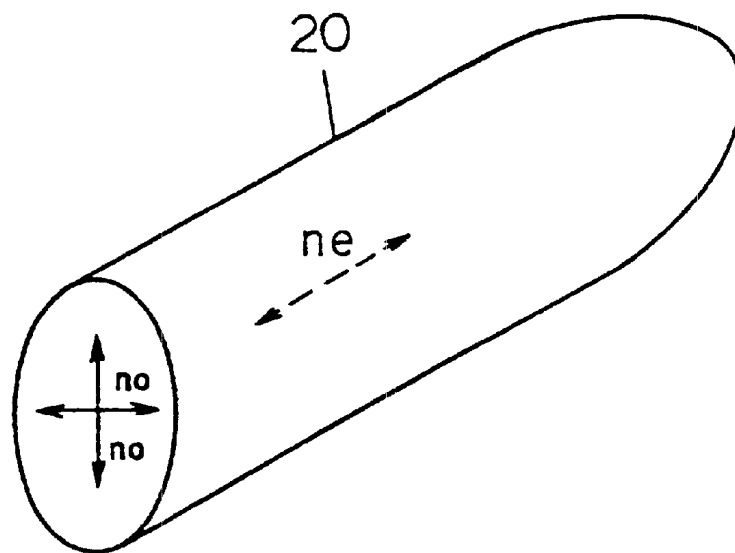
Fig. 2 (b)

ON STATE

LIGHT
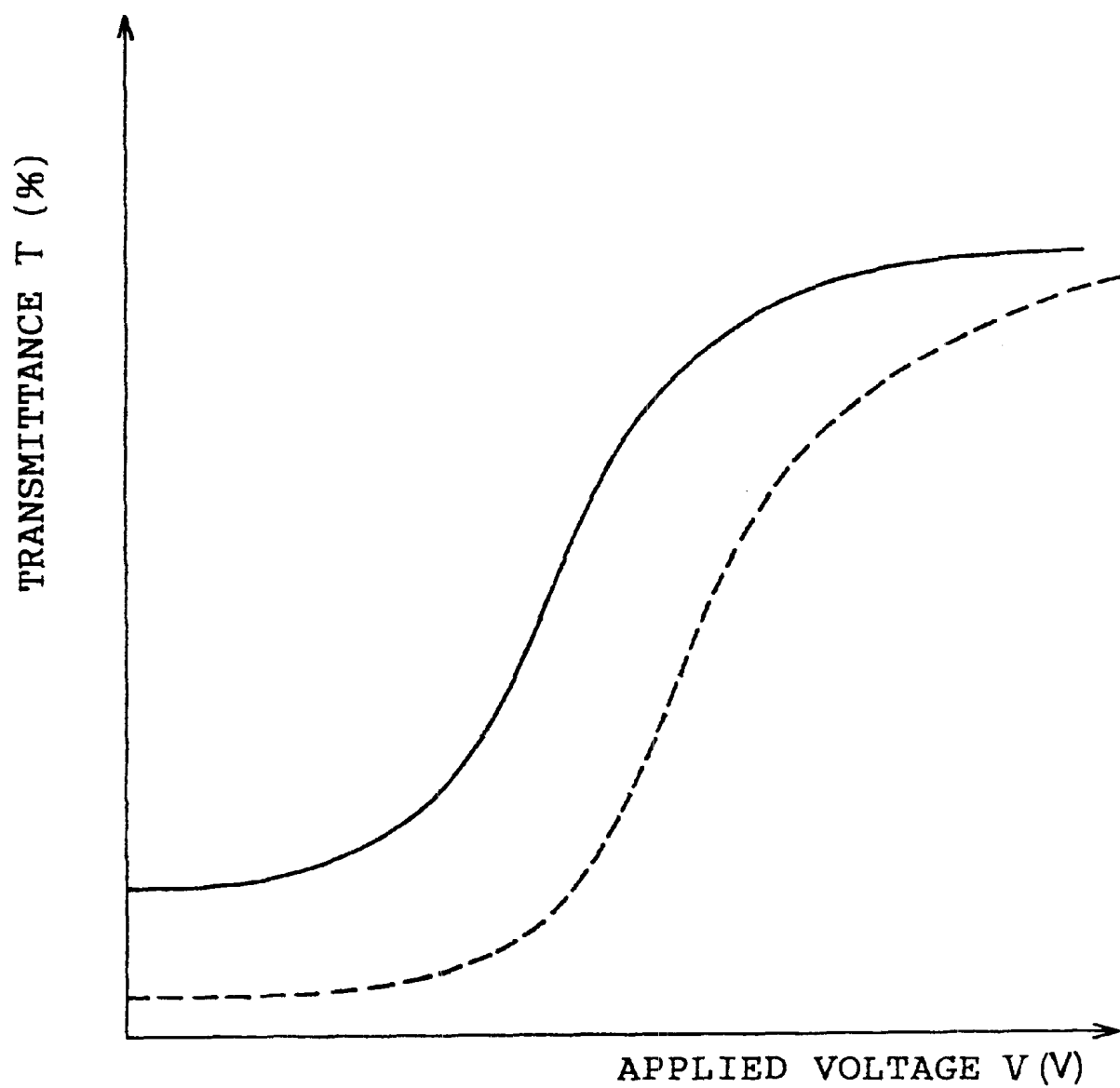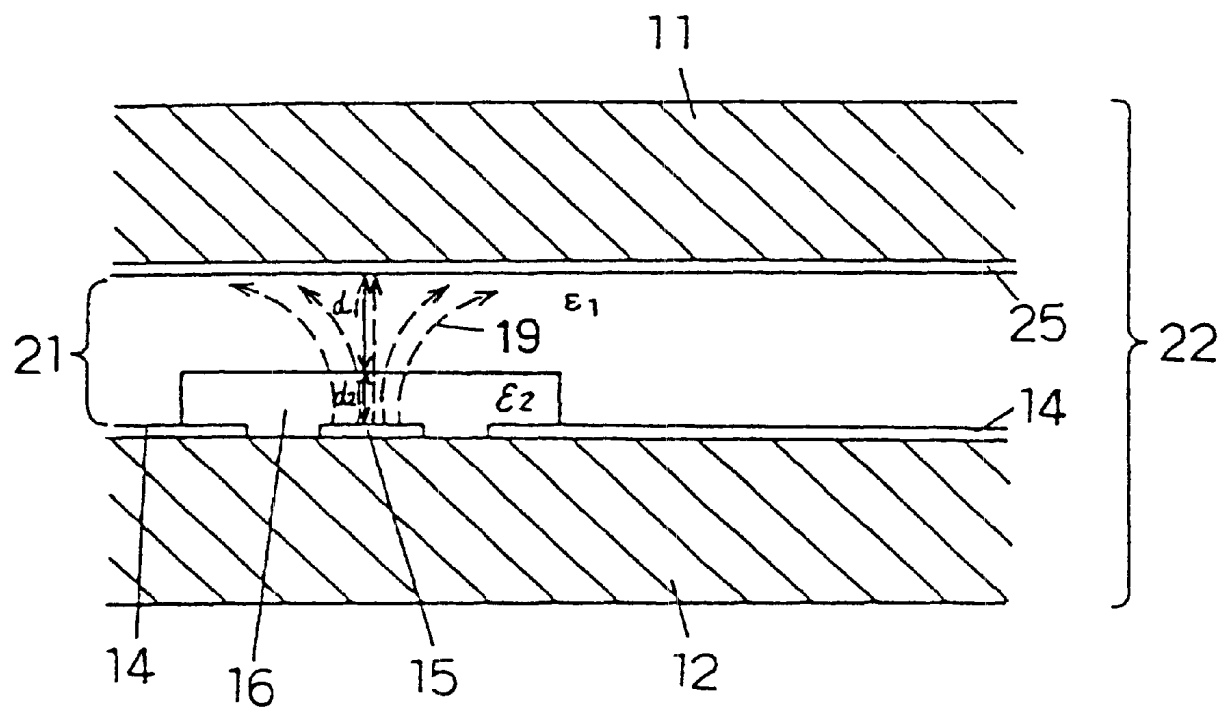
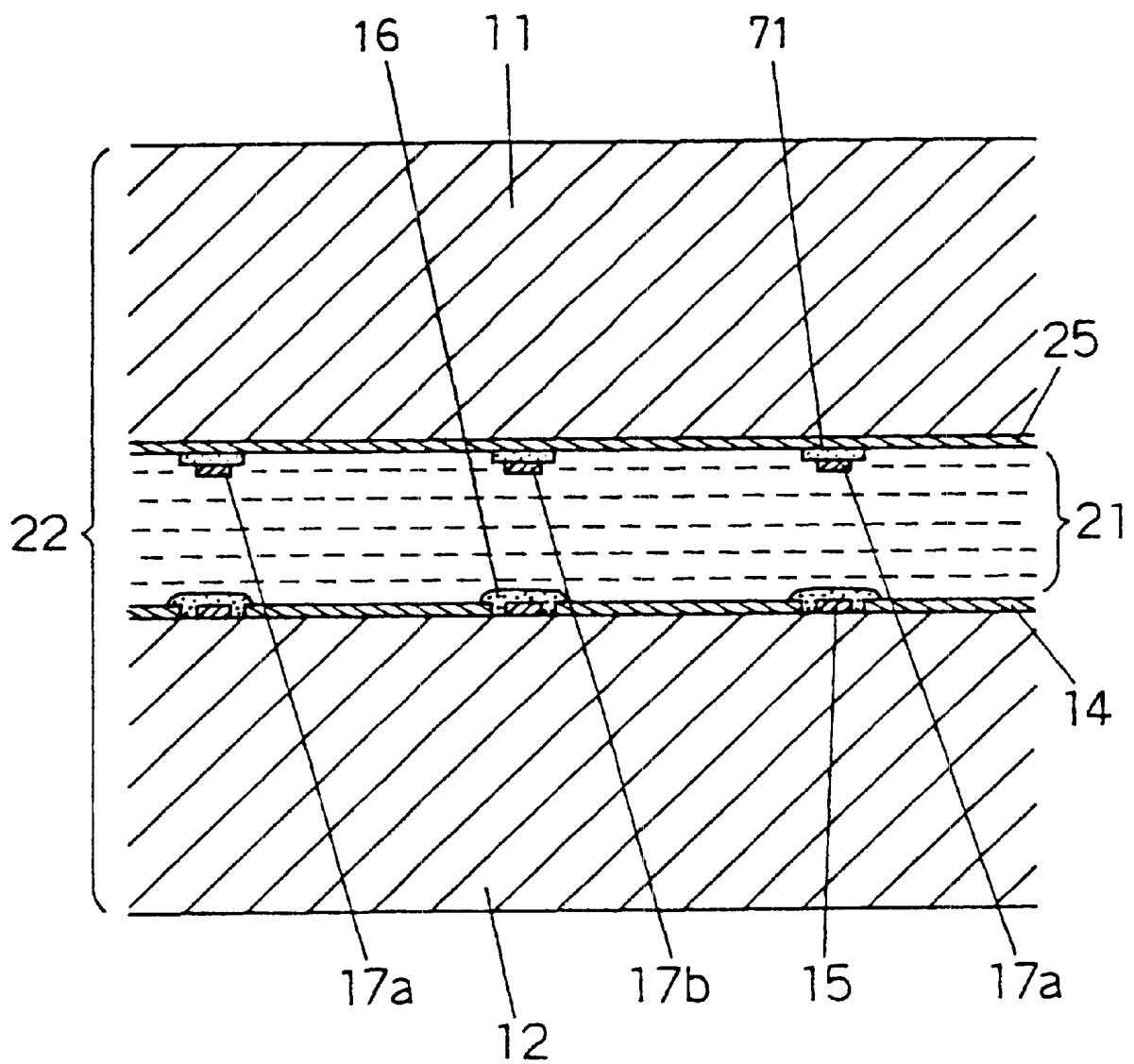Fig. 3 (a)

Fig. 3 (b)
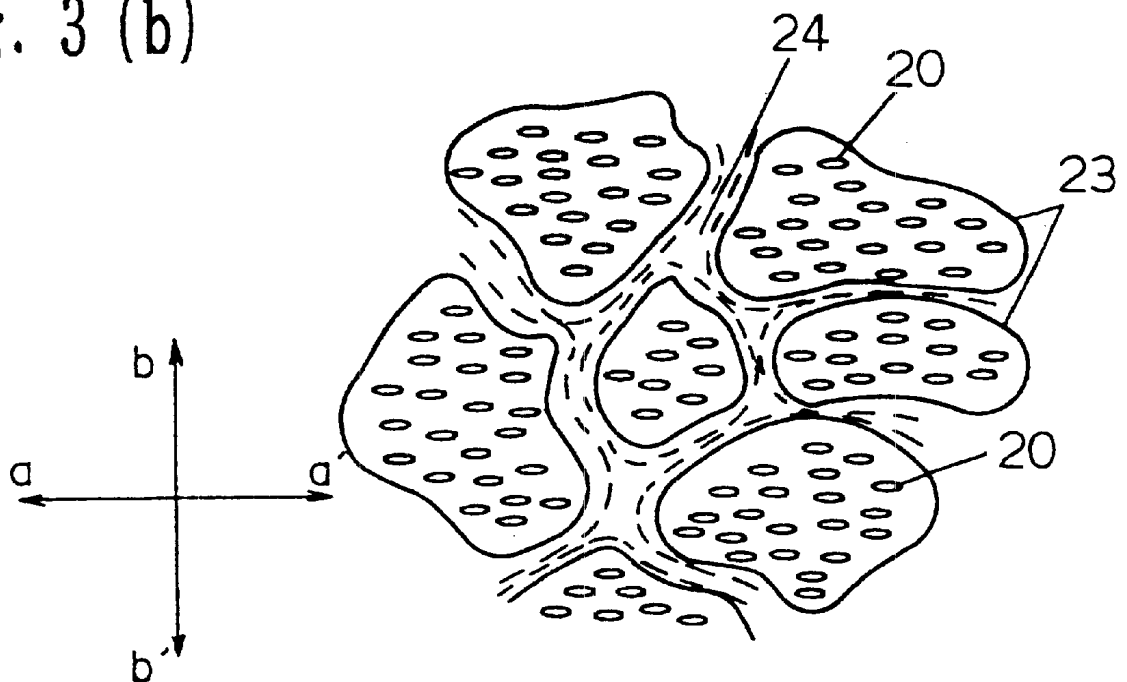
Fig. 4
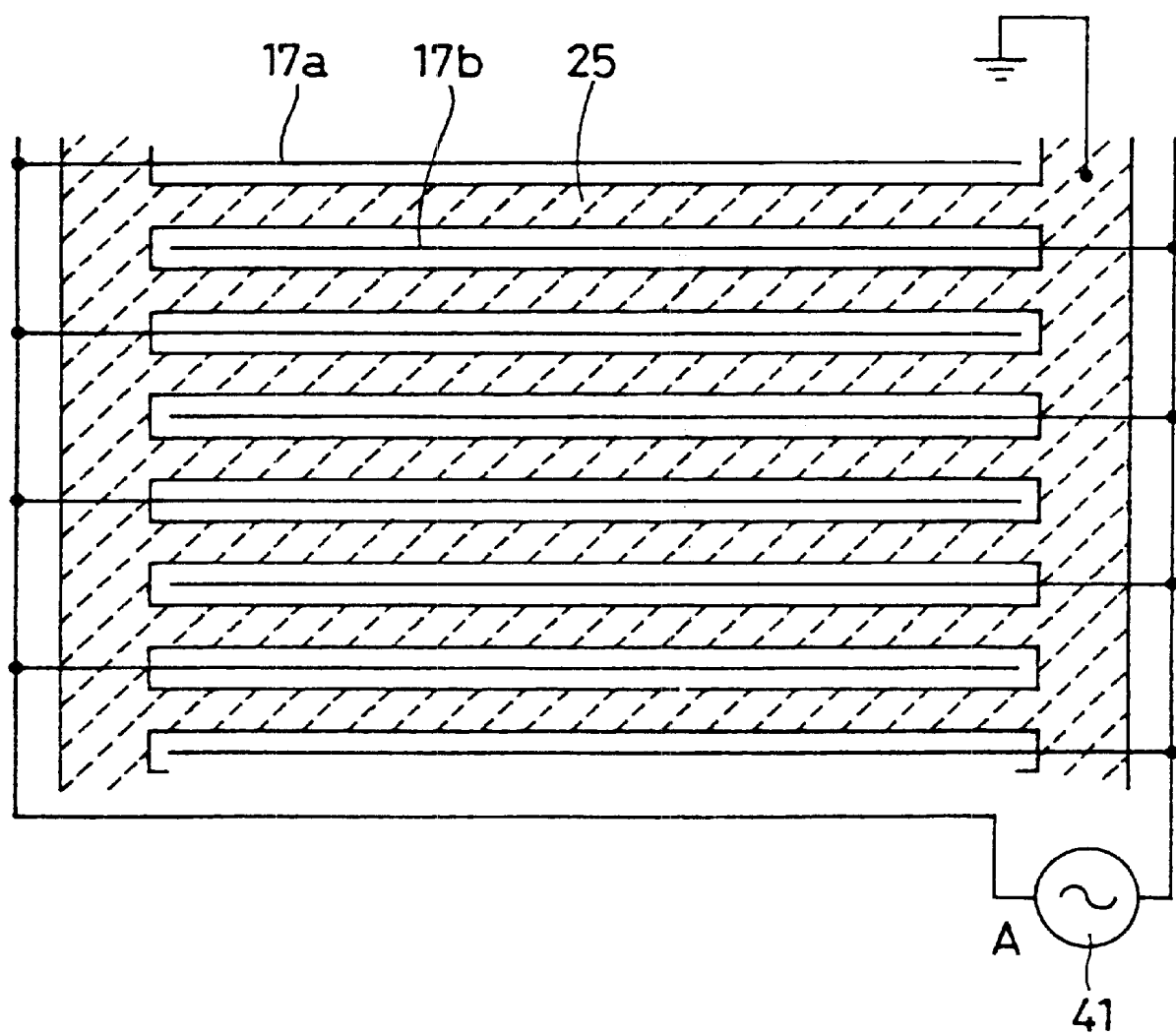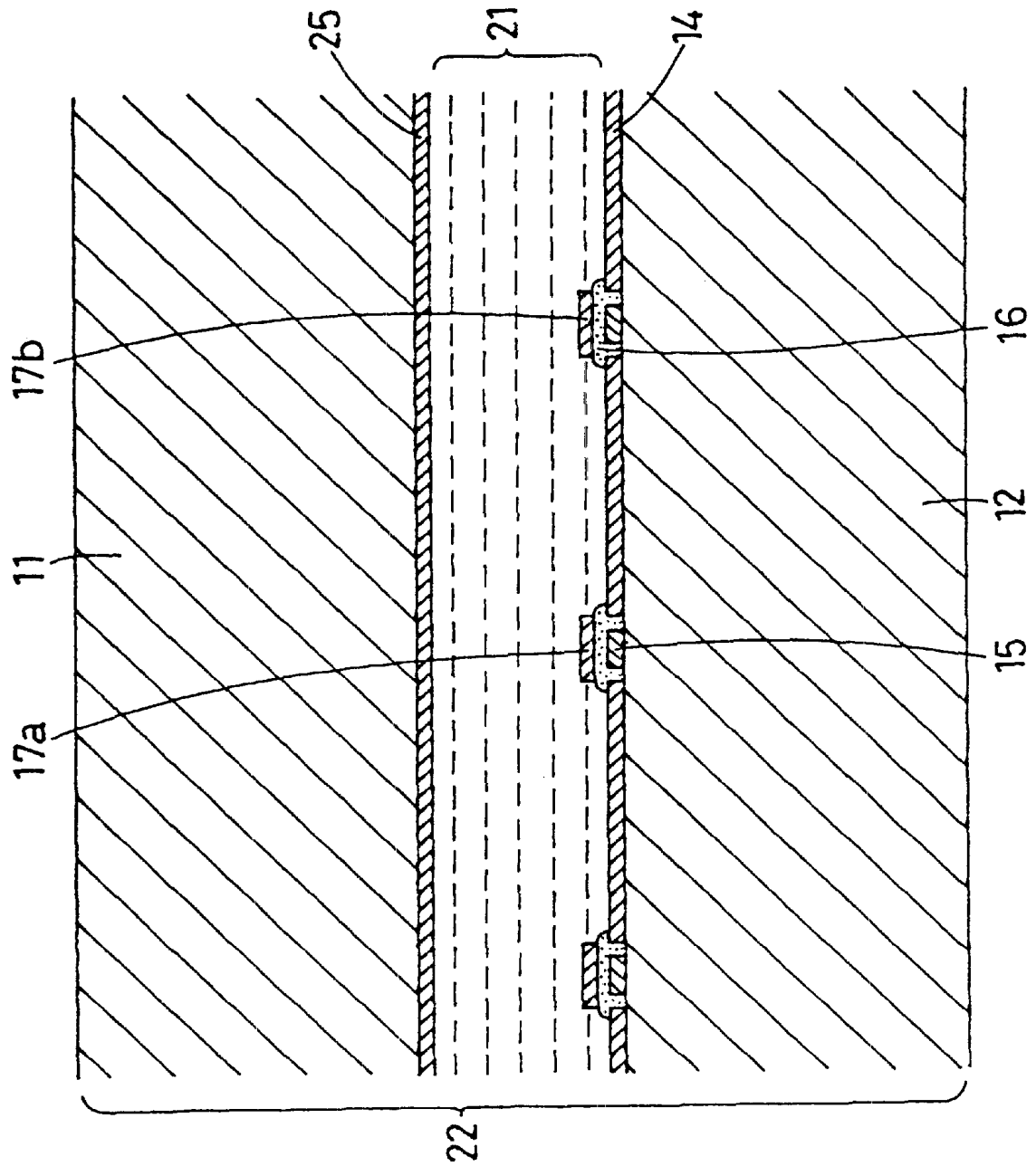

41 : SIGNAL LINE

Fig. 5

Fig. 6

Fig. 7

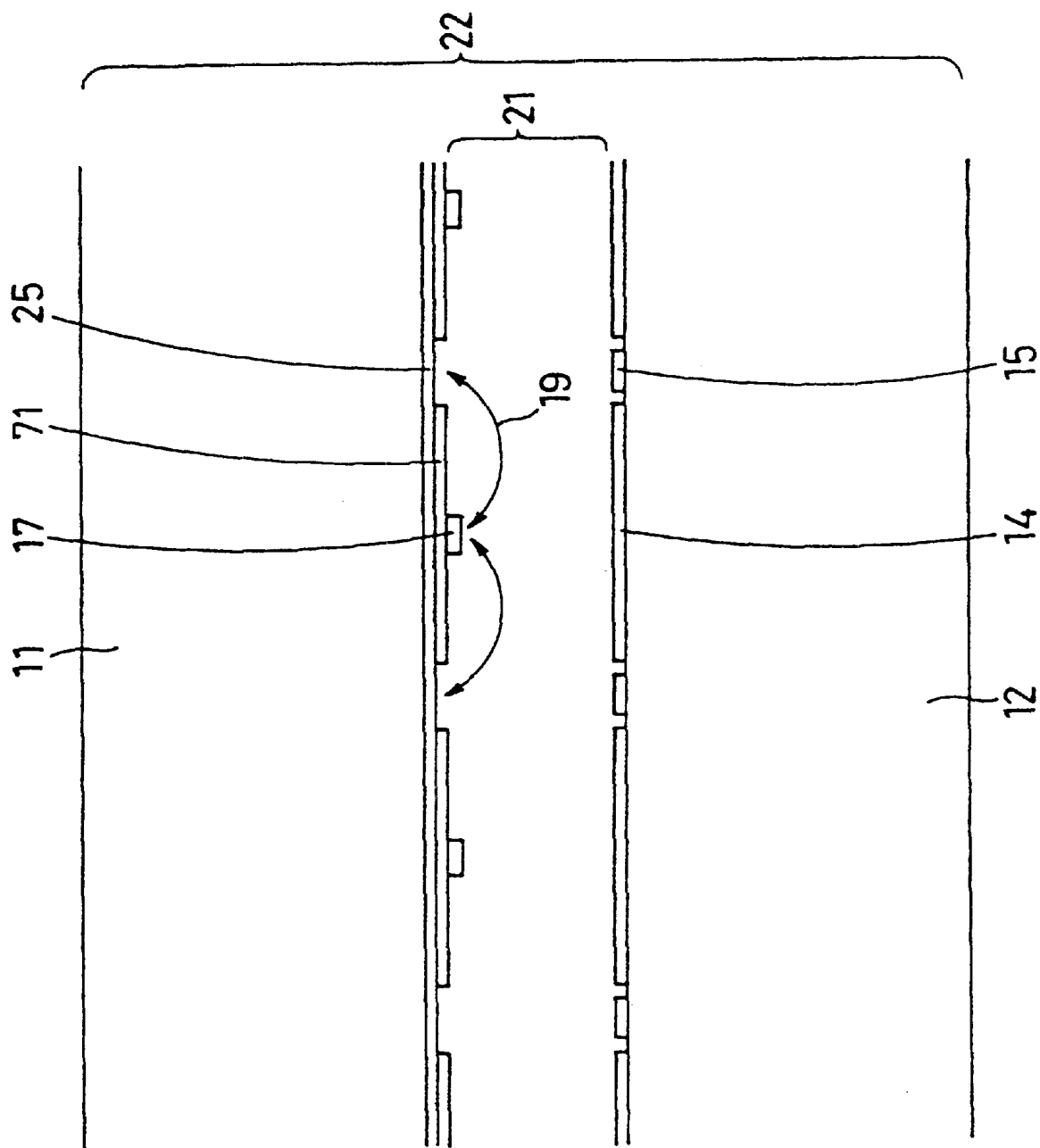71 : INSULATING FILM

Fig. 8

Fig. 9

Fig. 10

Fig. 11

Fig. 12

17a
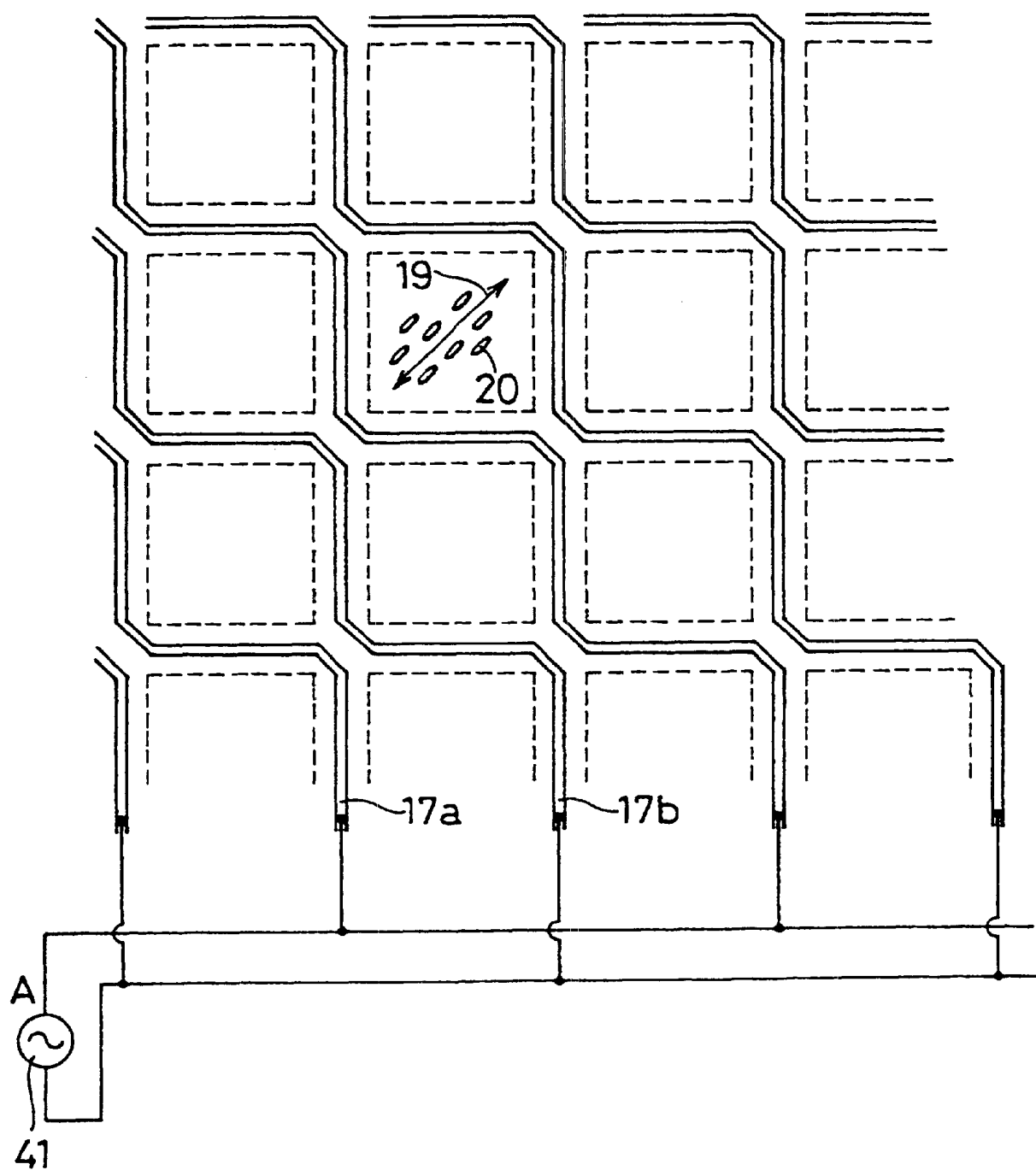
17b

17a
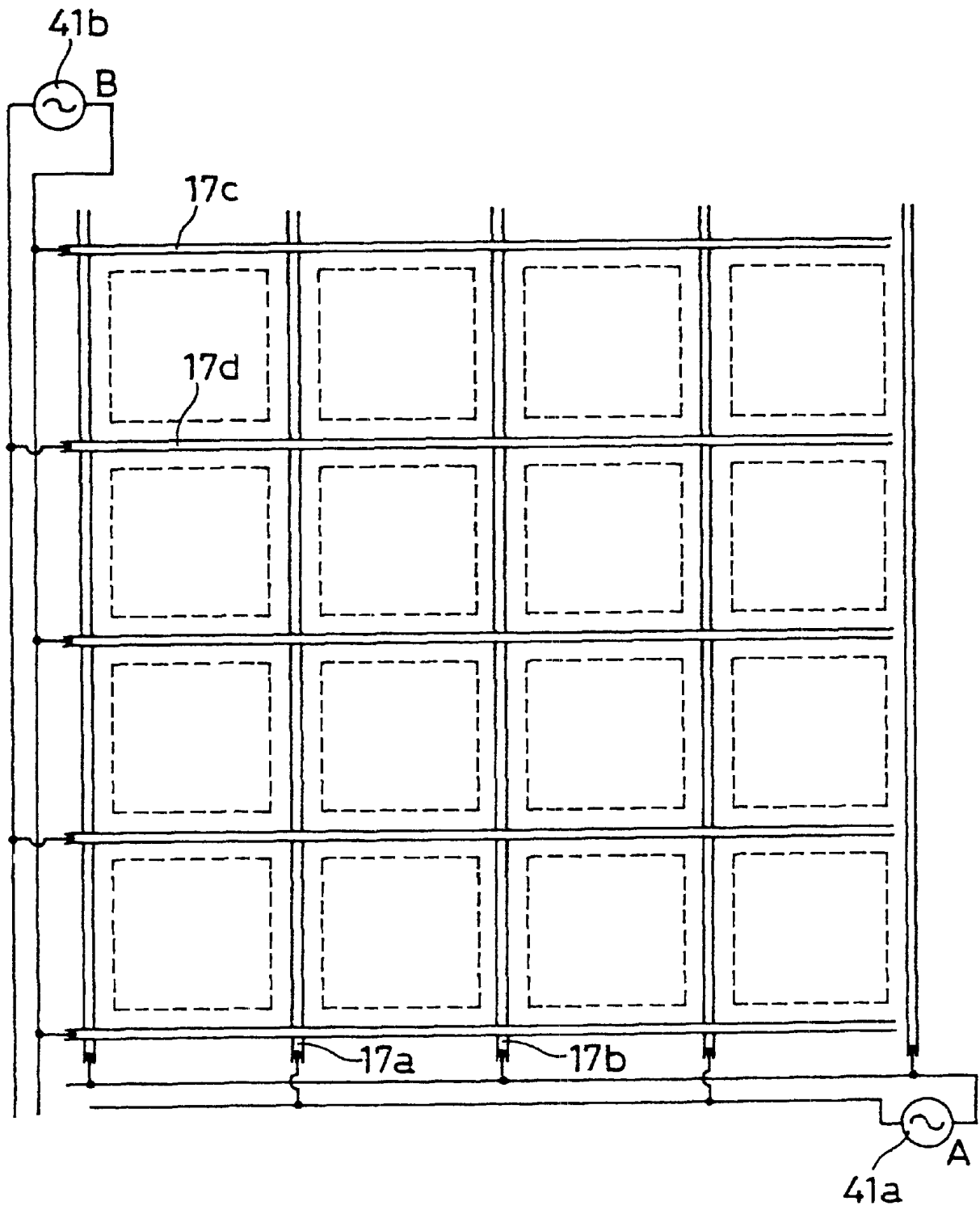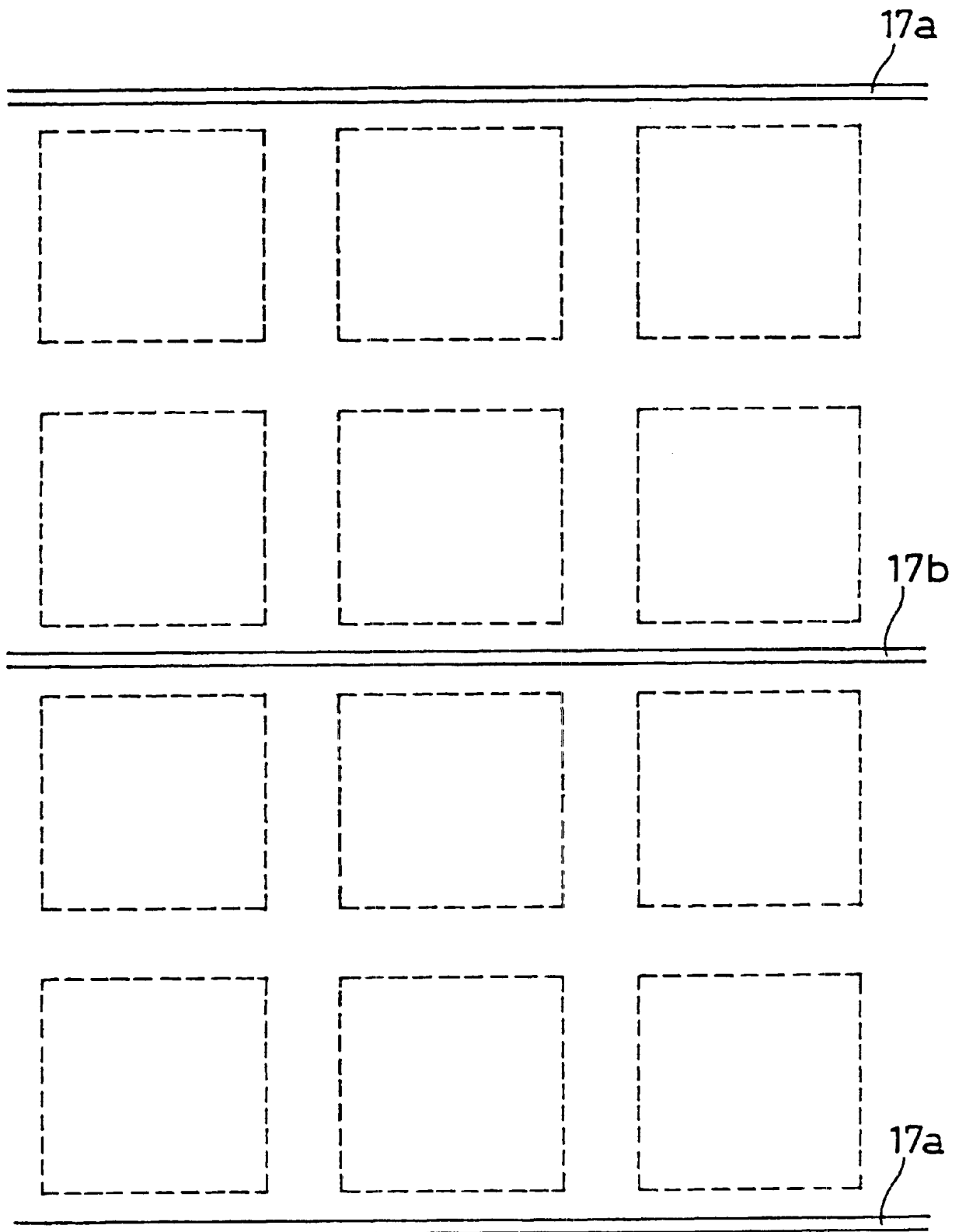
Fig. 13 (a)

131 : POLARIZING PLATE

132 : POLARIZATION AXIS

133 : TRANSVERSE ELECTRIC FIELD GENERATION DIRECTION
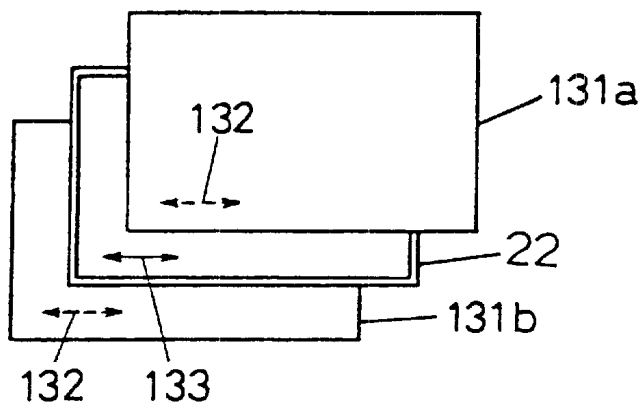
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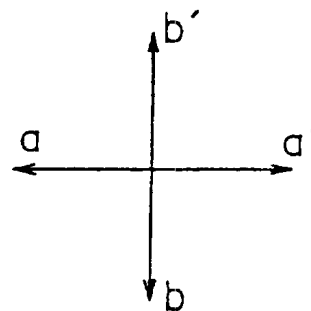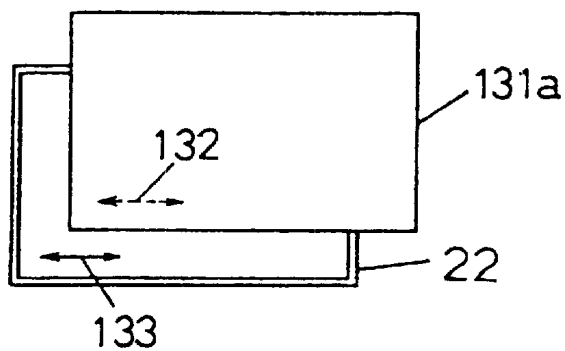
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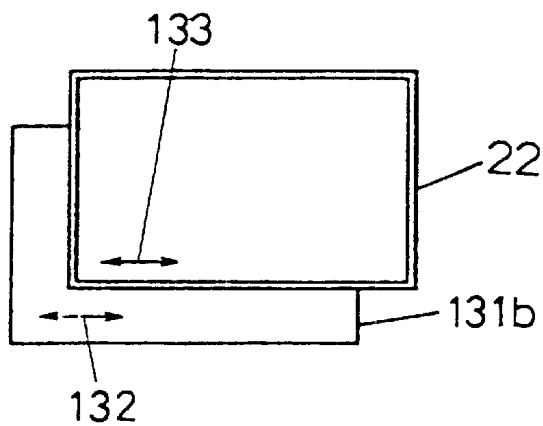
F i g. 1 4 (a)

F i g. 1 4 (b)

F i g. 1 4 (c)

Fig. 15

151 : COLOR FILTER

152 : RESIN LIGHT SHIELDING FILM

153 : PROTECTIVE FILM

154 : INSULATING FILM

155 : TFT
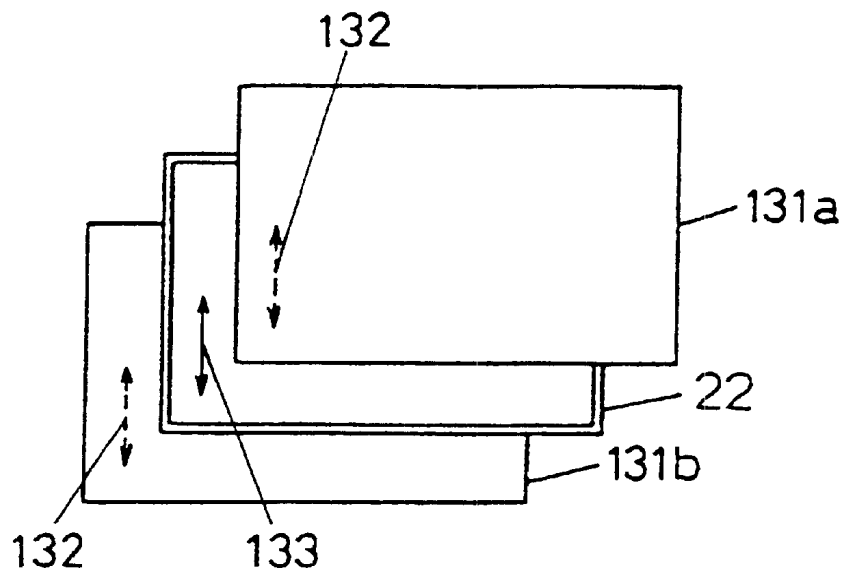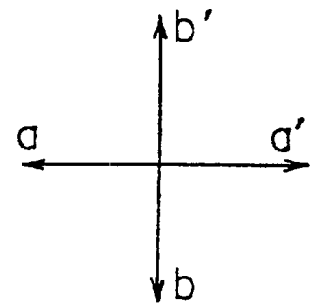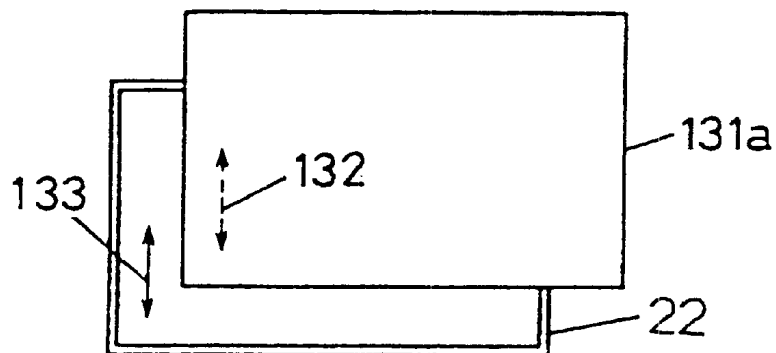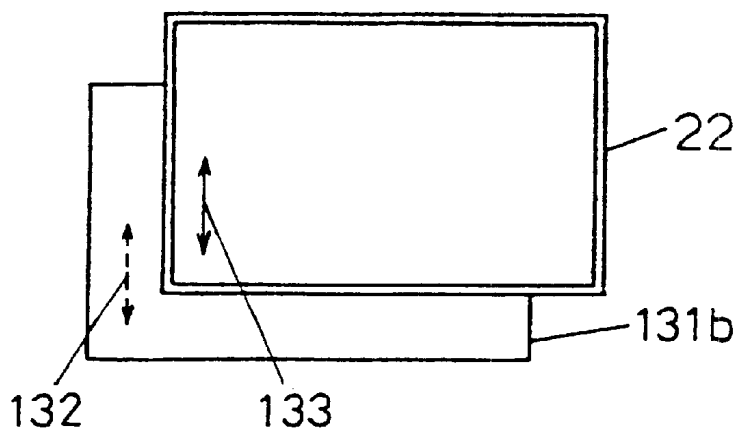
Fig. 16

161 : BEAD
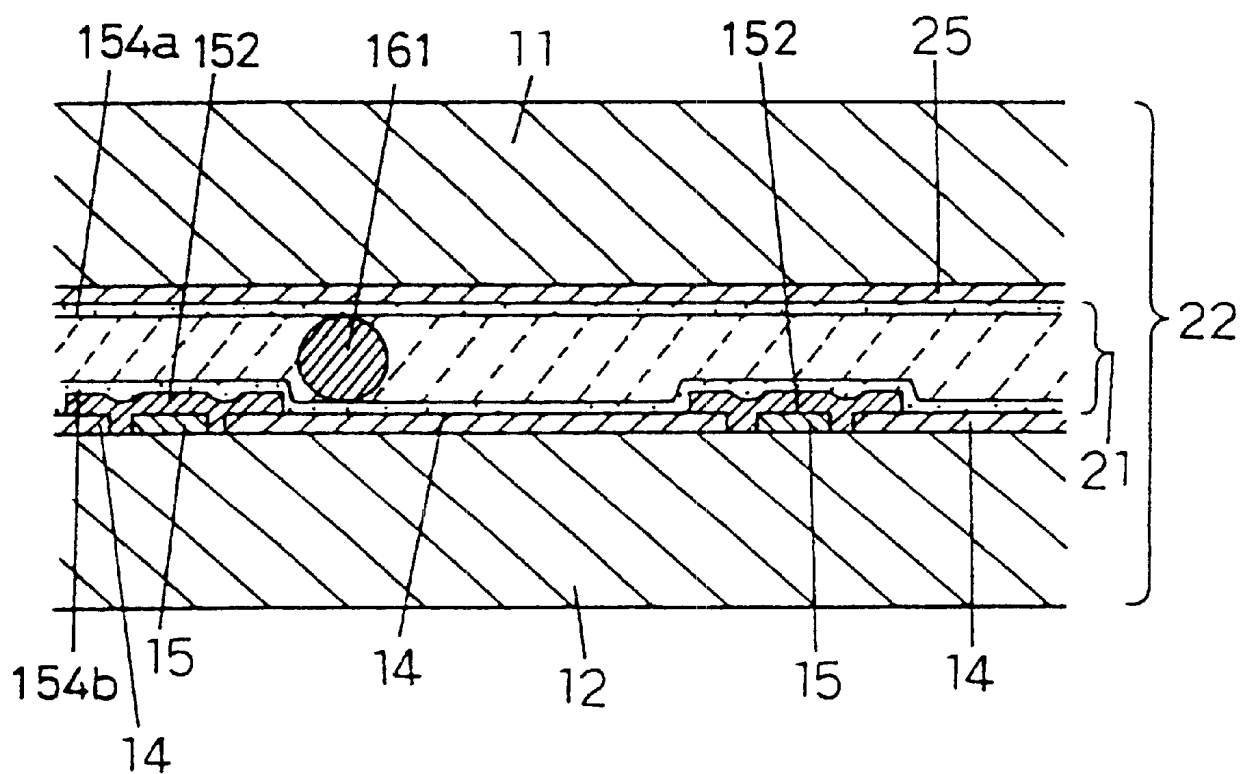
Fig. 17

15 : SOURCE SIGNAL LINE

Fig. 18

ULTRAVIOLET RAYS

183

181

A B A B

182

21

14

15

12

181 : MASK

182 : SEPARATION FILM

183 : ULTRAVIOLET RAY
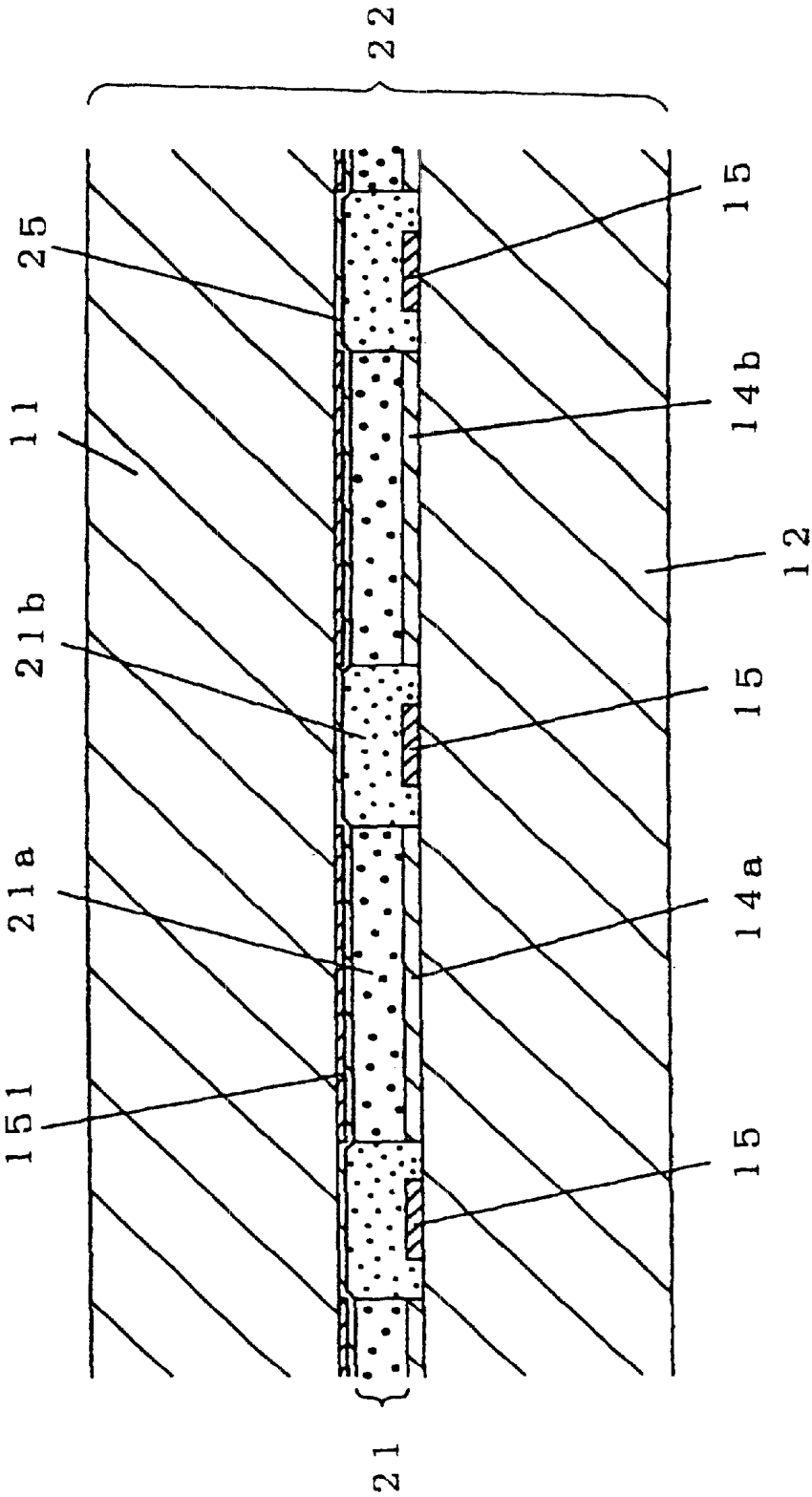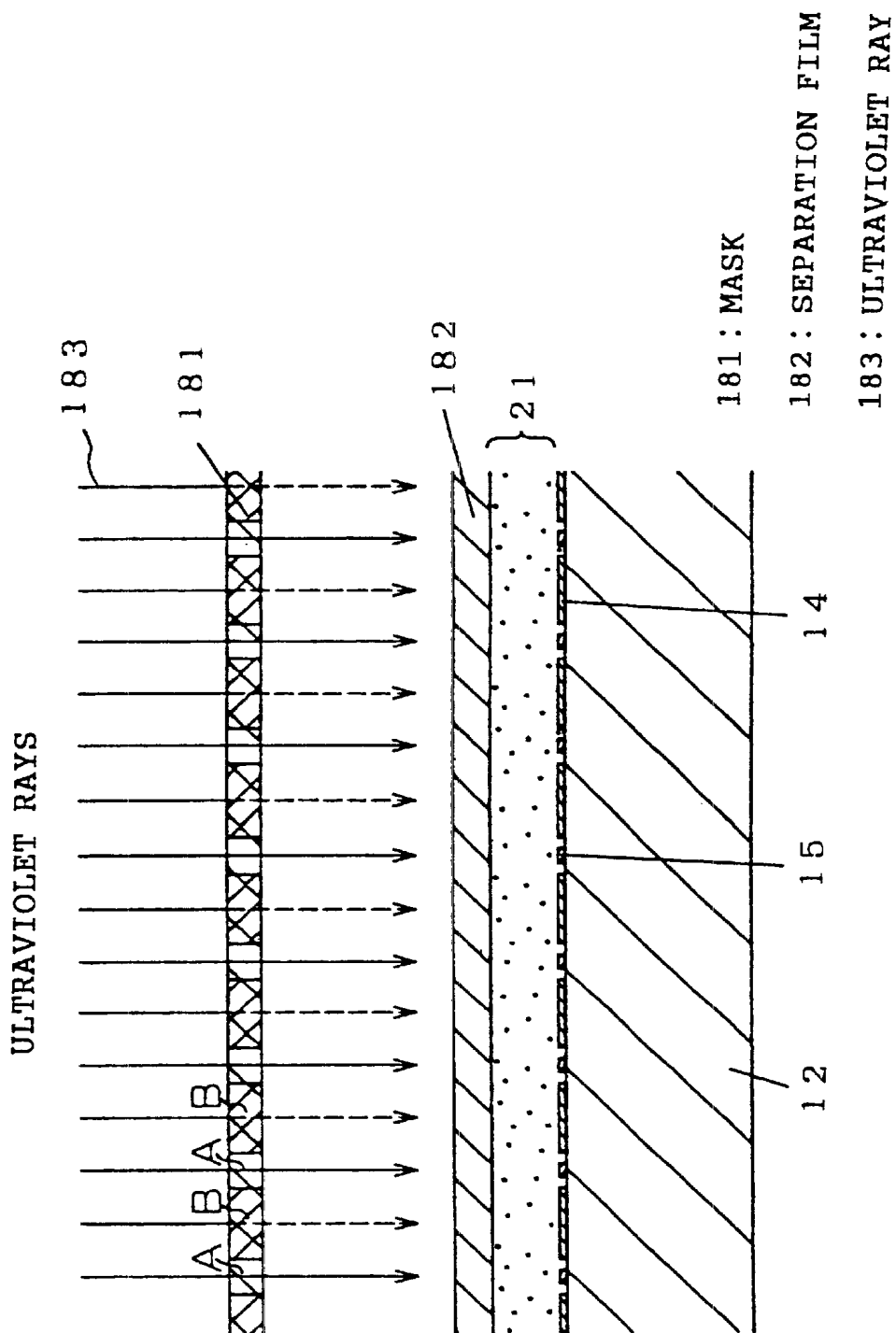
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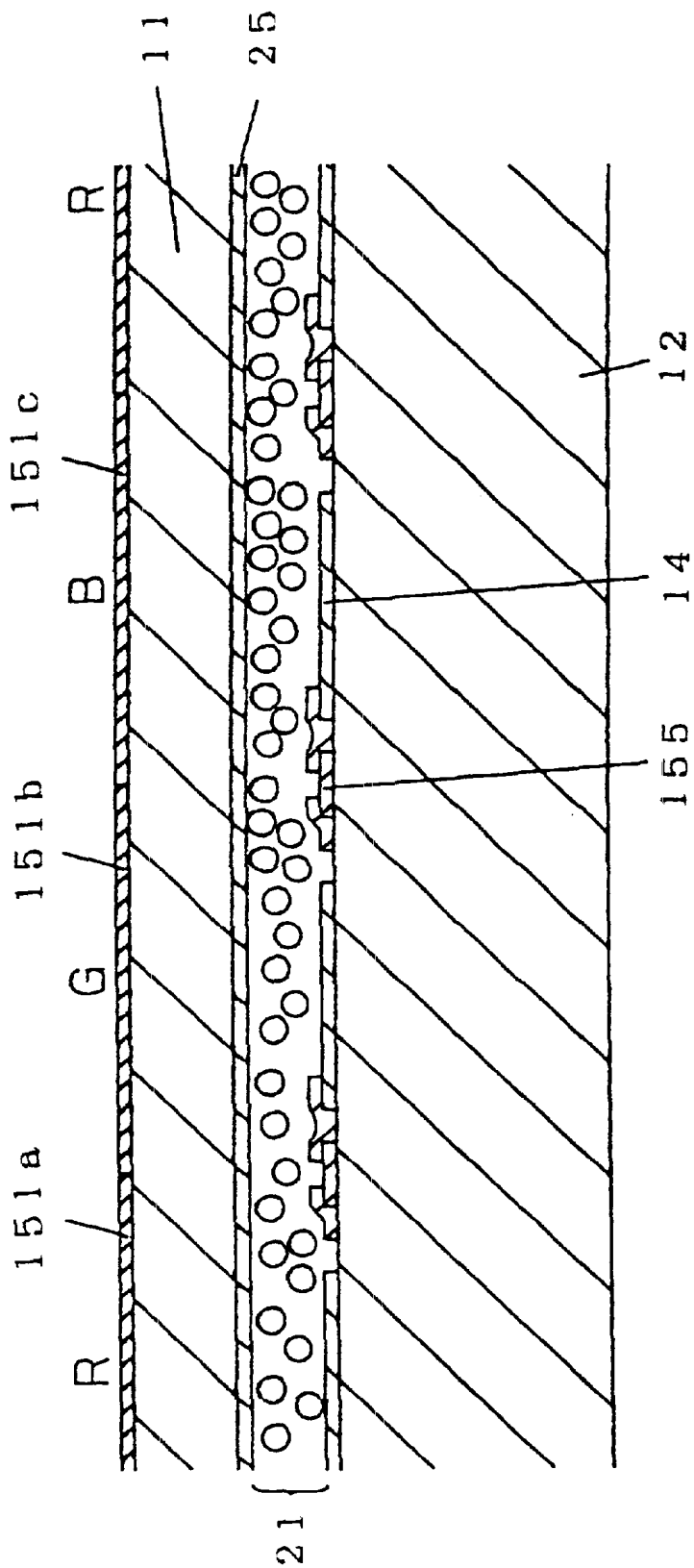
Fig. 20

201: INSULATING FILM

202: LIGHT SHIELDING FILM

Fig. 21

211: AIR COAT

212: COMMON ELECTRODE

213: ANTIREFLECTION FILM

214: SMOOTHING FILM
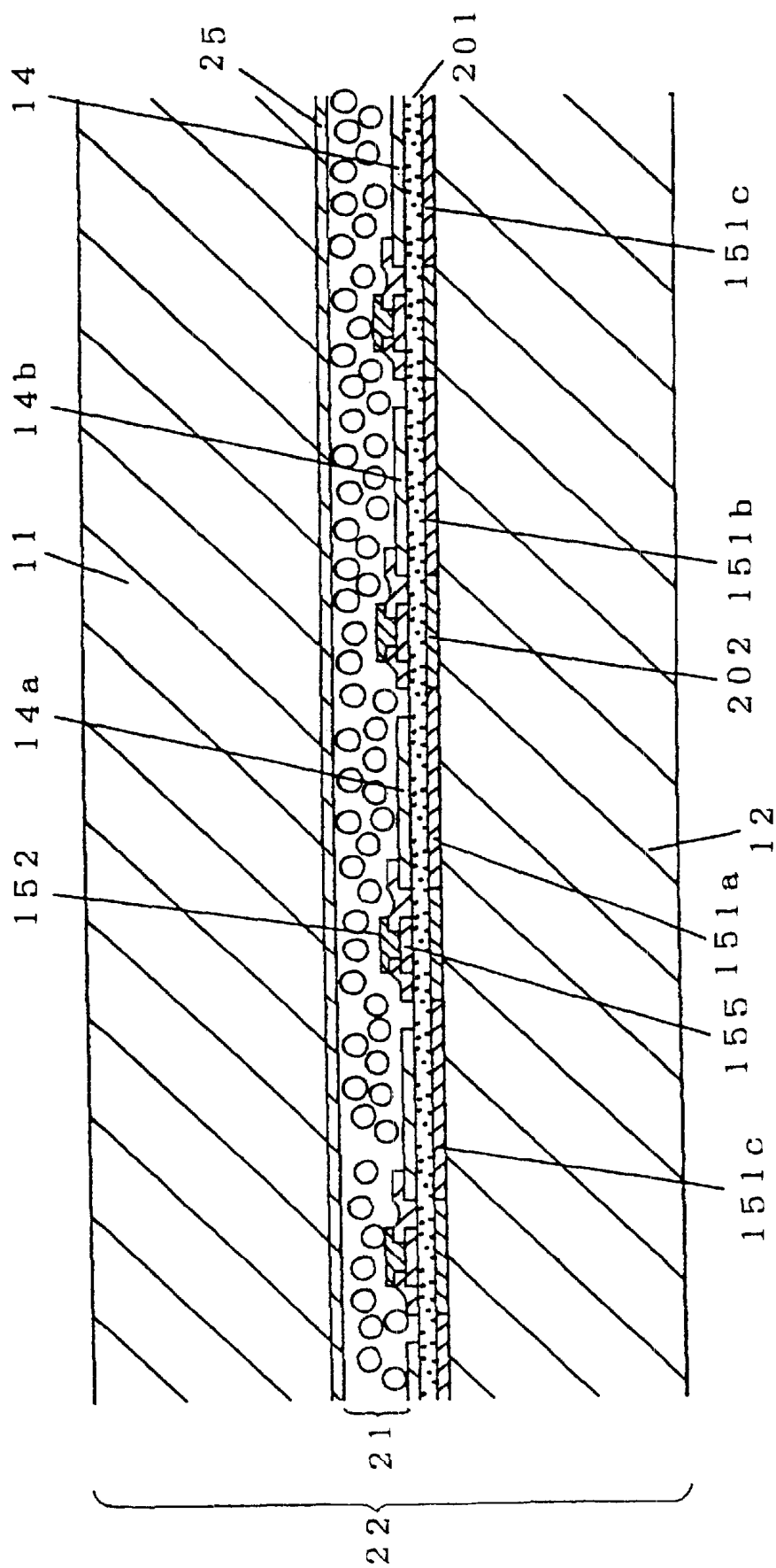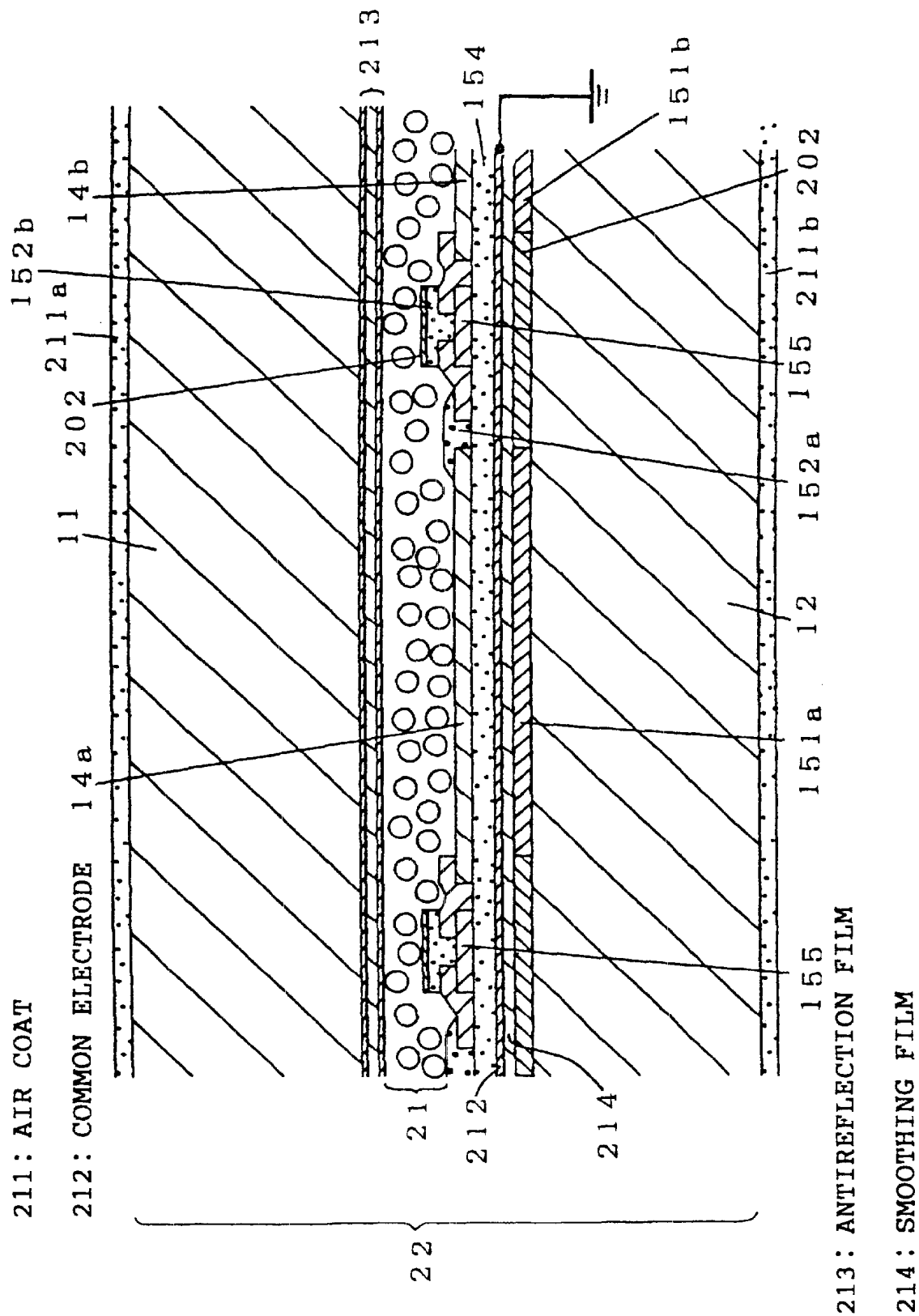
F i g. 22 (a)

221: DIELECTRIC THIN FILM

——— 2 2 1 b

——— 2 5

——— 2 2 1 a

F i g. 22 (b)

——— 2 5

——— 2 2 1 a

F i g. 22 (c)

——— 2 5

——— 2 2 1 a
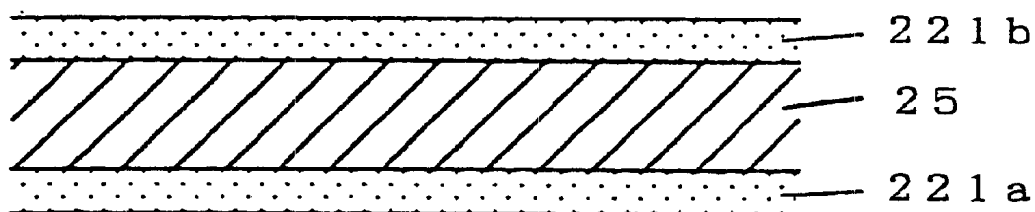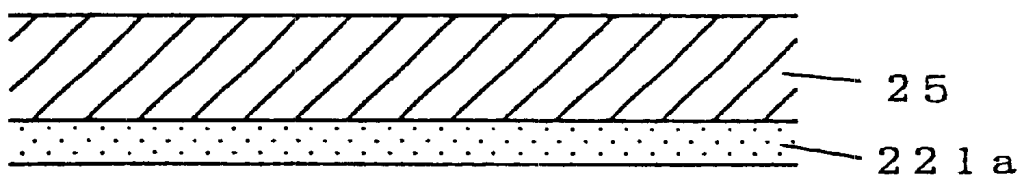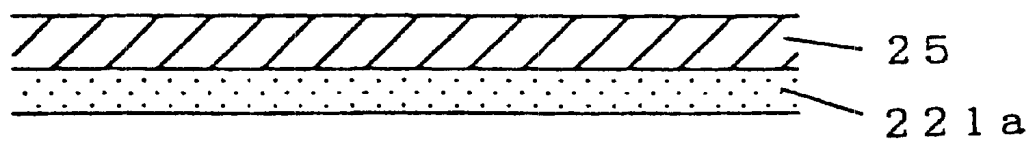
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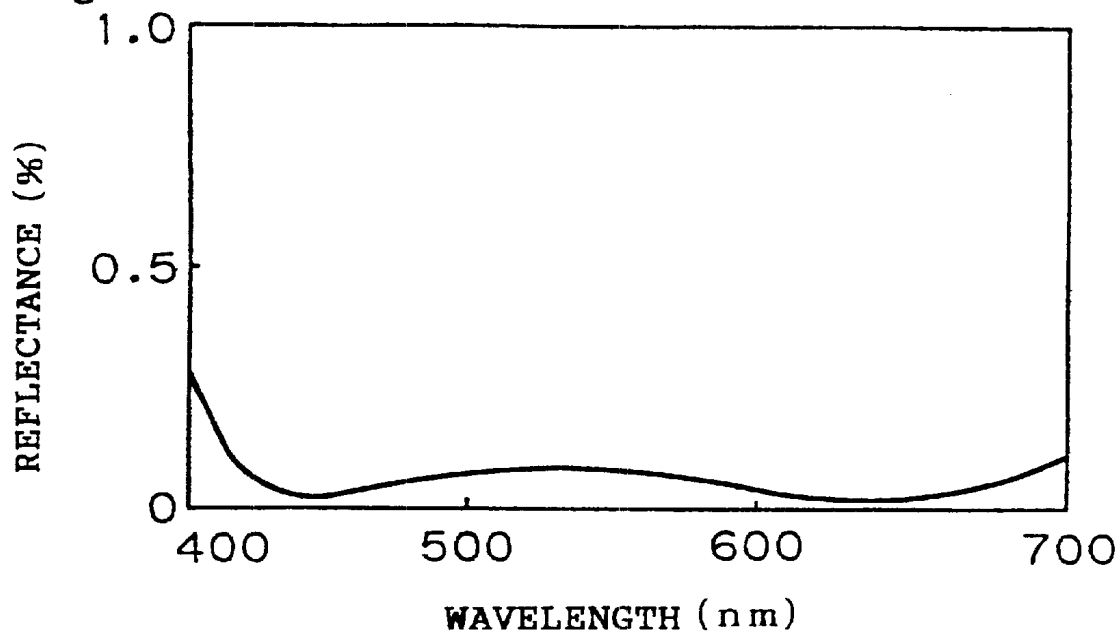
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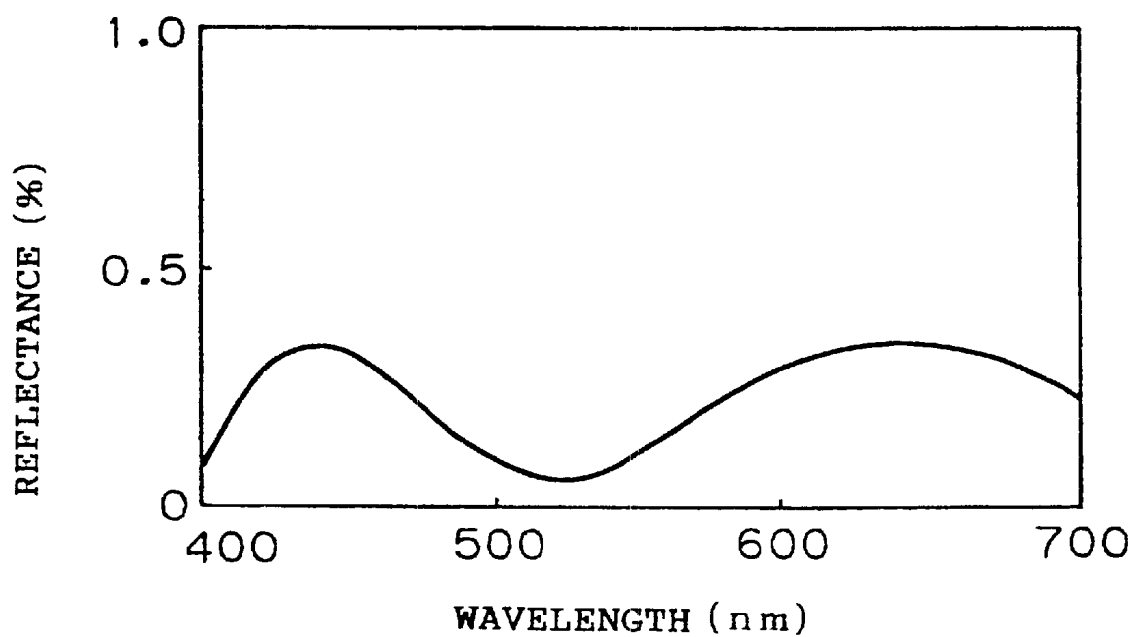
Fig. 25

Fig. 26

Fig. 27

Fig. 28

ULTRAVIOLET RAYS
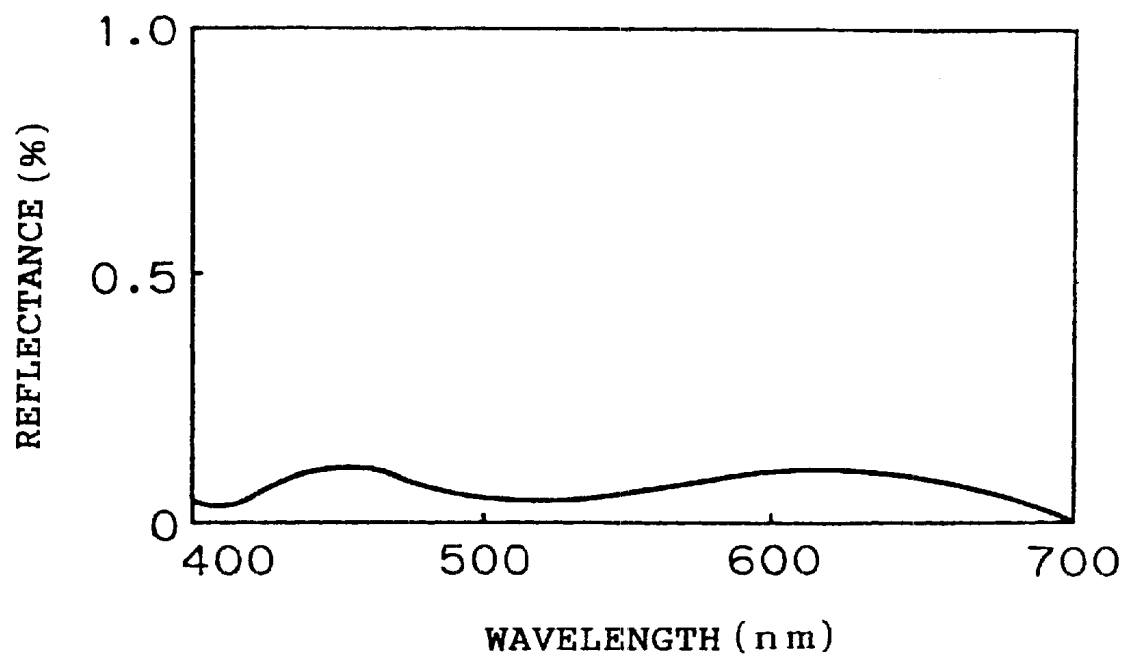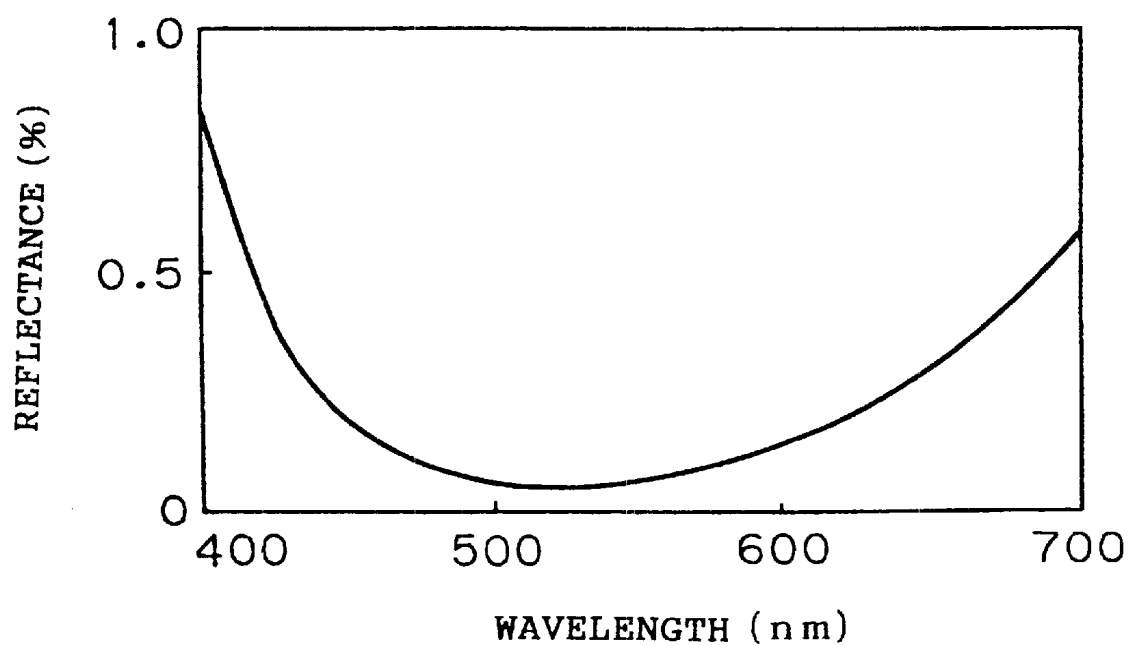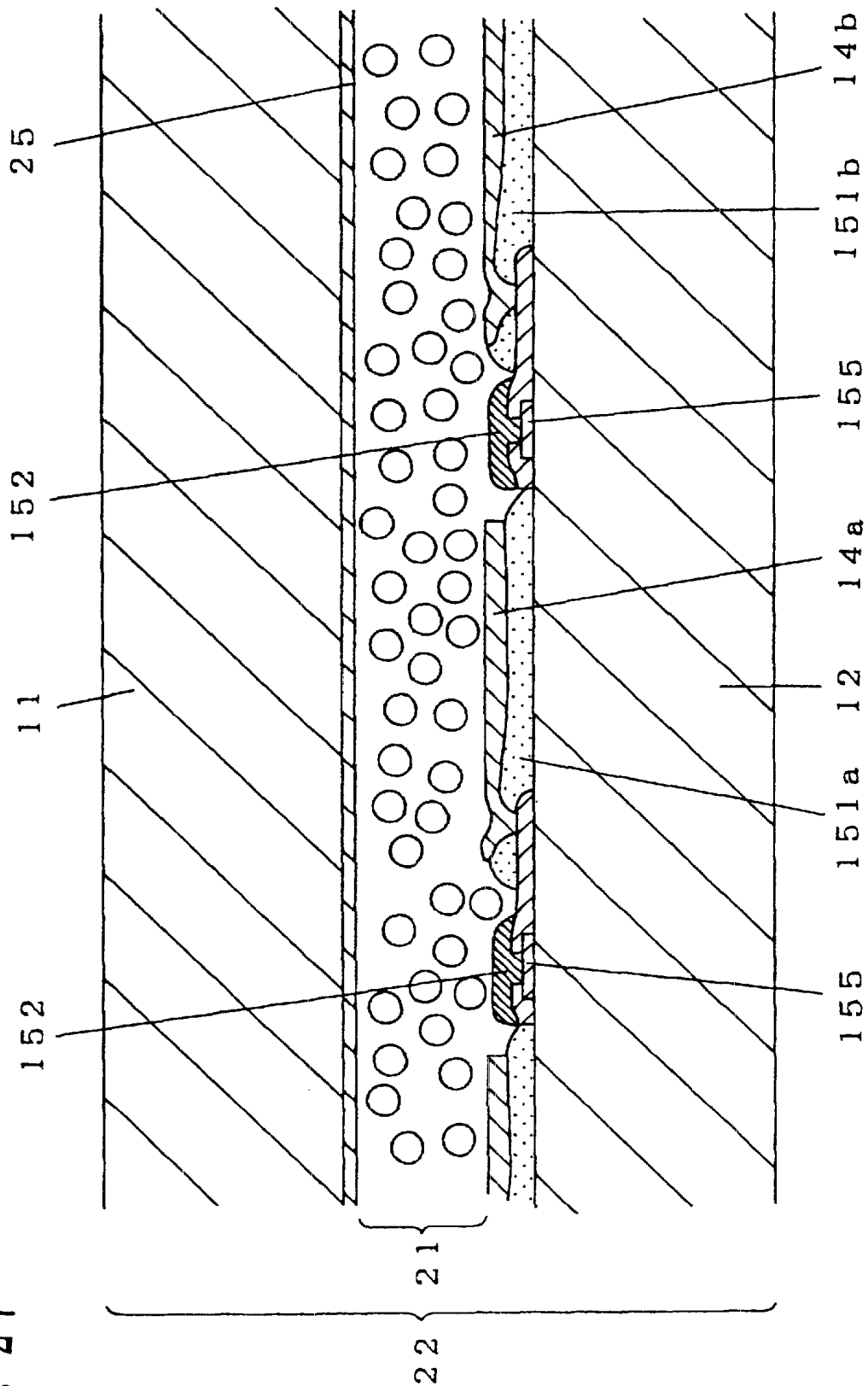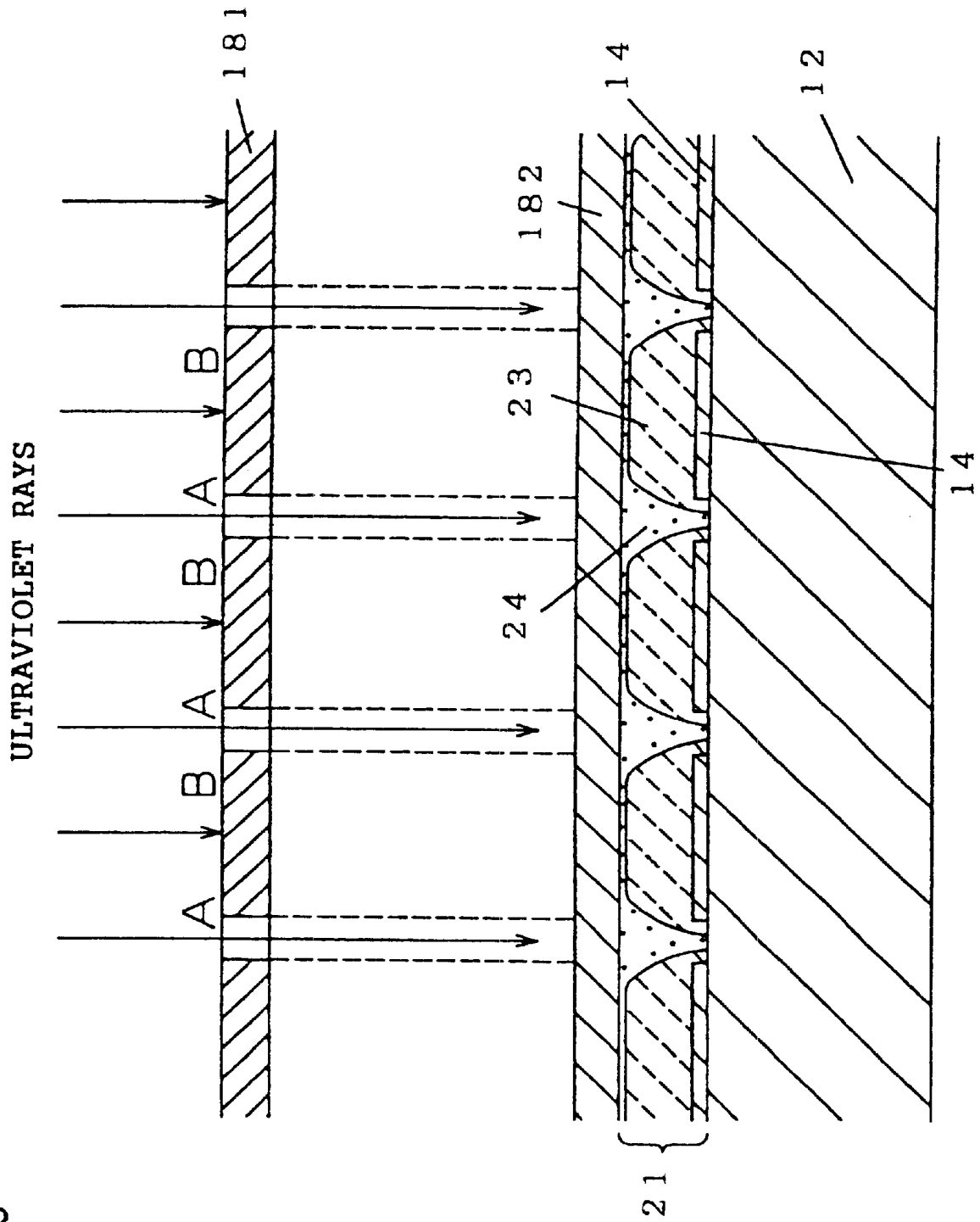
Fig. 29

291: LASER LIGHT

291a

291b

182

21

12
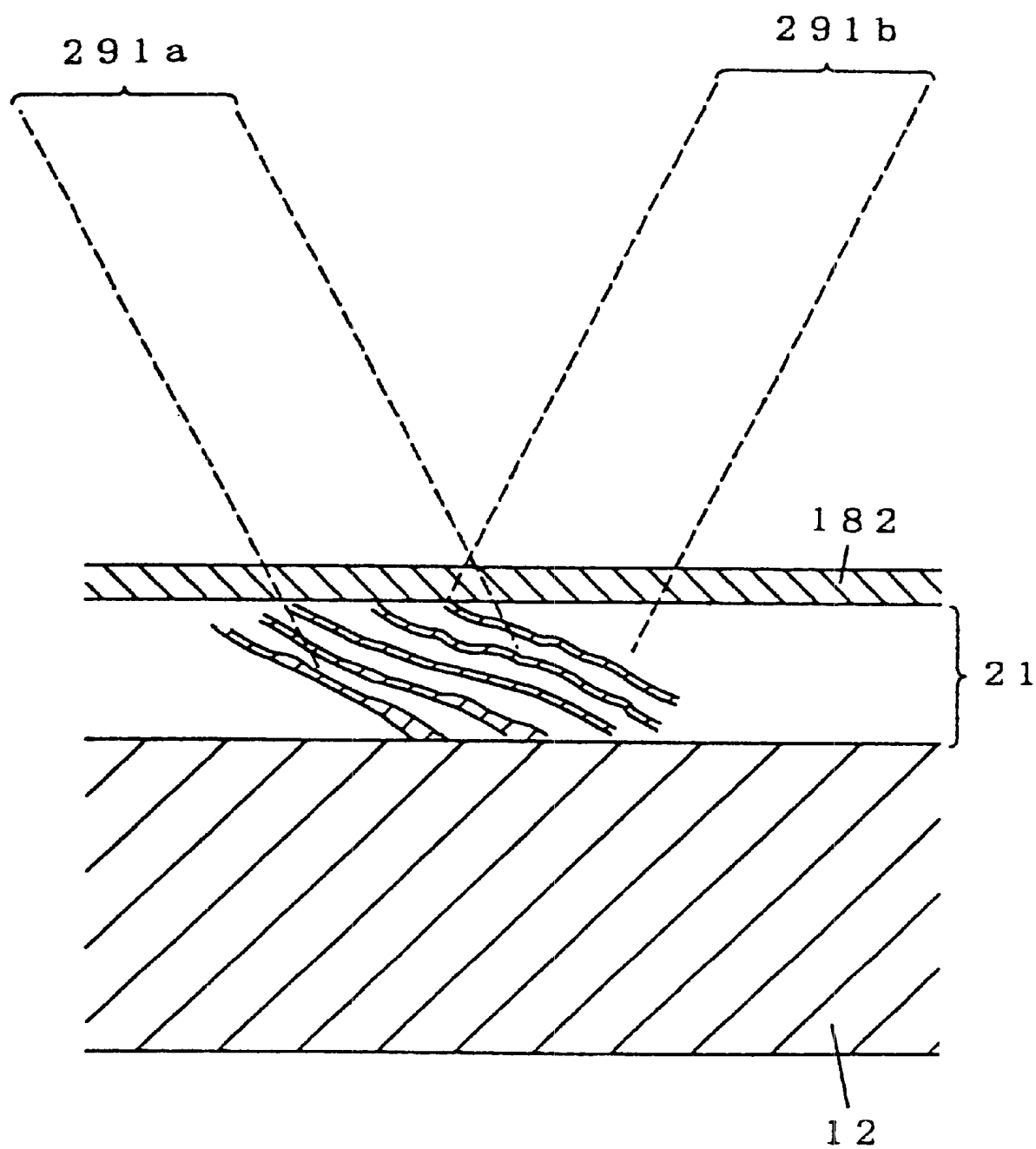
Fig. 30

301: RESIN PARTICLE

302: LIQUID CRYSTAL
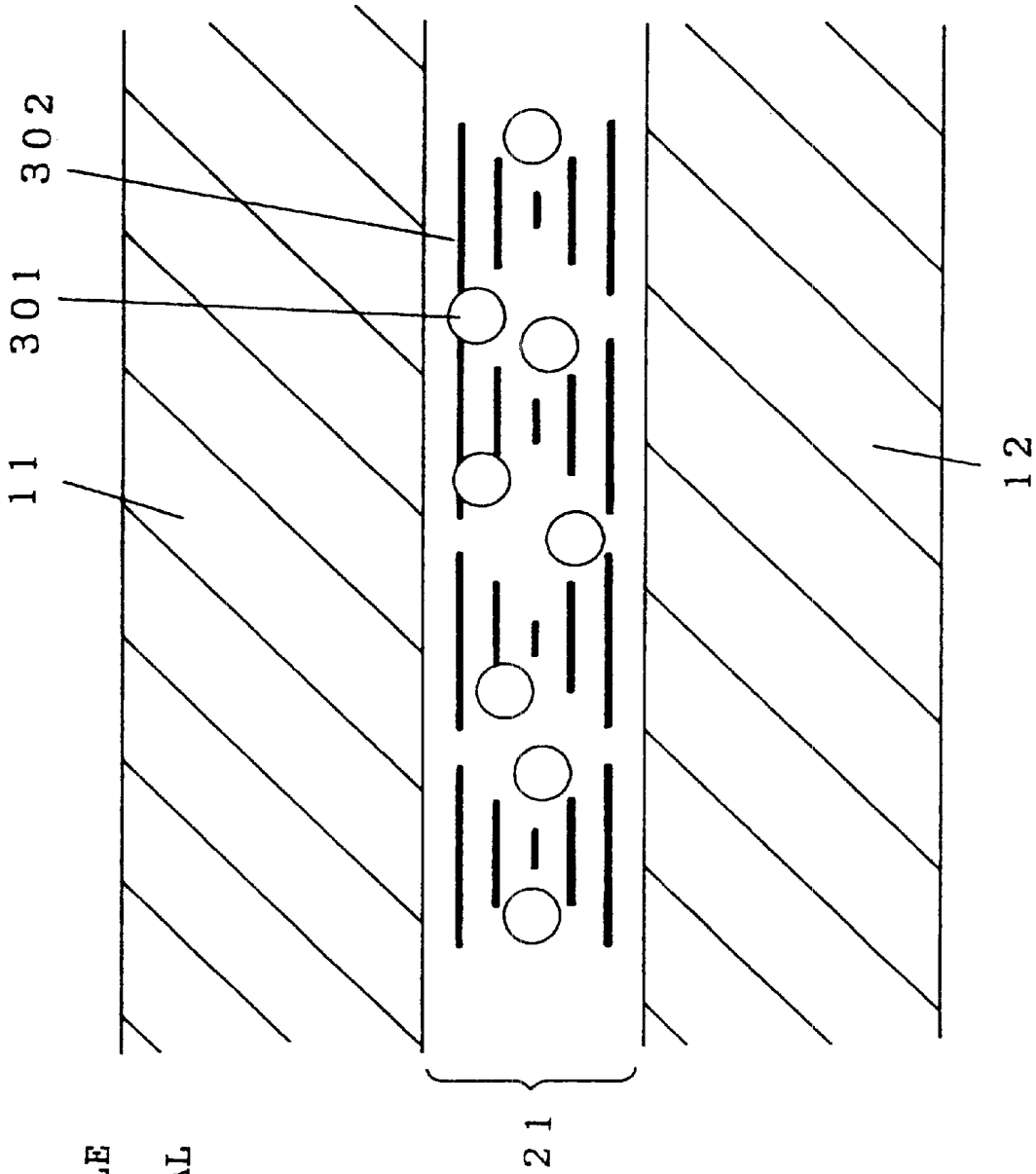
Fig. 31

311: LIGHT IRRADIATION MEANS

312: PRESS ROLLER

313: SUPPLY ROLLER

314: WIND-UP ROLLER

315: MIXED SOLUTION

Fig. 32

331: FILTER

Fig. 33

Fig. 34

341: OPENING

331a   331b   181   331c

R	G	B
B	R	G
G	B	R

341
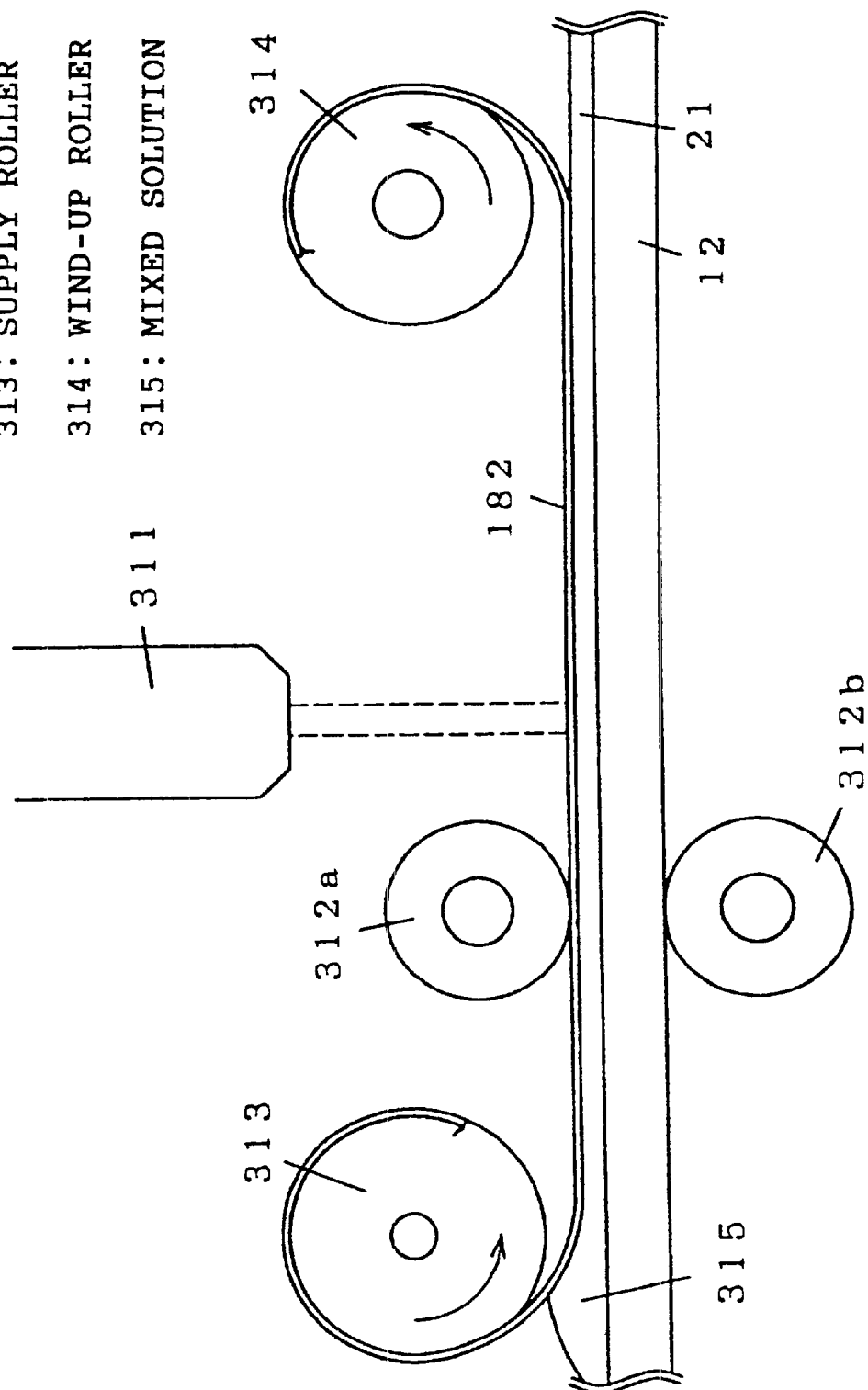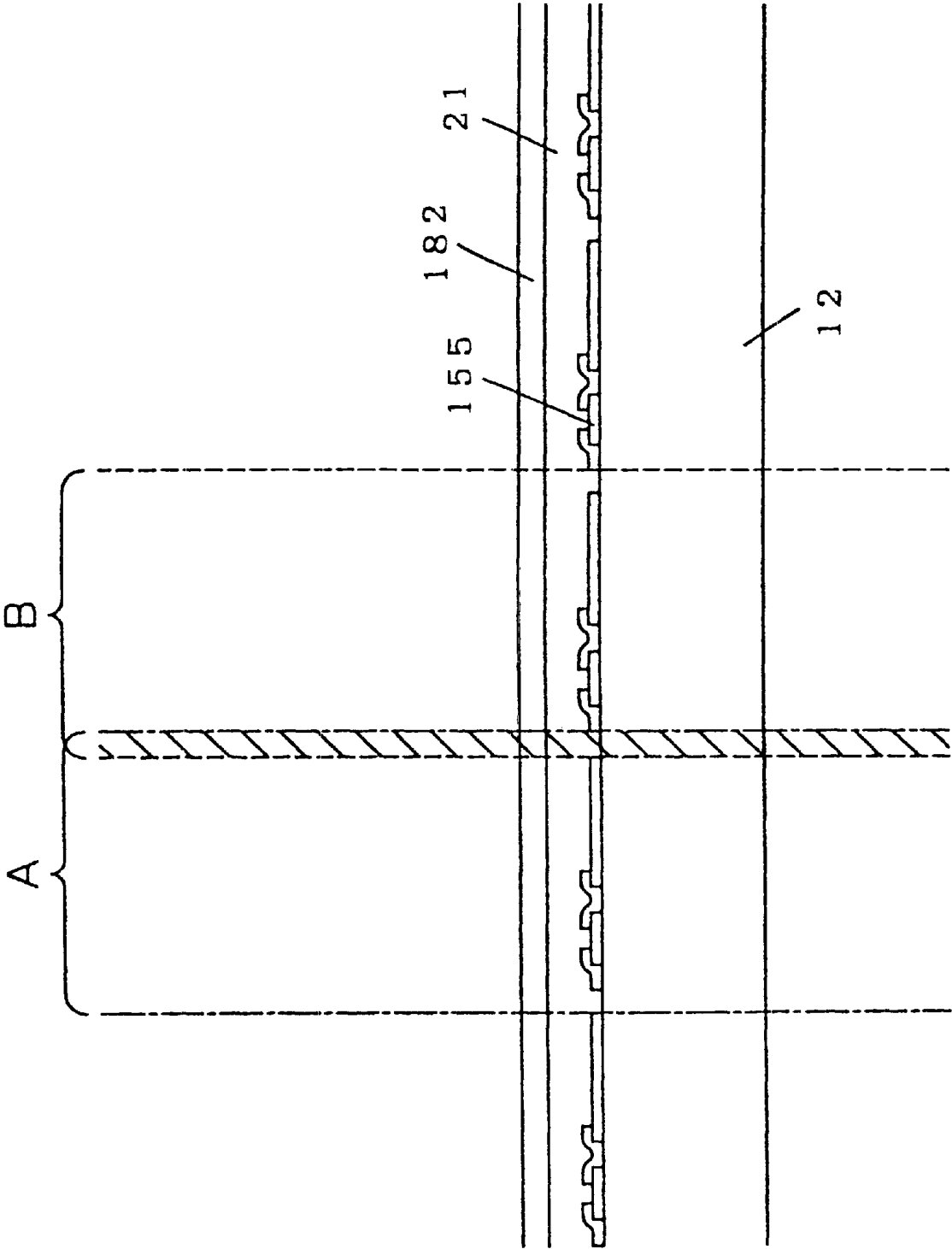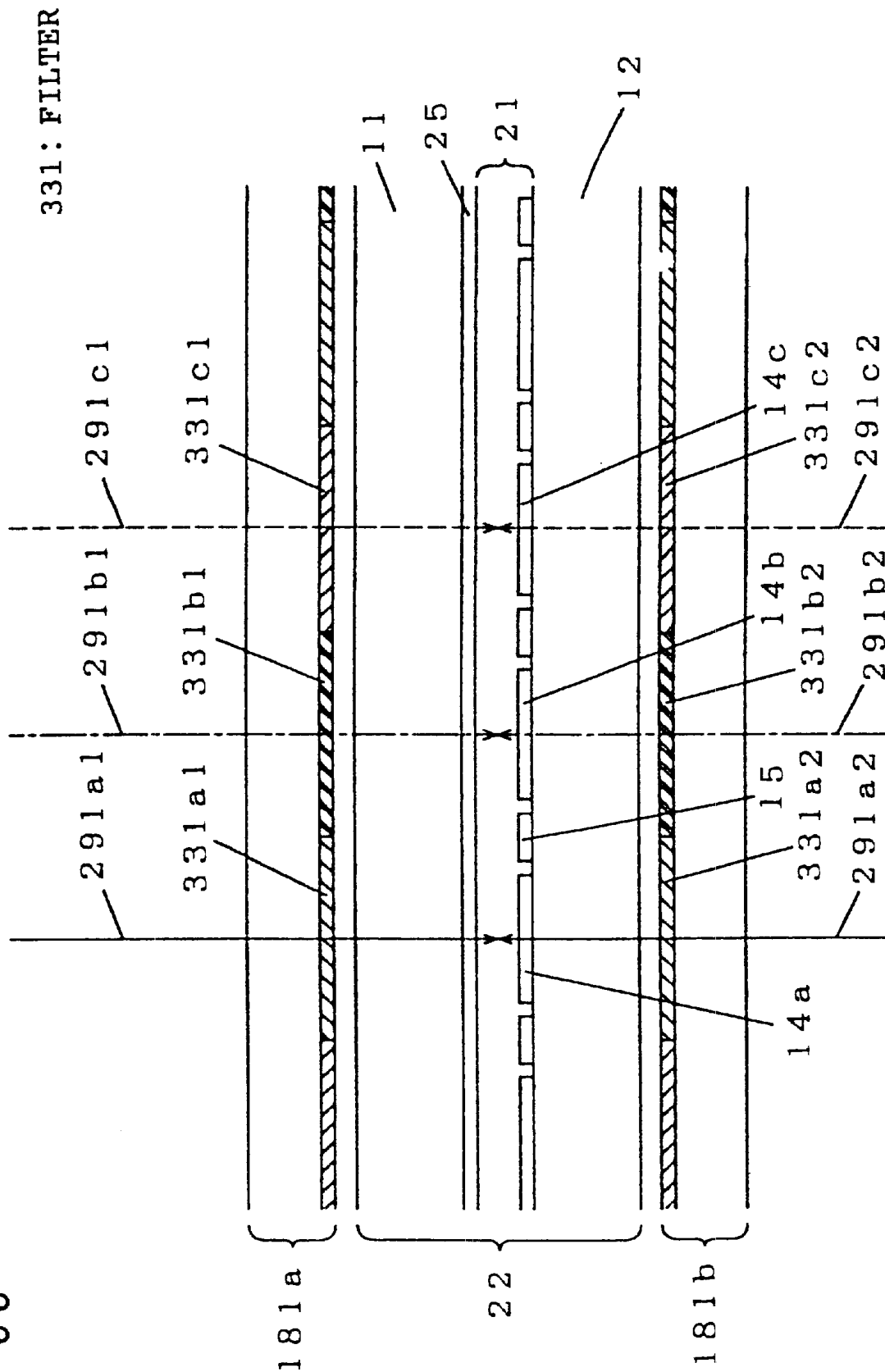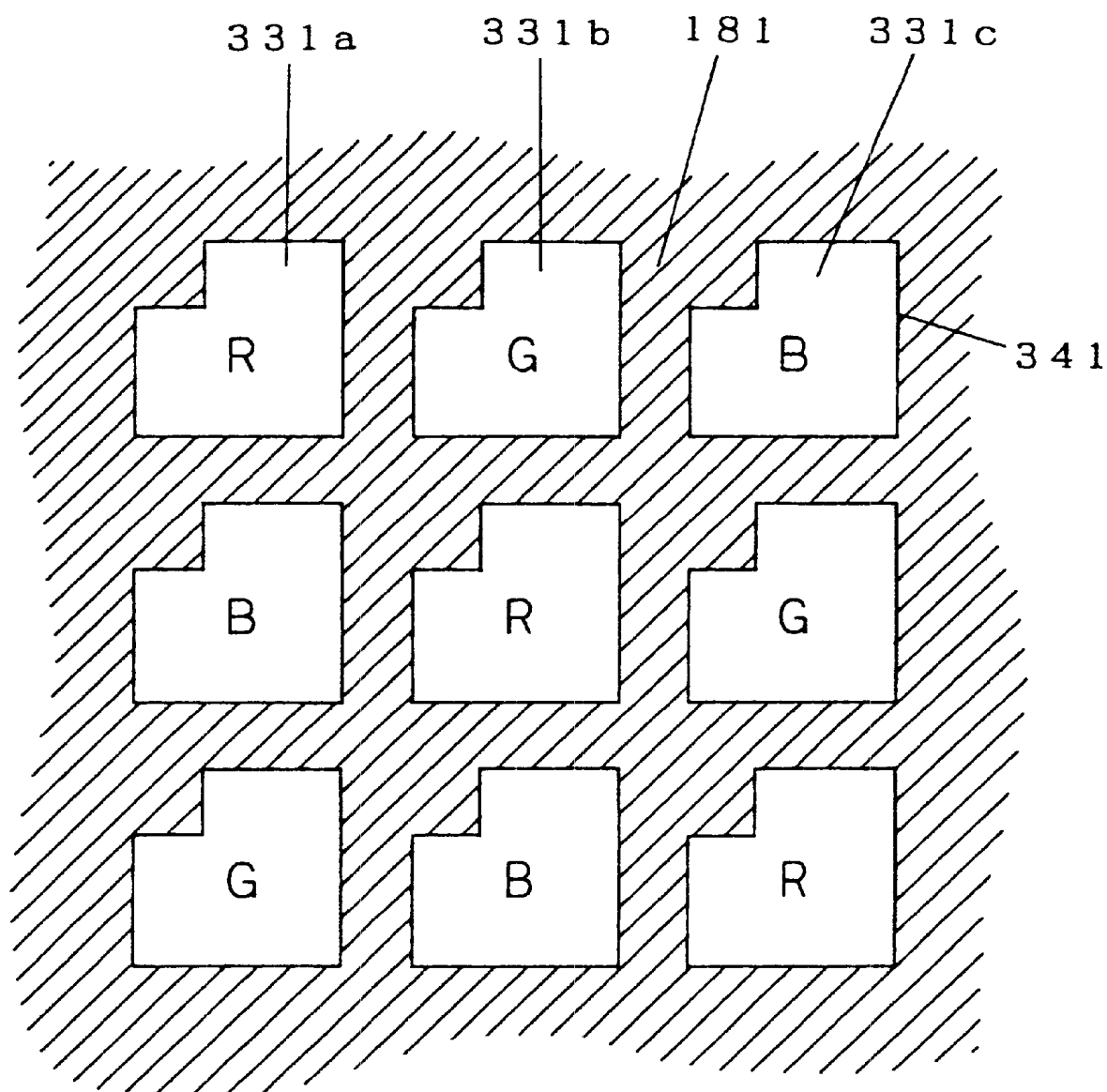
Fig. 35

351: SUBSTRATE

352: INERT GAS LAYER

361 : SEAL RESIN

Fig. 36

371: ADHESIVE LAYER

25

371

151c

151b 202

202 152

151a 202

11 151a

21

22

12

14

155
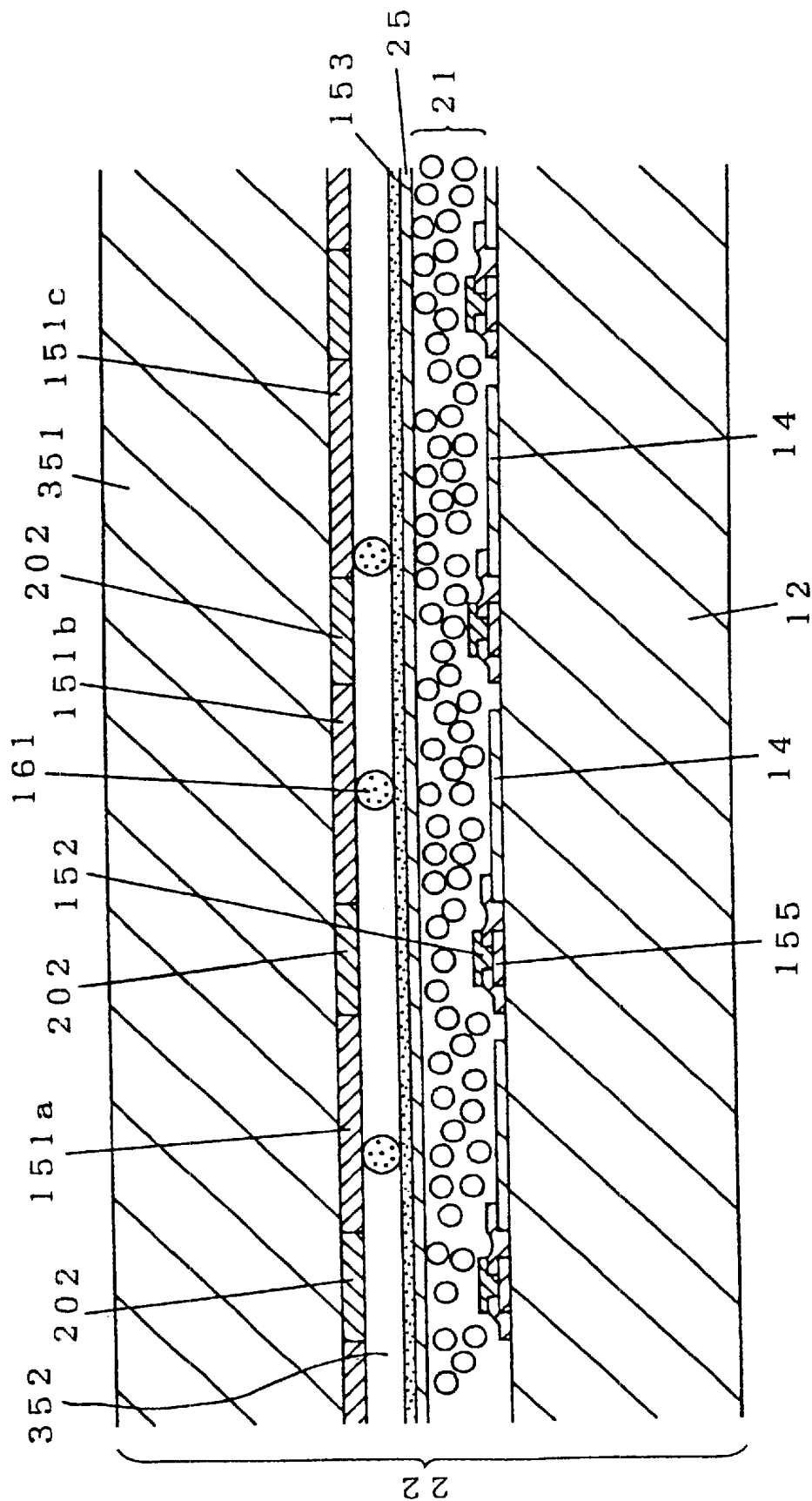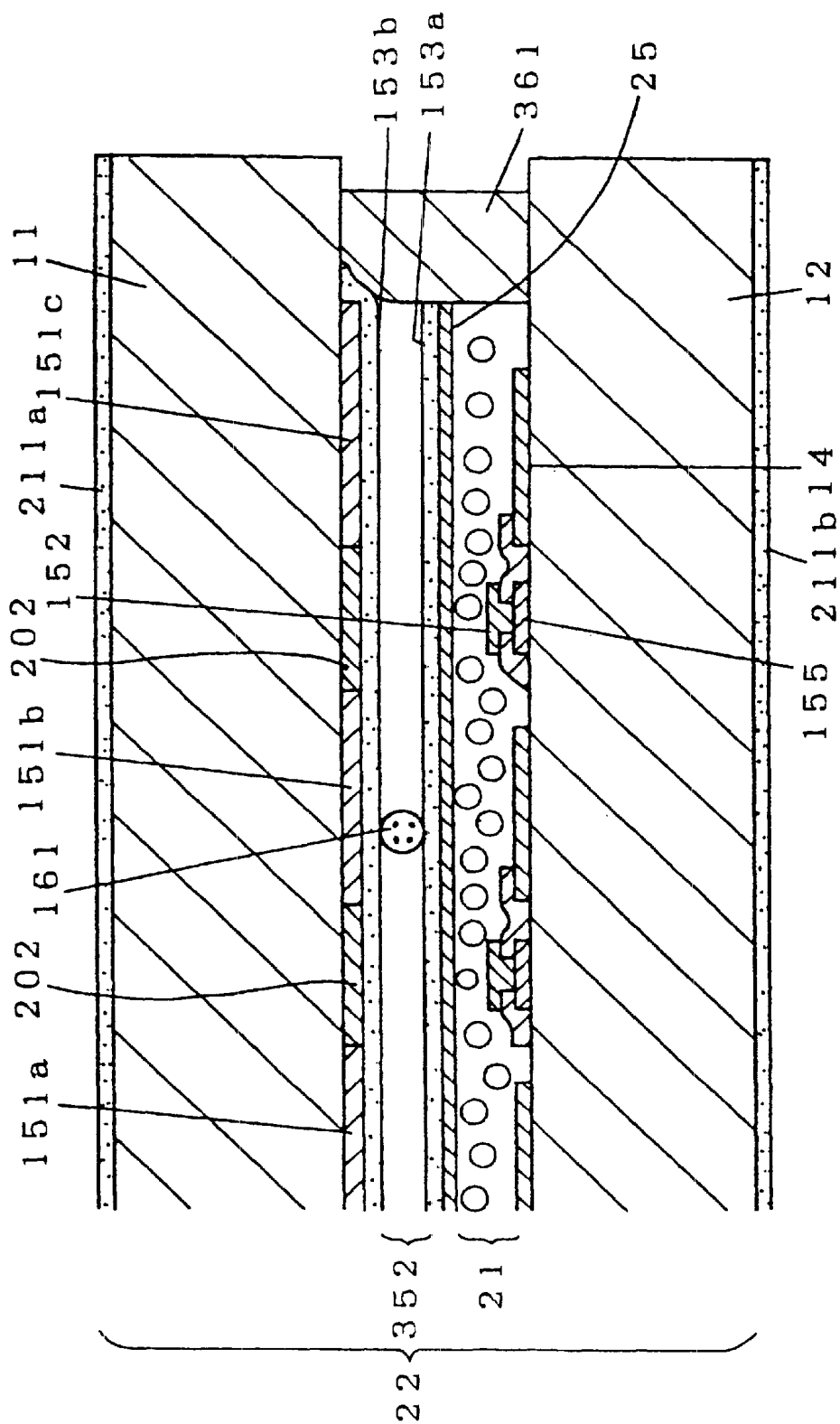
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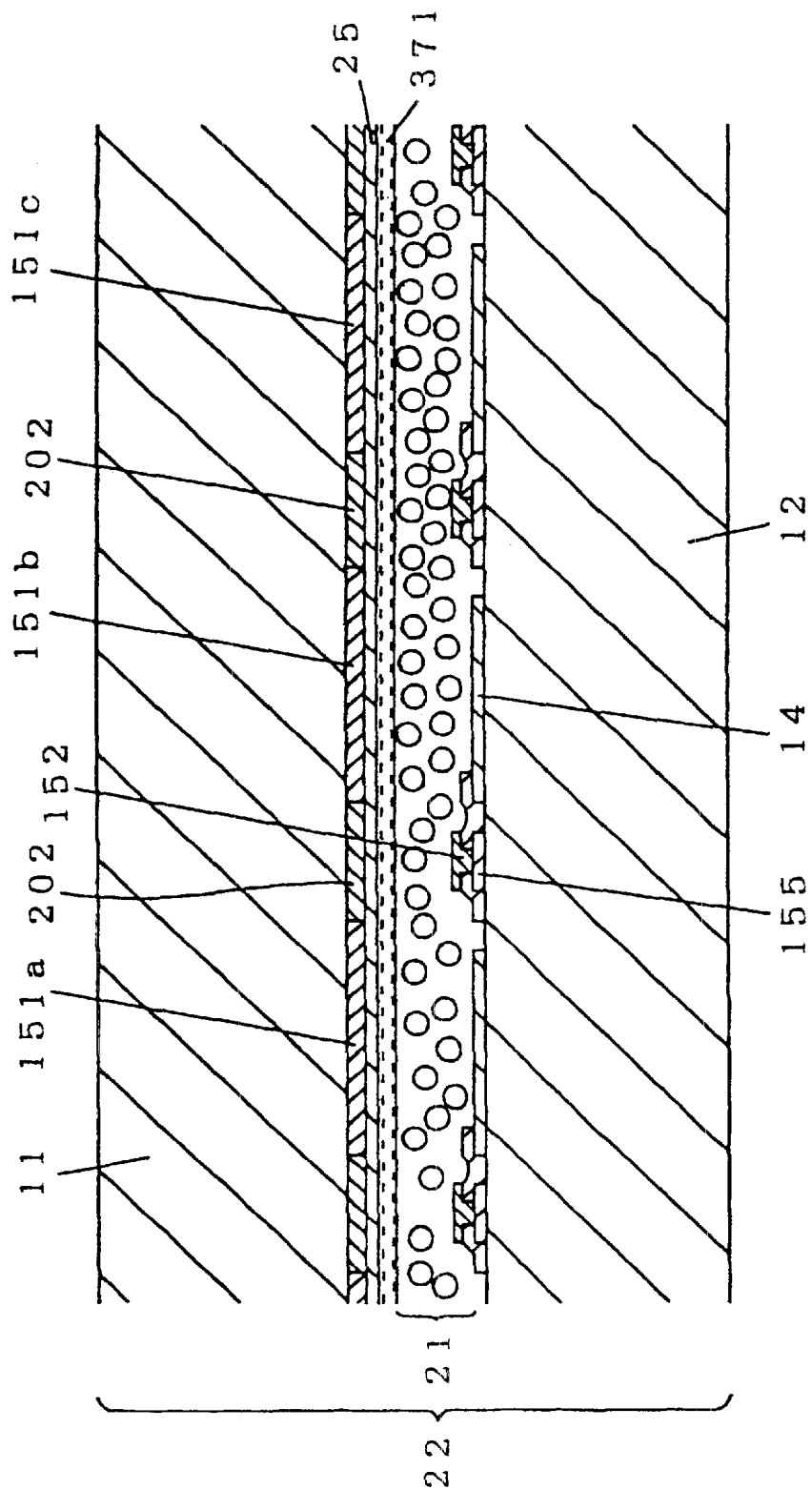
Fig. 38

14a : REFLECTING ELECTRODE   382 : CONNECTING PORTION

381 : LIGHT ABSORBING FILM

F i g. 3 9 (a)

ULTRAVIOLET RAYS

182

}315

14

155   12

F i g. 3 9 (b)

}21

14

155   12

F i g. 3 9 (c)

161 202 151 11

25

}21

14

155   12

F i g. 3 9 (d)

161 202 151 11

25

371

}21

14

155   12
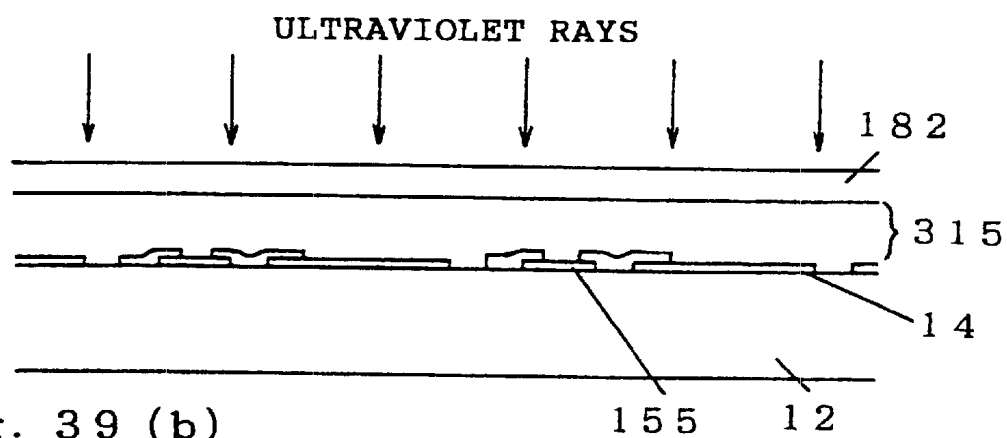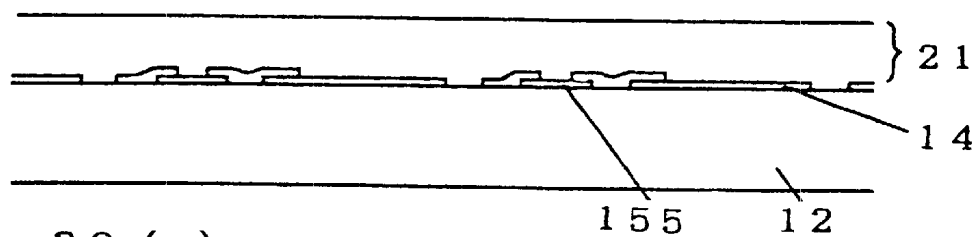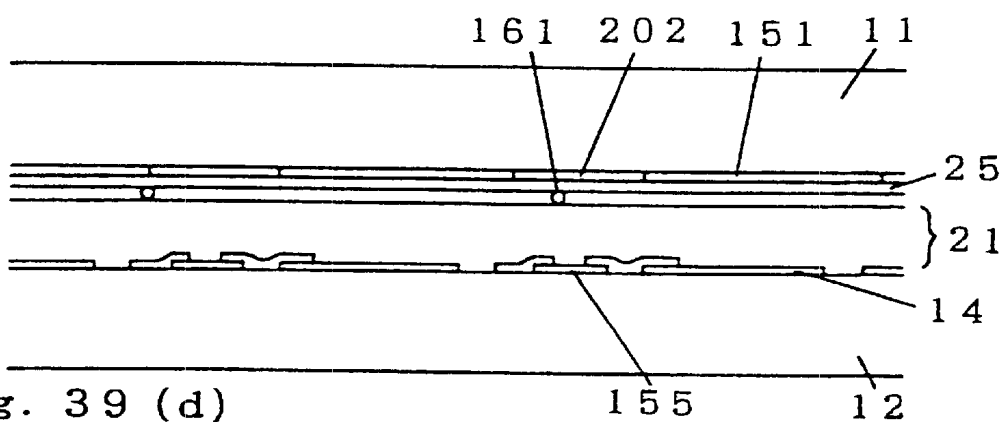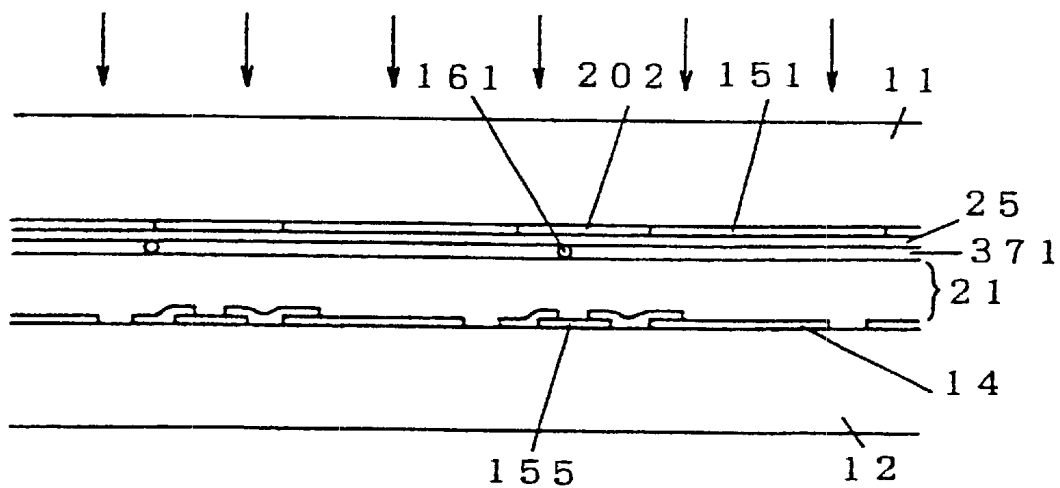
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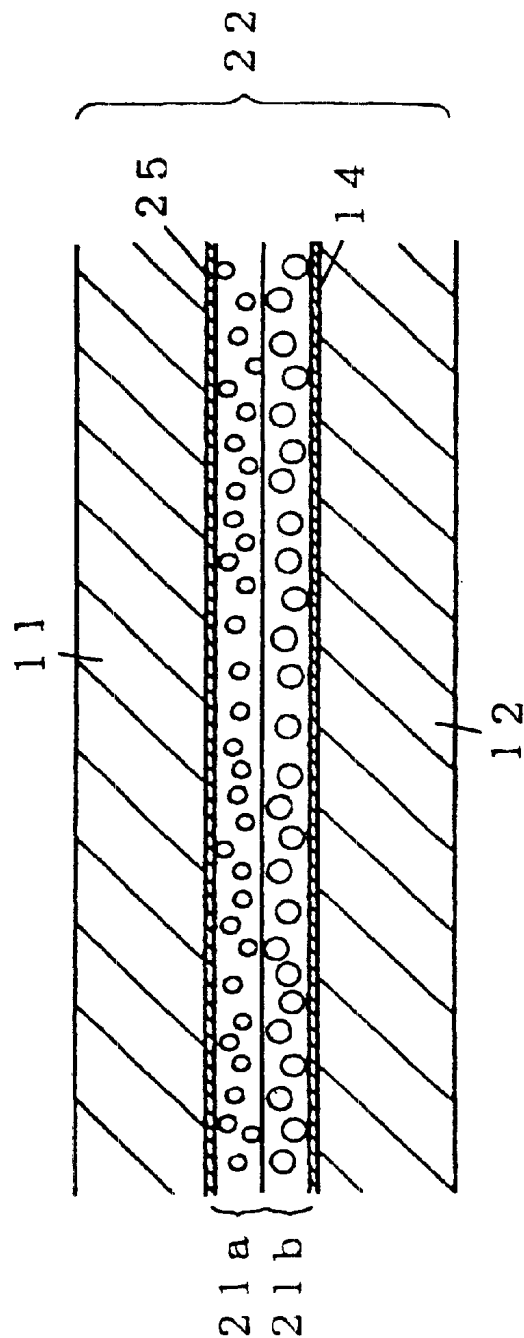
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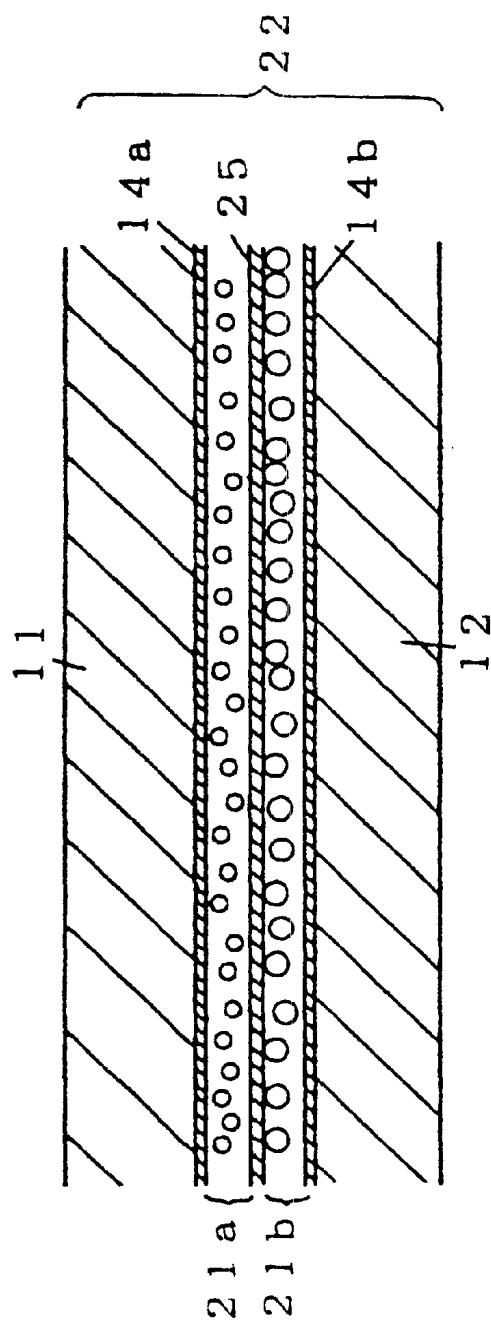
Fig. 42

421: STRIPE ELECTRODE

Fig. 43

Fig. 44

Fig. 45

Fig. 46

21b

21a

212

382

155

152

212

12

14

11

25

21b

21a

Fig. 47

471 : METAL WIRE

472 : GATE SIGNAL LINE
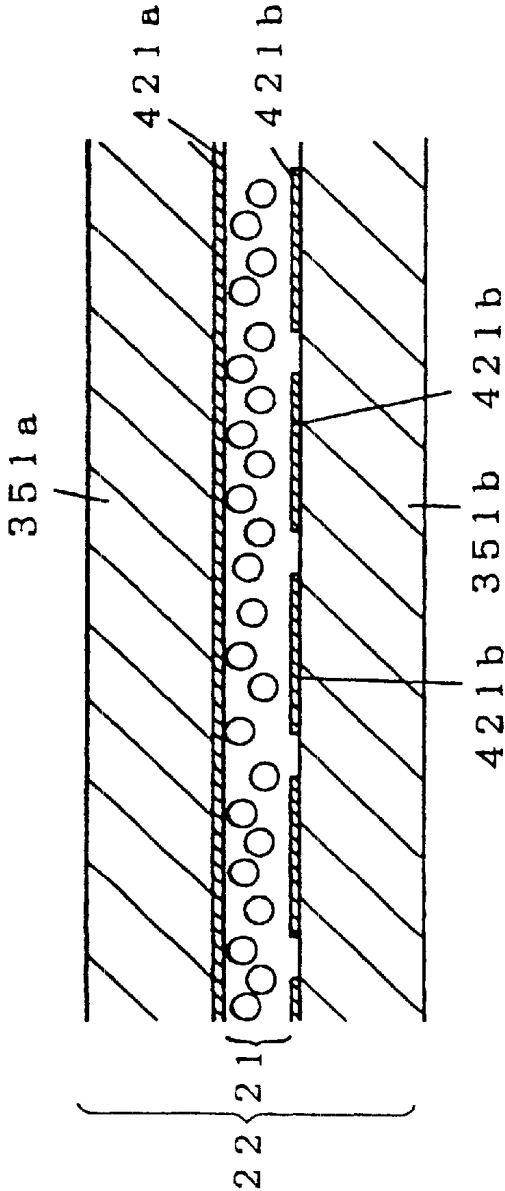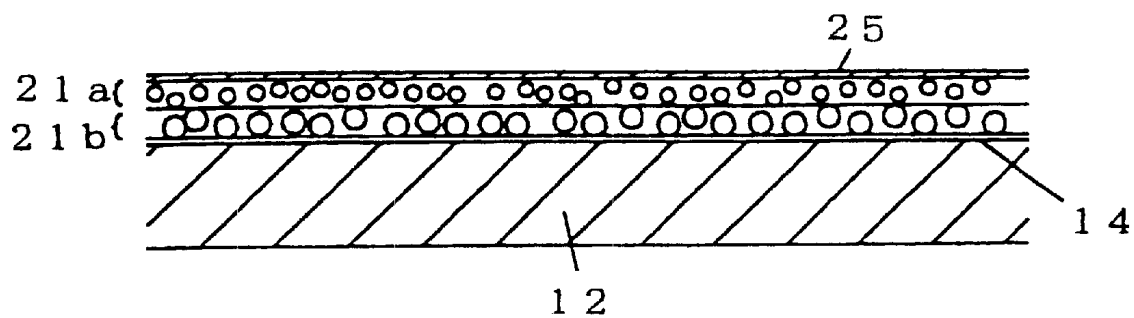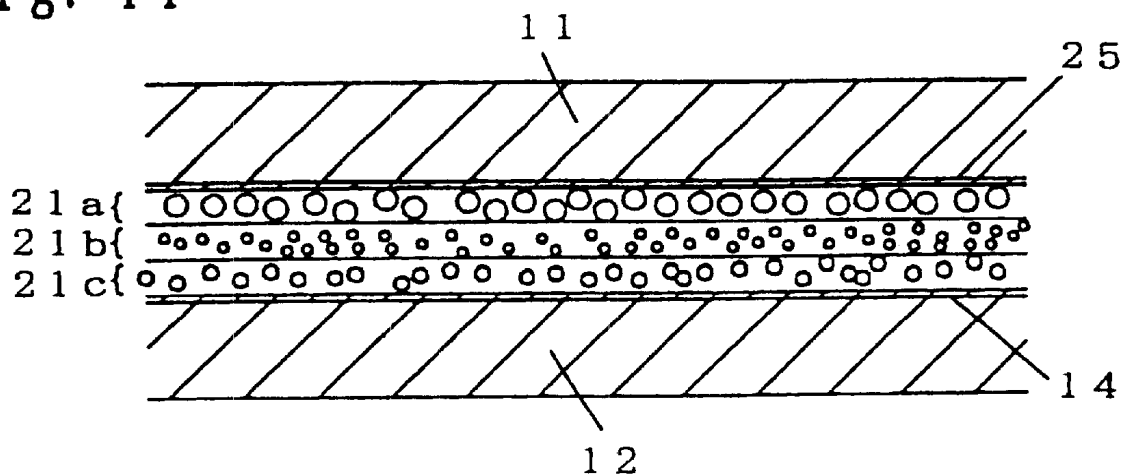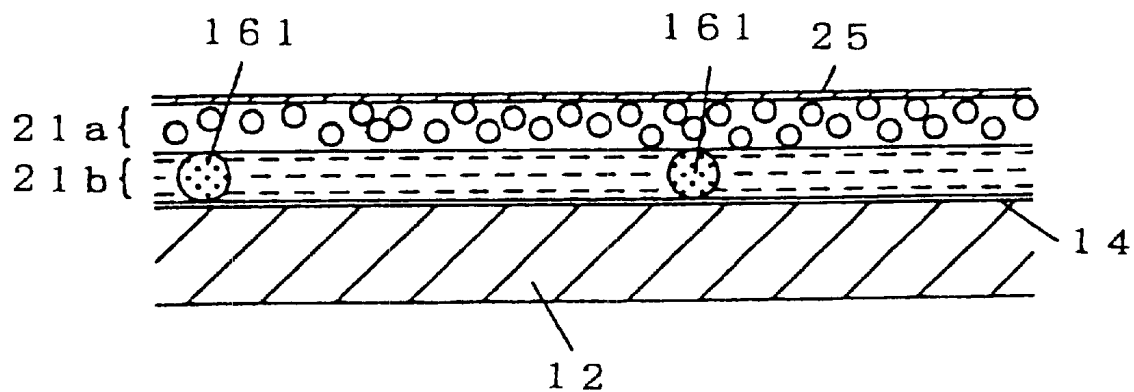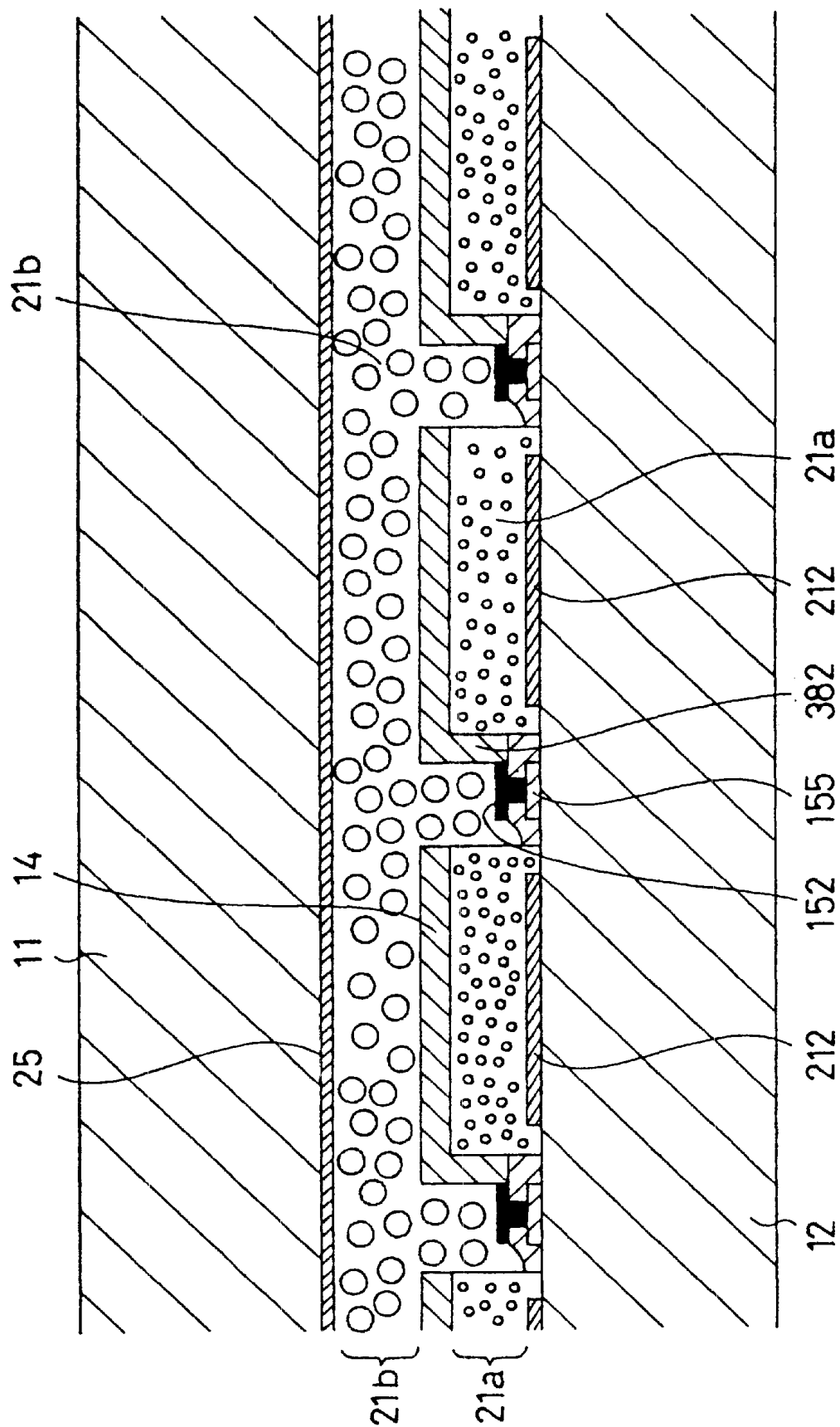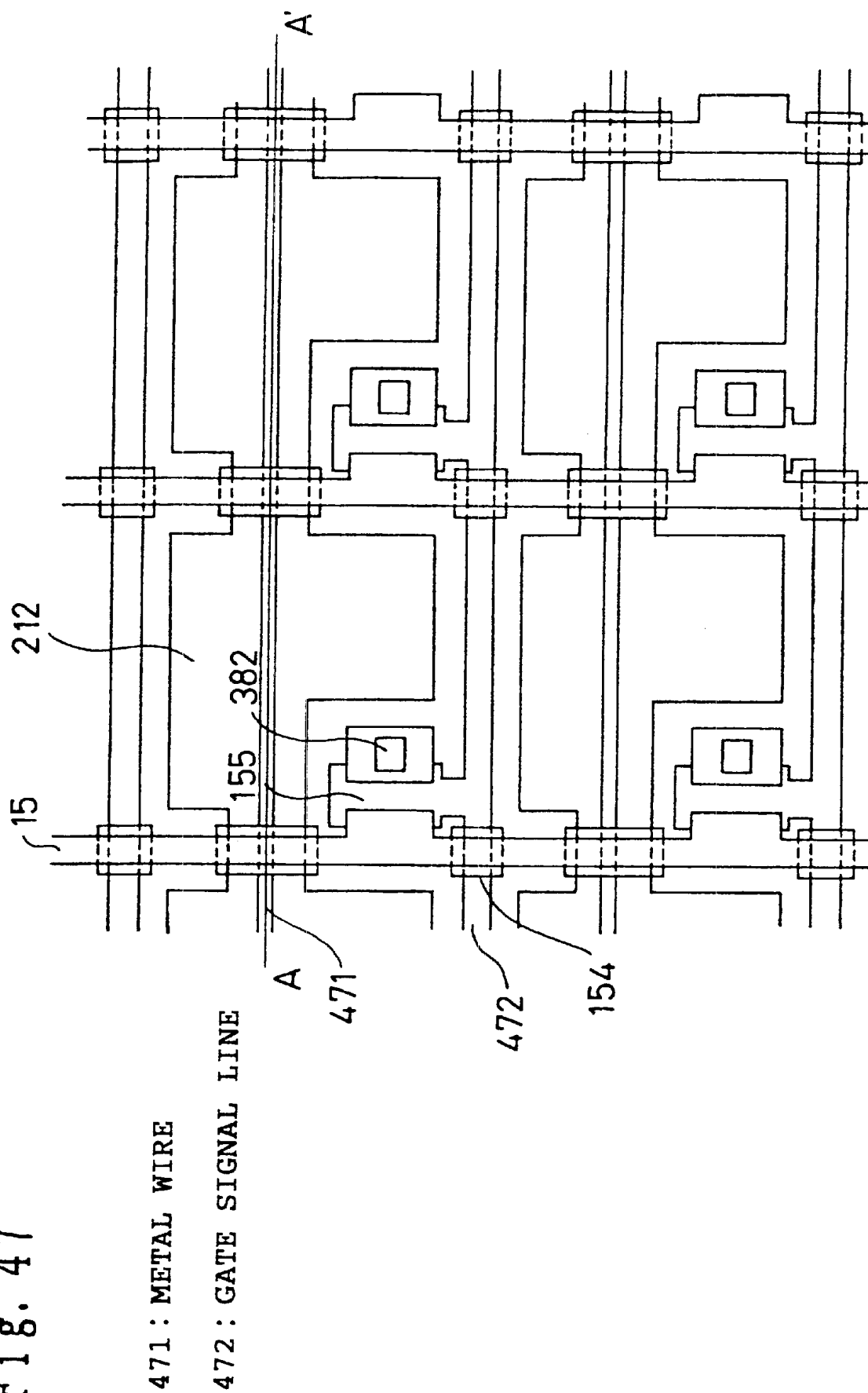
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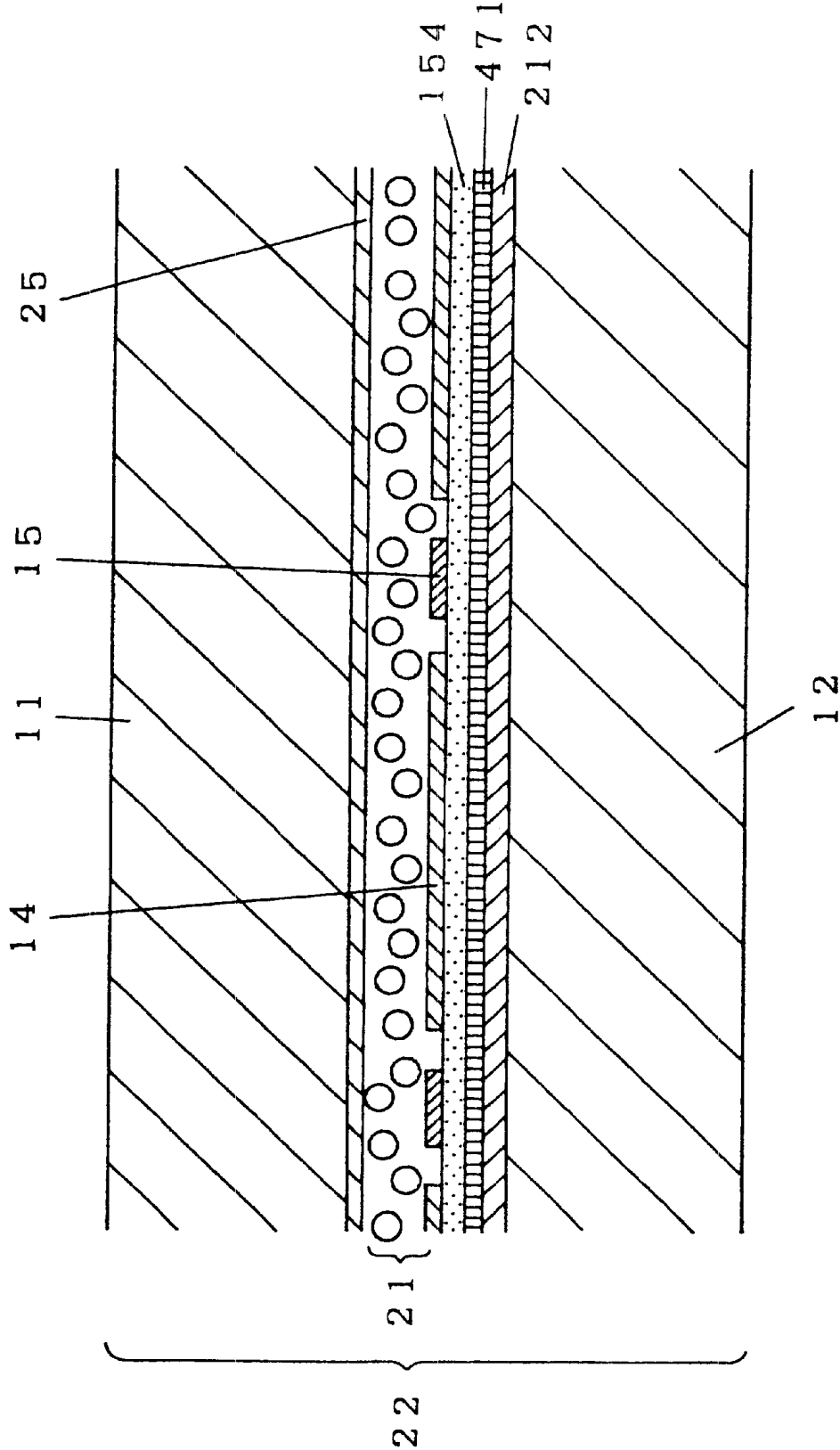
Fig. 49

491 : Y DRIVE CIRCUIT

492 : X DRIVE CIRCUIT
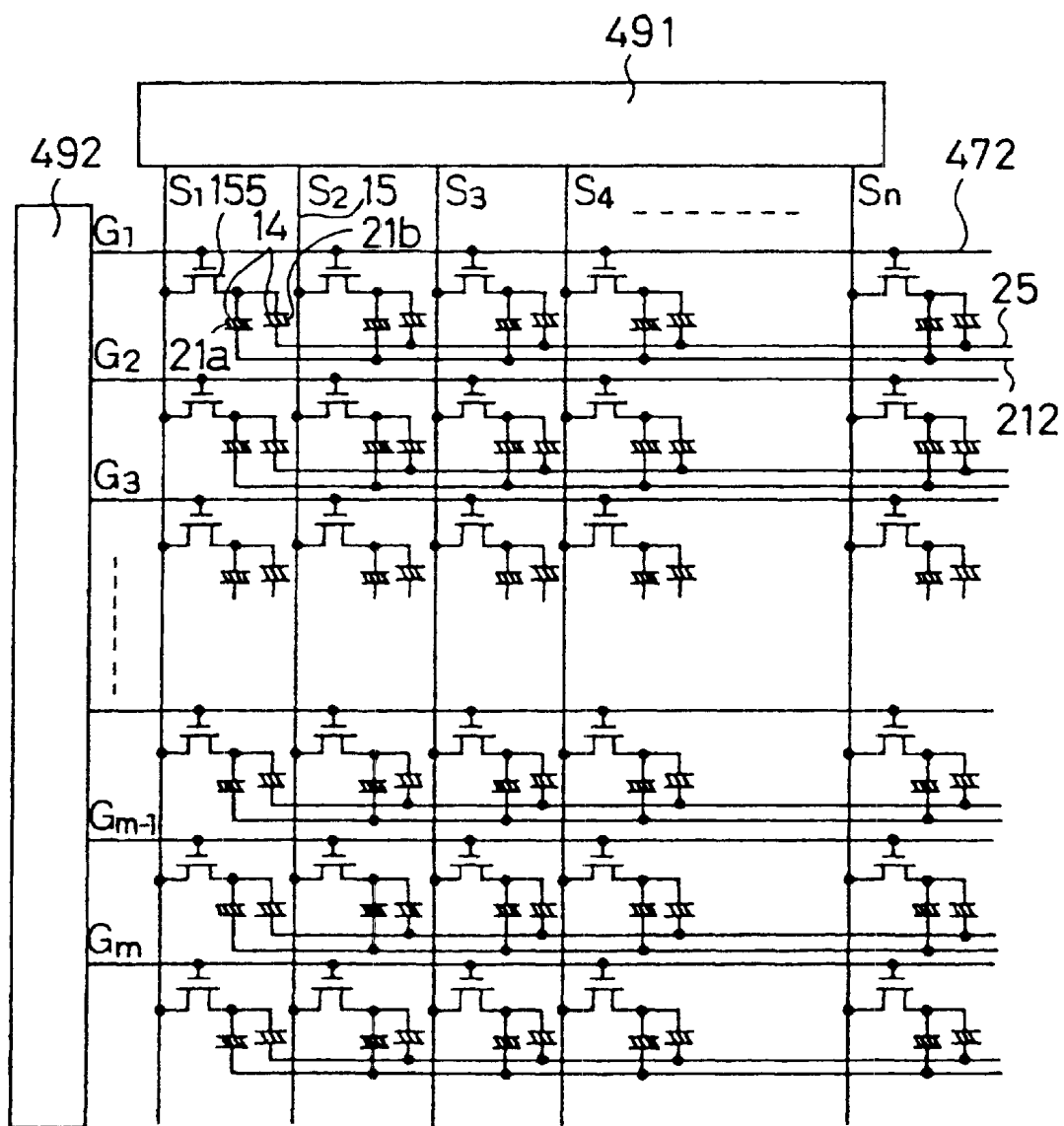
Fig. 50
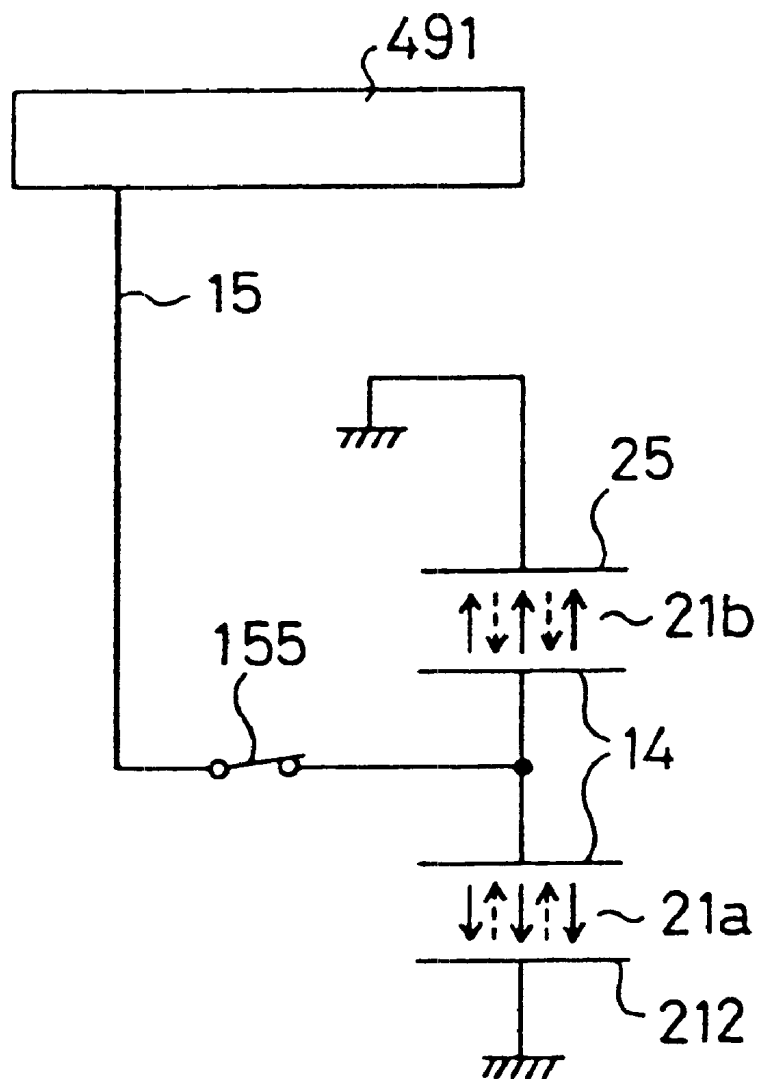
Fig. 51 (a)
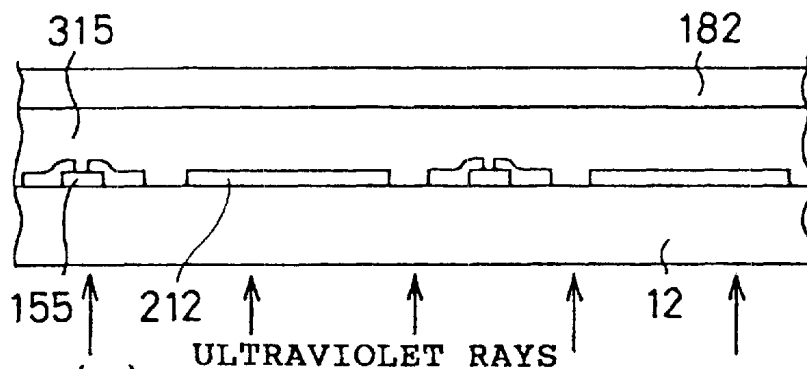
315   182

155   212   12

ULTRAVIOLET RAYS

Fig. 51 (b)

21a

A   B

155   212   12

Fig. 51 (c)

382   14   21a

155   212   155   12

Fig. 51 (d)

ULTRAVIOLET RAYS

11

25

21b

14

382

155   212   21a   12

Fig. 52

15b   14b   12b

21b{
21a{

                                                              25

15a   14a   12a

Fig. 53 (a)

15   14

12

Fig. 53 (b)

315   161   161

15   14

12

Fig. 53(c)

312

161   182   315

14   15

12

Fig. 53 (d)

161   182

14   15   } 21

12

Fig. 54

541: DRIVER CIRCUIT

542: LIGHT SHIELDING FILM

Fig. 55

Fig. 56

571: SPACE
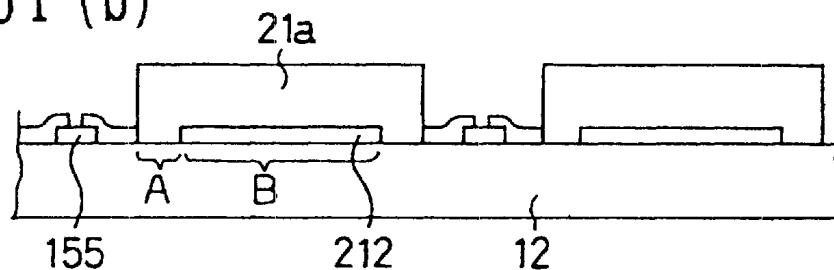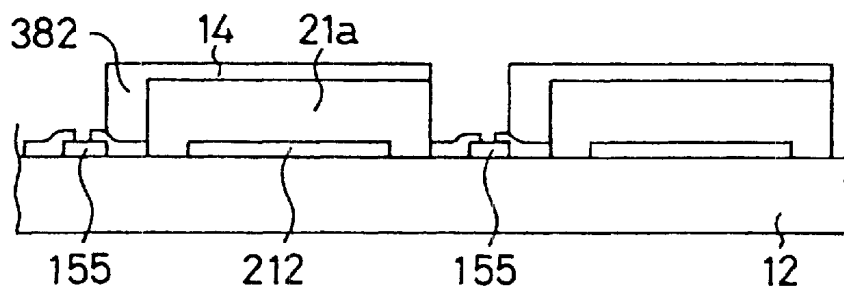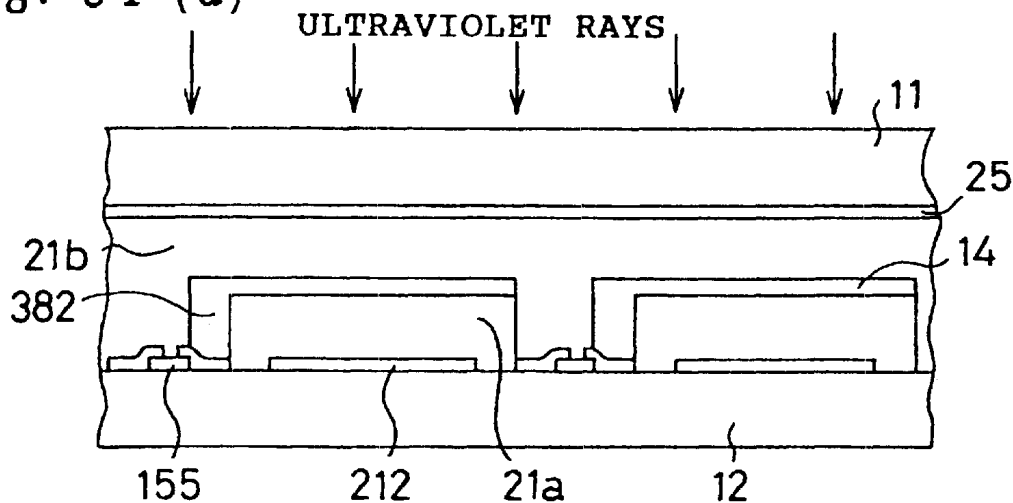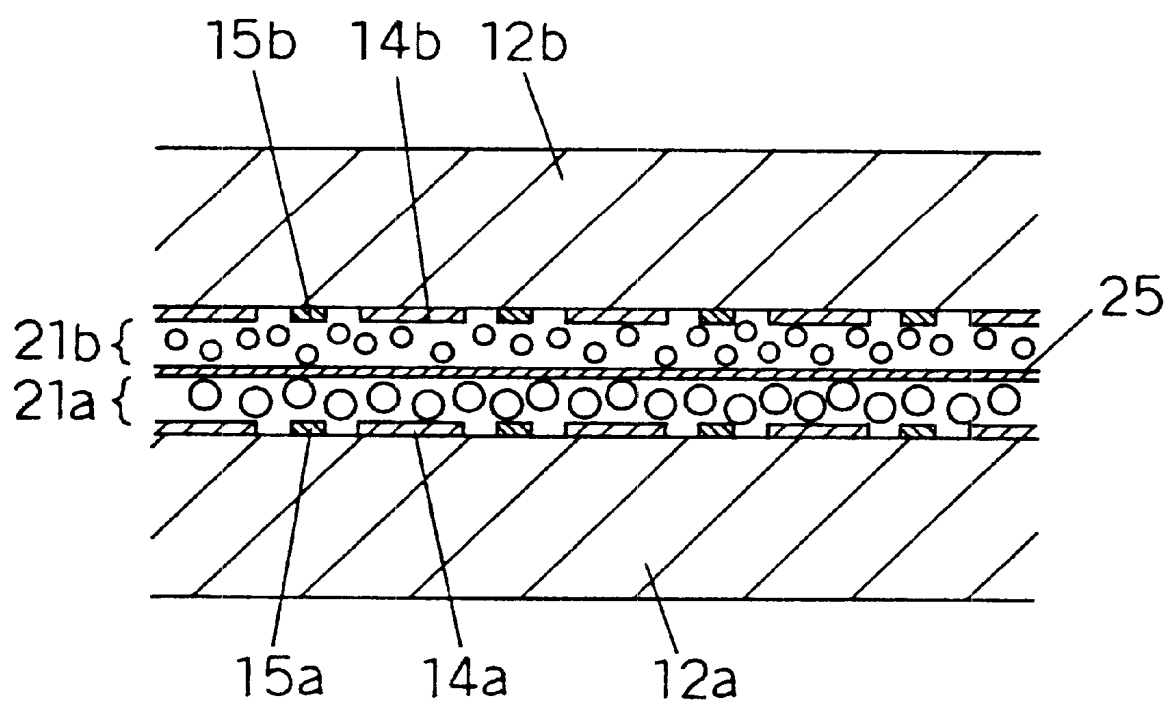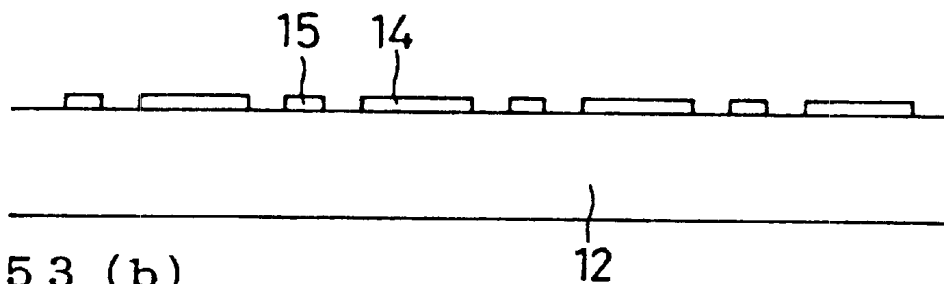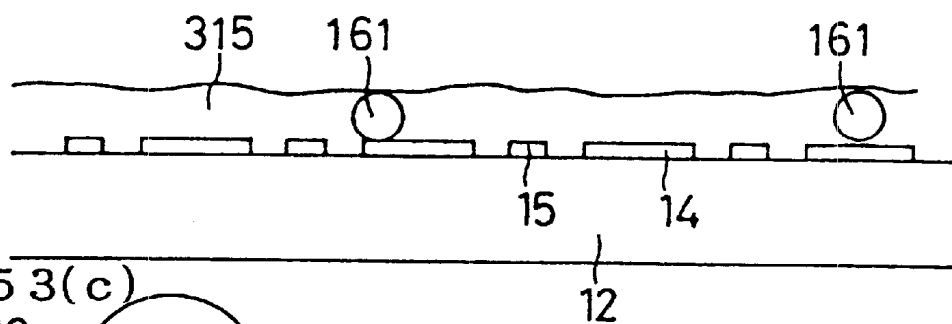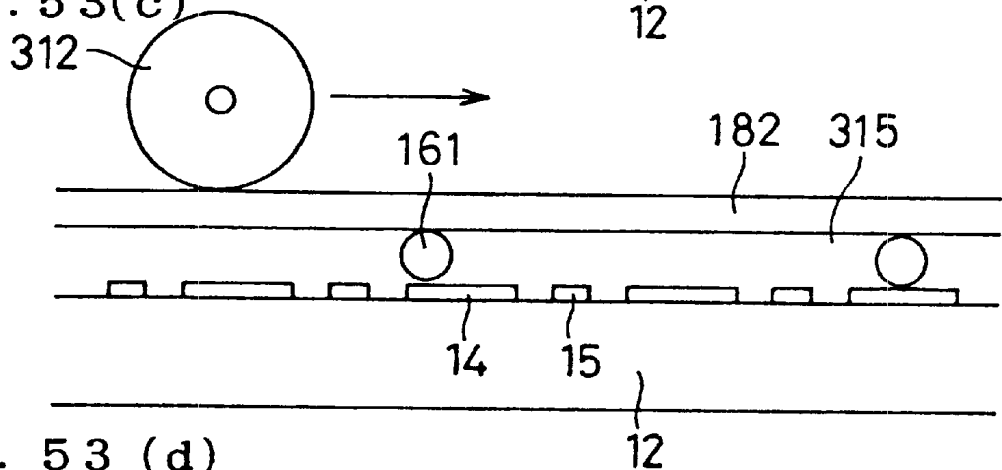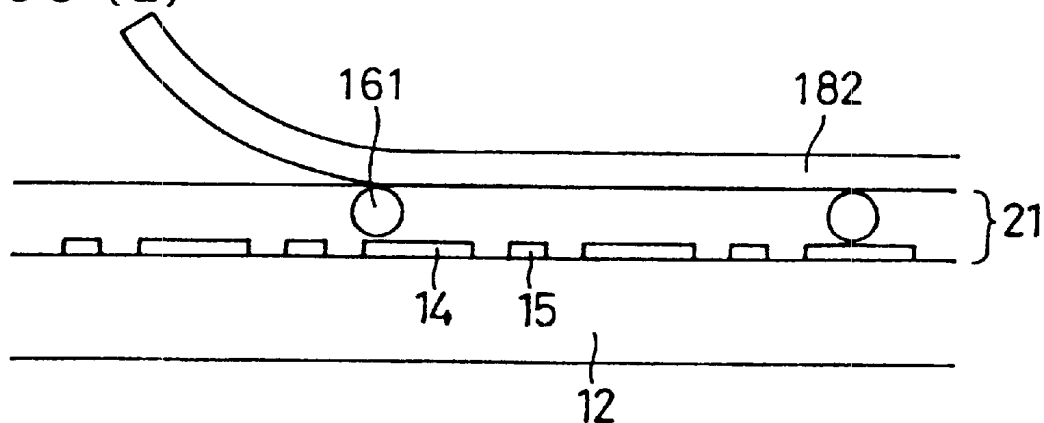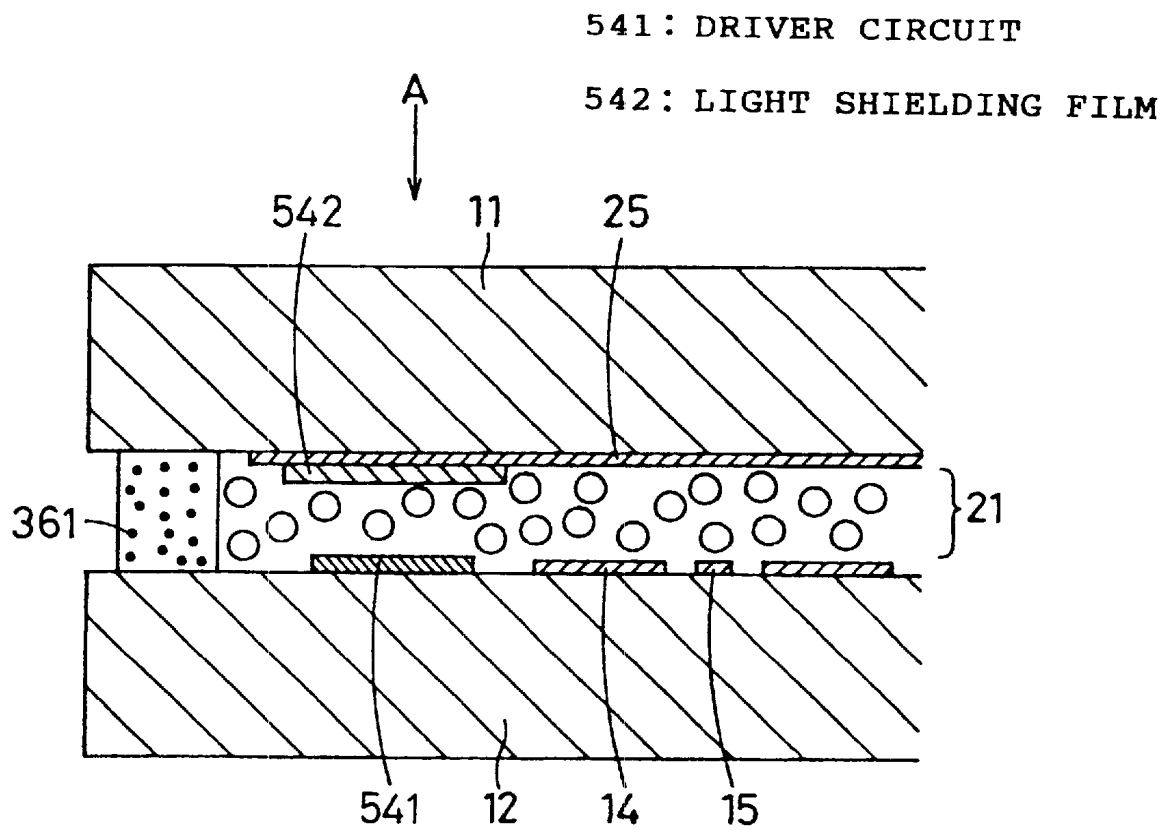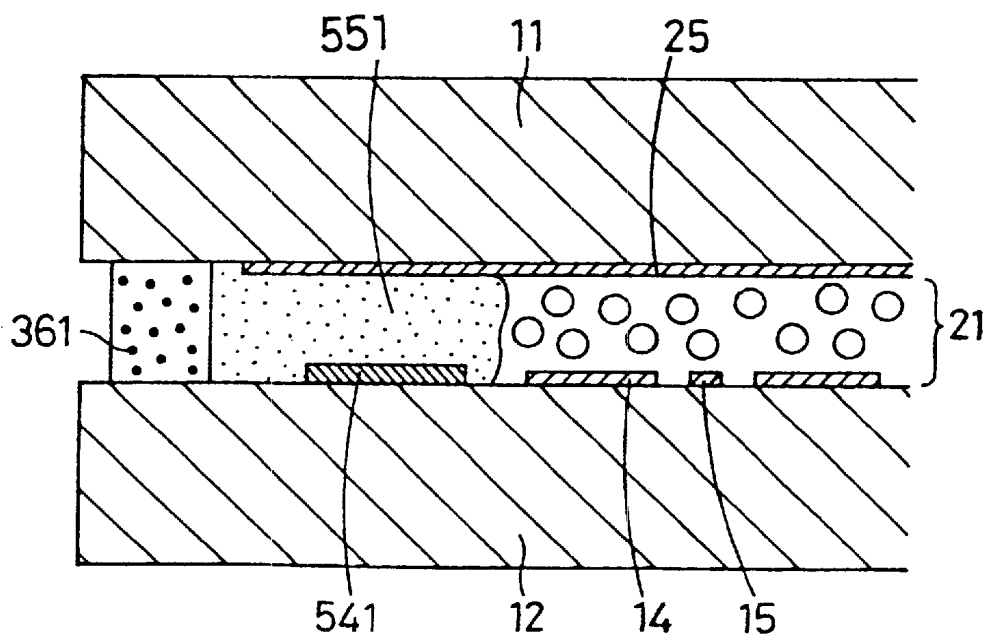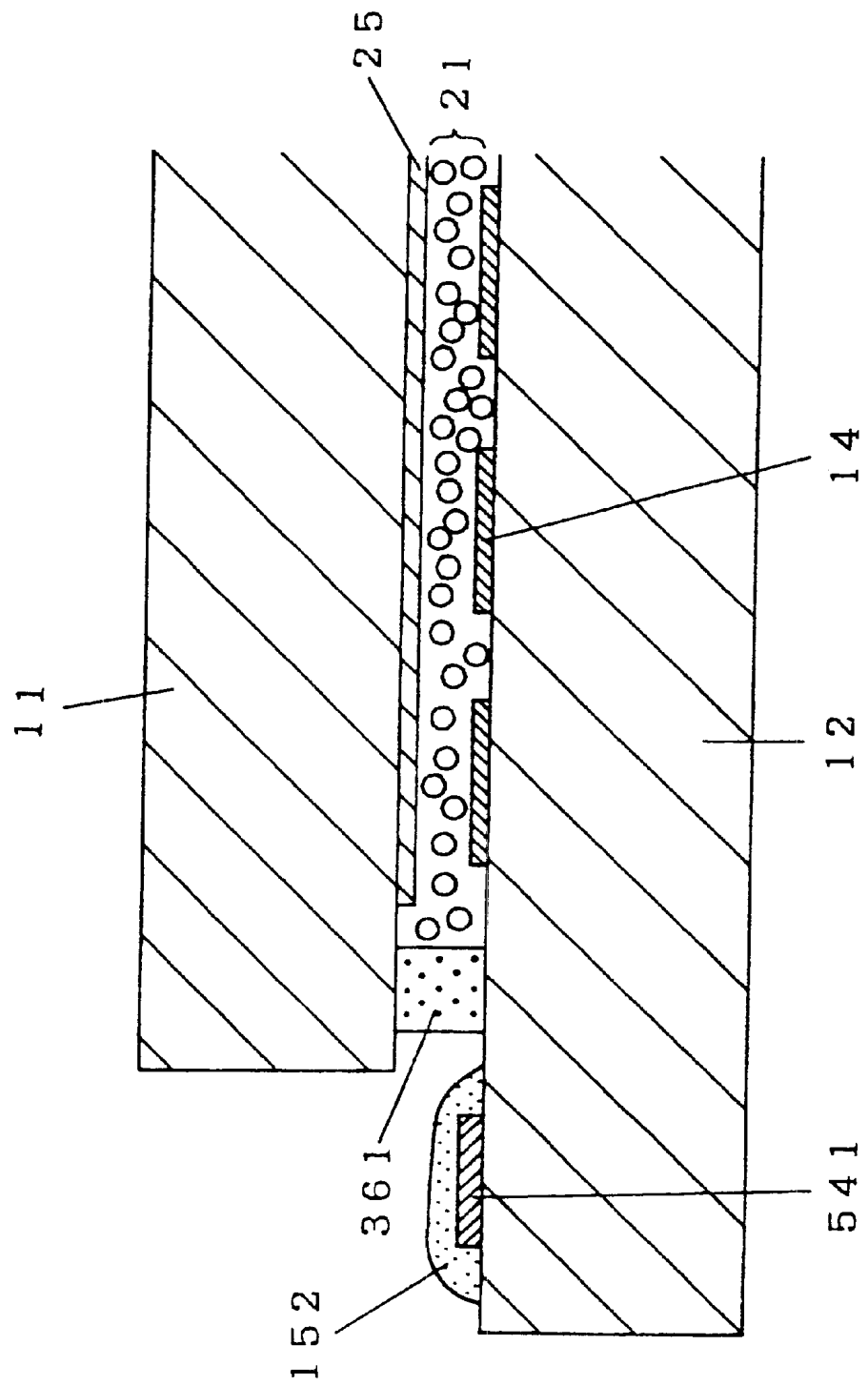
Fig. 57
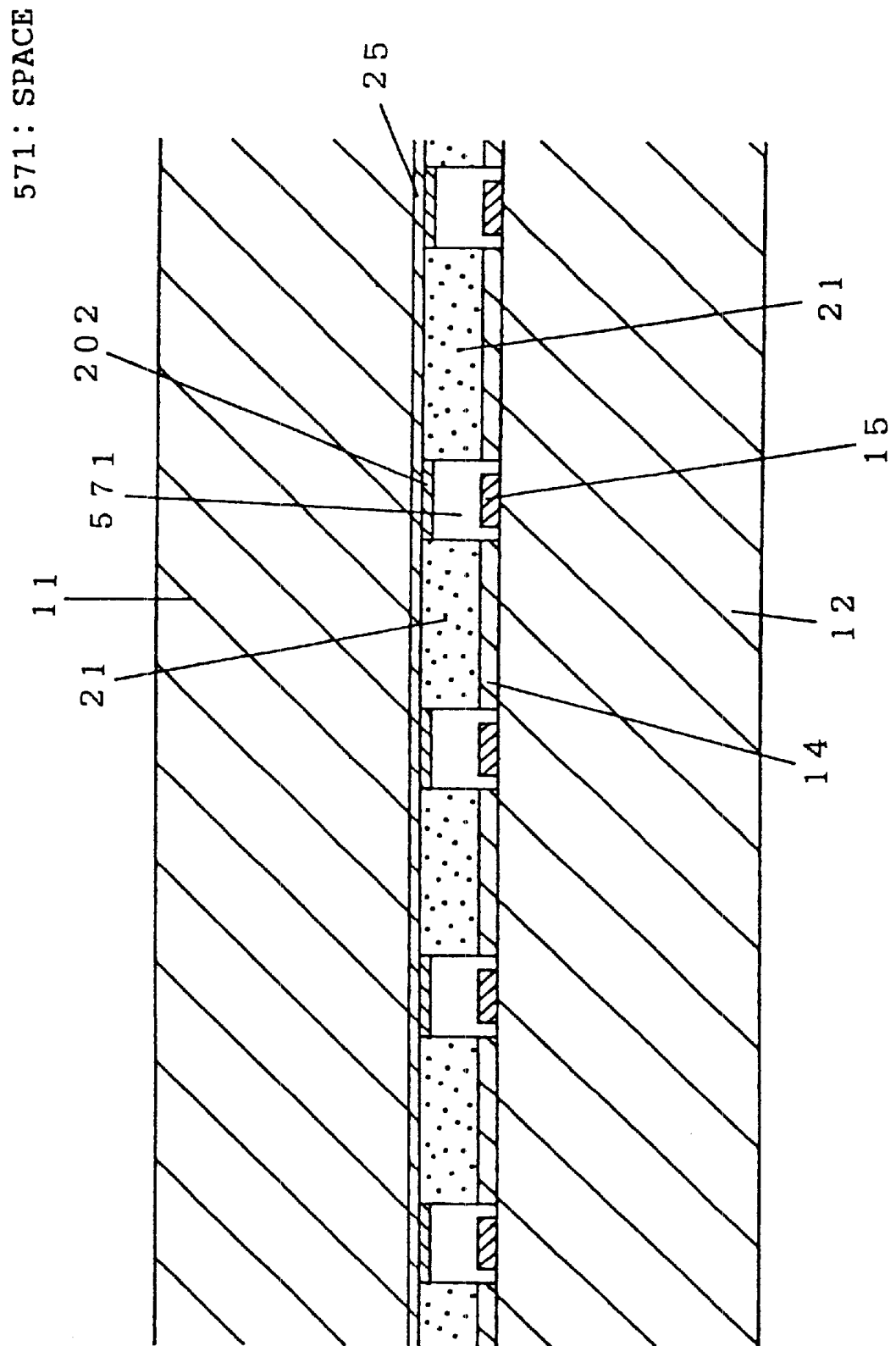
Fig. 58

19 : ELECTRIC FORCE LINE
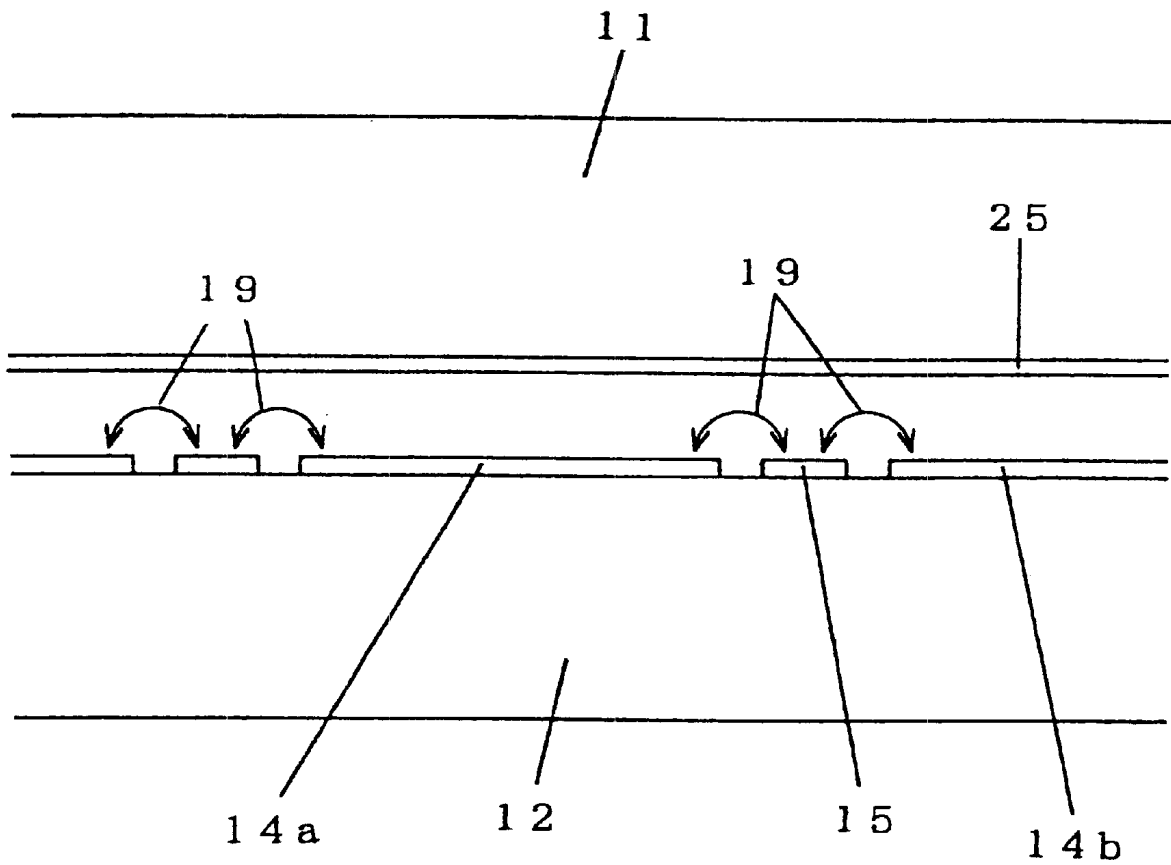
F i g. 5 9 (a)

202: LIGHT SHIELDING PATTERN

ULTRAVIOLET RAYS

183
161 202 181

} 3 1 5

1 2   1 4   1 5

F i g. 5 9 (b)

1 6 1   3 1 5   2 1   3 1 5   2 1

A   B   A

1 2   1 4   1 5

F i g. 5 9 (c)

1 6 1   2 1   2 1

B

1 2   1 4   1 5

F i g. 5 9 (d)

1 6 1   1 1   2 1

2 5

1 2   1 4   **571**   1 5   2 0 2
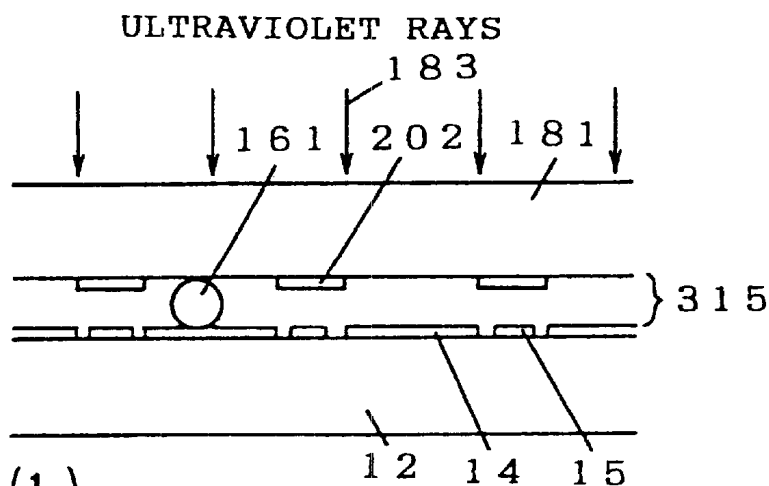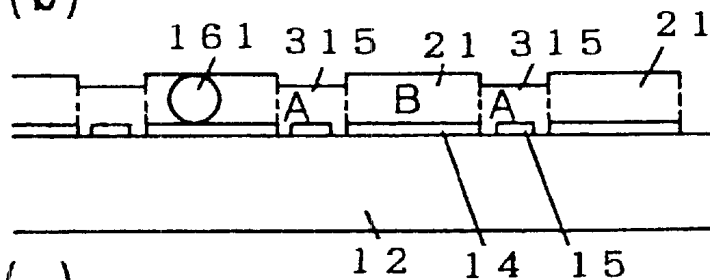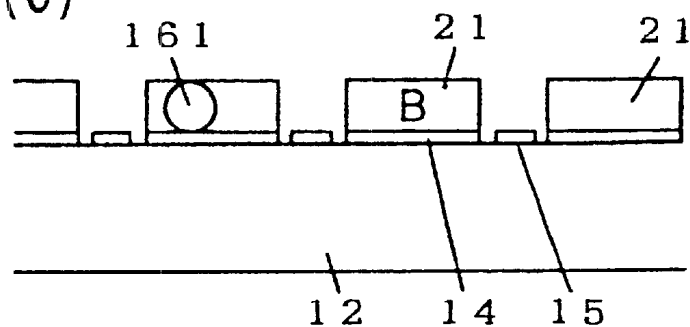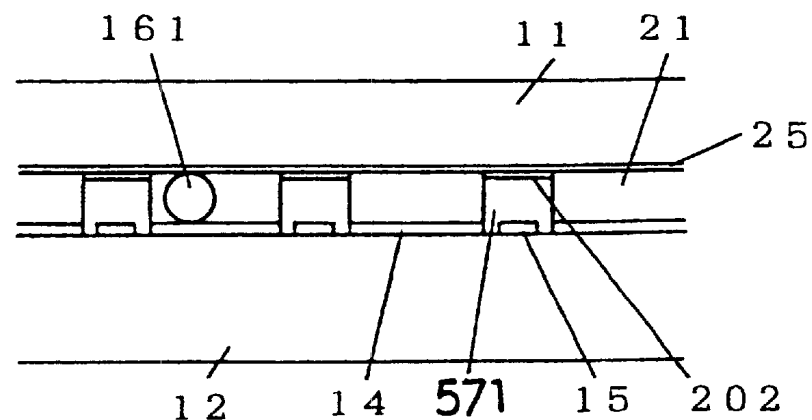
Fig. 60

Fig. 61

Fig. 62

F i g. 6 3 (a)

ULTRAVIOLET RAYS   183c   181

315a

202a   202a

14c   14b   15   12   14a

F i g. 6 3 (b)

14b   21c   15

12

F i g. 6 3 (c) ULTRAVIOLET RAYS

21c   315b 183b   181

202b   202b

315b   14c   14b   12   14a

F i g. 6 3 (d)
14c   15   14a

12

F i g. 6 3 (e)   ULTRAVIOLET 14b
21a   21c   RAYS   21b 183c 21a   183c
11

25

}21

14a

14c   14b   15   12
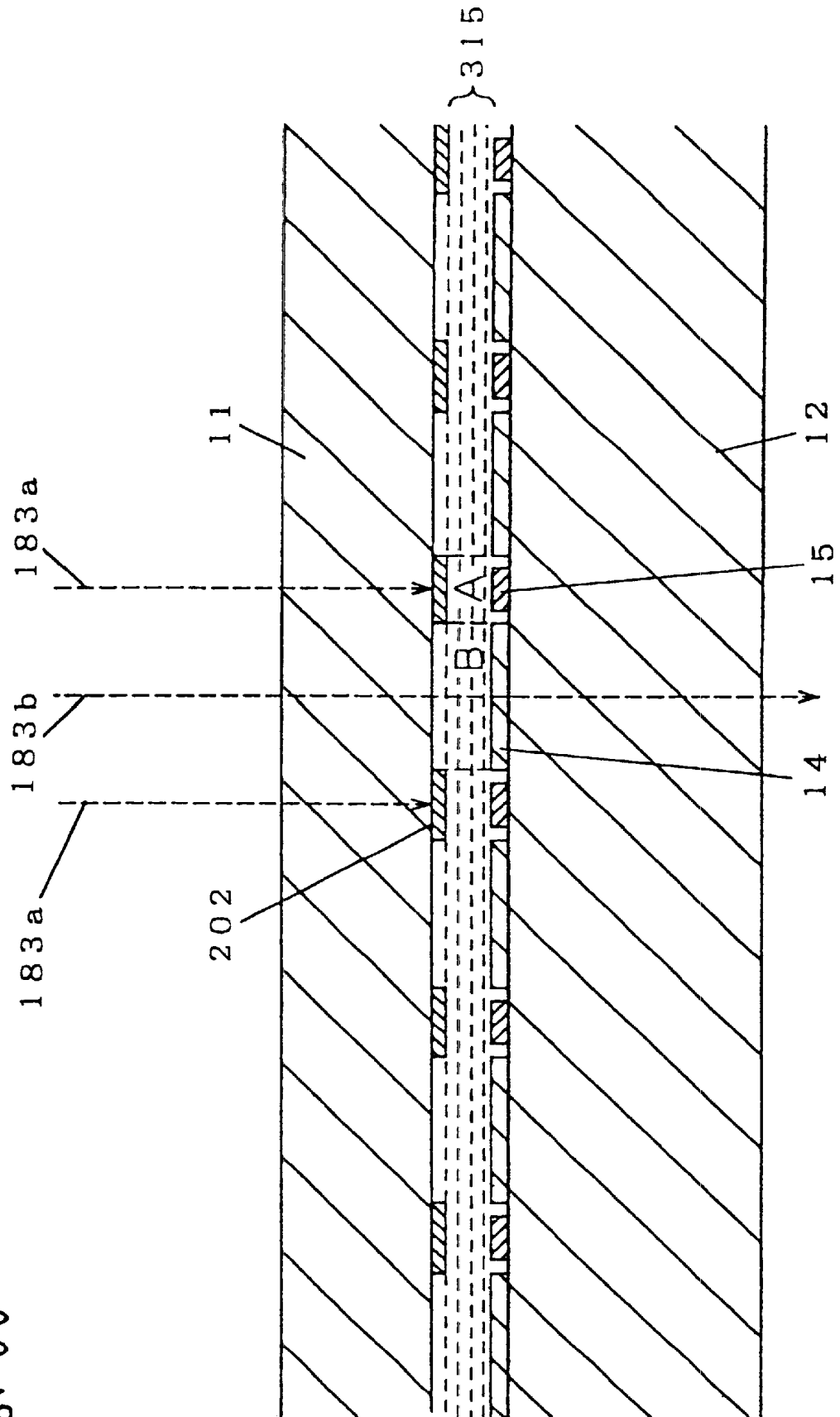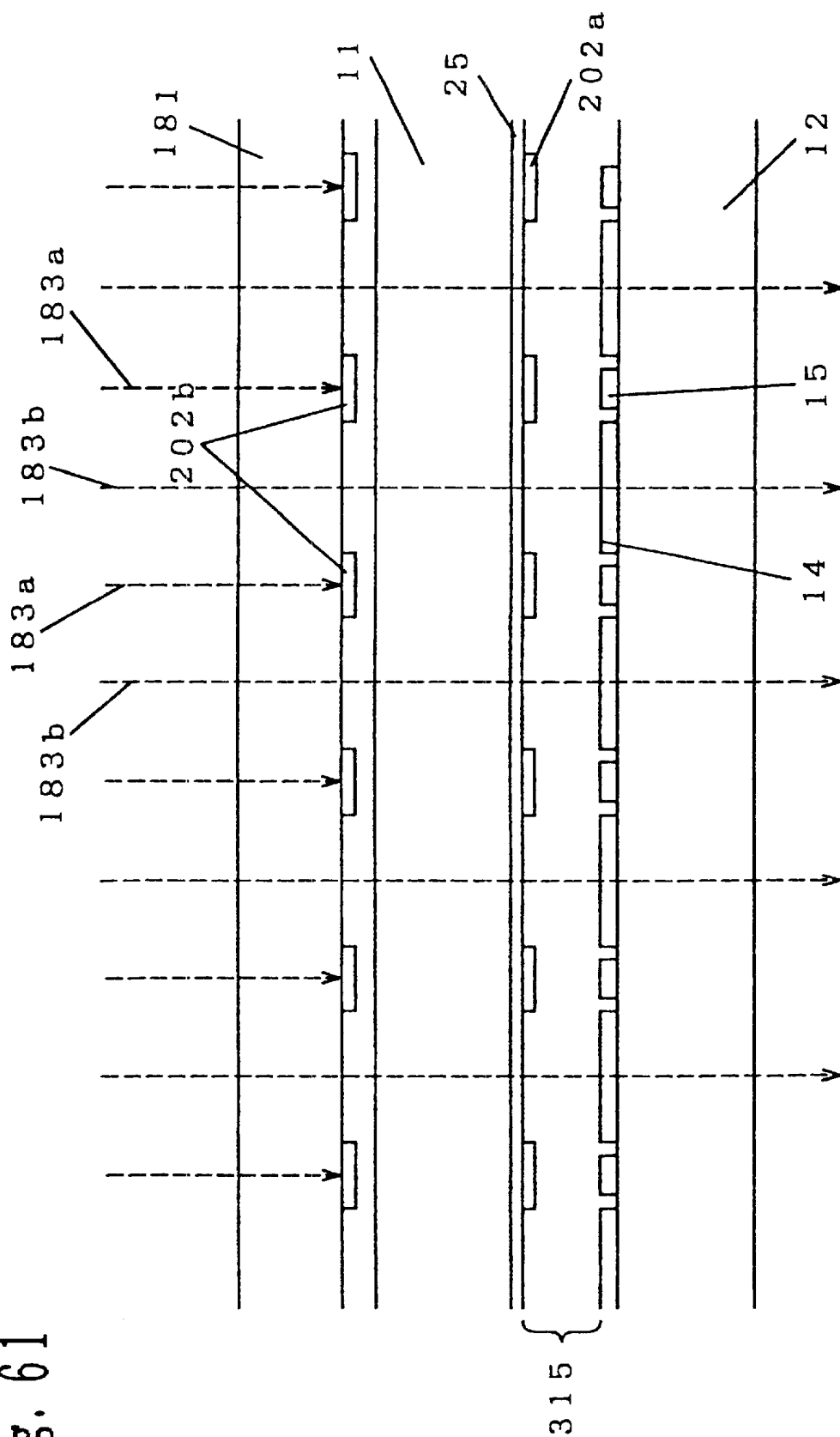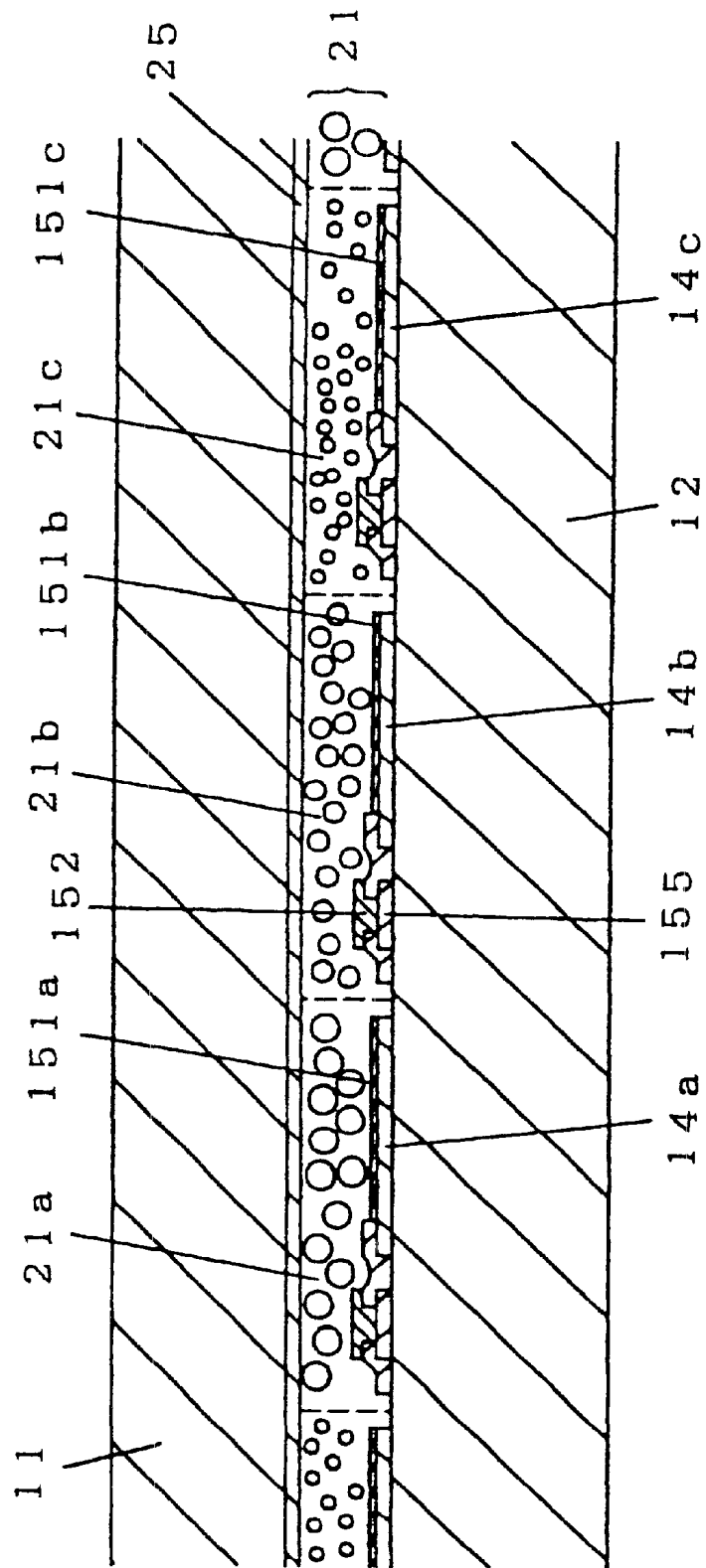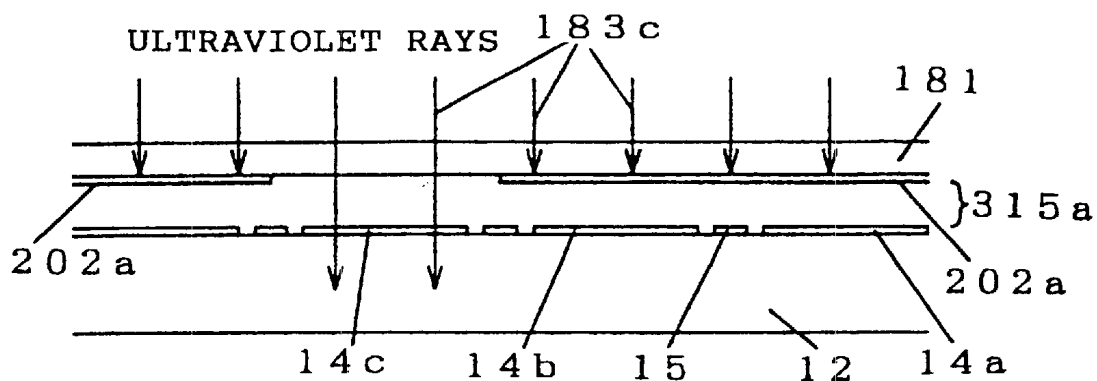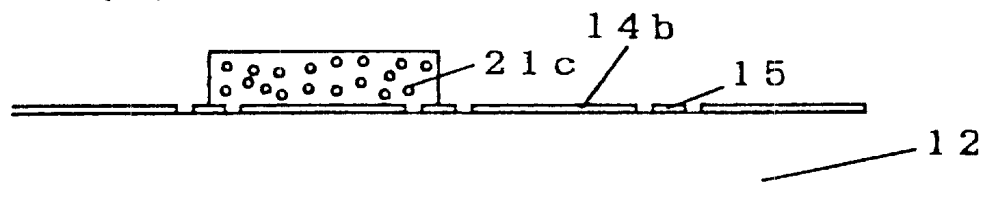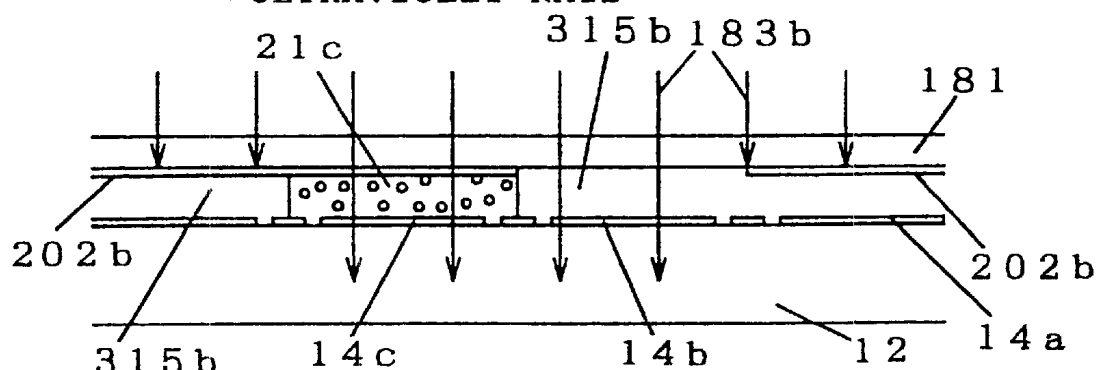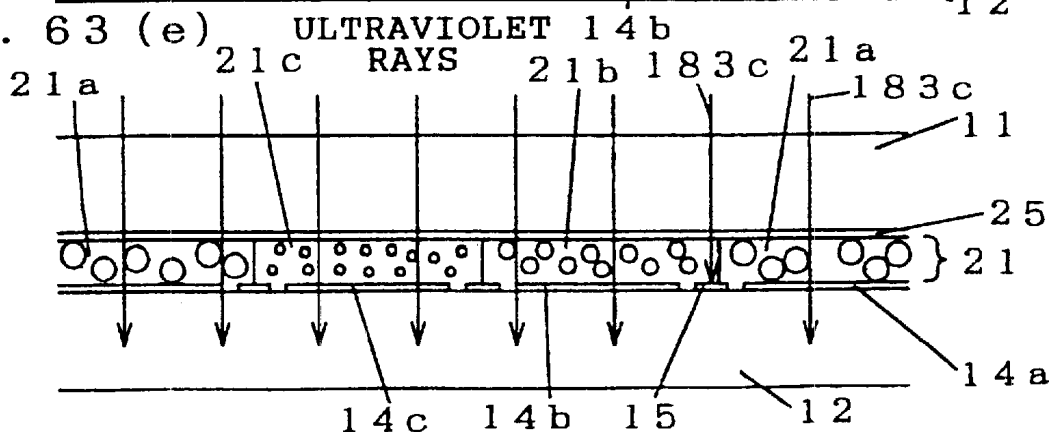
Fig. 64

642: TRANSPARENT SUBSTRATE

641: MICROLENS

Fig. 65
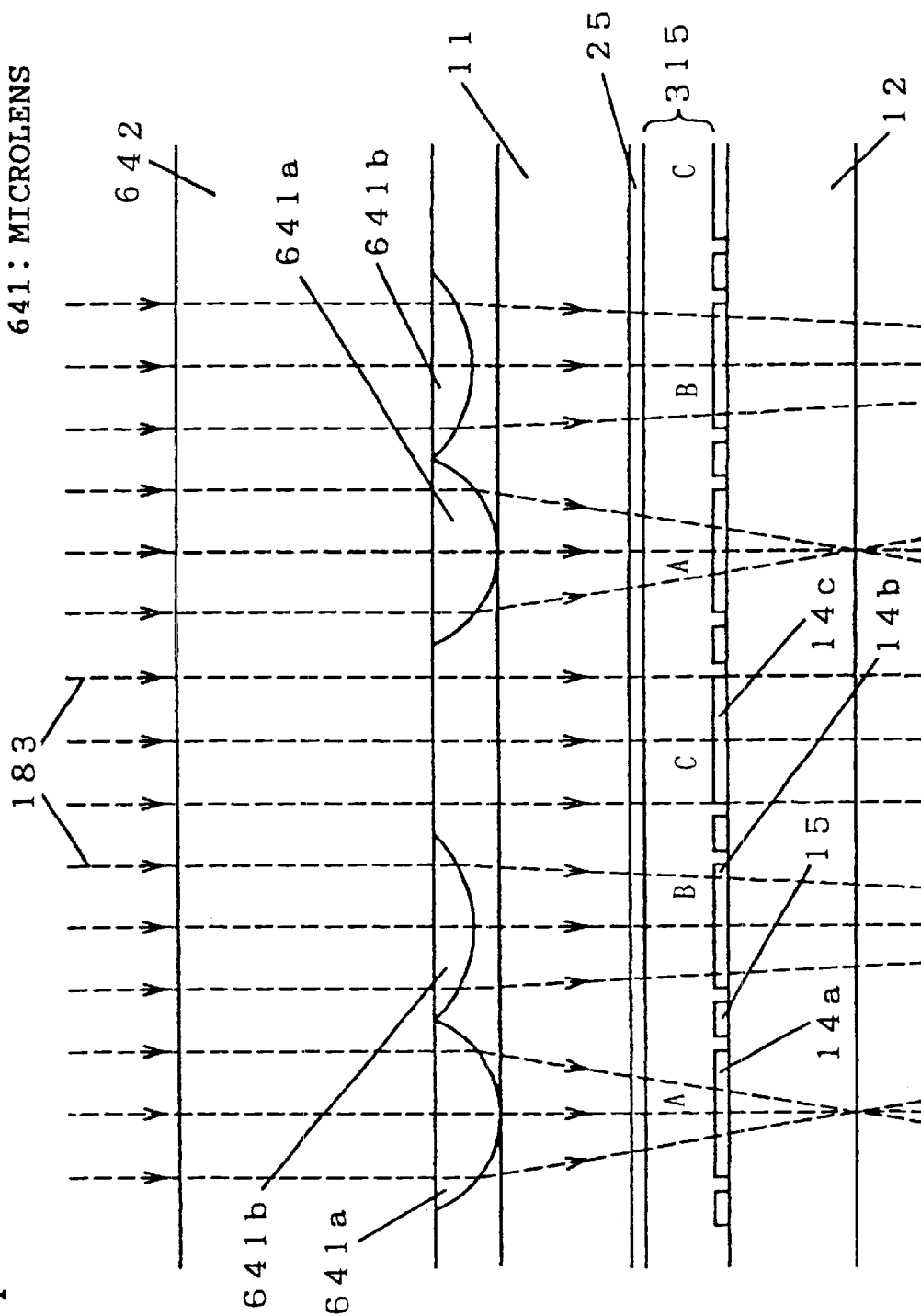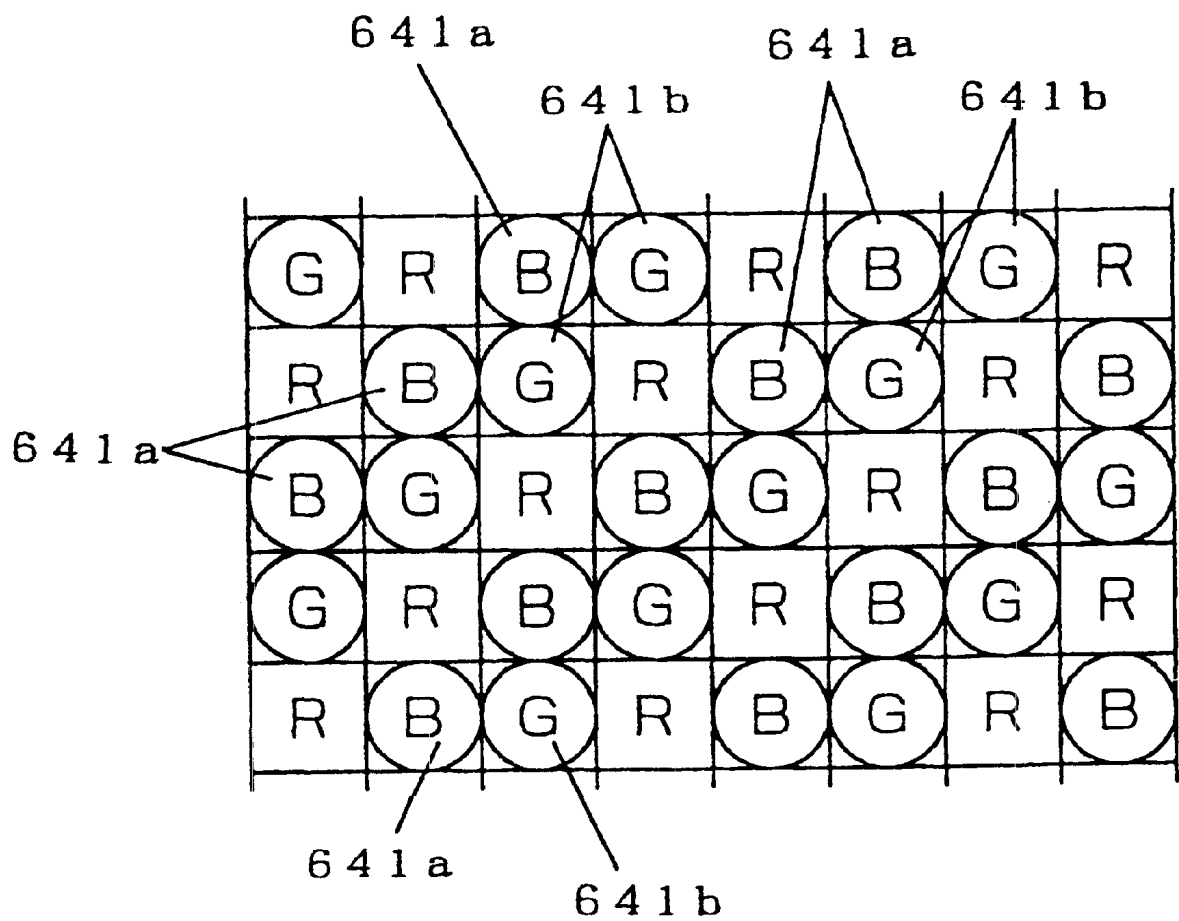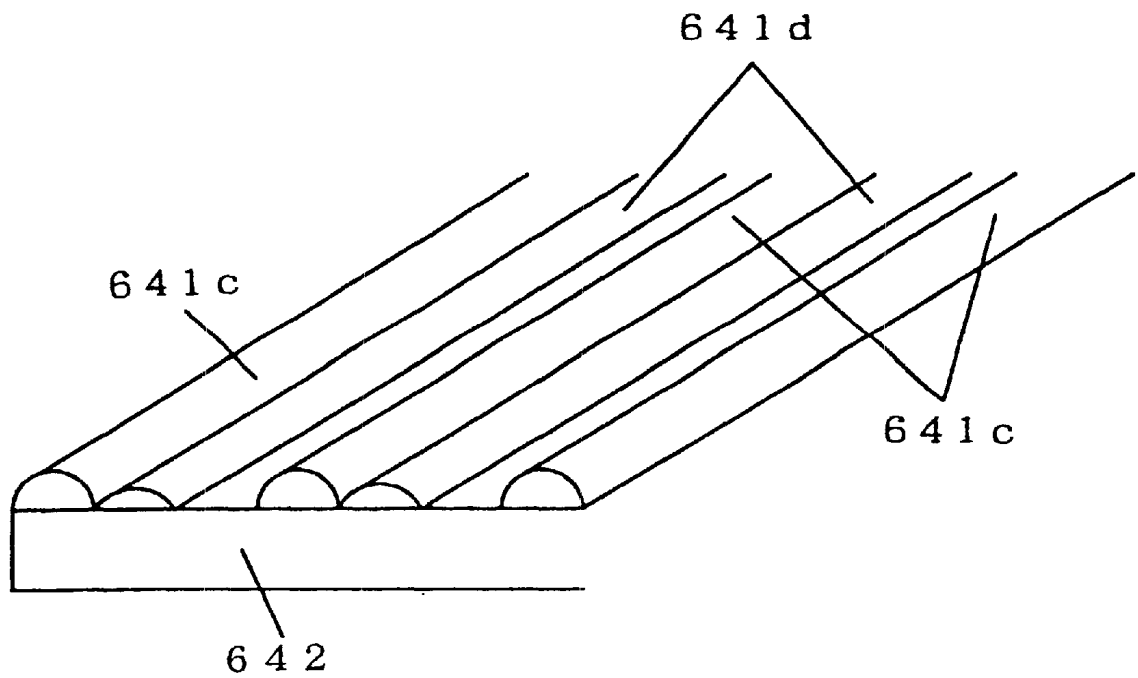
Fig. 66 (a)

641d

641c

641c

642

Fig. 66 (b)

B	G	R	B	G	R	B	G	R
B	G	R	B	G	R	B	G	R
B	G	R	B	G	R	B	G	R
B	G	R	B	G	R	B	G	R
B	G	R	B	G	R	B	G	R
B	G	R	B	G	R	B	G	R

Fig. 67 (a)

671: PRISM

6 4 2

6 7 1

Fig. 67 (b)

6 4 2

6 4 1

Fig. 68 (a)

6 4 2   6 7 1 c   6 7 1 c

6 7 1 a   6 7 1 b   6 7 1 a   6 7 1 b

Fig. 68 (b)

6 4 1 c   6 4 2   6 4 1 c

6 4 1 a   6 4 1 b   6 4 1 a   6 4 1 b

691: LIGHT BINDING AGENT

Fig. 69

642

691

11

202

25

315

183

641

641

641

641

12

14

15

14

Fig. 70

Fig. 71 (a)

OFF STATE

11

25

14

12

21

Fig. 71 (b)

ON STATE

11

25

14

12

21

Fig. 71 (c)

11

25

14

12

21

=

+

711
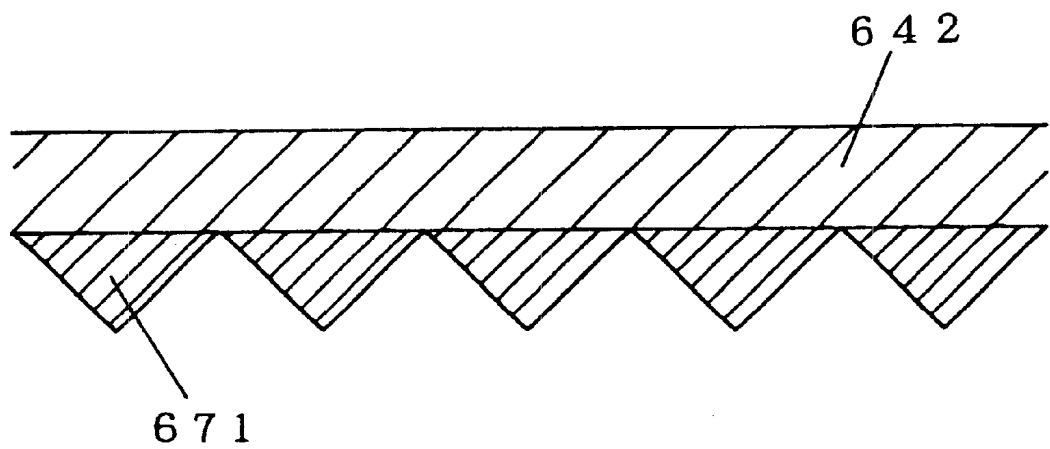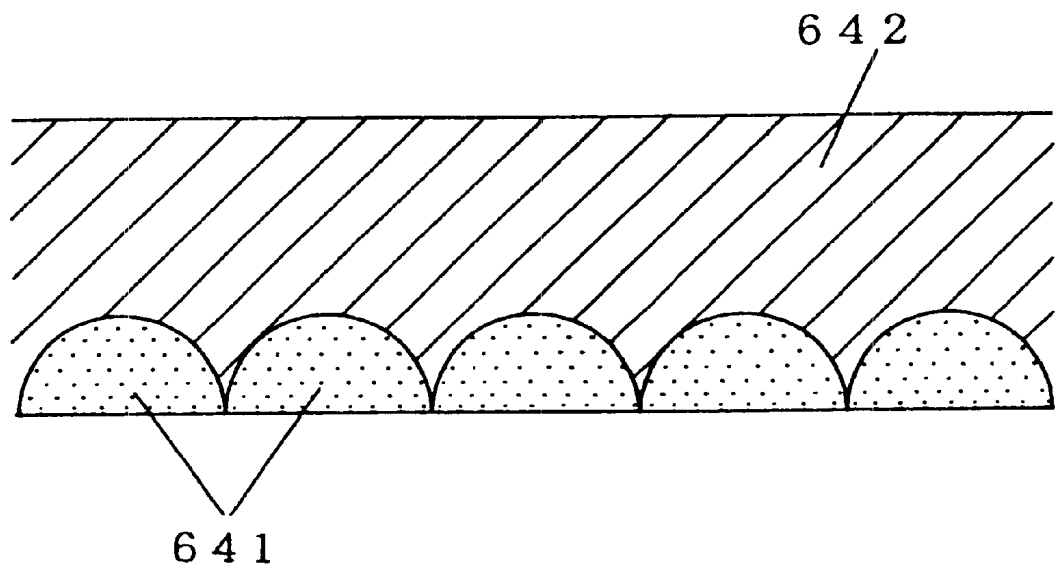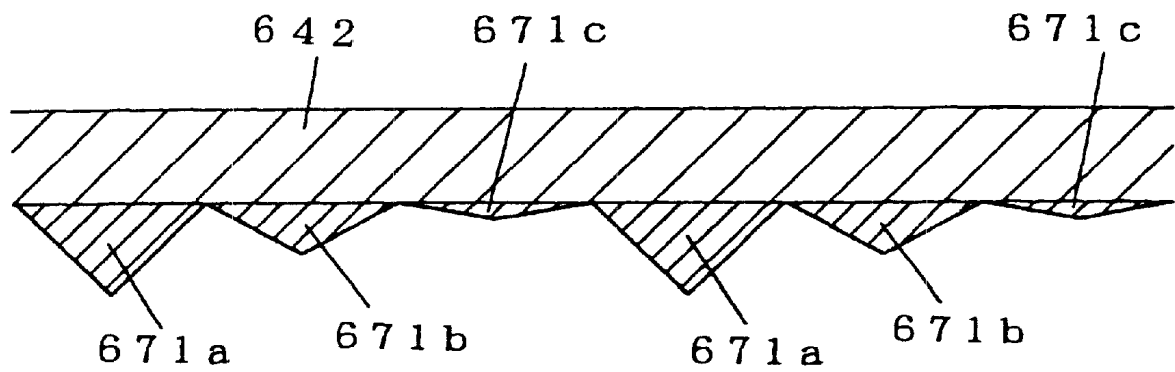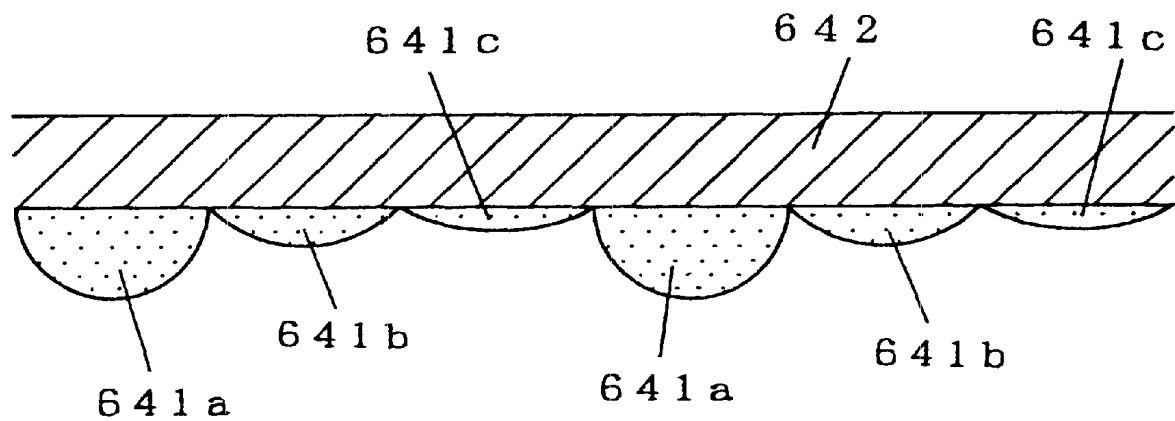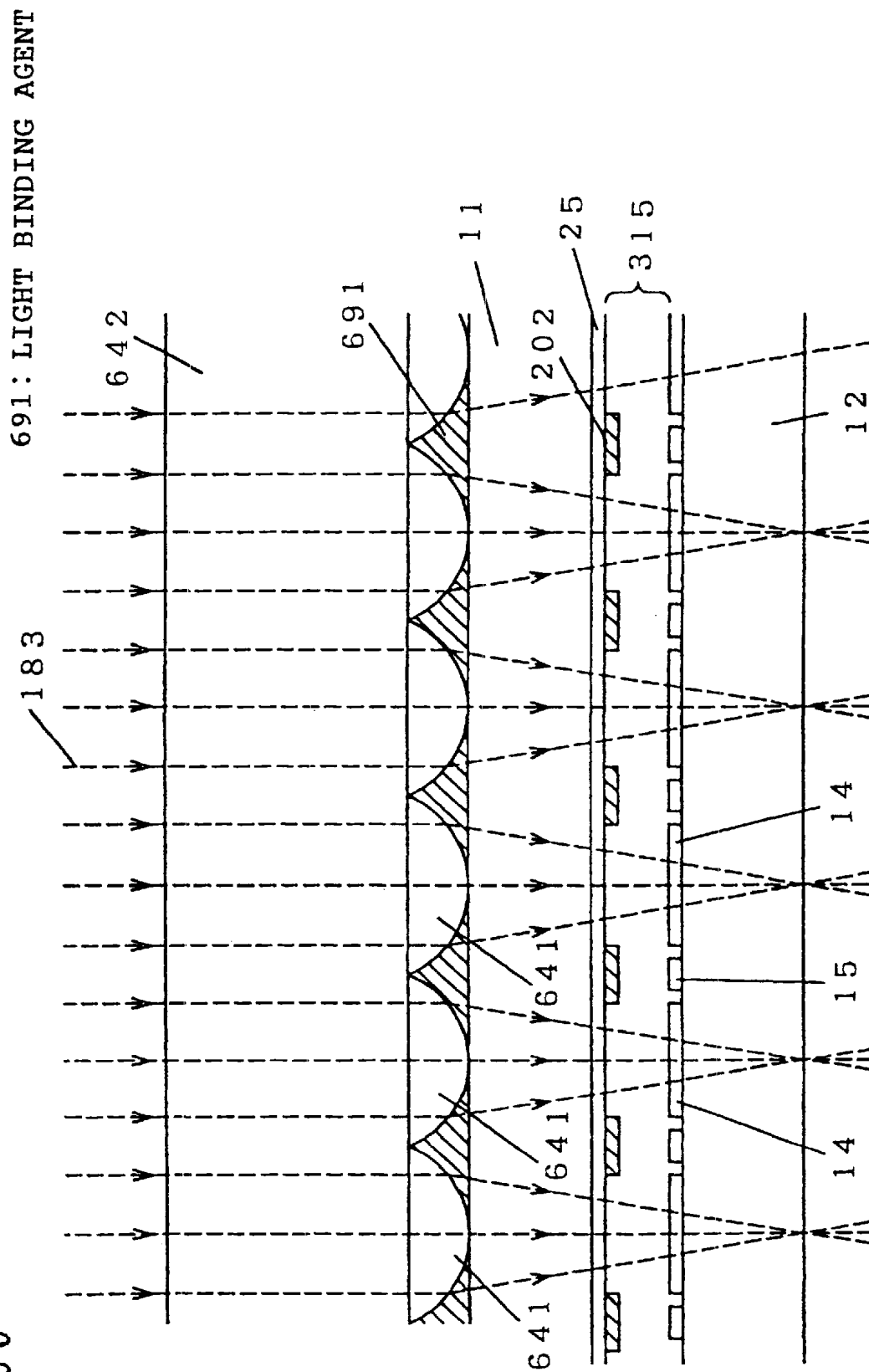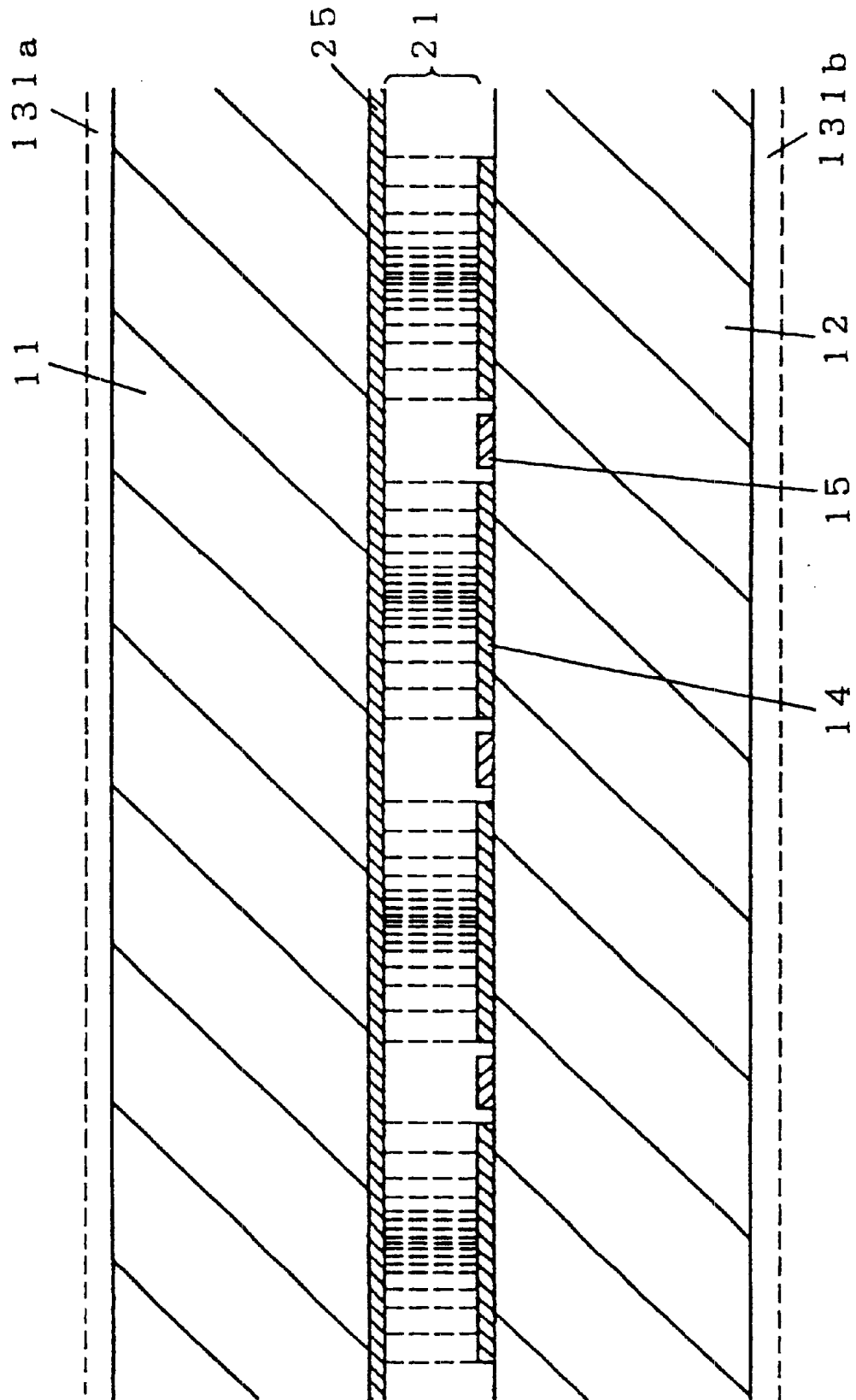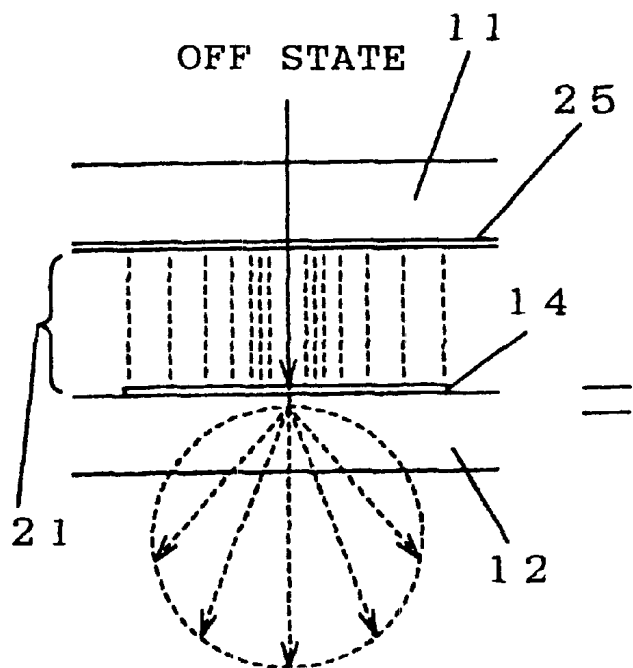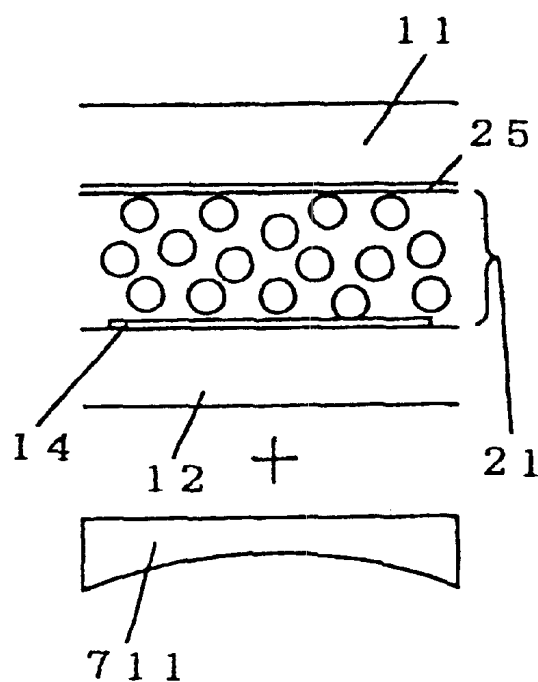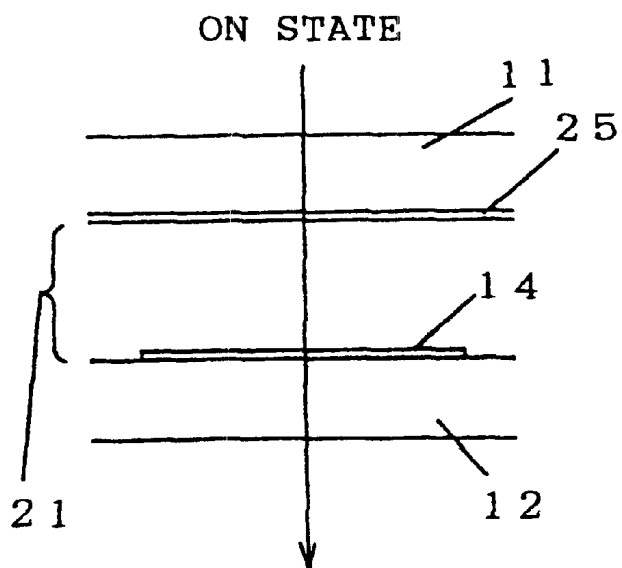
Fig. 72
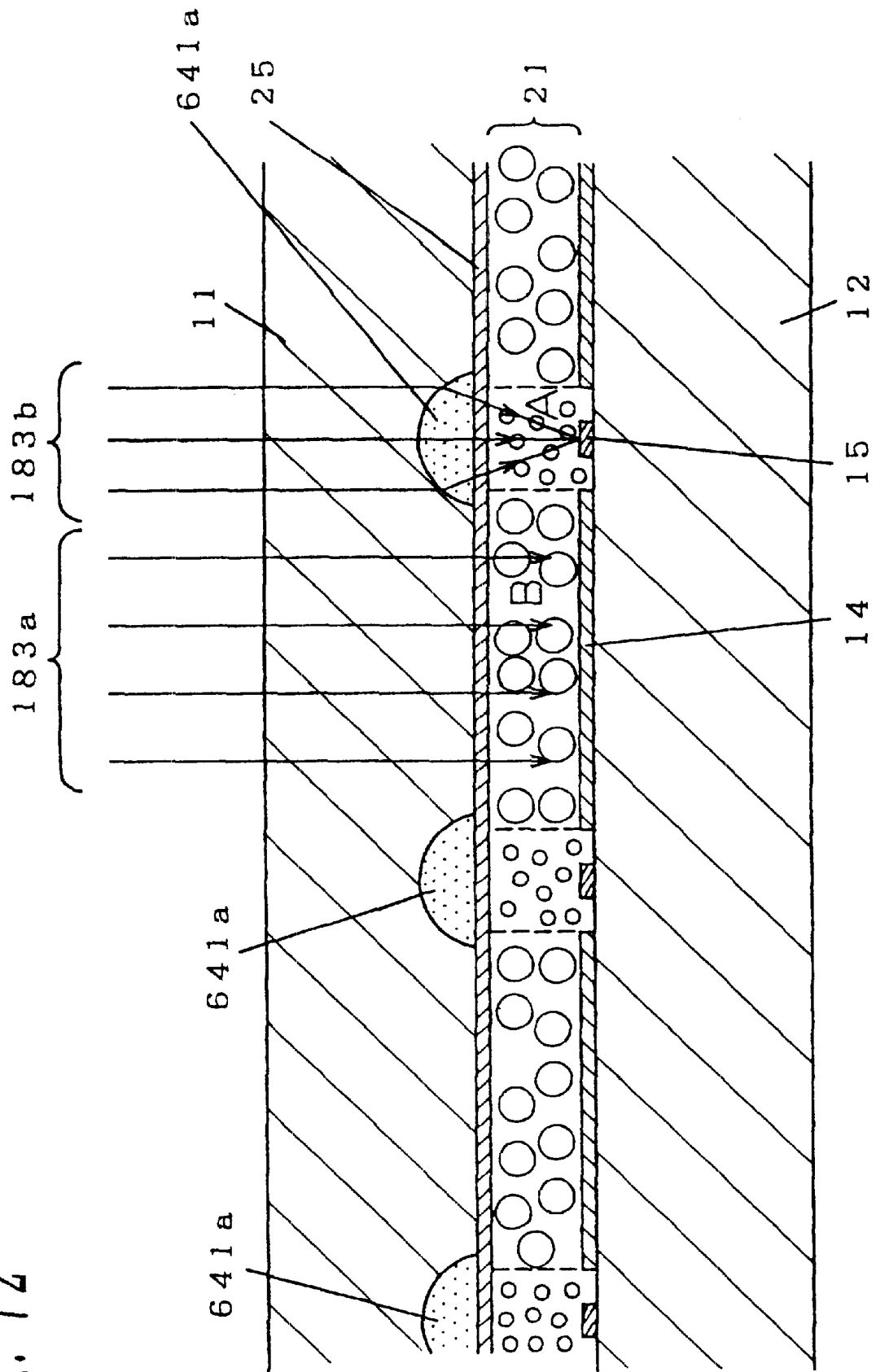
Fig. 73

732: SUPPLY TUBE   736: SEAL RUBBER

733: EXHAUST TUBE   737: REFLECTING PLATE

734: DIFFUSING PLATE   738: HEATER TABLE (MOUNTING TABLE)

731: LENS 735: LIGHT BINDING LIQUID 739: HEATER

741: INFRARED-RAY REFLECTING FILM

742: ULTRAVIOLET-RAY REFLECTING FILM

743: TRANSPARENT SUBSTRATE

744: INFRARED RAY

745: TEMPERATURE SENSOR

Fig. 74

Fig. 75 (a)

Fig. 75 (b)

761: SUPPORT

762: CASING

Fig. 76

732

731

183

735

734

743

733

742

761

22

761

762

761
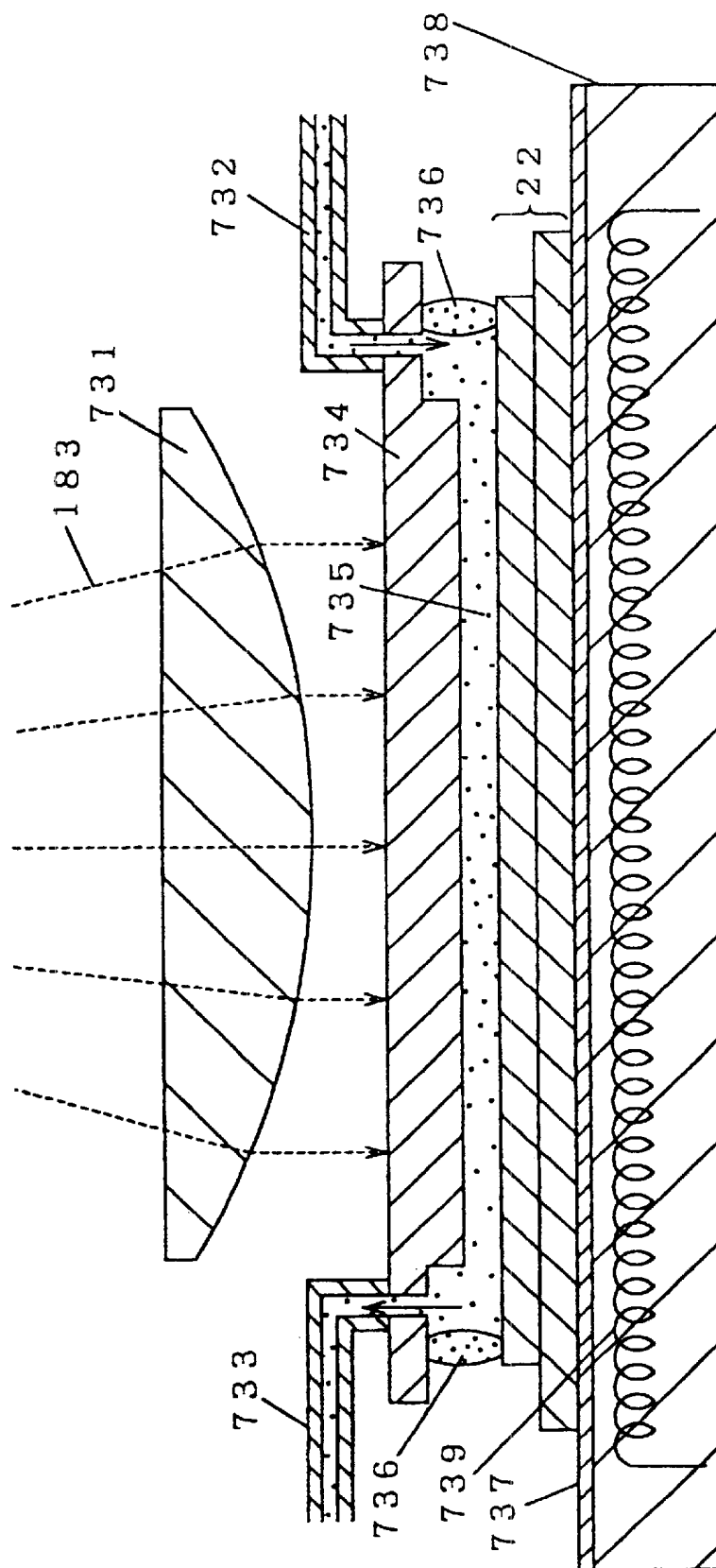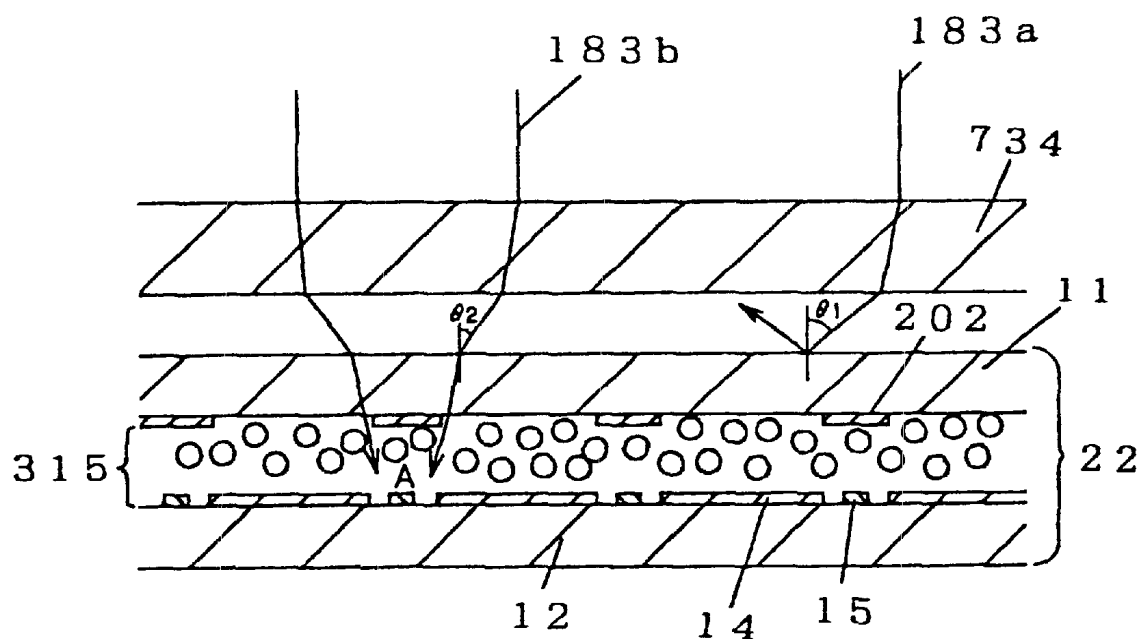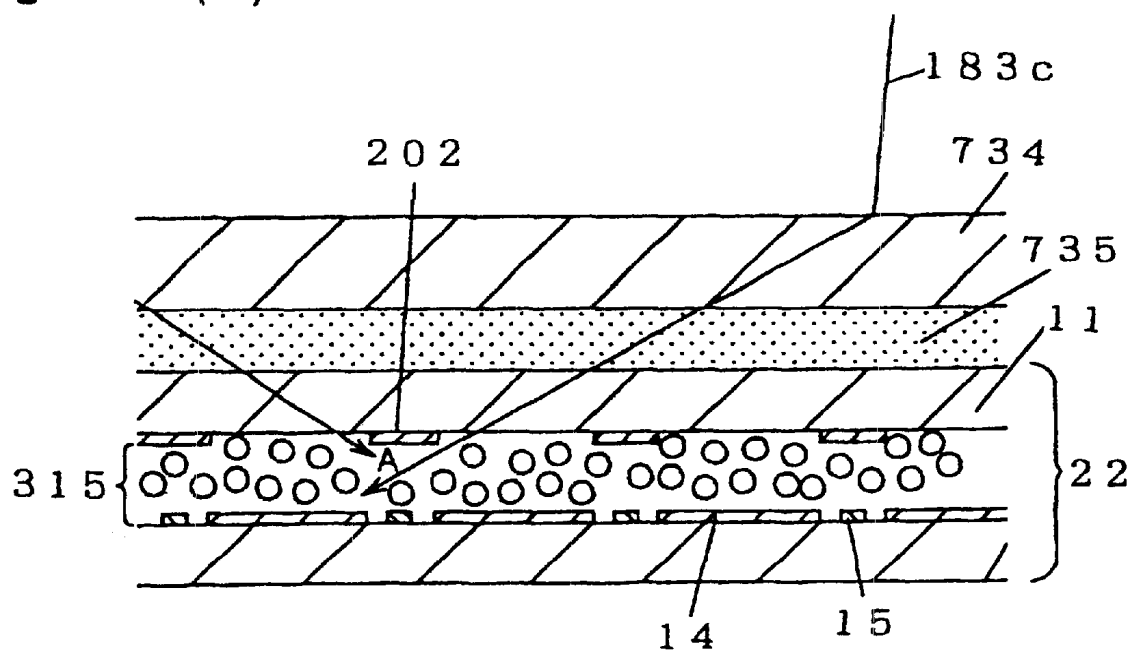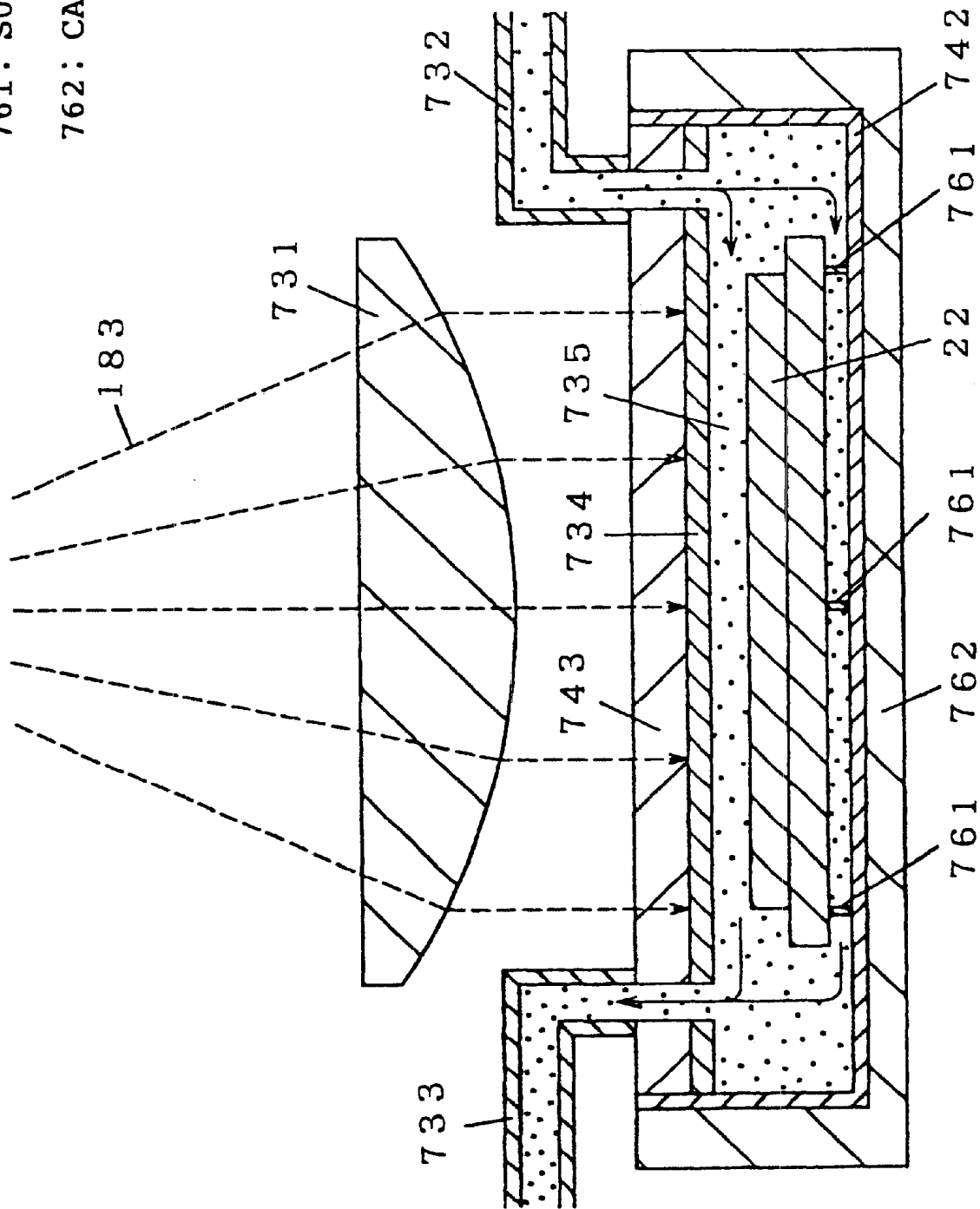
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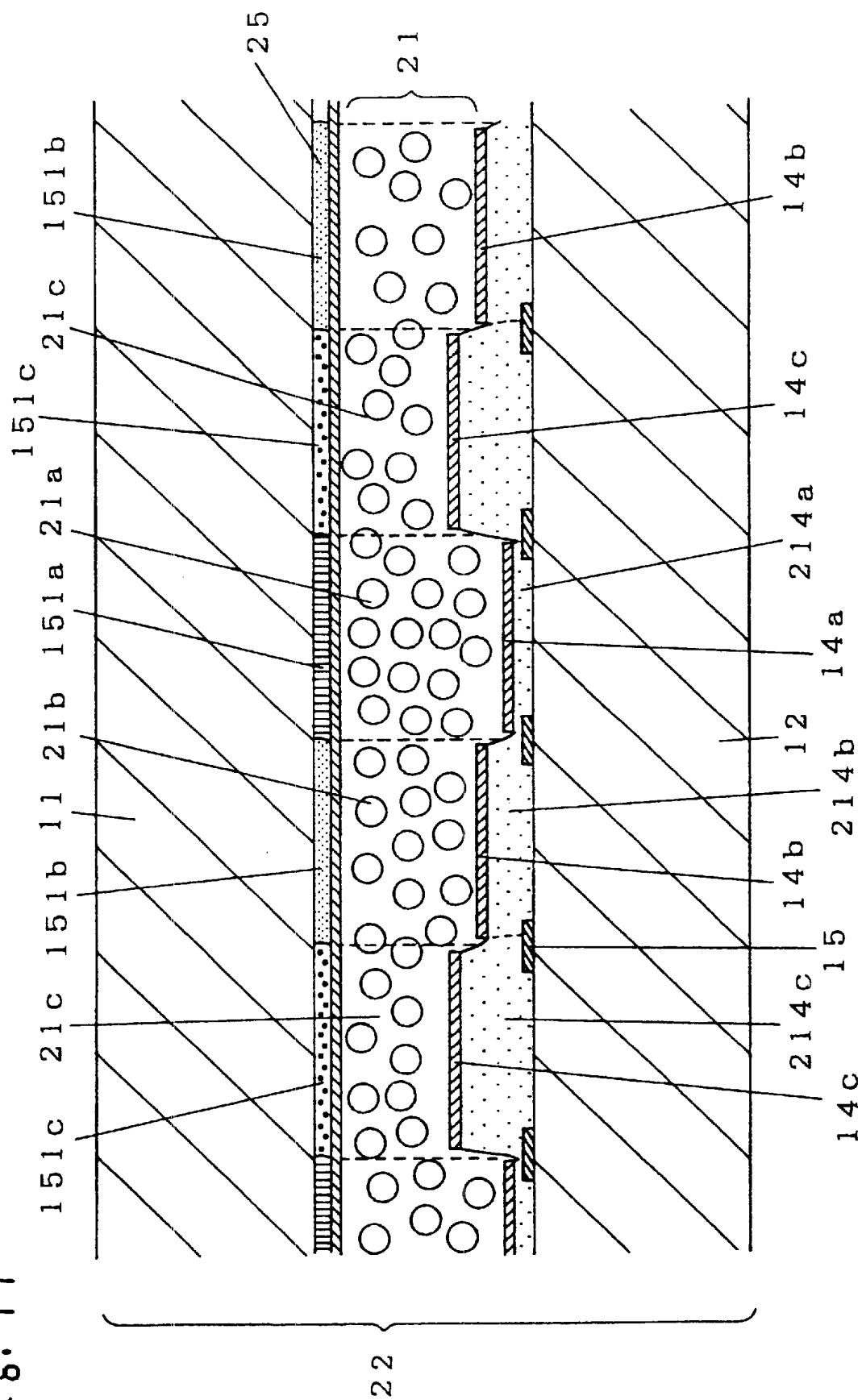
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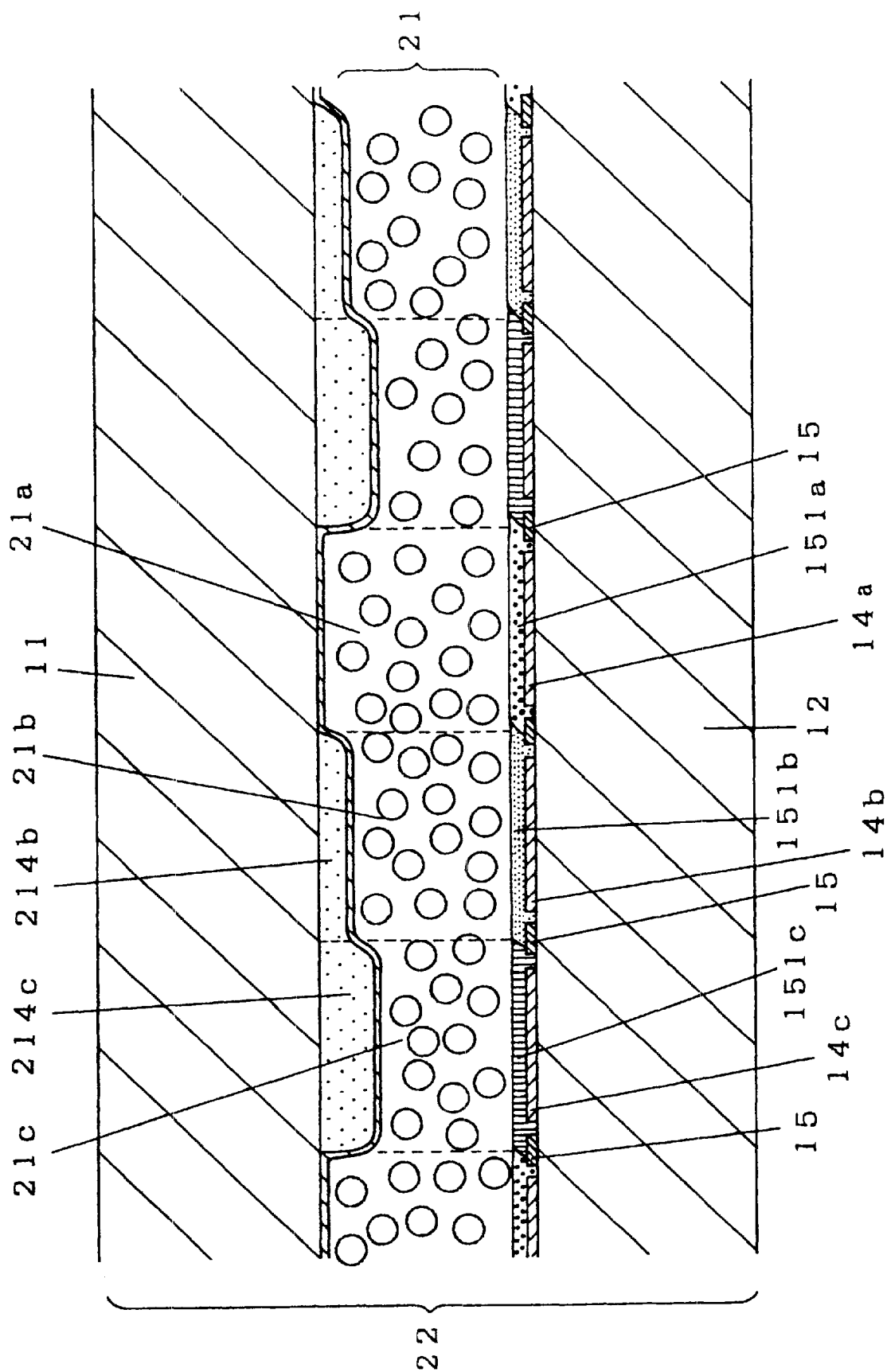
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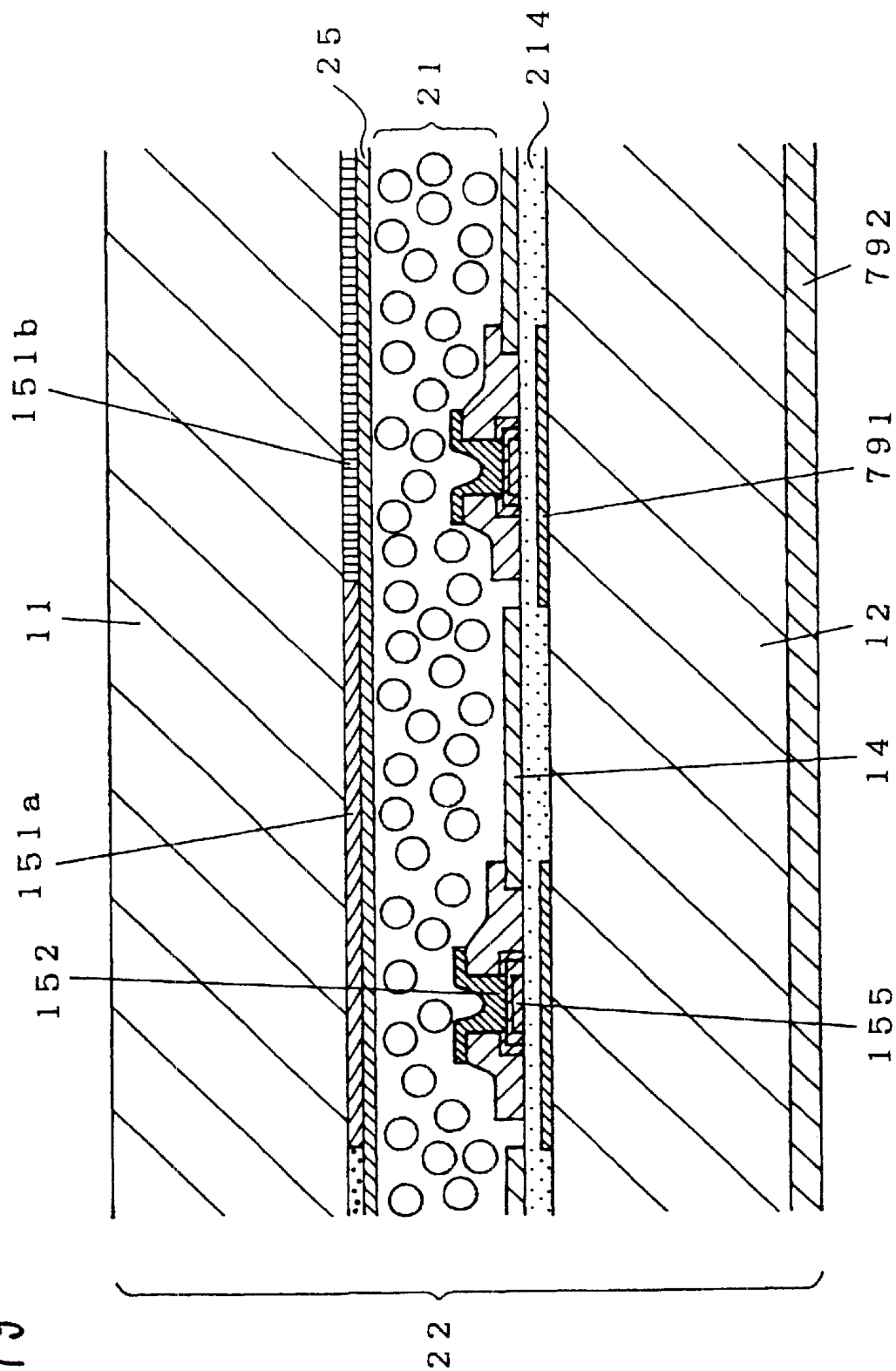
791: LIGHT SHIELDING FILM

792: REFLECTING FILM

Fig. 80

7 9 1

3 4 1
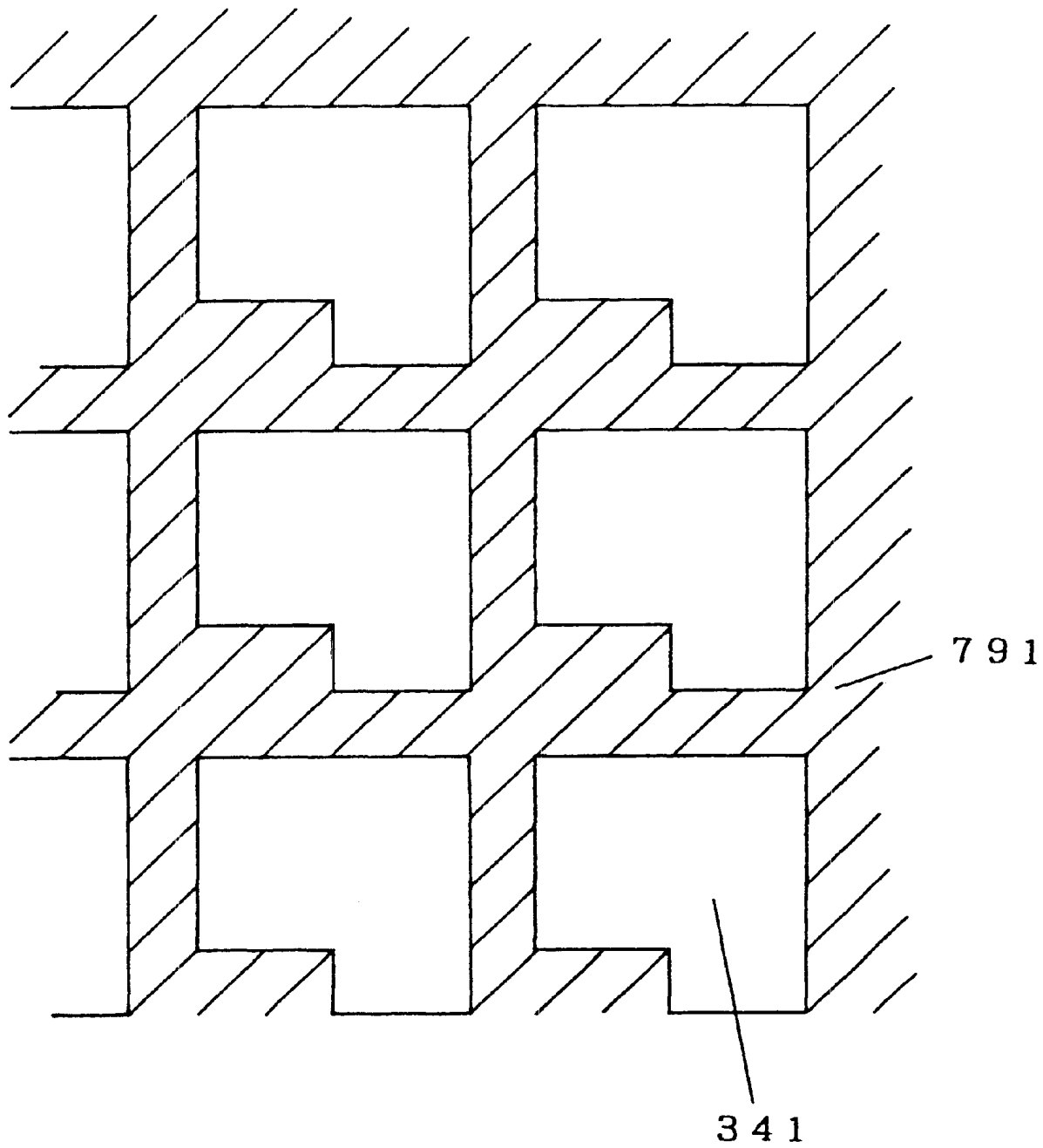
Fig. 81

811: SiO₂ LAYER
812: DIELECTRIC FILM

Fig. 82

821 : IRREGULARITY FILM

822 : EMBOSSED SHEET
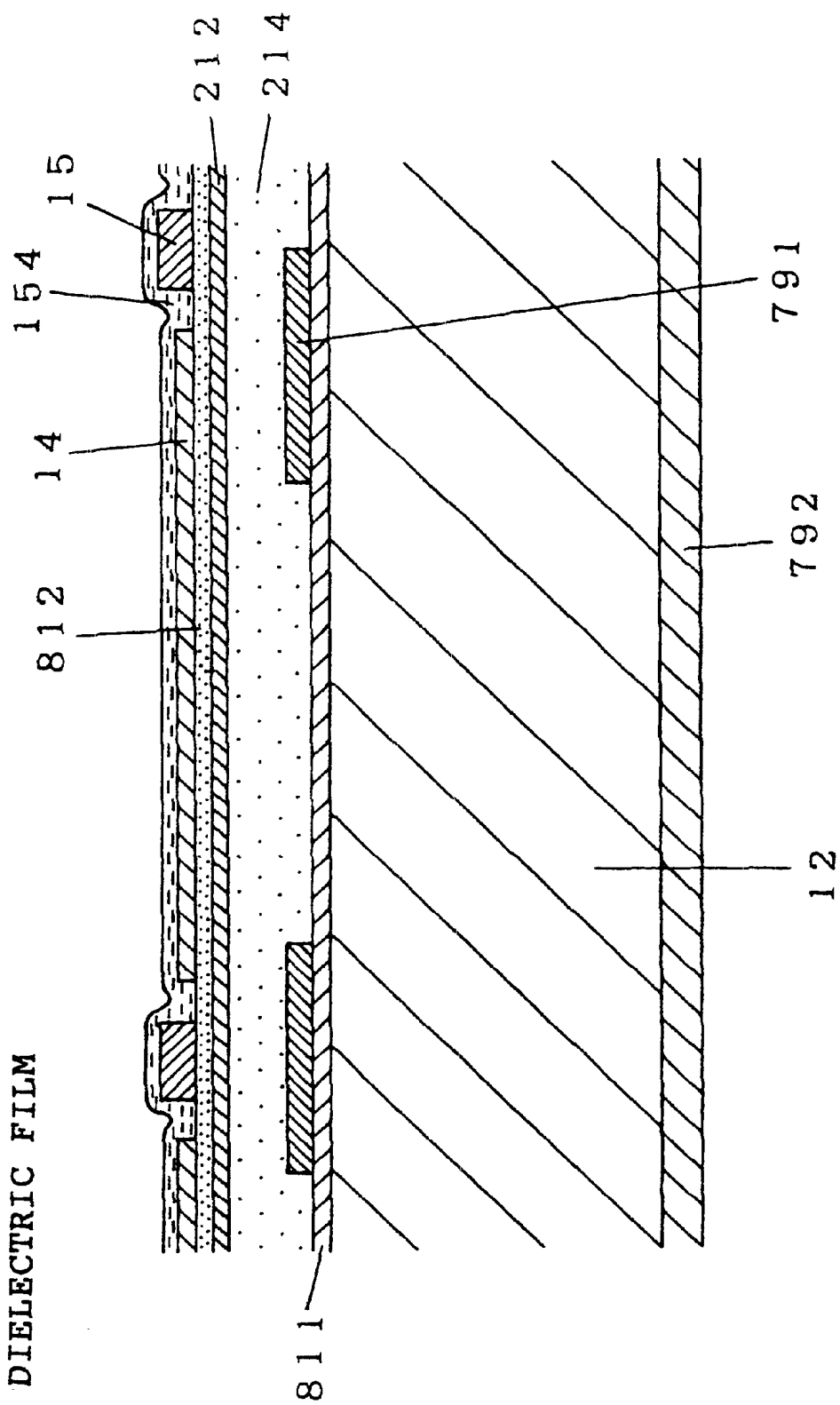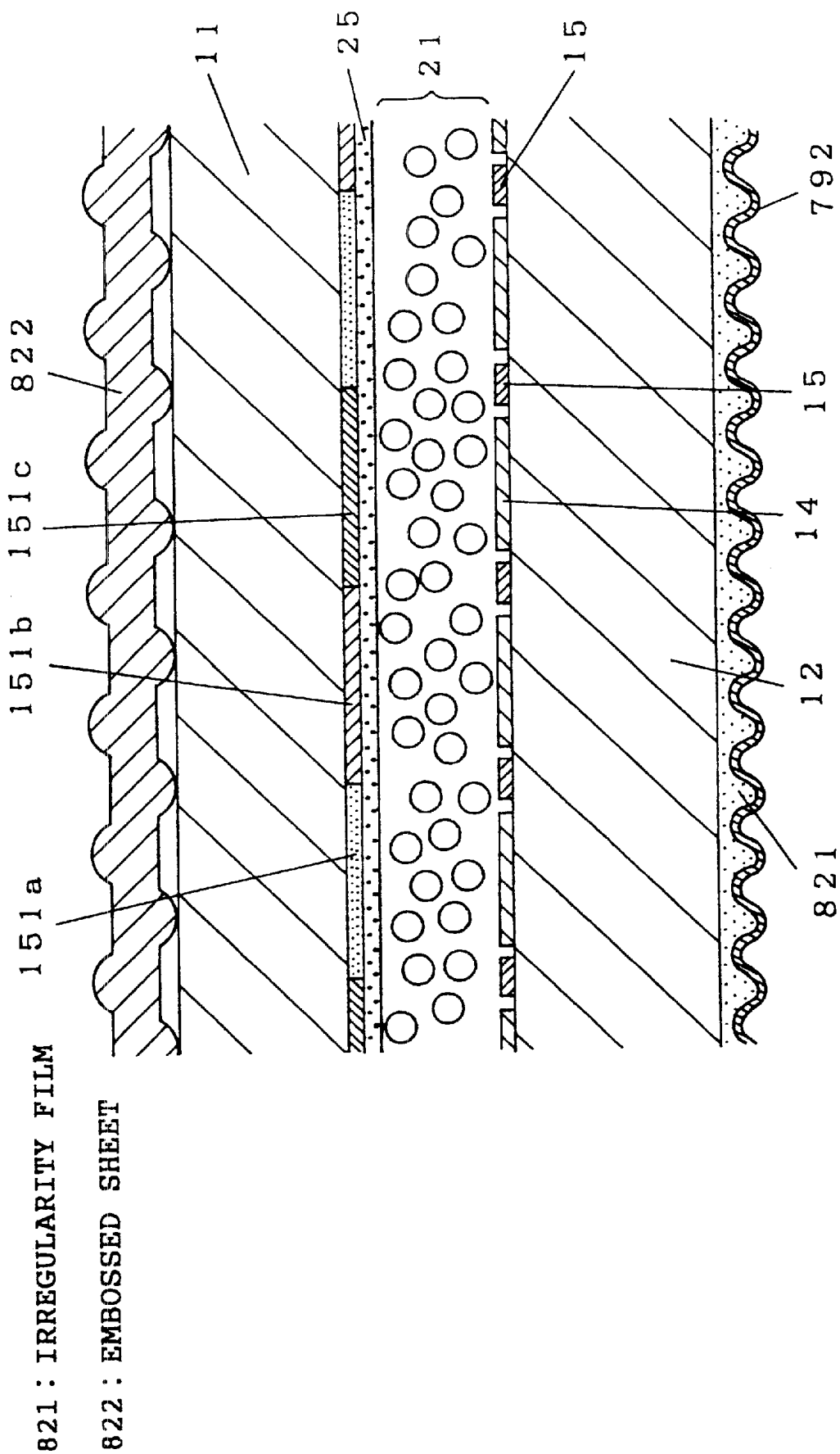
Ｆ ｉ ｇ . 8 3 (a)

831 : ULTRAVIOLET-RAY SETTING RESIN

315
14
15

12

Ｆ ｉ ｇ . 8 3 (b)

11
151
315 {
15
14
12

183

Ｆ ｉ ｇ . 8 3 (c)

183
831
12
14
21 {
15
151
11

Ｆ ｉ ｇ . 8 3 (d)

312
821

21 {

Ｆ ｉ ｇ . 8 3 (e)

792
821
12
14
21 {
15
151
11
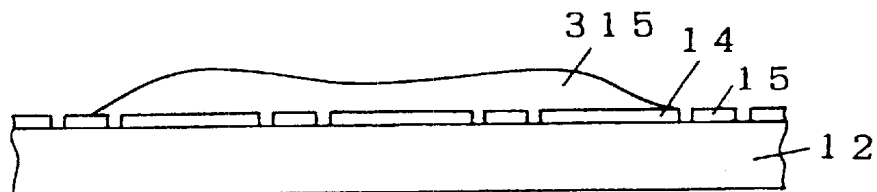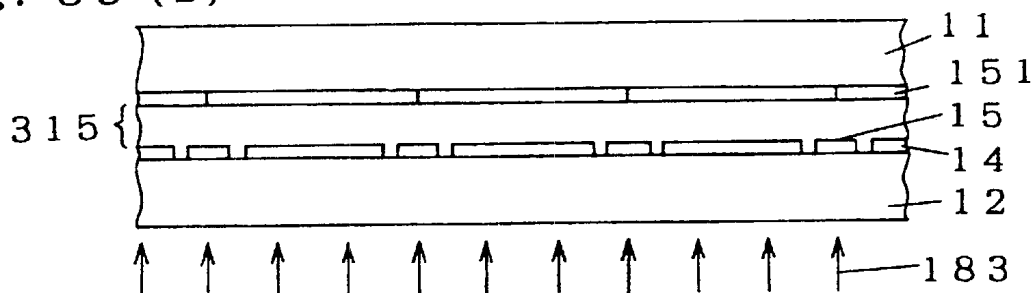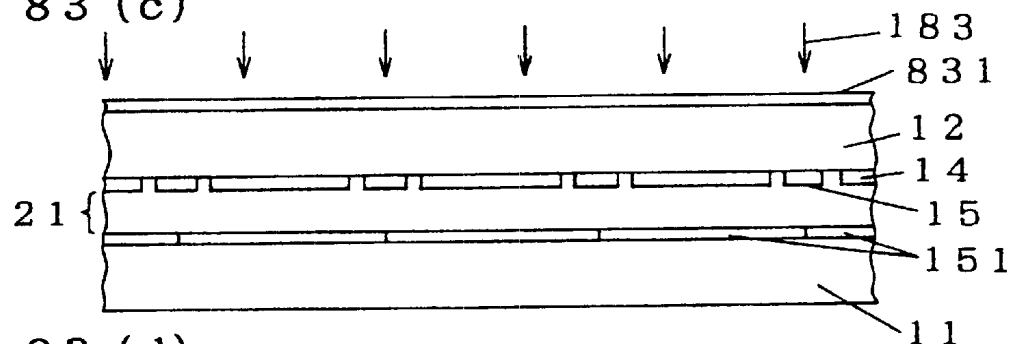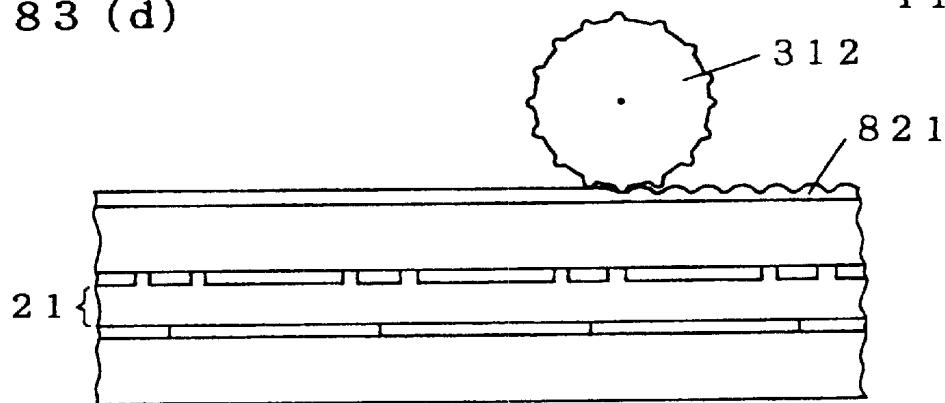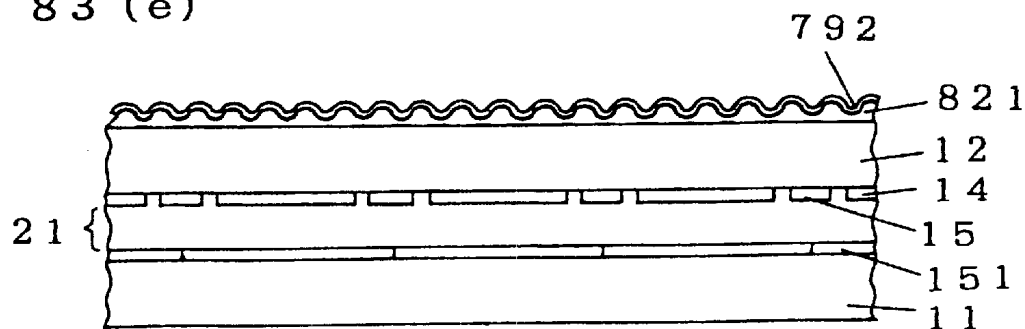
Fig. 84 (a)

841 : LIGHT SCATTERING LAYER
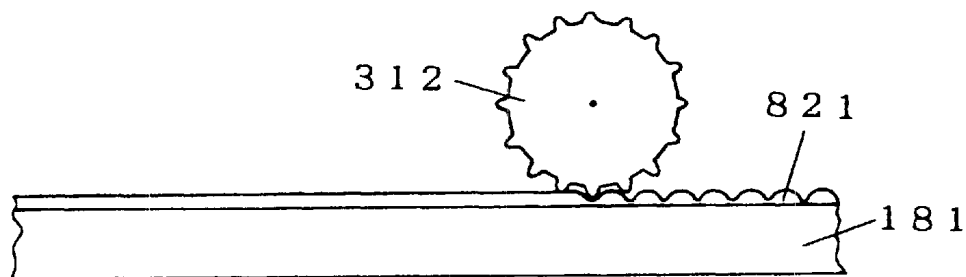
Fig. 84 (b)

Fig. 84 (c)

Fig. 84 (d)

Fig. 85

Fig. 86

14b : REFLECTING ELECTRODE

861 : BUFFER LAYER

Fig. 87 (a)

831

12

Fig. 87 (b)

183

12

Fig. 87 (c)

154

12

Fig. 87 (d)

14 b
154
12

Fig. 87 (e)

14 b
154
12
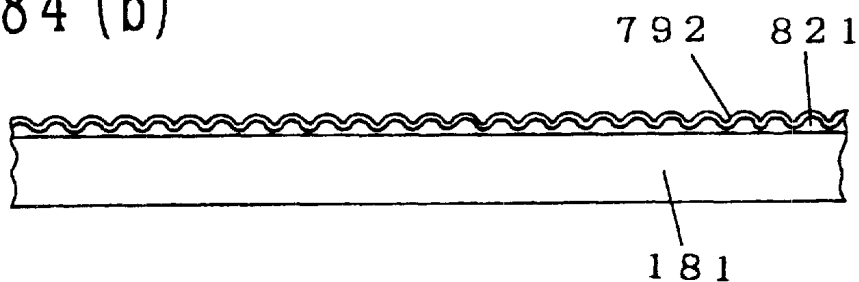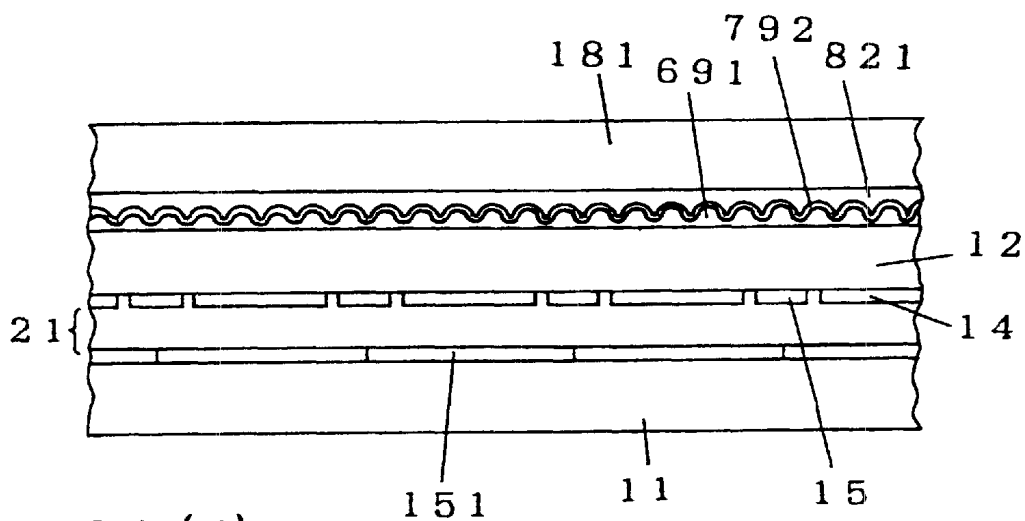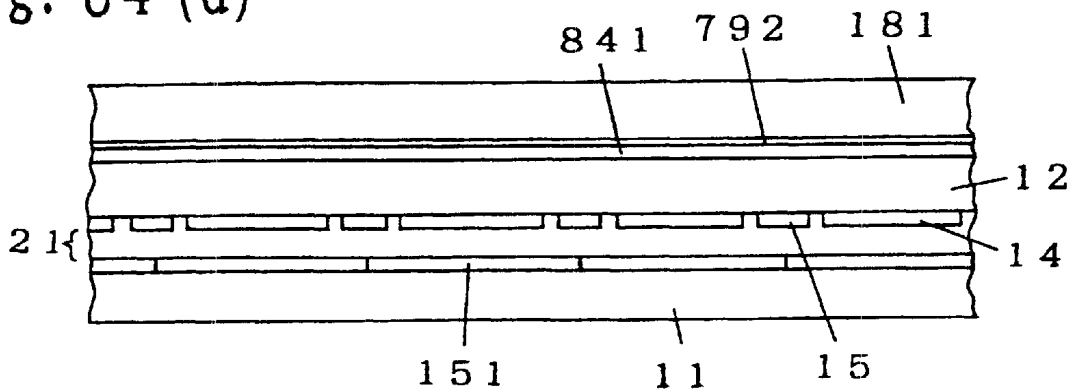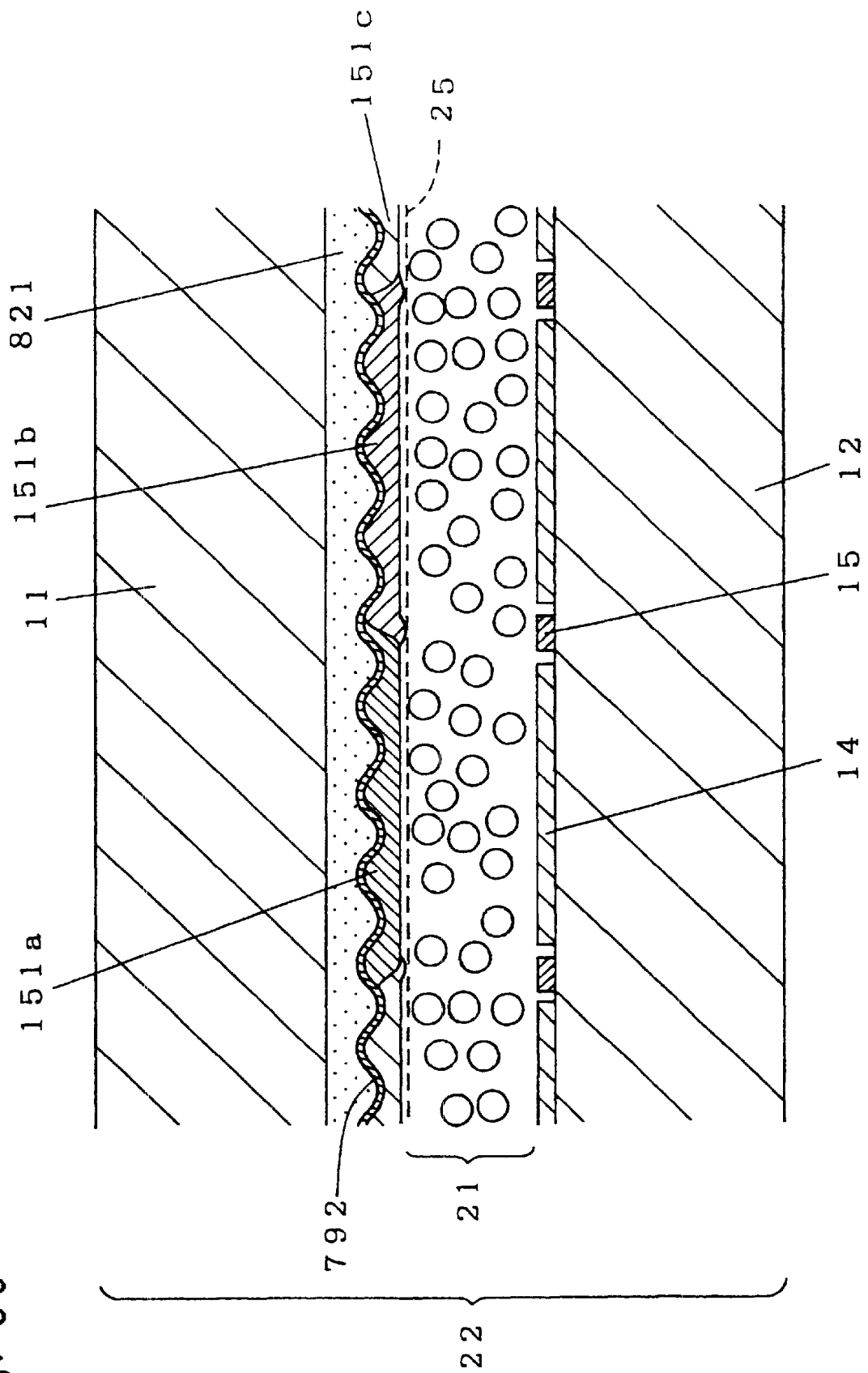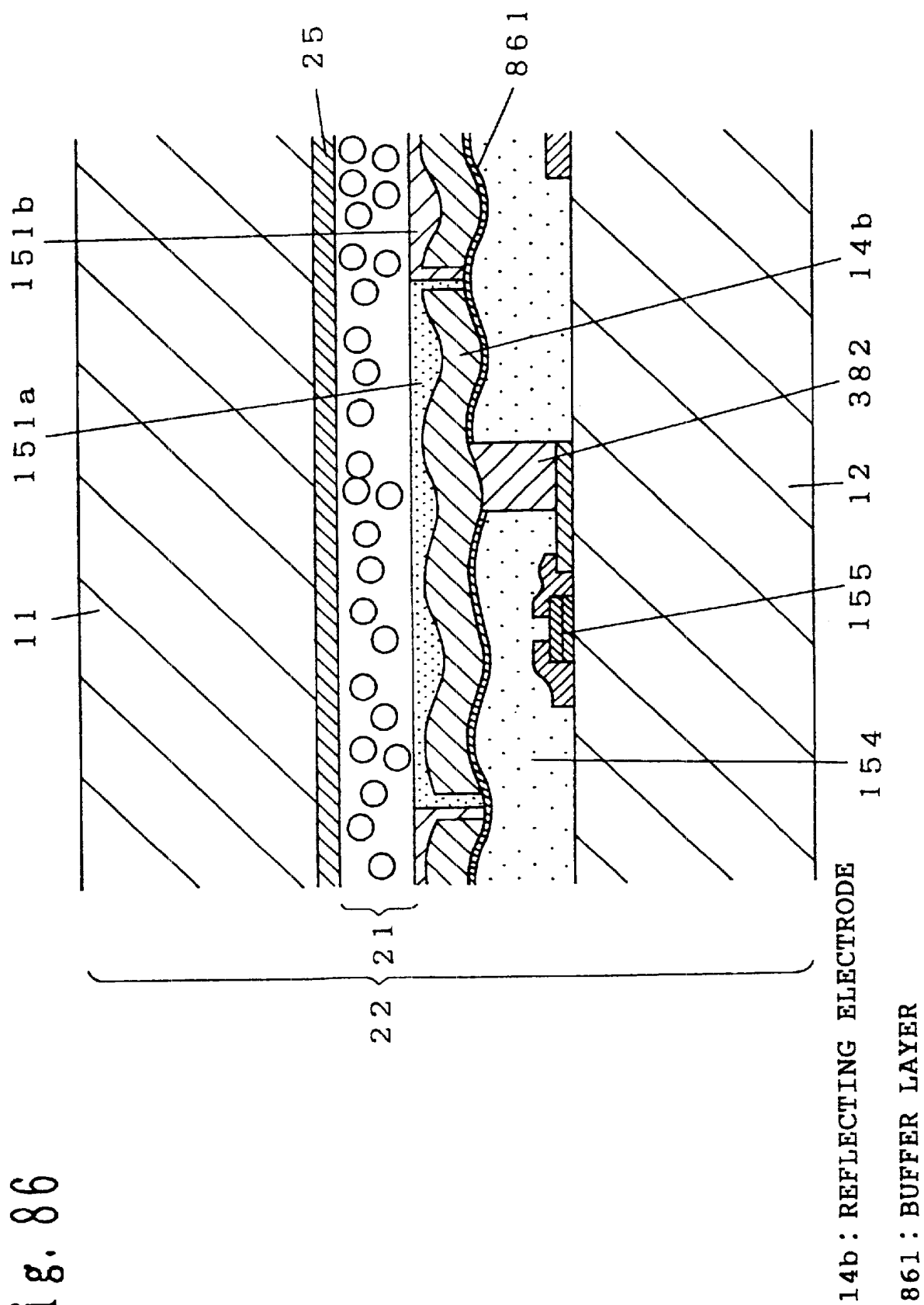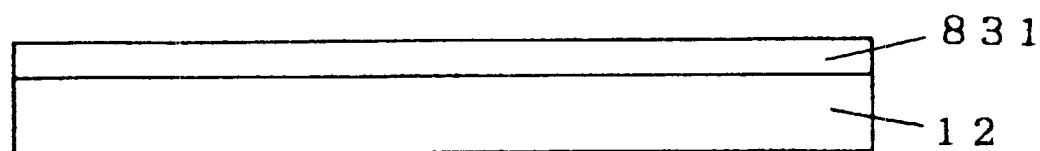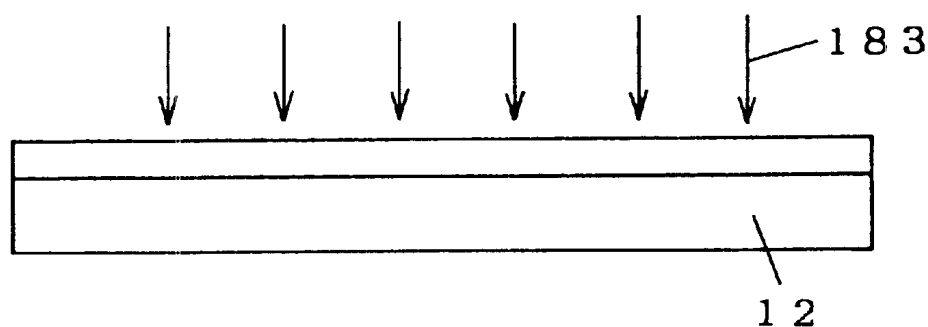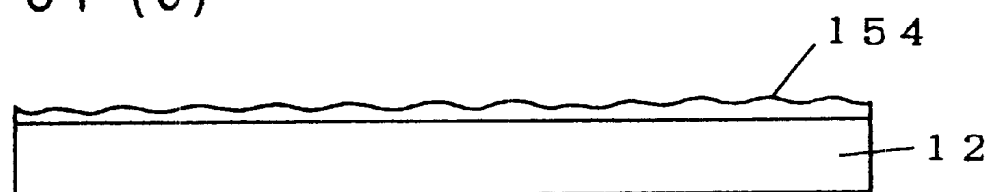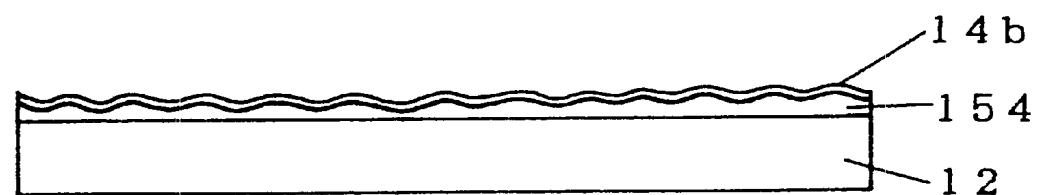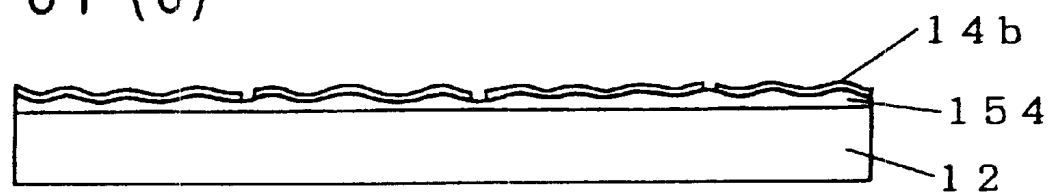
Fig. 88
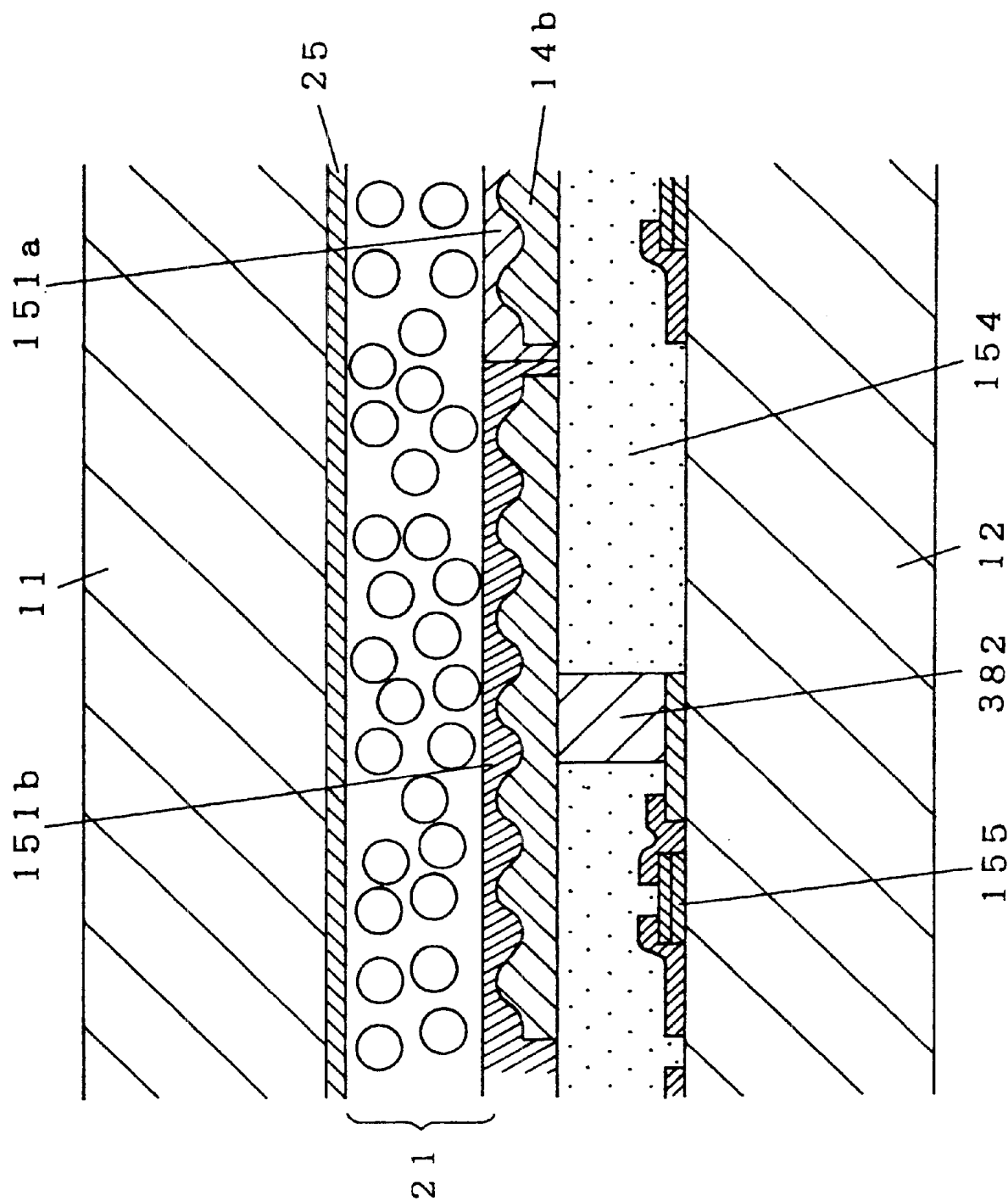
Fig. 89

891 : DIELECTRIC MIRROR

892 : PIXEL ELECTRODE (ITO)
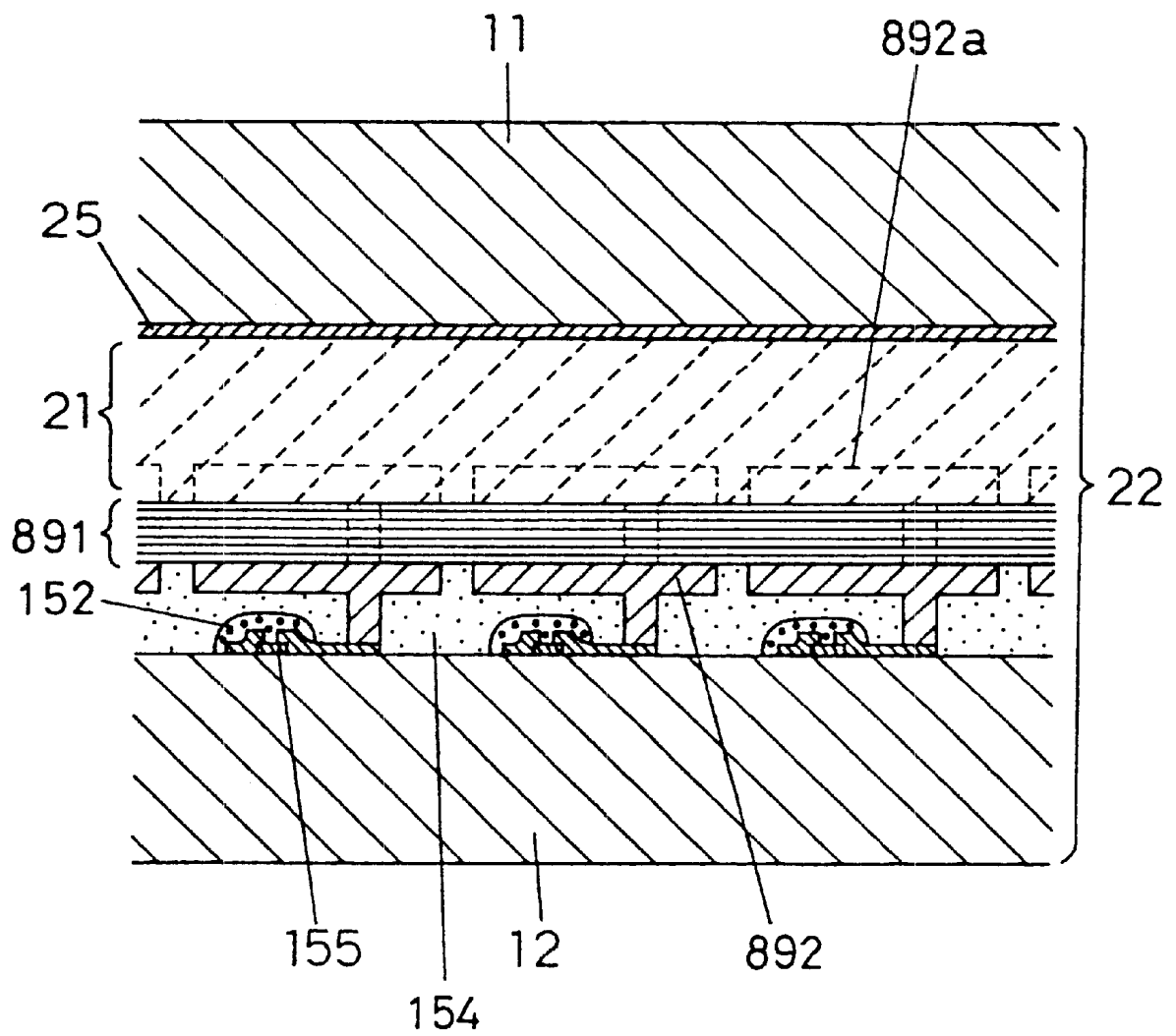
Fig. 90
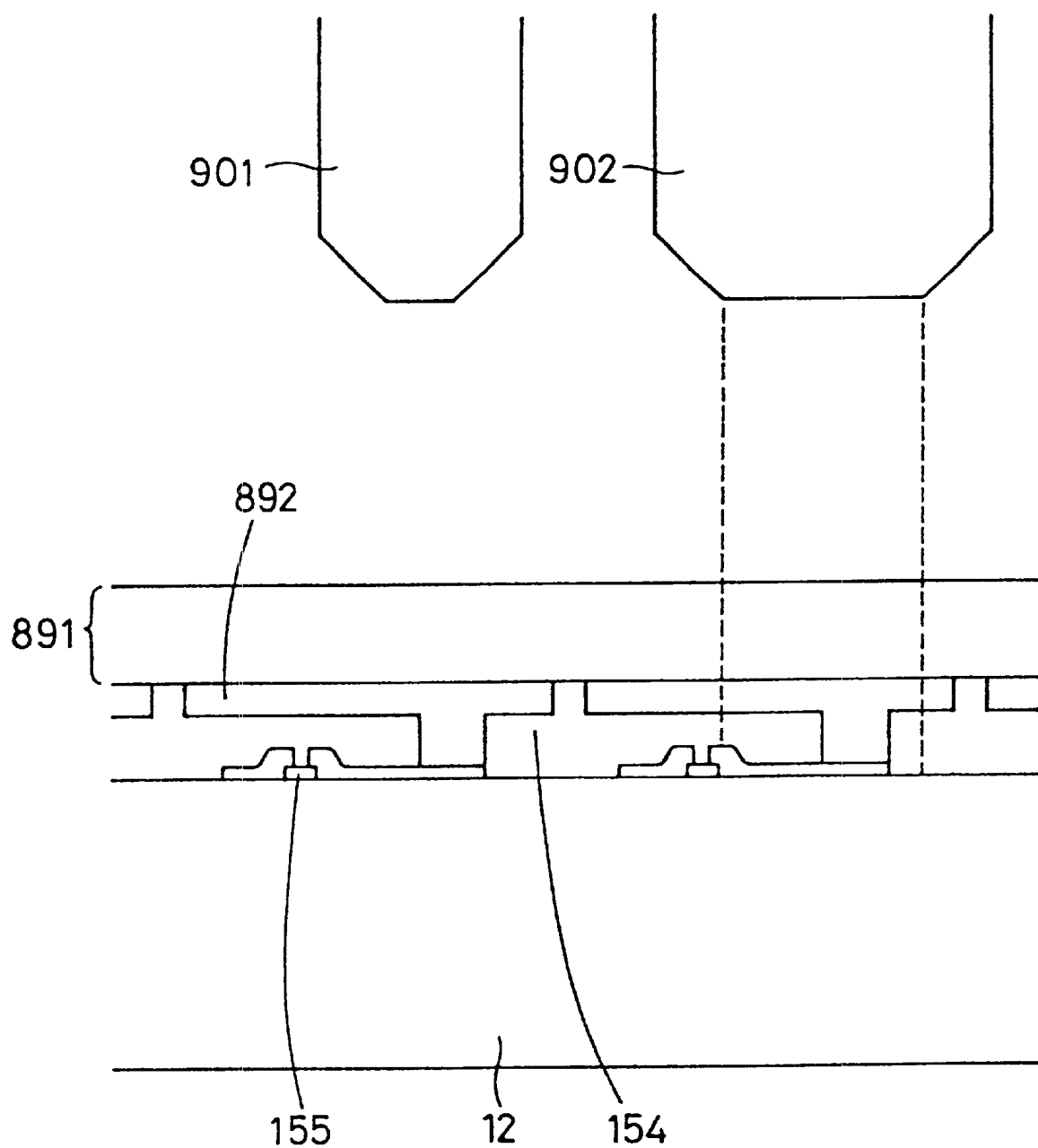
901: LASER TRIMMING APPARATUS

902: INFRARED-RAY CAMERA

Fig. 91
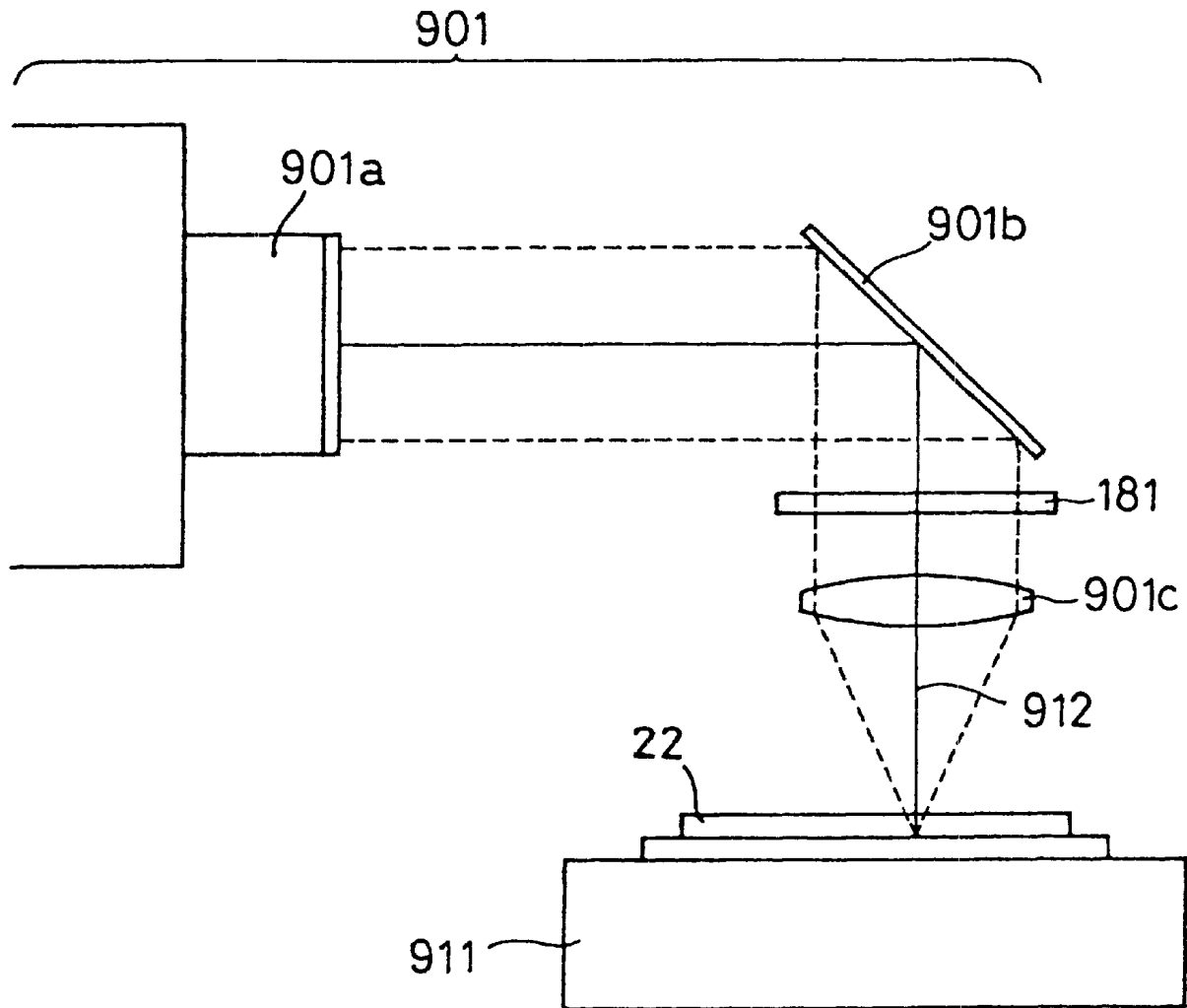
901a : LASER LIGHT GENERATION APPARATUS

901b : MIRROR

901c : CONDENSER LENS

911: XY STAGE

912: LASER LIGHT

Fig. 92

921: RADIATING PLATE

922: ADHESIVE AGENT
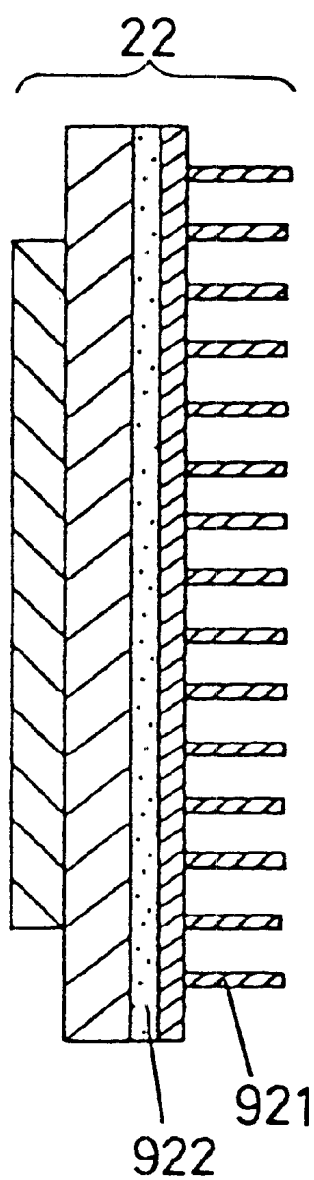
Fig. 93
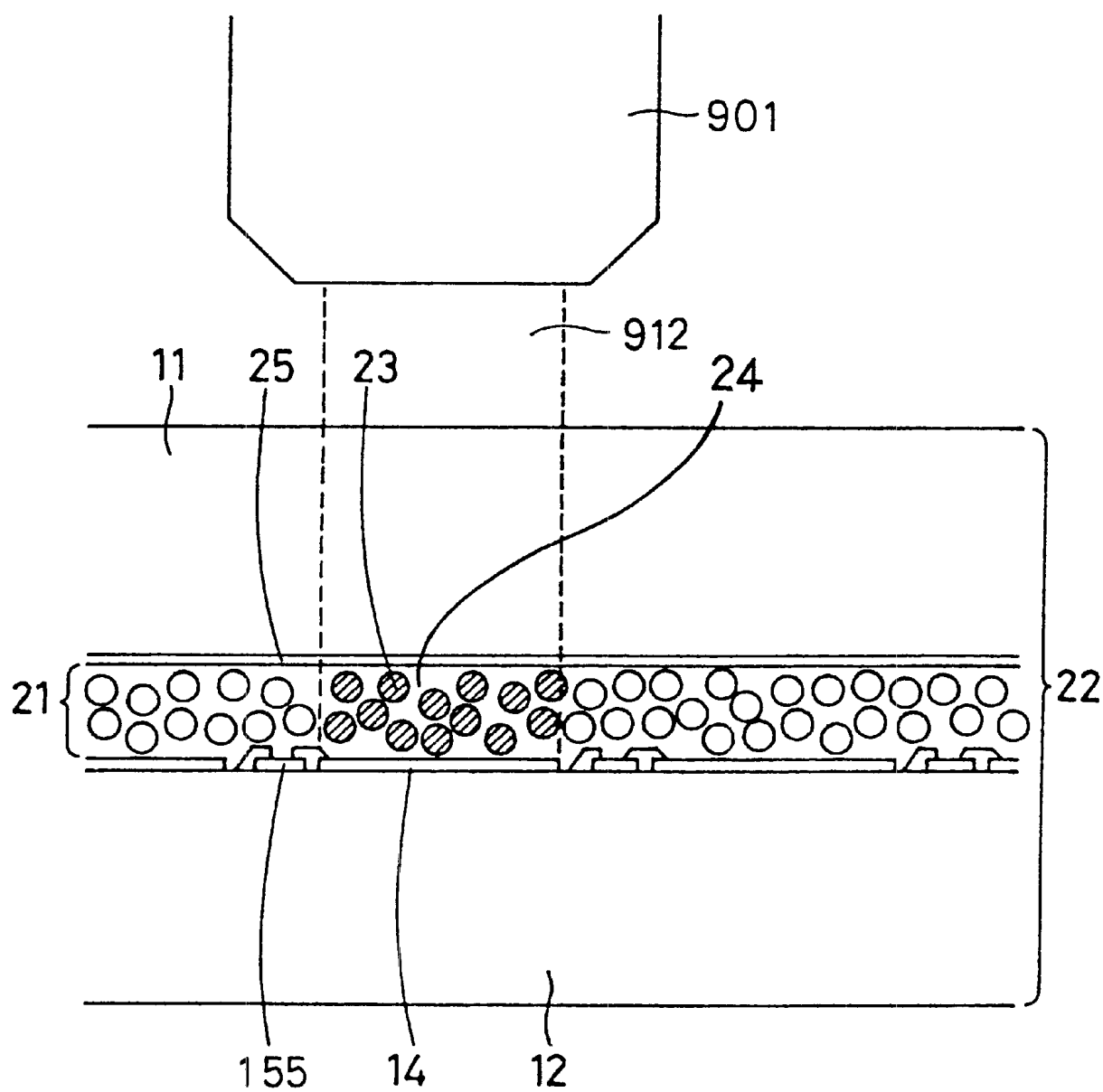
Fig. 94
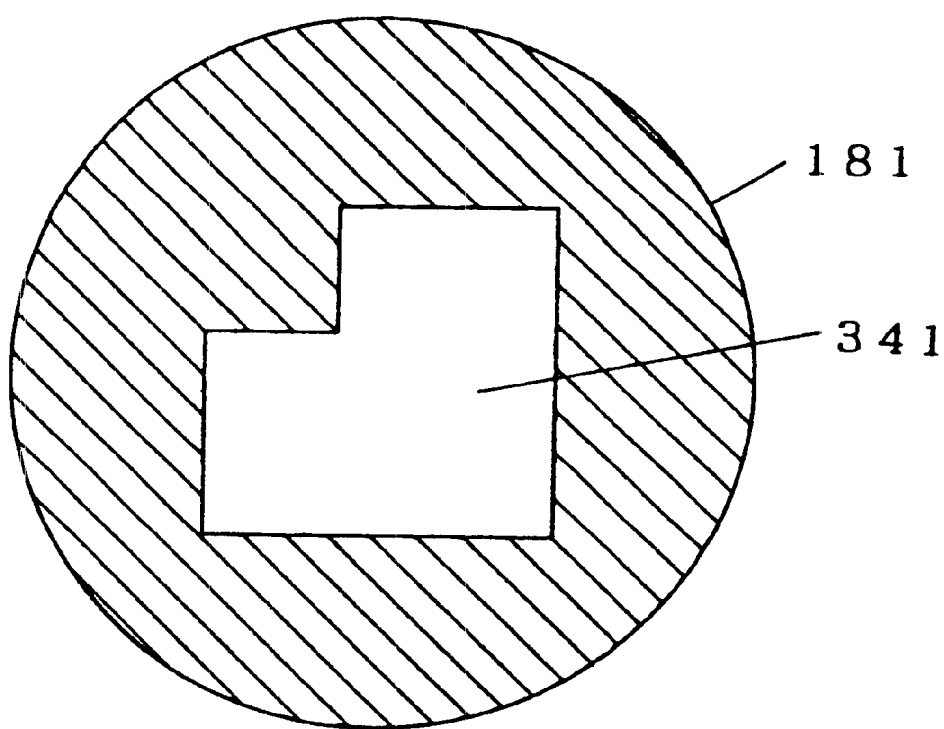
Fig. 95
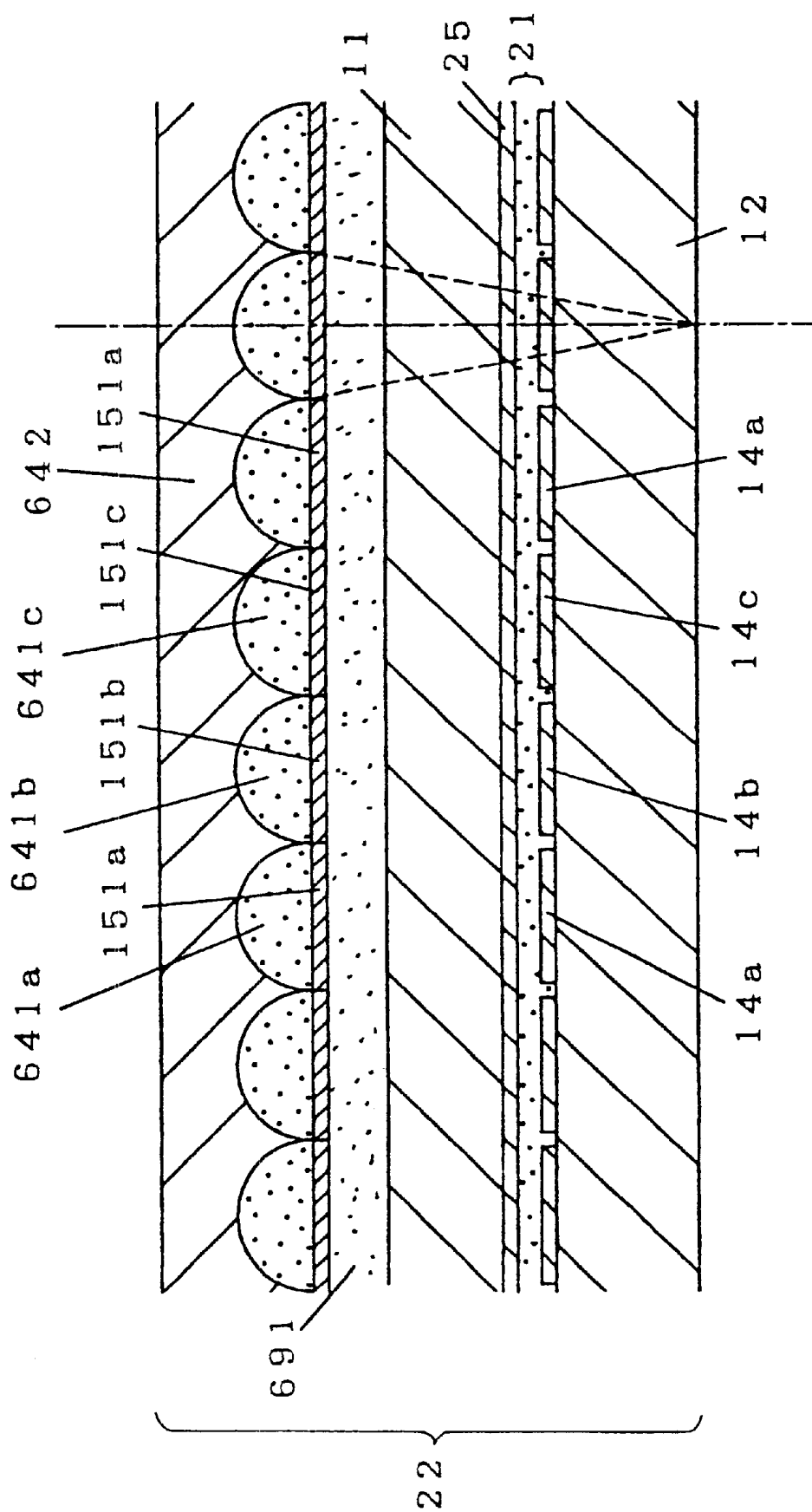
Fig. 96
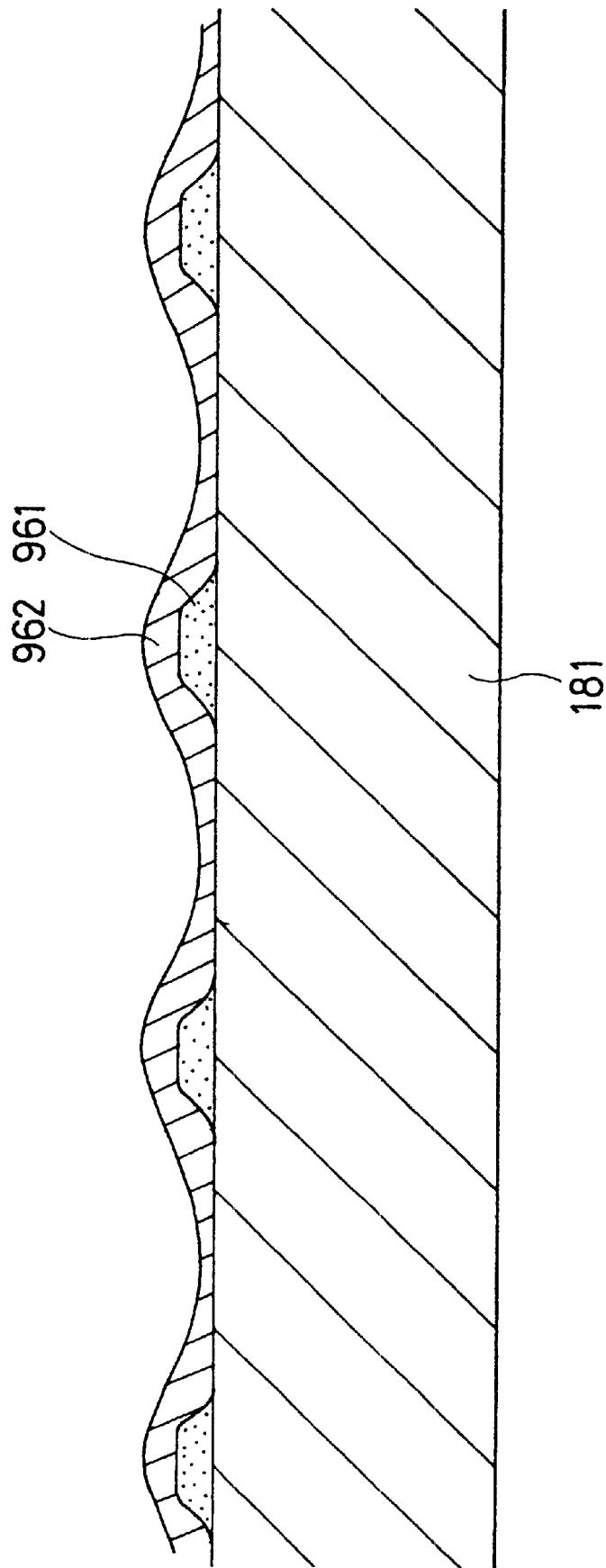
961: PROTRUDING PORTION

962: TRANSPARENT RESIN FILM

Fig. 97
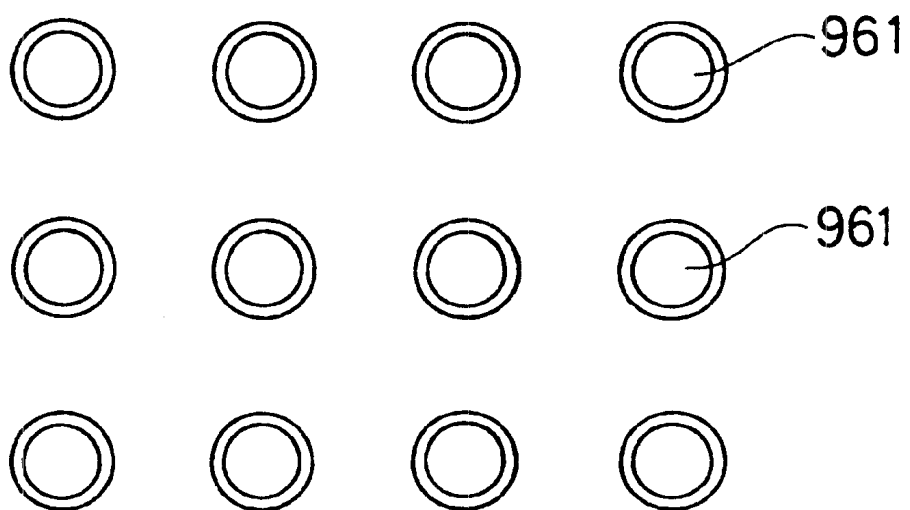
Fig. 98
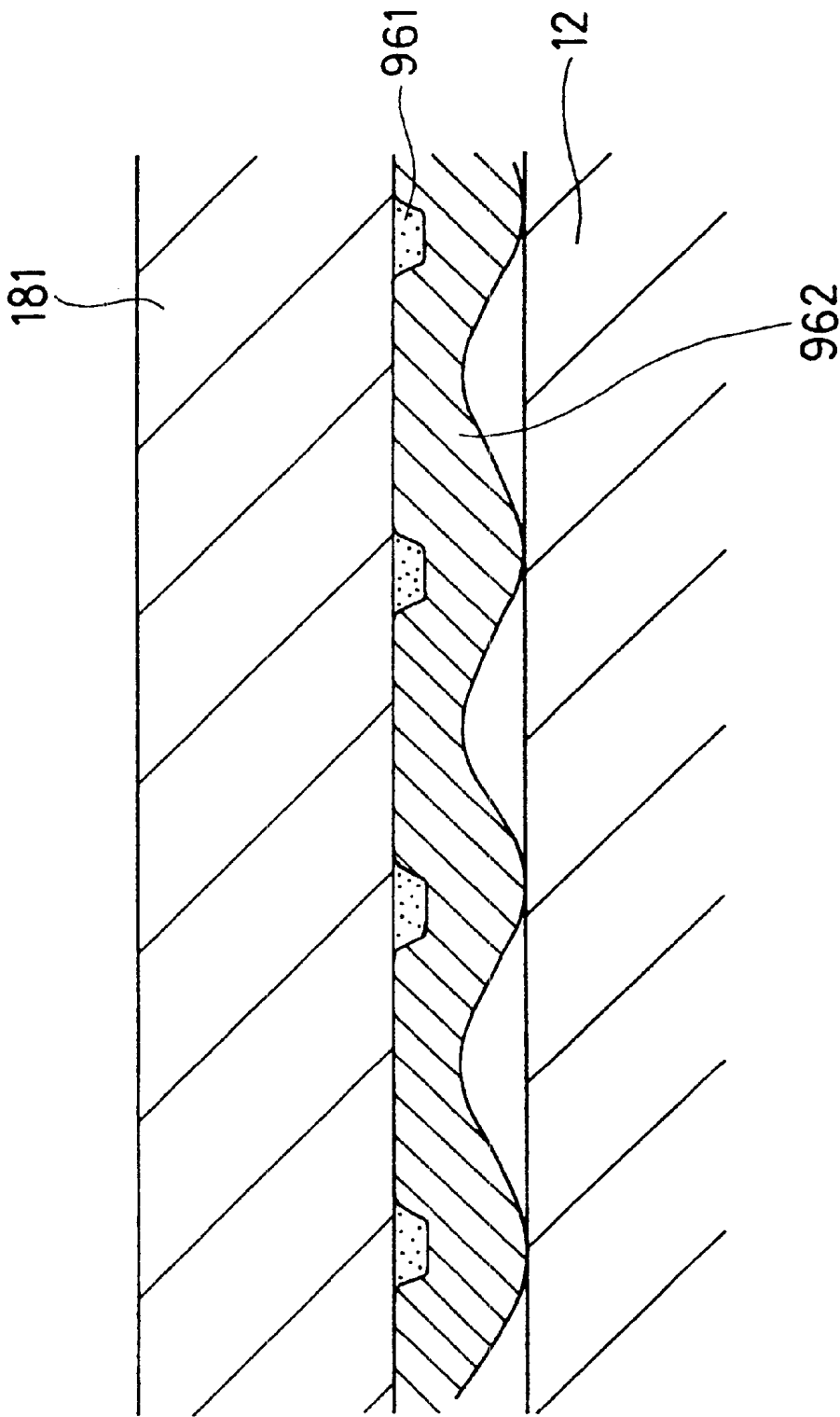
Fig. 99 (a)

991 : TRANSPARENT THIN FILM

992 : METALLIC THIN FILM

992
991

181

Fig. 99 (b)

992

181

Fig. 99 (c)

961

181

Fig. 99 (d)

962
961

181

Fig. 100

961   962   792

181

Fig. 101 (a)

962

Fig. 101 (b)

961a

962a

B

B'

181
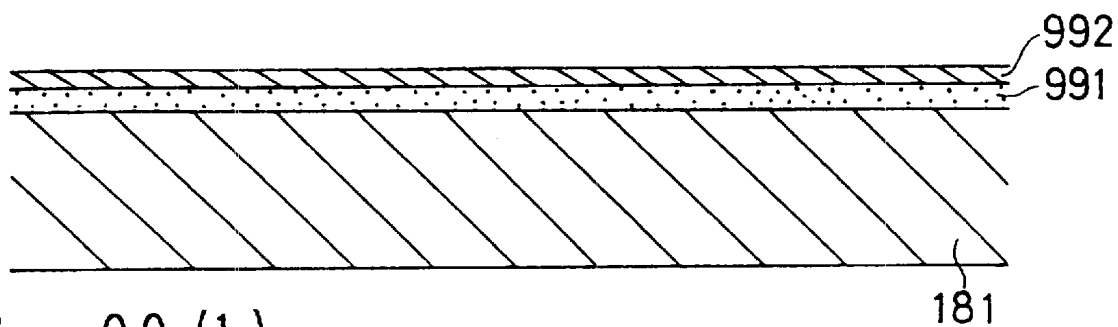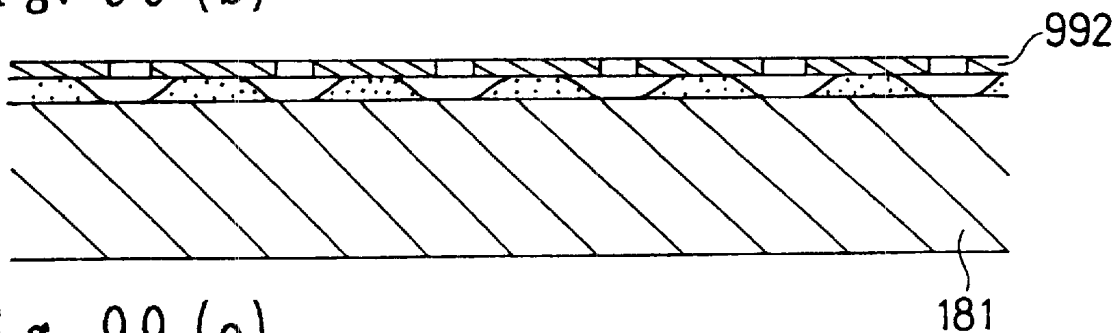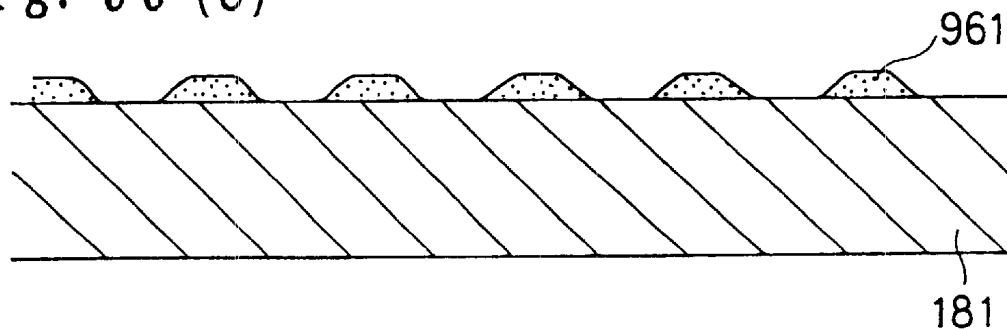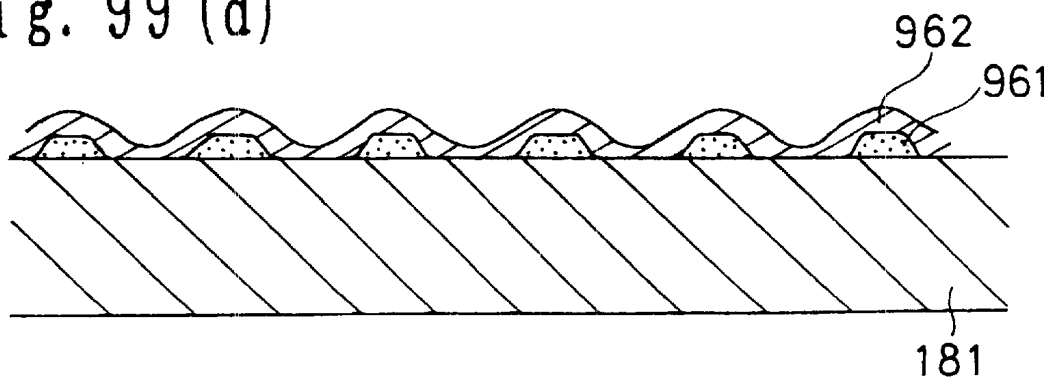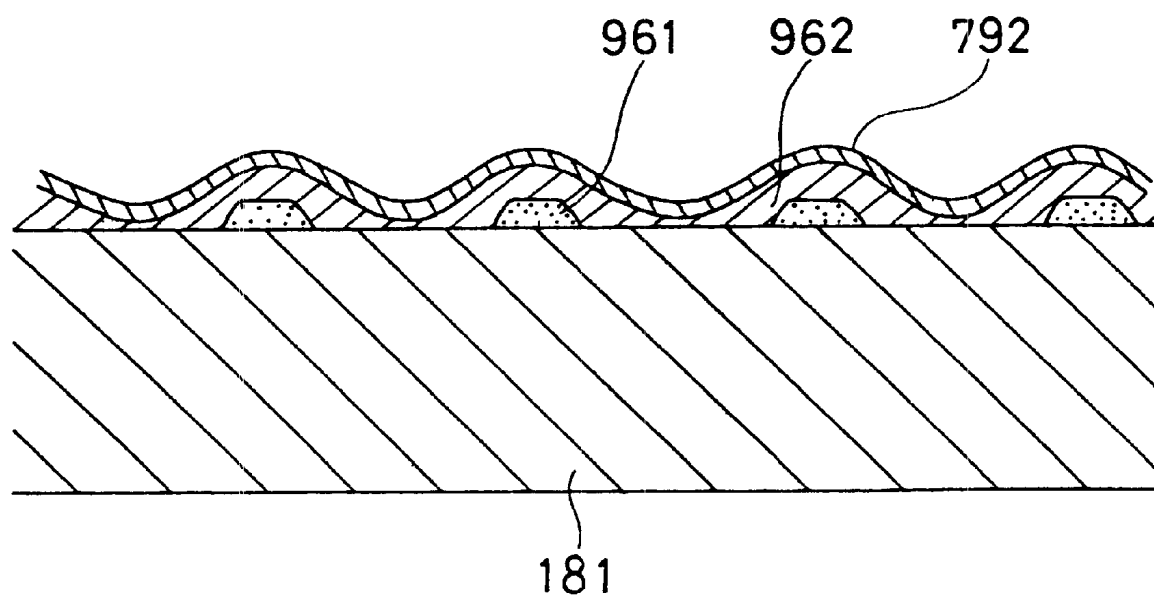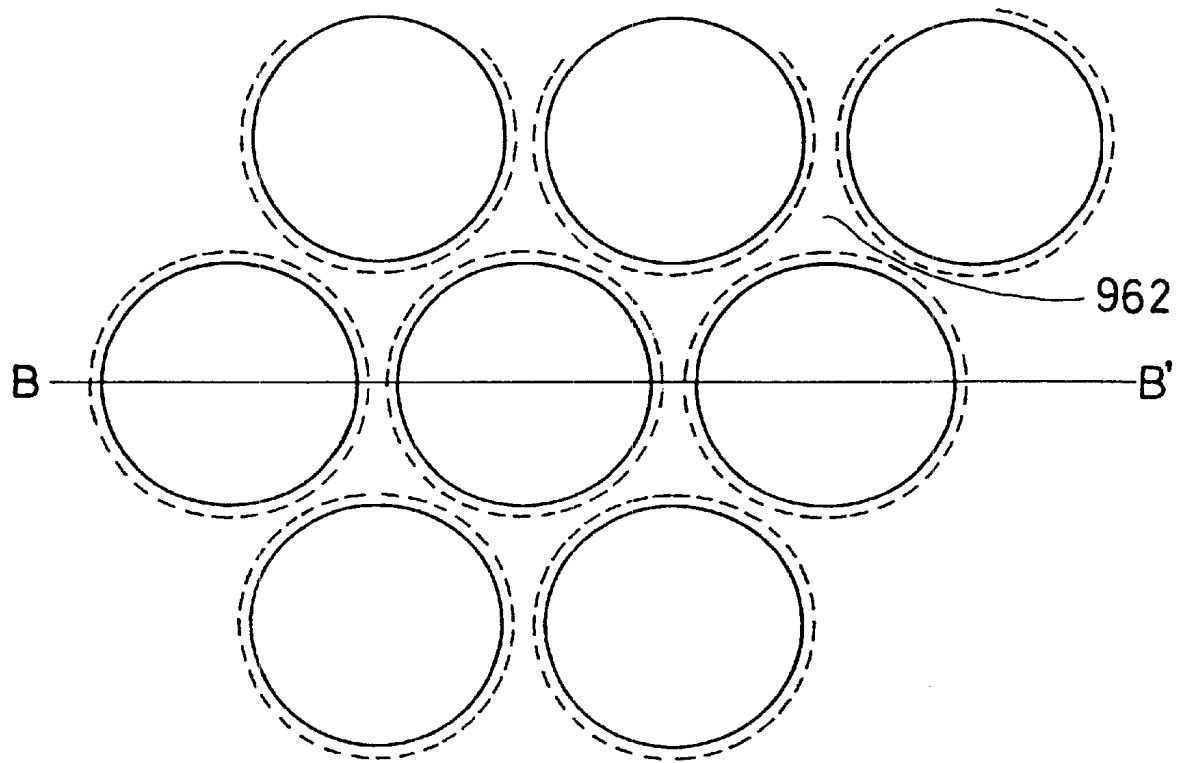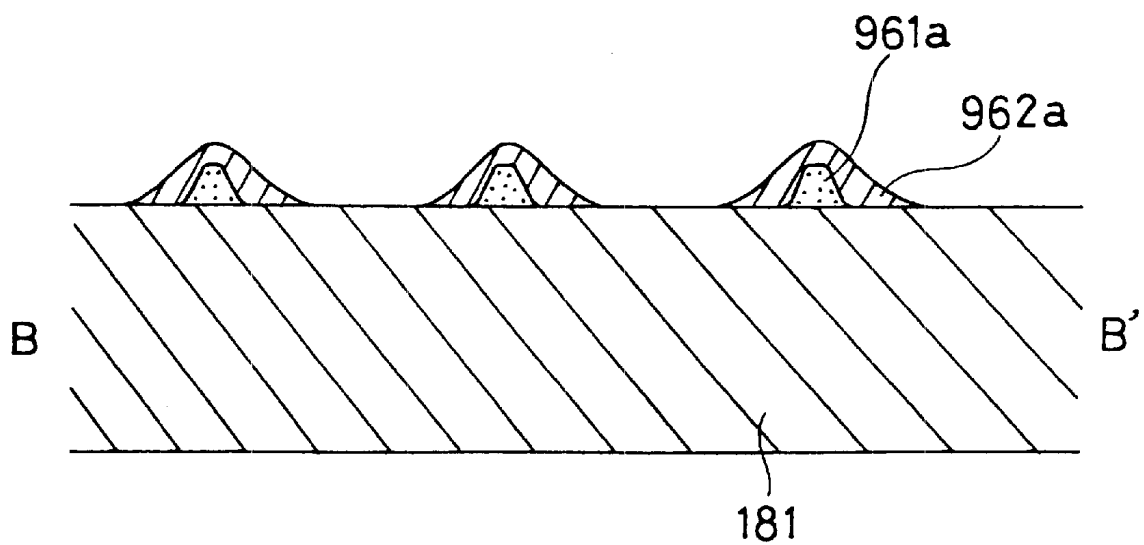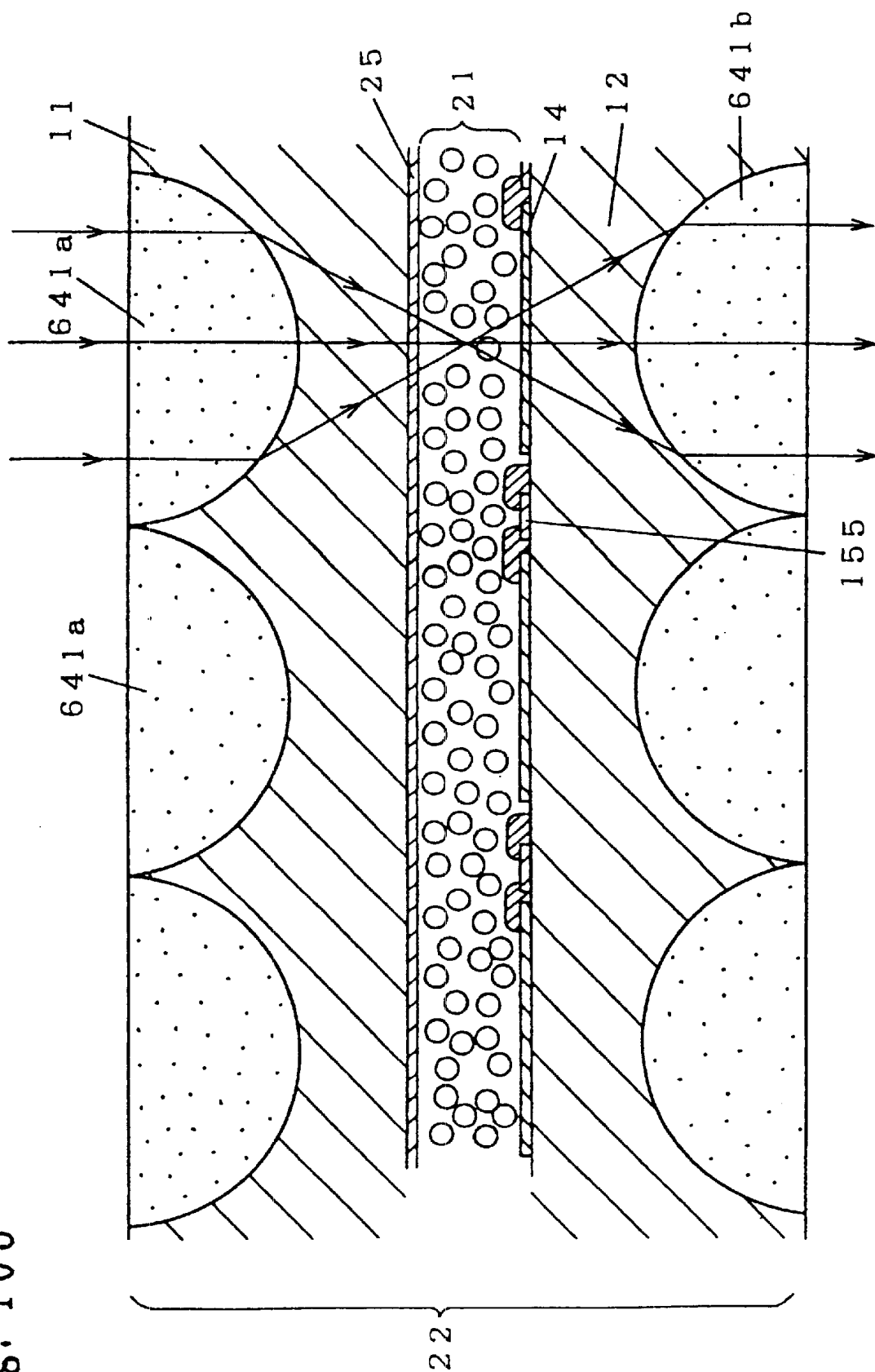
Fig. 102

Fig. 103

Fig.104

641c : FLESNEL LENS
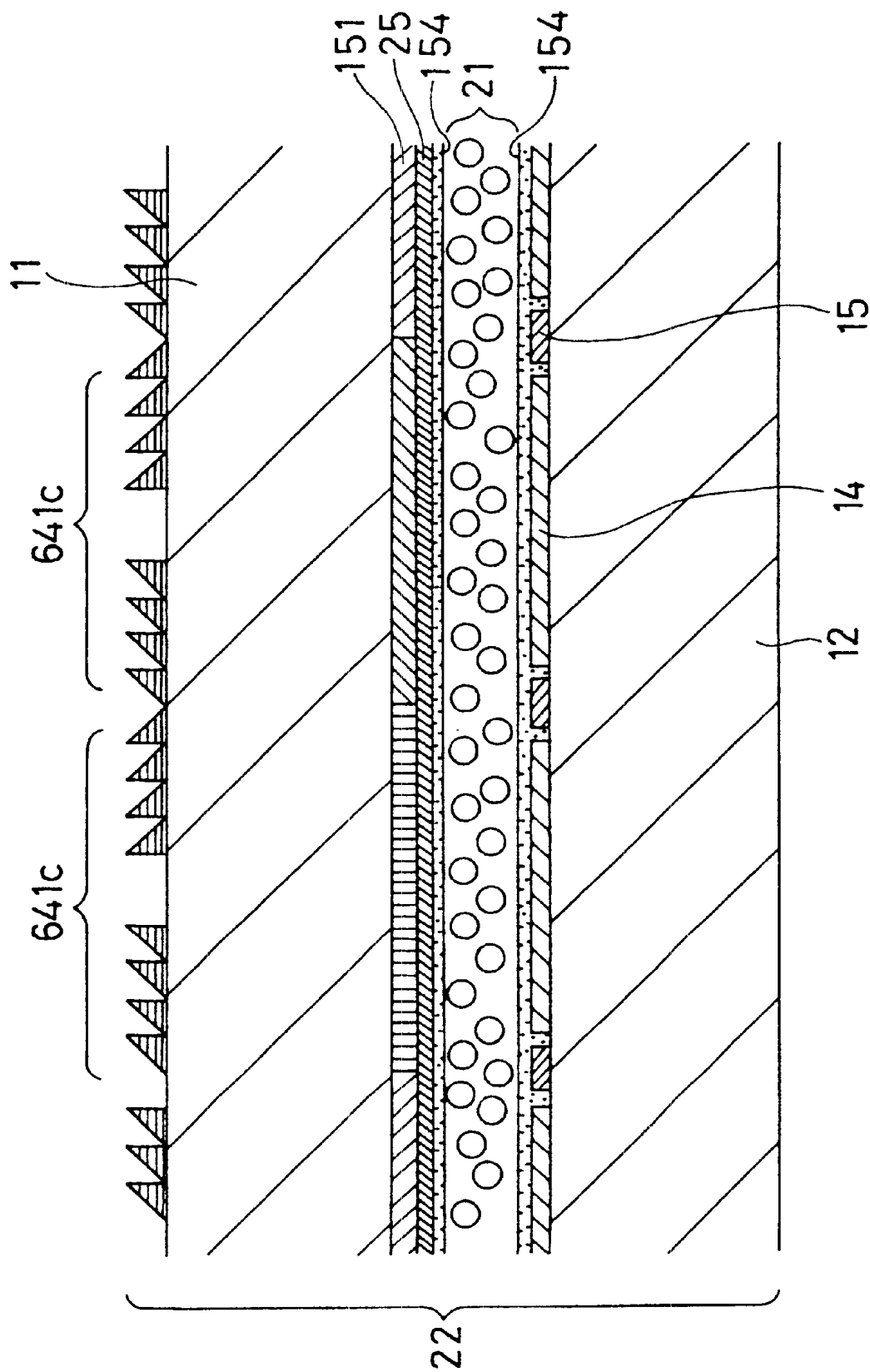
Fig. 105
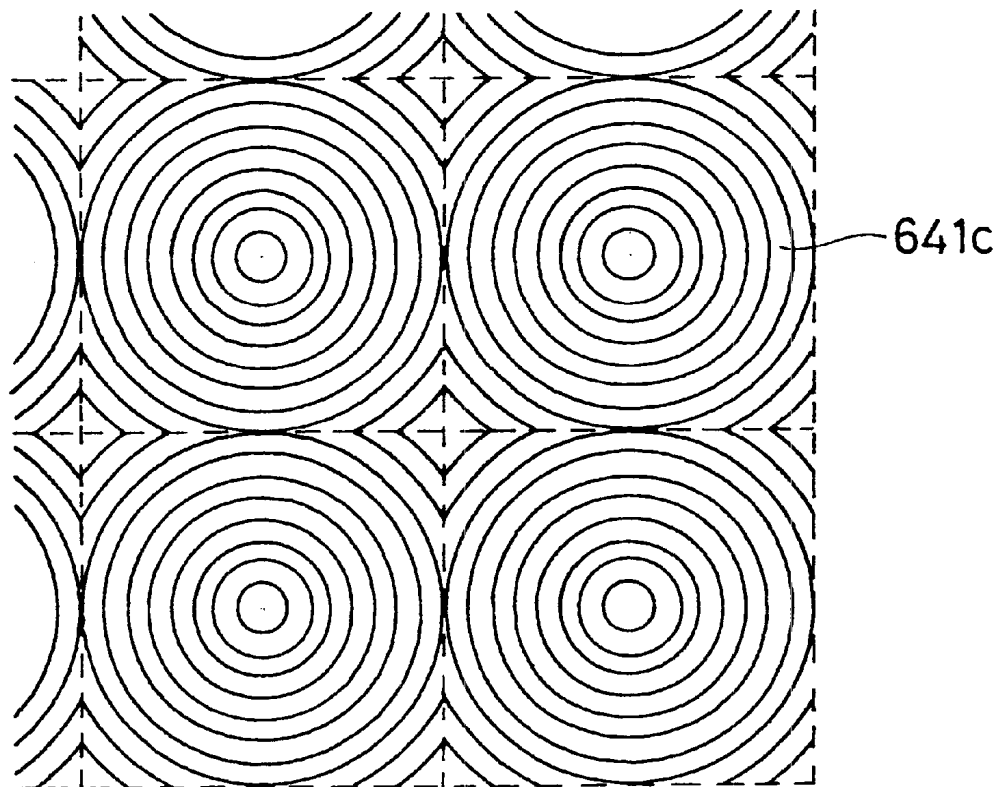
Fig. 106

1061 : PRISM SHEET

1062 : MICROLENS SHEET
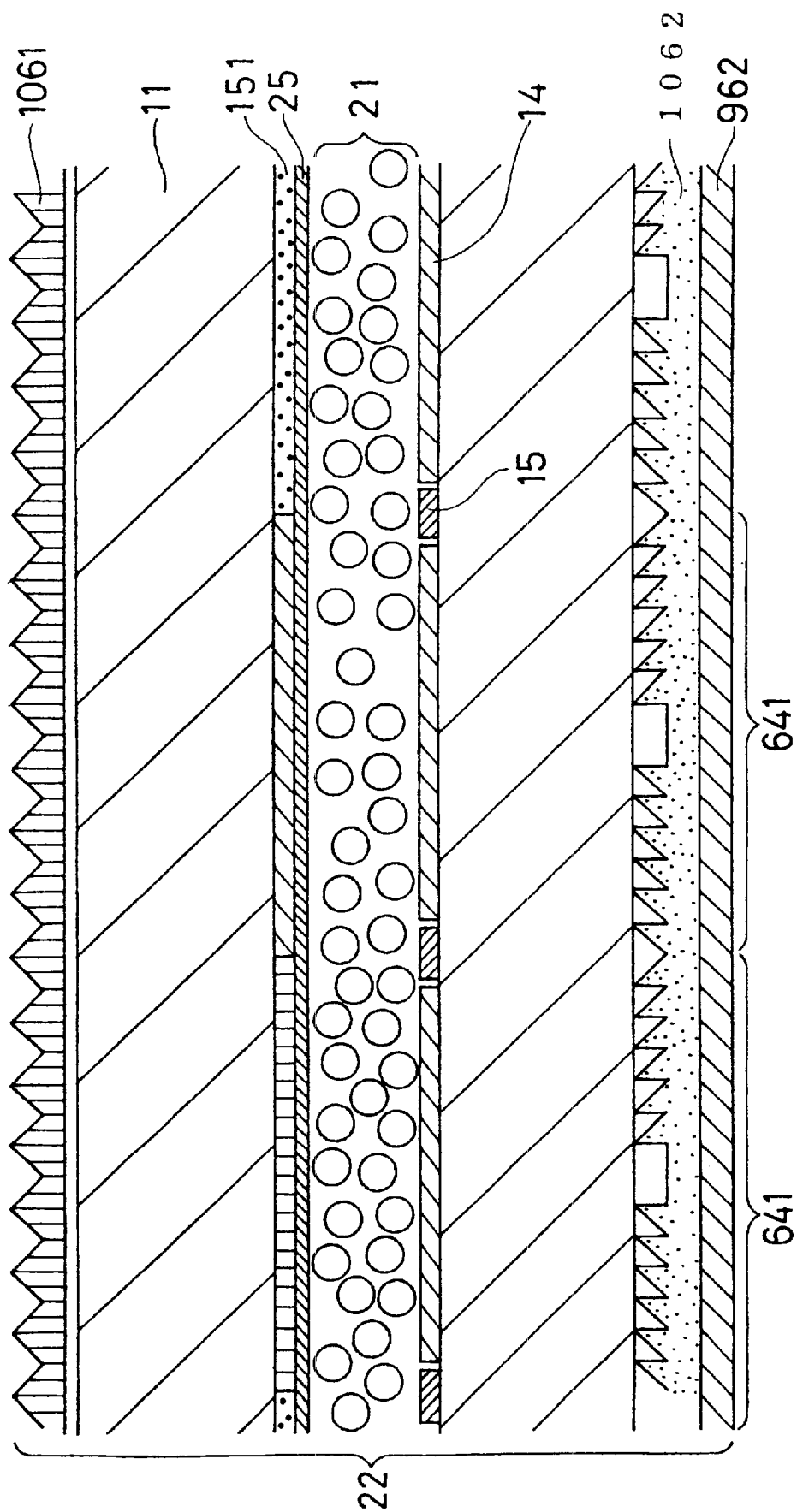
Fig. 107
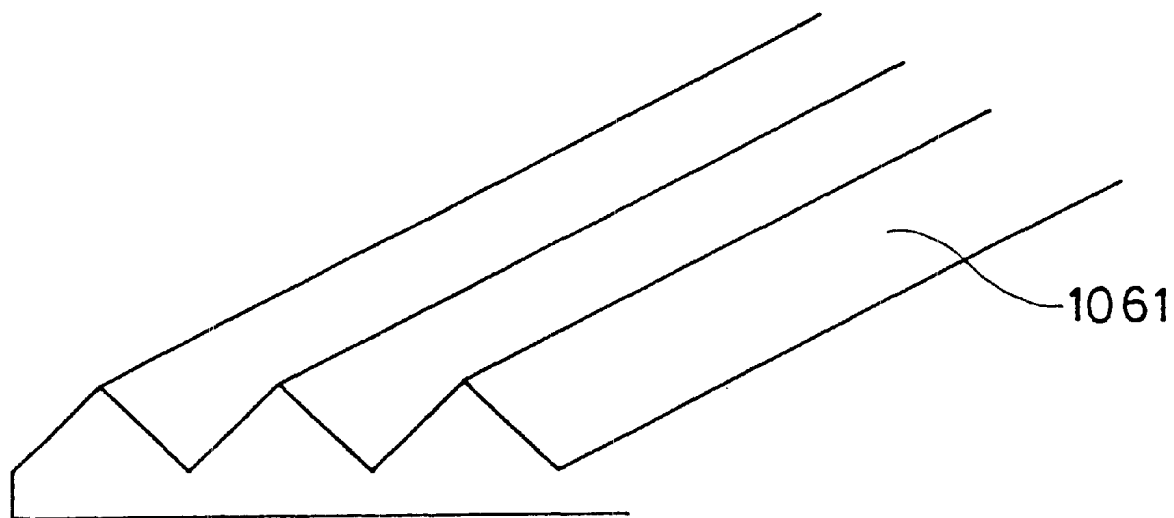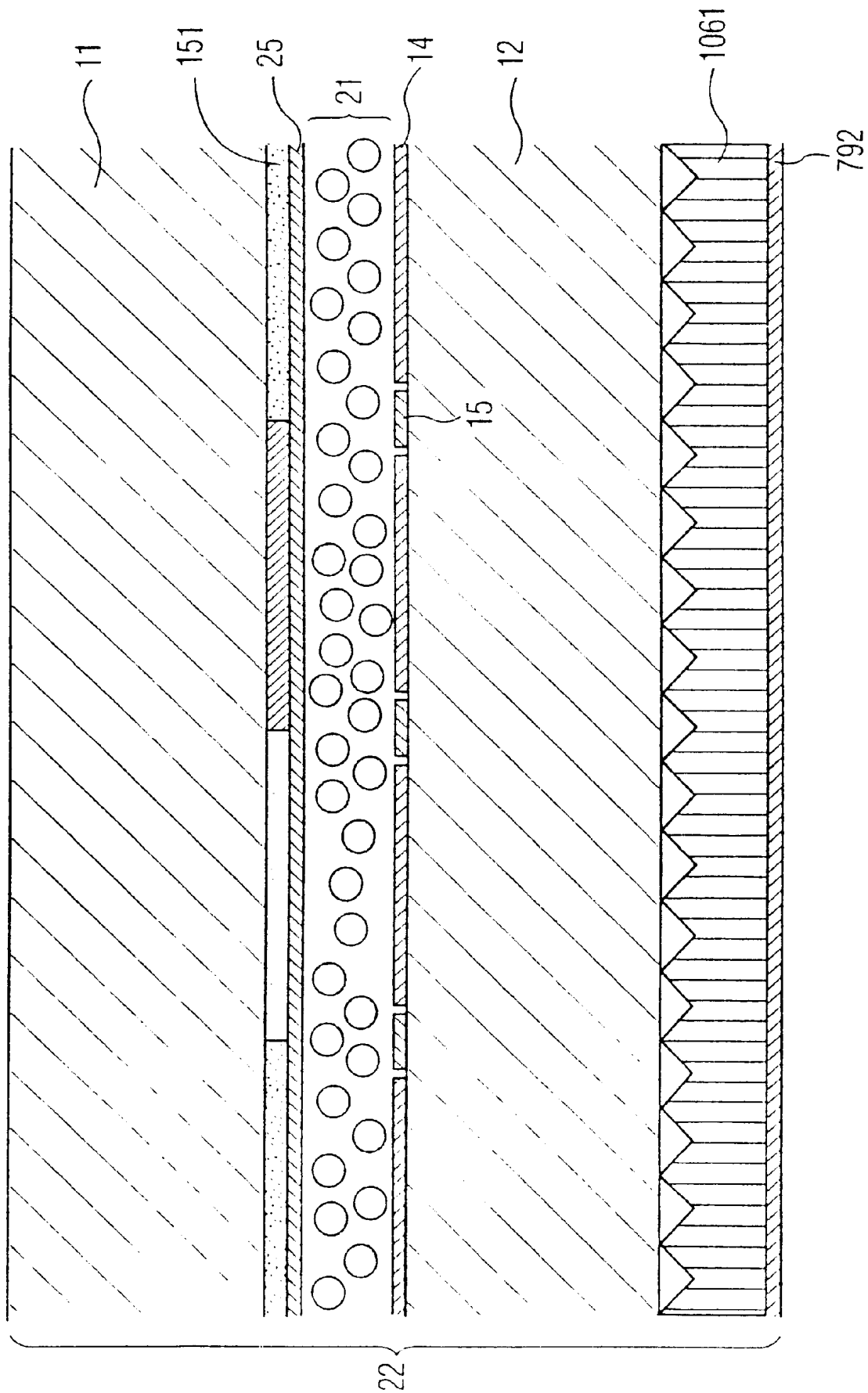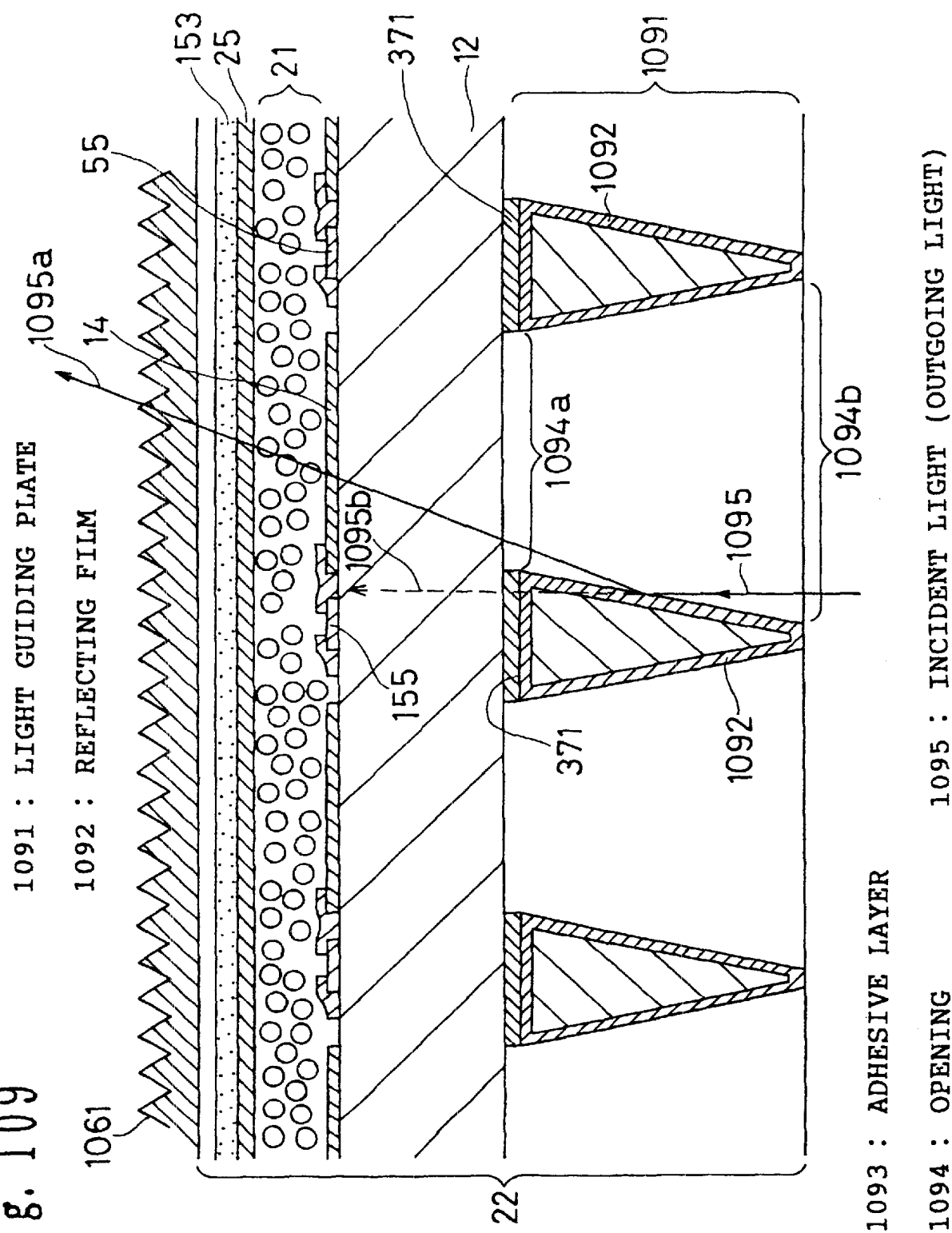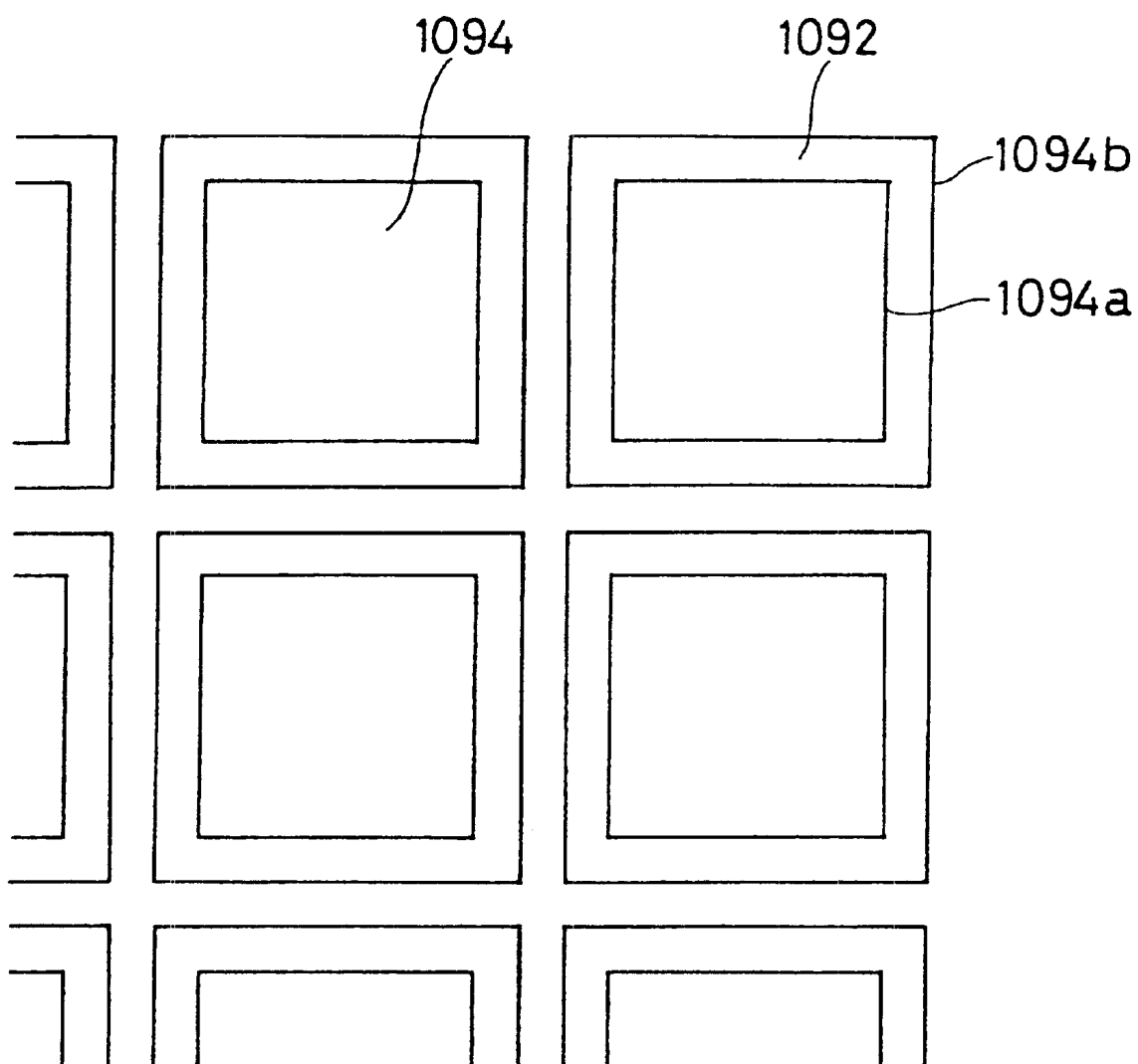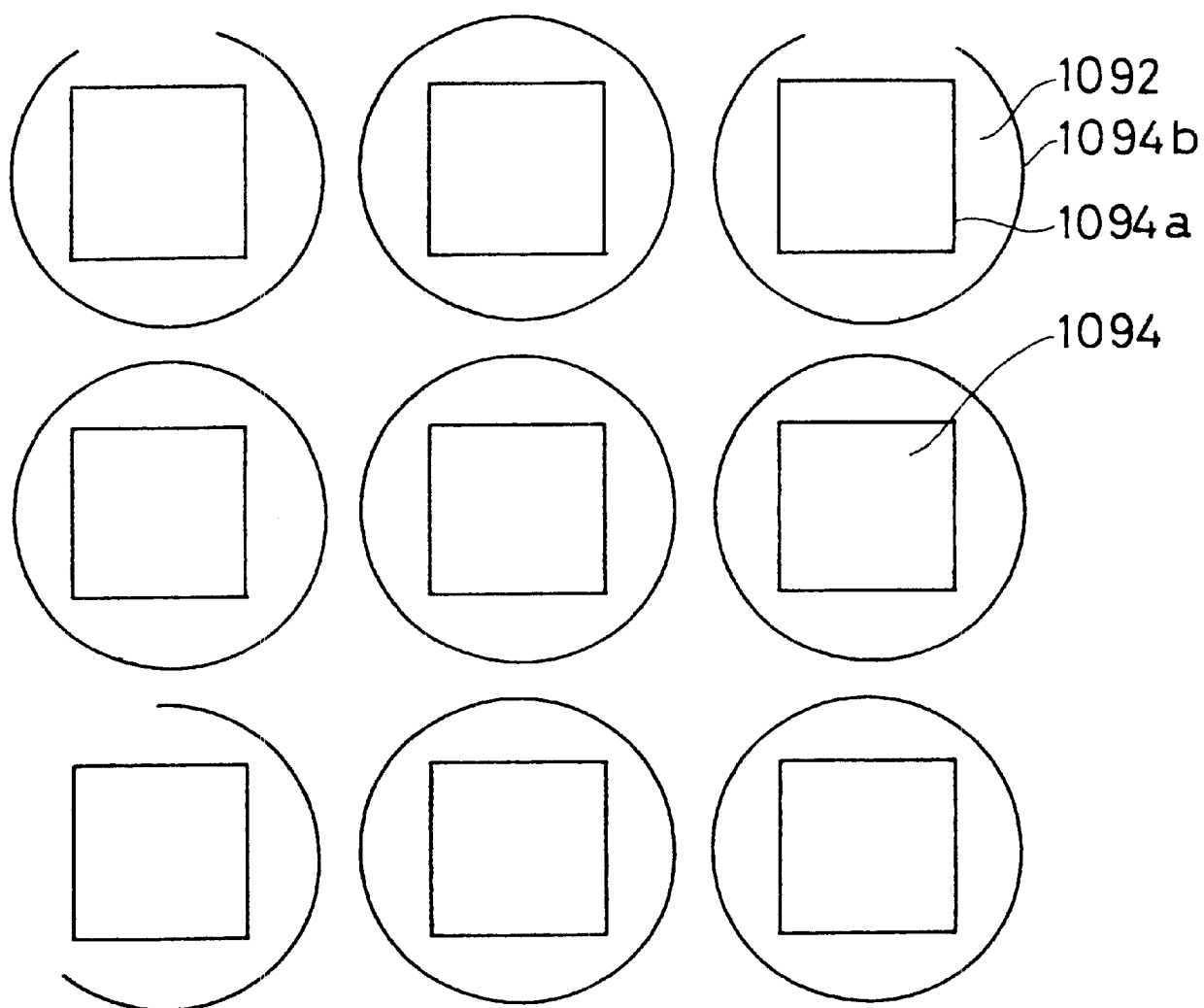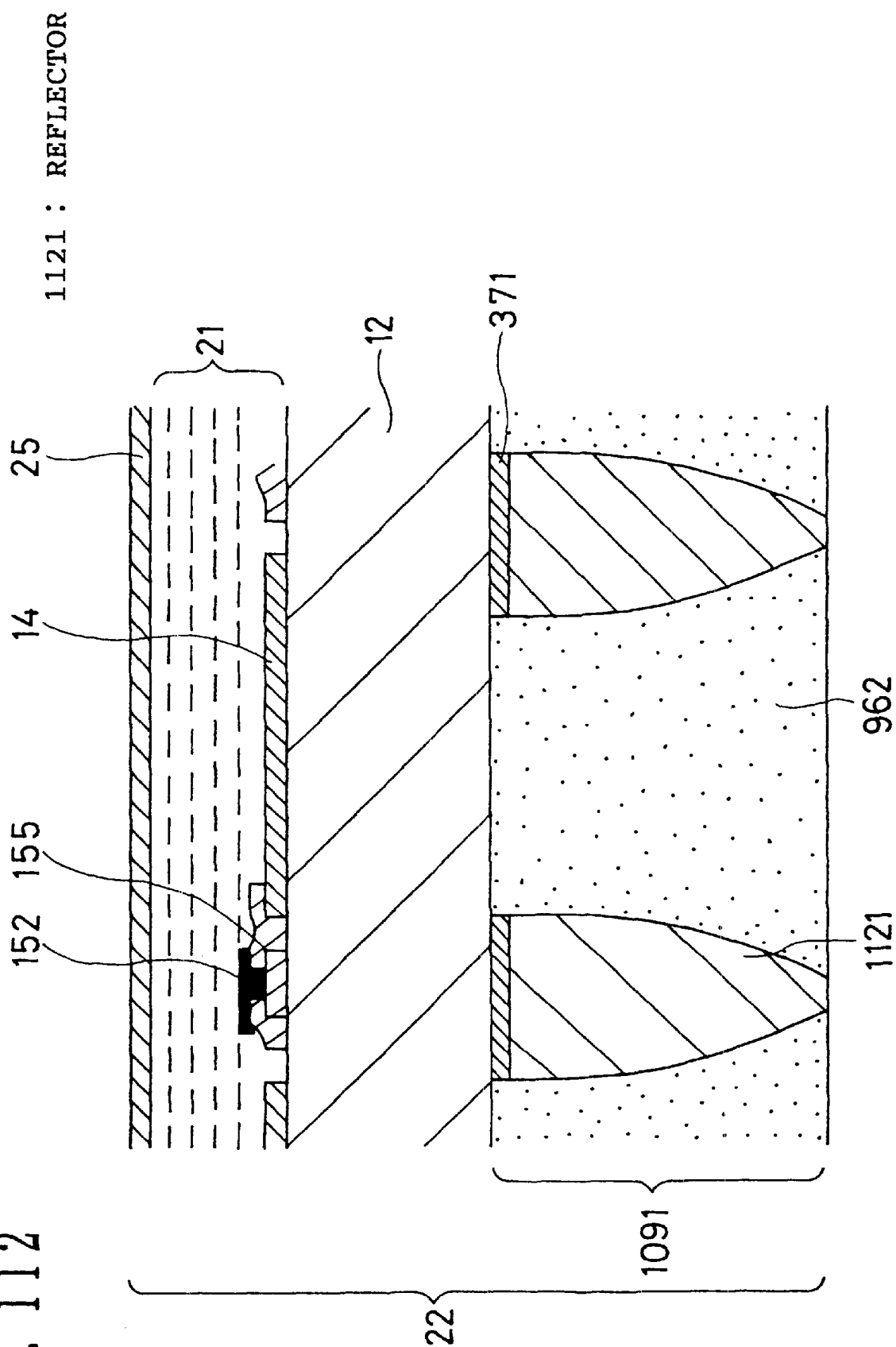
1061

FIG. 108

Fig. 109

153
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371
12
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1095a
14
1091
1092
1094a
1095b
155
371
1092
1095
1094b
1061
22

1091 : LIGHT GUIDING PLATE

1092 : REFLECTING FILM

1093 : ADHESIVE LAYER

1094 : OPENING

1095 : INCIDENT LIGHT (OUTGOING LIGHT)

INCIDENT LIGHT (OUTGOING LIGHT)

Fig. 110

1094   1092   1094b

1094a

Fig. 111

Fig. 112

1121 : REFLECTOR
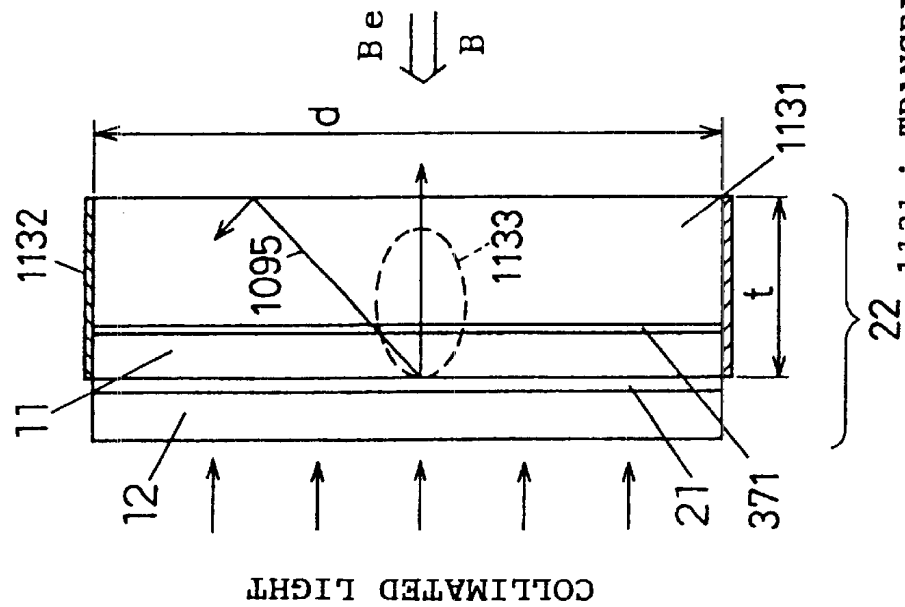
Fig. 113 (b)

Fig. 113 (a)
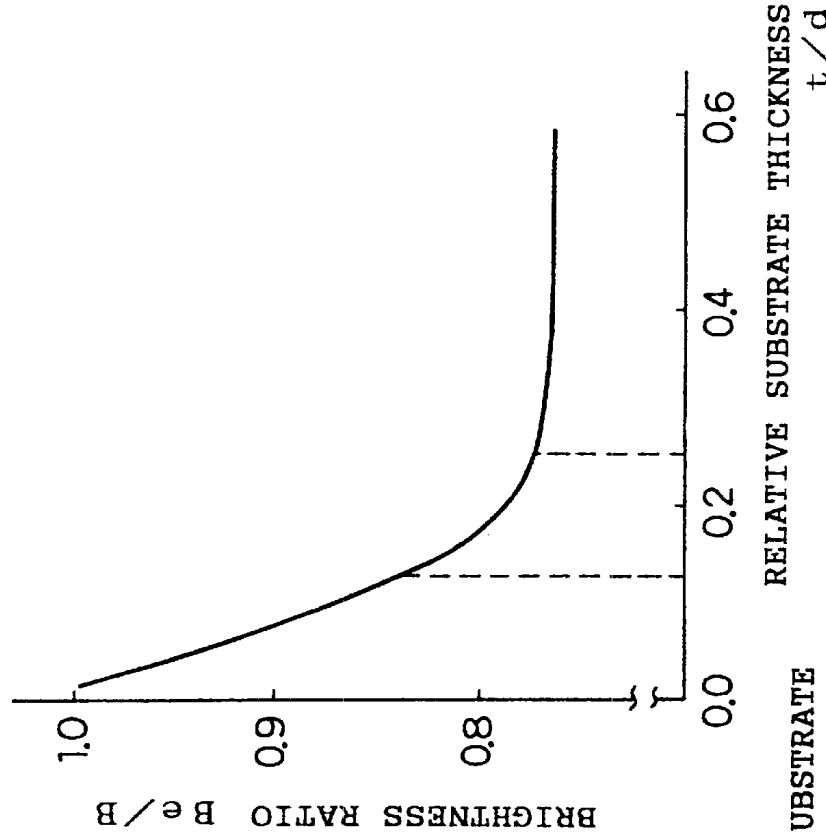
1131 : TRANSPARENT SUBSTRATE

1132 : LIGHT ABSORBING FILM

1133 : SCATTERED LIGHT

Fig.114(a)
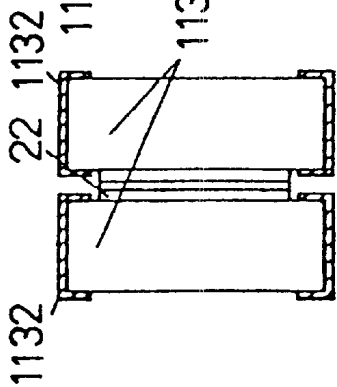
Fig.114(b)
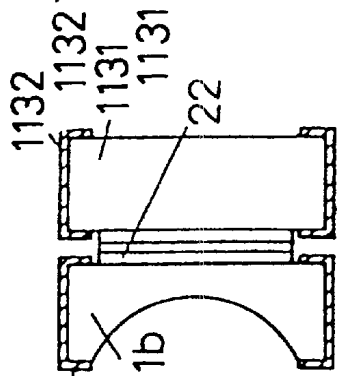
Fig.114(c)
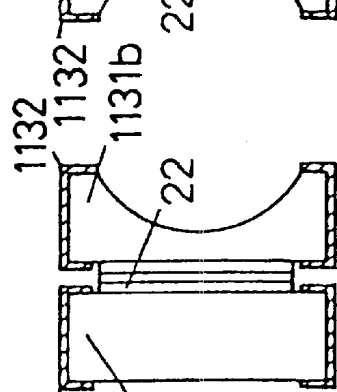
Fig.114(d)
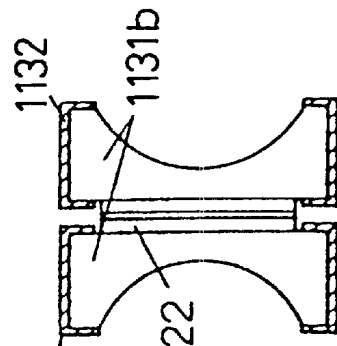
Fig.114(e)
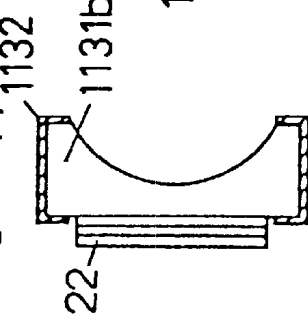
Fig.114(f)
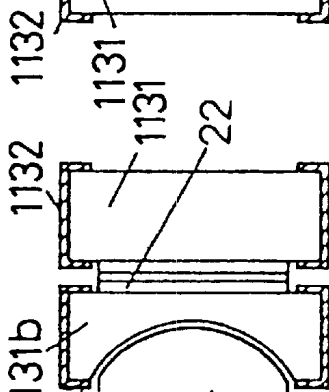
Fig.114(g)
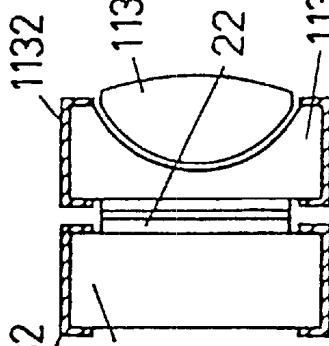
Fig.114(h)
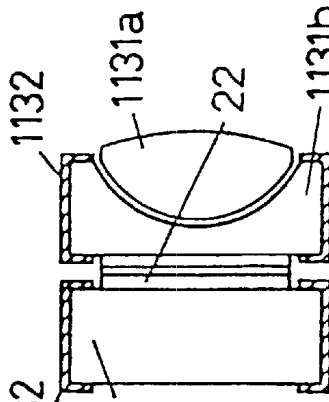
Fig.114(i)
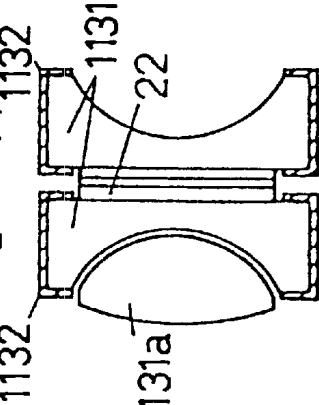
Fig.114(j)
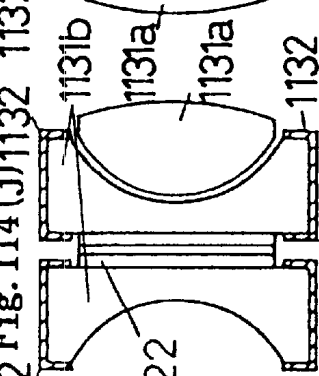
Fig.114(k)
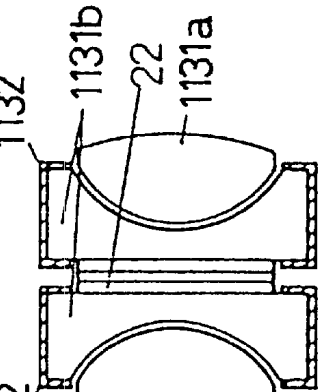
1131a : POSITIVE LENS

1131b : CONCAVE LENS

1132
1131b

1132
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1131

22

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1131

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1132
1132
1131b
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1132
1131b

1132
1131a
1131b

1131a
1131b

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1132
1131
1131

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1132
1131a
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1132
1131b
22

1132
1131b
22

1132
1132
1131b
22

1131a
1131a

1132

1132

1131b
22
1131a

1131a
1131a

22

1132

1131a

Fig. 115

22

921   922   1131

Fig. 116

1161 : CASING

1162 : PAWL

INCIDENT LIGHT
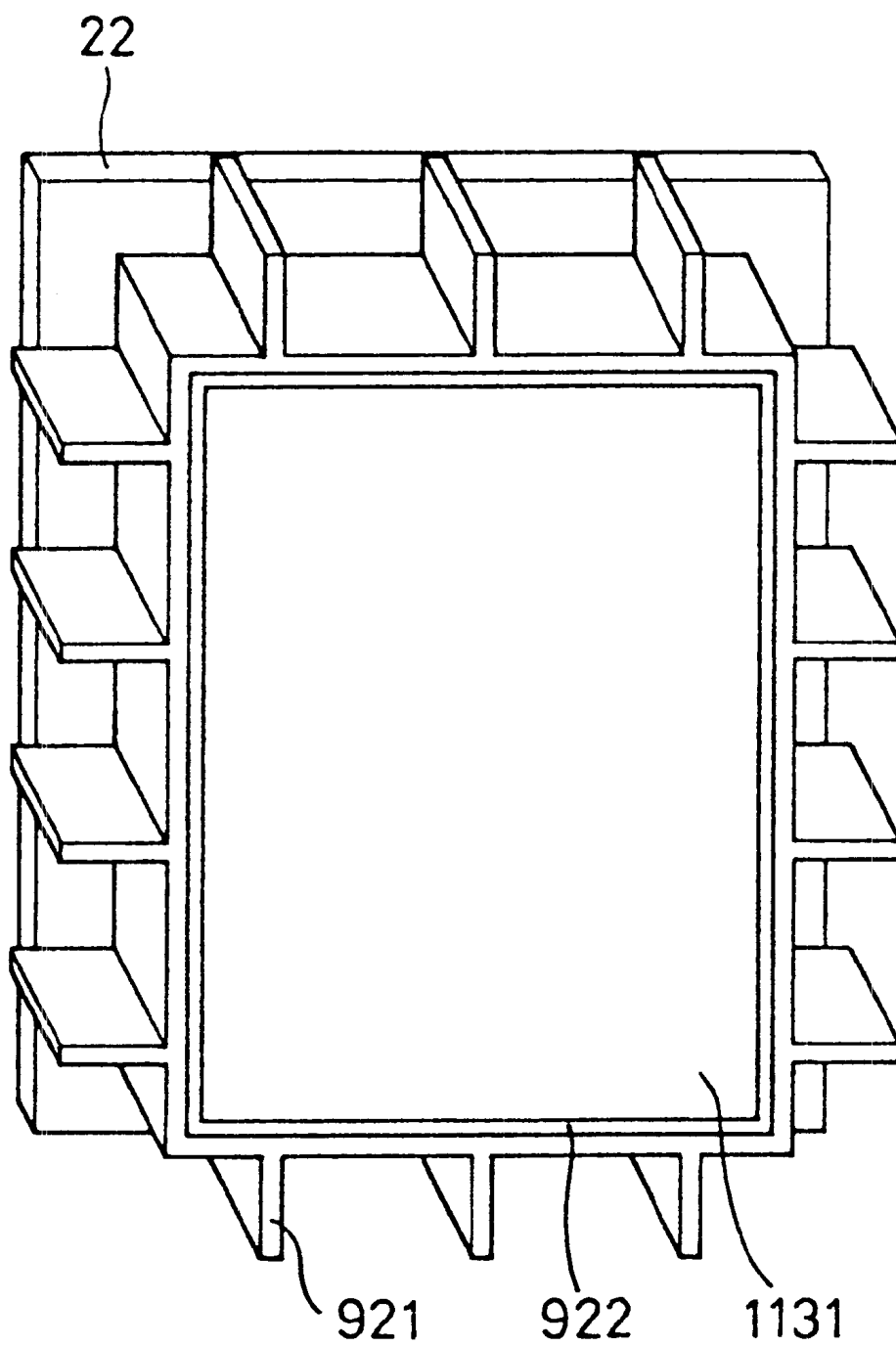
1171 : LID

1172 : ETHYLENE GLYCOL
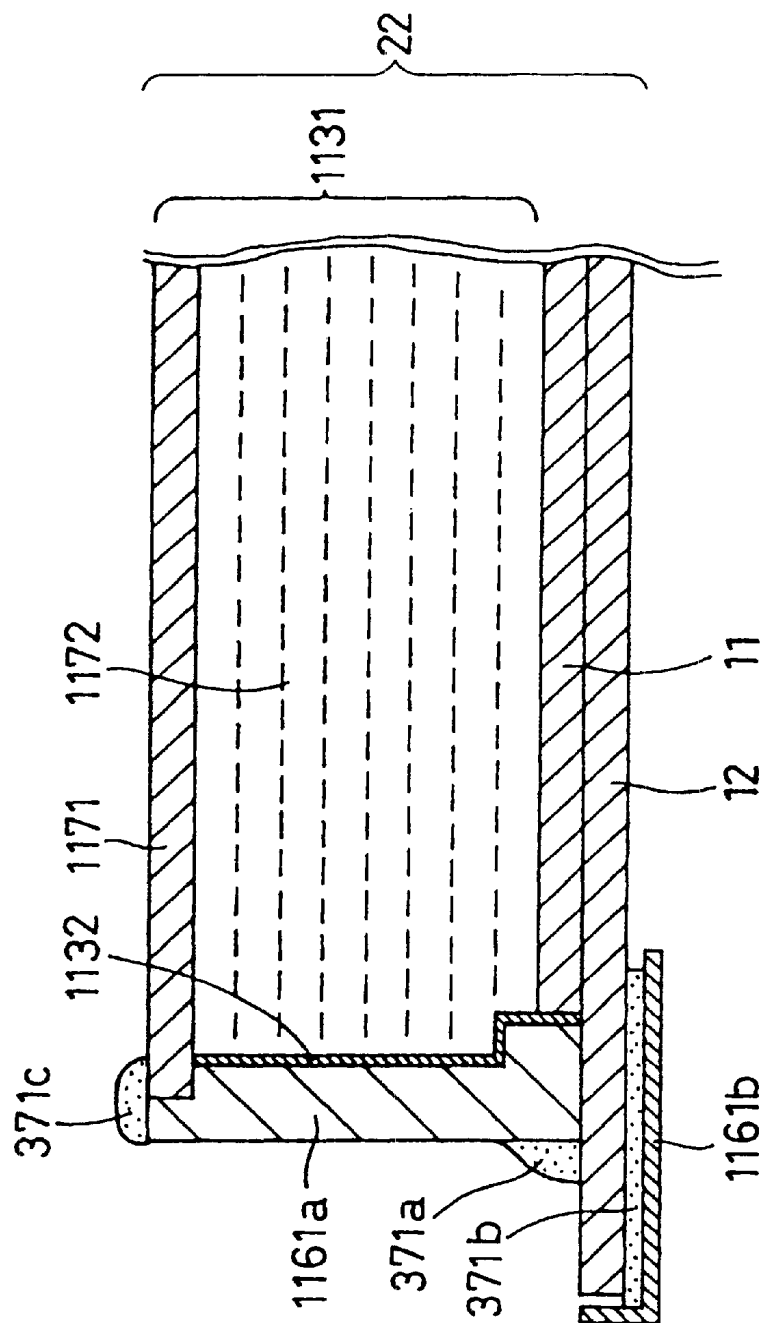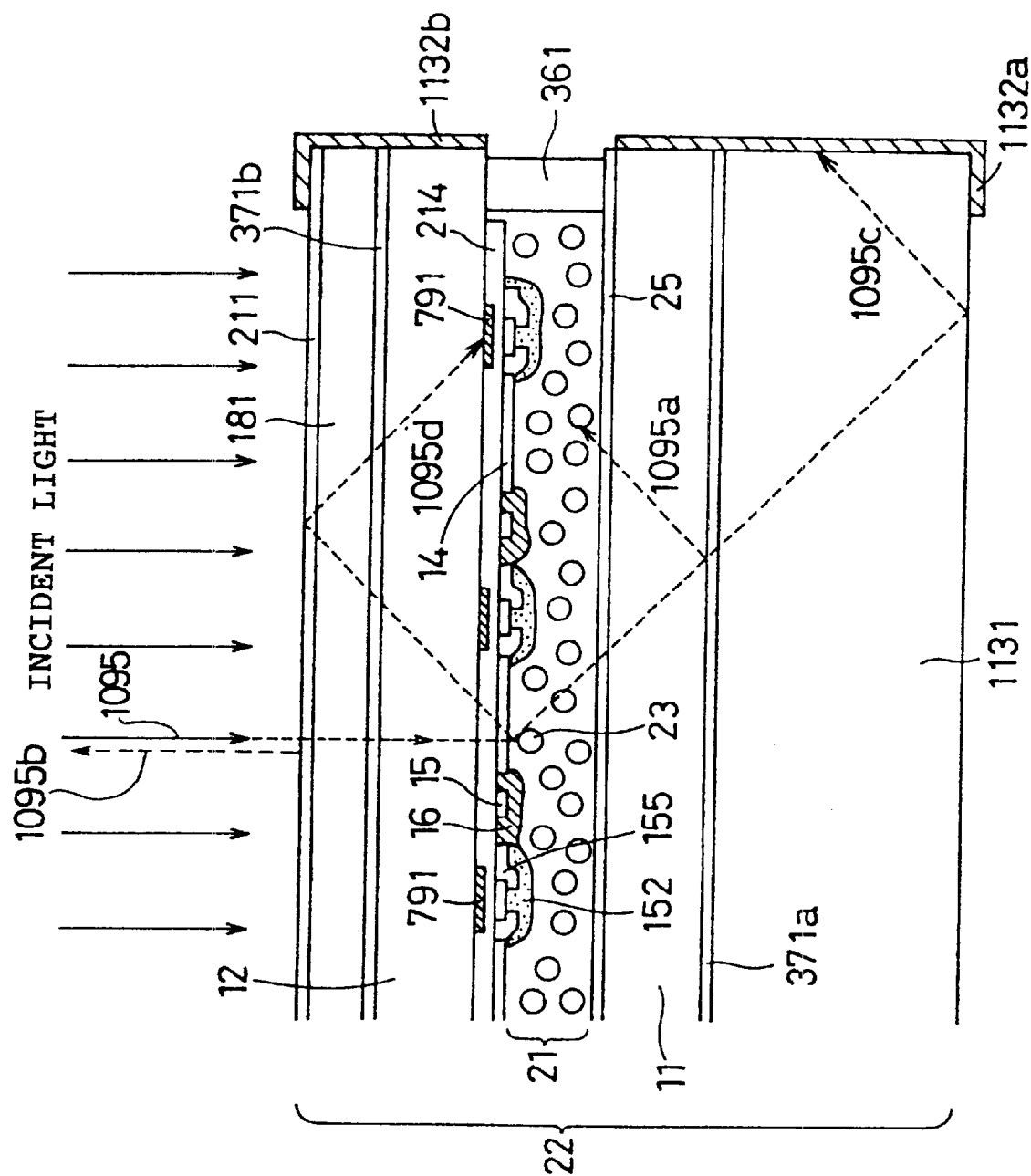
Fig. 117

Fig. 118

Fig. 119

1191 : OR CIRCUIT

1192 : SWITCH CIRCUIT

1193 : SIGNAL LINE CAPACITOR

1194 : ADDITIONAL CAPACITOR

Fig. 120 (a)

VIDEO SIGNAL 1

Fig. 120 (b)

VIDEO SIGNAL 2

Fig. 120 (c)

CNT SIGNAL

(n + 2)nd LINE

(n + 1)st LINE

nth LINE

1H

IMAGE DISPLAY
PERIOD S

h

H

L

Fig. 121

VIDEO SIGNAL 1

VIDEO SIGNAL 2

A/D   1211

LINE MEMORY   1212

ARITHMETIC CIRCUIT   1213

D/A   1214

1121 : A/D

1212 : LINE MEMORY

1213 : ARITHMETIC CIRCUIT

1214 : D/A
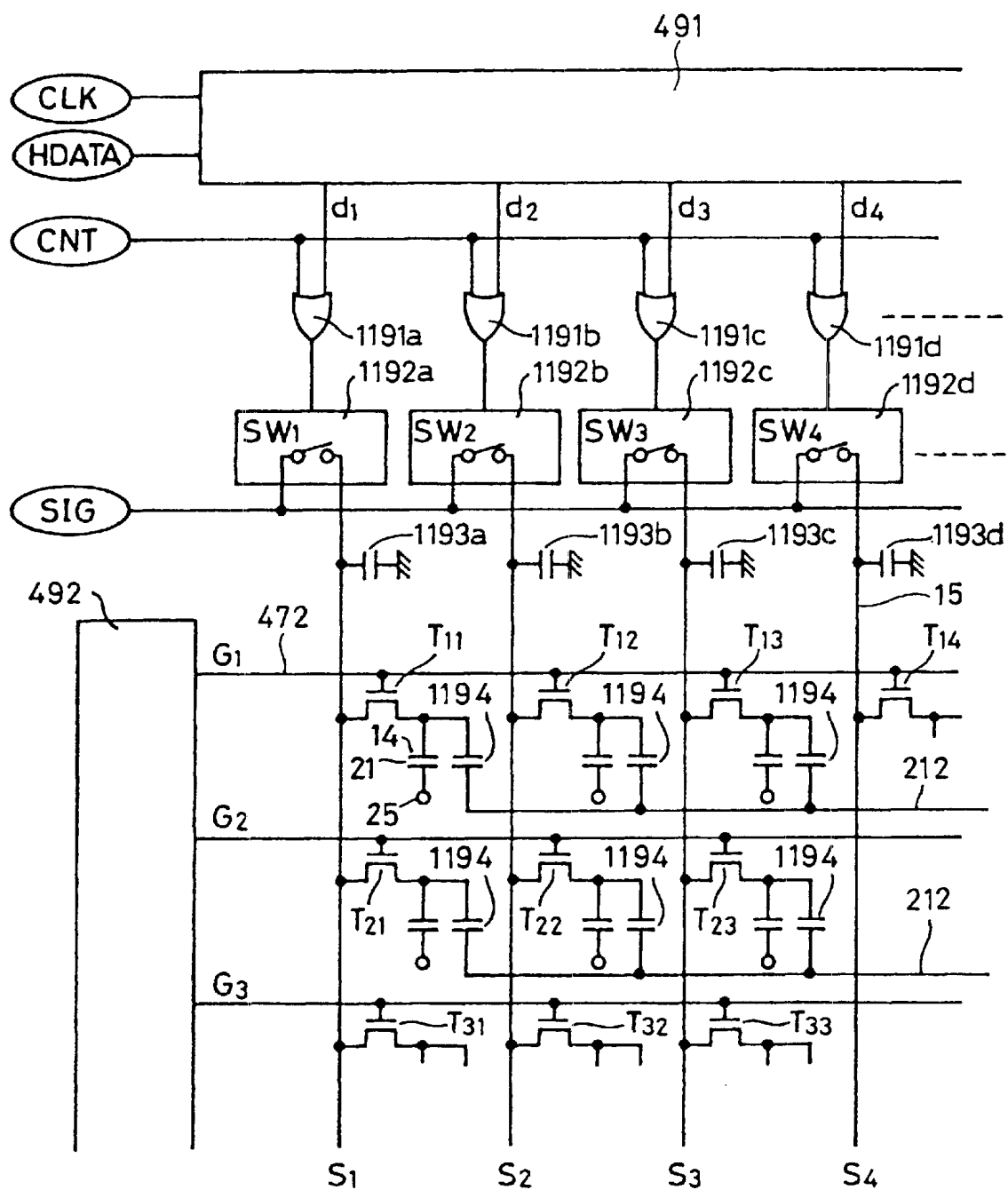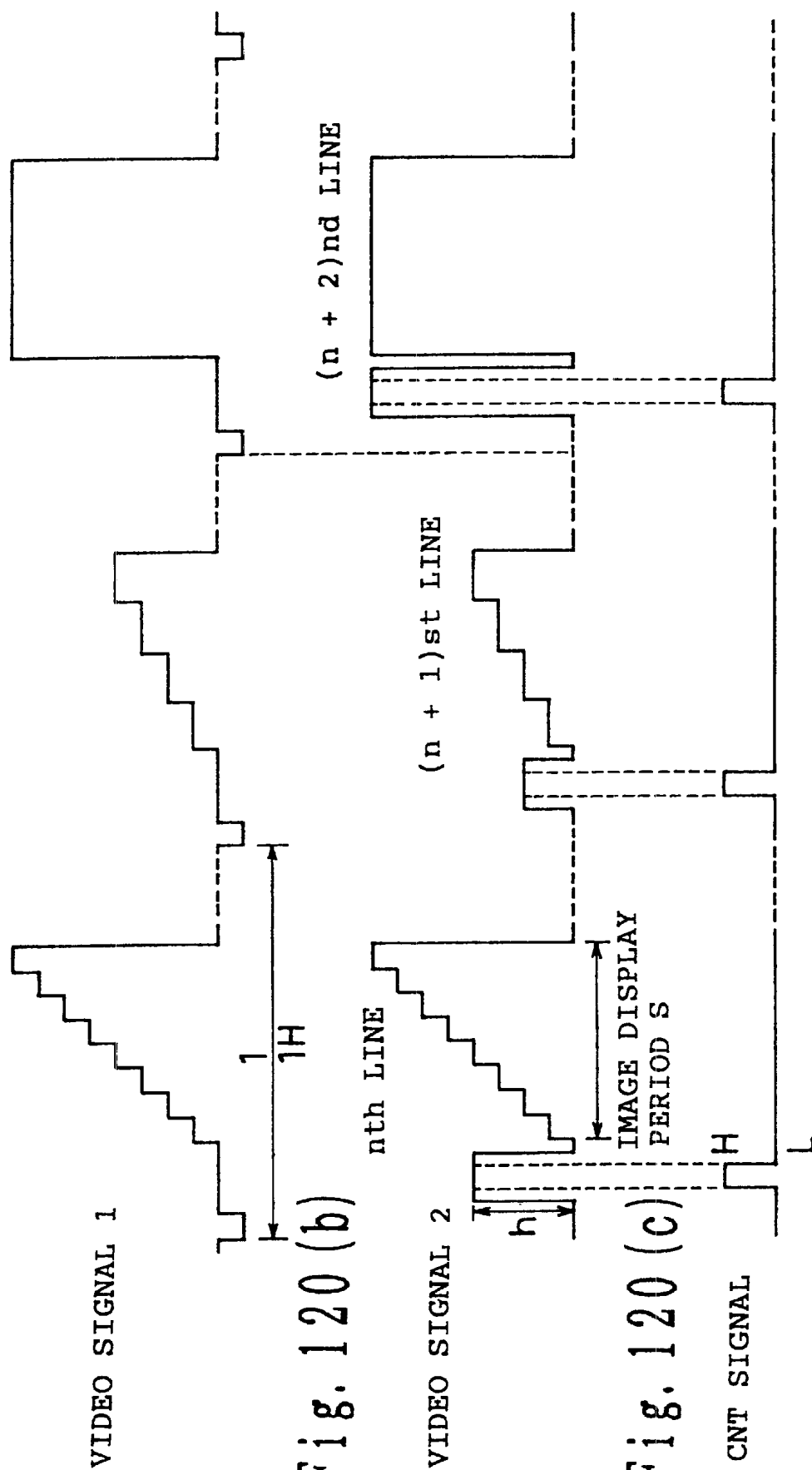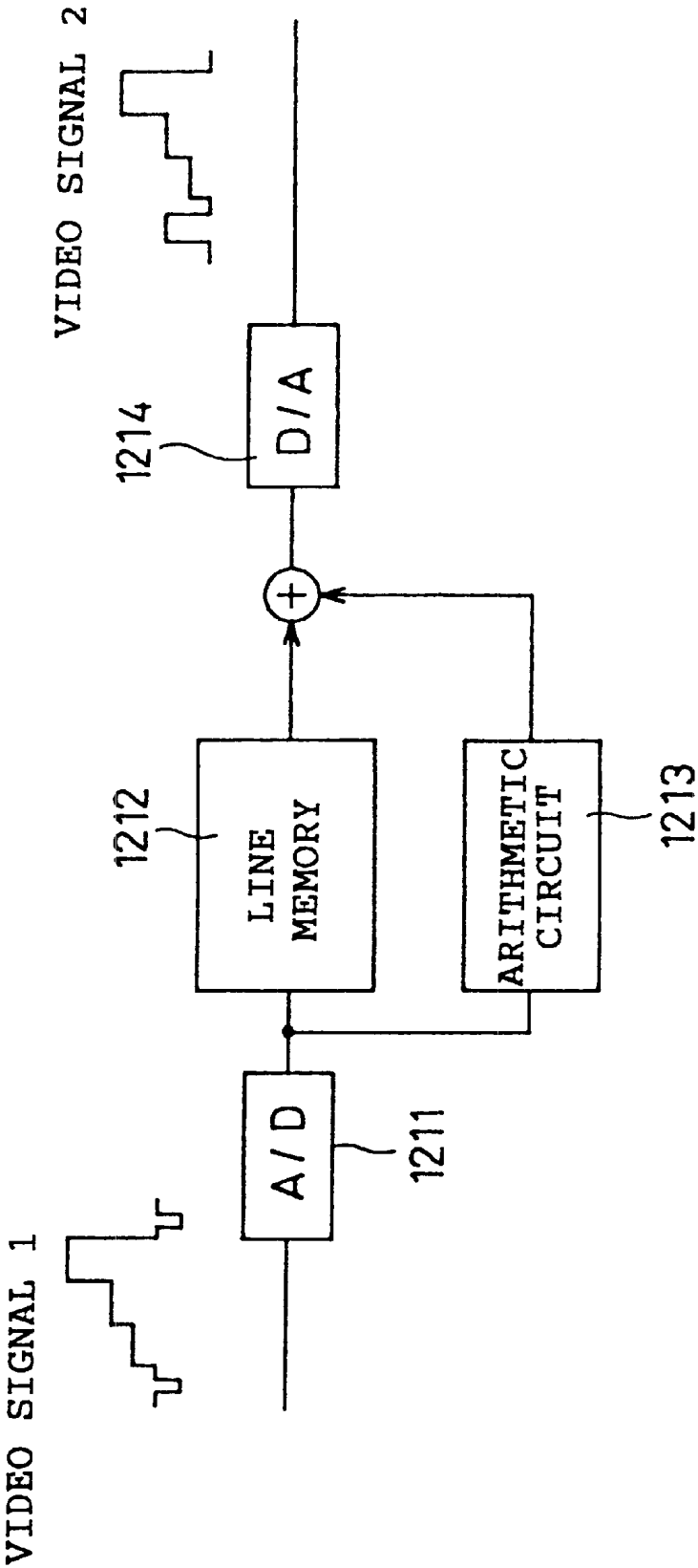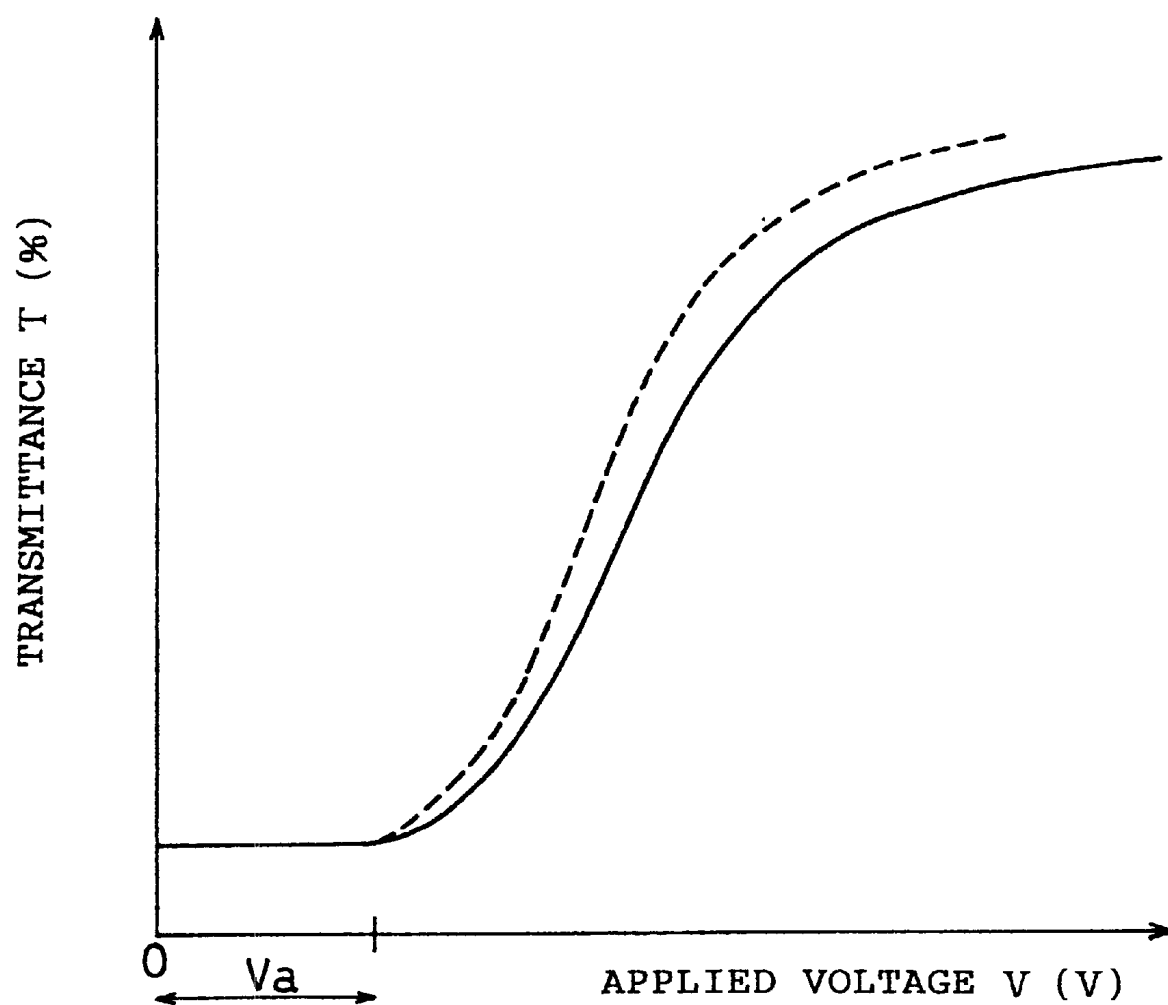
Fig. 122

Fig. 123 (a)
HD

Fig. 123 (b)

Fig. 123 (c)

Fig. 123 (d)
CNT SIGNAL

1H
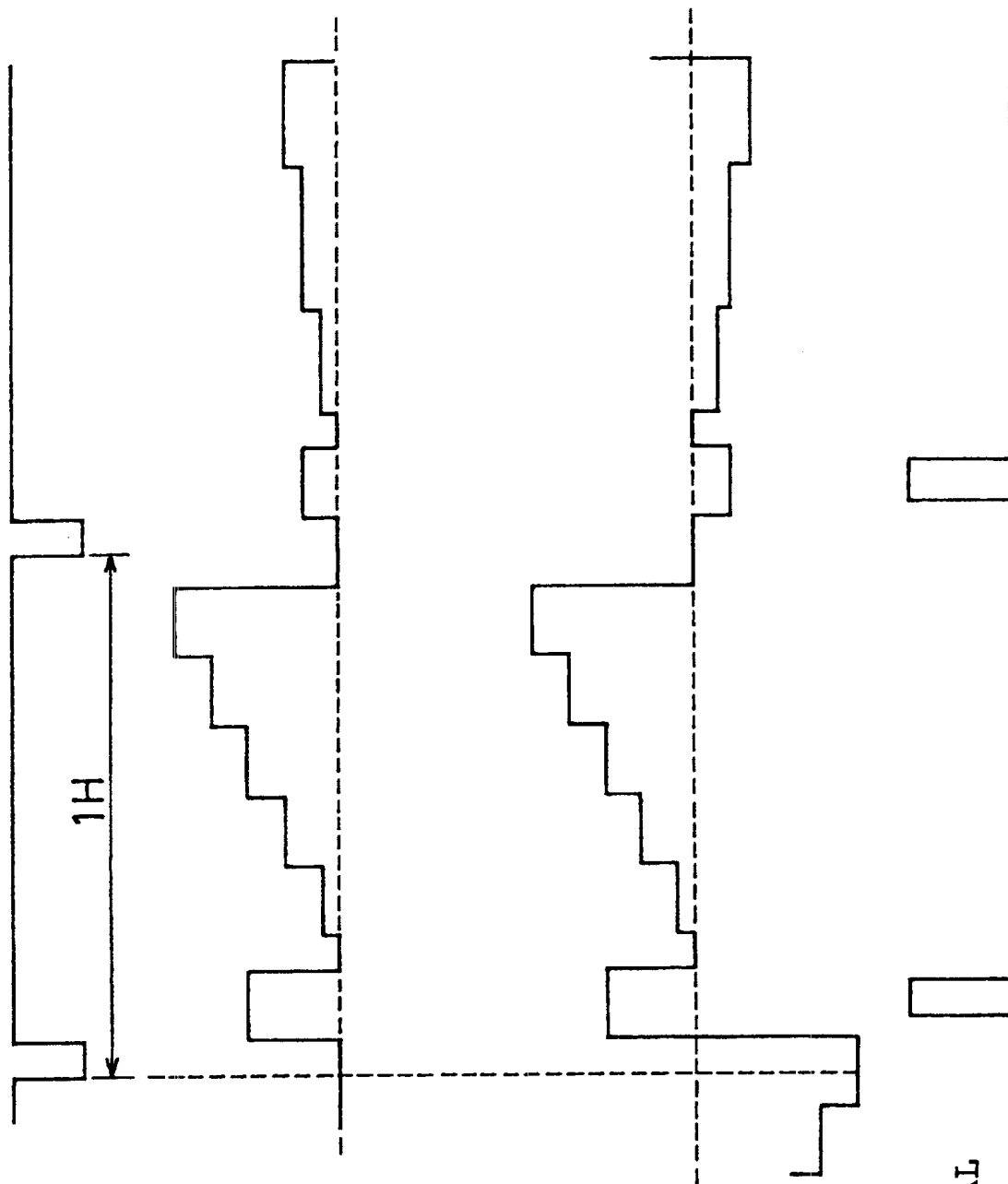
Fig. 124

1241 : BUFFER
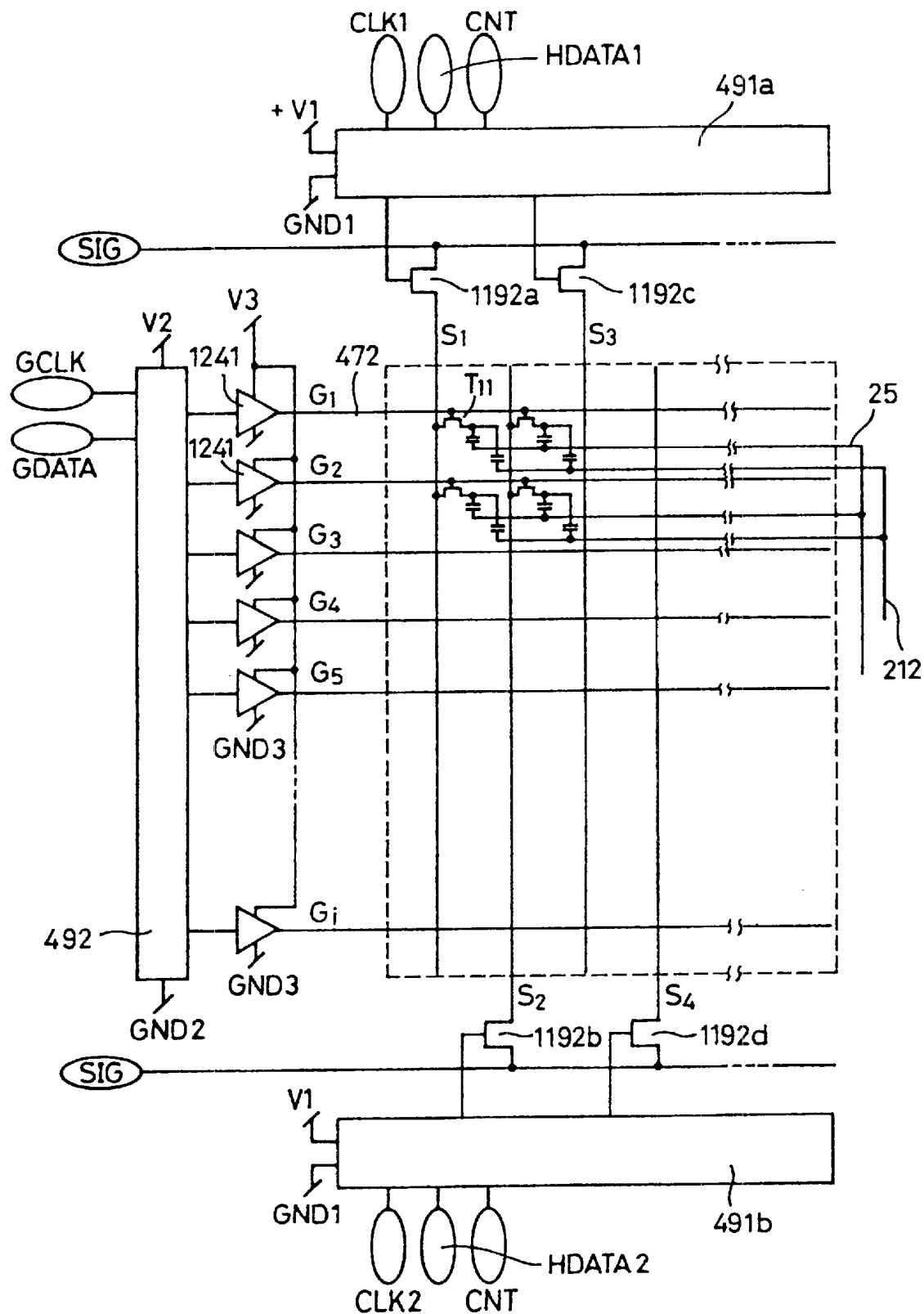
Fig. 125
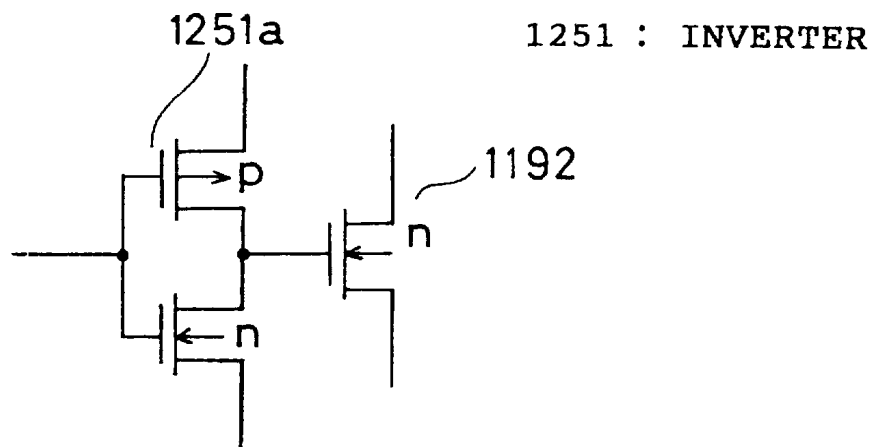
1251a   1251 : INVERTER

1192

Fig. 126 (a)

1251d   1251b   1192   1251c

Fig. 126 (b)

491

SIG   1192

1251d 1251b   15   1251c   SHIFT REGISTER

W4   W3   W2   W1
L4   L3   L2   L1

Fig. 127

Fig. 128 (b)

Fig. 128 (a)

1281 : SIGNAL SOURCE

1282 : VIDEO SIGNAL CIRCUIT
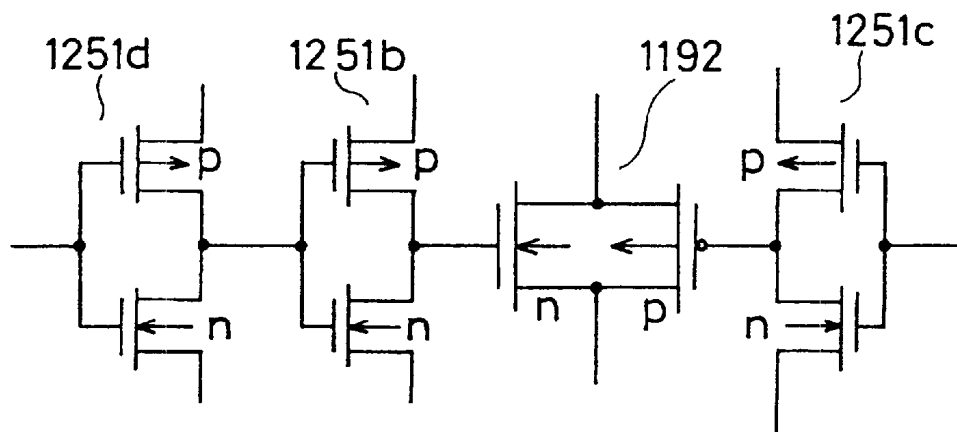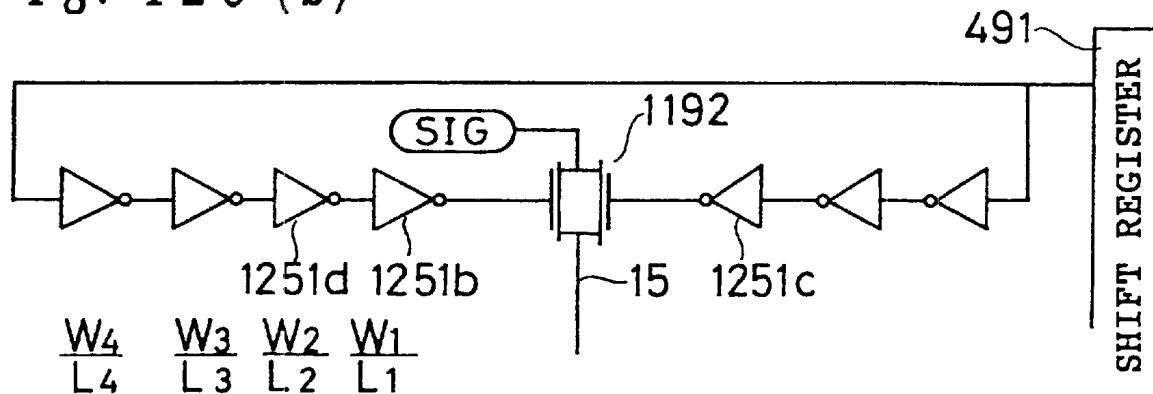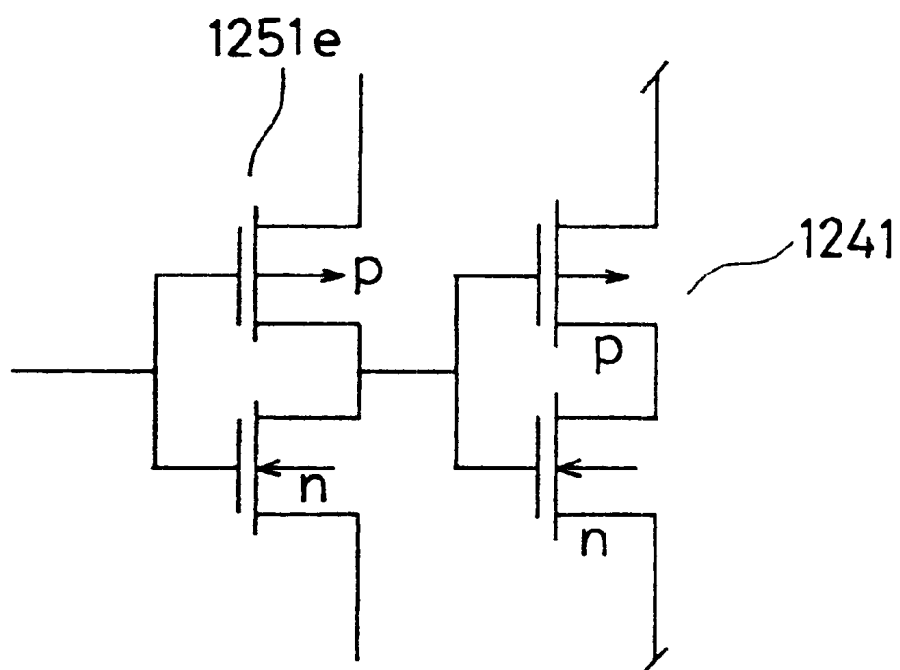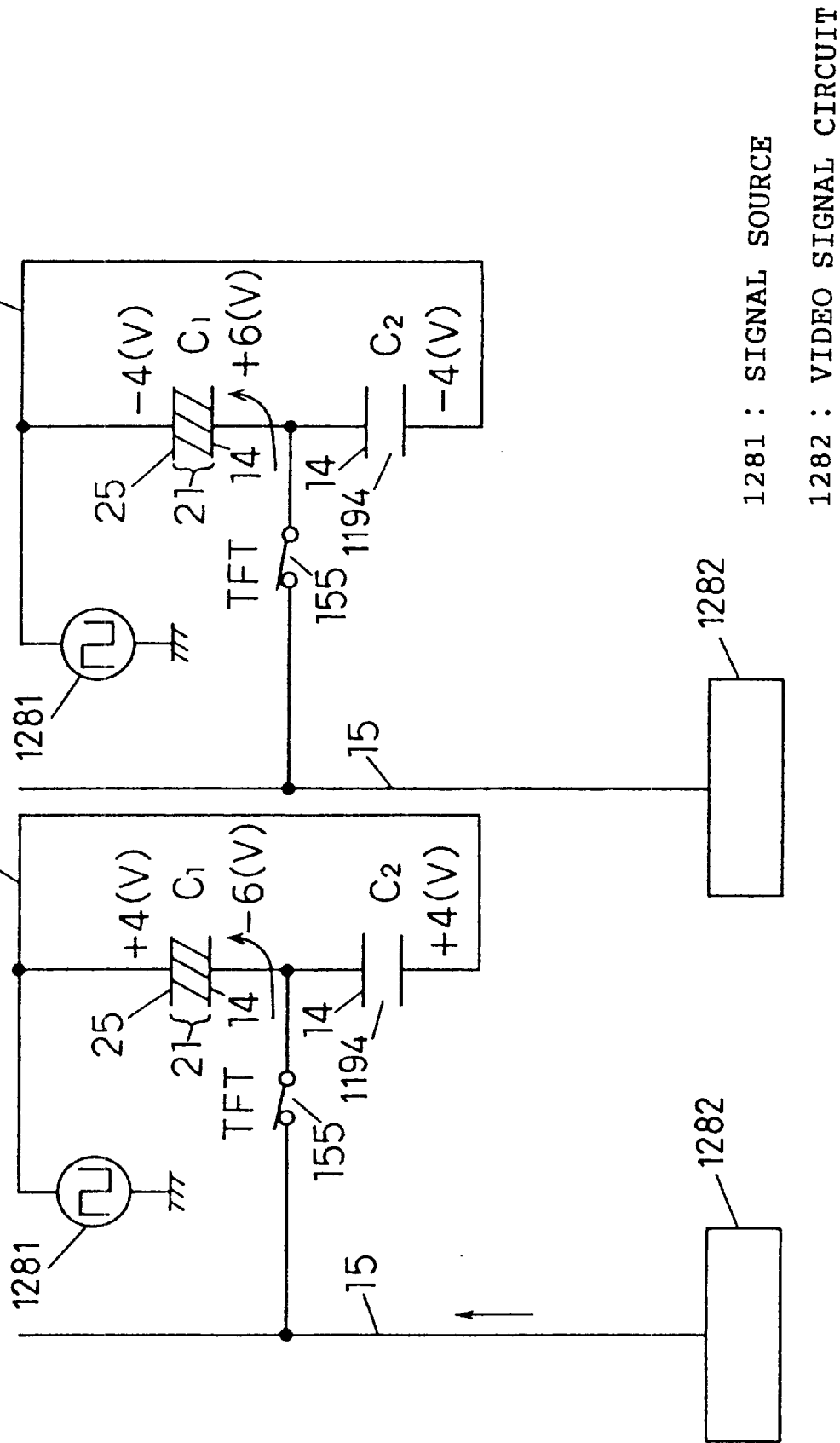
Fig. 129

1291 : PIXEL

Fig. 130

Fig. 131

1311 : DISPLAY IMAGE

1311

SCANNING DIRECTION

Fig. 132

INPUT SIGNAL WAVEFORM (VIDEO SIGNAL)
TO SOURCE DRIVER CIRCUIT

APPLIED SIGNAL TO
COUNTER ELECTRODE

V_0

V_{SI}

SIGNAL CENTER

1H

+

−

Fig. 133

INPUT SIGNAL WAVEFORM (VIDEO SIGNAL)
TO SOURCE DRIVER CIRCUIT

APPLIED SIGNAL WAVEFORM
TO COUNTER ELECTRODE

V_{S2}
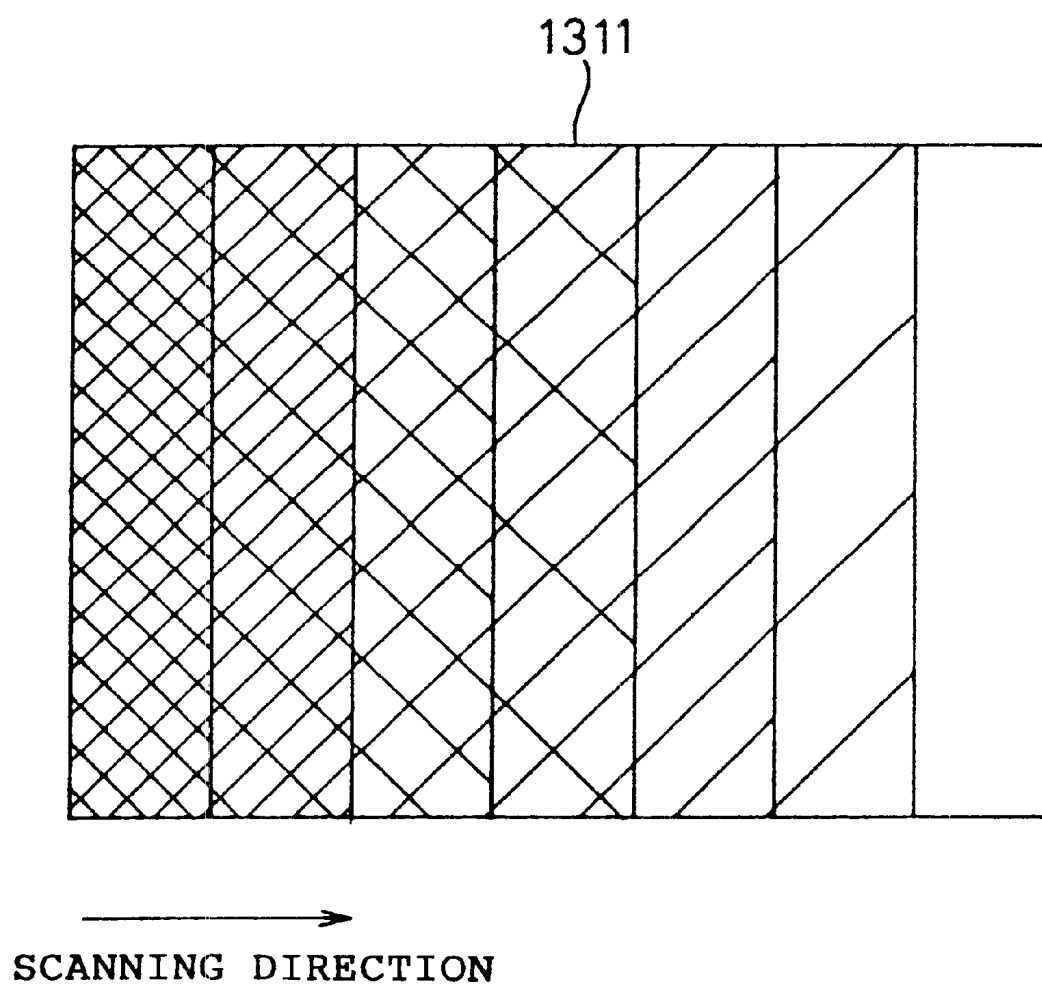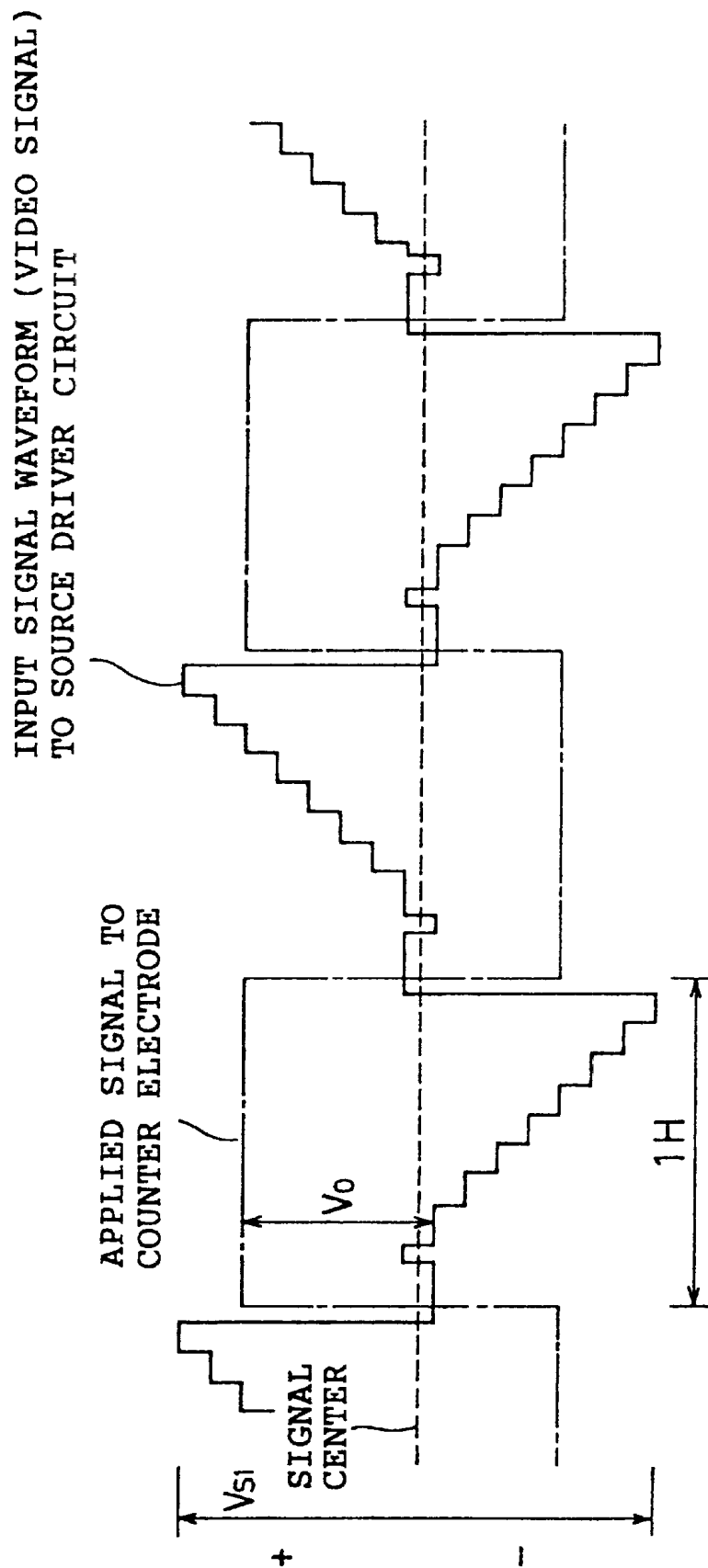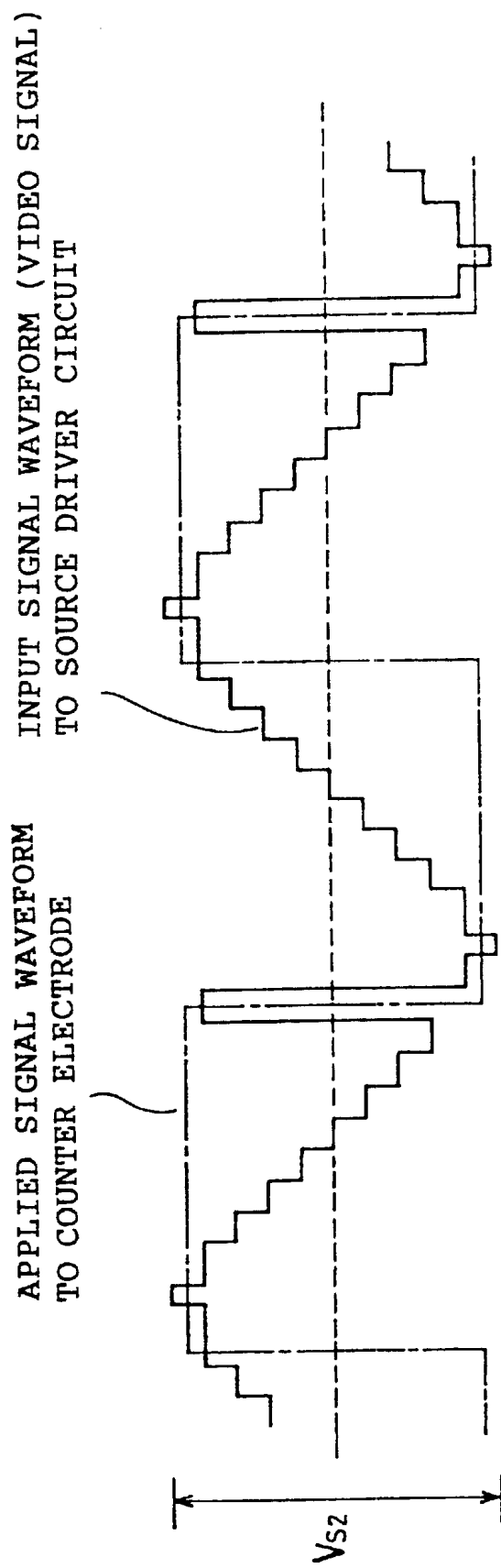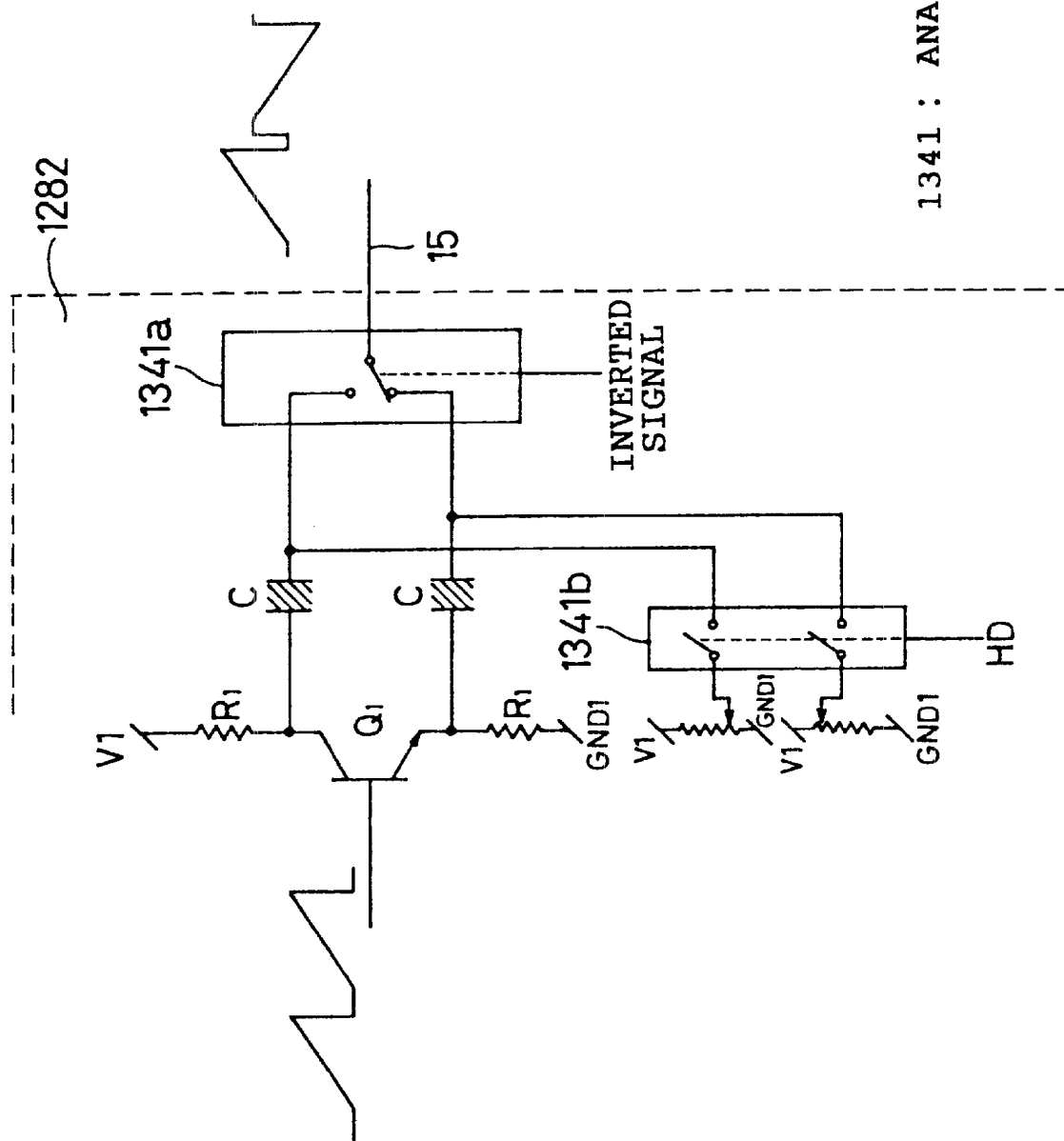
Fig. 134

1341 : ANALOG SWITCH

Fig. 135
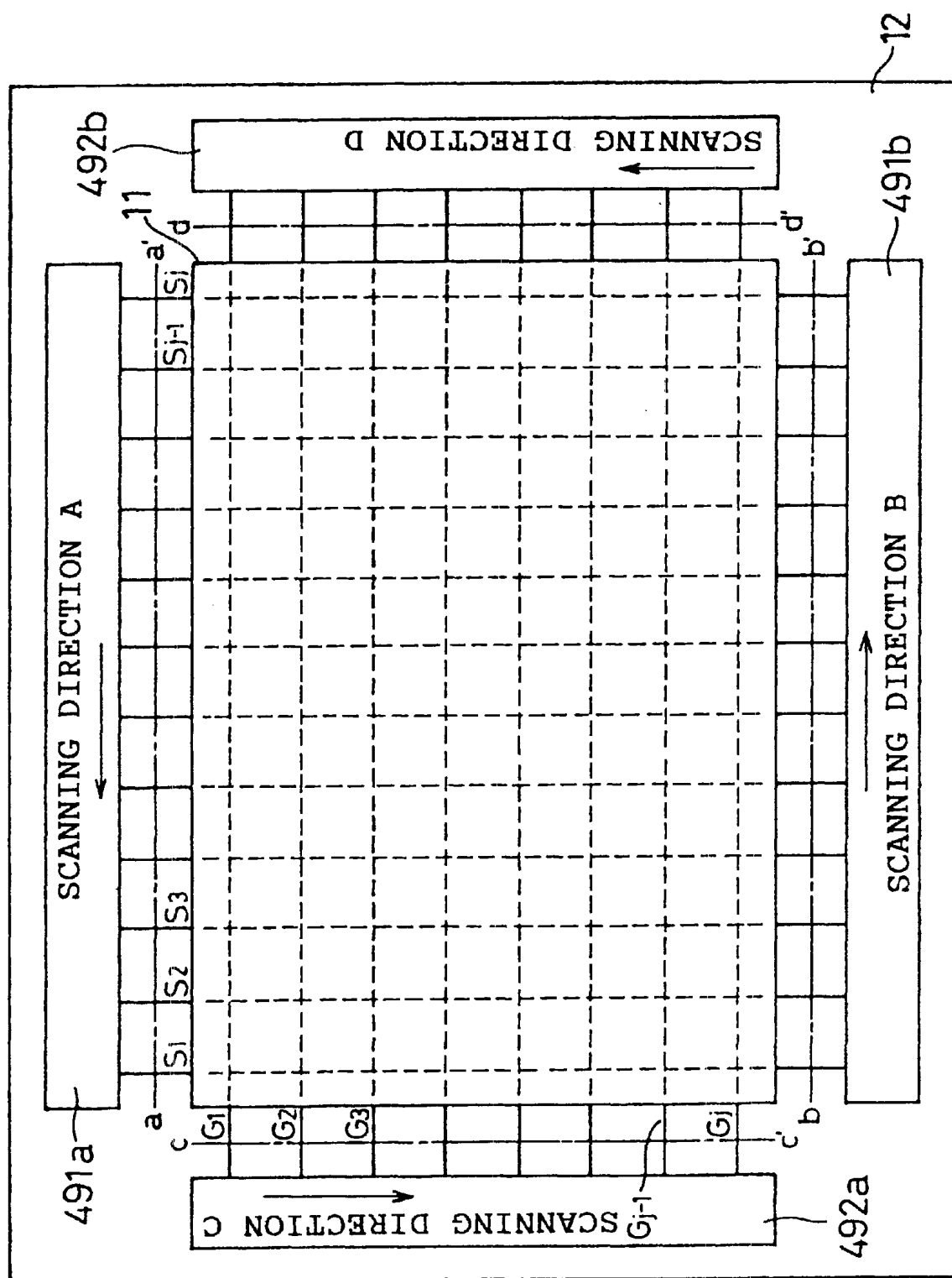
Fig. 136

1361 : SCANNING DIRECTION

1361a   1361b   1361c

Fig. 137

1361a   1361b   1361c
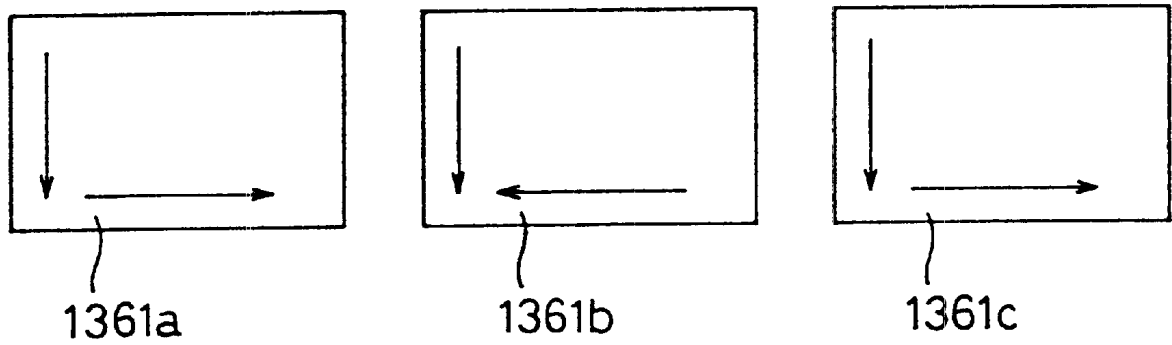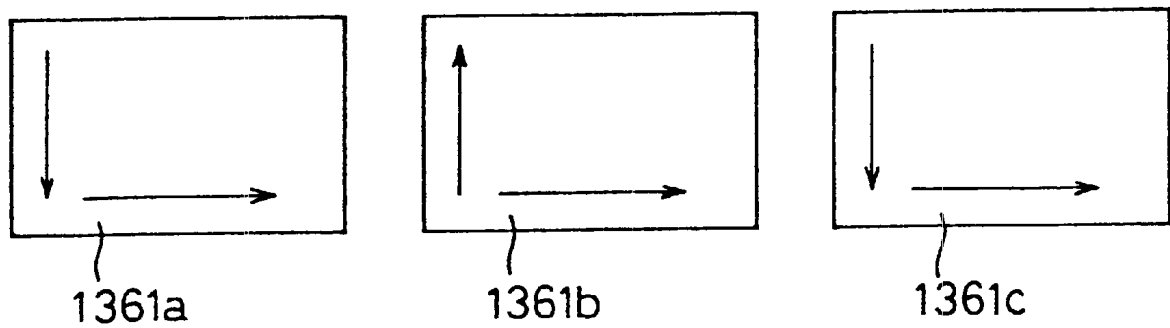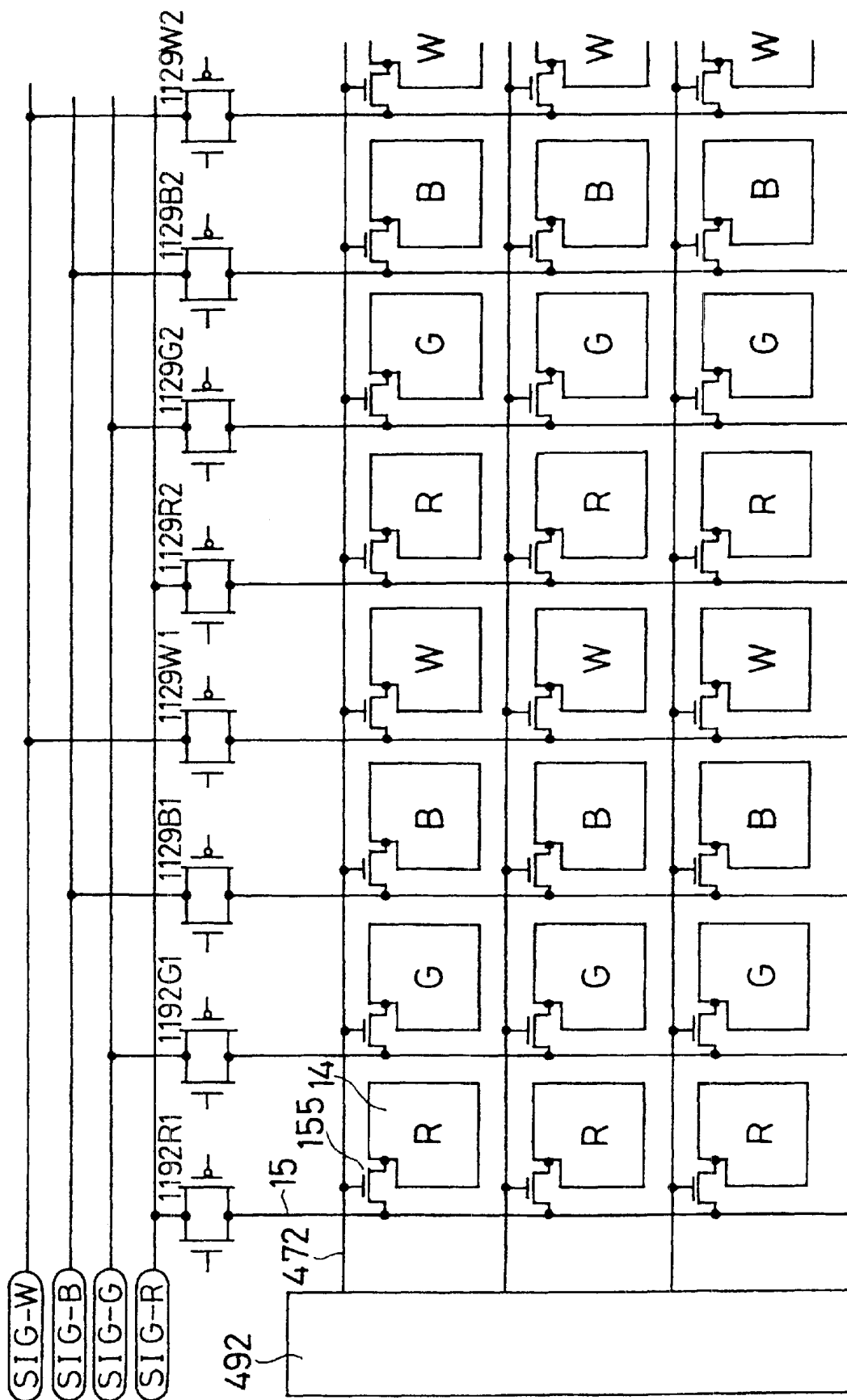
Fig. 138

Fig. 139 (a)

1291a   1291d

R	G	B	R	G	B	R	G	B	R	G
+	−	+	+	−	+	+	−	+	+	−
R	G	B	R	G	B	R	G	B	R	G
−	+	−	−	+	−	−	+	−	−	+
R	G	B	R	G	B	R	G	B	R	G
+	−	+	+	−	+	+	−	+	+	−
R	G	B	R	G	B	R	G	B	R	G
−	+	−	−	+	−	−	+	−	−	+
R	G	B	R	G	B	R	G	B	R	G
+	−	+	+	−	+	+	−	+	+	−
R	G	B	R	G	B	R	G	B	R	G
−	+	−	−	+	−	−	+	−	−	+
R	G	B	R	G	B	R	G	B	R	G
+	−	+	+	−	+	+	−	+	+	−

Fig. 139 (b)

1291a   1291e

R	G	B	W	R	G	B	W	R	G	B
−	+	−	+	−	+	−	+	−	+	−
R	G	B	W	R	G	B	W	R	G	B
+	−	+	−	+	−	+	−	+	−	+
R	G	B	W	R	G	B	W	R	G	B
−	+	−	+	−	+	−	+	−	+	−
R	G	B	W	R	G	B	W	R	G	B
+	−	+	−	+	−	+	−	+	−	+
R	G	B	W	R	G	B	W	R	G	B
−	+	−	+	−	+	−	+	−	+	−
R	G	B	W	R	G	B	W	R	G	B
+	−	+	−	+	−	+	−	+	−	+
R	G	B	W	R	G	B	W	R	G	B
−	+	−	+	−	+	−	+	−	+	−

Fig. 140 (a)

1291

R	G	B	W	R	G	B	W	R	G	B

R	G	B	W	R	G	B	W	R	G

W	R	G	B	W	R	G	B	W	R	G

W	R	G	B	W	R	G	B	W	R

B	W	R	G	B	W	R	G	B	W	R

B	W	R	G	B	W	R	G	B	W

G	B	W	R	G	B	W	R	G	B	W

Fig. 140 (b)

1291

R	G	B	W	R	G	B	W	R	G	B

W	R	G	B	W	R	G	B	W	R

G	B	W	R	G	B	W	R	G	B	W

R	G	B	W	R	G	B	W	R	G

B	W	R	G	B	W	R	G	B	W	R

R	G	B	W	R	G	B	W	R	G

B	W	R	G	B	W	R	G	B	W	R

Fig. 141

1411 : LIGHT SOURCE   1411c : UVIR CUT FILTER

1411a : LAMP   1412 : COLOR PURITY ENHANCEMENT FILTER

1411b : CONCAVE MIRROR   1413 : LENS

1414 : ROTARY FILTER

1415 : PROJECTION LENS   1416 : OPTICAL AXIS
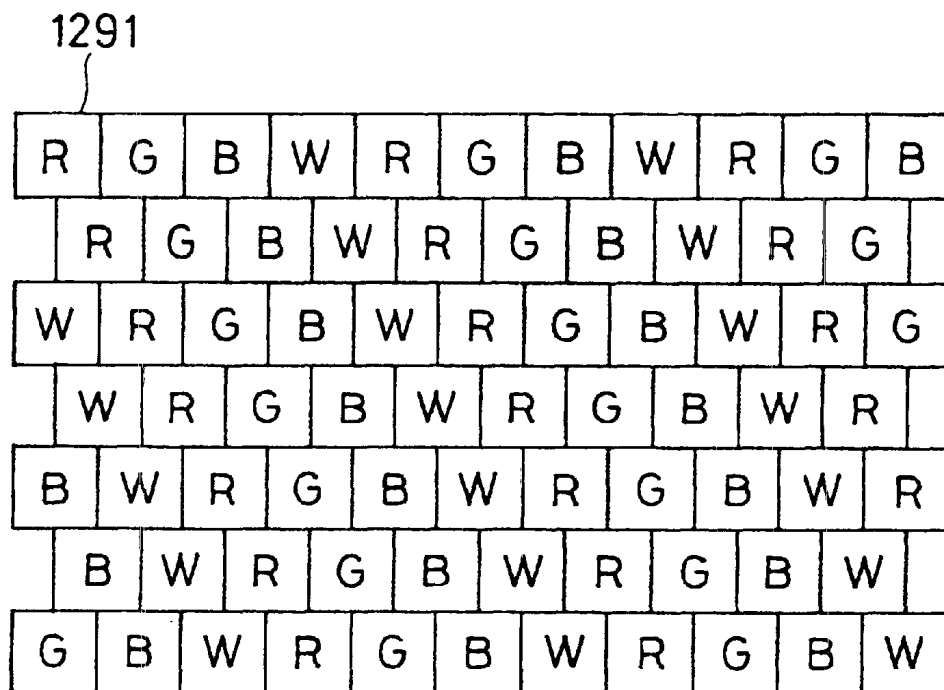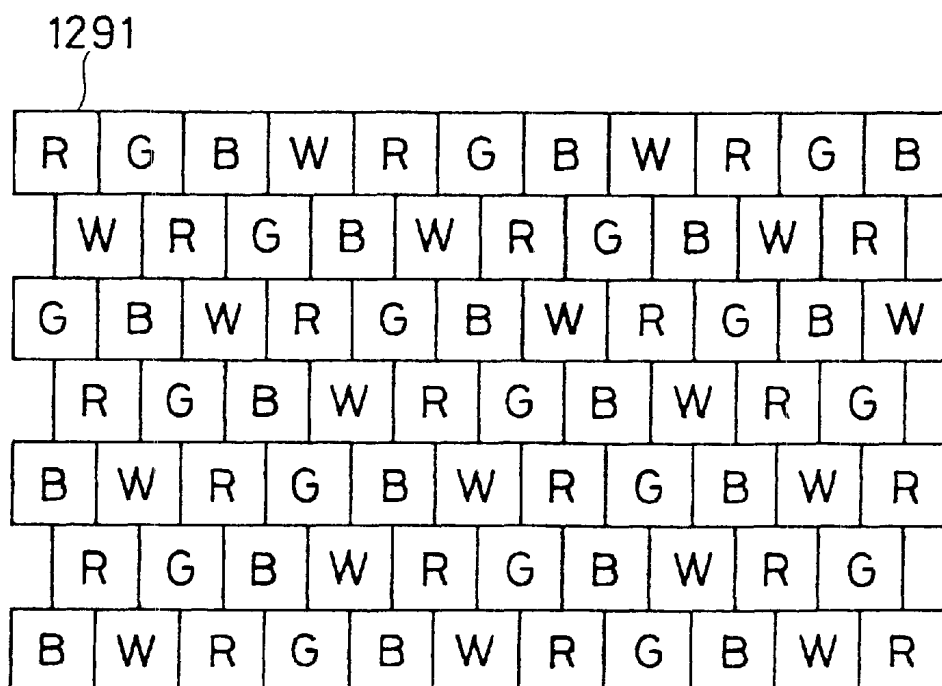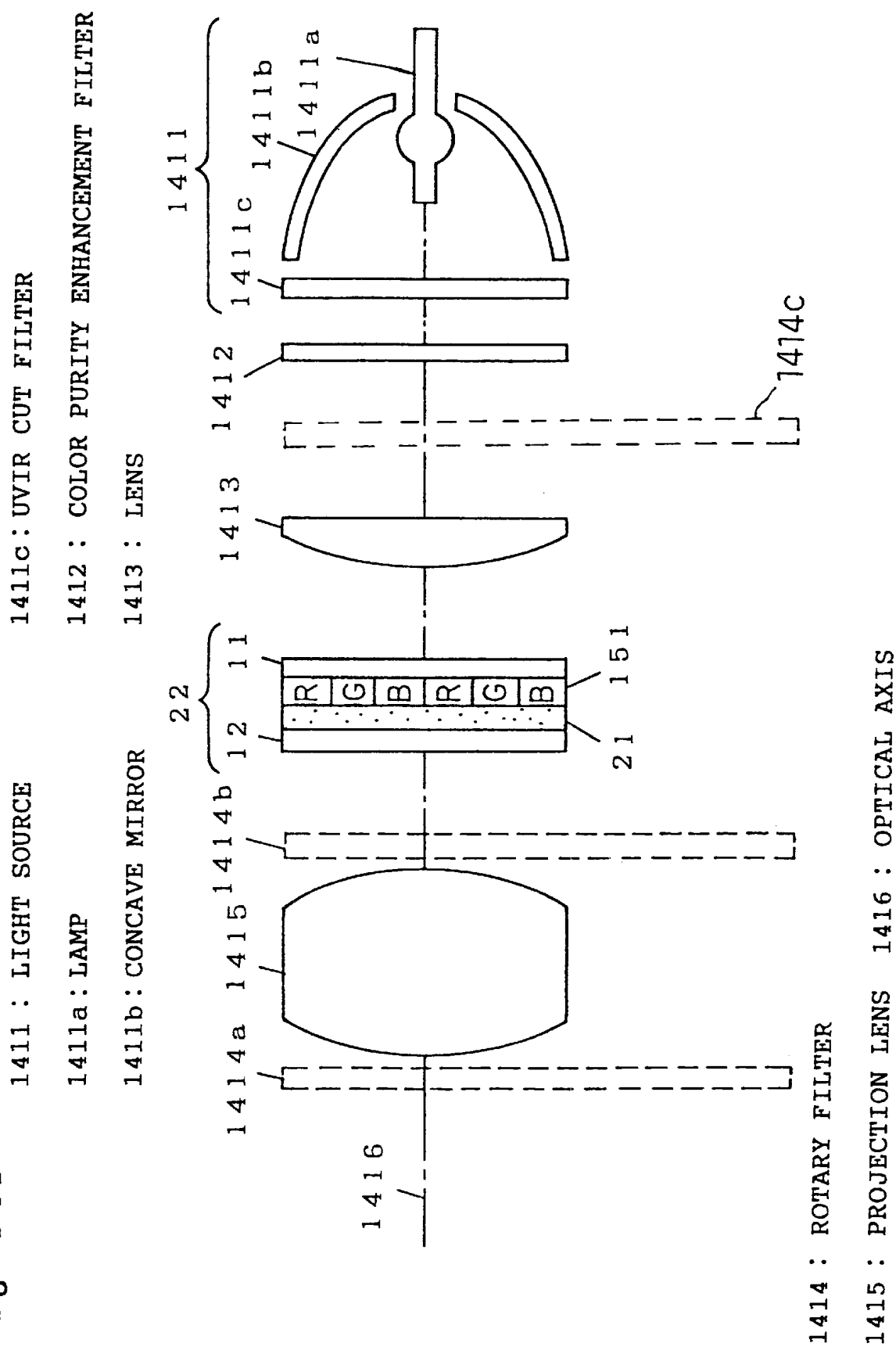
Fig. 142

1422, 1423 : DIELECTRIC MULTILAYER FILM

1424, 1425 : DIELECTRIC THIN FILM
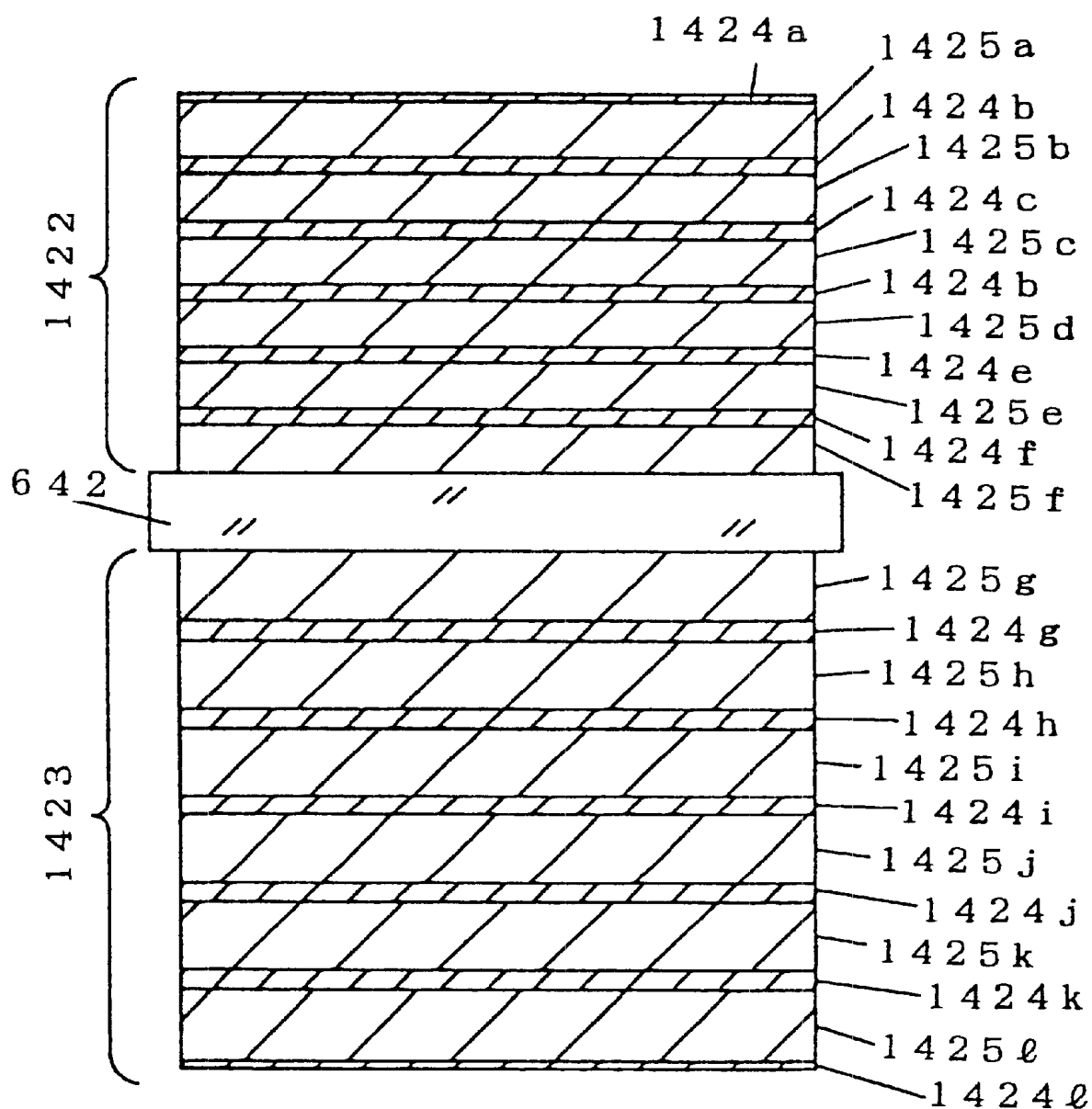
Fig. 143

1432, 1433 : DIELECTRIC MULTILAYER FILM

1434, 1435 : DIELECTRIC THIN FILM

Fig. 144

WAVELENGTH λ (nm)

TRANSMITTANCE T (%)
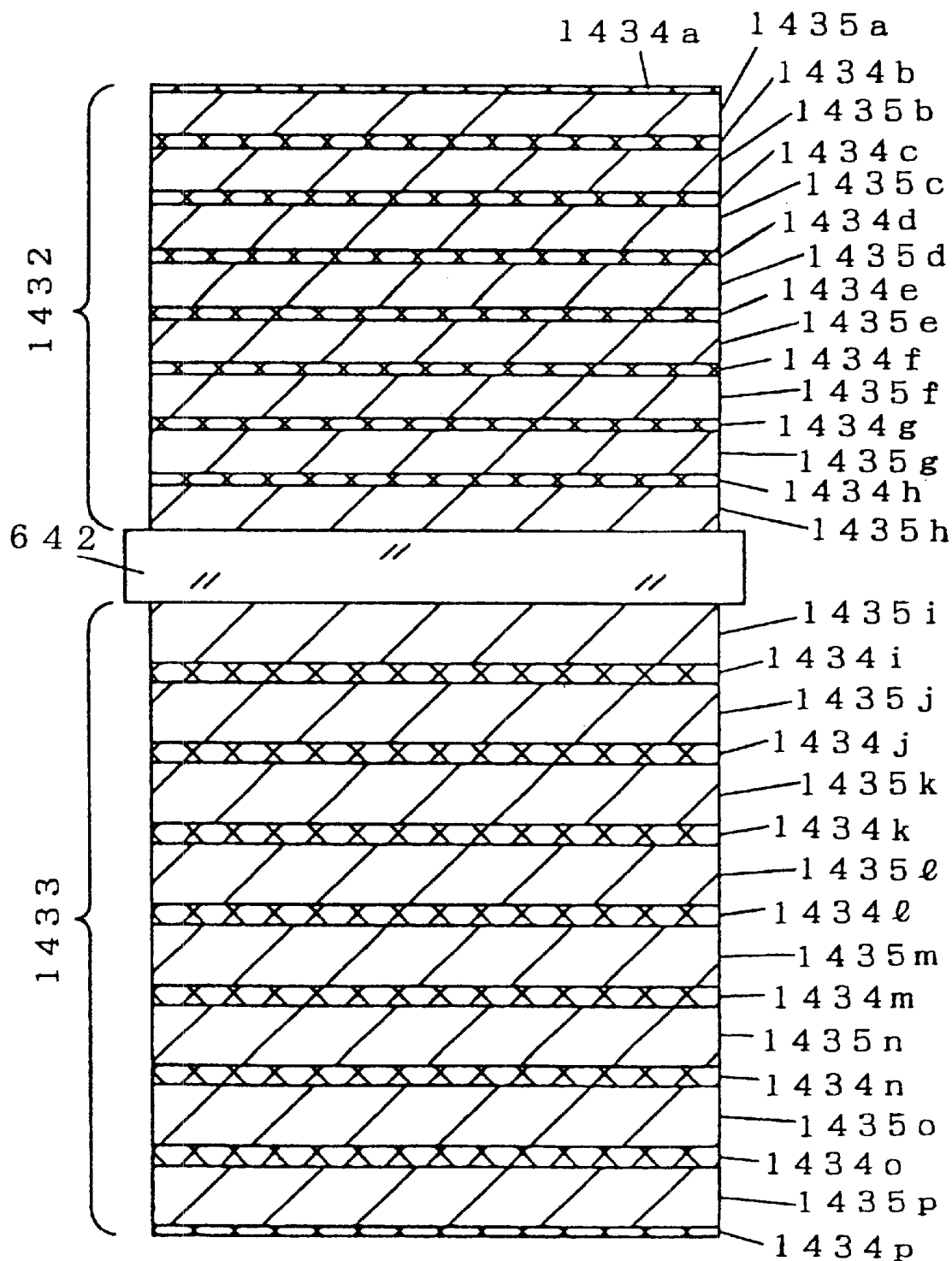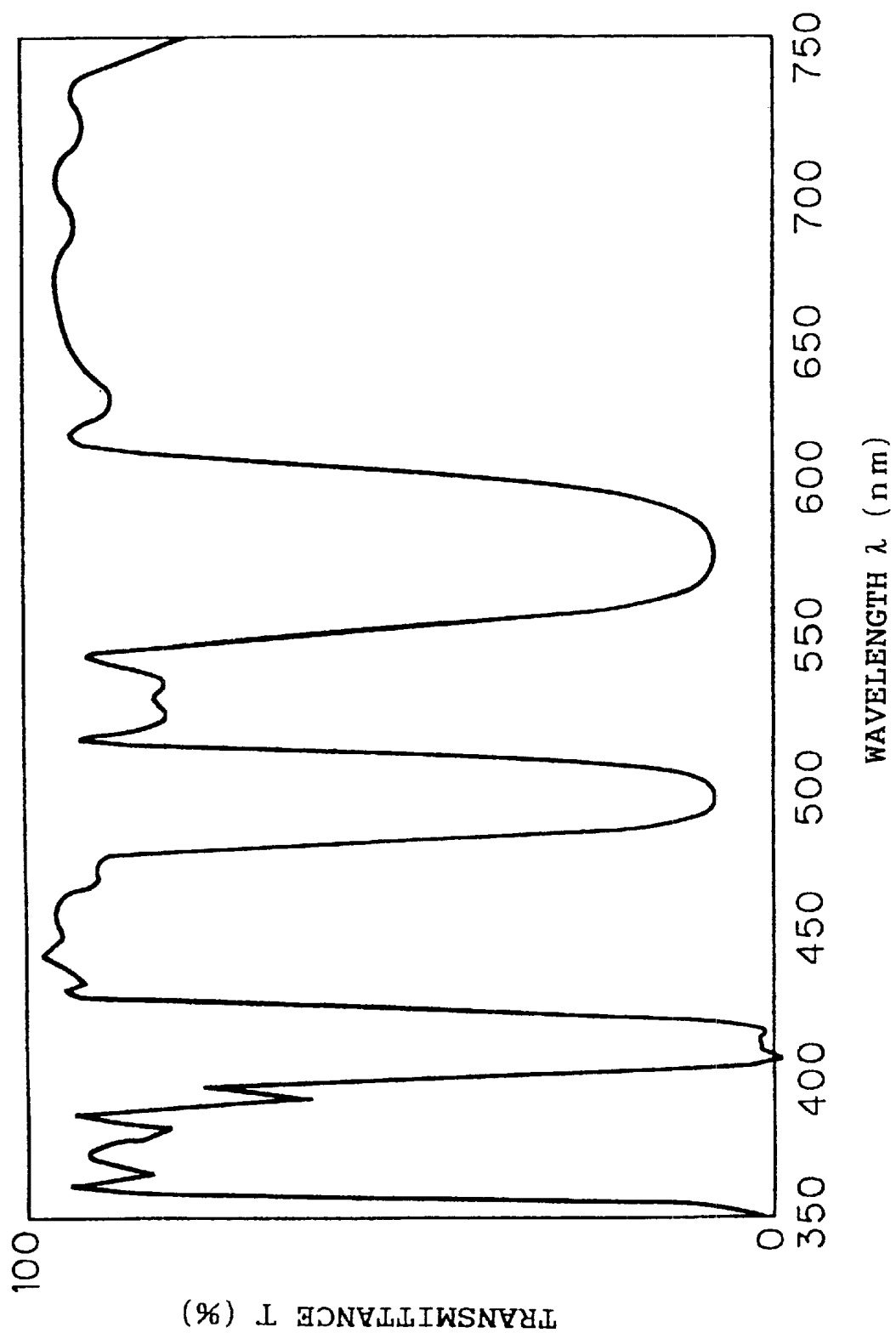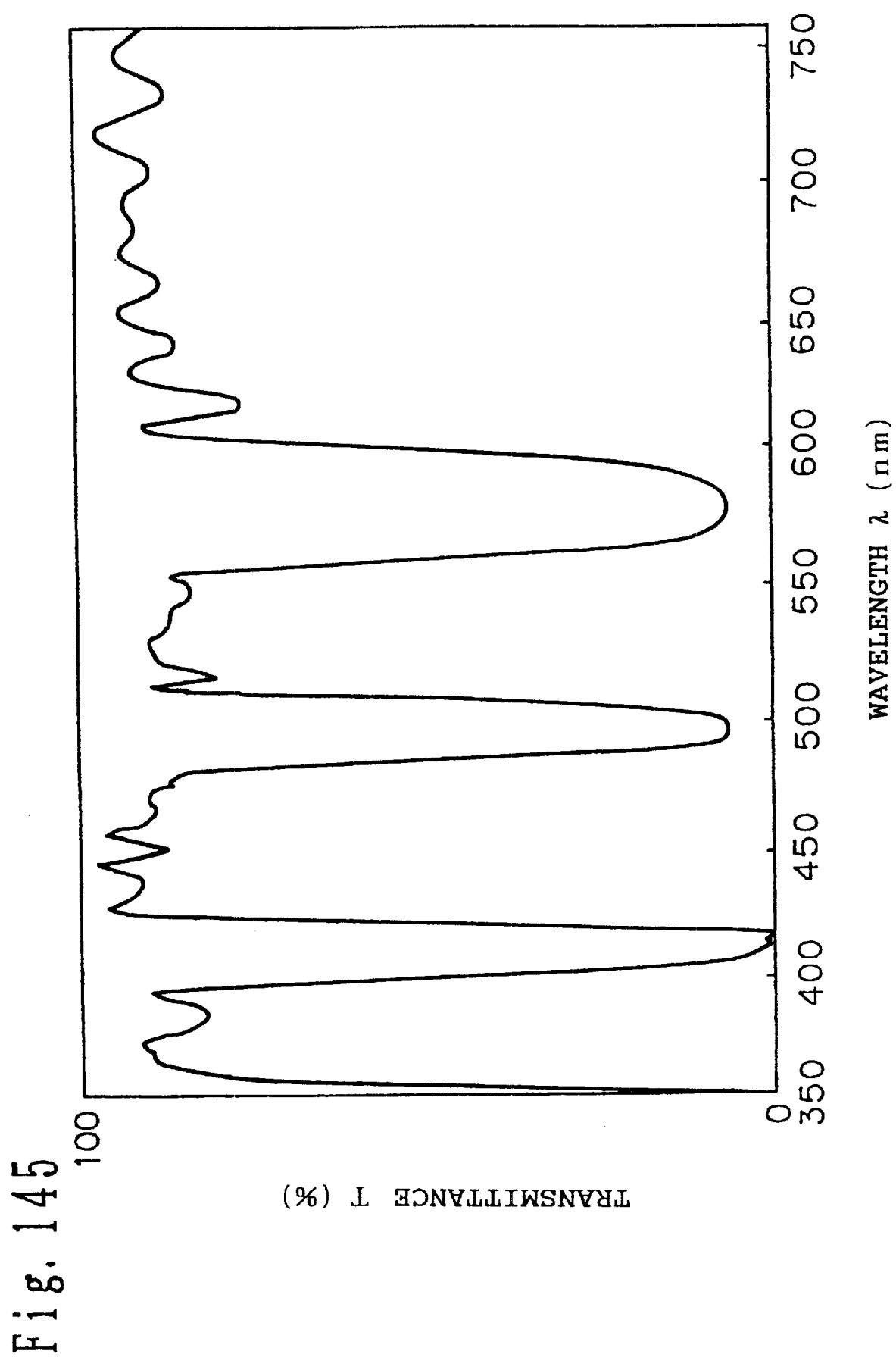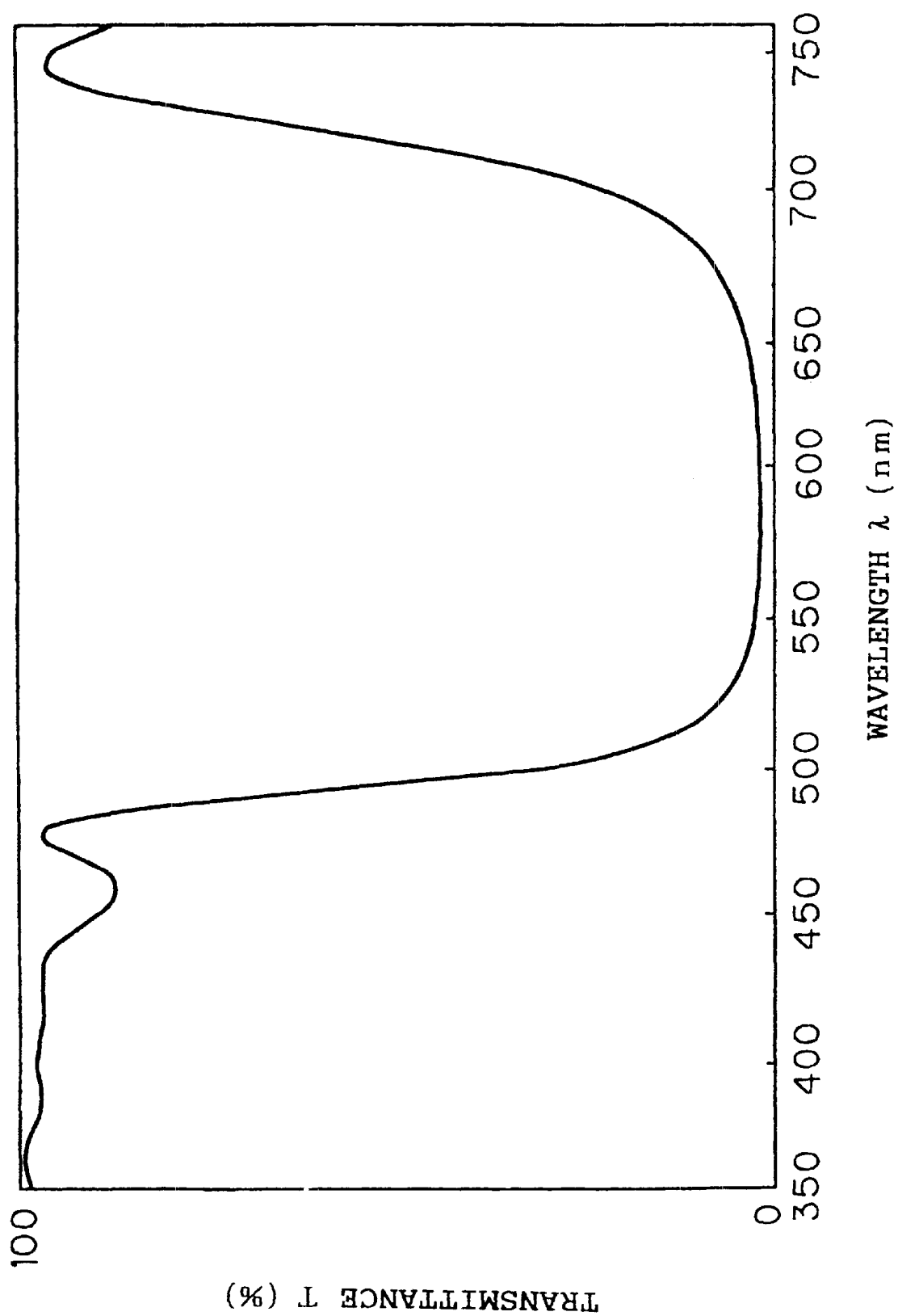
Fig. 145
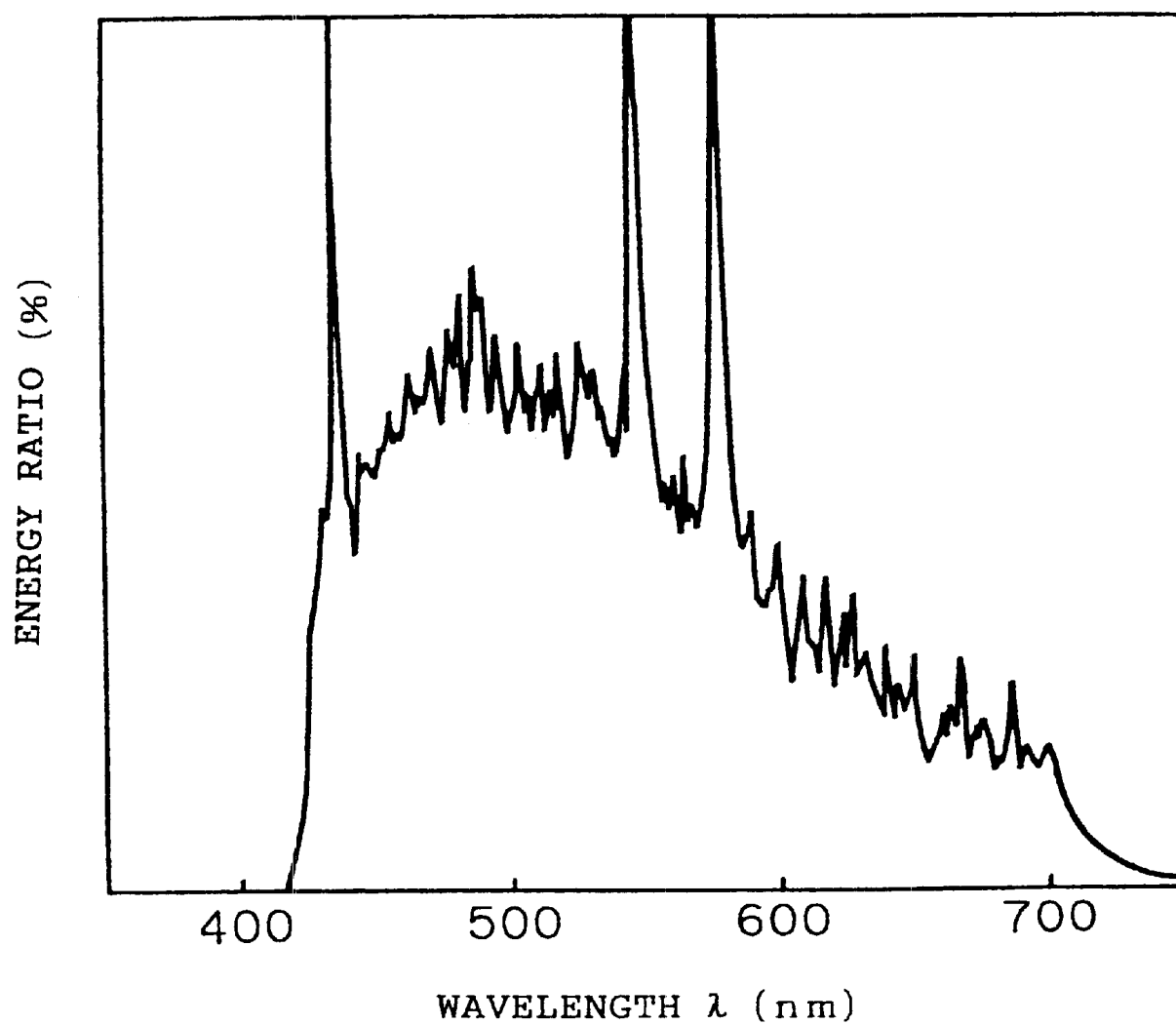
Fig. 146
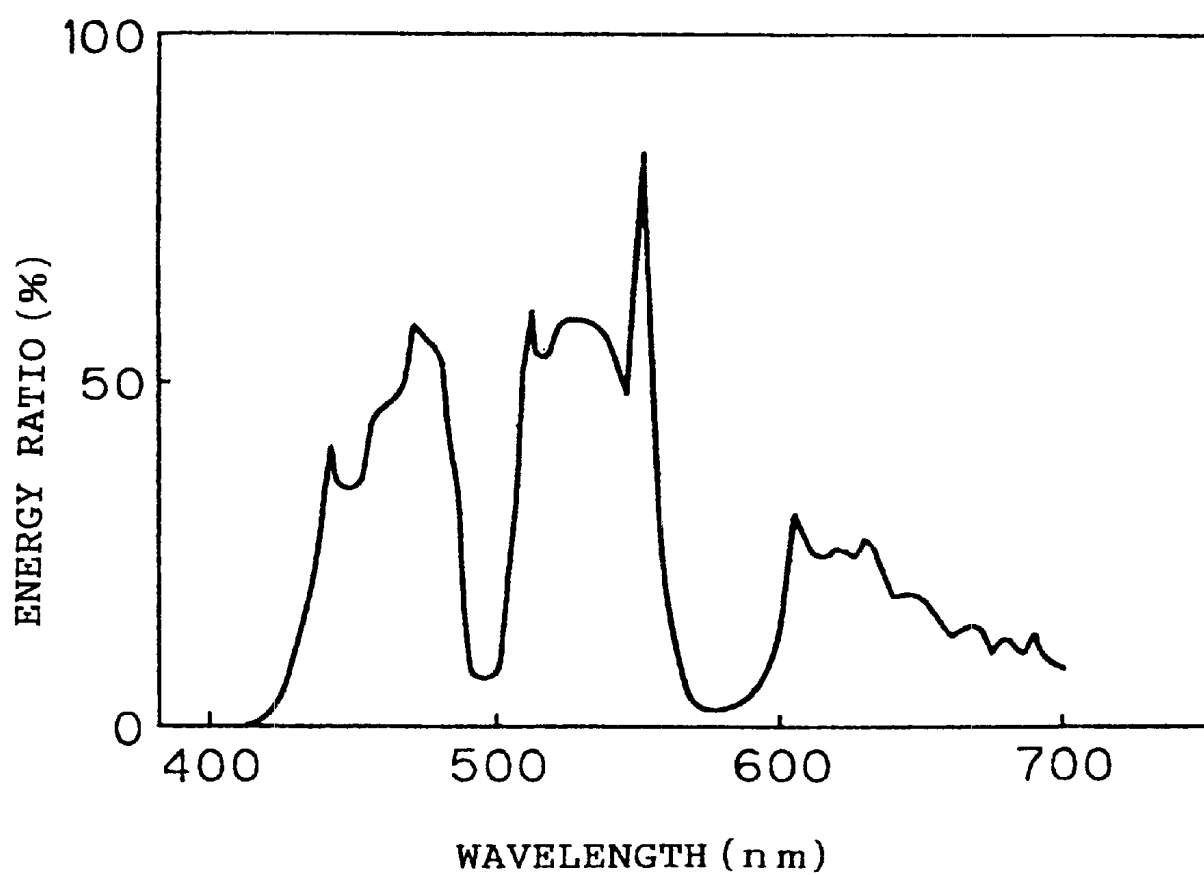
Fig. 147

Fig. 148

F i g . 1 4 9 (a)
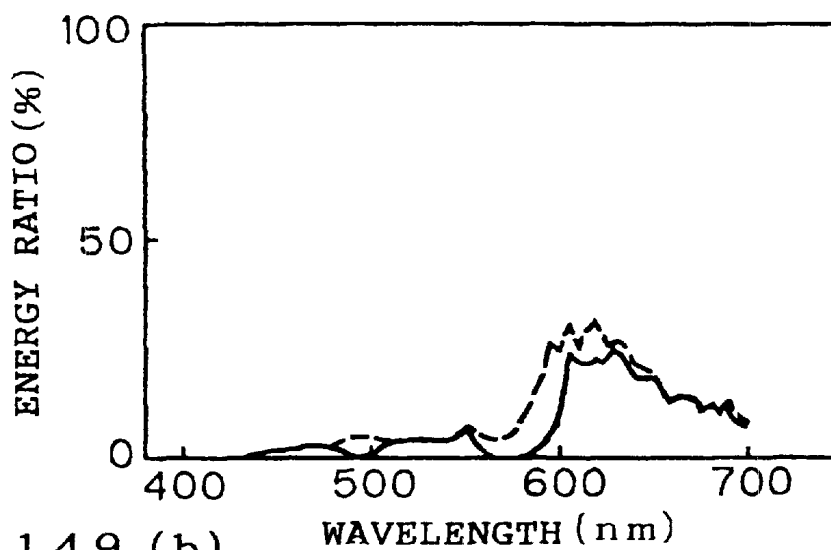
F i g . 1 4 9 (b)
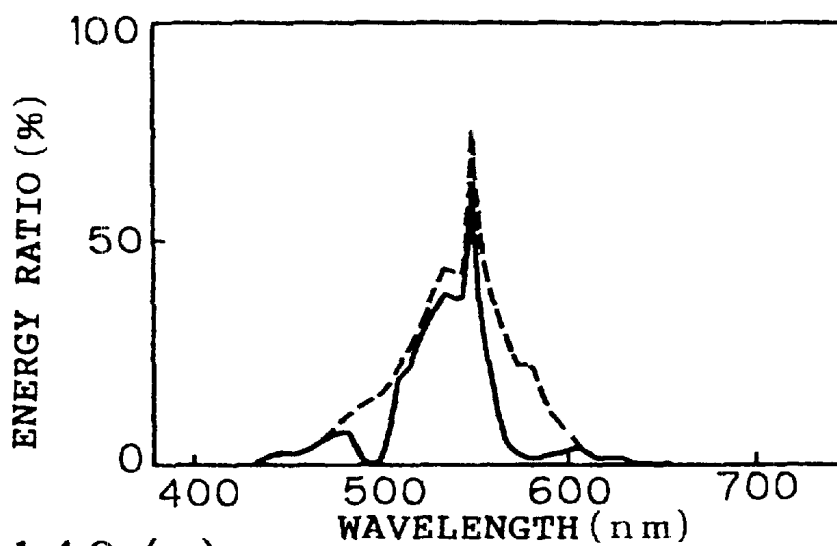
F i g . 1 4 9 (c)
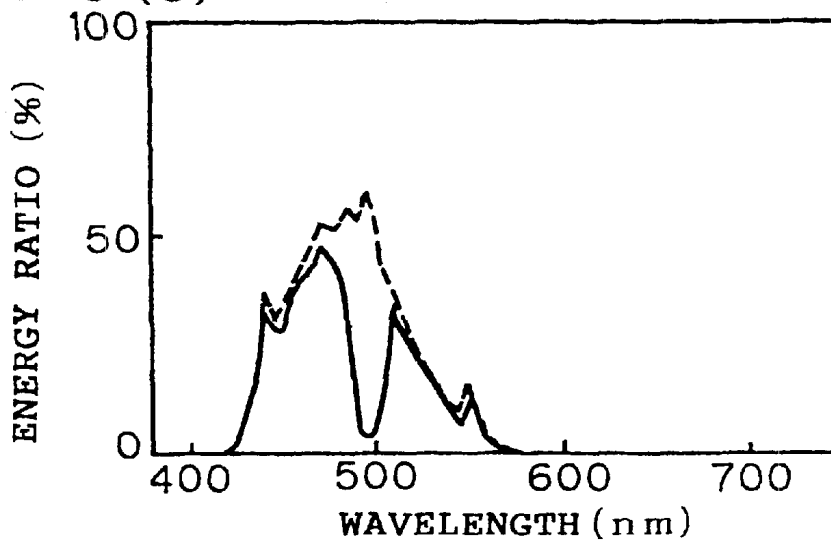
Fig. 150

——●—— EMBODIMENT OF THE PRESENT INVENTION

---○--- PRIOR ART
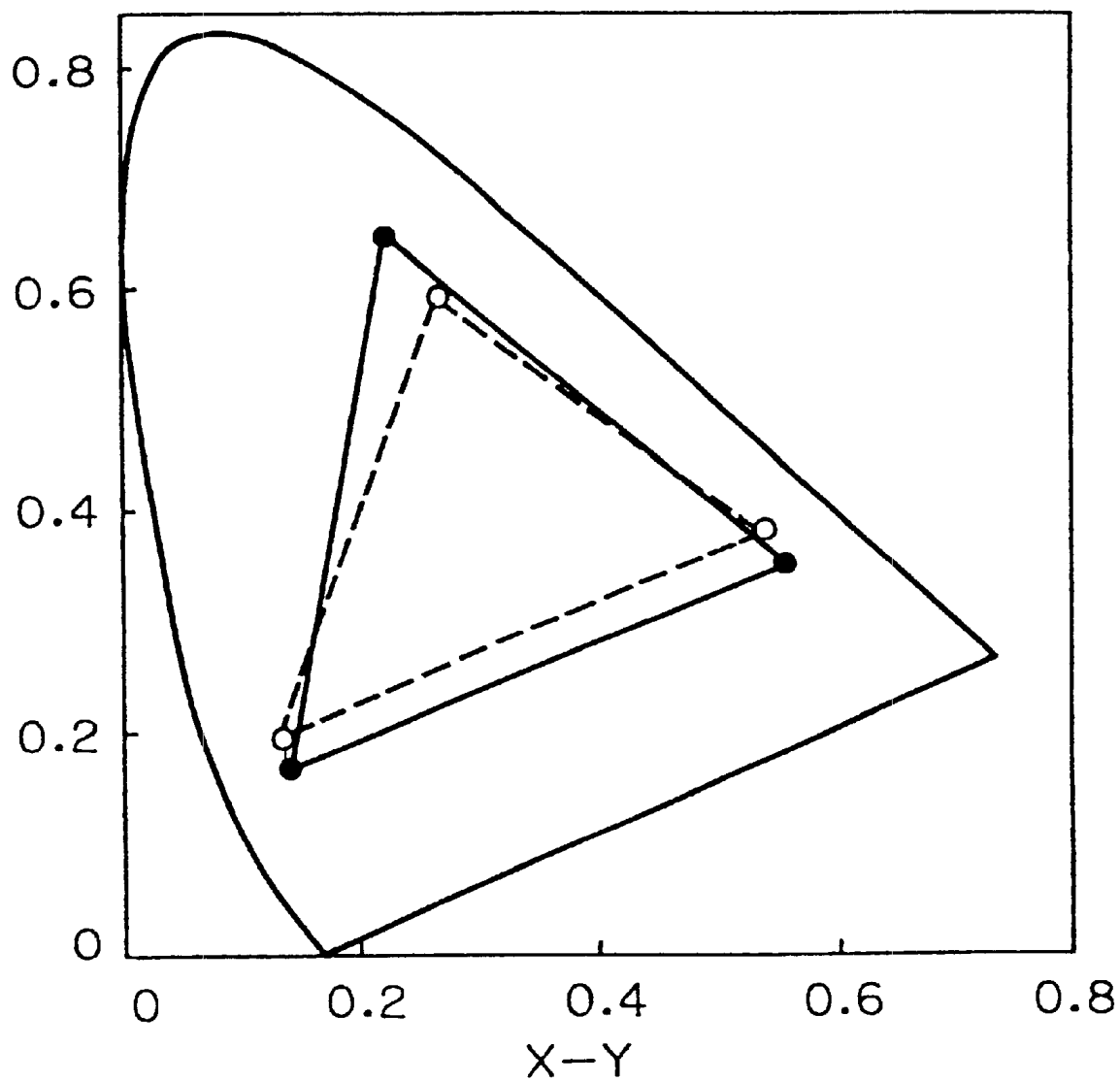
Fig. 151

1501 : SCREEN

Fig. 152

Fig. 153

1531 : POSITIONING TOOL   1535 : CASING

1532 : LAMP SOURCE   1536 : LENS DRIVE PORTION

1533 : CONTROL BUTTON   1537 : MOUNTING PORTION

1534 : COOLING FAN   1539a-d SWITCH (DETECTION PORTION)

Fig. 154

Fig. 155

1551 : OPTICAL SYSTEM BLOCK

1552 : MIRROR

1535

1501

1552b

1552a

1415

1551
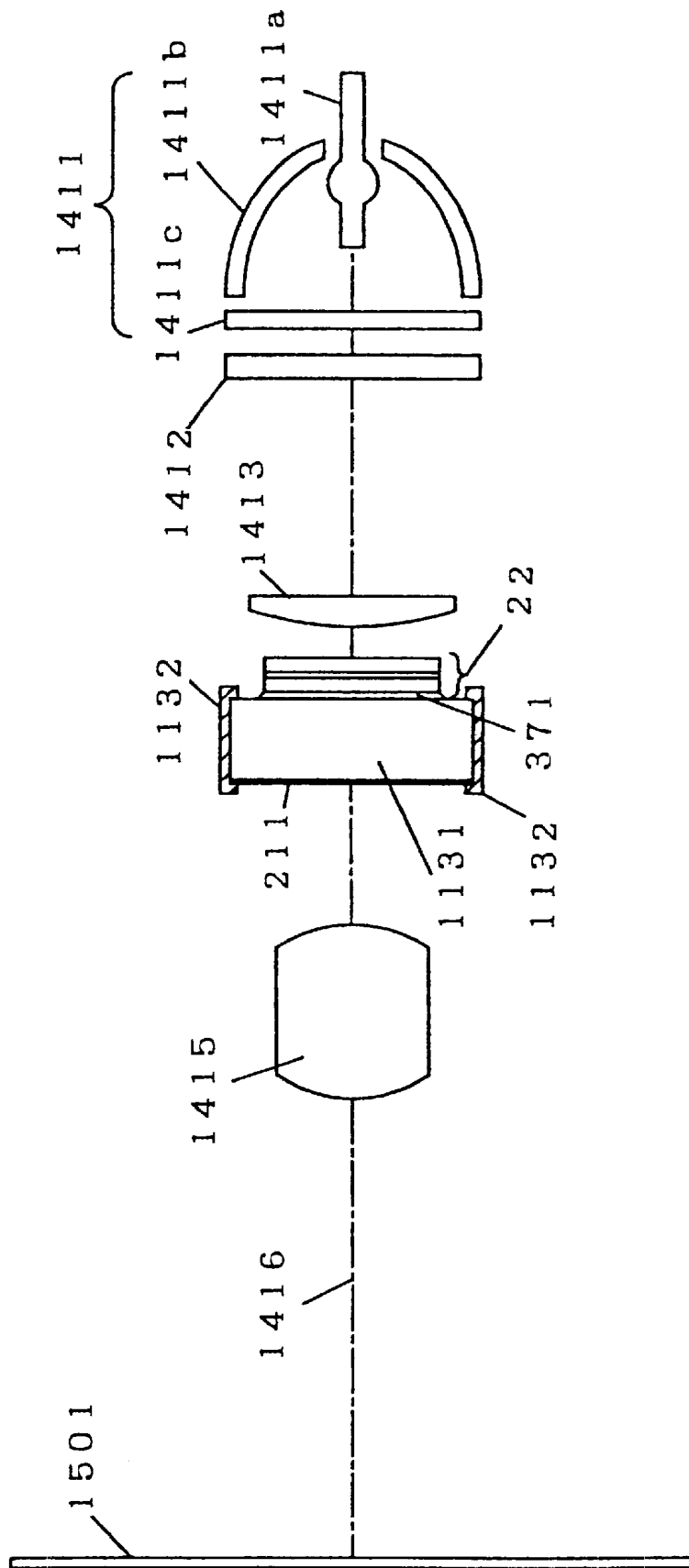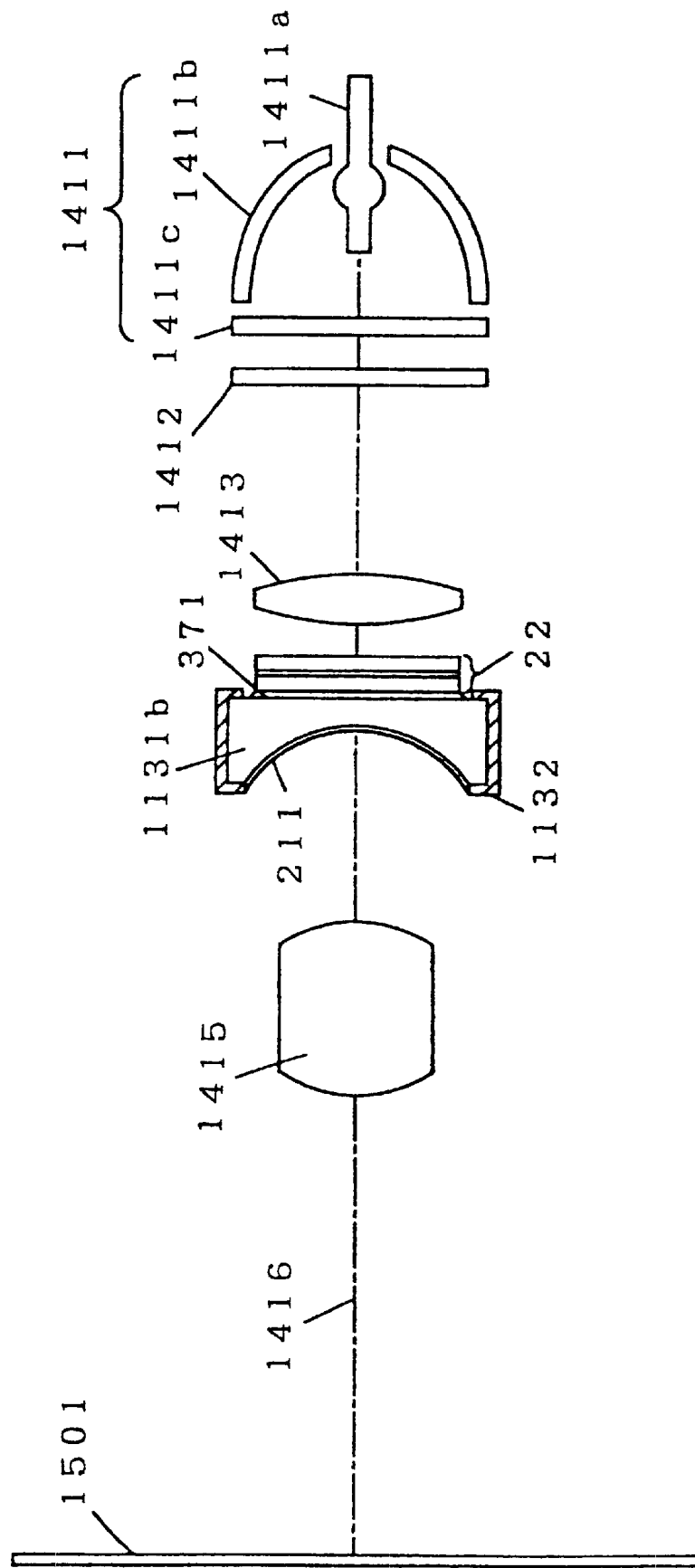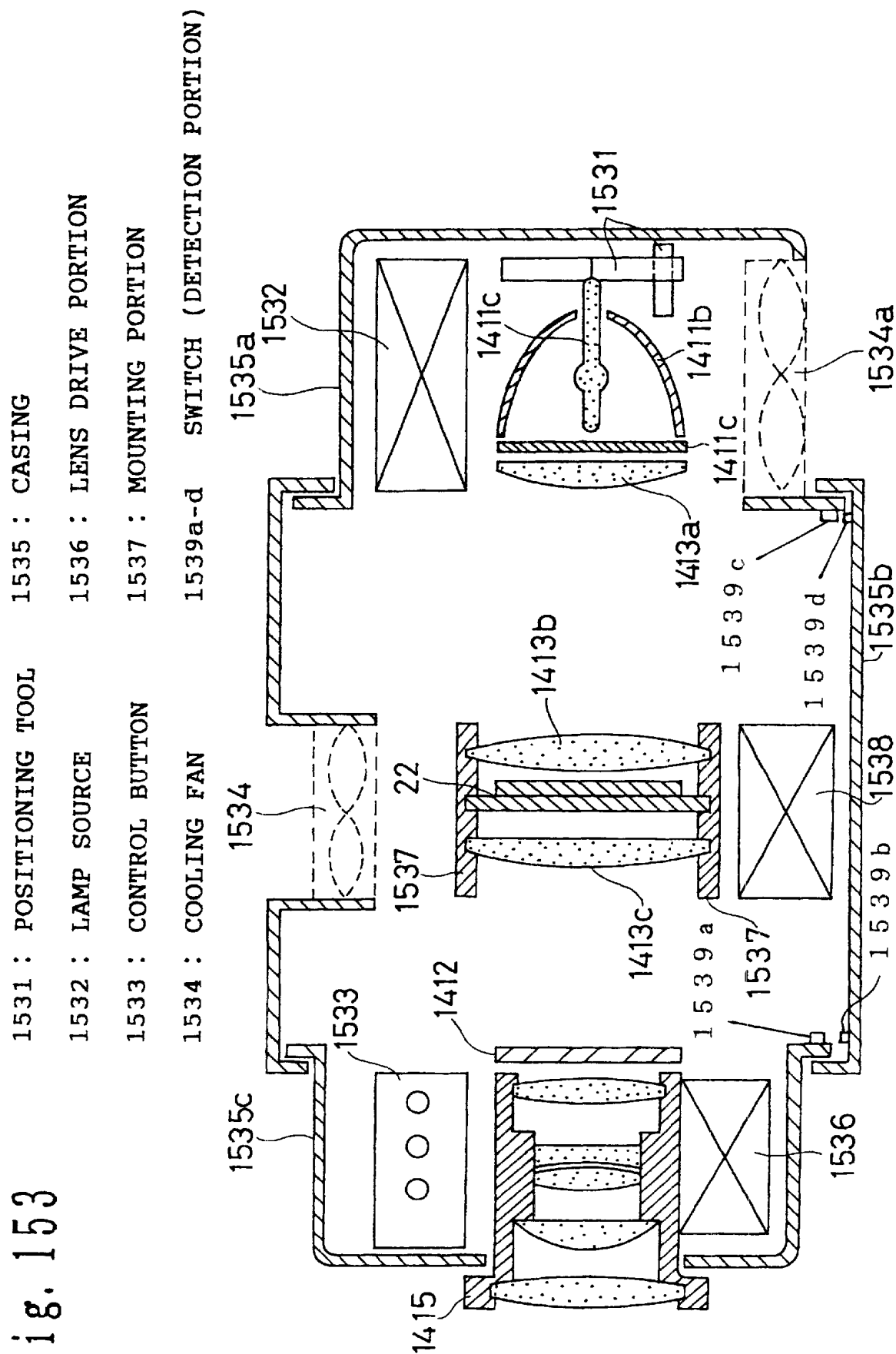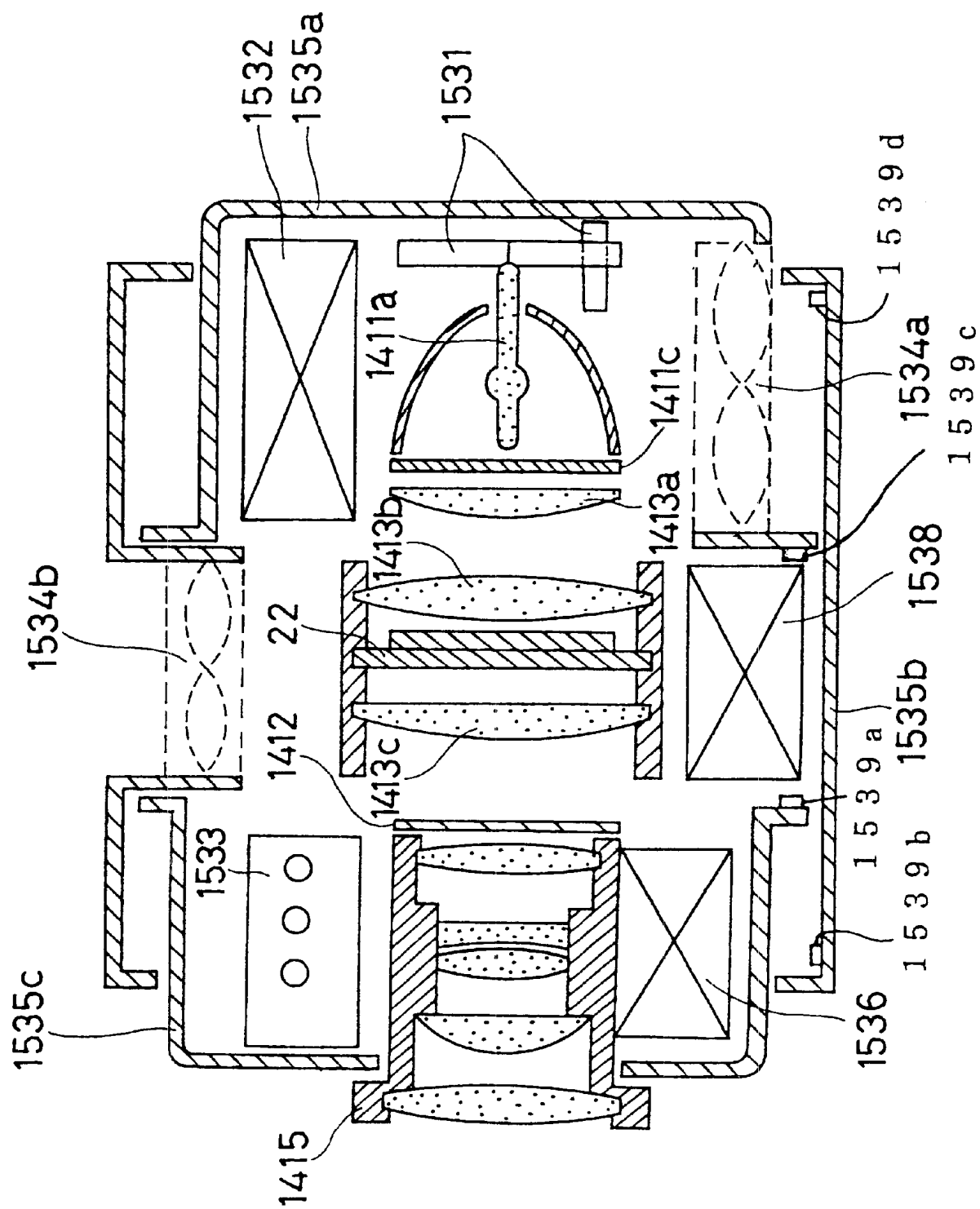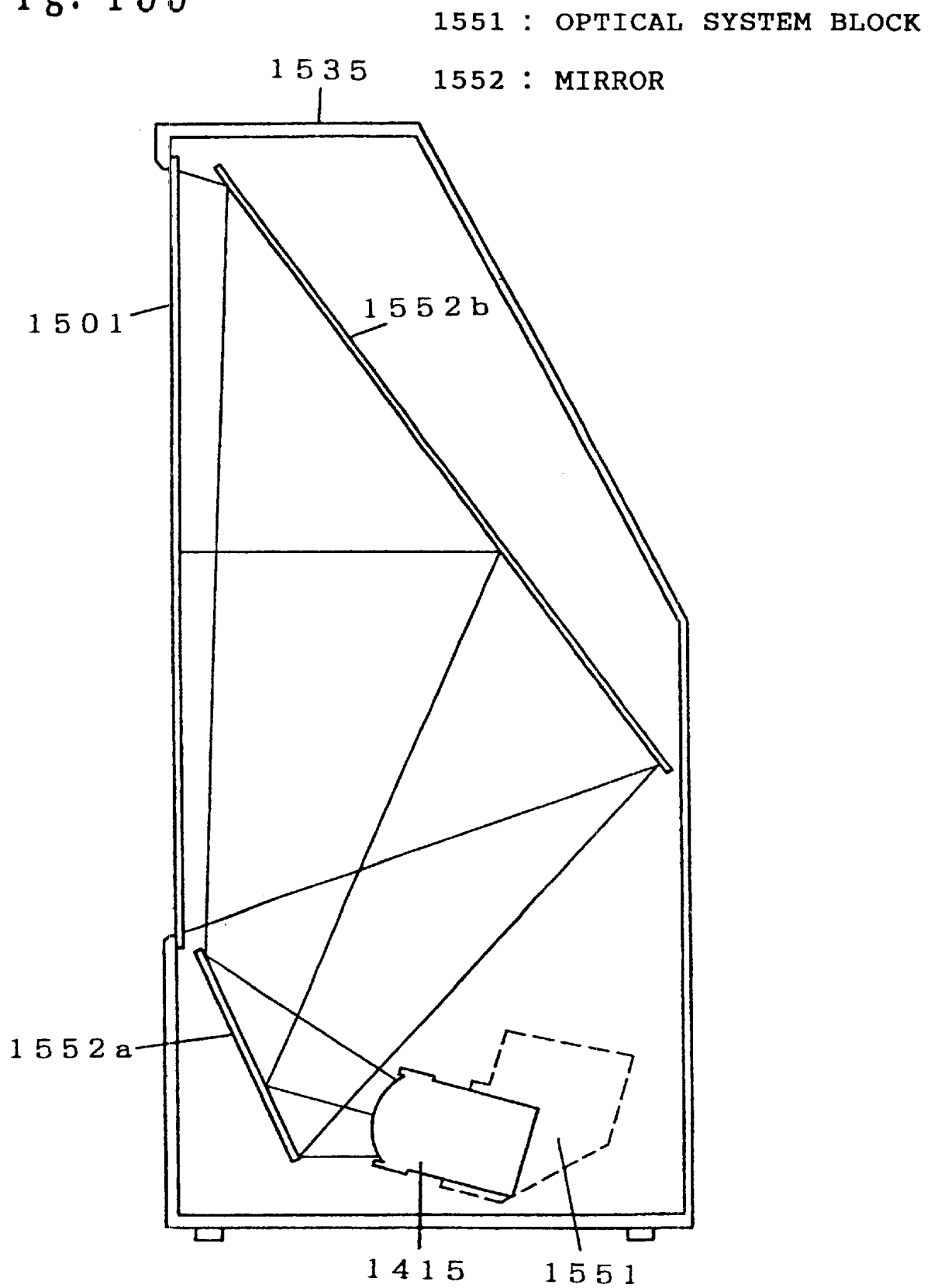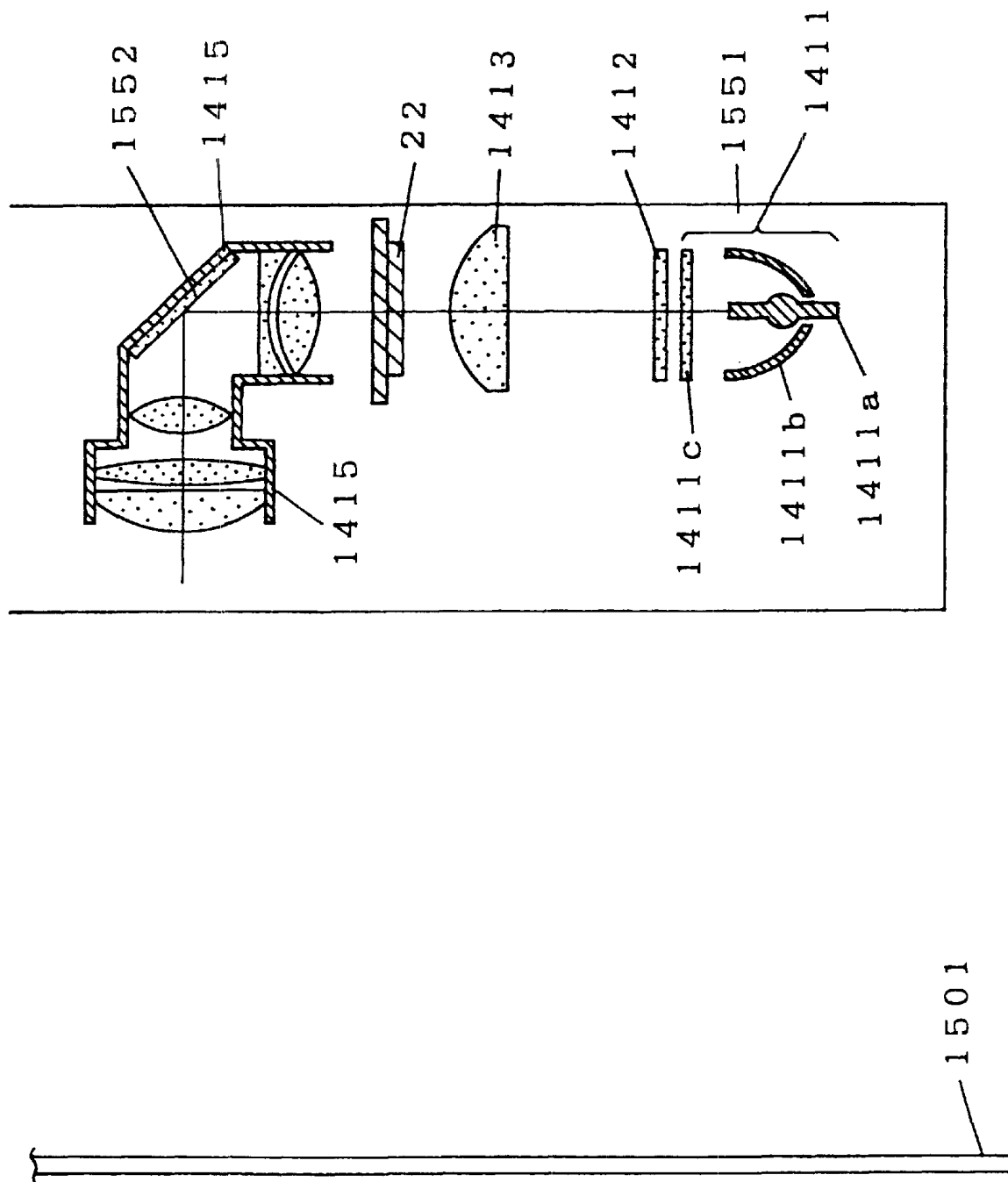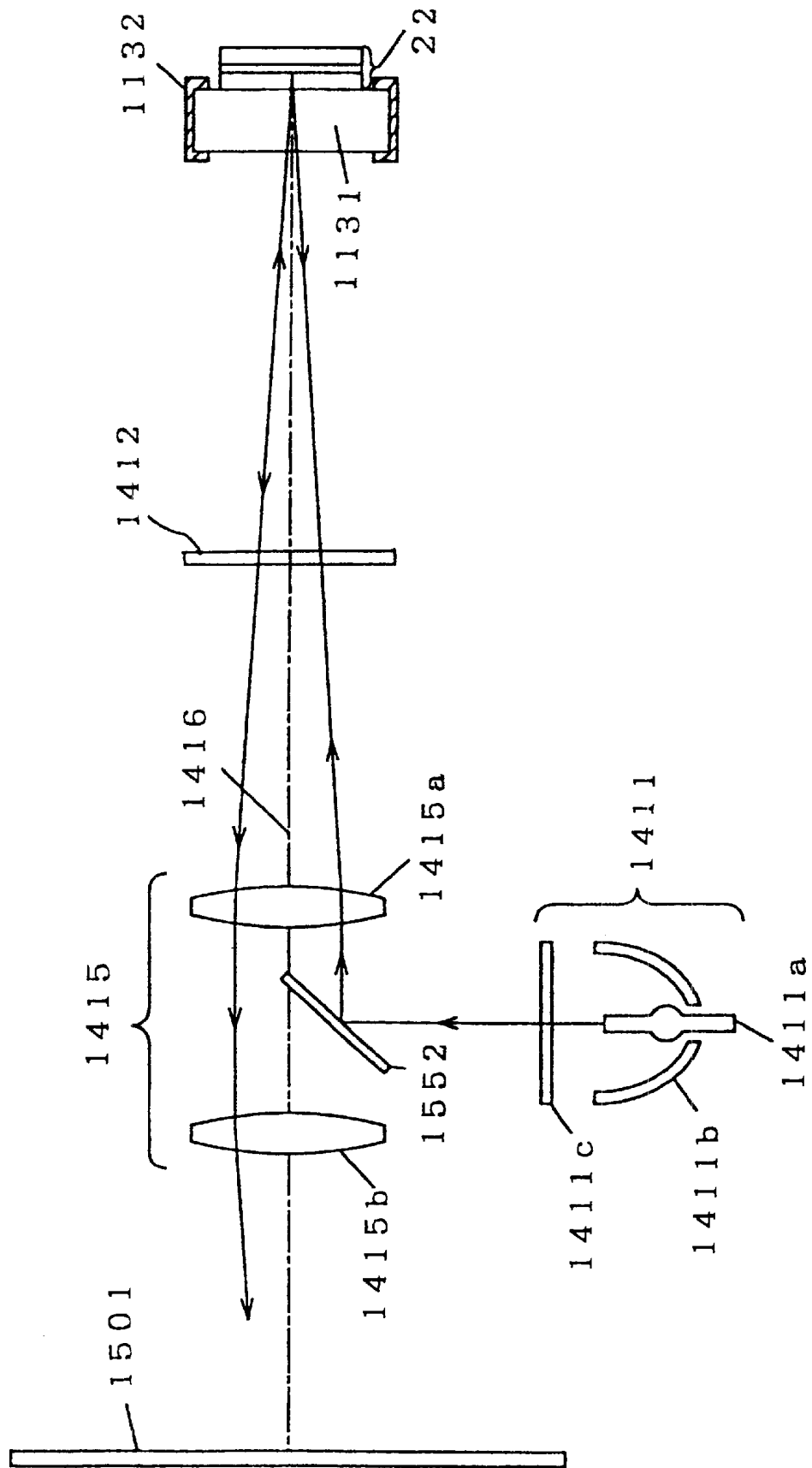
Fig. 156

Fig. 157

Fig. 158

1581 : POLARIZATION BEAM SPLITTER (BSP)

1582 : LIGHT SEPARATING SURFACE
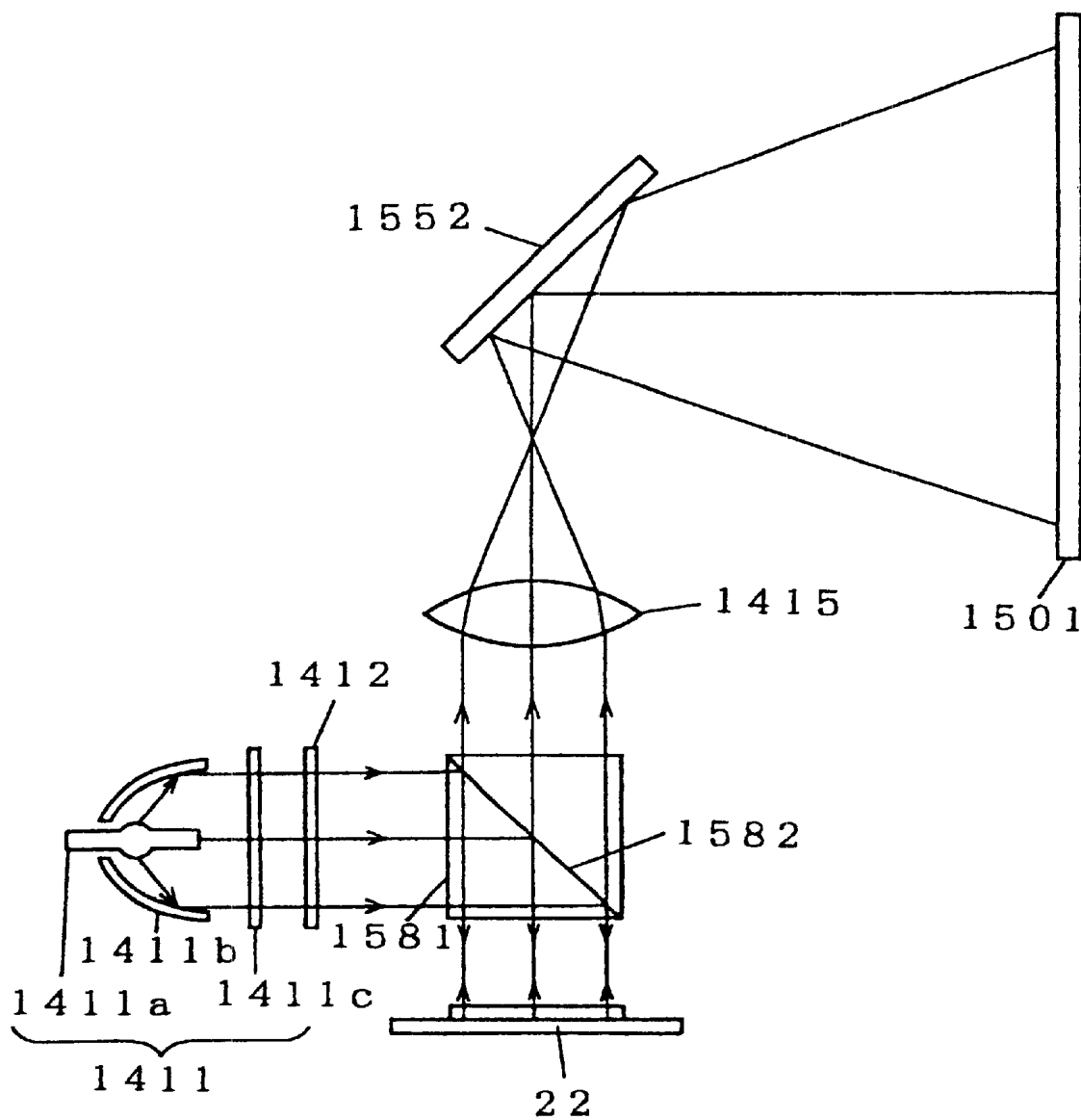
Fig. 159

1591 : DICHROIC PRISM

1592 : LENS PLATE

1593 : LENS

1594 : BAND CUT FILTER
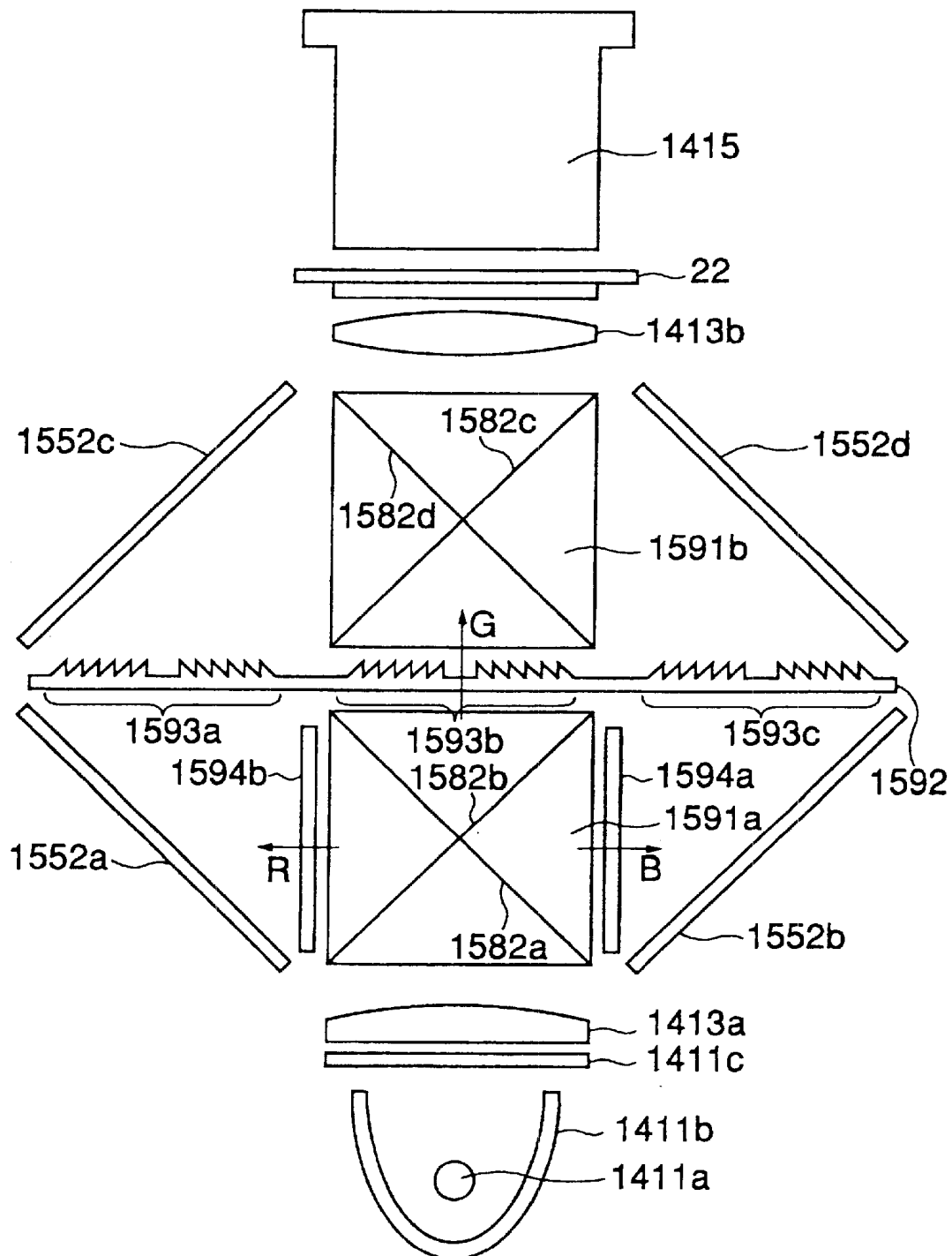
Fig. 160
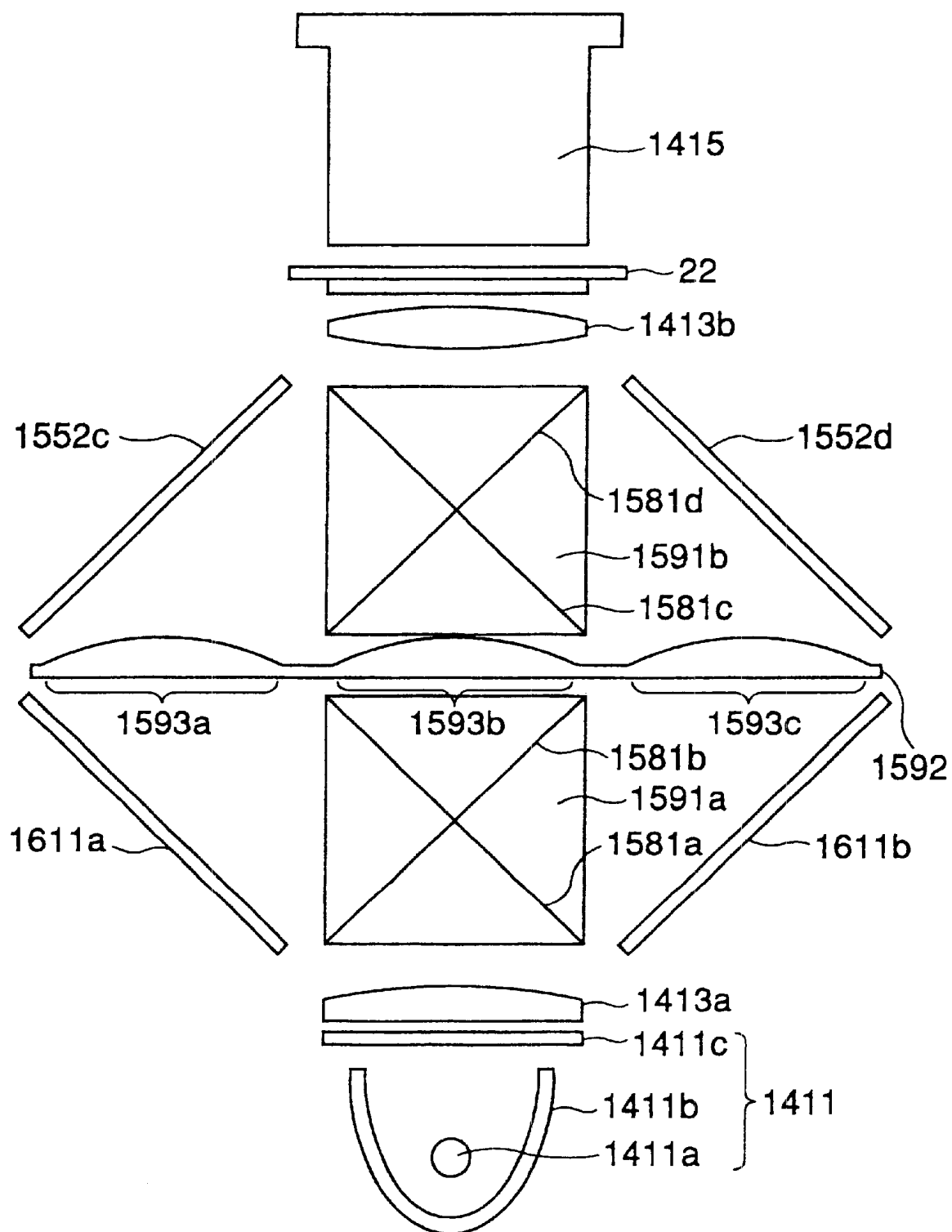
Fig. 161

1611 : DICHROIC MIRROR

Fig. 162 (a)

REFLECTANCE

B   G   R

Fig. 162 (b)

k

REFLECTANCE

B   G   R
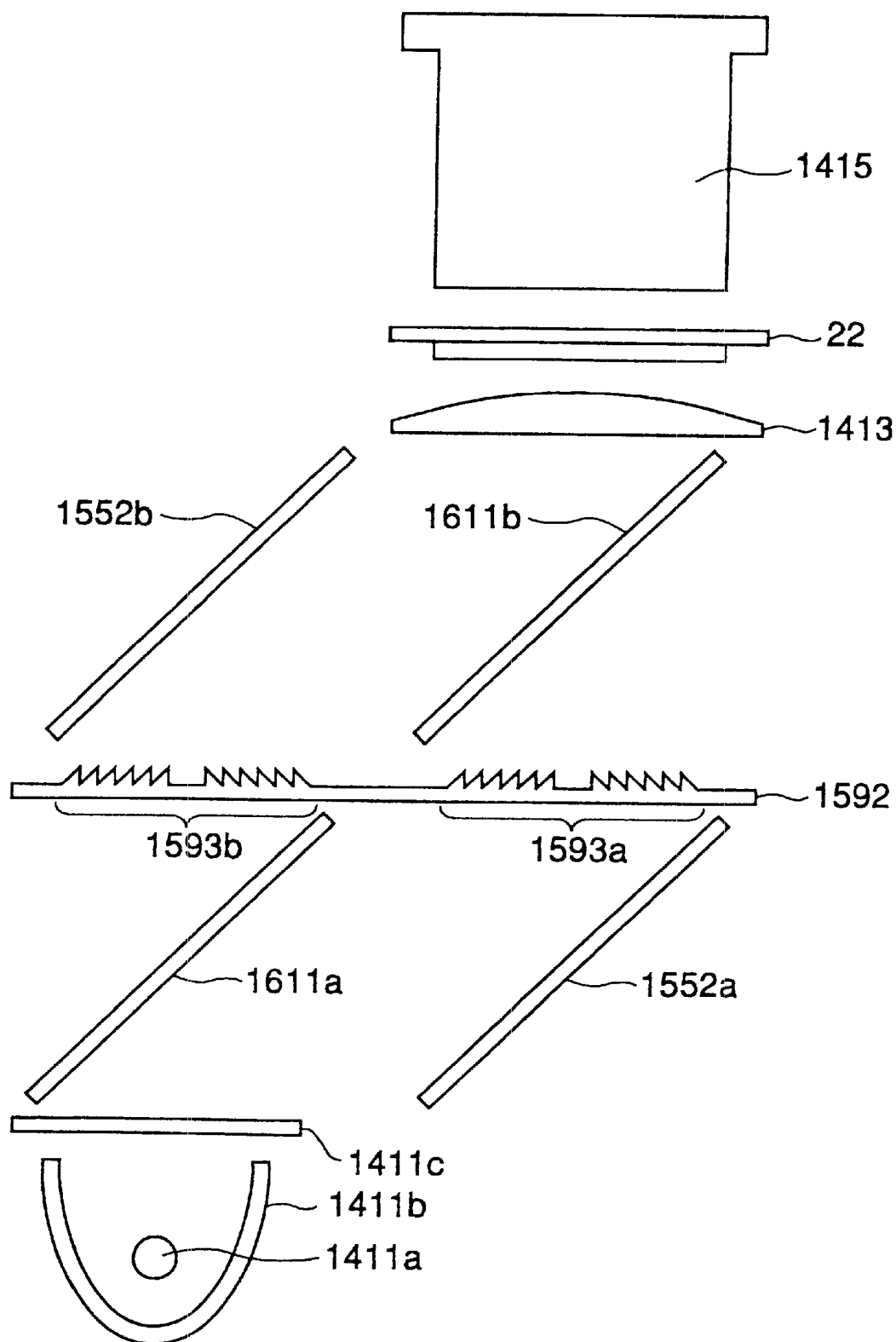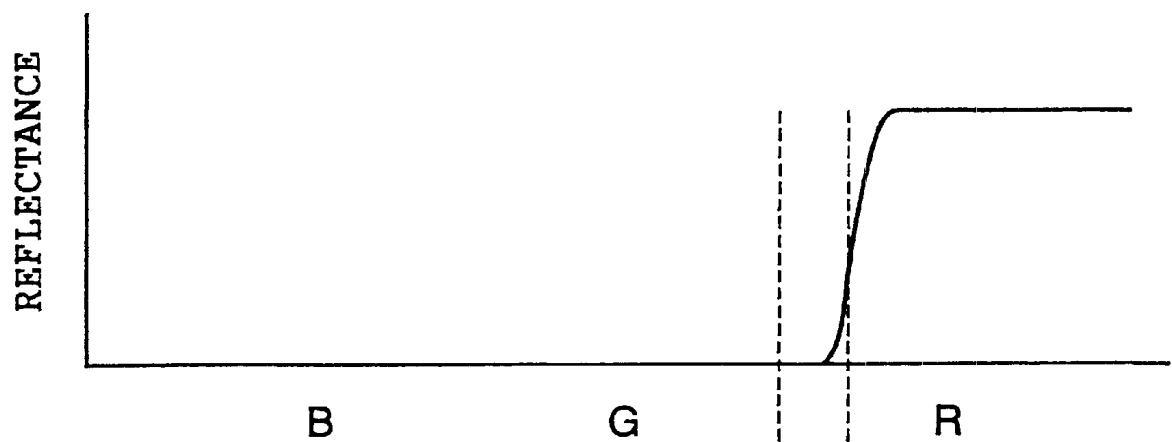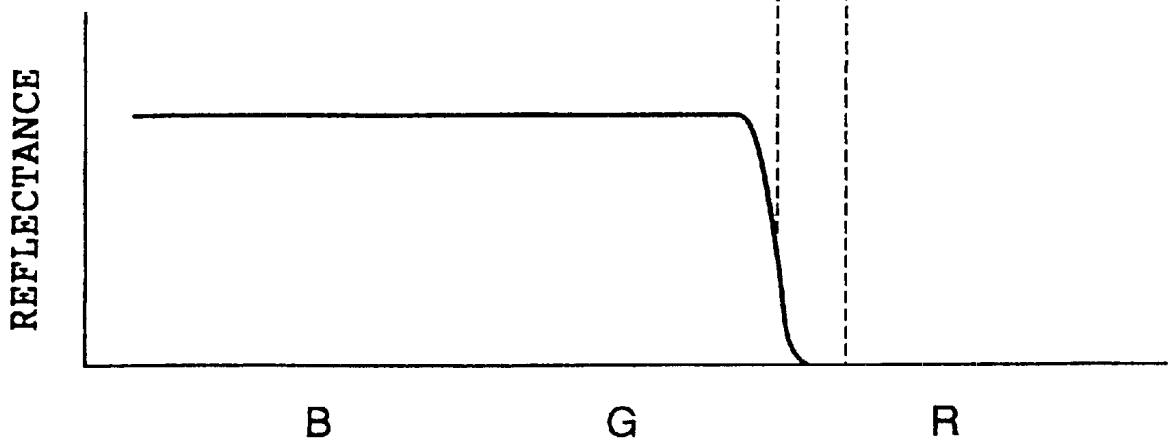
Fig. 163

1631 : DISPLAY AREA
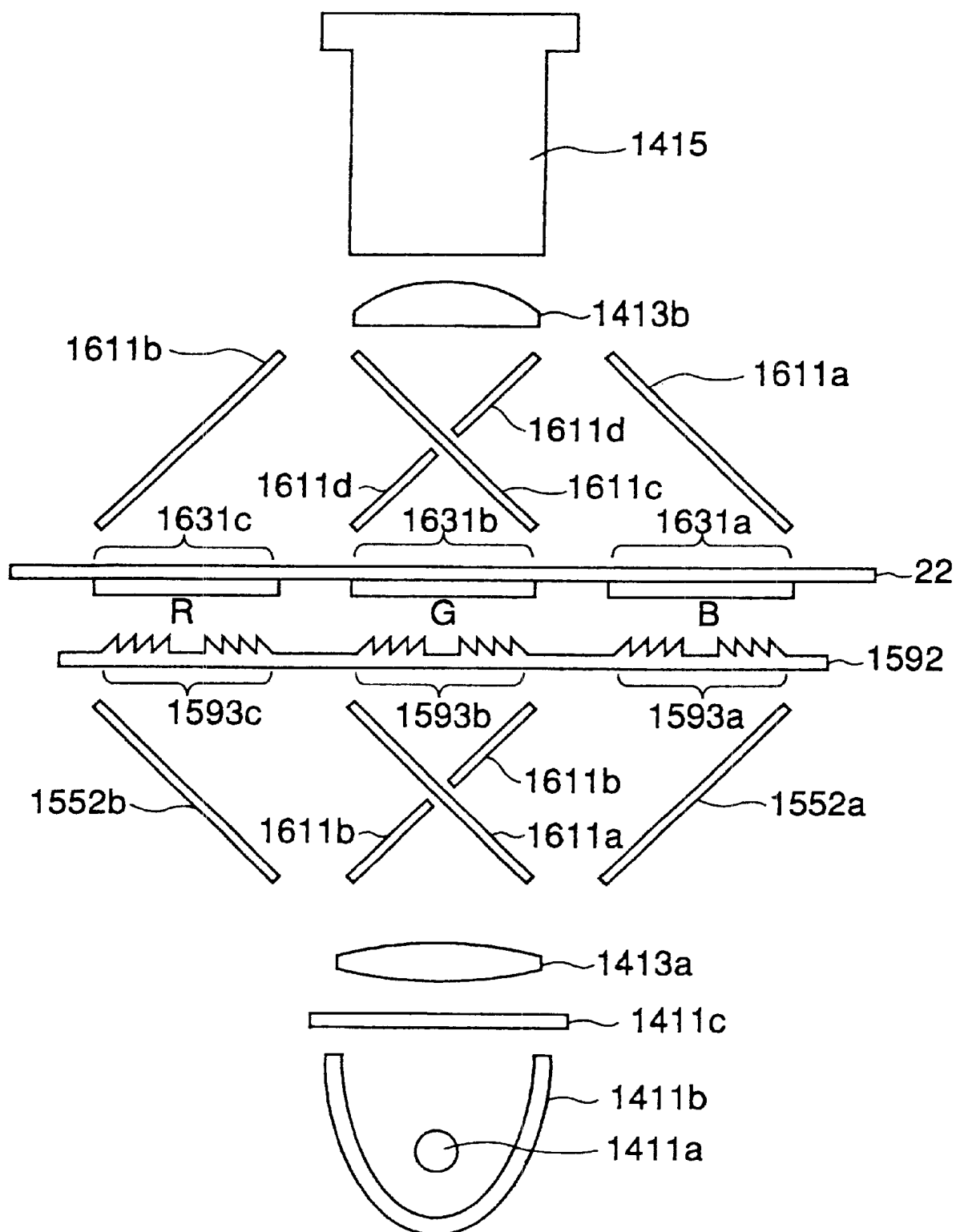
Fig. 164
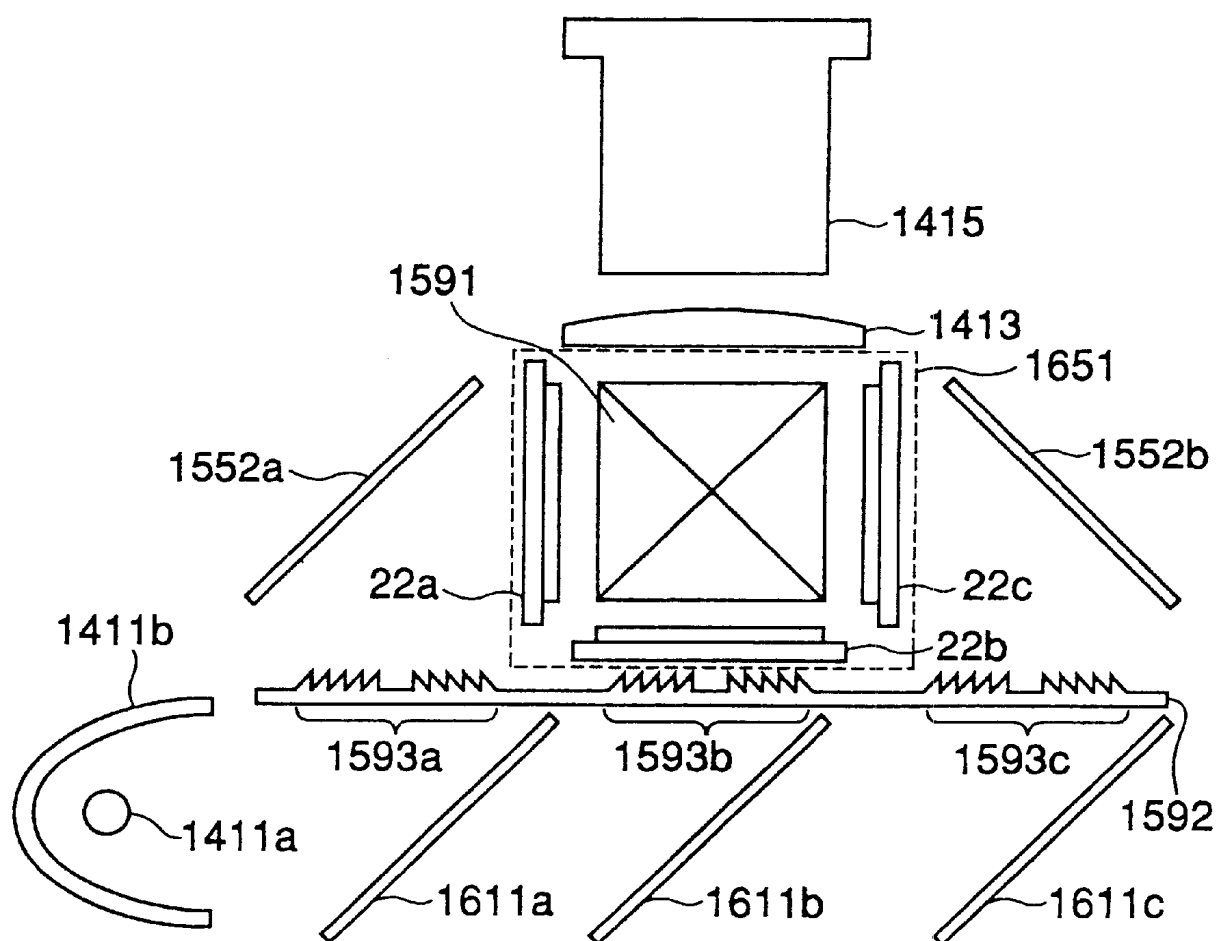
Fig. 165 (a)

1651 : CASING

1652 : PELTIER ELEMENT (ELECTRONIC COOLING ELEMENT)

Fig. 165 (b)

Fig. 166

Fig. 167

1415

1413

1552b

1651b

1611c

22c

1651a

22a

1611b

22b

1552a

1611a
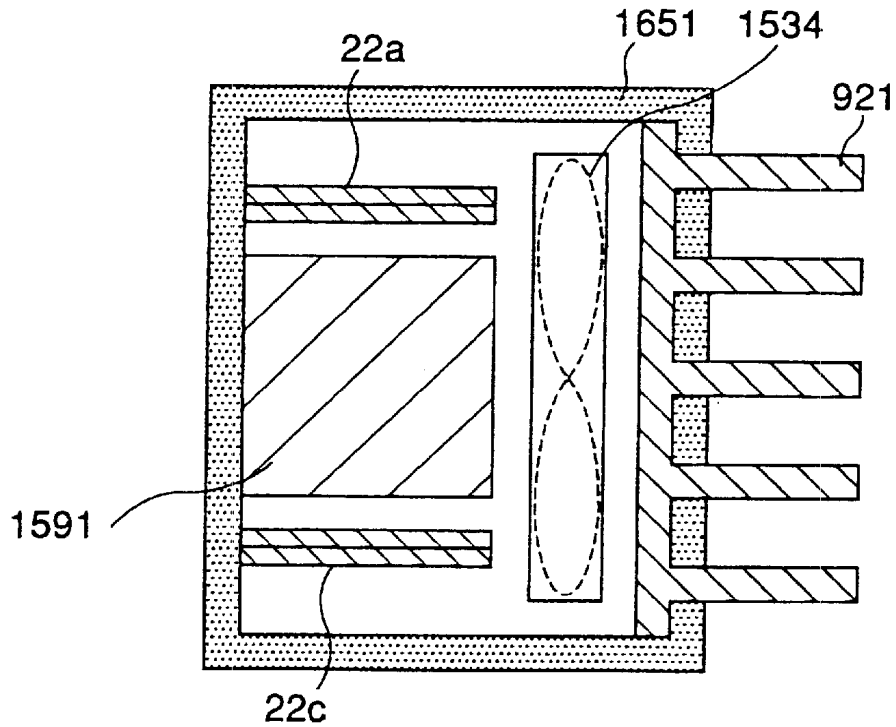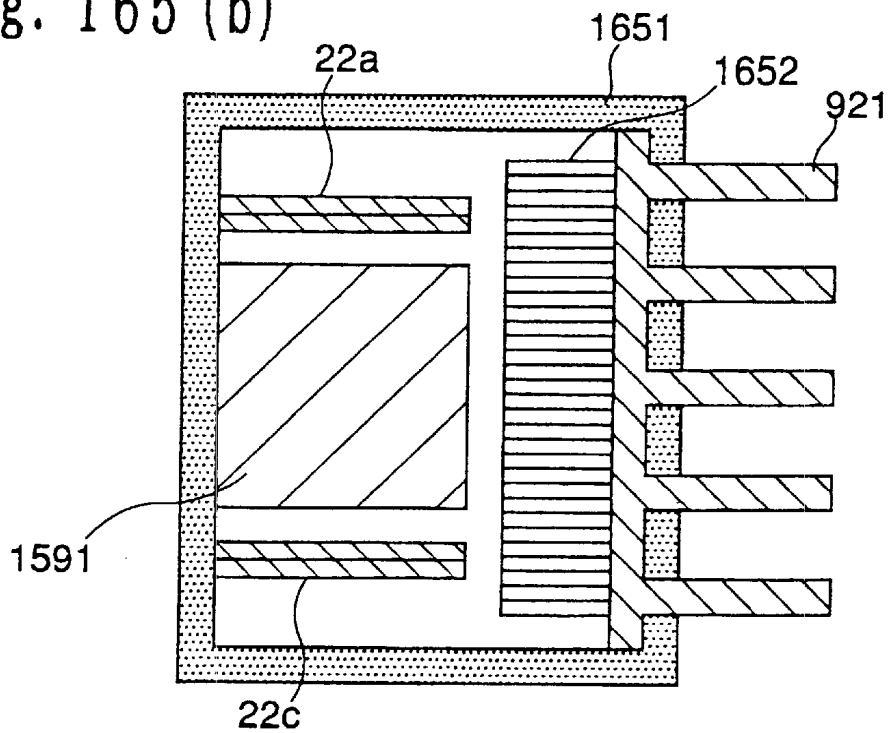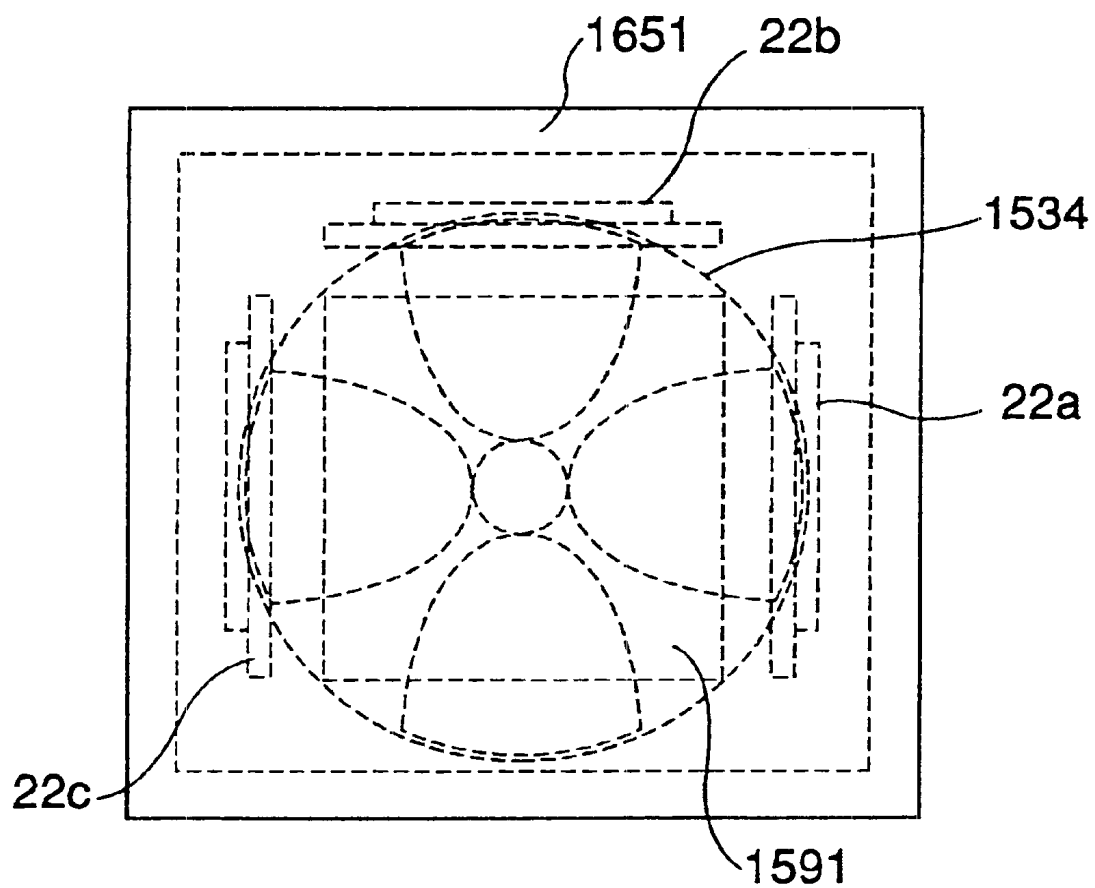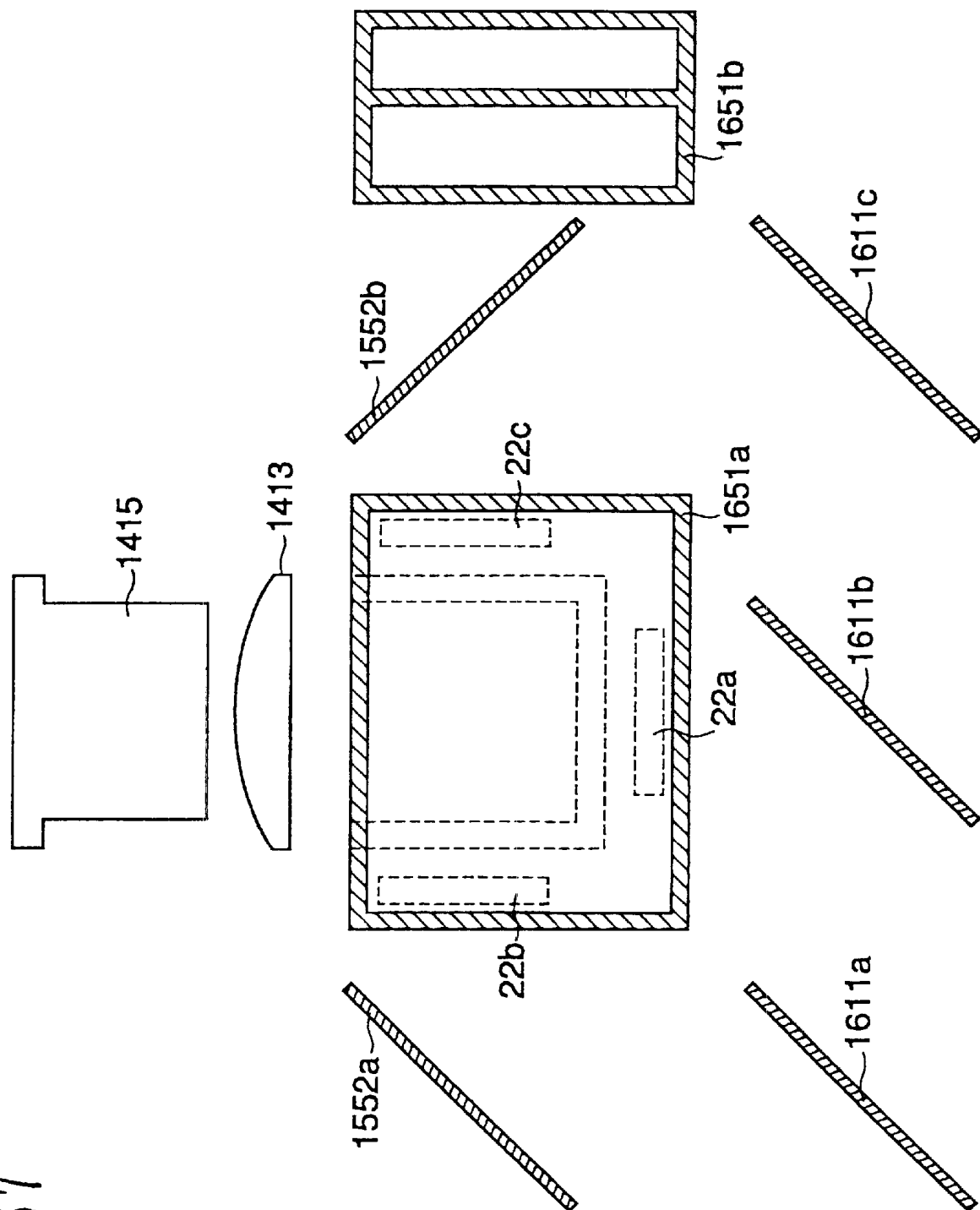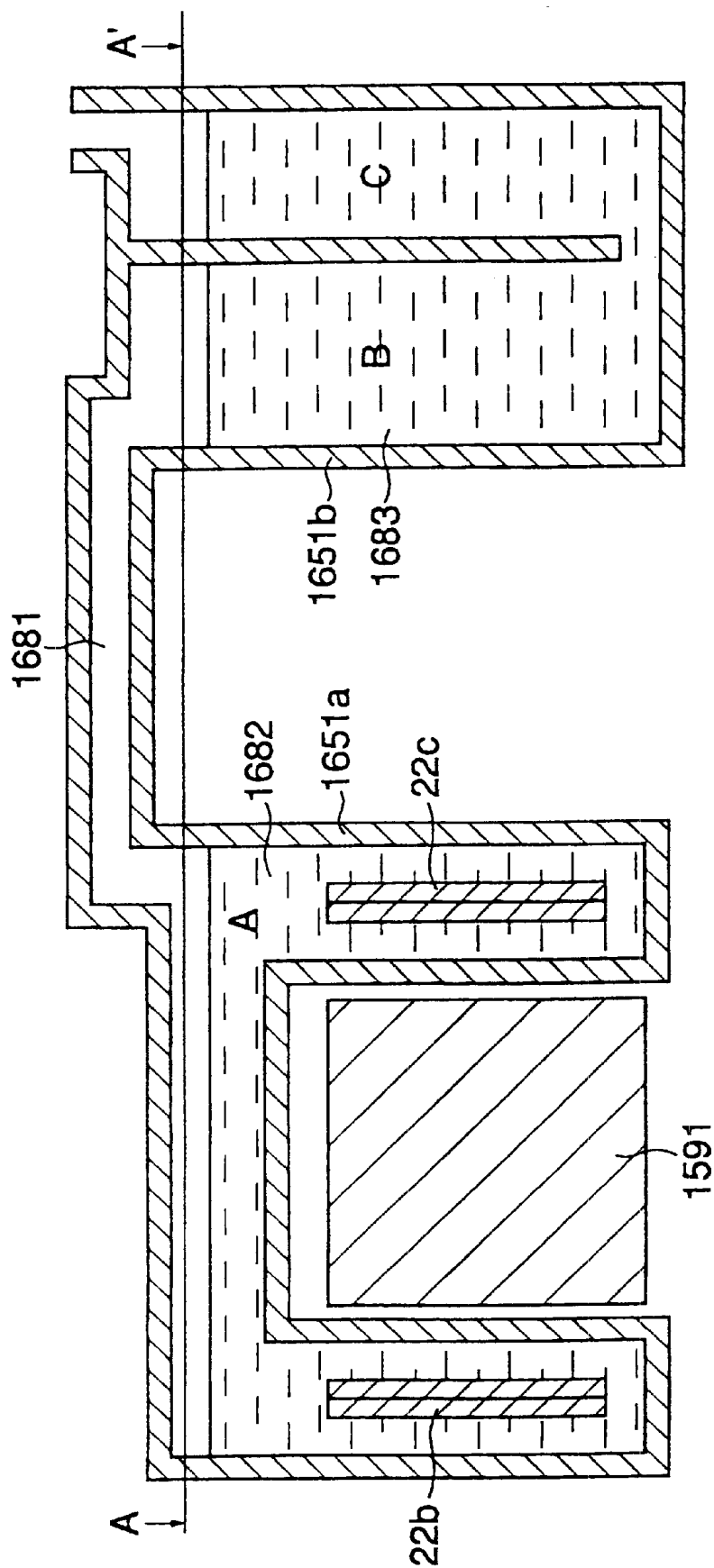
Fig. 168

1681 : NITROGEN GAS

1682 : COOLING LIQUID

1683 : SEAL LIQUID

Fig. 169 (a)

1691 : CURRENT SOURCE   1693 : WIRE

1692 : SWITCH   1694 : CONNECTING POINT

1695 : LEAD WIRE
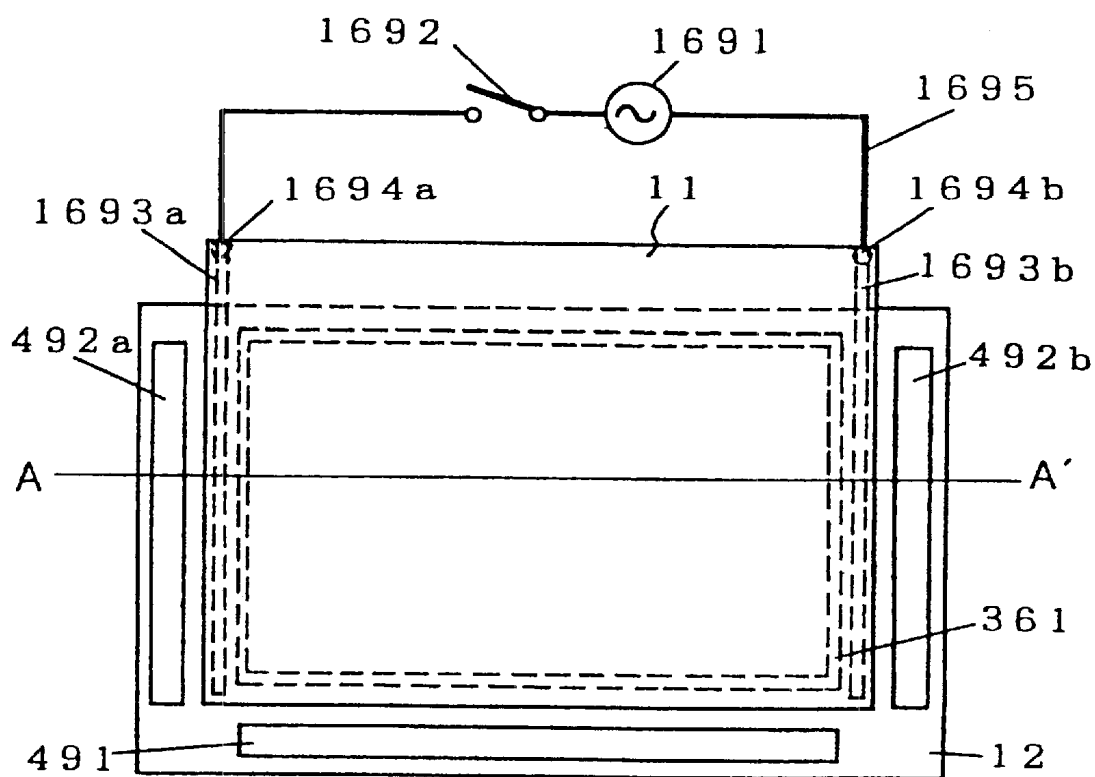
Fig. 169 (b)
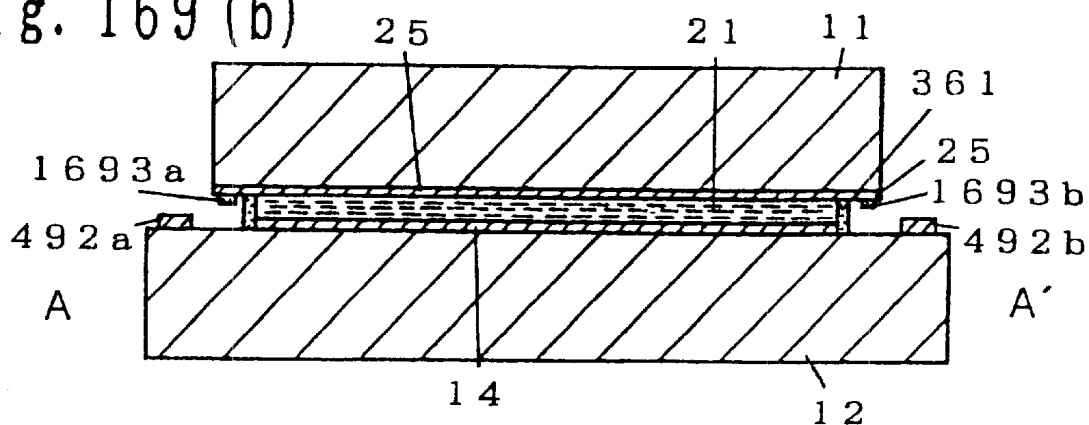
Fig. 170
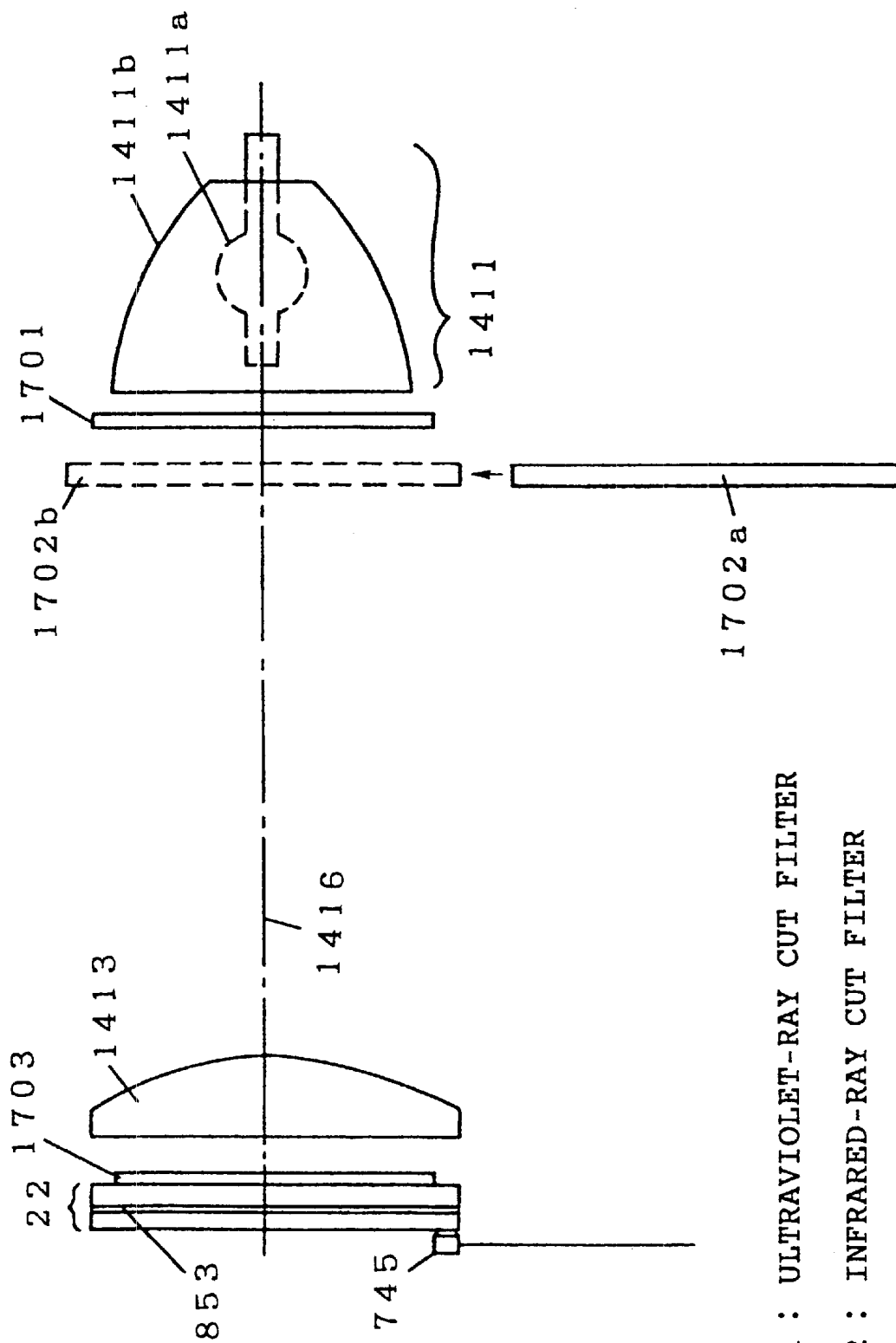
1701 : ULTRAVIOLET-RAY CUT FILTER

1702 : INFRARED-RAY CUT FILTER

1703 : INFRARED-RAY ABSORBING FILTER

Fig. 171

1711 : MOTOR

1712 : DAMPER

1411a

1411b

591

1711

1702

1712
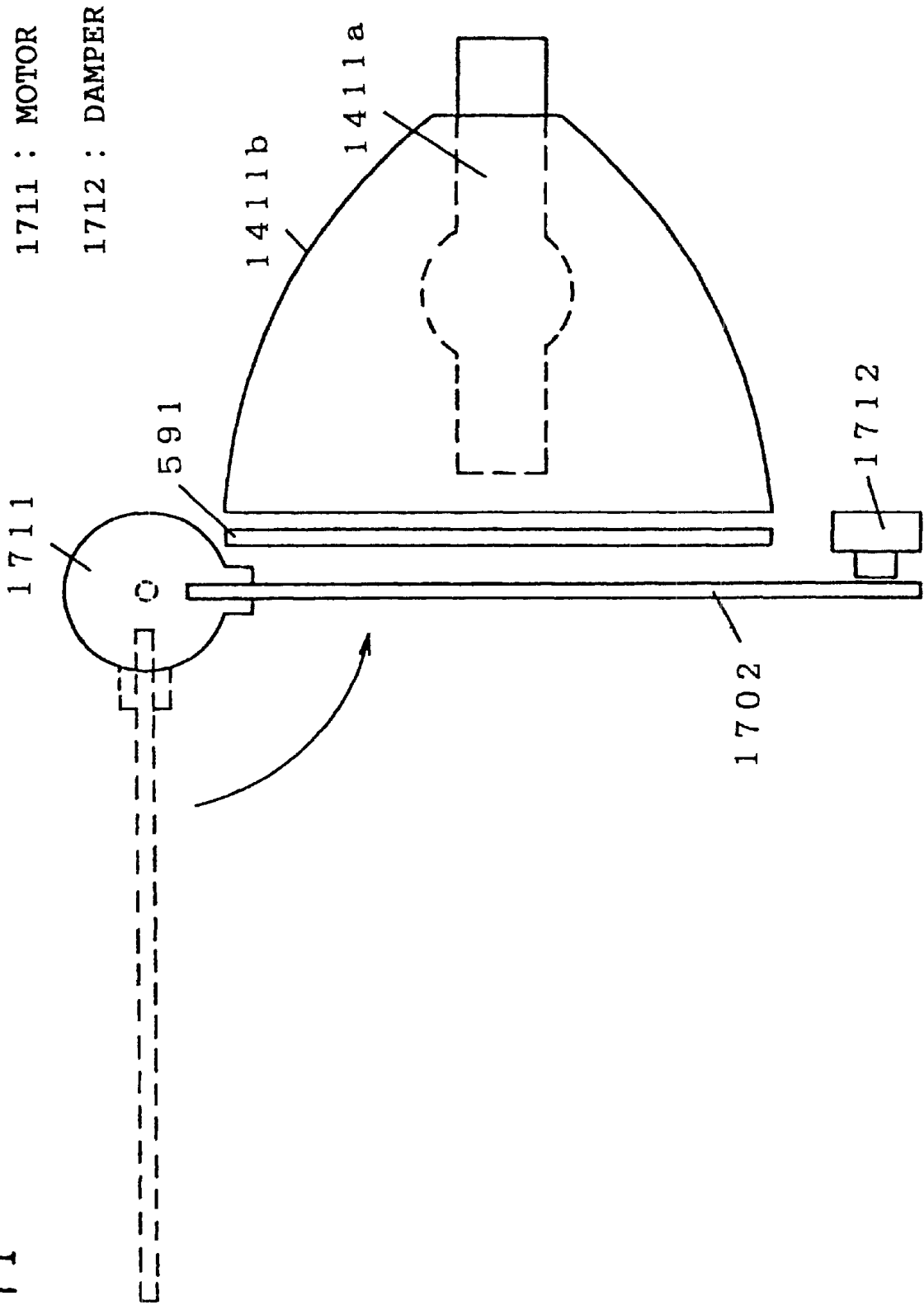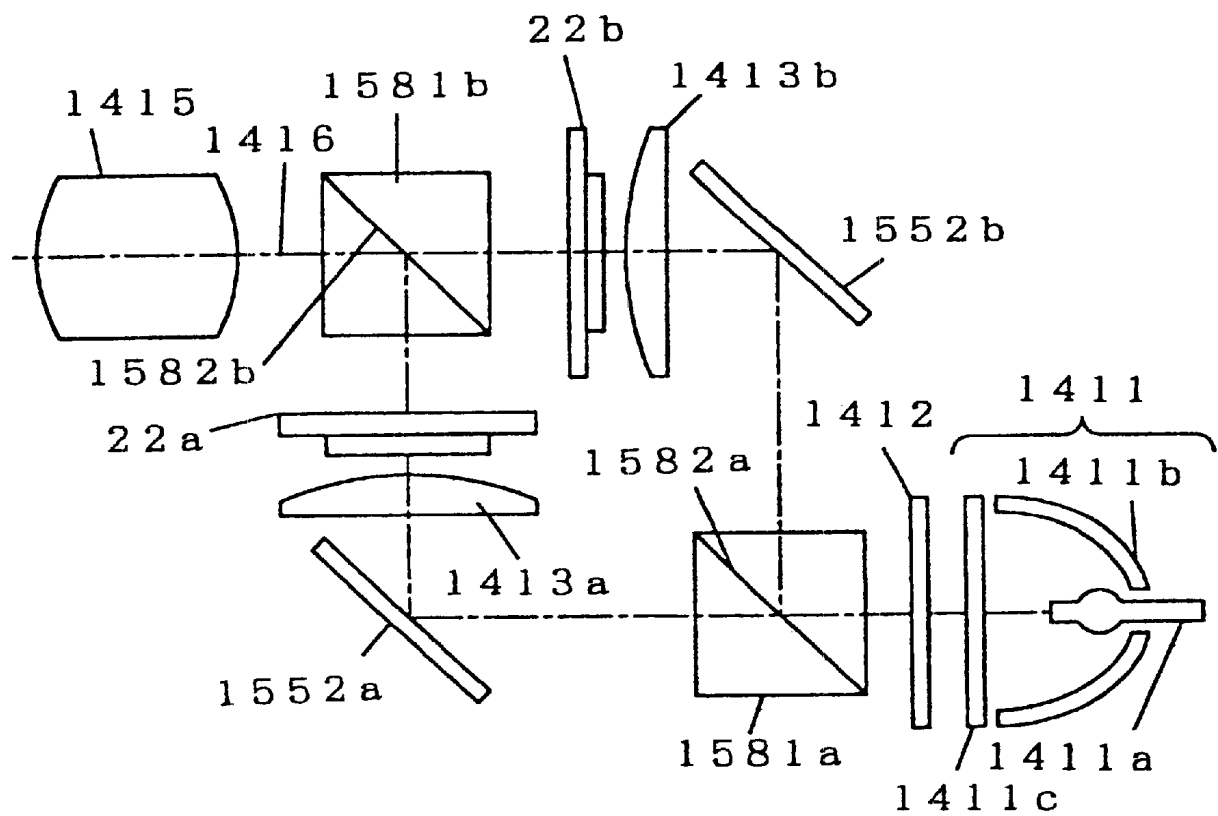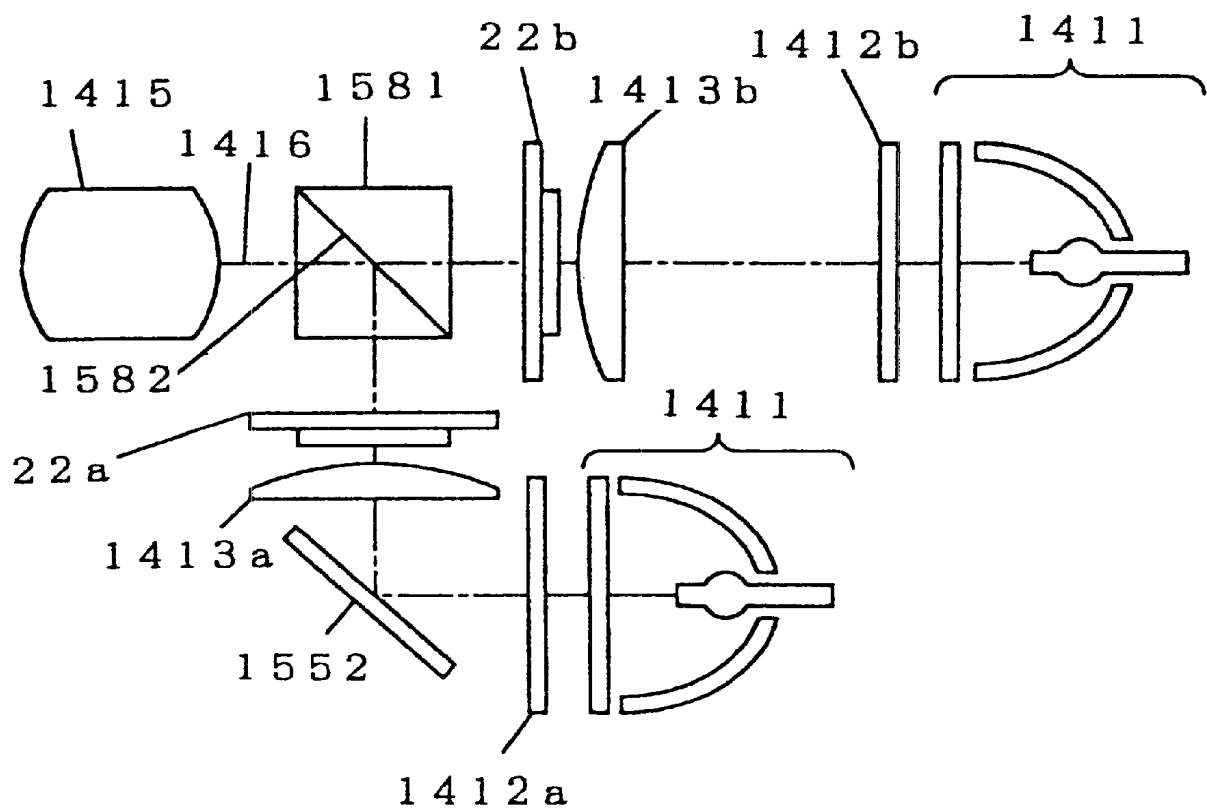
Fig. 172

Fig. 173

Fig. 174

1741 : HALF-WAVE PLATE

1742 : POLARIZING PLATE

Fig. 175

1751a : R FILTER

1751b : B FILTER

1752 : REFLECTING PRISM
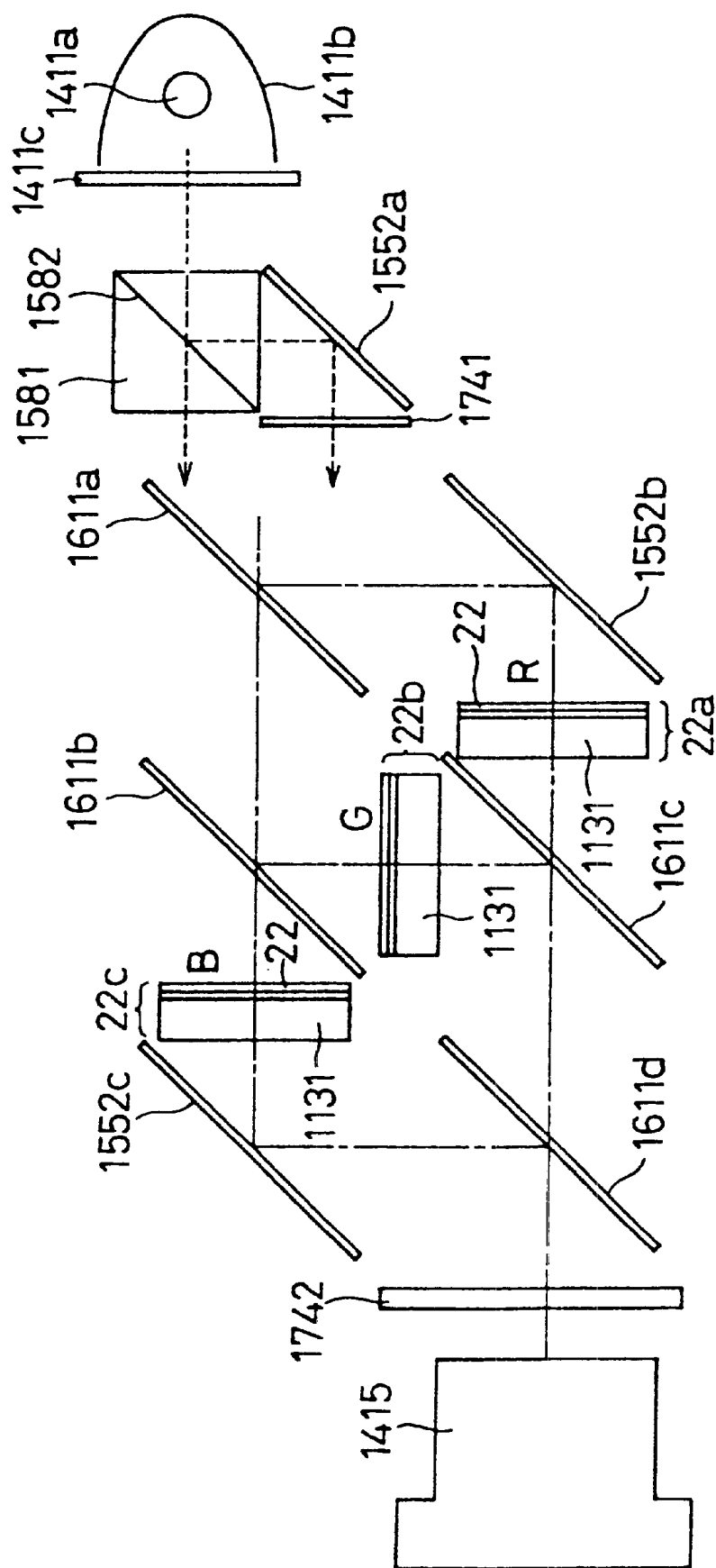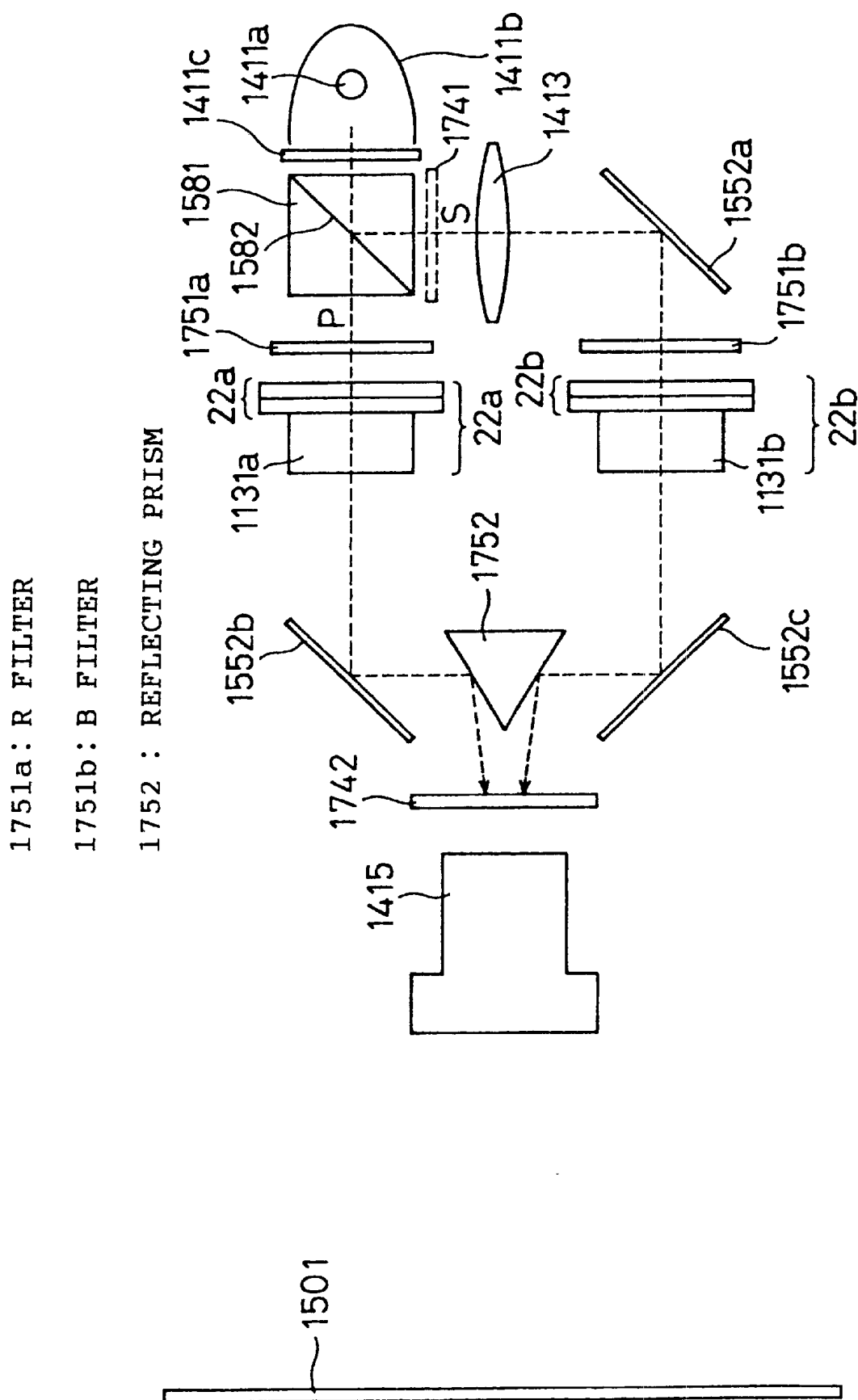
Fig. 176

1761 : RELAY LENS

1762 : APERTURE
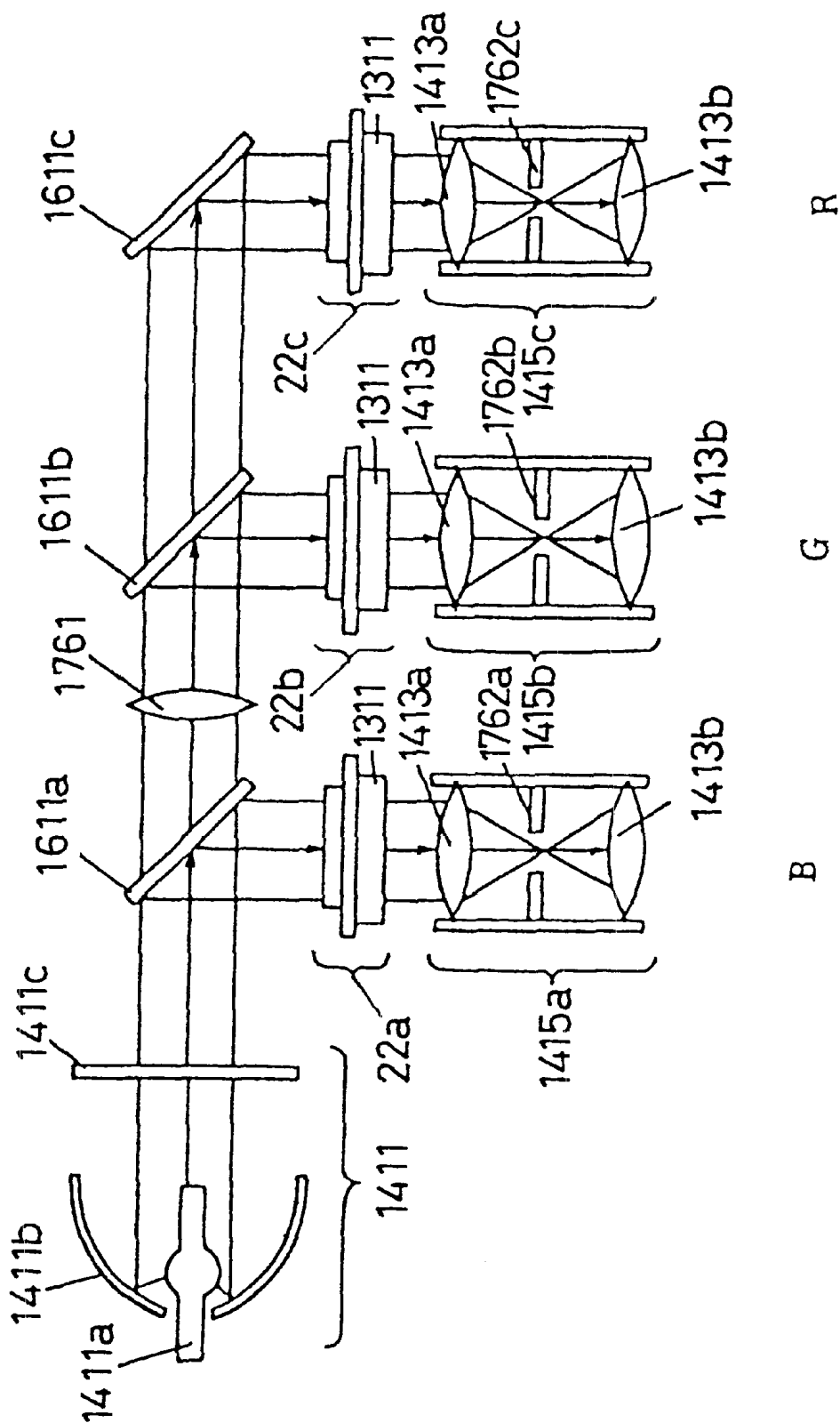
Fig. 177

1771 : FIELD LENS
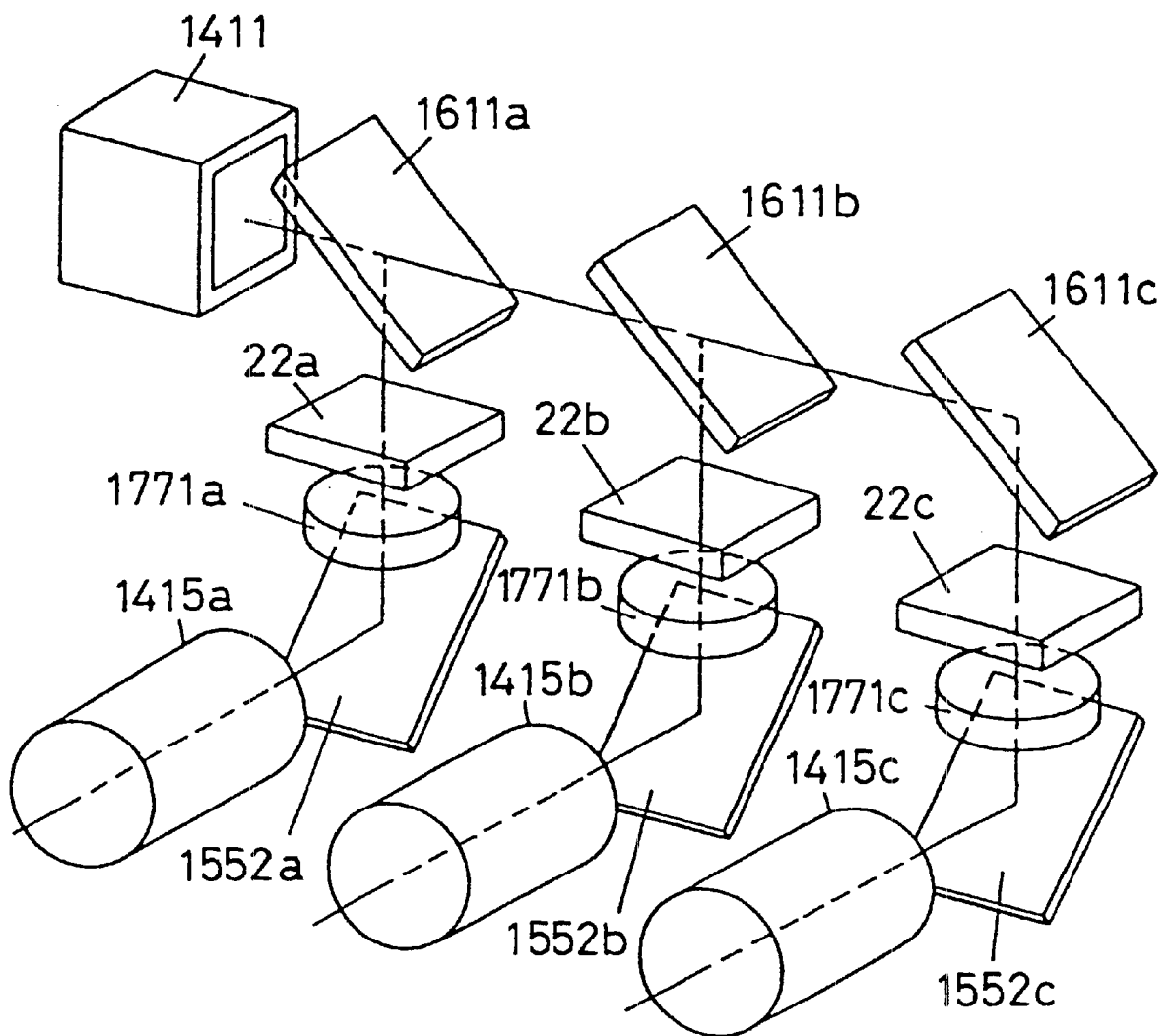
Fig. 178
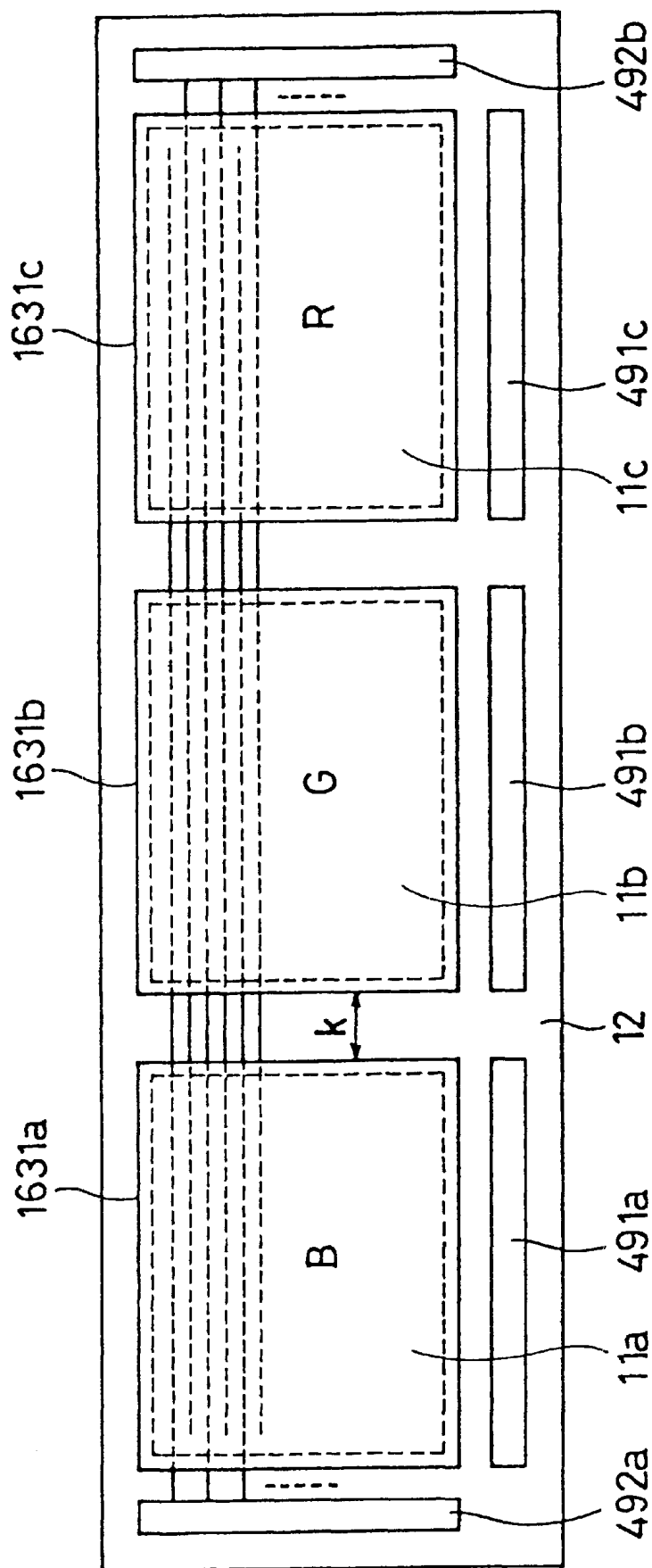
Fig. 179
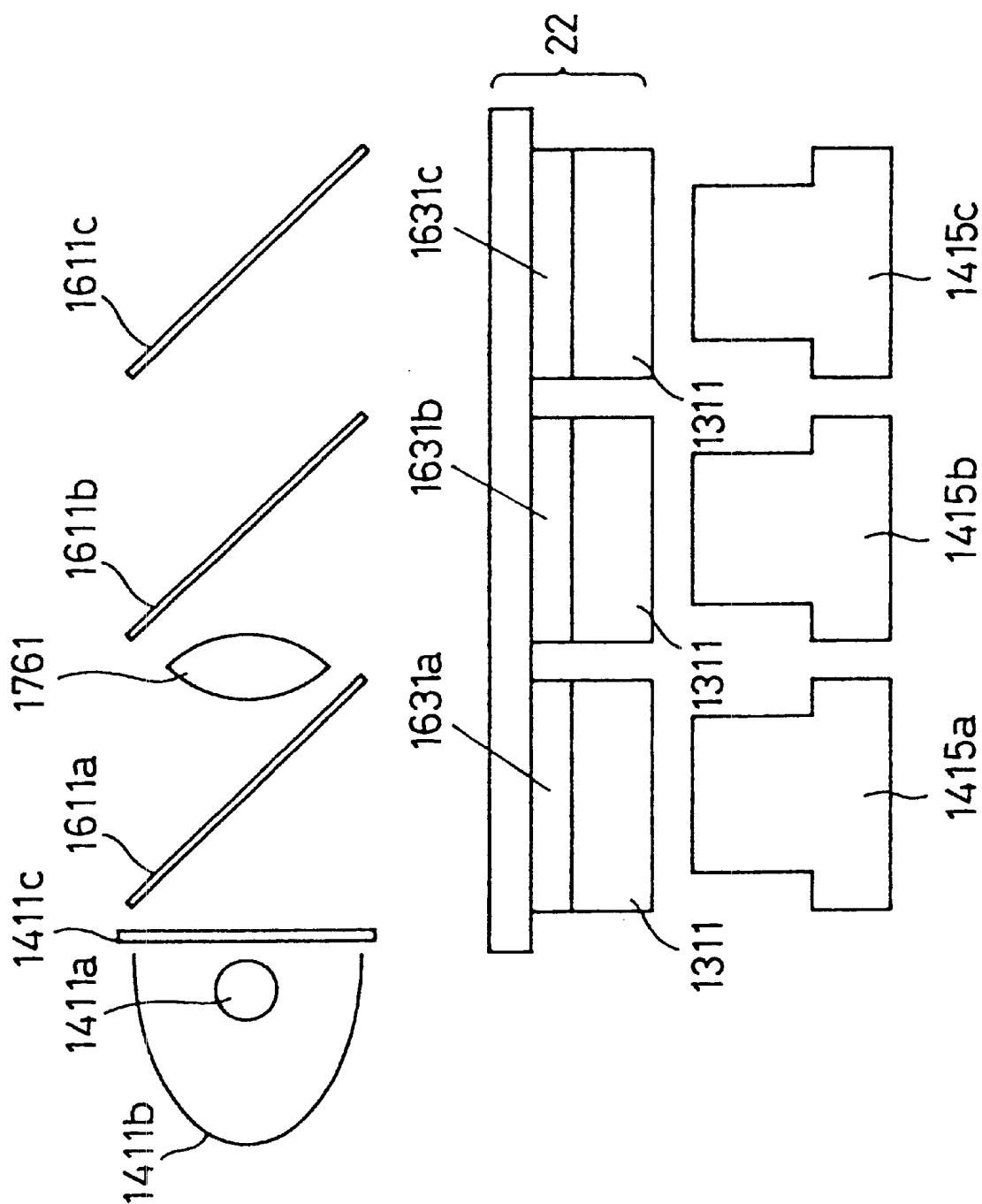
Fig. 180

1801 : SEPARATION WALL

1801

1411

1552a

1552b

1611a

1535

1611c

1771a

22c

1311

R

1771b

1611b

22b

G

22c 1771c

1311

B

1611d

1552c

1415

Fig. 181

1811a: INCIDENT AXIS

1811b: EXIT AXIS

Fig. 182

Fig. 183 (a)

INCIDENT ANGLE 45°

SPECTRAL TRANSMITTANCE OF DICHROIC MIRROR 523a

Fig. 183 (b)

INCIDENT ANGLE 45°
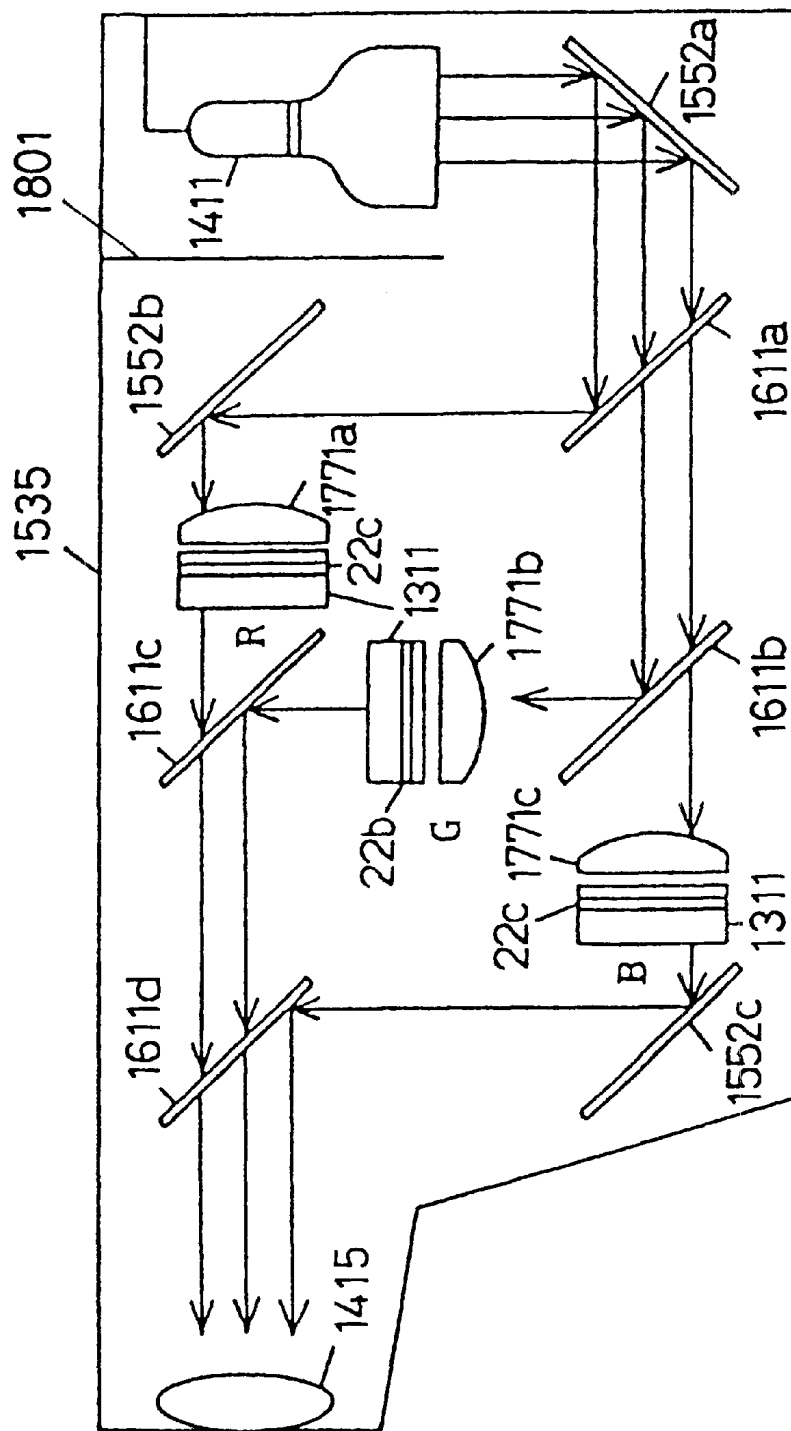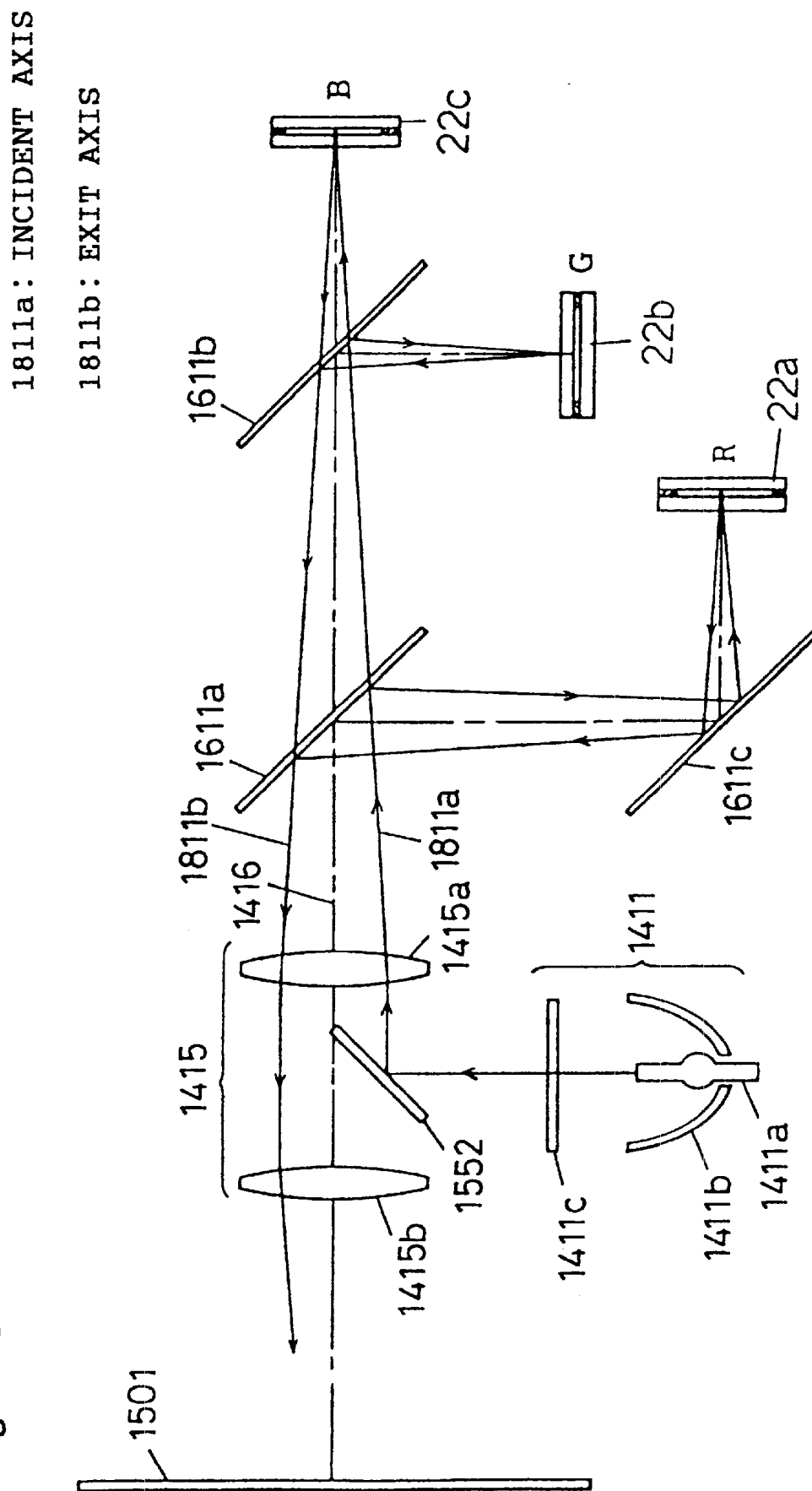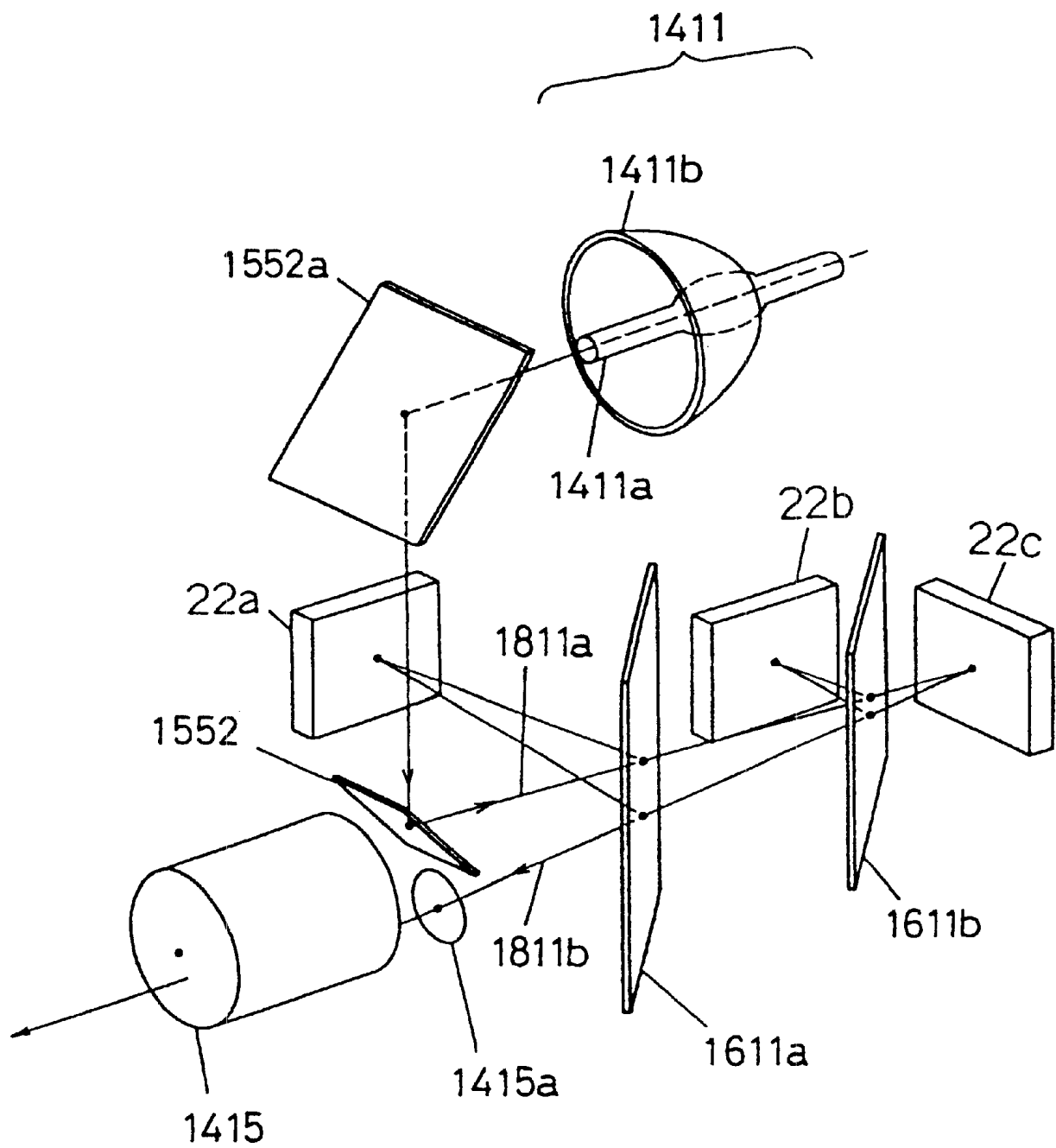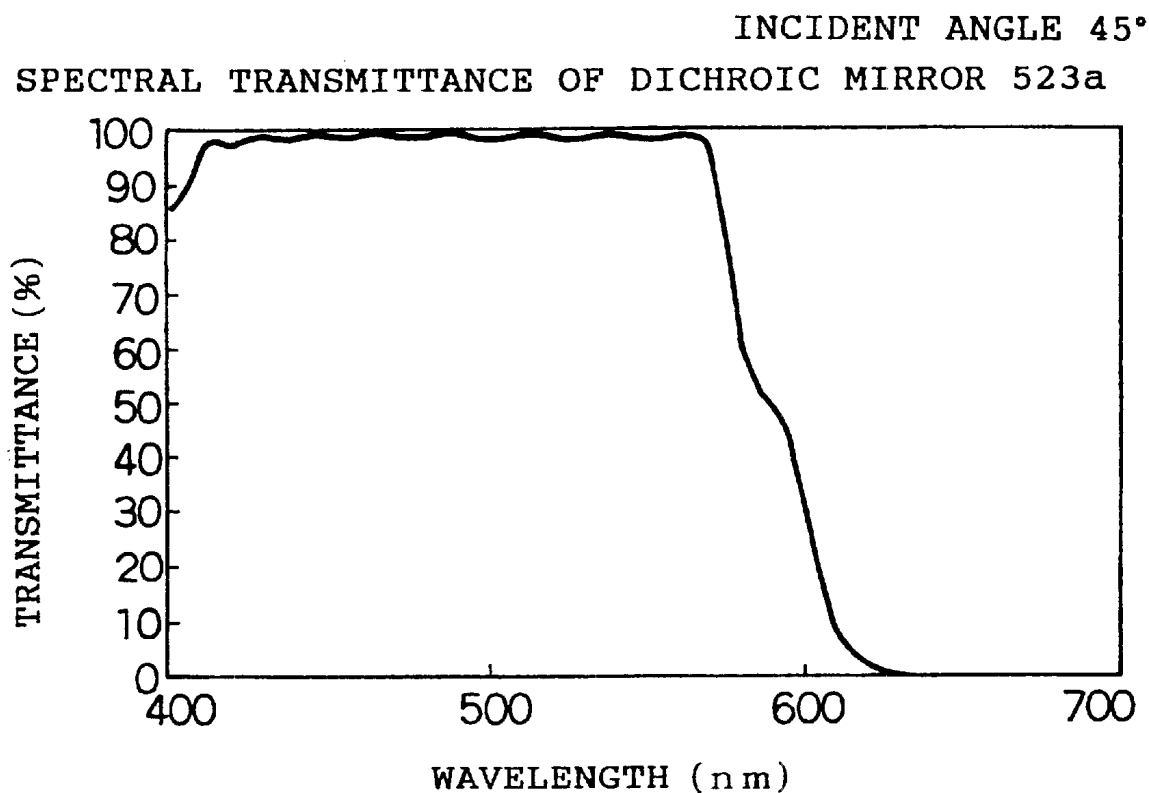
SPECTRAL TRANSMITTANCE OF DICHROIC MIRROR 523b
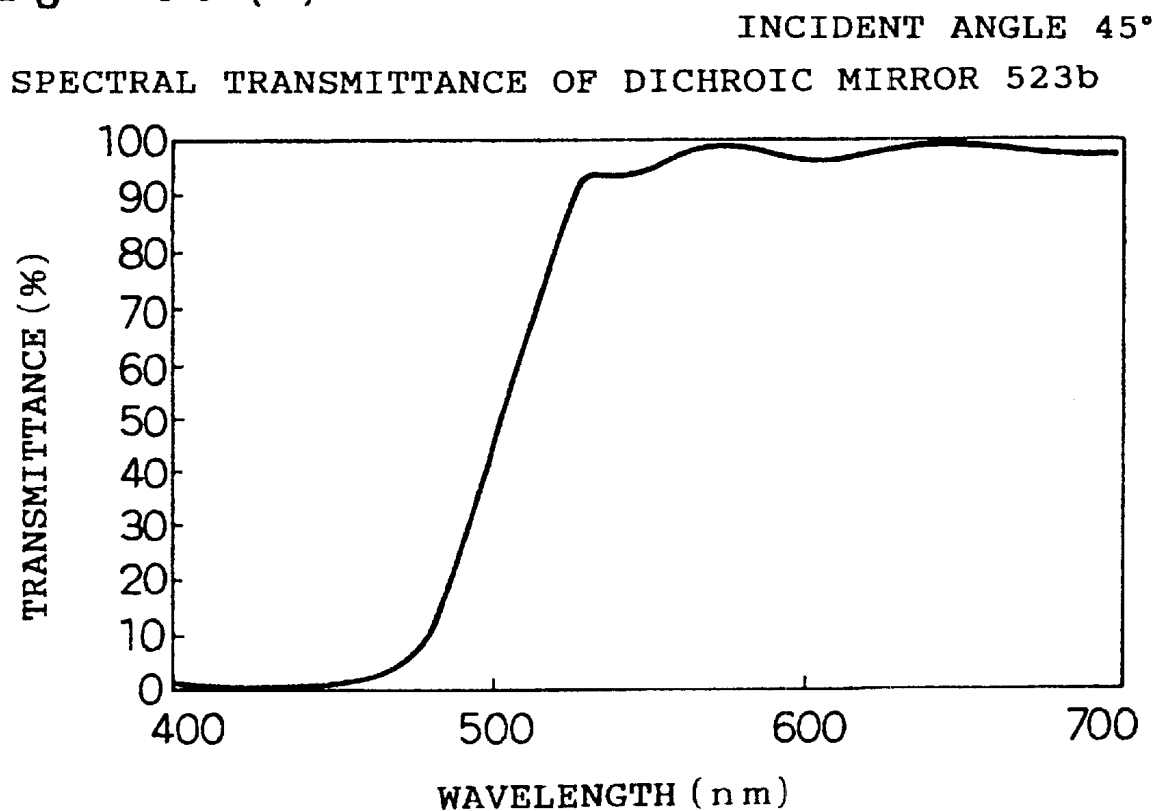
Fig. 184 (a)

SPECTRAL TRANSMITTANCE OF DICHROIC MIRROR 523a

INCIDENT ANGLE 50°

INCIDENT ANGLE 40°

WAVELENGTH (n m)
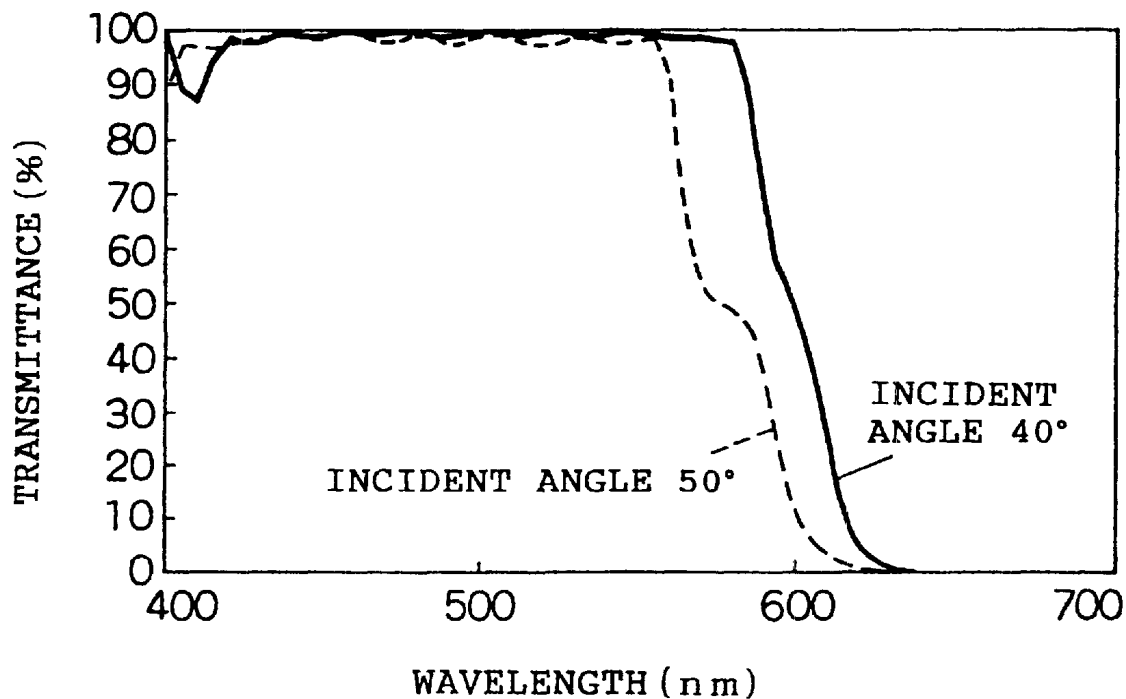
Fig. 184 (b)

SPECTRAL TRANSMITTANCE OF DICHROIC MIRROR 523b

INCIDENT ANGLE 50°

INCIDENT ANGLE 40°

WAVELENGTH (n m)
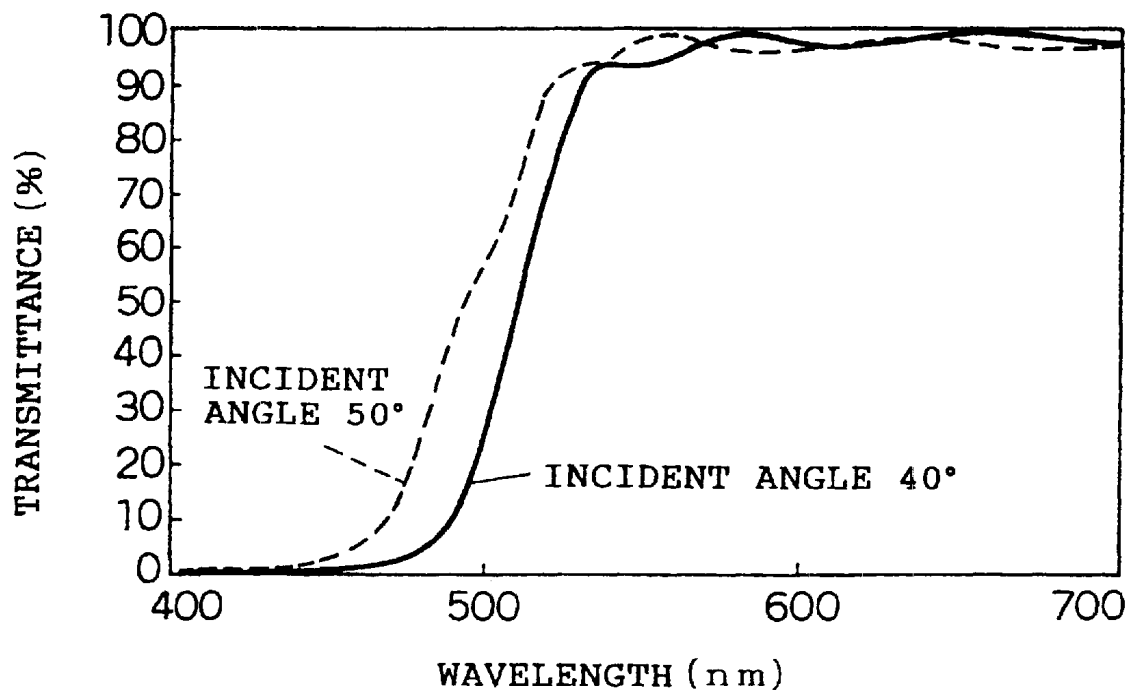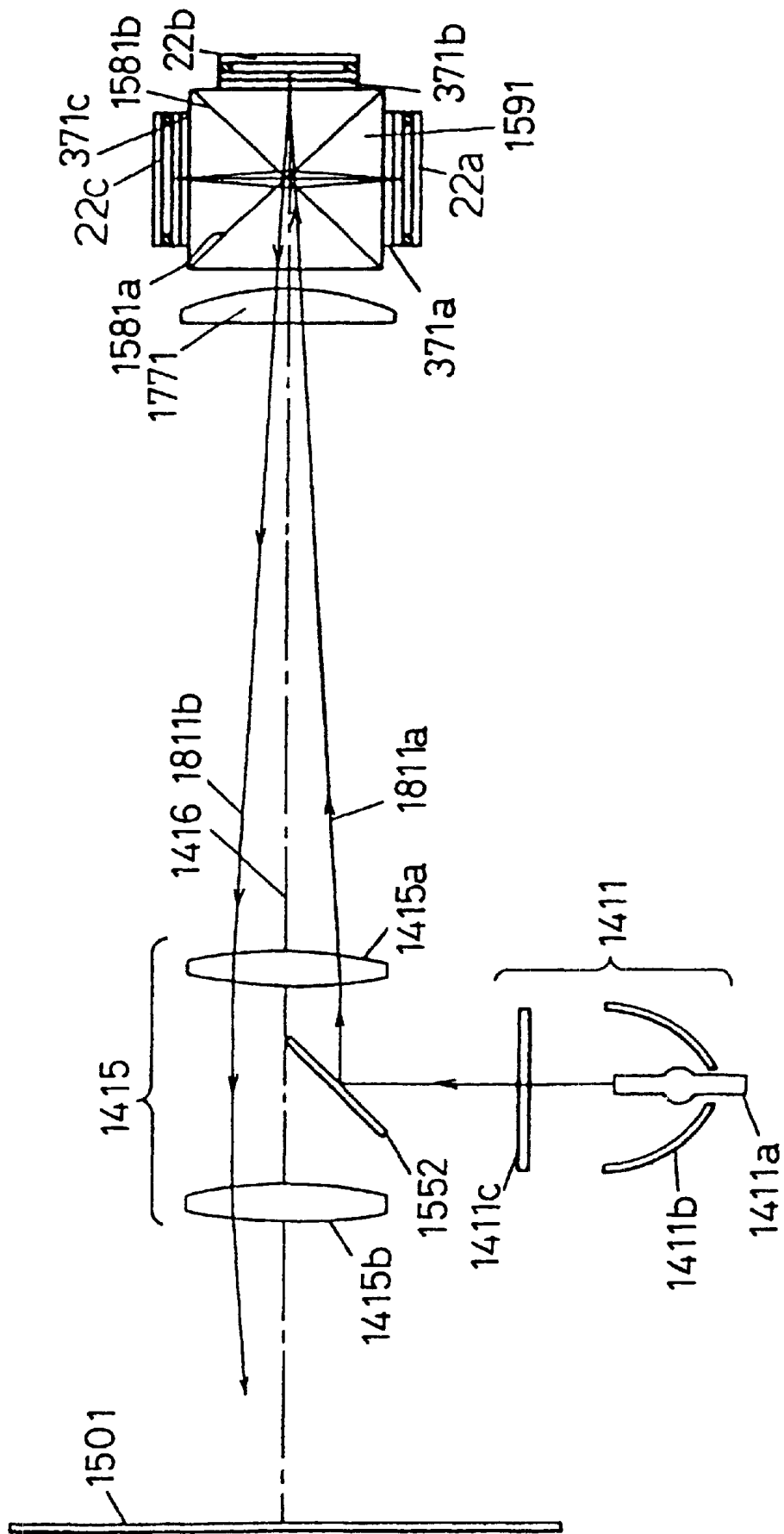
Fig. 185

Fig. 186

1861 : LIGHT INCIDENCE-EXIT SURFACE

1871 : LENS

Fig. 187

1411a
1411b
1871a
1871b
1871c
1611a
1611b
1552b
1771a
22a
371a
1591a
1132
1581a
1771b
22b
371b
22c
1132
1771c
371c
1591c
1552a
1591b
1132
1581b
1132
1132
1132
1415
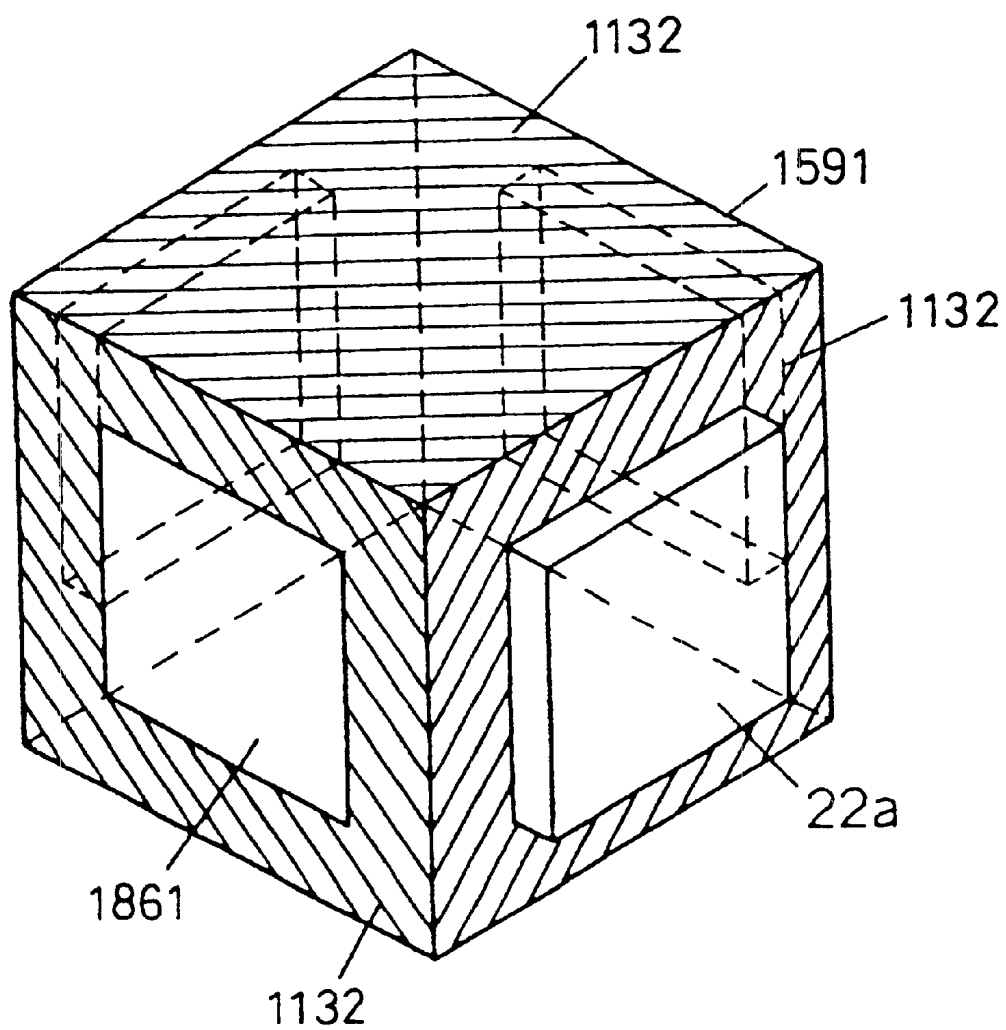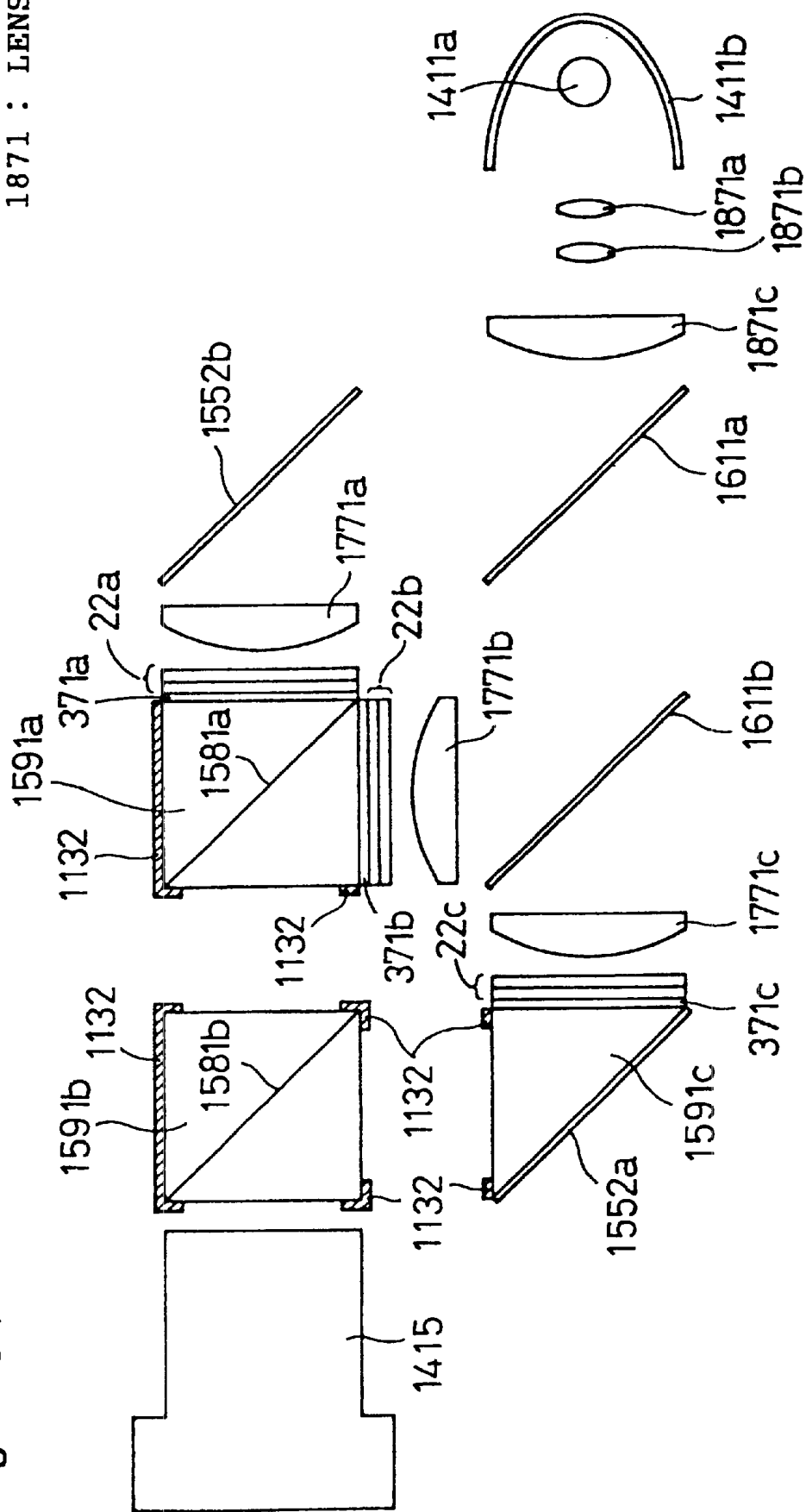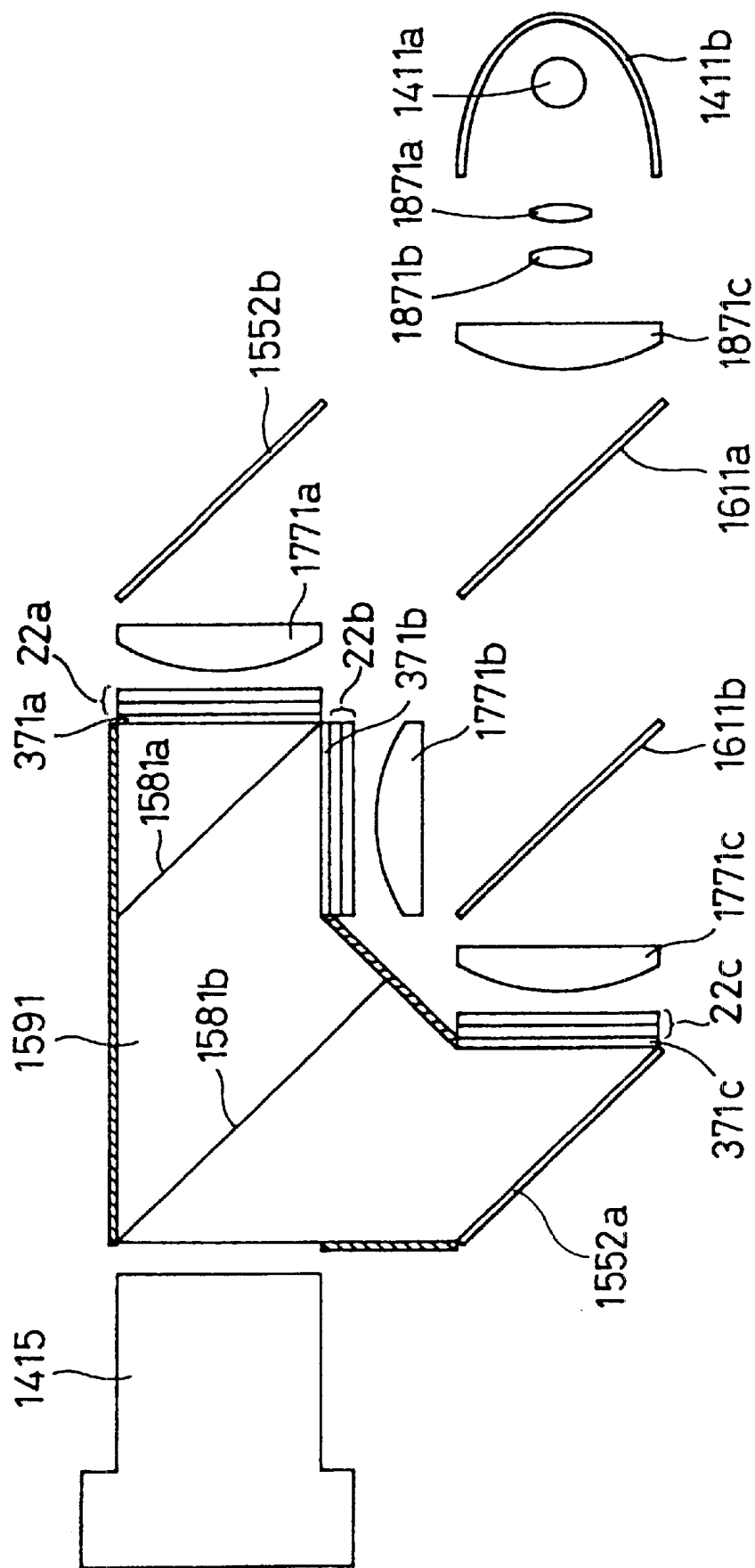
Fig. 188

Fig. 189

1891a : REAR GROUP LENS   1896 : DIAPHRAGM (ILLUMINATION LIGHT SIDE)

1891b : FRONT GROUP LENS   1897 : OUTPUT LENS

1892 : ILLUMINANT   1898 : DIAPHRAGM (PROJECTION LENS SIDE)

1893 : REAL IMAGE   1899 : INPUT LENS

1894 : INPUT LENS ARRAY   1900 : CENTER LENS

1895 : CENTER LENS ARRAY   1901 : SECONDARY ILLUMINANT
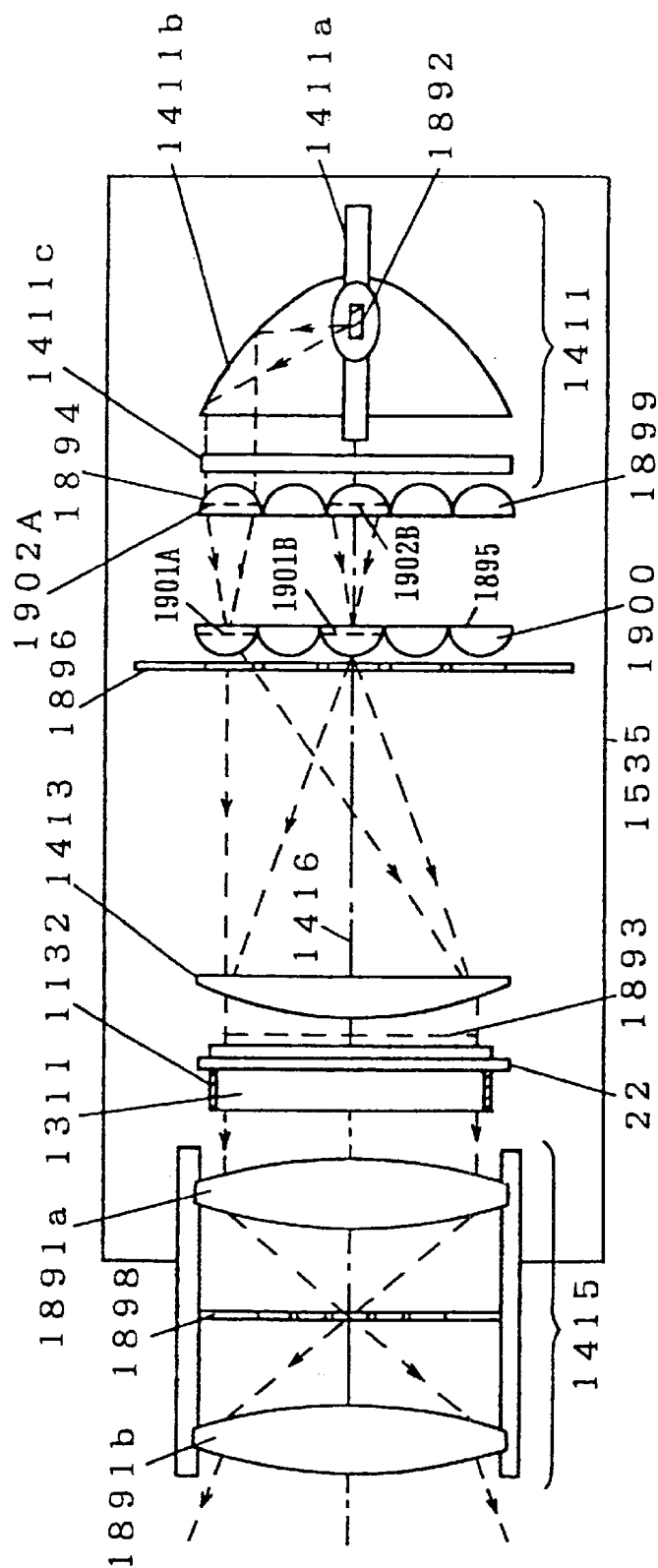
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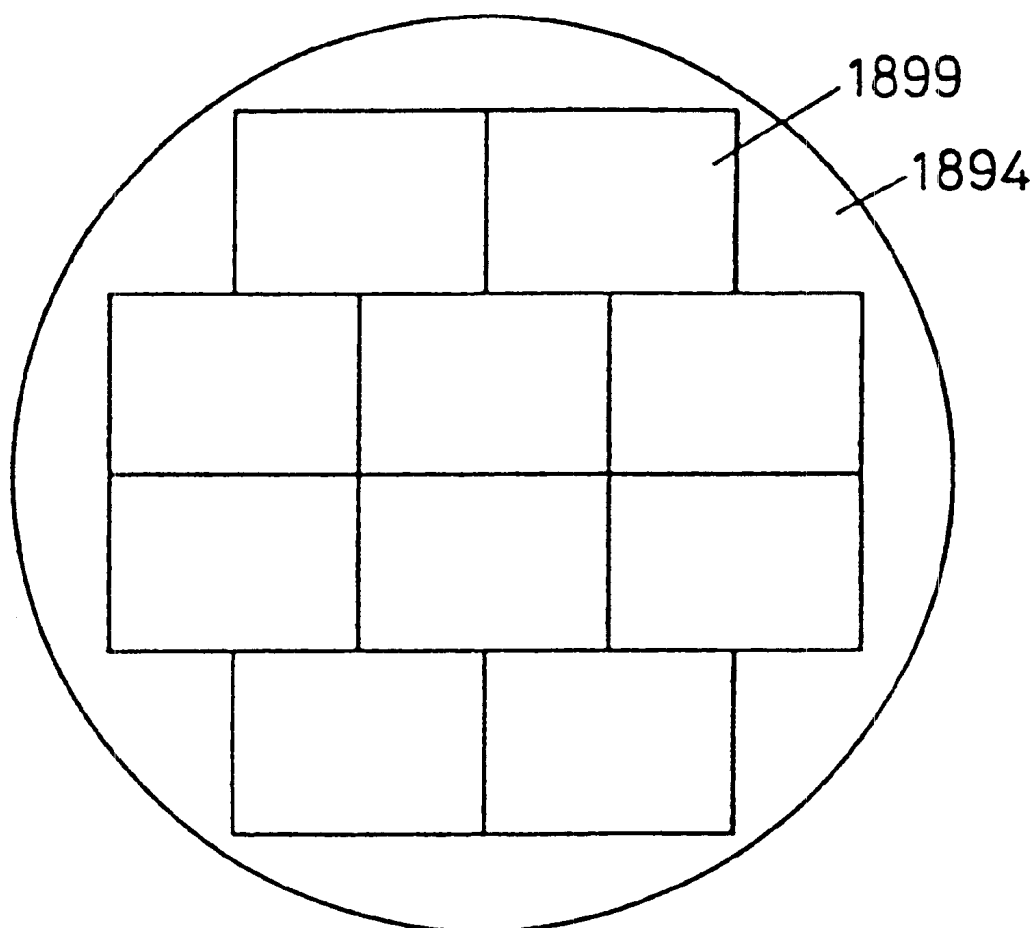
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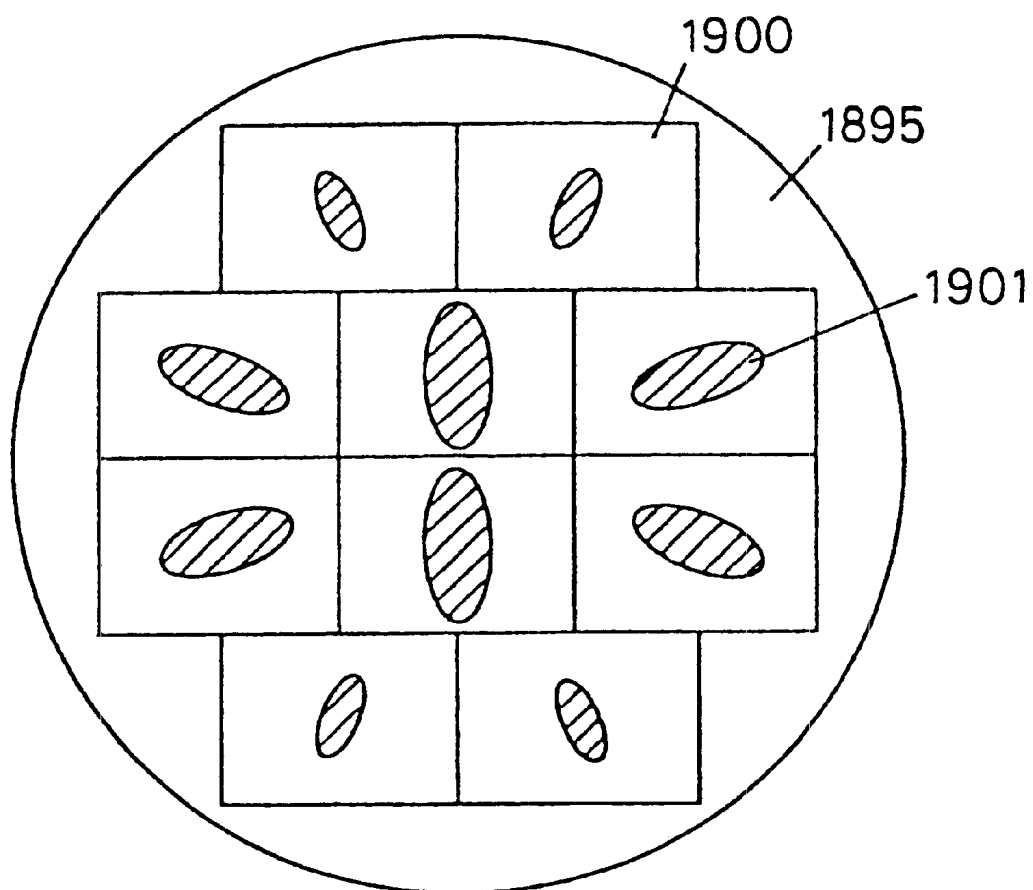
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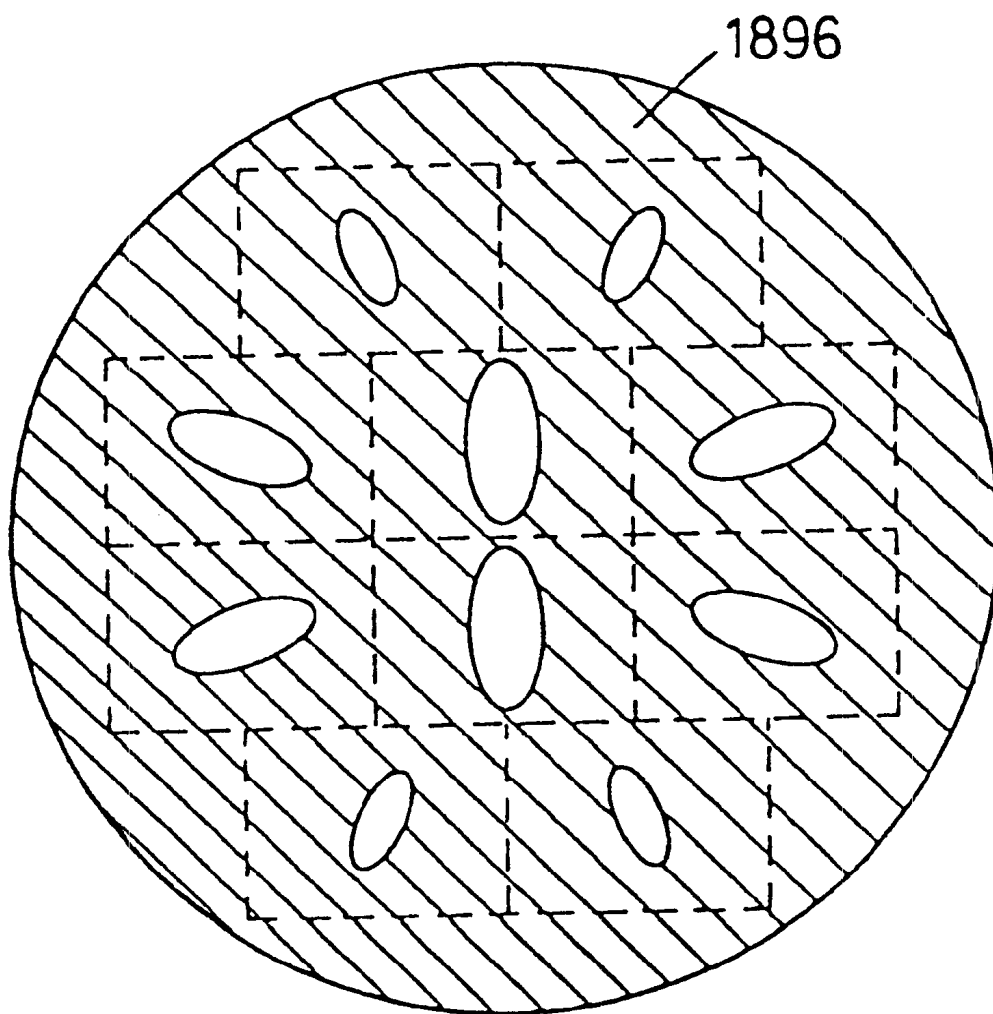
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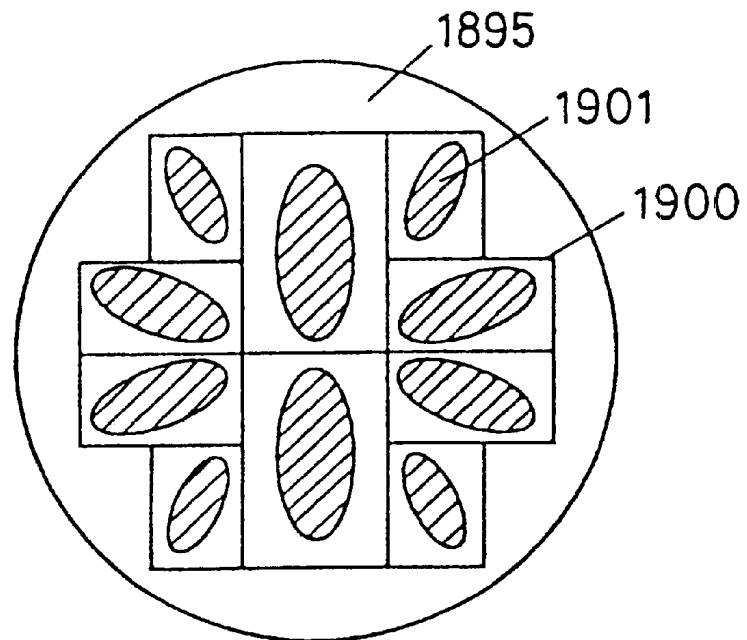
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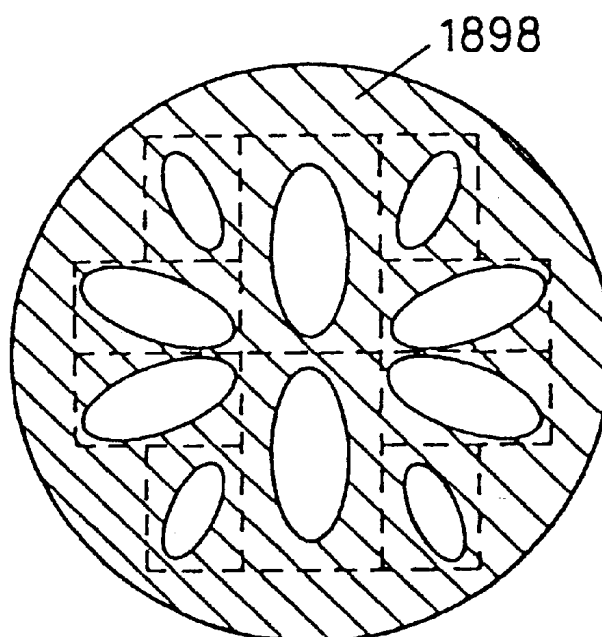
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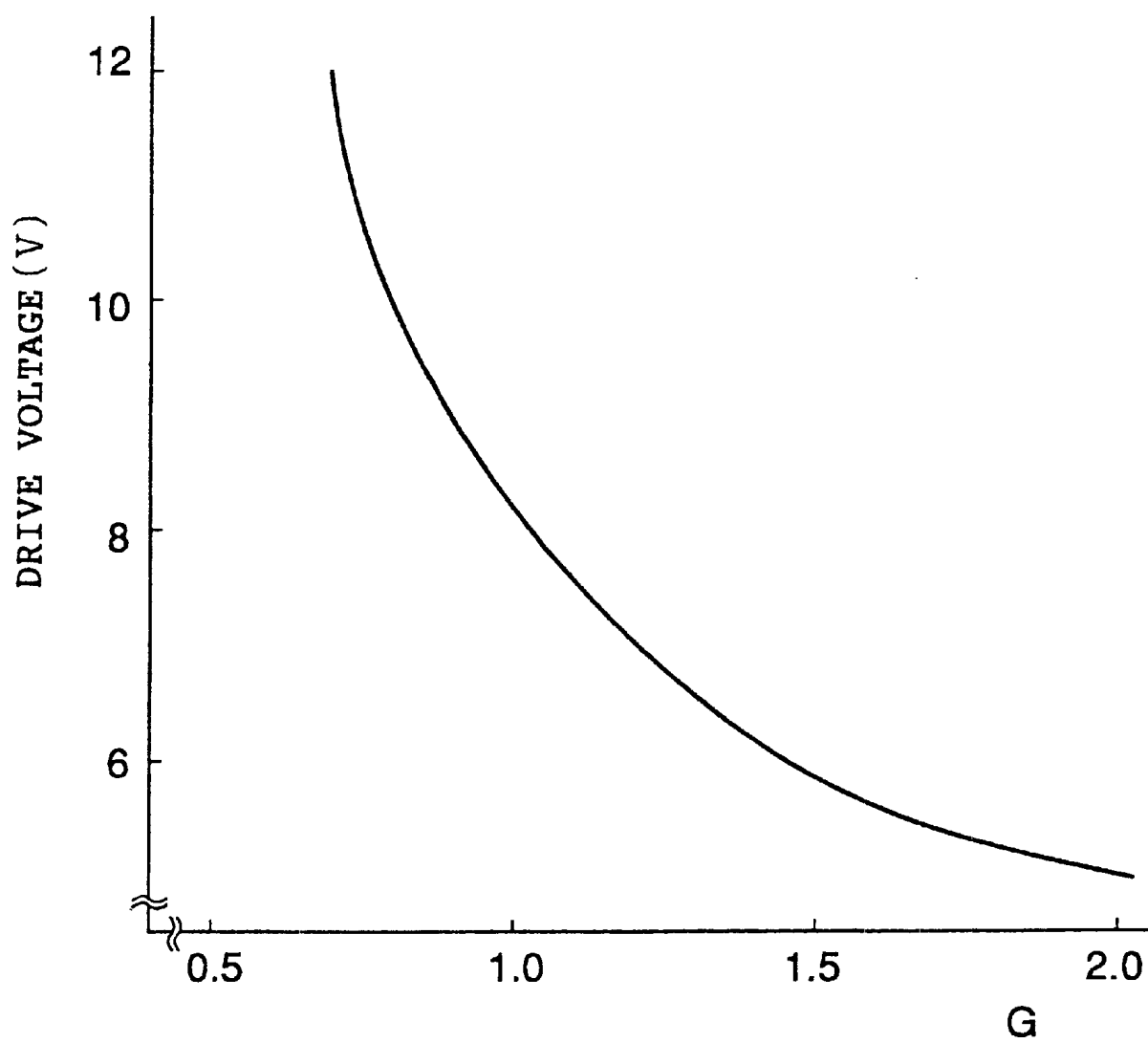
Fig. 196

Fig. 197

Fig. 198

Fig. 199

Fig. 200

Fig. 201

2011 : PRISM
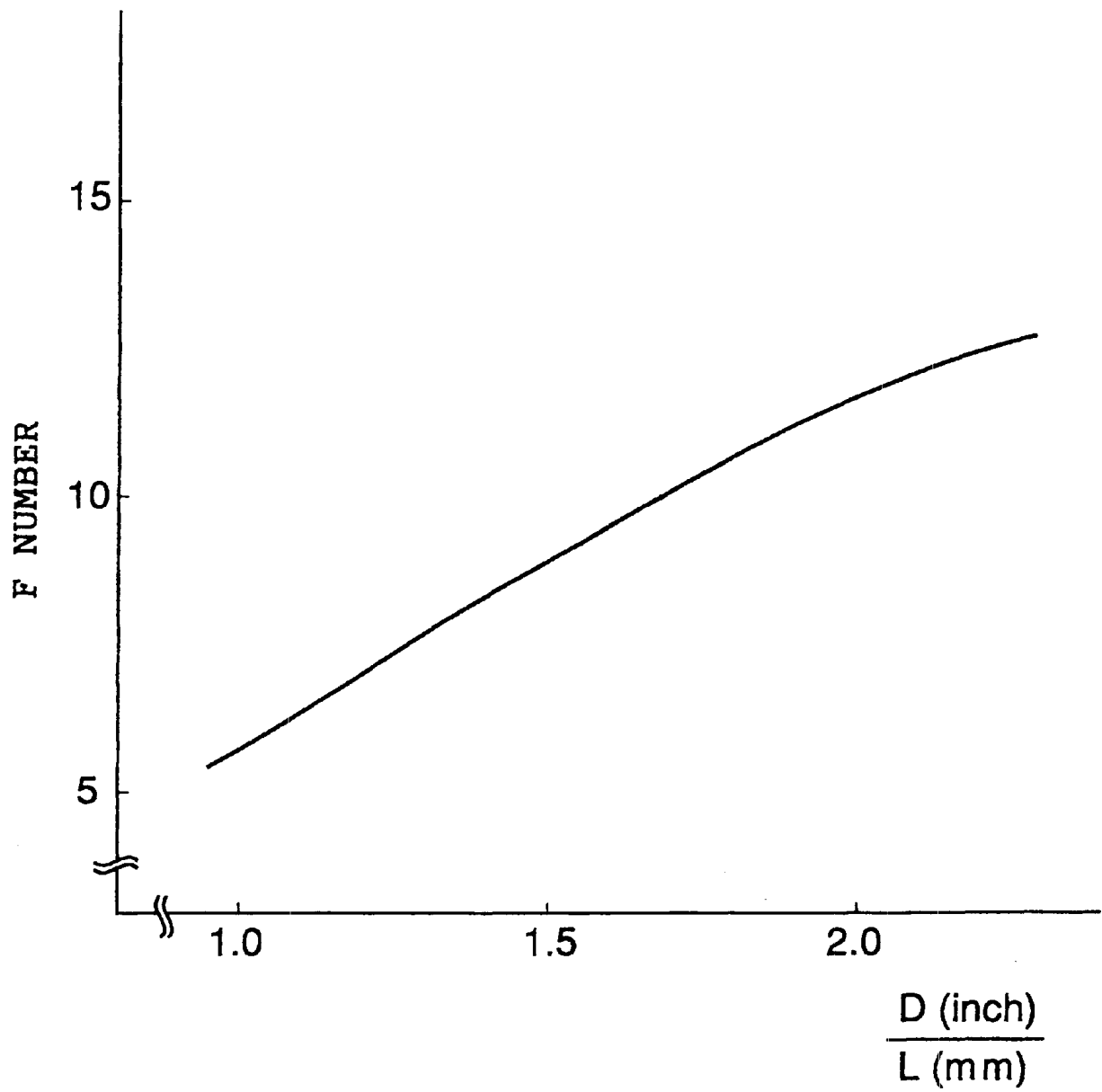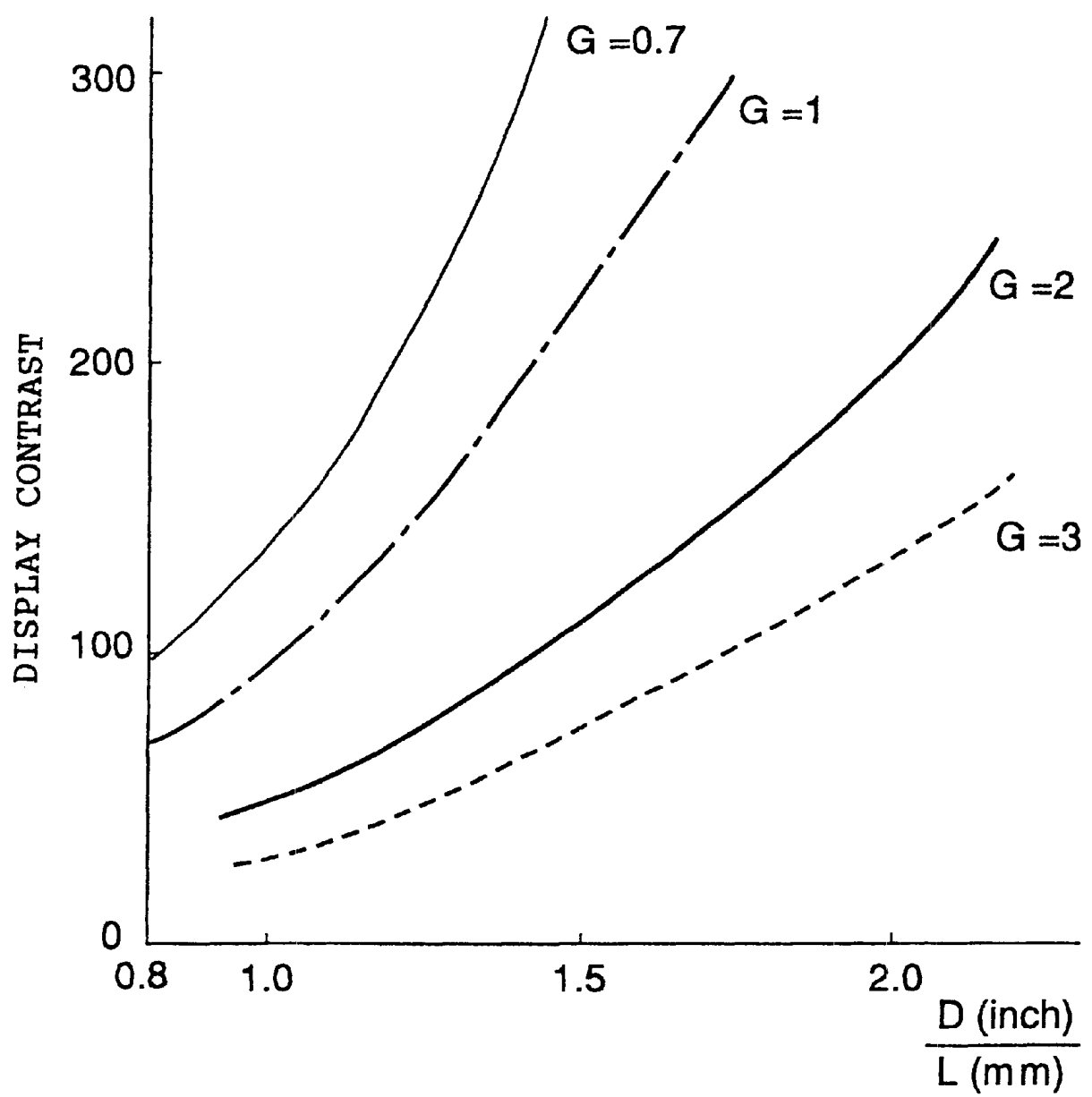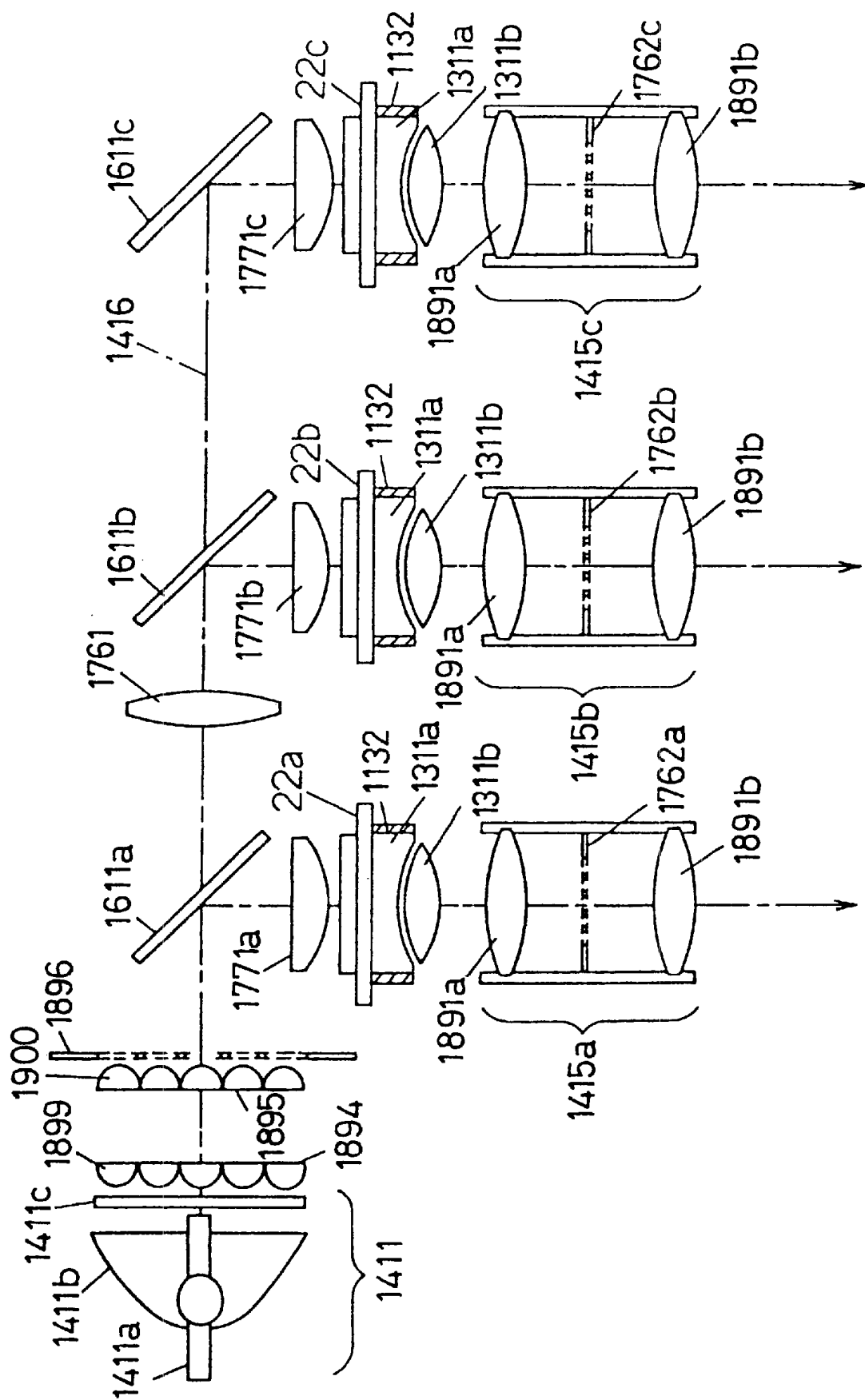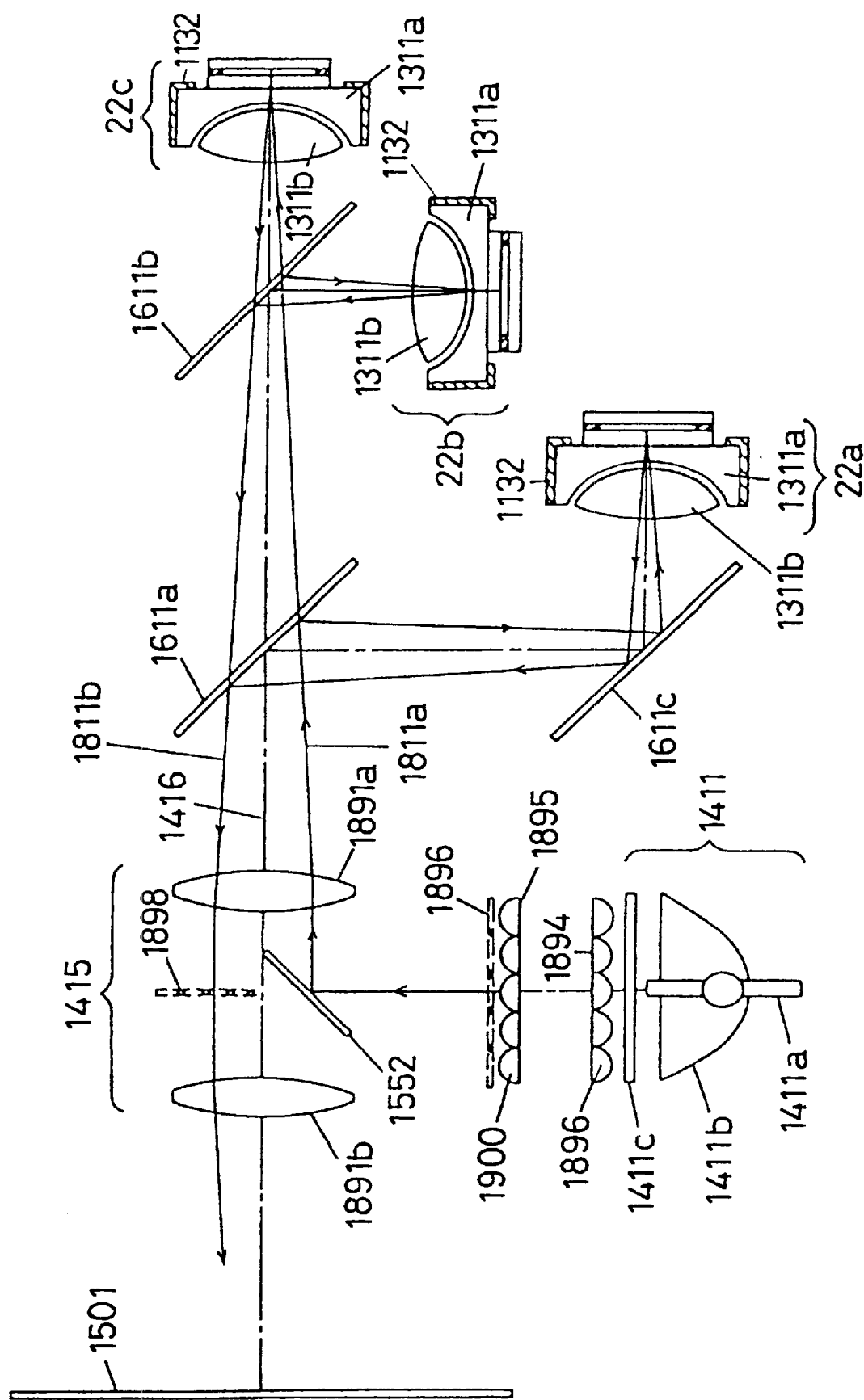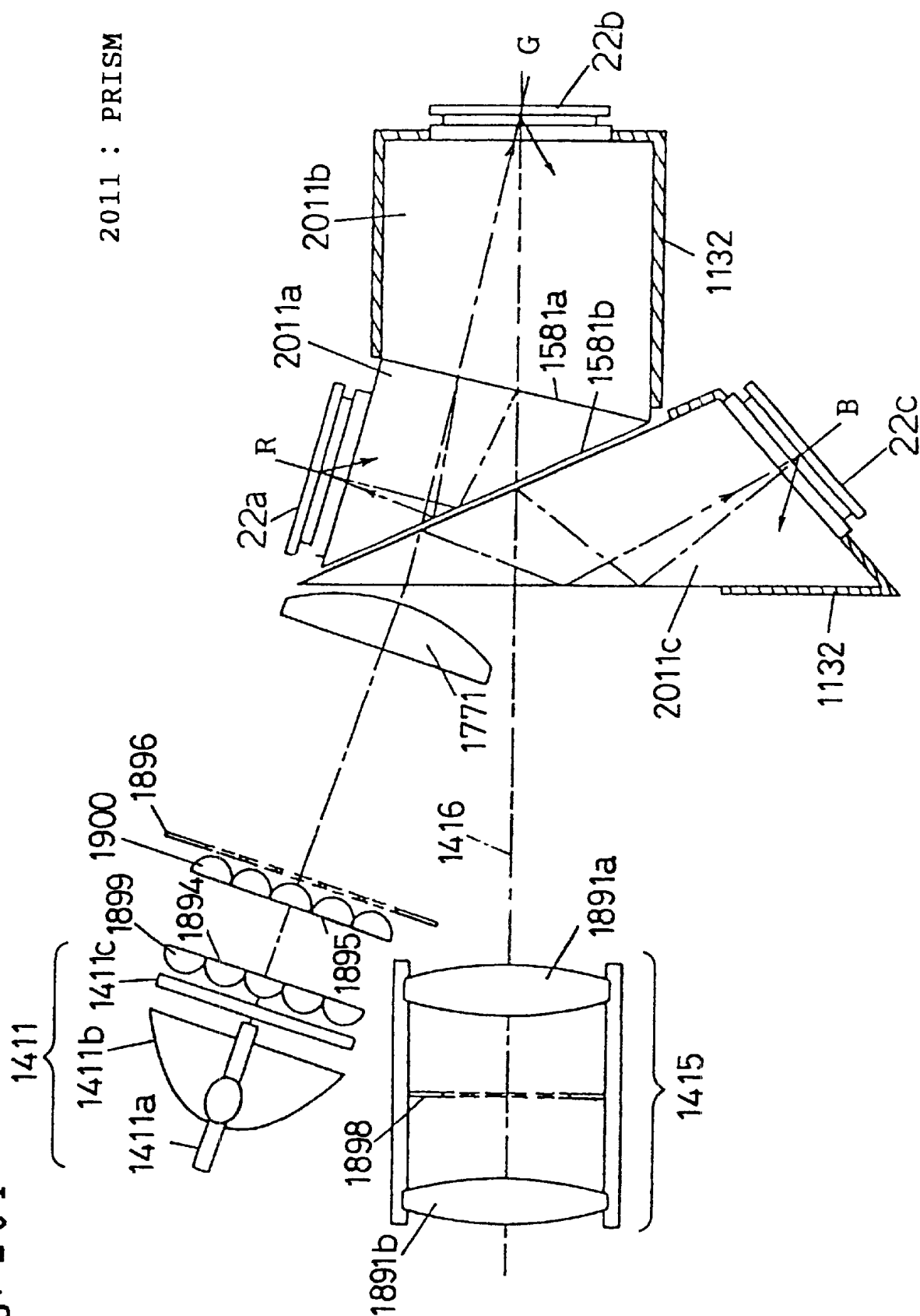
Fig. 202

2022 : TRANSMISSION RANGE OF PROJECTED LIGHT

2023 : ROTATIONAL CENTER
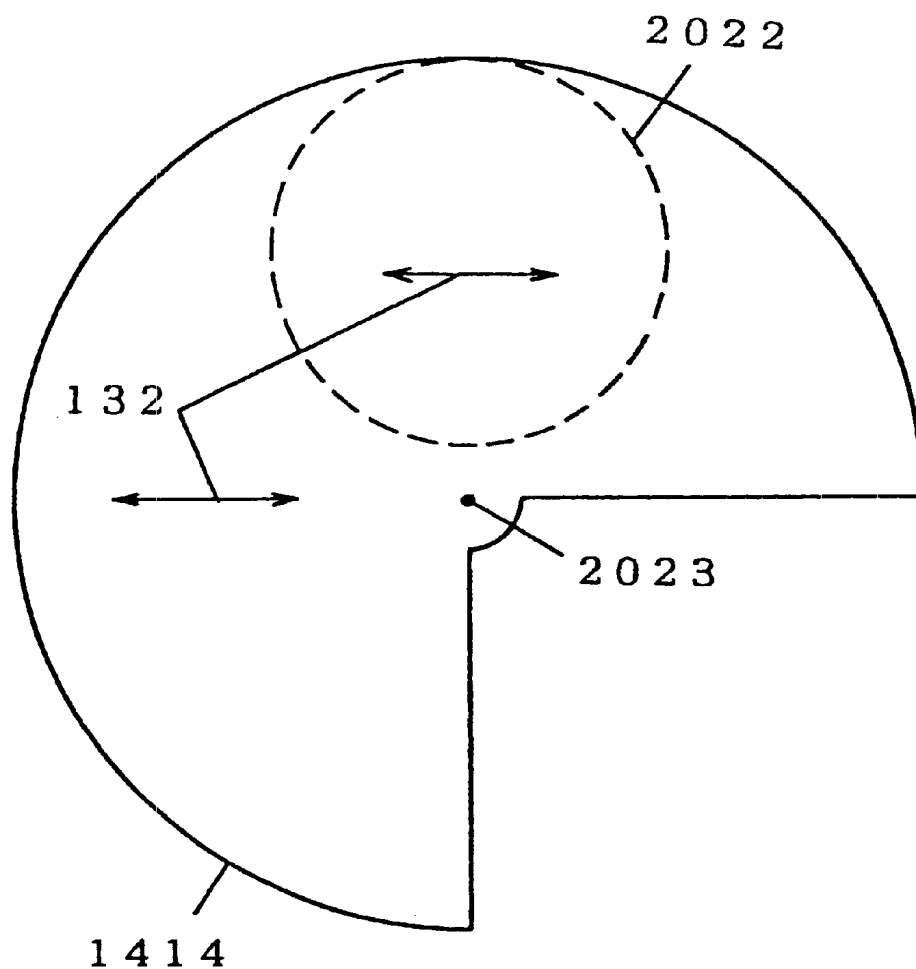
Fig. 203

2031 : POLARIZATION SCREEN
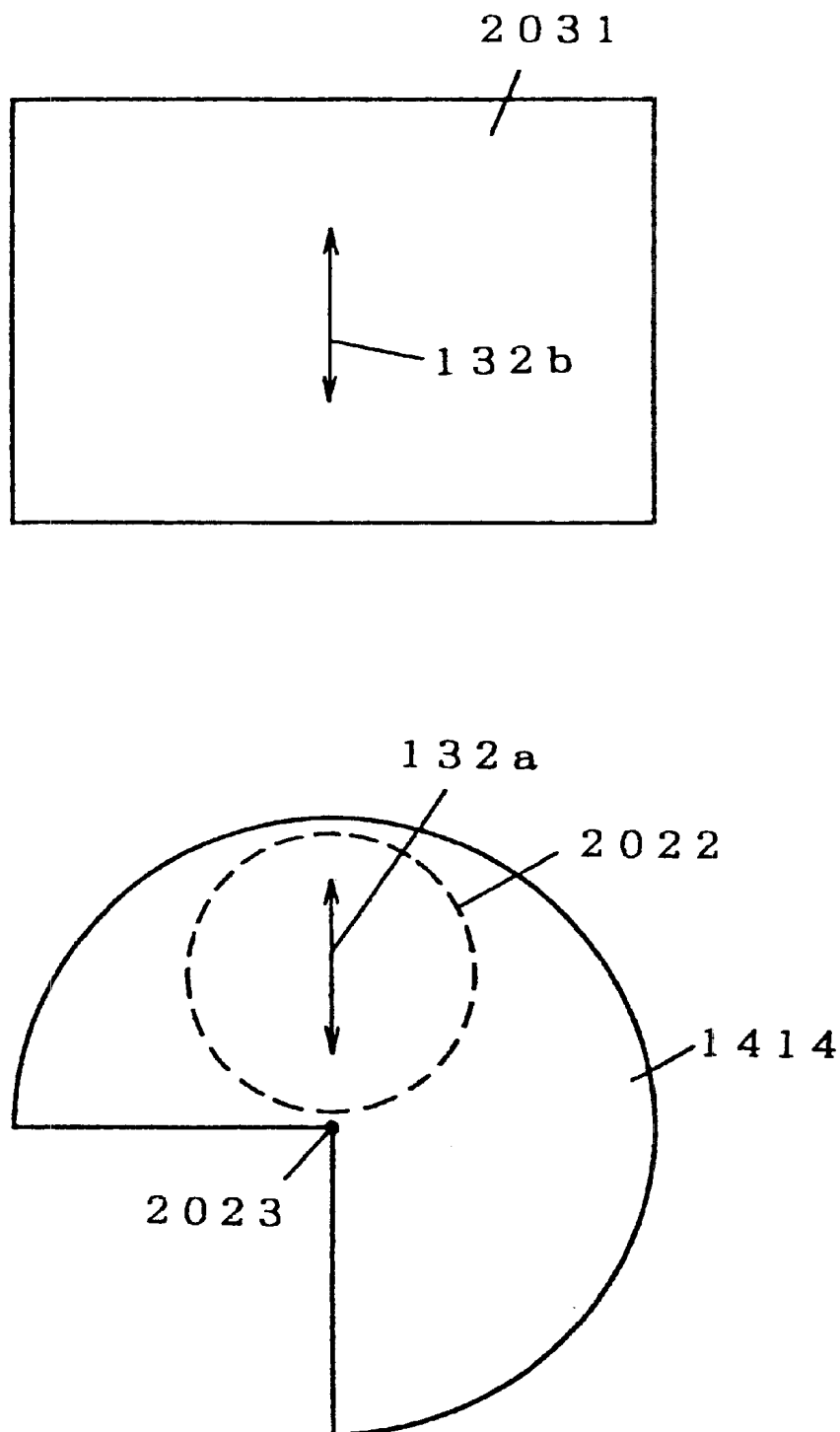
Fig. 204

2031 : POLARIZATION SCREEN

Fig. 205

2031

132b

2022

132a

1414

2023
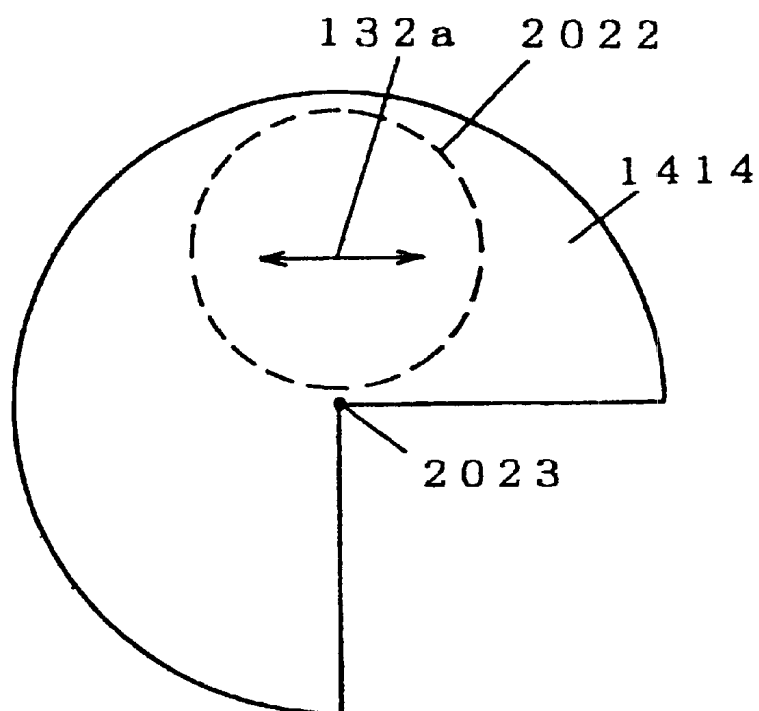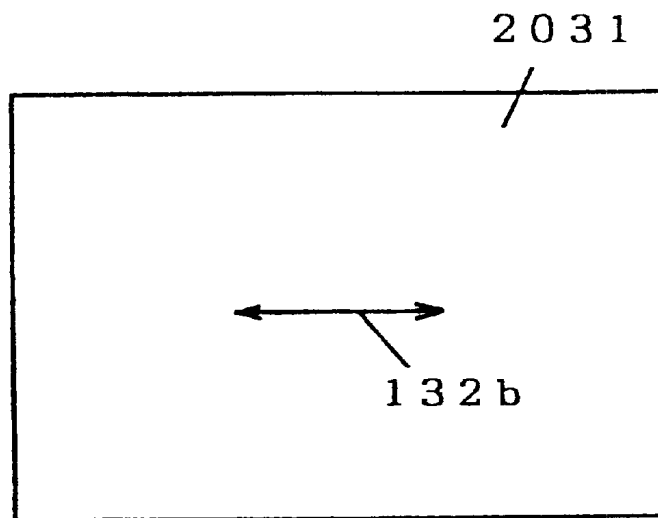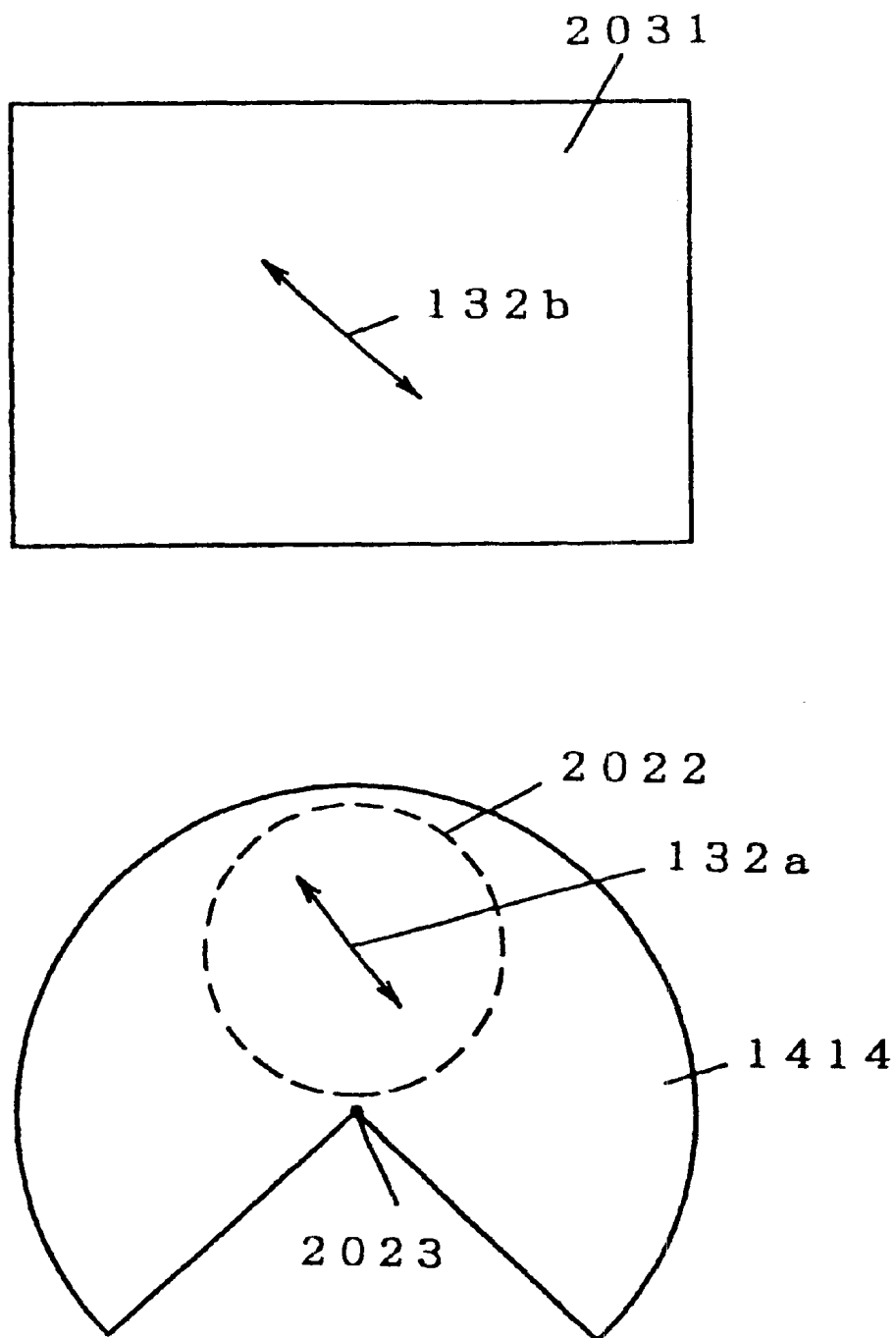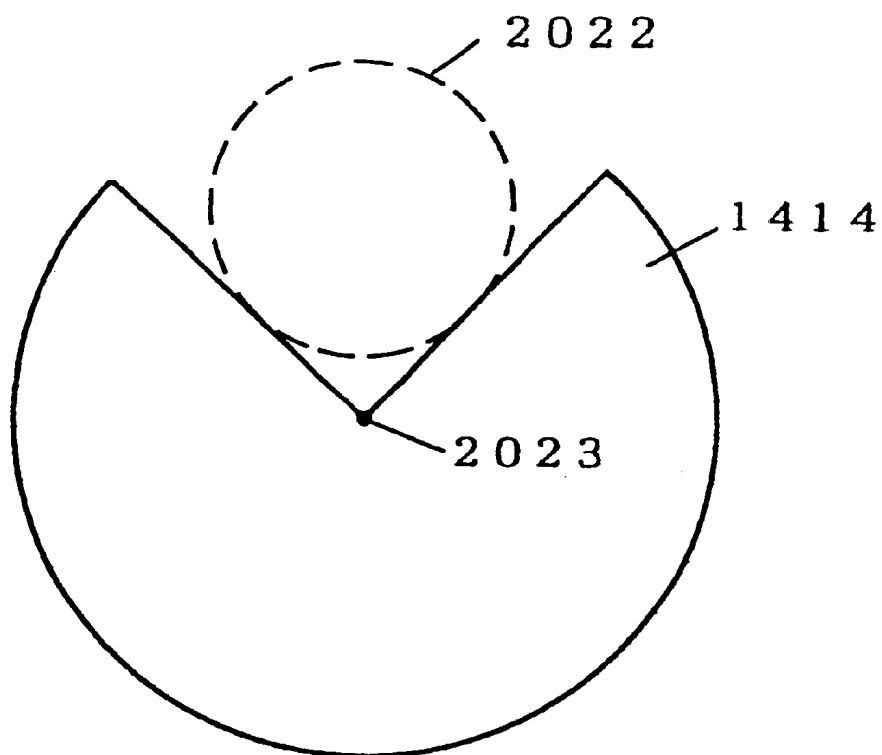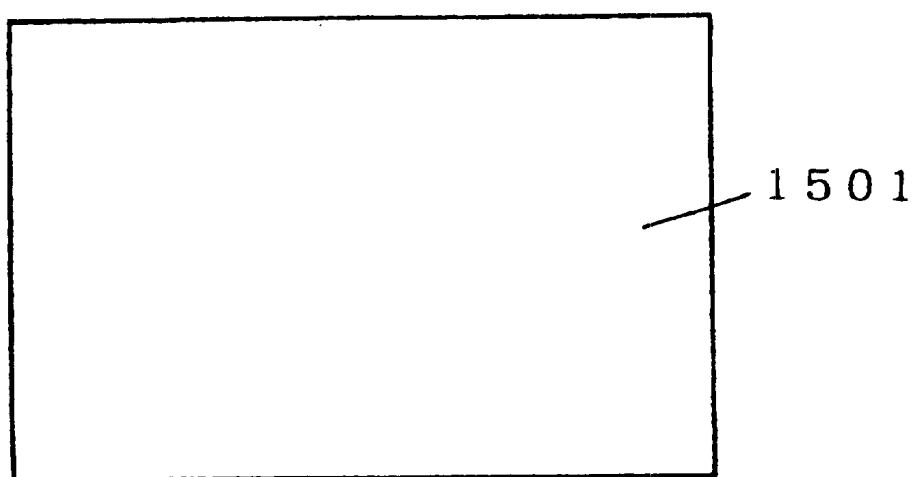
Fig. 206

Fig. 207

2072 : CORRECTION FILTER
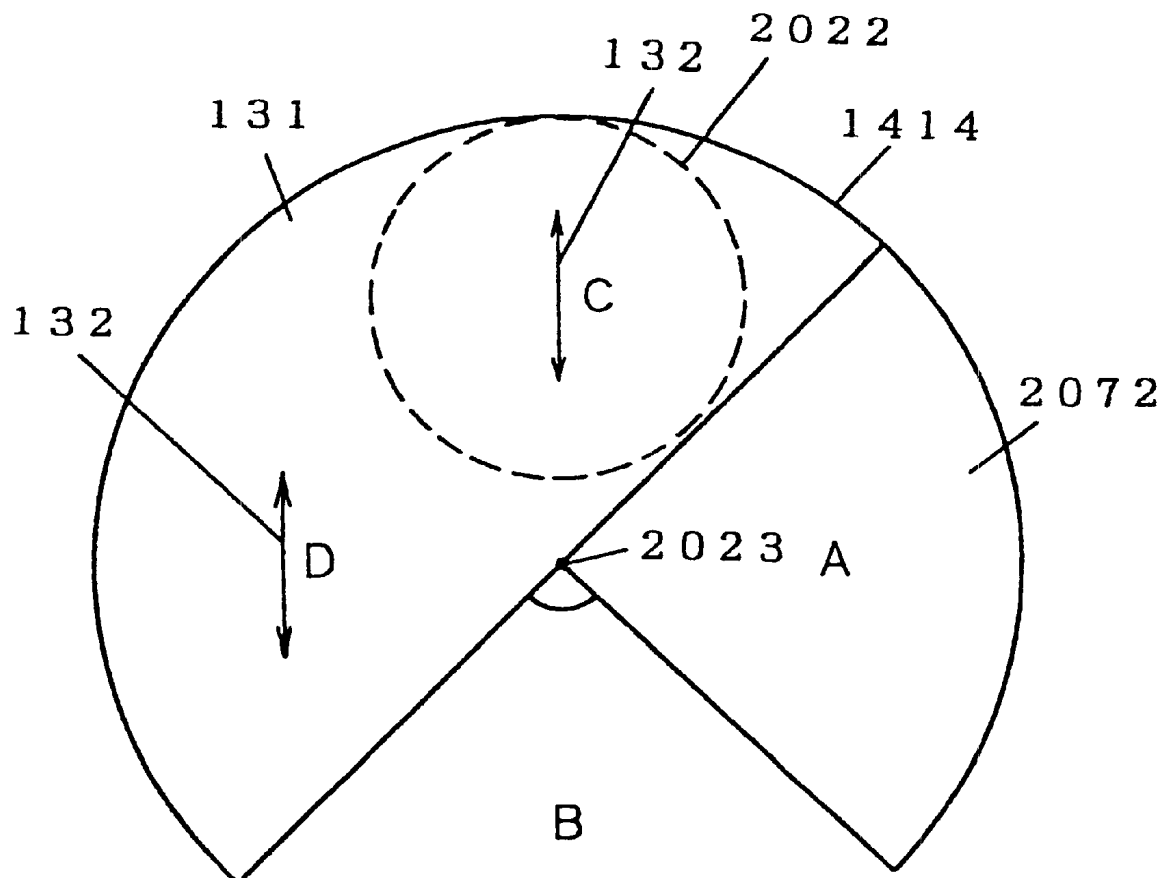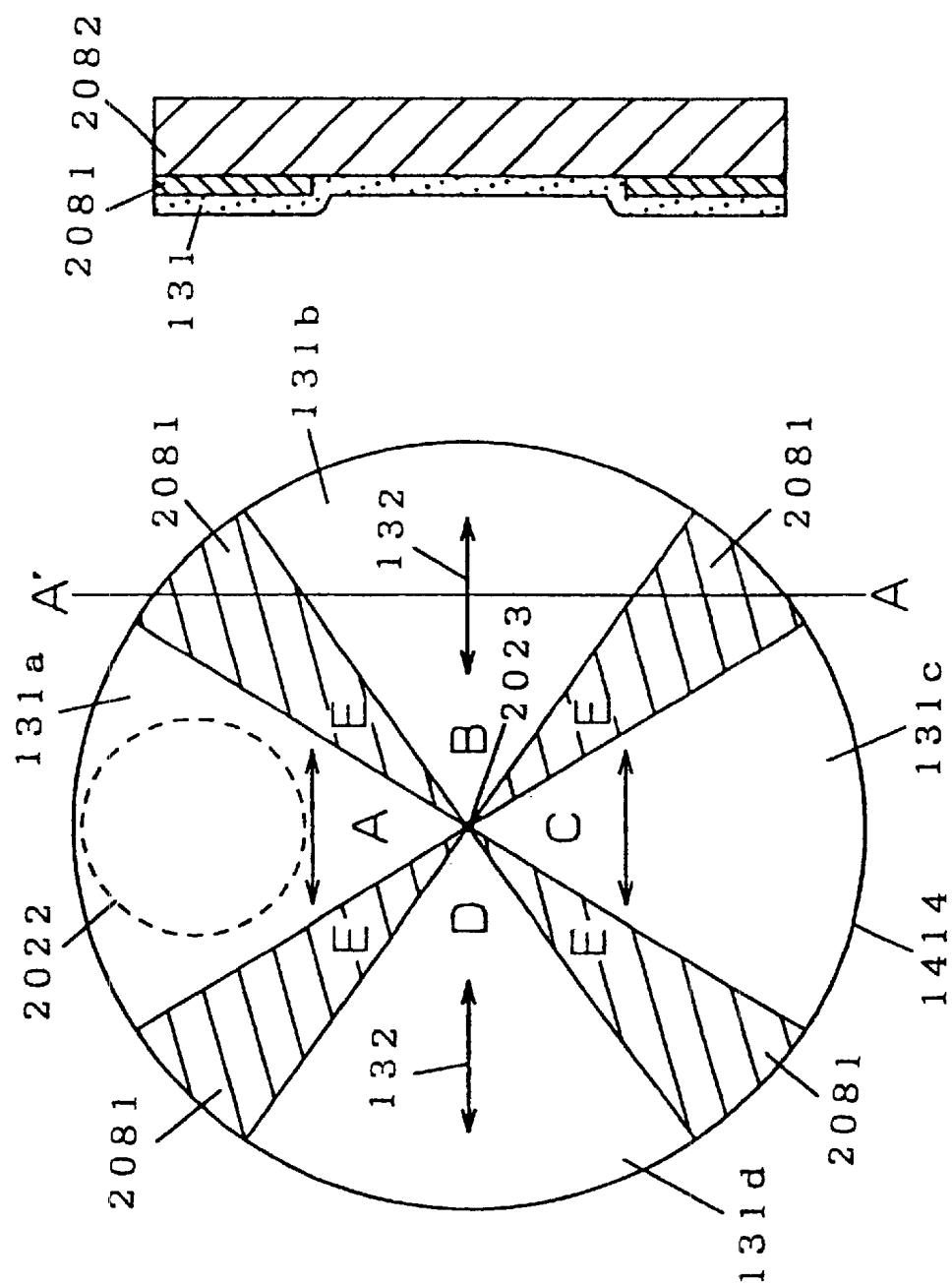
Fig. 208 (b)

2081 : LIGHT SHIELDING FILM

2082 : TRANSPARENT SUBSTRATE

Fig. 208 (a)
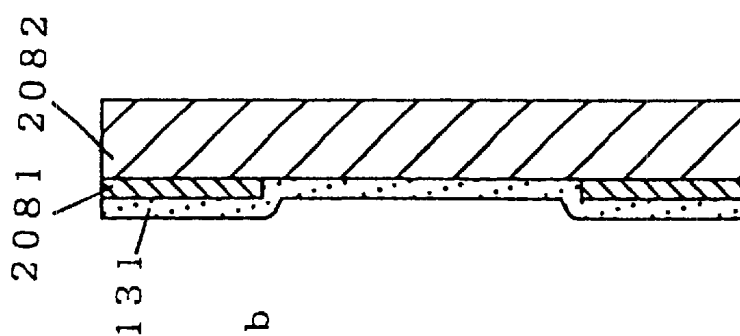
F i g. 209 (a)

2091 : POLARIZING EYEGLASSES

1 5 0 1

1 3 2

2 0 2 2

1 4 1 4

1 3 1 a   1 3 1 b   2 0 9 1

F i g. 209 (b)

1 5 0 1

1 3 2

2 0 2 2

1 4 1 4

1 3 1 a   1 3 1 b   2 0 9 1

Fig. 210

2101 : DRUM

2102 : LIGHT SHIELDING PORTION

2103 : LIGHT TRANSMITTING PORTION

2102a

2101

2103a

2102b

2103d

1413a

2103b

1413b 22

2023

2102d

1416

2102c

1415

2103c

Fig. 211 (a)

2102d

2103c

22

1631

Fig. 211 (b)

2103d

2102d

2103c

22

1631
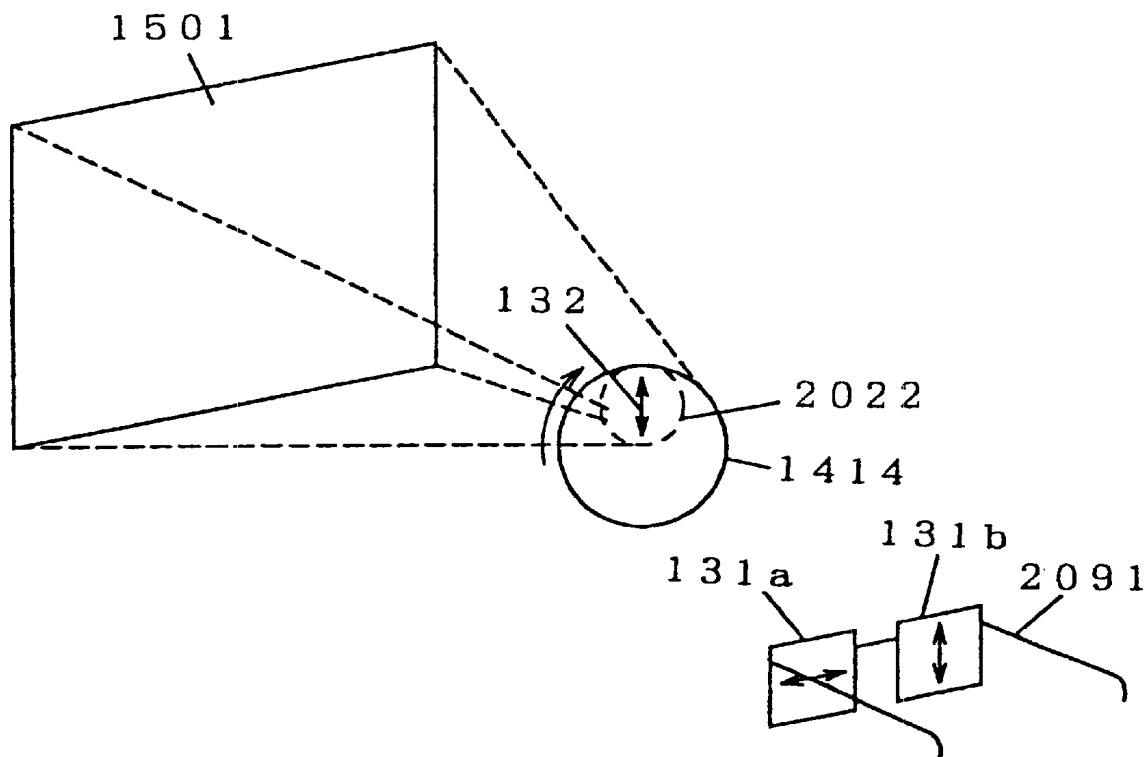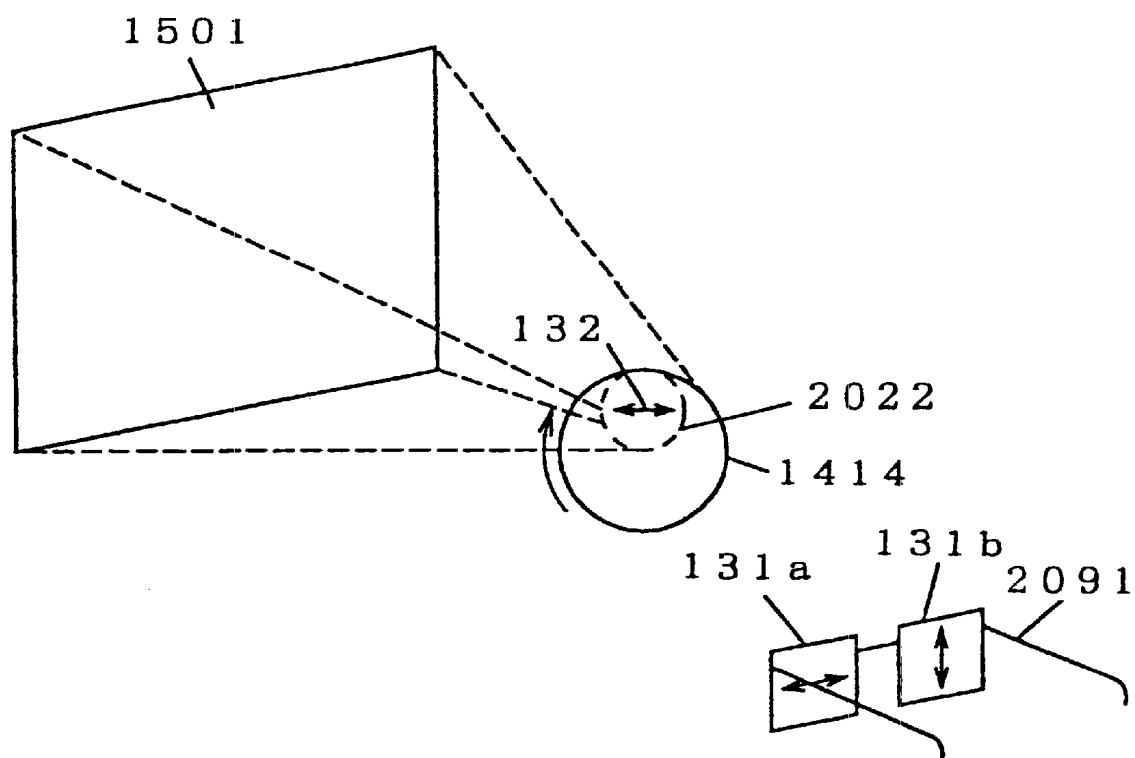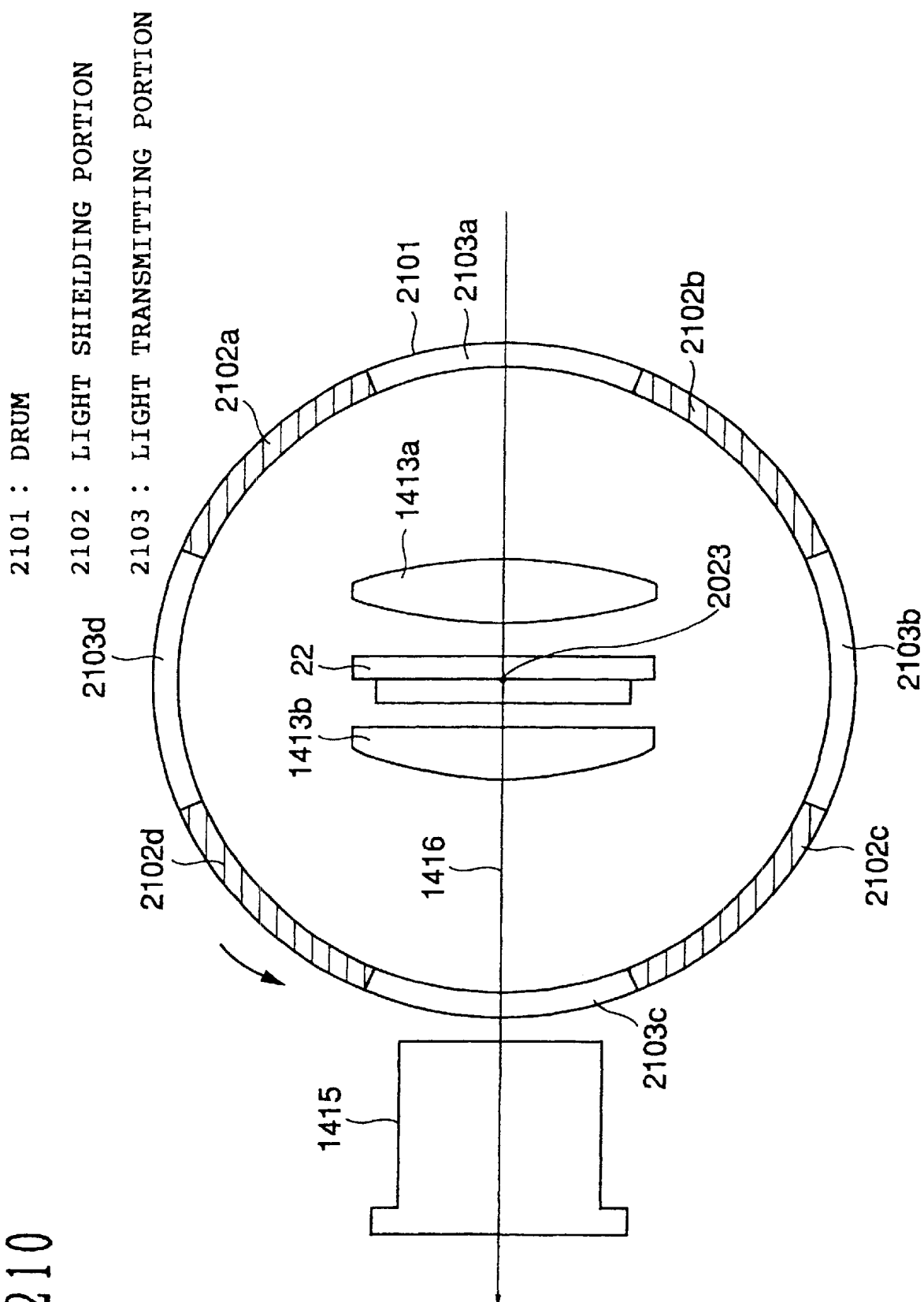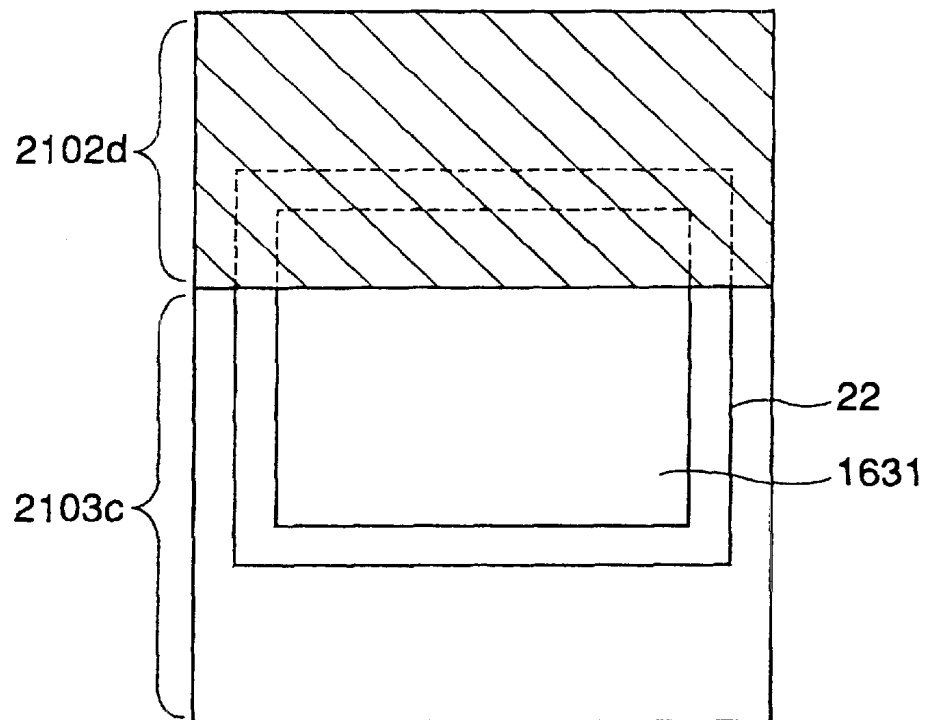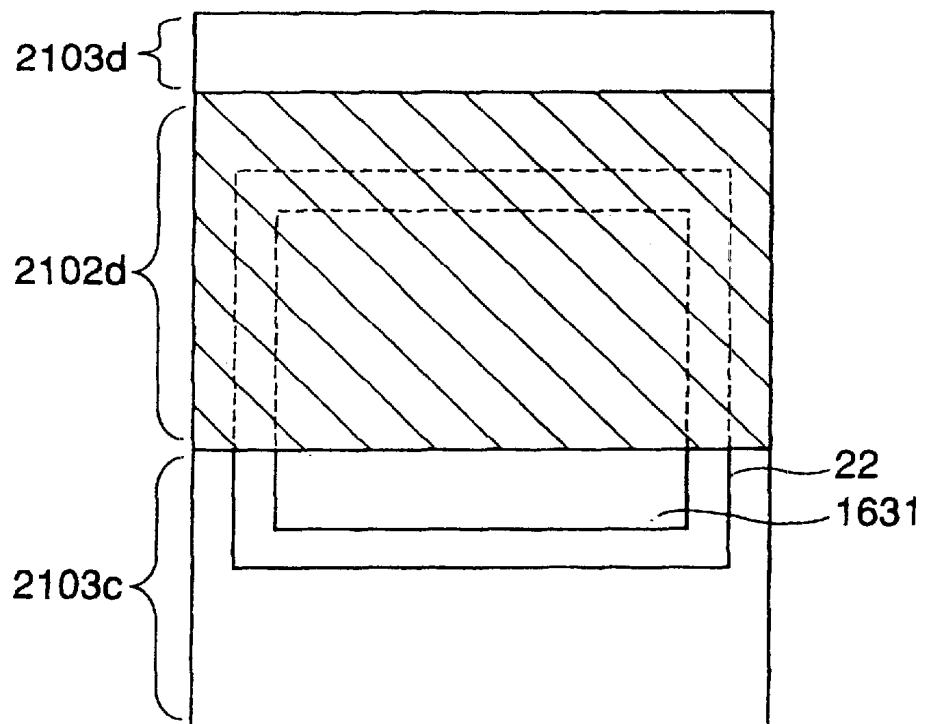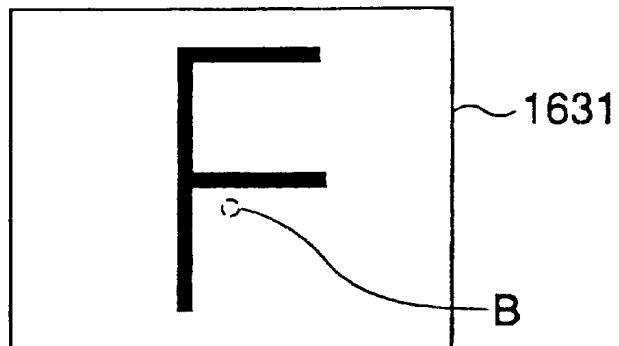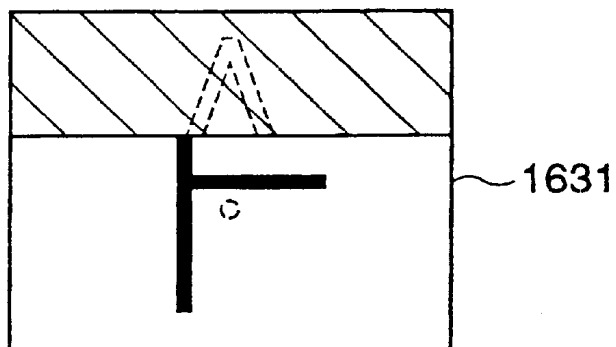
Fig. 212 (a)

Fig. 212 (b)

Fig. 212 (c)
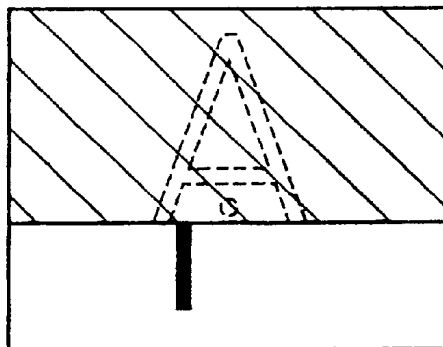
Fig. 212 (d)

Fig. 213

Fig. 214

Fig. 215 (a)

~1631

Fig. 215 (b)

~1631

A

Fig. 215 (c)

~1631

Fig. 215 (d)

~1631

B

Fig. 216

2161 : A/D CONVERSION CIRCUIT

2162 : F MEMORY

2163 : RASTER SETTING CIRCUIT

2164 : DOUBLE SPEED READ CIRCUIT

2165 : SIGNAL DIVIDING CIRCUIT

2161
A/D
CONVERSION
CIRCUIT

2162
F
MEMORY

2163
RASTER
SETTING
CIRCUIT

2164
DOUBLE SPEED
READ CIRCUIT

2165
SIGNAL
DIVIDING
CIRCUIT

SIG
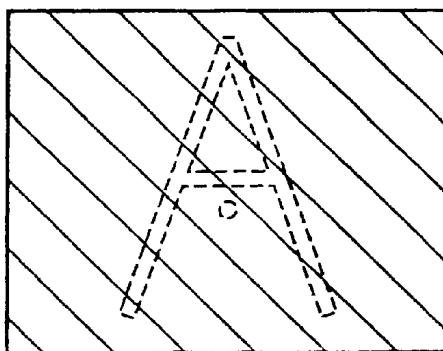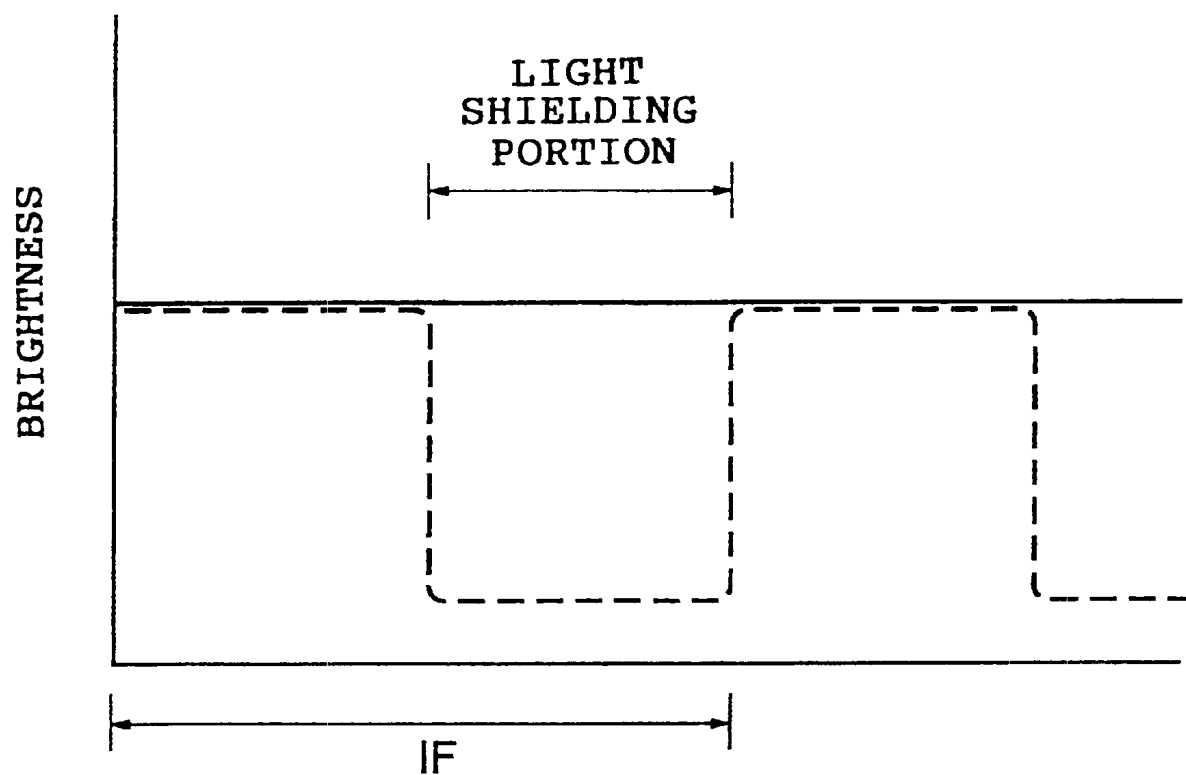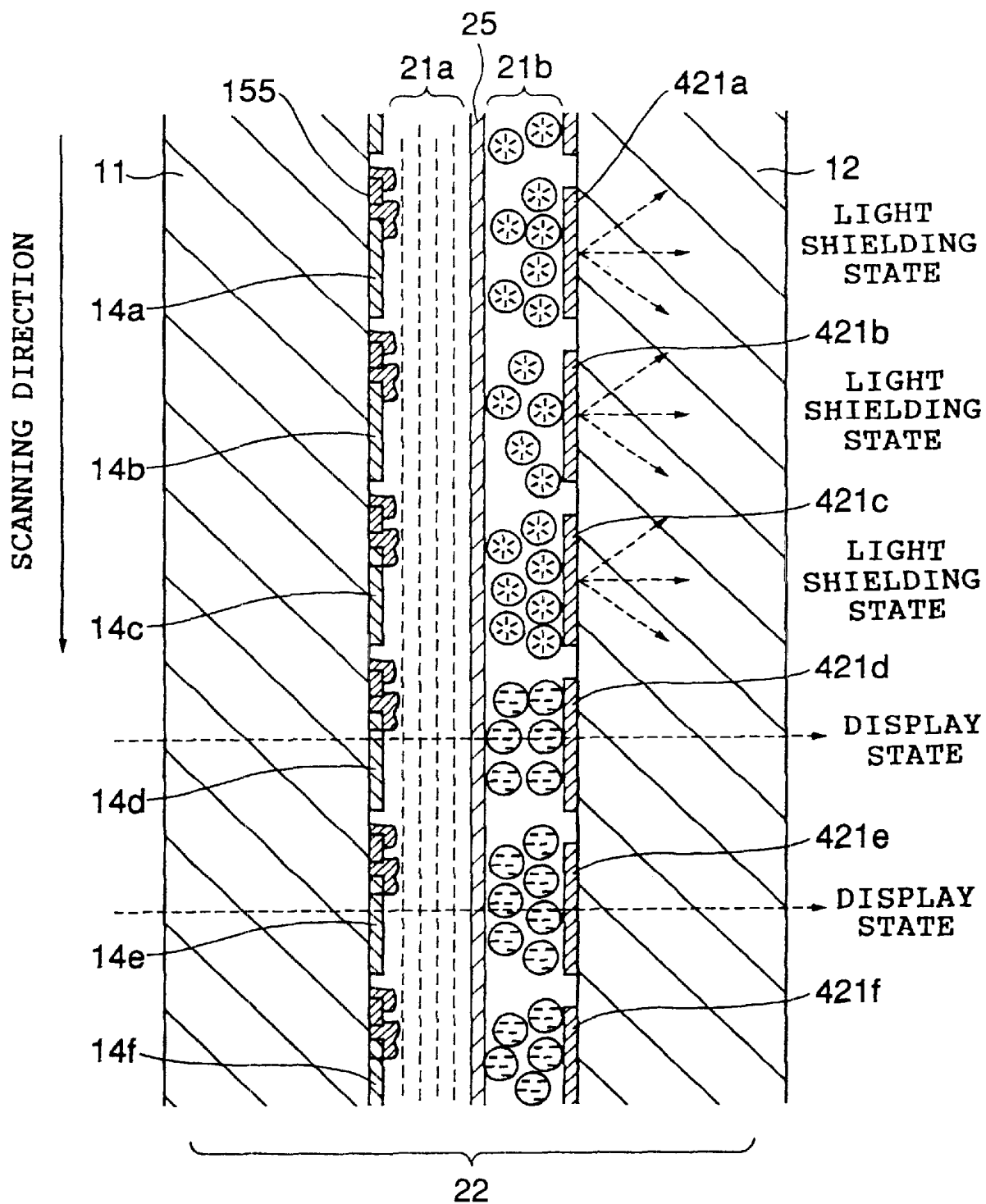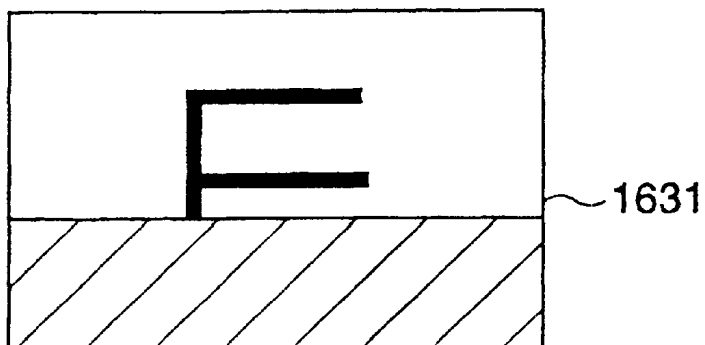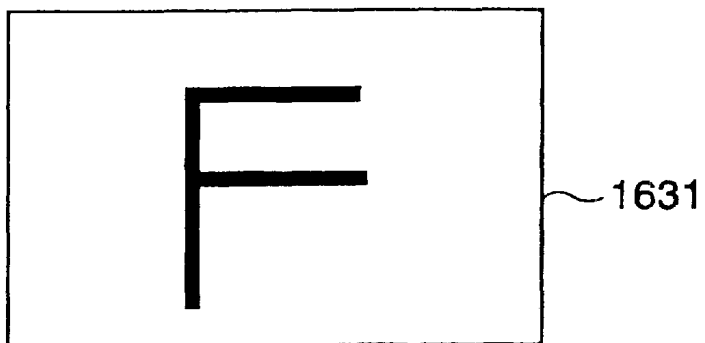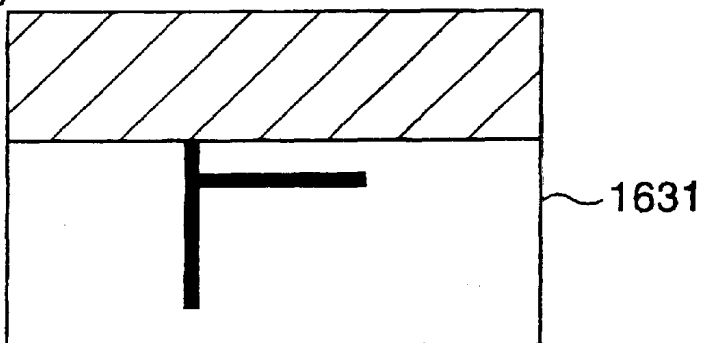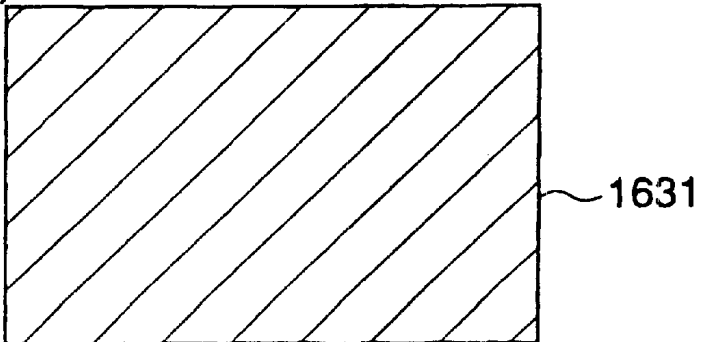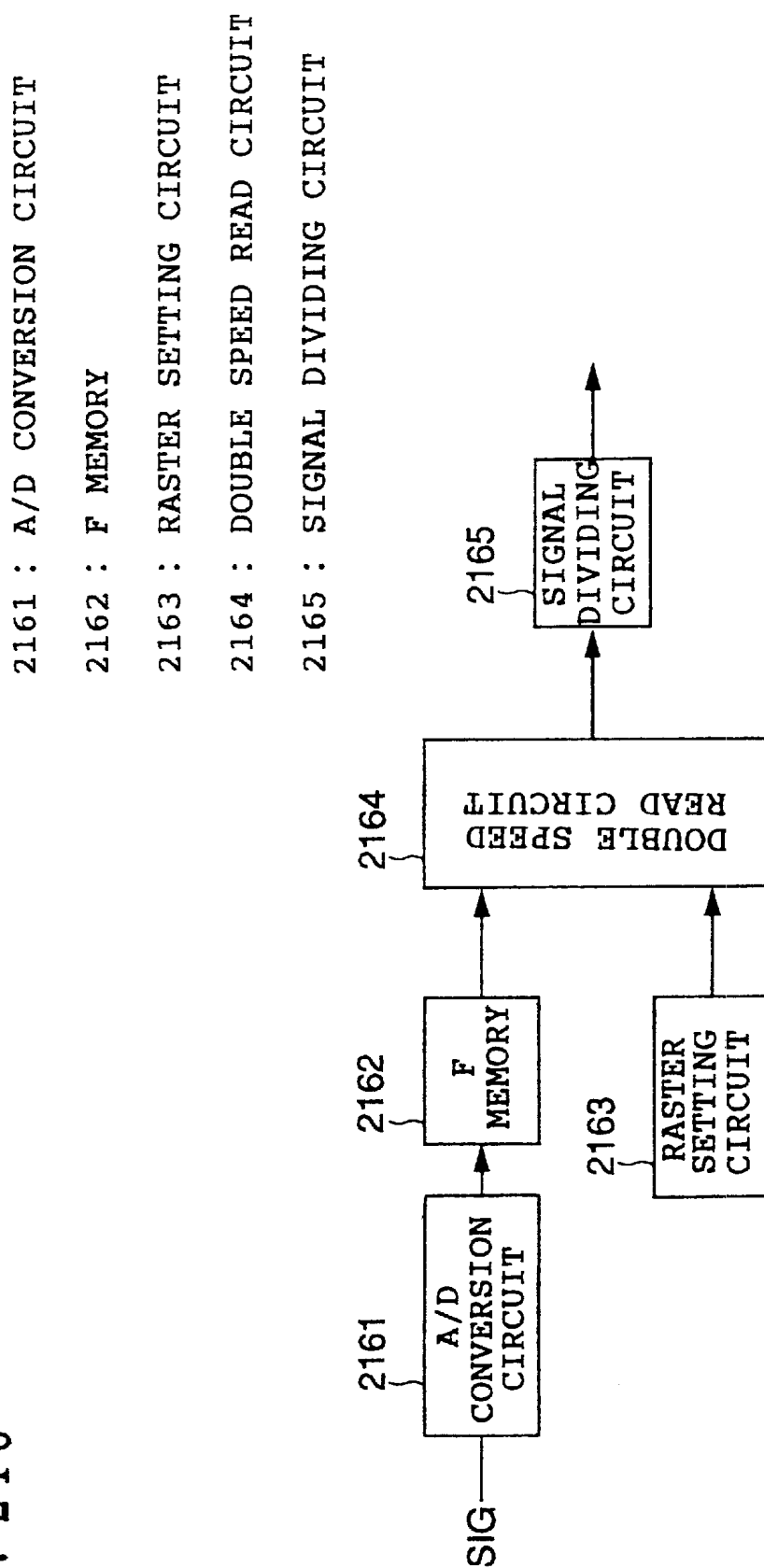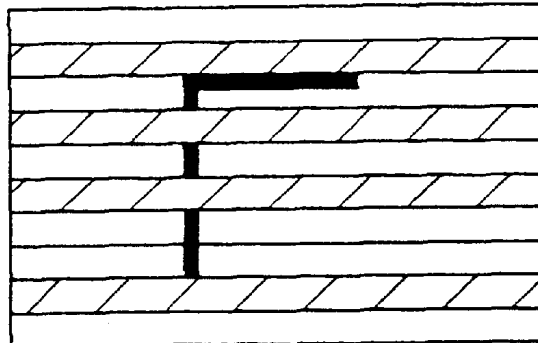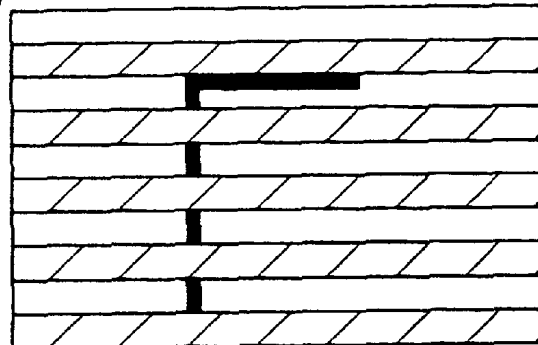
Fig. 217 (a)

Fig. 217 (b)

Fig. 217 (c)
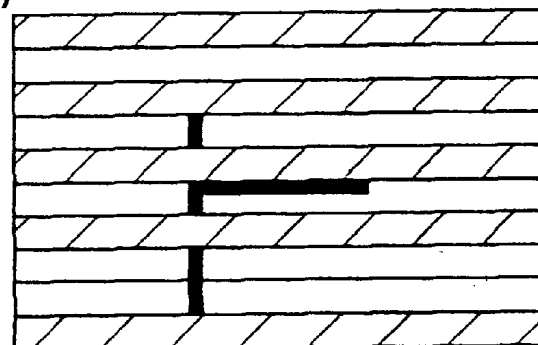
Fig. 217 (d)
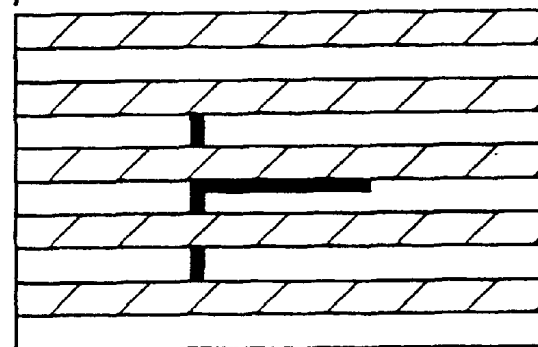
A

B

Fig. 218

2186 : BODY

2187 : EYEPIECE RUBBER

2188 : MOUNTING BRACKET
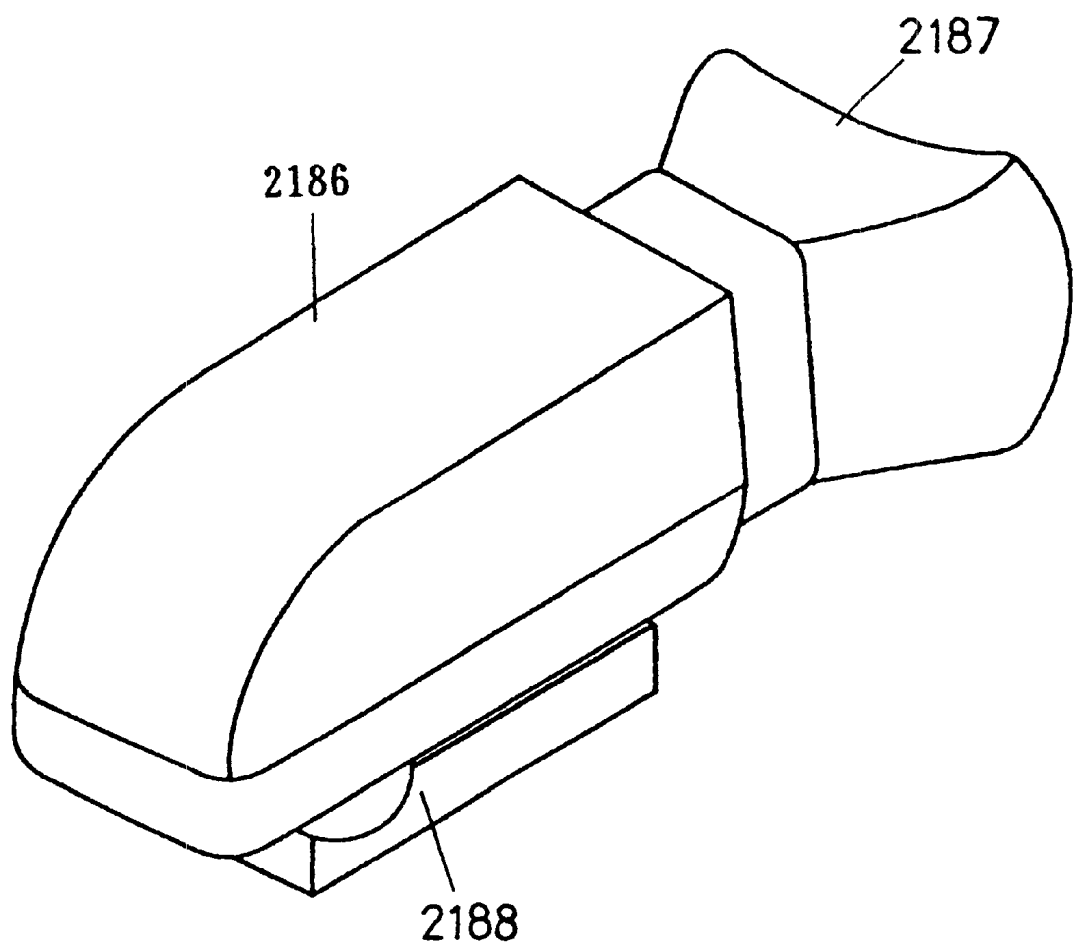
Fig. 219

2181 : LIGHT SOURCE (LIGHT EMITTING LAMP)

2182 : APERTURE

2183 : CONDENSER LENS

2184 : EYEPIECE RING

2185 : EYEPIECE

2189 : HOLE
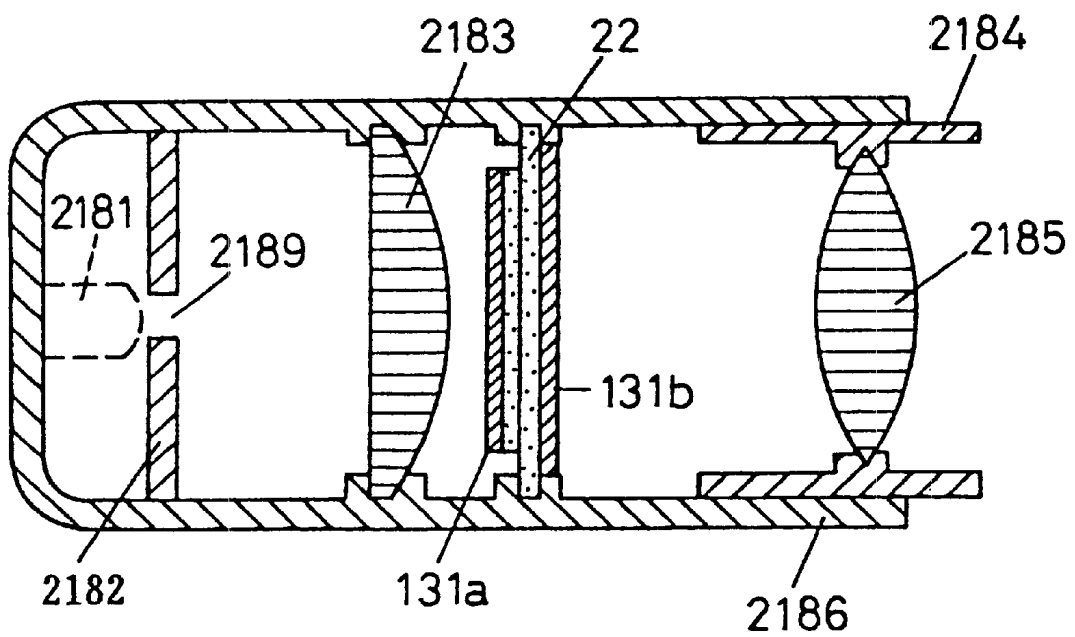
Fig. 220 (a)

2201 : CASING

2202 : ILLUMINANT

2203 : FILAMENT

2204 : ANODE

2205 : LIGHT SHIELDING FILM
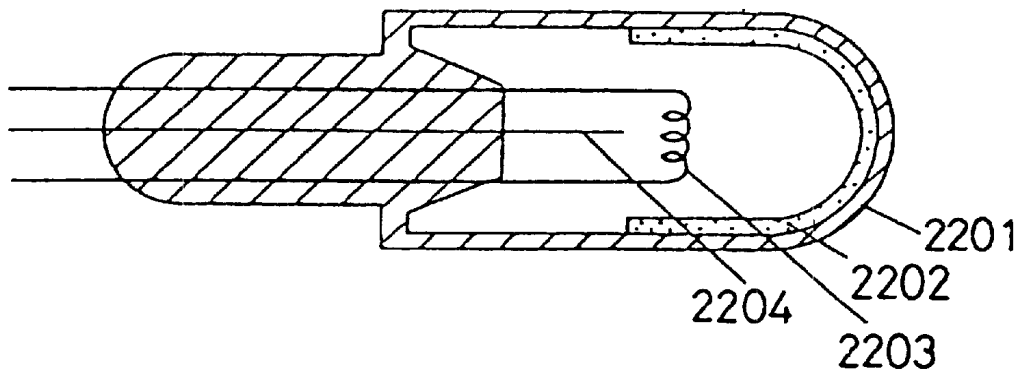
Fig. 220 (b)
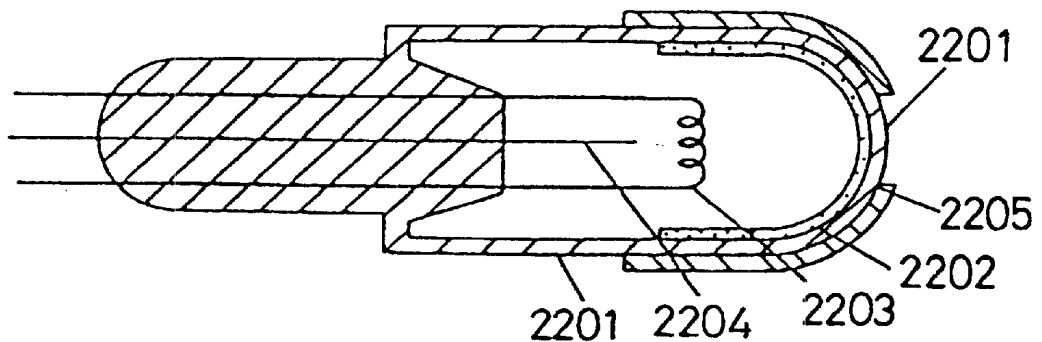
Fig. 221

2201a : INNER CASING

2201b : OUTER CASING

2211 : CIRCUIT SUBSTRATE

2212 : CONNECTOR

2213 : SOLDER
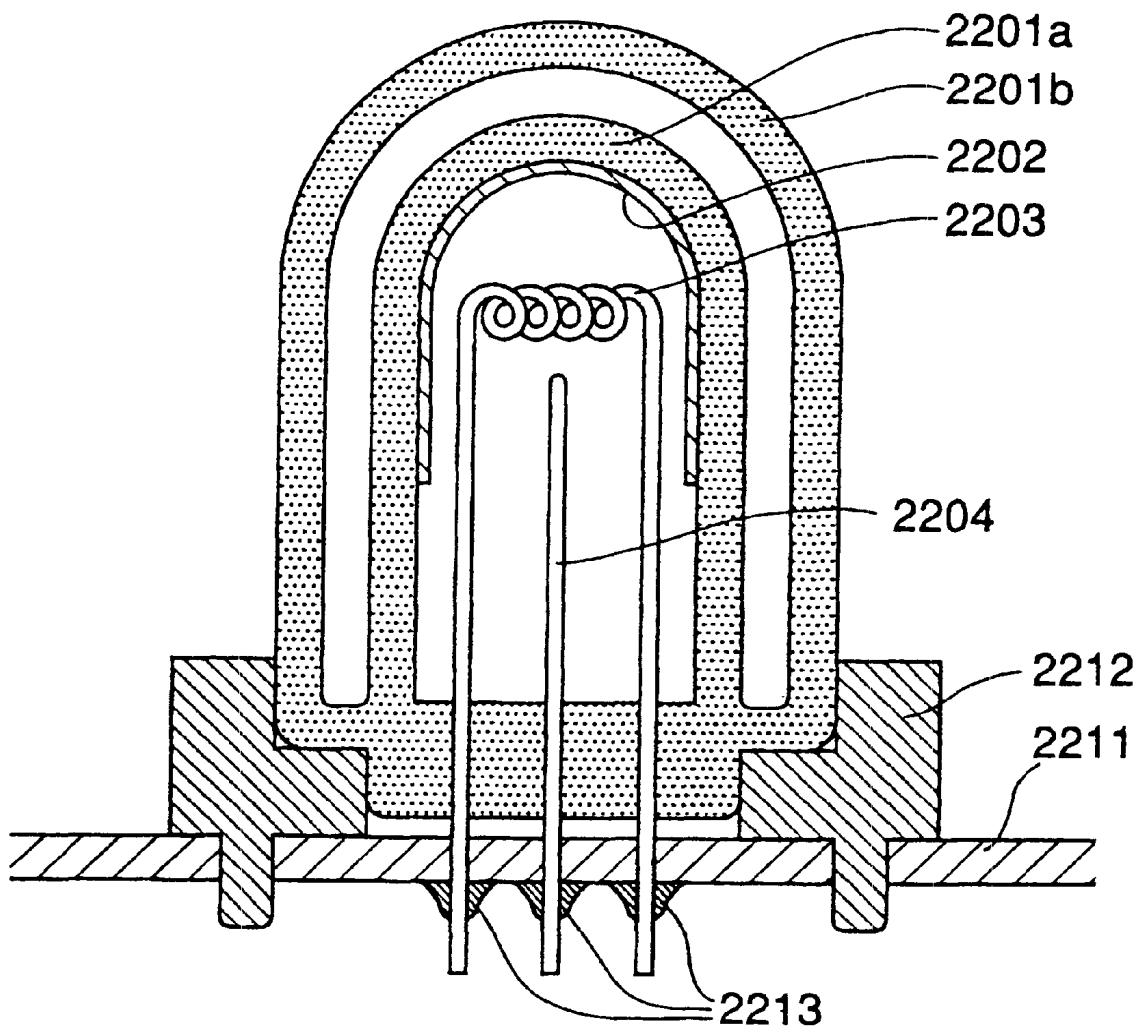
Fig. 222
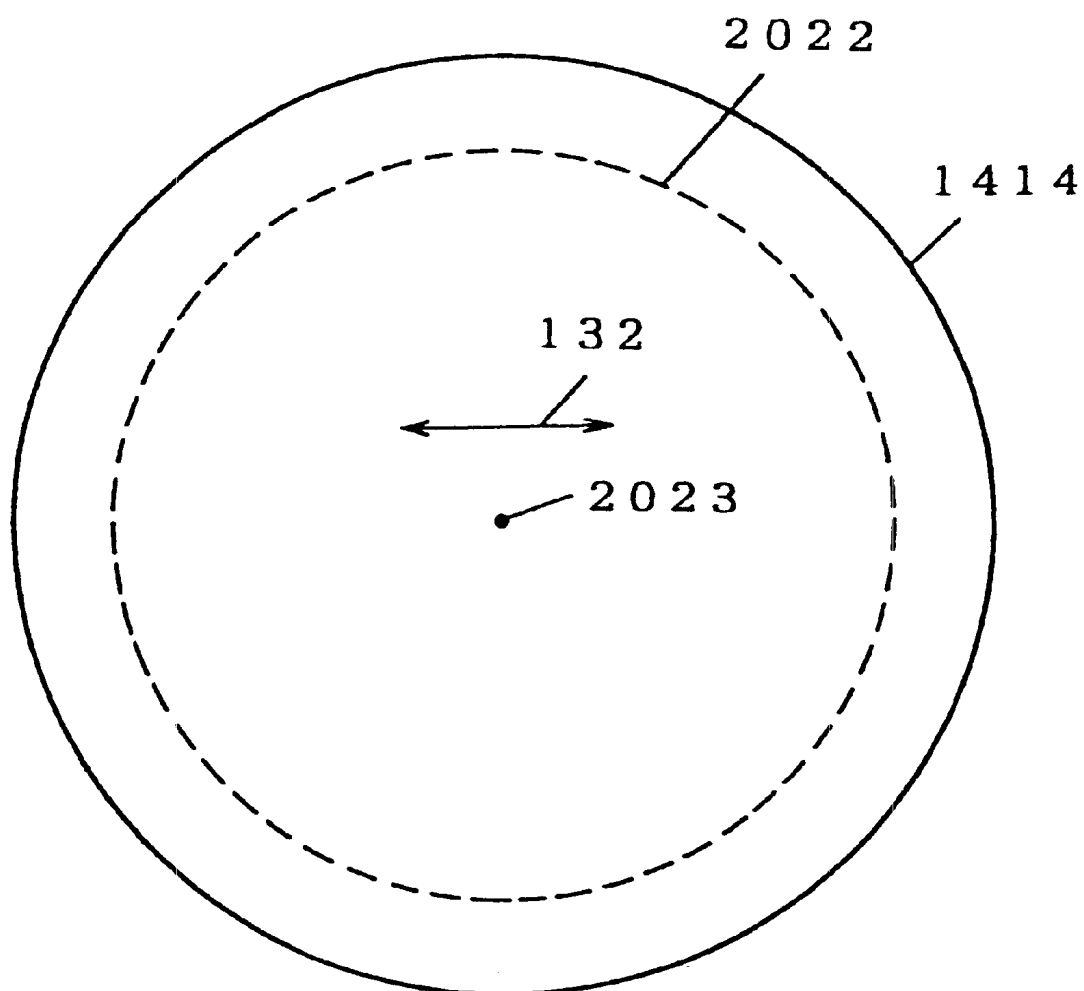
Fig. 223

2231 : OBSERVER'S EYE
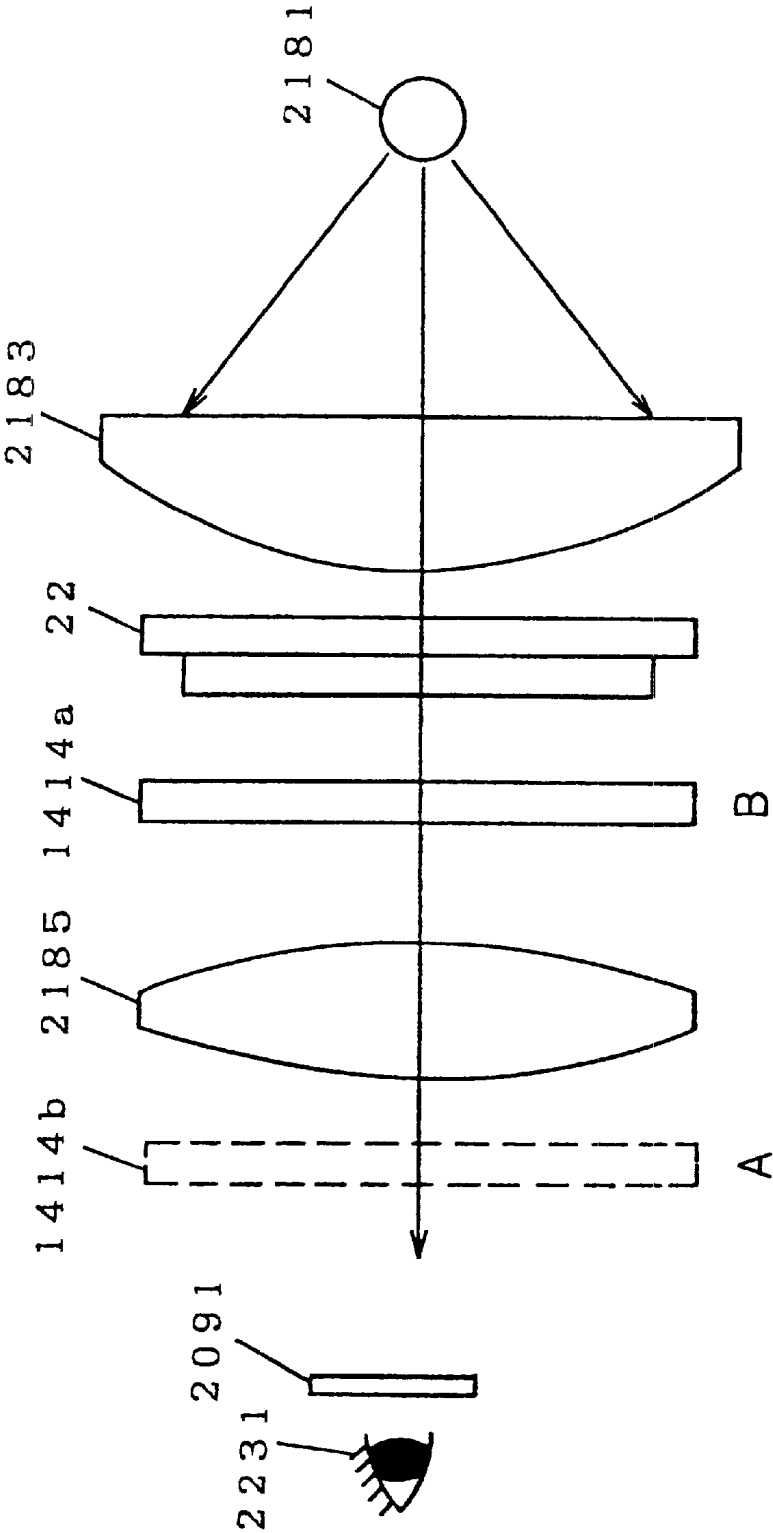
Fig. 224

2241 : SURFACE LIGHT SOURCE

1414   2 2   2 2 4 1

2 1 8 5

2 0 9 1
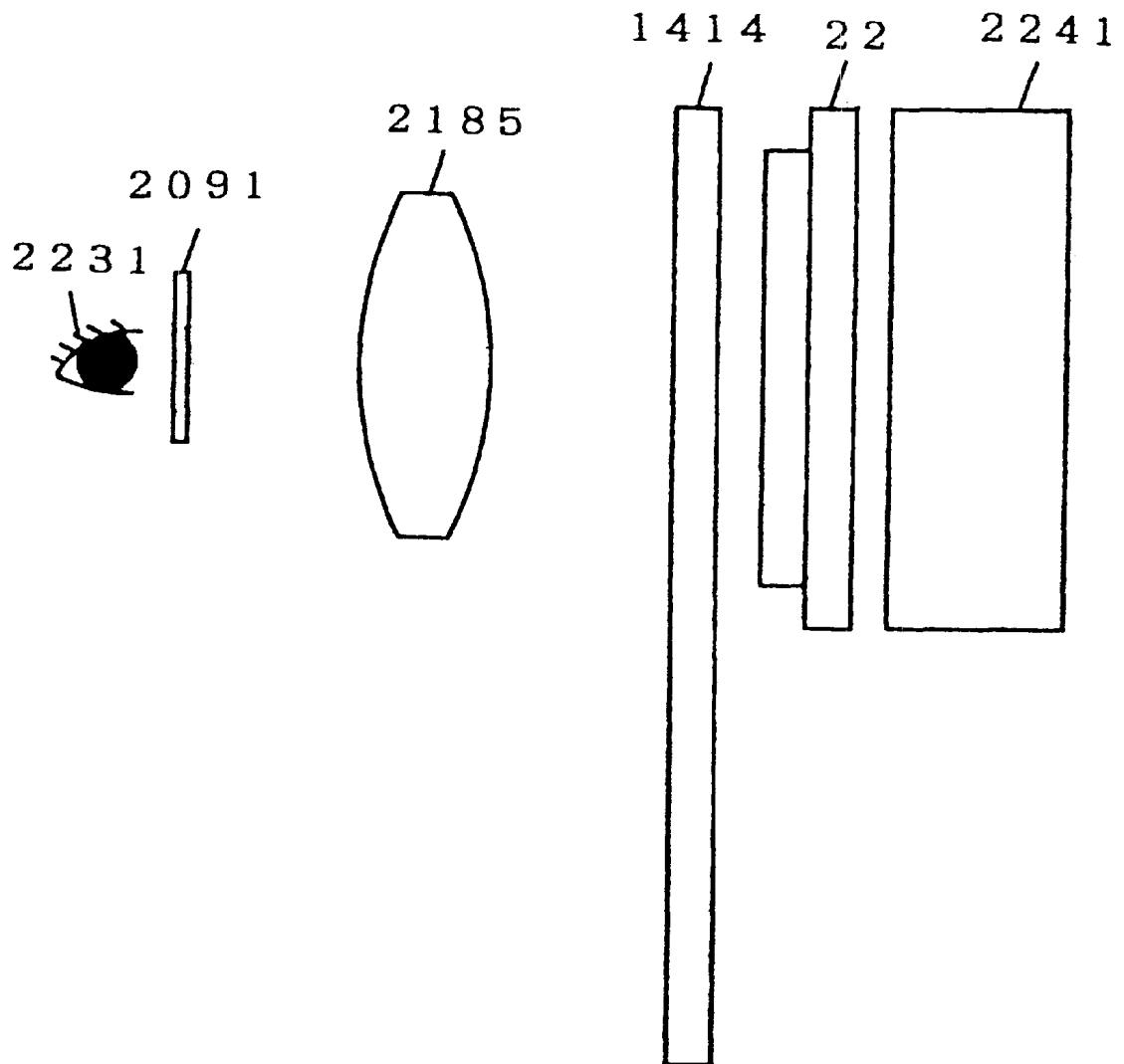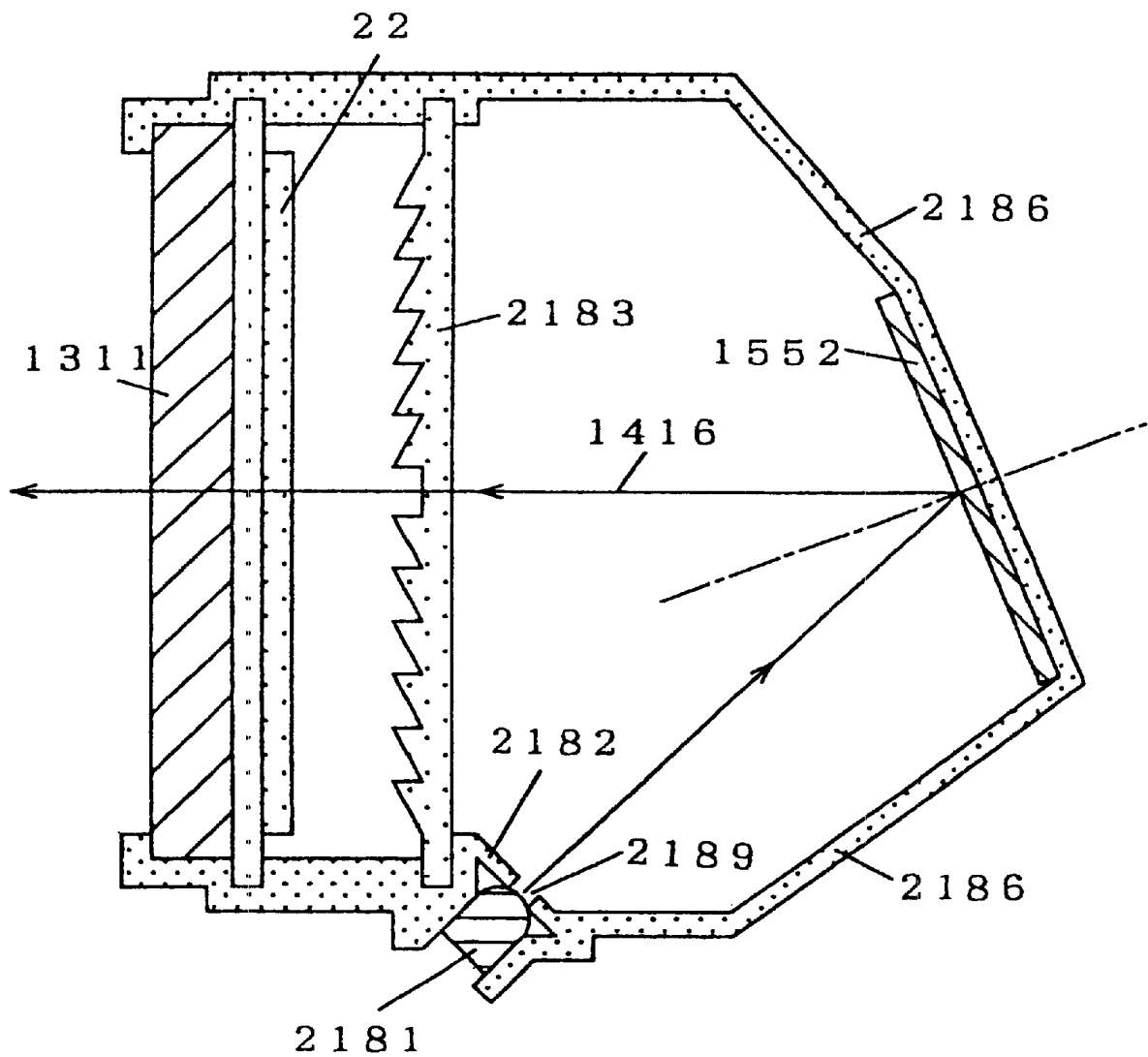
2 2 3 1

Fig. 225

Fig. 226

2261 : LIGHT GUIDING PLATE

2262 : FLUORESCENT TUBE

2263 : REFLECTING SHEET

131b

22

131a

1061

2261

d2

2262

d1

2263
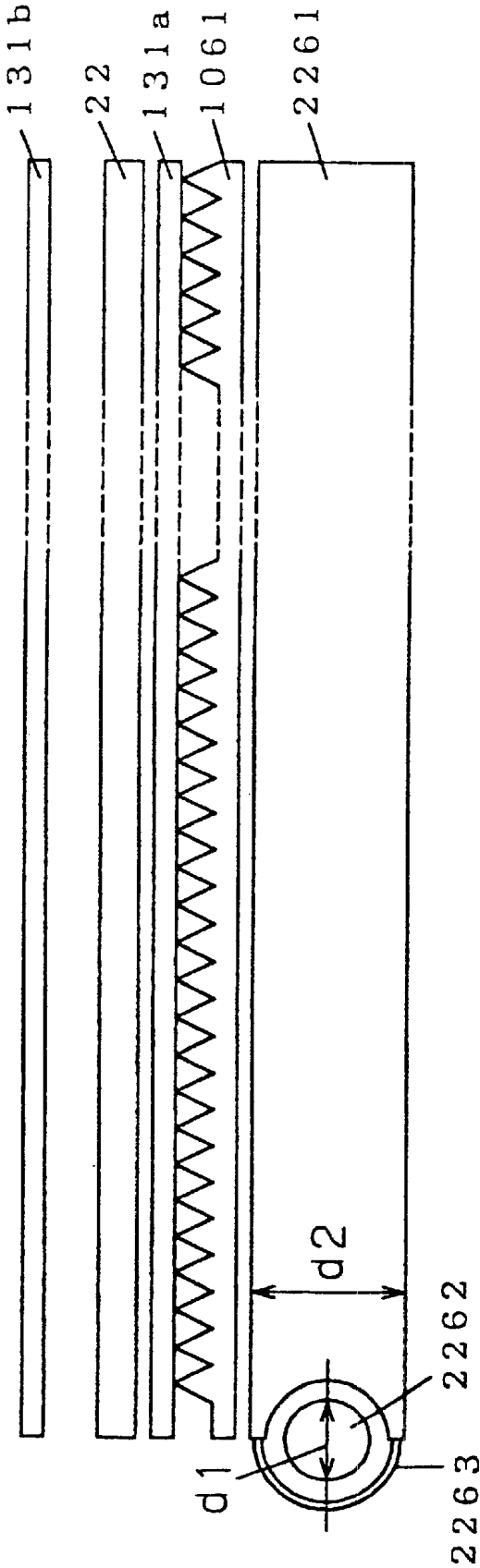
Fig. 227

2231 : SIMPLE MATRIX PANEL

2231 22a
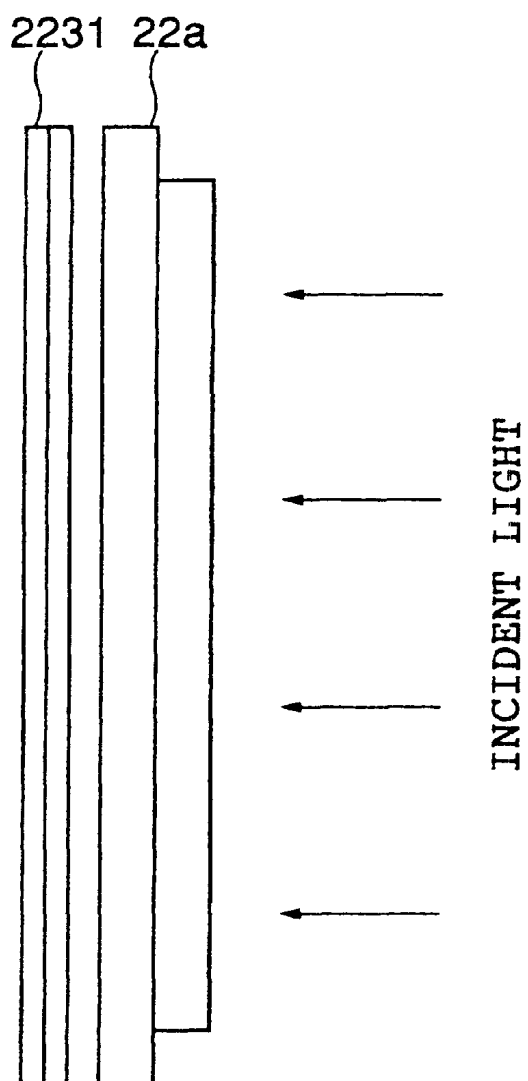
INCIDENT LIGHT

Fig. 228
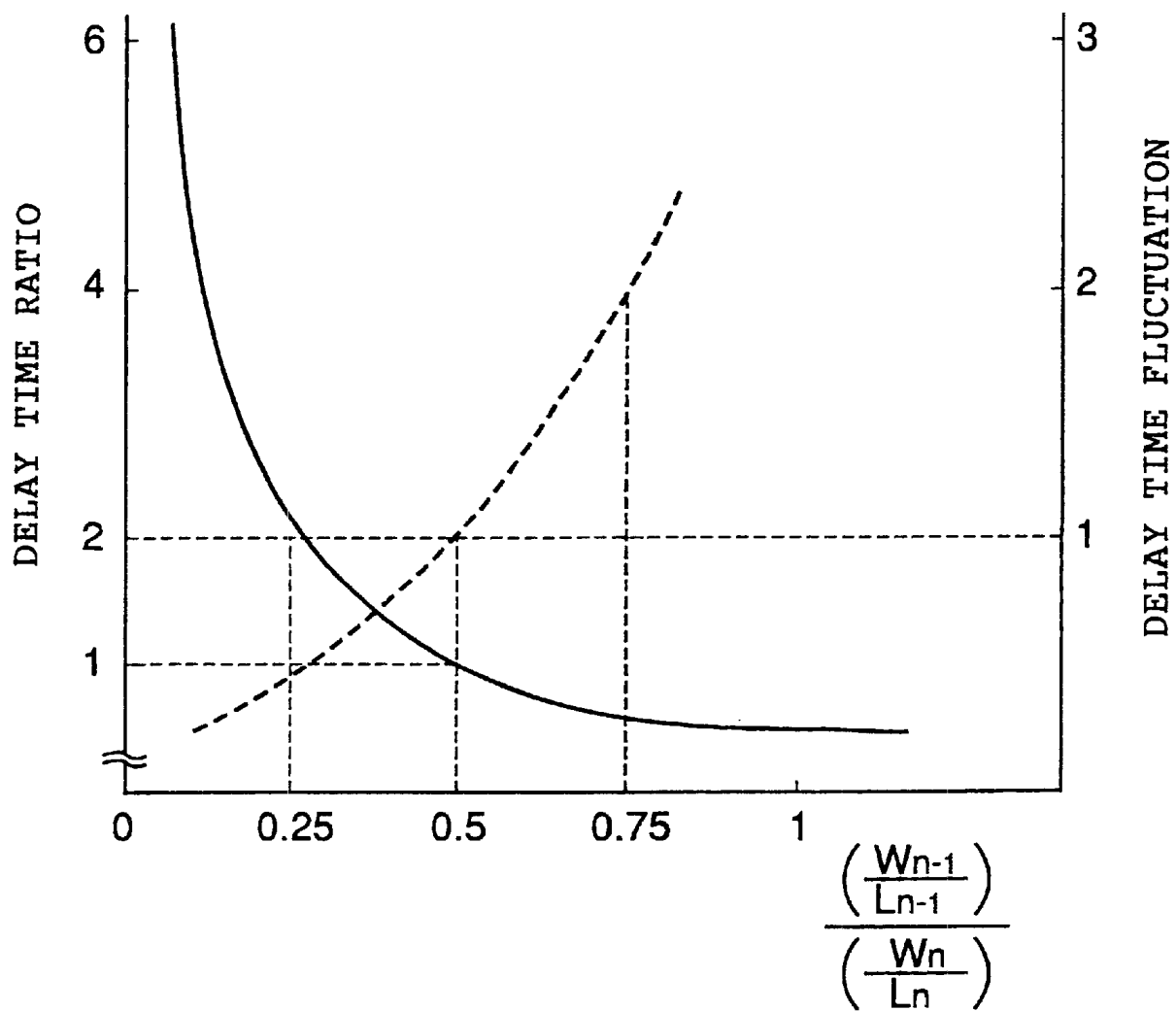
LIQUID CRYSTAL DISPLAY PANEL INCLUDING A LIGHT SHIELDING FILM TO CONTROL INCIDENT LIGHT

This application is a division of U.S. patent application Ser. No. 08/993,250, filed Dec. 17, 1997 now U.S. Pat. No. 6,219,113.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a display panel, a method of fabricating the display panel, a method of driving the display panel, a method of correcting a defect in the display panel, and a display employing the display panel.

2. Description of the Related Art

Twisted nematic (TN) liquid crystals making use of the optical rotation of a liquid crystal have presently been employed in available projection displays (liquid crystal projectors) and view finders.

The TN liquid crystal display panel employing the TN liquid crystal needs to employ a polarizing plate to modulate light.

Conventional units such as the aforementioned, however, have poor light utilization efficiency, because the polarizing plate absorbs approximately 70% of incident light. For this reason, the TN liquid crystal display panel has the problem that high brightness display cannot be realized.

The TN liquid crystal display panel also needs a rubbing process, because there is a need to orient liquid crystal molecules. The conventional rubbing process, however, will easily cause a manufacturing defect because it needs high technology. For this reason, there is a problem of panel cost being increased.

SUMMARY OF THE INVENTION

The objective of the present invention is to provide a display panel, a method of fabricating the display panel, a method of driving the display panel, a method of correcting a defect in the display panel, and a display employing the display panel in consideration of the conventional problems mentioned.

The first liquid crystal display panel of the present invention comprises, for example, a first electrode substrate (11), a second electrode substrate (12), a liquid crystal layer (21) interposed between said first electrode substrate (11) and said second electrode substrate (12) for forming an optical image as the change of a light scattering state, and a plurality of wires (17) formed on at least one or the other of said first electrode substrate (11) and second electrode substrate (12), wherein the liquid crystal molecules (20) in said liquid crystal layer are oriented by an electric field (19) produced between said wires adjacent on the same substrate.

Also, for example, a polarizing plate (131) is arranged on either the incident side or exit side of the liquid crystal display panel (22) or on both sides. An electric force line (19) is produced parallel to the substrate by the aforementioned adjacent wires (called a transverse electric field wire) (17). Along this electric force line (19), the liquid crystal molecules (20) are oriented. If the liquid crystal molecules (20) are oriented, polarization dependency will occur in a specific direction. If the specific direction is aligned with the polarization axis (132) of the polarizing plate, a scattering characteristic will be enhanced.

In the second display panel of the present invention, a liquid crystal layer (21) and a counter electrode (25), for

example, are formed. Then, a color filter (151) is filter directly on the counter electrode (25). Irradiation of ultraviolet rays is performed after formation of the counter electrode (25) and before formation of the color filter (151). As an example of the color filter, there is an interference filter consisting of a dielectric multilayer film and a filter colored with gelatin. Also, the color filter (151) is formed with a protective film (153) for preventing mechanical rapture.

In the third display panel of the present invention, a color filter (151) and a black matrix as a light shielding film (202), for example, is formed on an array substrate (12) and then, on the color filter (151) a thin film (201) having a smoothing and insulating function is formed. On m, this thin film (201), a TFT (155) and a signal line (15), etc. are formed. Thereafter, a counter substrate (11) formed with a counter electrode (25) and the array substrate (12) are held with a predetermined space and then, the space is filled with a mixed solution (315) containing liquid crystal and resin. The phase separation of the mixed solution (315) is performed by irradiating ultraviolet rays from the side of the counter substrate (11).

In the fourth display panel of the present invention, a color filter (151) is not formed on a counter electrode (25). The color filter (151) is formed on another substrate (351). The substrate (351) and the counter electrode (25) are held with a predetermined space by beads (161). The space is filled with an inert gas (352), etc., and the peripheral portion is sealed with seal resin (361) for preventing leakage of said gas.

In the fifth display panel of the present invention, a substrate (11), formed with a color filter (151) and a counter electrode (25), is pasted on a PD liquid crystal layer (21) by an adhesive layer (371). It is preferable that the adhesive layer (371) employ the same material as the resin of the liquid crystal layer (21).

In the sixth display panel of the invention, a counter substrate (11), for example, is thinned, and on the counter substrate (11) a color flter (151) is formed. The relation between the thickness t of the counter substrate (11) and the diagonal length d of a pixel needs to meet the following equation. The color filter (151) is formed after ultraviolet rays are irradiated on the liquid crystal layer (21).

$$10d \geq t \qquad \text{[expression 13]}$$

In the seventh display panel of the present invention, a first PD liquid crystal layer is formed between a pixel electrode (14) and a common electrode (212), and a second PD liquid crystal layer is formed between the pixel electrode (14) and a counter electrode (25). If voltage is applied to the pixel electrode, the first and second PD liquid crystal layers will be caused to be in a light transmitting state at the same time. Since the sheet resistance value of the common electrode (212) is reduced, a metal wire (471) is formed along the common electrode (212).

A light shielding film 542 is formed above or below a driver circuit (541), etc. which drives the display panel of the present invention. The light shielding film (542) shuts out light that is incident on the driver circuit (541). Or, instead of the light shielding film (542), the driver circuit (541) is enclosed with a light absorbing resin (541).

In the eighth display panel of the present invention, for example, a light modulating layer (21) is not formed between pixel electrodes (14), but space is assured. Also, on a signal line (15) a BM (202) is formed. Preferably, an inert gas (352) is injected into the aforementioned space. A

fabrication method fabricates a mask **181** having a light shielding film (**202**) formed so as to correspond to the space between pixel electrodes (**14**), and irradiates ultraviolet rays (**183**) through the mask (**181**). The ultraviolet rays (**183**) irradiated on the light shielding film (**202**) is reflected or absorbed. For this reason, the resin under the light shielding film (**202**) is not set. After irradiation of the ultraviolet rays (**183**), if the unset resin (**315**) is washed, space can be formed on a signal line.

In the ninth display panel of the invention, a color filter (**151**), for example, is formed on a pixel electrode (**14**). A PD liquid crystal layer (**21**) varies the average particle diameter of a waterdrop-like liquid crystal or the average pore diameter of a polymer network in accordance with the color of the color filter (**151**). When the color filter (**151**) is red (R), the average particle diameter or average pore diameter is increased, and when the color filter (**151**) is blue (B), the average particle diameter or average pore diameter is reduced. The size of the average particle diameter or average pore diameter is adjusted by varying the strength of ultraviolet rays to be irradiated and/or the kind and content of liquid crystal and resin. Also, as shown in FIG. **28**, the size is adjusted by irradiating ultraviolet rays with the use of a transparent substrate (**642**) formed with microlenses (**641**) different in focal distance. The microlenses (**641**) may be replaced with prisms, as shown in FIG. **67**.

The tenth display panel of the present invention is constituted, for example, so that the content of the resin component on a pixel electrode (**14**) is increased and also the content of the liquid crystal component of the peripheral portion of the pixel electrode (**14**) is increased. The refractive index of a liquid crystal is higher than that of resin. For this reason, in the display panel shown in FIG. **70**, the refractive index of the central portion on the pixel becomes lower than that of the peripheral portion of the pixel. Therefore, if the refractive index of the liquid crystal component in a mixed solution (**315**) is higher than that of the resin component, each pixel will serve as a concave lens.

The eleventh display panel of the present invention is provided, for example, with a microlens array (**641**). By forming a microlens array substrate (**642**) and a color filter (**151**), color display is realized without forming the color filter (**151**) on a liquid crystal layer (**21**). Also, the microlenses (**641**) may be colored red (R), green (G), and blue (B).

The microlens (**641**) has both the function of a microlens and the function of a color filter (**151**). The microlens may be replaced with a Fresnel lens.

Also, if the microlens (**641**) is formed between pixel electrodes (**14**), the same effect as the BM (**202**) formed between pixel electrodes (**14**) can be obtained.

In the twelfth display panel of the present invention, thin film or thick film consisting of resin is formed on the lower layer of a counter electrode or a pixel electrode, and the film thickness of a liquid crystal layer (**21**) is varied according to the color of the pixel electrode (**14**). A red pixel is made thicker in film thickness than a blue pixel. Preferably, the average particle diameter of the waterdrop-like liquid crystal of the red pixel is made larger than that of the waterdrop-like liquid crystal of the blue pixel.

In the thirteenth display panel of the present invention, a reflecting surface with irregularities, for example, is formed on one side of the substrate of the display panel. Alternatively, irregularities are formed on a surface (counter electrode **25** or pixel electrode **14**) contacting a liquid crystal layer, and a color filter (**151**) is formed on the irregular surface.

In the fourteenth display panel of the present invention, a pixel electrode (**14**) is formed from ITO, and on the ITO a

dielectric mirror (**891**) is formed. If voltage is applied to the pixel electrode (**14**), a liquid crystal layer (**21**) will be caused to be in a light transmitting state. The correction of a pixel defect is performed by (irradiating) laser light from the dielectric mirror side.

In the microlens of the present invention, a microlens array is formed, for example, by forming on a substrate a thin film pattern which becomes a core, coating a resin solution on the substrate, and by setting the resin solution. A microlens array substrate with concave or convex lenses can be formed according to the shape of the thin film pattern. Also, a reflection type microlens array can be fabricated by forming thin metal film on the aforementioned microlenses.

To narrow the directivity of light emerging from the display panel of the present invention, a microlens array or a prism sheet is arranged on a light reflecting surface or the light exit surface of the display panel. Also, a light guiding plate is arranged on the light incidence surface of the display panel.

The display panel of a fifteenth invention is constituted, for example, so that current flows through a counter electrode (**25**). Wires (**1693**) are formed on both ends of the counter electrode (**25**), and if a switch (**1692**) is closed, current will flow between wires (**1693***a*) and (**1693***b*). When current flows through the counter electrode (**25**), it is converted to heat and then, a liquid crystal layer (**21**) is heated and the temperature of the liquid crystal layer is raised to a predetermined value.

The driver circuit of the display panel of the present invention is constituted, for example, by transistors formed with a high-temperature polysilicon technique, a single crystal polysilicon technique, or a low-temperature polysilicon technique. Inverters of multiple stages are connected to the output of the shift register of the driver circuit. The output of the inverter of the last stage is connected to the gate of an analog switch. The analog switch outputs a video signal to a source signal line (**15**).

The display panel of the present invention needs to meet the following relation:

$$10D \leq \frac{W}{L} \leq 50D \qquad \text{[expression 14]}$$

where W is the width of the gate of a transistor constituting an inverter, L is the length of the gate, and D is the diagonal length of a display area on the liquid crystal display panel.

Also, the display panel needs to meet the following relation:

$$\frac{200D}{\mu p} \leq \frac{W}{L} \leq \frac{1200D}{\mu p} \qquad \text{[expression 15]}$$

where μp (cm^2/V*sec) is the mobility of the P-channel transistor.

In addition, the display panel needs to meet the following relation:

$$0.25 < (W_{n-1}/L_{n-1})/(W_n/L_n) < 0.75 \qquad \text{[expression 16]}$$

where W_{n-1} is the length of the gate of the (n–1) st inverter, L_{n-1} is the length of the gate, W_n is the width of the gate of the nth inverter of the next stage, and L_n is the length of the gate.

Furthermore, the relation between the power source voltage V_1 for the inverter connected to the gate of the analog switch (**1192**) and the power source voltage V_2 for outputting a logic signal to the signal input terminal of the inverter

needs to meet the following equation. Note that the power voltage for the shift register is V_2.

$$V_2 < V_1 \qquad \text{[expression 17]}$$

In the display panel of a fifteenth invention, a concave lens-shaped or plate-shaped transparent substrate is mounted on a light incidence surface or light exit surface. The transparent substrate has a radiating plate mounted thereon. Also, the transparent substrate is filled with liquid or gel.

In the sixteenth display panel of the present invention, four color pixels, for example red(R), green(G), blue(B), and brightness (W) pixel are arranged in the form of a mosaic. For the pixels, signals different in polarity for each frame are written.

The defect correction method of the present invention is, for example, a defect correction method for a polymer dispersion liquid crystal display panel. In this method, laser light is irradiated on the liquid crystal layer (21) of the liquid crystal display panel to change the quality of the liquid crystal layer (21).

The defect correction apparatus of the present invention is, for examle, a defect correct apparatus for display panel which comprises observation means for detecting at least either the position of the pixel electrode (14) of a display panel or the position of the switching element (155) by infrared rays, laser light irradiation means (901) for irradiating laser light, and positioning means (911) for positioning the liquid crystal panel so that the position detected by the observation means (902) and the position at which the laser light is irradiated are superimposed with each other.

The display according to the present invention is, for example, provided with video signal processing means for computing an average amplitude value from a video signal during a video signal period in one horizontal period and then computing a first voltage from the computed average amplitude value and source signal application means for applying the first voltage to a plurality of source signal lines during a blacking period in one horizontal period.

In the first display panel drive method of the present invention, for example, an average amplitude value is computed from a video signal period in one horizontal period. Then, voltage is computed from the computed average amplitude value. The computed voltage is applied during a horizontal blanking period so that each pixel of the liquid crystal display panel has a desired transmittance.

In the second display panel drive method of the present invention, for example, the polarity of a video signal which is applied to a counter electrode (25) is inverted for each horizontal scanning period. Then, a video signal is applied from a source driver circuit (491) to a source signal line (15) with the potential of said counter electrode (21) as reference, and also the polarity of said video signal is inverted for each horizontal scanning period.

In the third display panel drive method of the present invention, for example, a video signal is converted to a digital signal and retained in memory as data. Then, the retained data is read out at a double speed and written by the display panel. In the remaining half frame (or half field) period, black display is written to the display panel at the same double speed. In other words, this method performs black display→image display→black display→image display in the recited order.

In the fourth display panel drive method of the present invention, for example, a display panel is arranged within a cylindrical light shielding member formed with slits, and an image on the display panel is gradually shut out from the upper portion of the screen.

The first display panel fabrication apparatus of the present invention is, for example, constituted so that a mixed solution (315) is, supplied to the space between a separation film 182 and a substrate (12) and pressed by a press roller (312). Ultraviolet rays (183) is supplied in the form of lines to the mixed solution 315. After phase separation of the mixed solution, the separation film (182) is wound up by a wind-up roller (314).

The second display panel fabrication apparatus of the present invention is provided, for example, with a mounting table for placing a display panel (22). The mounting table has a heater (739) for heating the panel (22) to a predetermined temperature. Liquid or gel (735) is supplied to the space between a diffusing plate (734) and the display panel (22) through a supply tube (732). The peripheral portion is sealed by seal rubber (736) so that liquid or gel does not leak. Ultraviolet rays (183) are irradiated on the display panel (22) through the light diffusing plate (734). The ultraviolet rays (183) are scattered by the diffusing plate (734) and are irradiated evenly on the entire mixed solution of the display panel.

The third display panel fabrication apparatus of the present invention is constituted, for example, so that ultraviolet rays can be irradiated from the back surface of a display panel (22). The mixed solution of the display panel (22) can be heated to a predetermined temperature by the infrared rays. On the front surface of the display panel (22) an infrared-ray reflecting plate (741) is arranged. The reflecting plate (741) reflects the infrared rays transmitted through the display panel (22) and heats a mixed solution (315) from the front surface of the display panel (22) as well. Liquid or gel (735) is supplied to the space between a diffusing plate (734) and the display panel (22) by a supply tube (732). Ultraviolet rays (183) are irradiated from the side of a counter electrode (25) formed on the front surface of the display panel (22) onto the mixed solution (315) through the diffusing plate (734). On the back surface of the display panel (22) an ultraviolet ray reflecting plate (742) is arranged. The reflecting plate (742) reflects ultraviolet rays (183) and accelerates the phase separation of the mixed solution from the back surface of the display panel as well.

In the fourth display panel fabrication apparatus of the present invention, a display panel (22) is housed within a casing (742) and the periphery of the display panel (22) is filled with liquid or gel (735). On the interior surface of the casing (742) a reflecting plate (742) is formed, and the reflecting plate reflects the ultraviolet rays (183) irradiated through a diffusing plate (734). For this reason, ultraviolet rays (183) are irregularly reflected within the casing (742), and consequently, ultraviolet rays are irradiated from the entire circumference of the display panel (22) on a mixed solution (315).

The first projection type display of the present invention is provided, for example, with a discharge light emitting lamp, a liquid crystal display panel, secondary-illuminant formation means for focusing light emitted from the discharge light emitting lamp to form a secondary illuminant, a projection lens for projecting an optical image formed by the liquid crystal display panel, first lens aperture means arranged on a light incidence side of said liquid crystal display panel, and second lens aperture means arranged on a light exit side of said liquid crystal display panel.

The relation with the effective F number F of the projection lens needs to meet the following equation:

$$\frac{3DG}{2L} \le F \le \frac{4DG}{L} \qquad \text{[expression 18]}$$

$$G = \pi B / E$$

where D (inch) is the diagonal length of the display area of the liquid crystal display panel and L (mm) is the arc length of the discharge light emitting lamp.

In the second projection type display of the present invention, a display panel with color filters in the form of a mosaic is employed as a light valve. On the exit side of a light source (1414) a color purity enhancing filter (1412) for enhancing color purity is arranged. Also, on the exit side of the display panel (22) a polarizing plate (131) is arranged, and the polarizing plate (131) is detachable from an optical axis (1416).

The third projection type display of the present invention is constituted so that an infrared-ray cut filter (1702) is detachable from an optical axis (1416). It is preferable that an infrared-ray absorbing filter (1703) be arranged on the light incidence surface of a display panel (22). In the case of low temperature, the infrared-ray cut filter (1703) is not inserted in the optical axis (1416) immediately after the lamp is lit. For this reason, the display panel (22) is heated by radiation heat and the temperature of the liquid crystal layer (21) is quickly raised. The temperature of the liquid crystal layer (21) is detected by a temperature sensor (745). If the temperature of the liquid crystal layer (21) reaches a predetermined value, the infrared-ray cut filter (1702) will be inserted in the optical axis (1416).

In the fourth projection type display of the present invention, for example, a rotary filter (1414) is arranged in an optical axis (1416). The rotary filter 1414 is formed by bonding a polarizing plate (131) to a substrate. However, the quarter area does not have the polarizing plate (131). The rotary filter (1414) is constituted so that it is rotatable on a rotational center (2023). If the rotary filter (1414) is rotated, the direction of the polarization axis (132) of the transmission range (2022) of light which is projected onto a screen (1501) will be changed. The rotary filter 1414 rotates in synchronization with the vertical synchronizing signal (VS) in a video signal. The rotary filter (1414) is rotated 90° for each vertical period. Also, an image for the right eye and an image for the left eye are switched for each frame and displayed on the display panel (22).

In the fifth projection type display of the present invention, for example, at least either the distance between a display panel (22) and a lamp (1411a) or the distance between the display panel (22) and a projection lens (1415) can be contracted. This projection type display is also provided with a mechanism for fine adjustment of lamp position. When the projection type display is carried, the overall length thereof is contracted. When the projection type display is used, the overall length is extended so that an image on the display panel (22) can be projected onto a screen by a projection lens.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an explanatory diagram of the display panel of the present invention forming on a counter electrode substrate the wires for producing a transverse magnetic field;

FIG. 2 is an explanatory diagram of the operational principles of a polymer dispersion liquid crystal display panel;

FIG. 3 is an explanatory diagram explaining the polarization dependency of the polymer dispersion liquid crystal display panel;

FIG. 4 is an explanatory diagram for explaining the operational principles of the display panel of the present invention;

FIG. 5 is an explanatory diagram for explaining the characteristic of the display panel of the present invention;

FIG. 6 is an explanatory diagram for explaining the operation of the display panel of the present invention;

FIG. 7 is a sectional view of the display panel of the present invention;

FIG. 8 is a sectional view of the display panel in an embodiment of the present invention;

FIG. 9 is an explanatory diagram of the operation of the display panel in another embodiment of the present invention;

FIG. 10 is an explanatory diagram of the operation of the display panel in another embodiment of the present invention;

FIG. 11 is an explanatory diagram of the operation of the display panel in another embodiment of the present invention;

FIG. 12 is an explanatory diagram of the operation of the display panel in another embodiment of the present invention;

FIG. 13 is an explanatory diagram as polarizing plates are arranged in the light incidence and emergence of the display panel of the present invention;

FIG. 14 is an explanatory diagram as polarizing plates are arranged in the light incidence and emergence of the display panel of the present invention;

FIG. 15 is a sectional view of the display panel of the present invention arranging a color filter on the counter electrode;

FIG. 16 is a sectional view of the display panel of the present invention arranging an insulating film on a surface which contacts a liquid crystal layer;

FIG. 17 is a sectional view of the display panel of the present invention forming liquid crystal layers of particle diameters of two kinds;

FIG. 18 is an explanatory diagram of the fabrication method of the display panel of the present invention shown in FIG. 17;

FIG. 19 is a sectional view of the display panel in another embodiment of the present invention;

FIG. 20 is a sectional view of the display panel of the present invention forming a color filter and a light shielding film under the pixel electrode;

FIG. 21 is a sectional view of the display panel of the present invention forming a common electrode under the pixel electrode;

FIG. 22 is an explanatory diagram of the anti-reflection structure in the display panel of FIG. 21;

FIG. 23 is a spectral distribution diagram showing the characteristic of the display panel of the present invention;

FIG. 24 is a spectral distribution diagram showing the characteristic of the display panel of the present invention;

FIG. 25 is a spectral distribution diagram showing the characteristic of the display panel of the present invention;

FIG. 26 is a spectral distribution diagram showing the characteristic of the display panel of the present invention;

FIG. 27 is a sectional view of the display panel in another embodiment of the present invention;

FIG. 28 is an explanatory diagram of the fabrication method of the polymer dispersion liquid crystal display panel, etc.;

FIG. **29** is an explanatory diagram of the fabrication method of the polymer dispersion liquid crystal display panel, etc.;

FIG. **30** is an explanatory diagram of the structure of the polymer dispersion liquid crystal display panel;

FIG. **31** is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention;

FIG. **32** is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention;

FIG. **33** is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention;

FIG. **34** is an explanatory diagram of a m ask employed in the fabrication method explained in FIG. **35**;

FIG. **35** is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. **36** is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. **37** is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. **38** is a sectional view of the reflection type liquid crystal display panel of the present invention;

FIG. **39** is an explanatory diagram of the fabrication method of the display panel of the present invention shown in FIG. **37**, etc.;

FIG. **40** is an explanatory diagram of the structure of the light modulating layer of the liquid crystal display panel of the present invention;

FIG. **41** is an explanatory diagram of the structure of the light modulating layer of the liquid crystal display panel of the present invention;

FIG. **42** is an explanatory diagram of the structure of the light modulating layer of the liquid crystal display panel of the present invention;

FIG. **43** is an explanatory diagram of the structure of the light modulating layer of the liquid crystal display panel of the present invention;

FIG. **44** is an explanatory diagram of the structure of the light modulating layer of the liquid crystal display panel of the present invention;

FIG. **45** is an explanatory diagram of the structure of the light modulating layer of the liquid crystal display panel of the present invention;

FIG. **46** is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. **47** is an explanatory diagram of the liquid crystal display panel shown in FIG. **46**;

FIG. **48** is an explanatory diagram of the liquid crystal display panel shown in FIG. **46**;

FIG. **49** is an equivalent circuit diagram of the liquid crystal display panel of the present invention shown in FIG. **46**;

FIG. **50** is an explanatory diagram of the operation of the liquid crystal display panel of the present invention shown in FIG. **46**;

FIG. **51** is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention shown in FIG. **46**;

FIG. **52** is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. **53** is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention shown in FIG. **52**;

FIG. **54** is a sectional view of the liquid crystal display panel of the present invention forming a light shielding film on the driver circuit;

FIG. **55** is a sectional view of the liquid crystal display panel of the present invention forming a light absorbing layer on the driver circuit;

FIG. **56** is a sectional view of the liquid crystal display panel of the present invention forming the light absorbing layer on the driver circuit;

FIG. **57** is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. **58** is an explanatory diagram of the liquid crystal display panel of the present invention shown in FIG. **57**;

FIG. **59** is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention shown in FIG. **57**;

FIG. **60** is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention;

FIG. **61** is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention;

FIG. **62** is a sectional view of the liquid crystal display panel of the present invention;

FIG. **63** is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention shown in FIG. **62**;

FIG. **64** is an explanatory diagram of the fabrication method of the liquid crystal display panel in another embodiment of the present invention;

FIG. **65** is an explanatory diagram of the substrate **181** in FIG. **64**;

FIG. **66** is an explanatory diagram of the substrate **181** in FIG. **64**;

FIG. **67** is an explanatory diagram of the substrate **181** in FIG. **64**;

FIG. **68** is an explanatory diagram of the substrate **181** in FIG. **64**;

FIG. **69** is an explanatory diagram of the fabrication method of the liquid crystal display panel in another embodiment of the present invention;

FIG. **70** is a sectional view of the liquid crystal display panel of the present invention;

FIG. **71** is an explanatory diagram of the operation of the liquid crystal display panel of the present invention shown in FIG. **70**;

FIG. **72** is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. **73** is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention;

FIG. **74** is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention;

FIG. **75** is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention;

FIG. **76** is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention;

FIG. **77** is a sectional view of the liquid crystal display panel of the present invention;

FIG. **78** is a sectional view of the liquid crystal display panel of the present invention;

FIG. 79 is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 80 is an explanatory diagram of the light shielding film of the liquid crystal display panel of FIG. 79;

FIG. 81 is a sectional view of the display panel of FIG. 79;

FIG. 82 is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 83 is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention shown in FIG. 82;

FIG. 84 is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention shown in FIG. 82;

FIG. 85 is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 86 is a sectional view of the reflection type liquid crystal display panel in another embodiment of the present invention;

FIG. 87 is an explanatory diagram of the fabrication method of the liquid crystal display panel of the present invention shown in FIG. 86;

FIG. 88 is a sectional view of the reflection type liquid crystal display panel in another embodiment of the present invention;

FIG. 89 is a sectional view of the reflection type liquid crystal display panel in another embodiment of the present invention;

FIG. 90 is an explanatory diagram of the defect correction of the liquid crystal display panel of the present invention;

FIG. 91 is an explanatory diagram of the defect correction of the liquid crystal display panel of the present invention;

FIG. 92 is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 93 is an explanatory diagram of the defect correction method of the liquid crystal display panel of the present invention;

FIG. 94 is an explanatory diagram of a mask employed in the defect correction of the liquid crystal display panel of the present invention;

FIG. 95 is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 96 is a sectional view of the microlens array substrate of the present invention;

FIG. 97 is an explanatory diagram of the microlens array substrate of the present invention;

FIG. 98 is a sectional view of the liquid crystal display panel attaching the microlens array substrate of the present invention;

FIG. 99 is an explanatory diagram of the fabrication method of the microlens array substrate of the present invention;

FIG. 100 is a sectional view of the microlens array substrate in another embodiment of the present invention;

FIG. 101 is a plan view and a sectional view of the microlens array substrate in another embodiment of the present invention;

FIG. 102 is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 103 is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 104 is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 105 is a plan view of the microlens section in FIG. 104;

FIG. 106 is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 107 is a perspective view of a prism sheet;

FIG. 108 is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 109 is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 110 is a plan view of the liquid crystal display panel of FIG. 109;

FIG. 111 is a plan view of the liquid crystal display panel of FIG. 109;

FIG. 112 is a part-sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 113 is an explanatory diagram explaining the characteristic of the liquid crystal display panel of the present invention;

FIG. 114 is an explanatory view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 115 is a perspective view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 116 is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 117 is a sectional view of the liquid crystal display panel in another embodiment of the present invention;

FIG. 118 is an explanatory diagram explaining the operation of the liquid crystal display panel in another embodiment of the present invention;

FIG. 119 is an equivalent circuit diagram explaining the drive method of the liquid crystal display panel of the present invention;

FIG. 120 is an explanatory diagram of the drive method of the liquid crystal display panel of the present invention;

FIG. 121 is a block diagram of the drive circuit of the liquid crystal display panel of the present invention;

FIG. 122 is an explanatory diagram explaining the drive method of the liquid crystal display panel of the present invention;

FIG. 123 is an explanatory diagram explaining the drive method of the liquid crystal display panel of the present invention;

FIG. 124 is an equivalent circuit diagram of the drive circuit of the display panel of the present invention;

FIG. 125 is an explanatory diagram of the drive circuit of the display panel of the present invention;

FIG. 126 is an explanatory diagram of the drive circuit of the display panel of the present invention;

FIG. 127 is an explanatory diagram of the drive circuit of the display panel of the present invention;

FIG. 128 is an explanatory diagram of the drive method of the display panel of the present invention;

FIG. 129 is an explanatory diagram of the drive method of the display panel of the present invention;

FIG. 130 is an explanatory diagram of the drive method of the display panel of the present invention;

FIG. 131 is an explanatory diagram of the drive method of the display panel of the present invention;

FIG. 132 is an explanatory diagram of the drive method of the display panel of the present invention;

FIG. **133** is an explanatory diagram of the drive method of the display panel of the present invention;

FIG. **134** is an explanatory diagram of the drive method of the display panel of the present invention;

FIG. **135** is an explanatory diagram of the drive method of the display panel in another embodiment of the present invention;

FIG. **136** is an explanatory diagram of the drive method of the display panel in another embodiment of the present invention;

FIG. **137** is an explanatory diagram of the drive method of the display panel in another embodiment of the present invention;

FIG. **138** is an explanatory diagram of the drive method of the display panel in another embodiment of the present invention;

FIG. **139** is an explanatory diagram of the drive method of the display panel in another embodiment of the present invention;

FIG. **140** is an explanatory diagram of the drive method of the display panel in another embodiment of the present invention;

FIG. **141** is a constitution diagram of the projection =display of the present invention;

FIG. **142** is a constitution diagram of the color purity enhancing filter (optical filter)

FIG. **143** is a constitution diagram of the color purity enhancing filter (optical filter) in another embodiment of the present invention;

FIG. **144** is a characteristic diagram of the color purity enhancing filter (optical filter);

FIG. **145** is a characteristic diagram of the color purity enhancing filter (optical filter);

FIG. **146** is a characteristic diagram of the color purity enhancing filter (optical filter);

FIG. **147** is a spectral distribution characteristic diagram of a metal halide lamp;

FIG. **148** is a spectral distribution characteristic diagram of the light passed through the color purity enhancing filter (optical filter);

FIG. **149** is a spectral distribution characteristic diagram of the light passed through a color filter;

FIG. **150** is an X-Y chromaticity diagram;

FIG. **151** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **152** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **153** is a constitution diagram of the portable liquid crystal projector of the present invention,

FIG. **154** is a constitution diagram as the liquid crystal projector of FIG. **153** is contracted;

FIG. **155** is a constitution diagram of the projection television of the present invention;

FIG. **156** is a constitution diagram of the optical block of FIG. **155**;

FIG. **157** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **158** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **159** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **160** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **161** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **162** is a spectral distribution characteristic diagram of the dichroic mirror of the projection display of FIG. **161**;

FIG. **163** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **164** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **165** is an explanatory diagram of the cooling structure of the liquid crystal projector of the present invention;

FIG. **166** is an explanatory diagram of the cooling structure of the liquid crystal projector of the present invention;

FIG. **167** is an explanatory diagram of the cooling structure of the liquid crystal projector in another embodiment of the present invention;

FIG. **168** is an explanatory diagram of the cooling structure of the liquid crystal projector in another embodiment of the present invention;

FIG. **169** is an explanatory diagram of the temperature-dependent characteristic compensation method of the liquid crystal display panel of the present invention;

FIG. **170** is an explanatory diagram of the temperature-dependent characteristic compensation method of the liquid crystal display panel of the present invention;

FIG. **171** is an explanatory diagram of the temperature-dependent characteristic compensation method of the liquid crystal display panel of the present invention;

FIG. **172** is a constitution diagram of the liquid crystal display panel in another embodiment of the present invention;

FIG. **173** is a constitution diagram of the liquid crystal display panel in another embodiment of the present invention;

FIG. **174** is a constitution diagram of the liquid crystal display panel in another embodiment of the present invention;

FIG. **175** is a constitution diagram of the liquid crystal display panel in another embodiment of the present invention;

FIG. **176** is a constitution diagram of the liquid crystal display panel in another embodiment of the present invention;

FIG. **177** is a constitution diagram of the liquid crystal display panel in another embodiment of the present invention;

FIG. **178** is a plan view of the liquid crystal display panel in another embodiment of the present invention;

FIG. **179** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **180** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **181** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **182** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **183** is a spectral distribution characteristic diagram of the dichroic mirror of the projection display of FIG. **182**;

FIG. **184** is a spectral distribution characteristic diagram of the dichroic mirror of a conventional projection display;

FIG. **185** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **186** is an explanatory diagram of the dichroic prism of FIG. **185**;

FIG. **187** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **188** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **189** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **190** is an explanatory diagram of optical components employed in the projection display of FIG. **189**;

FIG. **191** is an explanatory diagram of optical components employed in the projection display of FIG. **189**;

FIG. **192** is an explanatory diagram of optical components employed in the projection display of FIG. **189**;

FIG. **193** is an explanatory diagram of optical components employed in the projection display of FIG. **189**;

FIG. **194** is an explanatory diagram of optical components employed in the projection display of FIG. **189**;

FIG. **195** is an explanatory diagram of the characteristic of the liquid crystal display panel of the present invention;

FIG. **196** is an explanatory diagram of the relation between the panel size lamp arc length and the F number of the projection display of the present invention;

FIG. **197** is an explanatory diagram of the relation between the panel size lamp arc length and the display contrast of the projection display of the present invention;

FIG. **198** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **199** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **200** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **201** is a constitution diagram of the projection display in another embodiment of the present invention;

FIG. **202** is an explanatory diagram of the rotary filter of the present invention;

FIG. **203** is an explanatory diagram of the rotary filter of the present invention;

FIG. **204** is an explanatory diagram of the rotary filter of the present invention;

FIG. **205** is an explanatory diagram of the rotary filter of the present invention;

FIG. **206** is an explanatory diagram of the rotary filter of the present invention;

FIG. **207** is an explanatory diagram of the rotary filter in another embodiment of the present invention;

FIG. **208** is an explanatory diagram of the rotary filter in another embodiment of the present invention;

FIG. **209** is an explanatory diagram of the three-dimensional display of the present invention;

FIG. **210** is an explanatory diagram of the projection display of the present invention improving a dynamic image display characteristic;

FIG. **211** is an explanatory diagram of the projection display of the present invention improving a dynamic image display characteristic;

FIG. **212** is an explanatory diagram of the method of driving the liquid crystal display panel of the present invention;

FIG. **213** is an explanatory diagram of the method of driving the liquid crystal display panel of the present invention;

FIG. **214** is an explanatory diagram of the method of driving the liquid crystal display panel of the present invention;

FIG. **215** is an explanatory diagram of the method of driving the liquid crystal display panel of the present invention;

FIG. **216** is an explanatory diagram of the method of driving the liquid crystal display panel of the present invention;

FIG. **217** is an explanatory diagram of the method of driving the liquid crystal display panel of the present invention;

FIG. **218** is an external appearance diagram of the view finder of the present invention;

FIG. **219** is a constitution diagram of the view finder of the present invention;

FIG. **220** is a constitution diagram of the light emitting lamp employed in the view finder;

FIG. **221** is a constitution diagram of the light emitting lamp employed in the view finder of the present invention

FIG. **222** is an explanatory diagram of the rotary filter employed in the view finder, etc.;

FIG. **223** is a constitution diagram of the view finder of the present invention;

FIG. **224** is a constitution diagram of the view finder of the present invention;

FIG. **225** is a constitution diagram of the view finder in another embodiment of the present invention;

FIG. **226** is a constitution diagram of the liquid crystal display of the present invention;

FIG. **227** is an explanatory diagram of the projection display in another embodiment of the present invention; and

FIG. **228** is an explanatory diagram of the driver circuit of the display of the present invention.

DESCRIPTION OF THE SYMBOLS

11 Counter substrate
12 Array substrate
14 Pixel electrode
15 Source signal line
16 Low dielectric film
17 Transverse electric field wire
18 Light shielding film
19 Electric force line
20 Liquid crystal molecule
21 Liquid crystal layer
22 Liquid crystal display
23 Waterdrop-like liquid crystal
24 Resin
25 Counter electrode
41 Signal line
71 Insulating film
131 Polarizing plate (polarization means)
132 Polarization axis
133 Transverse electric field generation direction
151 Color filter
152 Resin light shielding film (black matrix BM)
153 Protective film
154 Insulating film
155 TFT
161 Bead
15 Source signal line
181 Mask
182 Separation film (substrate) or separation film
183 Ultraviolet ray
201 Insulating film
202 Light shielding film

211 AIR coat
212 Common electrode
213 Antireflection film
214 Smoothing film
221 Dielectric thin film
291 Laser light
301 Resin particle (resin component crowded portion)
302 Liquid crystal component (liquid crystal excess portion)
311 Light irradiation means
312 Press roller
313 Supply roller
314 Wind-up roller
315 Mixed solution
331 Filter
291 Laser light (light beam)
314 Opening
315 Substrate
351 Inert gas layer
361 Seal resin
371 Adhesive layer
381 Light absorbing layer
382 Connecting portion
14a Reflecting electrode (reflection type pixel)
471 Metal wire
472 Gate signal line
491, 492, 541 Driver circuit (drive IC)
542 Light shielding film
571 Space (place with no light modulating layer)
19 Electric force line
231 Light shielding pattern
641 Microlens (light turning means)
671 Prism
691 Optical coupling agent (optical coupling layer)
711 Concave lens
731 Lens
732 Supply tube
733 Exhaust tube
734 Diffusing plate
735 Optical coupling liquid
736 Seal rubber (buffer object)
737 Reflecting plate (Reflecting sheet)
738 Heater table (mounting table)
739 Heater
741 Infrared-ray reflecting film
742 Ultraviolet-ray reflecting film
743 Transparent substrate
744 Infrared light
745 Temperature sensor
761 Support
762 Casing
791 Light shielding film (BM)
792 Reflecting film (reflection means)
811 Insulating thin film
812 Dielectric film
821 Irregularity film
822 Embossed sheet
831 Photosetting resin
841 Light scattering layer
861 Buffer layer
14b Reflecting electrode (pixel)
891 Dielectric mirror
892 Transparent electrode (ITO)
901 Laser trimming apparatus
902 Infrared ray camera
921 Radiating plate
922 Adhesive agent
901a Laser light generation apparatus

901b Mirror
901c Condenser lens
911 XY stage
912 Laser light
961 Convex portion (protruding portion)
962 Transparent resin film
991 Transparent thin film
992 Thin metal film
1061 Prism sheet
1062 Fresnel lens sheet
1091 Light guiding plate
1092 Reflecting film
1093 Adhesive layer
1094 Opening
1095 Incident light (Outgoing light)
1121 Reflector
1131 Transparent substrate
1132 Light absorbing film
1133 Scattered light
1131a, 1131b Lens (transparent substrate)
1161 Casing
1162 Pawl
1171 Lid
1172 Ethylene glycol (optical coupling liquid)
1191 OR circuit
1192 Switch circuit
1193 Signal line capacitor
1194 Additional capacitor
1211 A/D
1212 Line memory
1213 Arithmetic circuit
1214 D/A
1251 Inverter
1281 Signal source
1282 Image signal circuit
1291 Pixel
1311 Display screen
1341 Analog switch
1361 Scanning direction
1411 Light source
1411a Lamp
1411b Concave mirror
1411c UVIR cut filter
1412 Color filter
1413 Lens
1414 Rotary filter (color separation filter)
1415 Projection lens
1416 Optical axis
1422, 1423, 1432, 1433 Dielectric multilayer film
1424, 1425, 1434, 1435 Dielectric thin film
1501 Screen
1531 Positioning tool
1532 Lamp source
1533 Control button
1534 Cooling fan
1535 Casing
1536 Lens drive portion
1537 4Mounting portion
1538 Panel signal generation source
1551 Optical block
1552 Mirror
1581 Polarization beam splitter (polarization separation means (PBS))
1582 Light separation surface
1591 Dichroic prism (color separation means)
1592 Lens plate
1593 Lens

1594 Band cut filter (band cut mirror)
1611 Dichroic mirror
1631 Display area
1651 Casing
1652 Peltier element (electronic cooling element)
1681 Nitrogen gas (inert gas)
1682 Cooling liquid
1683 Seal liquid
1691 Current source
1692 Switch
1693 Wiring
1694 Connecting point
1701 Ultraviolet-ray cut filter (ultraviolet-ray absorbing filter)
1702 Infrared-ray cut filter (infrared-ray absorbing filter)
1703 Infrared-ray absorbing filter (infrared-ray cut filter)
1711 Motor
1712 Damper (buffer member)
1741 Half-wave plate
1742 Polarizing plate (polarization means)
1751 Filter
1752 Reflecting prism
1761 Relay lens
1762 Aperture
1771 Field lens
1801 Separation wall
1811 Light beam
1861 Light incidence surface
1871 Lens
1891a Rear group lens
1891b Front group lens
1892 Illuminant
1893 Real image
1894 Input lens array
1895 Central lens array
1896 Lens aperture (illumination light side)
1897 Exit lens
1898 Lens aperture (projection lens side)
1899 Input lens
1900 Central lens
1901 Secondary illuminant
2011 Prism (CDD prism)
2021 Rotational center
2022 Area that projected light passes through
2031 Polarization screen
2072 Correction filter (color filter)
2081 Light shielding film
2082 Transparent substrate
2091 Polarizing eyeglasses
2101 Drum (rotary body)
2102 Light shielding portion
2103 Light transmitting portion
2161 A/D conversion circuit
2162 F (field or frame) memory
2163 Raster setting circuit
2164 Double-speed read circuit
2165 Signal dividing circuit
2181 Light emitting lamp
2182 Aperture
2183 Condenser lens
2184 Eyepiece ring
2185 Eyepiece lens
2186 Body
2187 Eyepiece rubber
2188 Mounting bracket
2189 Hole
2201 Casing

2202 Fluorescent substance
2203 Filament
2204 Anode
2205 Light shielding film
2211 Circuit substrate
2212 Connector
2213 Solder
2231 Observer's eye
2241 Surface light source
2261 Light guiding plate
2262 Fluorescent tube
2263 Reflecting sheet
2231 Simple matrix panel

EMBODIMENTS

With regard to embodiments of the present invention according to the display panel, method of fabricating the display panel, method of driving the display panel, method of correcting a defect in the display panel, and a display employing the display panel, a description thereof will hereinafter be made referring to the drawings.

Initially, on the operation of a polymer dispersion liquid crystal (hereinafter referred to as a PD liquid crystal), a description thereof will be simply made with FIGS. 2(a) and (b). FIGS. 2(a) and 2(b) are explanatory diagrams of the operation of the PD liquid crystal. In the figures, liquid crystals in a waterdrop state (hereinafter referred to as waterdrop-like liquid crystals 23) are dispersed into a resin component (polymer) 24. A pixel electrode 14 is connected to a TFT (not shown). If the TFT is turned on and off, voltage will be applied to the pixel electrode 14 and the orientations of liquid crystals on the pixel electrode 14 will be varied, thereby modulating light. In the state in which no voltage is applied, as shown in FIG. 2(a), the liquid crystal molecules in each of the waterdrop-like liquid crystals 23 are oriented in irregular directions. In this state a refractive index difference occurs between the polymer 24 and the waterdrop-like liquid crystals (liquid crystal component) 23, and incident light scatters.

As shown in FIG. 2(b), if voltage is applied to the pixel electrode 14, the liquid crystal molecules will be of the same direction. If the refractive index as the liquid crystal molecules 20 are oriented in a constant direction has previously been matched with the refractive index of the polymer 24, the incident light will not scatter but will emerge from the array substrate 12. Note that as described later, the PD liquid crystal does not represent only a liquid crystal in a state of waterdrop but also represents a liquid crystal whose light modulating layer is constituted by a resin area and a liquid crystal area. The light modulating method is also not limited to changes in scattering and transmission. A display panel employing a polarizing plate is also within the technical range of the present invention.

In the invention of this specification the switching elements for applying voltage to the pixel electrodes 14, in addition to thin film transistors (TFTs), may be ring diodes, 2-terminal elements such as TFDs and MIMs, barrier caps, thyristors, MOS transistors, FETs, etc. Note that they are all called thin film transistors in a wide sense. Furthermore, the switching element is one such as a plasma addressing liquid crystal (PALC) that controls voltage which is applied to a liquid crystal layer by plasma, made on an experimental basis by SONY, SHARP, etc., and an optical write method, a heat write method, and a laser write method are also included. In other words, it represents switchable structure.

Also, since the display panel 22 (corresponding to the liquid crystal display 22 in the figure) of the present inven-

tion is one in which a driver circuit and a pixel switching element are mainly formed at the same time, the technical range of the invention includes one formed by a high-temperature polysilicon technique or with a single crystal, such as a silicon wafer, in addition to one formed with a low-temperature polysilicon technique. Of course an amorphous silicon display panel is also included within the technical range. In addition, the pixel electrode 14 includes a reflection type (method) formed with thin metal film and a dielectric mirror in addition to one formed with an ITO transparent electrode.

An counter electrode 25 is formed with a transparent electrode, and the material employs, for example, indium oxide and ITO. Between the aforementioned counter electrode 25 and the pixel electrode 14 the PD liquid crystal (liquid crystal layer) 21 is interposed. It is preferable that the liquid crystal material which is employed in the display panel 22 of the present invention be a nematic liquid crystal, a smectic liquid crystal, and a cholesteric liquid crystal. The liquid crystal material may also be a single kind of liquid crystal compound or two or more kinds of liquid crystal compounds and a mixture containing substances other than a liquid crystal compound.

Note that among the aforementioned liquid crystal materials, the nematic liquid crystal of the cyanobyphenyl system whose difference between an extraordinary refractive index n_e and an ordinary refractive index n_o is relatively high, or the nematic liquid crystal of the tolane or chloride system which is stable against a change with the passage of time is preferable, and among them, the nematic liquid crystal of the tolane system is most preferable, because it has a better scattering characteristic and the change with the passage of time is also difficult to occur.

It is preferable that the resin material be a transparent polymer. The polymer employs a light-setting type of resin from the standpoint of easiness of a fabrication process and separation from a liquid crystal phase. As a specific example, there is ultraviolet setting acrylic resin. Particularly, it is preferable that the resin contain acrylic monomer and acrylic oligomer which are polymerization-set by ultraviolet radiation. Among them, the light-setting acrylic resin with a fluoric group is preferable, because it can produce the PD liquid crystal 21 whose scattering characteristic is satisfactory and the change with the passage of time is also difficult to occur.

Also, it is preferable to employ the aforementioned liquid crystal material having an ordinary refractive index n_o of 1.49 through 1.54, and among them, it is preferable to employ the liquid crystal material whose ordinary refractive index n_o is between 1.50 and 1.53. In addition, it is preferable to employ the liquid crystal material whose refractive index difference Δn is 0.20 or more and 0.30 or less. If n_o and Δn become high, the heat-resisting property and light-resisting property will become worse and the temperature dependency will become great. If n_o and Δn are low, the heat-resisting property and light-resisting property will become better, but the scattering characteristic will become low and the display contrast will become insufficient.

From the aforementioned- and the result of the examination it is preferable to employ the nematic liquid crystal of tolane system in which ordinary refractive index n_o is between 1.50 and 1.53 and Δn is 0.20 or more and 0.30 or less, as the constitutional material of the liquid crystal material of the PD liquid crystal 21, and it is also preferable to adopt the light-setting acrylic resin having a fluoric group as the resin material.

Such high polymer forming monomers are, for example, 2-ethylhexyl acrylates, 2-hydroxyethyle acrylates, neopentylglycol acrylates, hexanedioar diacrylates, diethylenegylcol diacrylates, tripropyleneglycol diacrylates, polyethylenegycol diacrylates, trimethylolpropane triacrylates, and pentaerythritol acrylates.

For the oligomer and prepolymer, polyester acrylates, epoxy acrylates, and polyurethane acrylates are given as examples.

Also, in order to perform polymerization quickly, polymerization initiator may be employed. As this example, 2-hydroxy-2-methyl-1-phenylpropane-1-on ("Darocure 1173" manufactured by Merck Co.), 1-(4-isopropylphenyl)-2-hydroxy-2-methylpropane-1-on ("Darocure 1116" manufactured by Merck Co.), 1-hydroxycyclohexaphenylketone ("Irgacure 184" manufactured Ciba-Geigy Co.), benzylmethylketal ("Irgacure 651" manufactured by Ciba-Geigy Co.), etc., are given. In addition, a chain transfer agent, a light sensitizing agent, dyes, and a cross linking agent can be properly used as arbitrary components at the same time.

Note that when the resin material is set, the refractive index n_o is made nearly equal to the ordinary refractive index n_p of the liquid crystal material. When an electric field is applied to the liquid crystal layer 21, the liquid crystal molecules 20 are oriented in one direction and the refractive index of the liquid crystal layer 21 becomes n_o. Therefore, the refractive index n_o of the liquid crystal layer 21 becomes equal to the refractive index n_p of the resin material, and liquid crystal layer 21 goes to a light transmitting state. If there is a big difference between refractive indexes n_p and n_o, the liquid crystal layer 21 will not go to a transparent state completely even if voltage is applied to the liquid crystal layer 21, and the display brightness will be reduced. The difference in refractive index between n_p and n_o is preferable to be within 0.1 and more preferable to be within 0.05.

Although the rate of the liquid crystal material in the PD liquid crystal layer 21 is not prescribed here, generally it is about 40 to 95 wt %, preferably about 60 to 90 wt %. If it is 40 wt % or less, the quantity of the liquid crystal droplet will be insufficient and the scattering effect will be unsatisfactory. Also, if it is 95 wt % or more, there will be a strong tendency that the polymers and the liquid crystal will be separated into upper and lower layers, and the rate of the interface will become small and the scattering characteristic will be reduced.

The average particle diameter of the waterdrop-like liquid crystal 23 or the average pore diameter of the polymer network is preferable to be 0.5 μm or more and 3.0 μm or less, and among them, it is more preferable to be 0.8 μm or more and 2.0 μm or less. In the case where the light which is modulated by the PD liquid crystal display panel is a short wavelength (B light, for example), the average diameter is made small. In the case of a long wavelength (R light, for example), it is made large. If the average particle diameter of the waterdrop-like liquid crystal 23 or the average pore diameter of the polymer network is large, the voltage for causing the liquid crystal layer to be in a transmitting state will become low, but the scattering characteristic will be reduced. If it is small, the scattering characteristic will be enhanced but the voltage for causing the liquid crystal layer to be in a transmitting state will become high.

The PD liquid crystal in the present invention refers to one in which liquid crystals are scattered in a waterdrop state into resin, rubber, metal particles, or ceramic (barium titanate, etc.), one in which liquid crystals fill the sponge

shape (polymer network) of the resin or the like (polymer) 24, etc. In addition, the PD liquid crystal includes one in which resin layers are stacked with each other, such as that shown in Japanese Patent Laid-Open Nos. 6-208126, 6-202085, 6-347818, 6-250600, 5-284542, and 8-179320. Also, it includes one in which liquid crystal components are sealed in a housing medium in the form of a capsule, as shown in Japanese Patent Publication No. 3-52843. Furthermore, it also includes one which dichromatic and polychromatic pigments are contained in a liquid crystal or the resin and the like 24. Also, as similar constitution, there is structure (see FIG. 28) where liquid crystal molecules 20 are oriented along a resin wall and Japanese Patent Laid-Open No. 6-347765. These are also called the PD liquid crystal. Also, the PD liquid crystal includes one in which liquid crystal molecules 20 are oriented and resin particles 301 are contained in liquid crystal layer 21. Also, a liquid crystal employing ceramic such as barium titanate instead of resin is the PD liquid crystal. Furthermore, the PD liquid crystal includes one consisting of a single liquid crystal layer or two or more liquid crystal layers.

In other words, the PD liquid crystal represents all of liquid crystals in which a light modulating layer is constituted by a liquid crystal component and other material components. The light modulating method forms an optical image by mainly employing scattering-transmission, but it is not limited to this. The method may also be one which changes a state of polarization.

Note that in the specification of the present invention, while the liquid crystal layer 21 consists of the PD liquid crystal, it is not necessarily limited to the PD liquid crystal, depending upon the constitution, function, and usage of a display panel. The liquid crystal layer 21 may be a TN liquid crystal layer, a guest-host liquid crystal layer, a homeotropic liquid crystal layer, a ferroelectric liquid crystal layer, an anti-ferroelectric liquid crystal layer, or a cholesteric liquid crystal layer. Also, the drive method of the present invention is applied to a plasma display (PDP) and an organic EL display.

The film thickness of the liquid crystal layer 21 is preferable to be in a range of 5 to 20 μm and more preferable to be in a range of 8 to 15 μm. If the film thickness is thin, the scattering characteristic will become worse and the contrast will not be obtainable. Conversely, if it is thick, high-voltage drive will have to be performed. For this reason, the design of an X driver (also called a gate driver) 492 for generating a signal which turns on and off a TFT 155 and the design of a Y driver (also called a source driver) 491 for applying a video signal to a source signal line 15 will become difficult.

The film thickness control of the liquid crystal layer 21 employs black glass beads, black glass fibers, black resin beads, or black resin fibers, as shown in FIG. 16. Particularly, since black glass beads or black glass fibers are very high in light absorption and hard, the number of beads or fibers scattered in the liquid crystal layer 21 is reduced and therefore they are preferable.

As shown in FIG. 15, it is effective to form insulating films 154 between the pixel electrode 14 and the liquid crystal layer 21 and between the liquid crystal layer 21 and the counter electrode 25. For the insulating film 154, polyimide to be employed in the orienting film of a TN liquid crystal display panel, an organic substance such as polyvinyl alcohol (PVA), and an inorganic substance such as SiO$_2$, SiN$_x$, and Ta$_2$O$_3$ are exemplified. From the standpoint of adhesion, an organic substance such as polyimide is preferable.

The rate of holding electric charges can be enhanced by forming the insulating film 154 on the electrode. For this reason, high brightness display and high contrast display can be realized.

The insulating film 154 also has an effect of preventing the liquid crystal layer 21 and the electrode from being separated from each other. The aforementioned insulating film 154 fulfills a role as an adhesive layer and a buffering layer.

Also, if the insulating film 154 is formed, there is another advantage that the pore diameters (hole diameter) of the polymer network of the liquid crystal layer 21 or the particle diameters of the waterdrop-like liquid crystals become nearly even. It is believed that this is because even if organic substances remain on the counter electrode 25 and the pixel electrode 14, they will be covered with the insulating film 154. The covering effect is satisfactory in PVA than in polyimide. It is believed that this is because PVA is higher in wettability than polyimide. However, in the result of the reliability (light-resisting property, heat-resisting property, etc.) test of various insulating films 154 formed on the panel, the display panel on which polyimide to be employed in the orienting film of a TN liquid crystal was formed is satisfactory because there is almost no change with the passage of time. In the PVA, the holding rate tends to reduce.

Note that when forming the insulating film 154 with an organic substance, the film thickness is preferable to be in a range of 0.02 μm or more and 0.1 μm or less and, furthermore, more preferable to be 0.03 μm or more and 0.08 μm or less.

The counter substrate 11 and the array substrate 12 employ soda glass and silica glass substrates. In addition, they can also employ metal substrates, ceramic substrates, single crystal silicon substrates, and polycrystal silicon substrates. Also, they can employ resin film such as polyester film and PVA film.

FIG. 1 is an explanatory diagram of the liquid display panel of the present invention. The array substrate 12 is formed with pixel electrodes 14 consisting of ITO, source signal lines 15, gate signal lines (not shown), TFTS, and so on.

A low dielectric film 16 is formed on the source signal line 15, etc. This explanatory diagram is shown in FIG. 6. In the PD liquid crystal display panel 22 it is also important to prevent electromagnetic coupling between the source signal line 15, etc., and the pixel electrode 14. To the source signal line 15 an AC current is applied at all times. Therefore, between the pixel electrode 14 and the source signal line 15 an electric force line 19 is produced. On this electric force line 19 the liquid crystal molecules 20 are oriented, and "light escape" from the peripheral portion of the pixel electrode 14 occurs.

As the countermeasure, the source signal line 15, the gate signal line, and the vicinities of the signal lines are sealed with material (hereinafter referred to as low dielectric material) lower than the dielectric constant of the liquid crystal layer 21. For the low dielectric material, inorganic material such as SiO$_2$ and SiN$_x$, the polymer 24 of the liquid crystal layer 21, resist, and organic material such as polyvinyl alcohol (PVA) are exemplified.

As shown in FIG. 6, if the aforementioned low dielectric material is formed into a thin film shape or a thick film shape, the electromagnetic coupling between the signal line 15 and the pixel electrode 14 can be prevented. Of course, since the electromagnetic coupling between the signal line 15 and the counter electrode 25 can also be prevented, the

liquid crystal layer **21** on the low dielectric film **16** will almost always go to a scattering state.

In FIG. **6**, while the low dielectric material has been formed into a film shape, the present invention is not limited to this, but it may be formed into a column shape as shown in FIG. **7**. If it is formed into a column shape to make it the same as the film thickness of the liquid crystal layer **21**, the film thickness of the liquid crystal can be made a prescribed value without using beads.

The reason that the low dielectric column of the panel and the low dielectric film **16** can be easily formed is that the PD liquid crystal display panel does not need an orienting process such as a rubbing process which is required of the TN liquid crystal display panel. If the low dielectric column and the low dielectric film **16** have been formed, a rubbing cloth will be caught on the low dielectric column and low dielectric film **16** during the rubbing process, and the surfaces of the counter substrate **11** and the array substrate **12** cannot be rubbed well. For this reason a manufacturing defect will easily occur.

The low dielectric film **16** or the low dielectric column may be colored. If it is colored, it can absorb light irregularly reflected within the liquid crystal layer **21** and image quality will be enhanced. Black colors or pigments may be dispersed into resin. Like a color filter, gelatin or casein may also be colored with black acid dyes. As an example of the black colors, a fluorine color which becomes black by itself can be caused to emit a color and employed, and a mixed black consisting of a green color and a red color can also be employed.

On the counter substrate **11** the counter electrodes **25** are formed in the shape of stripes. In FIG. **1**, while the aforementioned counter electrodes **25** are formed along the source signal lines **15** by way of an example, the present invention is not limited to this example but they may be formed along the gate signal lines.

The end of the counter electrode **25** is formed with a light shielding film **18** consisting of Cr or Al. The film thickness is 1000 angstroms or more and 5000 angstroms or less. Also, it may be constituted into a multilayer consisting of Ti, Al, and Cr.

The light shielding film **18** is for preventing the light escape which occurs near a transverse electric field wire **17**. Near the transverse electric field wire **17** the liquid crystal molecules **20** are oriented at an angle perpendicular or nearly perpendicular to the counter substrate **11**. For this reason, the ordinary refractive index of the liquid crystal molecule **20** approaches n_o, and the difference between the refractive index of the liquid crystal and the refractive index n_p of the polymer **24** becomes small. In other words, since the liquid crystal layer **21** goes to a light transmitting state, light escape occurs. The light shielding film **18** shuts out light near to the transverse electric field wire **17**. The light shielding film **18** also has a role to reduce the resistance value of the counter electrode **25**. In the embodiment of FIG. **1**, since the counter electrodes **25** are cut in the shape of stripes, the resistance value becomes high. Normally, since the counter electrode **25** consists of ITO, the resistance value is high. If a portion of the light shielding film **18** is formed with metal material, the resistance value of the counter electrode **25** can be reduced.

The transverse electric field wire **17** may be formed with transparent material such as ITO. However, it is preferable that the transverse electric wire **17** be formed from a single kind of metal material or various kinds of stacked metal materials in order to reduce the resistance value, as with the

source signal line **15**. The thickness is at least 1000 angstroms or more, preferably 0.5 μm or more. Note that since almost no current flows through the transverse electric field wire **17**, the resistance value is allowed to be somewhat high. For the forming material, Ti, Al, Cr, molybdenum, tantalum molybdenum, etc., are exemplified.

If positive and negative voltages are applied to the transverse electric field wire **17**, electric force lines **19** will be produced in the liquid crystal layer **21**, as shown in FIG. **1**. The electric force lines **19** are produced parallel to the counter substrate **11** and the array substrate **12**. If the electric force lines **19** are produced, the liquid crystal molecules **20** will be oriented along the aforementioned electric force lines.

As also shown in FIG. **3**(*a*), in the case where the liquid crystal molecule **20** is material with a positive dielectric constant, it shows an extraordinary refractive index n_e in the major axis and an ordinary refractive index n_o in the minor axis. If the electric field (electric force line) **19** is applied to the liquid crystal layer **21**, the liquid crystal molecules **20** within the waterdrop-like liquid crystal **23** will be arranged in one direction in accordance with the electric field strength, as shown in FIG. **3**(*b*). If the electric field strength is weak, the liquid crystal molecules **20** will be in a randomly oriented state. If it becomes stronger, the liquid crystal molecules **20** will be oriented along the electric force line **19**.

In FIG. **3**(*b*) electric force lines are produced in a direction of aa'. Therefore, the liquid crystal molecule **20** is arranged with the major axis aligned with in the aa' direction in which the electric force line is produced. Now, if it is assumed that the rate of the polymer material **24** to the liquid crystal material is low and negligible, the refractive index of the liquid crystal layer **21** (as seen in a direction perpendicular to the array substrate **12**) will be n_e with respect to the polarization in the aa' direction, and the refractive index of the liquid crystal layer **21** will be n_o with respect to the polarization in the bb' direction. Therefore, ideally a refractive index of $(n_o + n_e)/2$ is obtained with respect to natural light.

In the case where the liquid crystal layer **21** is not oriented as shown in FIG. **3**(*b*) and also is in a no-electric field state, the liquid crystal molecules **20** are arranged three-dimensionally and randomly. Ideally, the refractive index at that time becomes $(2n_o + n_e)/3$. If a calculation is made with $n_o = 1.52$ and $n_e = 1.6$, it is found that the liquid crystal layer **21** in FIG. **3**(*b*) is higher in refractive index than the liquid crystal layer **21** in the no-electric field state.

In the case of the PD liquid crystal display panel, the scattering performance is enhanced as the difference in refractive index between the polymer **24** and the liquid crystal component becomes large. Therefore, the display contrast becomes high. In FIG. **5** the transmittance (T)-voltage (V) curve (called a T-V curve) is conceptually shown. A dotted line represents the case of the PD liquid crystal display panel having the constitution of the transverse electric field wire **17**, and a solid line represents the case of the PD liquid crystal display panel having no transverse electric field wire **17**. If the PD liquid crystal display panel has the transverse electric field wire **17**, the voltage to be applied to the pixel electrode **14** will tend to become somewhat high. However, sinking of a black color (small transmittance) can be realized, and display contrast can be considerably improved.

FIG. **4** is an explanatory diagram for more specifically explaining the operation of the transverse electric field wire

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17. The counter electrodes 25 are in the form of a plurality of stripes on the display area of the liquid crystal display panel, but they are connected to one at the peripheral portion. Also, the electric potential of the counter electrode 25 is connected to ground (GND).

The transverse electric field wires 17 alternately extend horizontally. They are made into one and connected to a signal source 41. Therefore, between the transverse electric field wires 17a and 17b an electric force line is produced by the output voltage of the signal source 41. The signal source 41 normally outputs a rectangular wave. The amplitude value of the rectangular wave is increased in proportion to pixel size.

The display of an image on the liquid crystal display panel 22 of the present invention is performed by applying voltage corresponding to a video signal to each pixel electrode 14. As the electric field between the counter electrode 25 and the pixel electrode 14 becomes stronger, the transmittance is enhanced. Conversely, if the electric field is small, the degree of scattering will become strong and black display will be obtained.

FIG. 7 is a sectional view of the liquid crystal display panel 22 in another embodiment of the present invention. A transverse electric field wire 17 is formed on an insulating film 71 so that it does contact a counter electrode 25. The insulating film 71 needs to have a thickness of at least 2000 angstroms or more. This is for preventing a short circuit between the wire 17 and the counter electrode 25. Also, in the case where Al is employed as the transverse electric field wire 17, attention is needed. This is because if the ITO of the counter electrode 25 contacts Al, a "battery" will be produced and cause corrosion. Therefore, in the case where Al is employed, sufficient attention must be paid to the occurrence of a pinhole in the insulating film 71. Preferably, the transverse electric field wire should use Cr or it should be constituted by a multilayer consisting Ti, Al, and Cr.

In the display panel of the present invention of the embodiment shown in FIG. 7, since the counter electrode 25 is a solid electrode (i.e., since the counter electrode 25 is not patterned into a stripe shape as in FIG. 1), the resistance value is sufficiently low. The rest constitution is the same as the embodiment of FIG. 1 and therefore a description thereof is omitted.

Note that in the specification of the present invention, in the case where components are the same or similar, a description thereof is omitted. Also, the same reference numerals denote the same or similar components. Furthermore, the matters described in the specification are applied to all drawings and contents. For example, the contents related to the PD liquid crystal 21 can be all applied to the embodiments of the present invention. The drawings are enlarged, reduced, and deformed for making a description easy.

In the constitution of FIG. 8 a transverse electric field wire 17 is formed on a source signal line 15 through a low dielectric film 16. The transverse electric field wire 17 is formed wider than that of the embodiment shown in FIG. 1. The reason for this is that the transverse electric field wire 17 is caused to have a "shielding effects which prevents the electric field, which occurs from the source signal line 15 to which a video signal is being applied, from reaching the liquid crystal layer 21. To make the "shielding effect" satisfactory, the width of the transverse electric field wire 17 is wider than that of the source signal line 15.

In the constitution of FIG. 8, the transverse electric field wire has the shielding effect and can realize stable display

having no image noise. However, the film thickness of the low dielectric film 16 needs to be made as thick as possible. The film thickness is made at least 0.5 μm or more, preferably 1 μm or more. This is because if the film thickness is thin, a capacitor will be formed between the source signal line 15 and the transverse electric field wire 17, and consequently, parasitic capacity will become large and load to the source driver circuit will be increased.

FIG. 9 shows the constitution where a transverse electric field wire 17 is formed on approximately the central portion of a pixel electrode 14. As with FIG. 7, an insulating film 71 is interposed between the wire 17 and a counter electrode 25 so that the wire 17 and the counter electrode 25 do not contact each other. The insulating film 71 is made wide as shown in FIG. 9 and formed above the entire area of the pixel electrode 14.

If constituted as described above, an electric force line 19 will occur between the counter electrode 25 and the transverse electric field wire 17, as well. For this reason, the rate of the liquid crystal molecules 20 oriented in a direction parallel to a counter substrate 11 is increased and the display contrast effect can be enhanced.

FIG. 10 shows the constitution where transverse electric field wires 17 are formed along two edges of a pixel electrode 14 on a counter substrate 11. Note that the transverse electric field wires 17 are not limited only to the counter substrate 11. It is a matter of course that the transverse electric field conductors may be formed on an array substrate 12 or on both the counter substrate 11 and the array substrate 12. The position of the pixel electrode 14 is represented by a dotted line.

As shown in FIG. 10, if the transverse electric field wires 17 are formed, an electric force line 19 will be produced in an oblique direction relative to the pixel electrode 14. Therefore, liquid crystal molecules 20 will also be oriented in an oblique direction. Also, the strength of the occurrence of the transverse electric field becomes strong and satisfactory display contrast can be realized.

FIG. 11 is a constitution diagram in which transverse electric field wires are formed both in the formation directions of gate signal lines and in the formation directions of source signal lines. The formation directions of the gate signal lines are assumed to be directions of 17c and 17d, and the formation directions of the source signal lines are assumed to be directions of 17a and 17b. On the intersections, insulating films are formed so that the transverse electric field wires 17c and 17d do not electrically contact the transverse electric field wires 17a and 17b.

Signal sources 41a and 41b output a rectangular wave or a sine wave. The amplitude of the aforementioned signal is increased in proportion to the space between the transverse electric field wires 17c and 17d and between the transverse electric field wires 17a and 17b. The reason for this is that if the space is wide, a strong electric field will be required to orient liquid crystal molecules 20.

Note that in the aforementioned embodiment, while the transverse electric field wire 17 has been formed so as to surround a single pixel, the present invention is not limited to this. As shown in FIG. 12, it is a matter of course that a single transverse electric field wire 17 may be arranged at an interval of 2 pixels or at an interval of 3 or more pixels.

Each pixel electrode 14 is formed with a TFT which serves as a switching device. Also, the TFT is formed with a light shielding film. The light shielding film is mainly for preventing the light scattered at a liquid crystal layer 21 from being incident on the semiconductor layer of the TFT. If

light is incident on the semiconductor, it will cause a photoconductor phenomenon due to which the TFT does not go to an OFF state or the OFF resistance of the TFT is reduced. For material for forming the light shielding film, acrylic resin with carbons scattered therein is exemplified. Also, various kinds of prime color pigment(red, green, blue, cyan, magenta, and yellow colors) may be optimally mixed together. Also, there is a method of forming an insulating thin film such as SiO_2 film on a TFT and then patterning and forming a thin metal film as a light shielding film on the insulating thin film. In addition, there is a method of depositing amorphous silicon thick to make a light shielding film. Additionally, it is preferable that the TFT adopt the inverted stagger structure in which the semiconductor layer is formed under the gate.

Note that in the PD liquid crystal display panel it is preferable that the switching device, such as a TFT, is formed by a polysilicon technique to prevent the occurrence of the photoconductor phenomenon. The polysilicon technique includes a high-temperature polysilicon technique which is a semiconductor technique for fabricating normal integrated circuits (ICs) and also includes a low-temperature polysilicon technique for forming an amorphous silicon film recently being developed and then crystallizing the amorphous silicon film. Particularly, it is preferable to form TFTs with the low-temperature polysilicon technique which can form a driver circuit directly on the array substrate 12 and also has a possibility of being able to fabricate panels at low cost. In the TFT formed with the aforementioned techniques, the occurrence of the photoconductor phenomenon is considerably reduced as compared with the TFT formed with the amorphous silicon technique which has presently put to practical use in portable televisions. For this reason it is most suitable for the PD liquid crystal display panel which performs light modulation by scattering-transmittance.

A description will hereinafter be made of the display panel of another embodiment of the present invention, referring to the drawings. FIG. 15 is a sectional diagram of the liquid crystal display panel of the present invention. An array substrate 12 is formed with pixel electrodes 14 consisting of ITO, source signal lines (not shown), gate signal lines (not shown), TFTs 155, etc.

On the TFT 155 a light shielding film consisting of resin (resin light shielding film) 152 is formed. The reason why it is formed with resin is for enhancing the adhesion between a liquid crystal layer 21 and the array substrate 12. For the resin, acrylic resin containing carbons and titanium dioxide and acrylic resin colored with colors and dyes are exemplified. Also, the light shielding film 152 may be formed with a composite film (two-layer chrome) consisting of metal chrome and chromium oxide.

Also, the reason that the light shielding film 152 is formed on the switching device such as the TFT 155 is for preventing light from entering the semiconductor layer of the TFT and MIM. If light enters, the photoconductor phenomenon will occur in the switching device such as the TFT 155 and the ON-OFF characteristic of the switching device will be degraded. If the light shielding film 152 is formed, there will be no possibility that light will be incident from the liquid crystal layer 21 on the aforementioned semiconductor layer.

The light shielding film 152 also has an effect of preventing light halation which occurs within the liquid crystal layer 21. The PD liquid crystal display panel scatters incident light, thereby performing light modulation (an optical image is formed). However, the scattered light is reflected at the interface between the panel and air and reflects irregularly

within the panel 22. The irregularly reflected light is causative of contrast degradation in the display panel 22.

The light shielding film 152 absorbs the aforementioned irregularly reflected light. For this reason the display contrast is enhanced. Therefore, the light shielding film 152 should be formed with material which absorbs incident light. The light shielding film for absorbing the aforementioned light is easily realizable by mixing carbon with resin. Also, from the standpoint of preventing irregular reflection, the light shielding film 152 should be formed on an area as wide as possible, such as an area (excluding an area present on the pixel electrode 14, i.e., an area between adjacent pixel electrodes and an area on the signal line) through which effective light for image display does not pass.

On the counter electrode 25 a color filter 151 is formed. For the color filter 151, there is exemplified a filter which is colored by employing dyes and colors in gelatin is exemplified. It is called a resin color filter. Also, light-setting type acrylic resin may be colored. In addition, there is exemplified a filter in which dielectric thin films consisting of inorganic materials having low and high refractive indexes are stacked in layers. It is called a dielectric color filter. The low refractive index layer employs either one of MgF_2, SiO_2, or Al_2O_3. The high refractive index layer employs TiO_2, ZnS, CeO_3, $ZrTiO_4$, HfO_2, Ta_2O_5, ZrO_2, and so on. If the optical film thicknesses of these dielectric films are adjusted according to the red, green, and blue of the color filter, a spectral characteristic which transmits required light will be obtained. This principle is well known and has been applied to dichroic mirrors, etc. In the color filter, attention should be paid to red color purity. If red color purity is insufficient, an image will become whitish and display quality will be reduced. It is preferable that the red color filter 151 employ a dielectric color filter and that the blue and green color filters employ an inexpensive resin color filter. The dielectric color filter is formed in correspondence with the shape of the pixel electrode by etching, and the resin color filter is formed by employing a technique such as printing.

In the case where the liquid crystal display panel 22 is a transmission type, the color filter 151 is constituted so that it selects and transmits a red (R) color, a green (G) color, or a blue (B) color. The same may be said of the case where the liquid crystal display panel 22 is a reflection type (for example, case where the pixel electrode 14 is formed with metal material, case where it is formed with a dielectric mirror, etc.). Note that the color of the color filter 151 is not limited to three colors, red, green, and blue. For example, the color filter 151 may be constituted so that it selects cyanogen, magenta, or yellow colors and then transmits or reflects the selected color.

The method of forming the resin color filter may be any of a coloring method, a printing method, an electrodeposition method, and a colorant method, but, for high photosensitive resin, a colorant method employing photo polymerization type acrylic or optical bridging type PVA is a suitable one.

Note that the display panel of the present invention will be described, taking as an example an active matrix display panel in which pixel electrodes 14 are arranged in the form of a matrix. However, the present invention is not limited to the active matrix display panel. The technical idea of the present invention described in this specification is also applicable to a method which does not have pixel electrodes clearly. For example, it is applicable to a simple matrix type display panel, a light write type display panel and a heat

write type display panel with no pixel electrodes, and a laser write type display panel. The display panel of the present invention may not be only a liquid crystal display panel but it may also be a display panel employing PLZT as a light modulating layer, an inorganic EL panel, an organic EL display panel, and a plasma display panel (PDP).

On the color filter **151** a protective film **153** is formed. The protective film **153** is formed for preventing the color filter **151** from being destroyed mechanically. It is also formed for preventing an entry of water to the liquid crystal layer **21**. For the material for forming the protective film, phenol resin, epoxy resin, acrylic light setting resin, urethane resin, silicon resin, rubber, etc., are exemplified. It may also be inorganic thin film such as SiO_2 film. Among them, acrylic light setting resin is suitable resin, because it can be easily coated by a spinner technique and a roller coater technique and a hardness of 4H or more is also obtained. Setting the resin is also easy because it can be performed only by radiating ultraviolet rays or visible light.

Note that it is preferable that the surface of the color filter **151** be given appropriate irregularities. This is called an embossing process. The reason for this is that light is reflected at the surface of the color filter **151** and the exterior can be prevented from changing. The irregularities on the surface are formed in a range of about 5 to 200 μm. Also, it is preferable that a thin film (not shown) with a refractive index of 1.55 to 1.85 be formed between the color filter **151** and the counter electrode **25**. If the thin film is formed, reflected light can be reduced.

A description will hereinafter be made of the fabrication method of the display panel, referring to FIG. **31**. FIG. **31** is an explanatory diagram of the fabrication method of the display panel of the present invention. Between the array substrate **12** and a separating film **182** which serves as separation means, a mixed solution **315** consisting of ultraviolet setting resin which is a sort of light setting resin and a liquid crystal component is held. Note that between the separating film **182** and the array substrate **12**, spacers and fibers are previously scattered or they are previously mixed with the mixed solution **315**. For the separating film **182**, silicon resin film, fluororesin film, and olefinic resin film such as polyethylene and polypropylene films are exemplified, and silicon resin and fluororesin, coated on the surface of resin film, are exemplified. Even in the case of the other materials, they can be adopted if they transmit ultraviolet rays and have a certain degree of flexibility. For example, glass substrates can also be employed.

Note that while the resin component of the mixed solution **315** employs ultraviolet setting resin, the present invention is not limited to this resin. The resin component may be a solution containing acrylic resin which is set by visible light, double-fluid setting resin such as epoxy resin, heat setting resin, or rubber resin. In other words, it will be sufficient if it can be phase-separated from a liquid crystal.

As an example, the components of the mixed solution **315** are as follows:

  (1) Liquid crystal: E-7 (manufactured by BDH) (80 wt %)
  (2) Ultraviolet setting resin: Mixture consisting of poly-ester acrylate (1.8 wt %) and 2-ethylhexyl acrylate (18 wt %)
  (3) Light setting initiator: Darocure 1173 (manufactured by MERCK) (0.2 wt %)

If ultraviolet rays are radiated to the aforementioned mixed solution **315**, a bridging reaction will occur within the light setting resin. With this bridging reaction, the liquid crystal component and the light setting resin component are

phase-separated from each other, and liquid crystal droplets are scattered into the light setting resin. At the same time, the light setting resin is set.

A description will next be made of tests performed to investigate the relation between the radiation quantity of light to the light setting resin and the average particle diameter of the liquid crystal.

The ultraviolet radiation quantities of the light setting resin are 100, 200, 300, 400, 500, 1000, 2000, and 2500 mJ/cm^2.

These liquid crystal display panels have been observed with a microscope, and it has been confirmed that in the liquid crystal display panel radiated only with ultraviolet rays of 400 mJ/cm^2 or less in the setting process, the average particle diameter of the liquid crystal has been increased to 5.5 μm or more and, in the liquid crystal display panel radiated with ultraviolet rays of 500 mJ/cm^2 or more in the setting process, the average particle diameter of the liquid crystal has been reduced to 1.0 to 3.0 μm. The measurement results of the contrasts of these liquid crystal display panels and the average particle diameter of the liquid crystal are shown in Table 1.

TABLE 1

Ultraviolet ray radiation quantity (mJ/cm^2)	100	200	300	400	500	1000	2000	2500
Contrast		25	37	46	51	98	108	110	110
Average particle diameter of a liquid crystal droplet (μm)	15.5	10.5	8.0	5.5	2.4	1.6	1.0	0.8

In the aforementioned embodiments, while a mixture consisting of polyester acrylate and 2-ethylhexyl acrylate has been employed as light setting resin, it may consist of 2-hydroxy-ethyl acrylate and trimethylol-propane triacry-late. Also, instead of light setting resin, heat setting resin may be employed to perform reaction by heat. In that case, when novolak heat setting resin is employed, hexamethyl-lenediamine (hexamine) can be employed as a setting agent.

Also, the liquid crystal may be E-8 (manufactured by BDH), ZLI 4792(manufactured by Merck Co.), or TL 202 (manufactured by Merck Co.), and the polymerization ini-tiator may be IRGACUA 184 (manufactured by Ciba-Geigy) or Irgacure 651 (manufactured by ciba-Geigy).

The aforementioned is the light radiation conditions, and it is a matter of course that the film thickness of the layer of the mixed solution **315** must be made even before light radiation. For this reason, as shown in FIG. **31**, after the mixed solution **315** has been held between the array sub-strate **12** and the separating film **182**, it is sandwiched between rollers **312a** and **312b** and the thickness is made even. Also, it is effective to vibrate the roller **312** with an ultrasonic wave to obtain satisfactory film thickness.

By holding the mixed solution **315** between the separating film **182** and the array substrate **12** and then vibrating the solution between the separating film **182** and the array substrate **12** with an ultrasonic wave, the film thickness of the liquid crystal layer **21** becomes even. In addition, the force that is given between the separating film **182** and the array substrate **12** is reduced.

The separating film **182** is sequentially supplied from a supply roller **313** and collected by a take-up roller **314**. After the film thickness of the liquid crystal layer **21** has been formed at a predetermined value with the roller **312**, ultra-

violet rays are radiated by light radiation means **311** and the mixed solution **315** is phase-separated from the liquid crystal layer **21**, thereby obtaining the PD liquid crystal layer **21**.

The light radiation means **311** is a high-pressure mercury lamp as an example and is an excimer laser (XeCl, etc.). From the light radiation means **311** light is radiated in the form of a line or a spot on the mixed solution **315**.

The range in which light is radiated by the light radiation means **311** is the size of the pixel and the overlapped portion (indicated by oblique lines) is between the pixel electrodes **14** as shown in FIG. **32**. The reason for this is that since light is radiated twice, the phase separation condition is not proper in the range indicated by oblique lines of FIG. **32**. Since the portion between the pixel electrodes **14** (i.e., portion on the source signal line **15**) makes no contribution to light modulation, the phase separation condition does not need to be proper. Of course the mixed solution **315** may be phase-separated, by employing a sheet of glass substrate or resin substrate instead of the separating film **182** and radiating ultraviolet rays (or visible light) on the entire display range at a time through the aforementioned substrate. In other words, after the film thickness of the mixed solution **315** has been made even over the entire panel **22**, it may be phase-separated by radiating ultraviolet rays over the entire panel. For the radiation condition, ultraviolet rays are radiated for 5 minutes at 50 mW/cm^2 with an extra-high pressure mercury lamp (trade name: CHM-3000, manufactured by OHKU).

The ultraviolet rays that are radiated are cut at 350 nm or less. This is because a wavelength of 350 nm or less degrades the liquid crystal component. For this reason the light emitted from the mercury lamp is radiated on the mixed solution through an ultraviolet cut filter (trade name: ultraviolet ray-35, manufactured by Toshiba). Also, it is preferable to cut infrared rays (whose wavelength is 0.8 μm or more) at the time of phase separation. For the infrared cut filter, a trade name of HAF-50S-30H (manufactured by SIGMA KOHKI) is exemplified.

After phase separation of the mixed solution **315**, the separating film **182** is removed from the light modulating layer (liquid crystal layer) **21**. Thereafter, ITO is deposited, thereby forming a counter electrode **25** on the light modulating layer **21**. As occasion demands, an insulating film **154** consisting of PVA is formed on the light modulating layer **21** and then the counter electrode **25** is formed.

Note that in the case of a black-and-white display panel, there is no need to form the color filter **151** on the counter electrode **25**. However, it is a matter of course that in the case of color display, there is a need to form the color filter **151** on the counter electrode **25**. For the arrangement of the color filters **151**, there are three kinds: mosaic form, triangle form, and stripe form. All of them may be applied to the display panel of the present invention. Note that the three kinds, mosaic form, triangle form, and stripe form are generically called mosaic form.

When forming the color filter **151** on the counter electrode **25**, it is preferable to form a protective layer (not shown) on the counter electrode **25**. As the protective layer, urethane resin, ultraviolet setting resin, acrylic resin, and styrene resin are exemplified. Among them, it is preferable to employ urethane resin.

On the color filter **151** the aforementioned protective layer (protective film) **153** is formed. It is preferable that the protective layer **153** employ acrylic ultraviolet setting resin. The aforementioned color filter **151** prevents the change in quality, degradation, and destruction of the PD liquid crystal layer **21**. Acrylic ultraviolet setting resin has a hardness of

about 4H. Therefore, there is no possibility that there will be a scratch on the color filter **151**.

In the aforementioned fabrication method, light from the extra-high pressure mercury lamp, as it is, is radiated on the mixed solution **315**, and the ultraviolet light and infrared light in an unnecessary range are cut with a filter. FIG. **18** is a diagram showing a method of radiating ultraviolet rays through a mask **181**.

The mask **181** is formed with a portion A in which the transmittance of ultraviolet rays is high and a portion B in which the transmittance is low. The portion whose transmittance is low can be easily formed by depositing a film of Cr onto the mask **181** and patterning it. The transmittance of ultraviolet light (visible light) can be freely set by adjusting the film thickness of the deposited film consisting of Cr.

The average particle diameter of the waterdrop-like liquid crystal of the PD liquid crystal or the average pore diameter of the polymer network varies with the radiation strength of ultraviolet rays. Note that the average particle diameter and the average pore diameter will hereinafter be generically referred to as an average diameter. Generally, if the radiation quantity of ultraviolet rays is increased, the average diameter will become smaller. If the radiation quantity of ultraviolet rays is reduced, the average diameter will be increased. If the average diameter becomes smaller, the voltage required to obtain a light transmitting state will become high, and if it is large, the voltage will become low. On the other hand, if the average diameter is small, the scattering characteristic will become high, and if it is large, the scattering characteristic will become low. Therefore, the average diameter has to be set so that the drive voltage and the scattering characteristic are adaptable at a required value.

As shown in FIG. **18**, the mask **181** is arranged so that the space between adjacent pixel electrodes **14** is positioned under the A portion of the mask **181** and the pixel electrode **14** is positioned under the B portion of the mask **181**. In this state, if ultraviolet rays are radiated, the state shown in FIG. **17** will be obtained. In the liquid crystal layer **21**b between the pixel electrodes **14**a and **14**b, the average diameter becomes small (0.8 μm or less). On the pixel electrode **14** the average diameter reaches a proper value (0.8 μm to 1.5 μm). The liquid crystal layer **21**a on the pixel electrode **14**a goes to a sufficient transparent state by a voltage application of 6 to 8 V. However, the liquid crystal layer **21**b will not almost go to a light transmitting state even if a voltage of 6 to 8 V is applied. In other words, the liquid crystal layer **21**b is in a scattering state (black display) at all times. This is convenient. The reason for this is that if black display is performed between the pixel electrodes **14**, it will function as a light shielding film (BM).

Also, in order to completely prevent leakage of light from the neighborhood of the signal line **15** and the space between the pixel electrodes **14**, a resin light shielding film **152** is formed as shown in FIG. **16**. The reason that resin is employed is for preventing separation between the PD liquid crystal layer **21** and the array substrate **12**.

If the mask **181** is employed, a liquid crystal layer **21** such as that shown in FIG. **28** can also be formed. In FIG. **28**, **24** denotes an area containing a great quantity of resin component (or an area including only resin) and **23** an area containing a great quantity of liquid crystal component (or an area including only liquid crystal). The liquid crystal molecules **20** in the liquid crystal component **23** are oriented along the wall surface of the resin **24**.

The A portion of the mask **181** transmits ultraviolet rays without considerably attenuating them, while the B portion reduces ultraviolet rays considerably or does not transmit

them. For this reason, the resin component of the mixed solution **315** present under the A portion begins to set, pulls in the peripheral resin, and pushes out the liquid crystal component to another portion. For this reason, it is believed that the area **24** containing a large quantity of resin component will form into a dome shape. In other words, the portion on the pixel electrode **14** almost forms a liquid crystal component. Such liquid crystal layer construction is also the PD liquid crystal defined by the present invention.

In the aforementioned embodiments, while light from the extra-high pressure mercury lamp is radiated on the mixed solution **315**, a laser may be employed. FIG. **33** is an explanatory diagram of a method of radiating laser light **291** on the mixed solution **315** to perform phase separation. A mask **181a** is formed with red, green, and blue filters **331**. The filters **331** are arranged in mosaic form, as shown in FIG. **34**. The filters **331** are also arranged so that they correspond to pixels. For the laser light **291**, white laser light is exemplified. As shown in FIG. **29** or FIG. **33**, if two laser light beams **291** are incident through the front surface or back surface of the display panel, they will interfere with each other and light strength will occur in the form of fringes. In the portion where light is strong, resin sets and the refractive index becomes low. In the portion where light is weak, the liquid crystal component is increased and the refractive index becomes high. Therefore, portions whose refractive index is high and portions whose refractive index is low are alternately arranged in layers. For this reason, an interference effect occurs and the PD liquid crystal layer **21** has the property that light with a specific wavelength is transmitted or reflected. Such a multilayered constitution is also the PD liquid crystal layer.

Even if two argon ion laser light beams of the same wavelength are employed, the PD liquid crystal layer **21** can be formed. One laser light beam is used as an object light beam, while the other is used as a reference light beam. This object light beam is caused to be incident through a first transparent substrate **11**, and the reference light beam which is the same laser light beam is caused to be incident through a second transparent substrate **12**. The object light beam and the reference light beam produce interference patterns. In the mixed solution **315**, photo polymerization is started at a portion whose interference light strength is high, and a high polymer phase with three-dimensional structure is formed. The liquid crystal phases are oriented nearly randomly and present in the three-dimensional structure of the high polymer phase.

At the time a laser light radiation of about 50 mJ/cm² has been performed and the aforementioned polymerization process has advanced, the laser light radiation is stopped. Then, even ultraviolet rays are radiated on the PD liquid crystal layer at a rate of about 500 mJ/cm². The entire layer is sufficiently polymerized and then the polymerization process is completed.

The PD liquid crystal layer **21** fabricated by such a method has a function of reflecting and scattering toward the side of an observer the illuminating light incident from the side of the observer with very high efficiency, because the three-dimensional structure of the high polymer phase is controlled as a reflection type hologram. In this embodiment the illuminating light with a wavelength of near 458 nm can be reflected and scattered with an efficiency of 90% or more and observed in a wide angle range. In the pixels to which a voltage of about 30 V is applied, since the liquid crystal molecules **20** are arranged in order, the aforementioned reflecting and scattering function disappears and therefore the liquid crystal layer becomes transparent.

According to this embodiment, as previously described, the structures of the liquid crystal phase and the high polymer phase of the PD liquid crystal layer **21** are controlled as reflection type hologram patterns, so a liquid crystal display panel with high contrast and a wide angle of visibility can be realized by the high backward scattering property.

To make pixels which select and reflect light in three wavelength bands on the same display panel, the following process is carried out.

With a mask, a hologram pattern which reflects light in a first wavelength band is made by laser light having a wavelength of 458 nm. Then, the mask is shifted one pitch, and a hologram pattern which reflects light in a second wavelength band is made by laser light having a wavelength of 514 nm. Finally, the mask is shifted further one pitch, and a hologram pattern which reflects light in a third wavelength band is made by laser light having a wavelength of 648 nm.

Each pattern is aligned with the position of a transparent electrode constituting a pixel, and R, G, and B pixels are arranged in mosaic form, as shown in FIG. **34**. The PD liquid crystal layer **21**, constituted in this manner, looks to be a white scattering surface to look at it. However, if voltage is applied to each pixel and the transmittance is changed, three colors, red, green, and blue will be observed, whereby a color image can be constituted.

Furthermore, in addition to the fabrication method using photo polymerization by laser light, described in the aforementioned embodiment, the light modulating layer **21** of the display panel of the present invention can be fabricated with various methods. It can be fabricated even by employing photosensitive resin, performing a developing process to make an interference fringe consisting of a resin layer and an air layer in the resin, and filling the interference fringe with a liquid crystal.

The example of an optical switch made by the latter method has been reported by Lawrence Domash ("Active Holographic Interconnects for Interfacing Volume Storage," SPIE Vol. 1662, p 211 (1992)). This is also the PD liquid crystal layer.

The monomer suitable for making the light modulating layer **21** having an interference effect by the aforementioned photo polymerization method can employ a liquid or low-melting-point unsaturated ethylene monomer, particularly acrylic or methacrylic esters. These may be, for example, multifunctional monomers such as trimethylolpropane triacrylates, or oligomers such as polyethylenegylcol diacrylates and urethane acrylates. These may be employed independently of each other or a combination of them can be employed. Furthermore, as occasion demands, other monomers, for example, styrene and carbazole may be employed together with the aforementioned.

The present invention is not limited to these monomers and oligomers. This invention can appropriately select and employ various monomers and oligomers known to those skilled in the art, such as monomers and oligomers usually employed for fabricating a polymer dispersion type liquid crystal or a photo polymerized compound for making a volume hologram such as that proposed in Japanese Patent Laid-Open No. 2-3082.

To perform photo polymerization by coherent light, a sensitizing color corresponding to the wavelength and an appropriate photo polymerization initiator are needed. They can be appropriately selected and employed from cyanide dyes, dyes such as cyclopentanes, diphenyl iodonium salt, a combination of the diphenyl iodonium salt and dyes, various quinones, and various combinations such as a combination of a triphenylimidazole dimer and hydrogen donors.

In addition, as shown in FIG. **30**, the PD liquid crystal layer includes one in which resin particles **301** float or are arranged in liquid crystals **302** of a liquid crystal layer **21**. The liquid crystals **302** of the liquid crystal layer **21** have been given an orienting process. Instead of the resin particles **301**, glass particles and fiber ceramic particles may be employed.

In the resin particles **301** shown in FIG. **30**, the resin particles **301** may be connected together by a polymer. If they are connected, the hysteresis will be reduced and the characteristics will be enhanced. The resin particle **301** is not necessarily in the form of a particle. For example, it may be in the form of a polygon, a disc, or a thin film. The resin particles may be arranged in a random state.

Also, it is preferable that the liquid crystal **302** be given an orienting process. The orientation is preferable to be between 150° and 200°. Particularly, the orientation is preferable to be near 180°. If the orienting process is performed, the angle of visibility will be enlarged. The resin particle **301** and the liquid crystal **302** may contain guest-host material. Furthermore, they may contain dyes and colors.

The display panel with the liquid crystal layer **21** shown in FIGS. **29** and **30** is also a polymer dispersion liquid crystal panel (PD liquid crystal panel). The PD liquid crystal panel means all panels in which the light modulating layer **21** has a resin component and a liquid crystal component regardless of whether or not a scattering state caused by light modulation changes, regardless of the use of a polarizing plate, regardless of the orientation of liquid crystal molecules, and regardless of the amount of liquid crystal. The resin component may be replaced with ceramic material. This is also included in the PD liquid crystal.

As shown in FIG. **31**, the reason that ultraviolet rays are radiated to phase-separate the mixed solution **315** before forming the color filter **151** is that if ultraviolet rays are evenly radiated on the mixed solution **315** on the display range, the entire surface of the display range will have an even scattering characteristic. The color filter **151** absorbs ultraviolet rays. For this reason, after formation of the color filter **151**, the mixed solution **315** cannot be phase-separated. The color filter **151** on which ultraviolet rays were radiated generates heat, and the mixed solution **315** is heated by the generated heat. For this reason, a satisfactory phase separation condition is not obtained. As a countermeasure for solving the aforementioned problems, the color filter **151** is formed after the phase separating process.

The PD liquid crystal is a solid. Therefore, after the separating film **182** is peeled, on that the counter electrode **25** can be easily formed. This method cannot be performed on a TN liquid crystal. This is because the TN liquid crystal is a solid. The technique for depositing ITO which becomes the counter electrode **25** onto a resin substrate in a range of normal temperature to 100° C. is well known in the prior art. Since the surface of the PD liquid crystal layer is of resin, ITO can be easily formed on the PD liquid crystal layer **25**. However, when peeling off the separating film **182**, a portion of the waterdrop-like liquid crystal groove is destroyed. For this reason, after the separating film **182** has been peeled, the substrate **12** is washed and dried. Then, an insulating film **154** is formed on the PD liquid crystal **21** as a protective film. After the process, the counter electrode **25** is formed.

Forming the color filter **151** onto the ITO does not become a problem. For example, it can be easily formed by coating red, green, and blue gelatins. If screen printing is performed, the irregularities on the surface of the color filter **151** can be easily formed by the meshes of the printing screen.

There is another method of radiating ultraviolet rays through the array substrate **12**. Of course, since the color filter **151** is not formed on the side of the array substrate **12**, ultraviolet rays can be radiated on the mixed solution **315** without being absorbed considerably.

However, in that case, ultraviolet rays are absorbed by the TFT **155** and the signal line **15**. The signal line **15** absorbing ultraviolet rays is heated and also heats the peripheral mixed solution **315**. It is also important to control temperature during phase separation to perform satisfactory phase separation (satisfactory scattering characteristic).

If the signal line is heated, the mixed solution **315** near the signal line will also be heated. For this reason the average diameter near the signal line becomes large. If the average diameter becomes large, the scattering characteristic will become worse. Therefore, light escapes from the peripheral portion of the signal line, resulting in a reduction in the display contrast.

In FIG. **15**, while the color filter **151** is formed on the side of the counter electrode **25**, forming the color filter **151** between the array substrate **12** and the pixel electrode **14** as shown in FIG. **20** is also desirable constitution. It is preferable that the color filter **151** be formed from an interference color filter. The reason for this is that the process of forming the TFT **155** includes a high-temperature process which reaches about 450 to 600° C. Resin color filters, such as acrylic and gelatin filters, will be degraded in the afore-mentioned high-temperature process.

In the construction of FIG. **20**, the dielectric R, G, and B color filters having R, G, and B are formed by stacking and patterning a plurality of dielectric films. Of course, in the case of two color filters, they can be formed by performing a patterning process twice. Thereafter, a light shielding film **202** is formed from Cr. The light shielding film **202** is employed for shutting out light which is incident from the back surface of the TFT **155** on the semiconductor layer. Of course, dielectric R, G, and B color filters may be superimposed and formed.

After formation of the color filter **151**, the insulating layer **201** is formed. The film thickness of the insulating layer **201** needs to be 5000 angstroms or more. It is formed by depositing a thin film consisting of SiO_2 and SxNx a plurality of times. The reason for this is for preventing pinholes and also removing irregularities on the color filter **151** to make it flat. However, if the film thickness is 1.5 μm or more, cracks will easily come to occur.

On the aforementioned insulating layer **201** the TFT **155** and the signal line **15** are formed in sequence. Thereafter, the mixed solution **315** is held between the counter substrate **11** and the array substrate **12** and ultraviolet rays are radiated through the side of the counter substrate **11**, thereby phase-separating the mixed solution **315**.

For the method of holding the mixed solution **315** between the array substrate **12** and the counter substrate **11**, a vacuum injection method of causing the space of the substrate to be in a vacuum state, then breaking the vacuum state, and injecting the mixed solution, a method of dropping the mixed solution **315** on the array substrate **12** or counter substrate **11** and pasting both substrates together, a roller coater method of coating the mixed solution **315** with a roller coater, and a spinner method of coating the mixed solution with a spinner are exemplified.

As previously described, if a difference in potential occurs between the pixel electrodes and between the pixel electrode and the TFT **155**, an electric force line will be produced and liquid crystal molecules will be oriented along the electric force line. If liquid crystal molecules are oriented along the

electric force line, polarization dependency will take place in the oriented portion and therefore light will escape. As the countermeasure, a dielectric film (low dielectric film) is formed between adjacent pixel electrodes **14** by material whose dielectric constant is lower than the liquid crystal component of the liquid crystal layer **21**. This low dielectric film **152** is shown in FIG. **21**.

For the material of the low dielectric film **152**, inorganic material such as SiO_2, SiN_x, parylene N, and SiOF, the polymer material of the liquid crystal layer **21**, a resist to be employed in semiconductor fabrication, PVA, and organic material such as plasma carbon fluoride (P-CF) are exemplified. If the aforementioned low dielectric film **152** is formed into a thin or thick film shape as shown in FIG. **20**, electromagnetic coupling can be prevented between the signal line **15** and the pixel electrode **14** and between adjacent pixel electrodes **14**. Since the electromagnetic coupling between the signal line **15** and the counter electrode **25** can also be prevented, the liquid crystal layer **21** on the low dielectric film **152** is almost always in a scattering state.

Particularly, plasma carbon fluoride (P-CF) or paliren N film can attain a dielectric constant of 3 or less which is lower than SiOF. SiOF film is suitable film because if it is formed by SiF_2H_2 gas, the dielectric constant can be reduced to 3.3. SiO_2 film containing hydrocarbons is also suitable film because if it is formed by phenyltrimethoxysilane material, degradation due to hygroscopicity can be prevented and the dielectric constant reduced to 3.1. Rokisan containing HSQ or Si—H coupling can be employed in a coating method.

In FIG. **21**, although the low dielectric film is formed into a film shape, the present invention is not limited to this, but it may be formed into a column shape. If the column-shaped dielectric is made the same as the film thickness of the liquid crystal layer **21**, beads **161** prescribing the film thickness of the liquid crystal layer can be omitted.

In the case where the low dielectric is formed into a column shape, it is preferable that it be formed on the side of the counter substrate **25**. Since there is no need to form the TFT **155**, the side of the counter substrate **11** is structurally simple. In addition, since the side of the counter substrate **11** is flat with respect to the substrate surface, the column-shaped low dielectric film **152** can be easily formed.

If the low dielectric film **152** is formed into a column shape, the column can maintain the film thickness of the liquid crystal layer **21** constant. Therefore, there is no need to scatter the beads **161**. For this reason the fabrication process of the liquid crystal display panel is simplified. In addition, since obstacles such as the beads **161** on the pixel electrode **14** can be omitted, satisfactory image display can be realized.

The reason that the column-shaped or thick dielectric film **152** can be thus easily formed is that the PD liquid crystal display panel does not need an orienting process such as a rubbing process which is required of the TN liquid crystal display panel. If the low dielectric column **152** is formed in the TN liquid crystal display panel, a rubbing cloth will be caught on the low dielectric column, and the surfaces of the counter substrate **11** and the array substrate **12** cannot be rubbed well.

The low dielectric film **152** may be colored. If it is colored, it can absorb light irregularly reflected within the liquid crystal layer **21** and image quality will be enhanced. Black colors or pigments may be dispersed into resin. Like the color filter **151**, gelatin or casein may also be colored with black acid dyes. As an example of the black colors, a

fluorine color which becomes black by itself can be caused to emit a color and employed, and a mixed black consisting of a green color and a red color can also be employed.

While the aforementioned materials are all black materials, the present invention is not limited to the black materials when the liquid crystal display panel of the present invention is employed as the light valve of a projection display unit. In the case where material is employed as the low dielectric film **152** of the liquid crystal display panel which modulates R light, it will be sufficient if it can absorb R light. Therefore, natural resin can be dyed with colors, and material with colors dispersed in synthetic resin can be employed. For example, from azoic dyes, anthraquinone dyes, phthalocyanine dyes, and triphenylmethane dyes, one appropriate kind or a combination of two kinds or more can be employed. Particularly, it is preferable that complementary colors be employed. For example, when incident light is blue, resin **152** is colored yellow.

In FIG. **27** there is shown another construction. The construction shown in FIG. **27** is fabricated by the following process. First, TFTs **155** are formed on a substrate **12**. Thereafter, a resin color filter **151** is formed, and it is patterned to make holes. Then, on the color filter **151**, ITO which becomes a pixel electrode **14** is deposited. The pixel electrode **14** and the drain terminal of the TFT **155** are connected together through the aforementioned hole.

It is preferable to form a thin SiO_2 film (not shown) as an intervening layer to enhance adhesion between the color filter **151** and the pixel electrode **14**.

If constructed as described above, the TFT requiring a high-temperature process can be formed before the color filter is formed. Therefore, the color filter **151** can employ an inexpensive resin color filter. The reason is that an etching liquid crystal such as hydrochloric acid, nitric acid, ferrate, or nitride hydracid, which is etched and employed when patterning ITO which becomes the pixel electrode **14** by wet etching, has an adverse effect, such as color fade-out and surface roughness, on a colored resin material constituting the color filter **151**. If an intervening layer is formed, this problem will be overcome. In addition to SiO_2, the intervening layer may be acrylic photosensitive resin. The photosensitive resin is suitable resin because it also functions as a smoothing layer.

On the surface of the display panel contacting air, an air coat **211** is formed. The air coat serves as an antireflection film. The air coat **211** has three-layer structure or two-layer structure. In the case of three-layer structure, it is employed to prevent reflection in a wide wavelength band of visible light and called a multicoat. In the case of two-layer structure, it is employed to prevent reflection in a specific wavelength band of visible light and called a V coat. The multicoat and the V coat are properly used depending upon the purpose of a liquid crystal display panel. Generally, the V coat is adopted in a projection display unit in which three display panels are employed as light valves. In the case where a liquid crystal display panel is employed as a direct display unit, it is preferable that the multicoat be adopted in a projection display unit in which color display is performed with a single display panel.

In the case of the multicoat, aluminum oxide (Al_2O_3) with an optical film thickness of $nd=\lambda/4$, zirconium (ZrO_2) with an optical film thickness of $nd_1=\lambda/2$, and magnesium fluoride (MgF_2) with an optical film thickness of $nd_1=\lambda/4$ are stacked and formed. Generally, a thin film is formed with $\lambda=520$ nm or a near value. In the case of the V coat, silicon monoxide (SiO) with an optical film thickness of $nd_1=\lambda/4$ and magnesium fluoride (MgF_2) with an optical film thick-

ness of $nd_1=\lambda/4$ are stacked and formed, or yttrium oxide (Y_2O_3) and magnesium fluoride (MgF_2) are stacked and formed with an optical film thickness of $nd_1=\lambda/4$. In the case where blue light is modulated, yttrium oxide (Y_2O_3) is preferable to silicon monoxide (SiO), because silicon monoxide has an absorption band on the blue side. From the stability of material, yttrium oxide is also preferable to silicon monoxide. The aforementioned n in nd_1 represents the refractive index of each thin film, d_1 the physical film thickness of the thin film, and λ the designed dominant wavelength.

It is preferable that transparent electrodes, such as the counter electrode **25** and pixel electrode **14**, be made by three-layer constitution consisting of a first dielectric thin film **221a**, an ITO thin film **25**, and a second dielectric thin film **221b**. The optical film thickness of the ITO thin film **25** as an electrode is $\lambda/2$. The optical film thickness of the first dielectric thin film **221a** and the optical film thickness of the second dielectric thin film **221b** are $\lambda/4$, respectively. This constitution is shown in FIG. **22**(*a*). In this embodiment, particularly in the case where the counter electrode is formed from ITO, it is described as an ITO thin film.

It is preferable that the refractive index of the first dielectric thin film **221a** and the second dielectric thin film **221b** be 1.60 or more and 1.80 or less. As an example, the refractive indexes of SiO, Al_2O_3, Y_2O_3, MgO, CeF_3, WO_3, and PbF_2 are exemplified.

An embodiment of the specific constitution is shown in Table 2 and the spectral reflectance is shown in FIG. **23**. As evident in the figure, the constitution of Table 2 can realize a characteristic of less than reflectance 0.1% over a wavelength band width of 200 nm or more and obtain an extremely high antireflection effect. In Tables of the present invention, while the refractive index of the liquid crystal layer **21** in a scattering state is 1.6, this value will change if the liquid crystal material and the polymer material change. When the refractive index of the liquid crystal layer in a scattering state is n_x, the refractive index of the first and second dielectric thin films n_1, and the refractive index of the ITO thin film n_2, a condition of $n_x < n_1 < n_2$ needs to be satisfied.

TABLE 2

| | | Dominant wavelength λ = 520 nm | |
Material	Refractive index	Optical film thickness (nm)	Physical film thickness (nm)
Glass substrate	1.52	—	—
SiO	1.70	130.0	76.5
ITO	2.00	260.0	130.0
SiO	1.70	130.0	76.5
Liquid crystal	1.60	—	—

It is preferable that the refractive index of the first dielectric thin film **221a** and the second dielectric thin film **221b** be 1.60 or more and 1.80 or less. In the embodiment of Table 2, although both films **221a** and **221b** employ SiO, either film or both films may employ any of Al_2O_3, Y_2O_3, MgO, CeF_3, WO_3, and PbF_2.

Table 3 shows the case where the first dielectric thin film **221a** and the second dielectric thin film **221b** are formed from Y_2O_3. The spectral reflectance is shown in FIG. **24**.

TABLE 3

| | | Dominant wavelength λ = 520 nm | |
Material	Refractive index	Optical film thickness (nm)	Physical film thickness (nm)
Glass substrate	1.52	—	—
Y_2O_3	1.78	130.0	73.0
ITO	2.00	260.0	130.0
Y_2O_3	1.78	130.0	73.0
Liquid crystal	1.60	—	—

The spectral reflectance of FIG. **24** has the tendency that it becomes slightly high in the areas of B light and R light, as compared with the case of FIG. **23**.

Similarly, Table 4 shows the case where the first dielectric thin film **221a** is formed from SiO and the second dielectric thin film **221b** is formed from Y_2O_3. The spectral reflectance is shown in FIG. **25**. The constitution of Table 4 realizes an extremely high antireflection effect of less than 0.1% over the entire area of visible light.

TABLE 4

| | | Dominant wavelength λ = 520 nm | |
Material	Refractive index	Optical film thickness (nm)	Physical film thickness (nm)
Glass substrate	1.52	—	—
SiO	1.70	130.0	76.5
ITO	2.00	260.0	130.0
Y_2O_3	1.78	130.0	73.0
Liquid crystal	1.60	—	—

Table 5 shows the case where the first dielectric thin film **221a** is formed from Al_2O_3 and the second dielectric thin film **221b** is formed from SiO. The spectral =reflectance is shown in FIG. **26**. The reflectance exceeds 0.5% in the areas of R light and B light, so it cannot be said that the constitution of Table 5 is a suitable one.

TABLE 5

| | | Dominant wavelength λ = 520 nm | |
Material	Refractive index	Optical film thickness (nm)	Physical film thickness (nm)
Glass substrate	1.52	—	—
Al_2O_3	1.62	130.0	80.3
ITO	2.00	260.0	130.0
SiO	1.70	130.0	76.5
Liquid crystal	1.60		

As previously described, if the dielectric thin films **221a** and **221b** are formed on both sides of the ITO thin film **25** to make three-layer constitution, this constitution can have an antireflection effect. Note that the spectral reflectance shown in FIGS. **23** through **26** will change if the refractive index of the liquid crystal layer **21** changes In other words, the reflectance depends upon liquid crystal material, so optimization design is important.

If the liquid crystal layer **21** is in direct contact with the ITO thin film **25** serving as an electrode, the degradation in the liquid crystal layer **21** will be easily accelerated. It is believed that the reason is that impurities in the ITO thin film **25** flow into the liquid crystal layer **21**. As in the aforemen-

tioned three-layer constitution, if the dielectric thin film **221** is formed between the ITO thin film **25** and the liquid crystal layer **21**, there will be no possibility that the liquid crystal layer **21** will be degraded. This is effective particularly when the dielectric thin film **221** is formed from Al_2O_3 or Y_2O_3.

When the dielectric thin film **221** is formed from silicon monoxide (SiO), there is the tendency that the refractive index of SiO is reduced. It is believed that the reason is that oxygen atom such as a small quantity of H_2O and O_2 in the liquid crystal **21** reacts with SiO and therefore SiO changes to SiO_2. In that sense, the constitutions of Tables 2 and 5 are unsuitable constitutions. However, there is no possibility that SiO will change to SiO_2 in a short time, and in practice, the constitutions can be adopted in many cases.

In the previous embodiment, although the optical film thickness of the first and second dielectric thin films **221** is $\lambda/4$ and the optical film thickness of the pixel electrode and the ITO thin film (counter electrode) **25** is $\lambda/2$, the optical film thickness of the first and second dielectric thin films **221** may be $\lambda/4$ and the optical film thickness of the ITO thin film **25** may be $\lambda/4$.

Furthermore, according to the theory of the antireflection film, when N is an odd number (≥ 1) and M an integer (≥ 1), the optical film thickness of the first and second dielectric thin films **221** may be $(N*\lambda)/4$ and the optical film thickness of the ITO thin film **25** $(N*\lambda)/4$, or the optical film thickness of the first and second dielectric thin films **221** may be $(N*\lambda)/4$ and the optical film thickness of the ITO thin film **25** $(M*\lambda)/2$.

Furthermore, as shown in FIG. **22(b)**, either the first dielectric thin film **221a** or the second dielectric thin film **221b** can be omitted. In that case, the antireflection effect is slightly reduced, but, in practice, the constitution is sufficient in many cases. Moreover, as shown in FIG. **22(c)**, the film thickness of the electrode **25** and the dielectric thin film **42** may be $\lambda/4$. Even in this case, the aforementioned theory of the antireflection film can be applied. As described above, if the electrode is formed into a layer structure, light reflection can be prevented at each electrode and therefore display contrast can be considerably enhanced.

Now, a description will be made of the fabrication unit of the display panel of the present invention. FIG. **73** is an explanatory diagram of the fabrication unit of the display panel of the present invention.

A heater **739** is arranged within a mounting base **738**. The heater **739** is employed to heat the mixed solution **315** to proper temperature. The surface of the mounting base **738** is smoothed, and a reflecting plate **737** is attached to the smoothed surface. The reflecting plate **737** may be formed directly on the mounting base **738** by employing a technique of depositing metal material such as aluminum (Al). It may also be a stainless plate.

A display panel **22** holding the mixed solution **315** is placed on the mounting base **738**. The exterior circumference of the display area of the display panel **22** is surrounded by seal rubber **736**. Between a diffusing plate **734** and the mounting base **738** a pressure of about 1 kg/cm² is applied, thereby making the film thickness of the mixed solution **315** even.

For the seal rubber **736**, butyl rubber and silicon rubber are exemplified. In addition, the seal rubber **736** may be any material if it has flexibility. For example, it may be silicon resin, a buffer such as styrene foam, a mechanical spring, and phenol resin.

The diffusing plate **734** may be, for example, opal glass. As this opal glass, there is DF0-150S-1 manufactured by SIGMA KOHKI. The opal glass is one in which a milky

glass layer containing a light diffusing substance (calcium fluoride) is pasted on the surface of a transparent glass layer. In addition, the opal glass can employ one in which Ti powder is contained in acrylic or polycarbonate resin. A diffusing plate consisting of resin, however, has the disadvantage that it easily absorbs ultraviolet rays which are employed when phase-separating the mixed solution **315**.

A supply tube **732** supplies liquid or water close to the refractive index of the substrate of the display panel **22**. For example, it supplies gel such as silicon and ethylene glycol, and liquid (called cobinding liquid) such as water, ethyl alcohol, and methyl salicylate. On the other hand, an exhaust tube **733** has a function of exhausting air present in the space between the diffusing plate **734** and the display panel **22** so that gel and liquid are smoothly supplied into the space. The fluid and gel, supplied from the supply tube, function as a Optical coupling layer which reduces or eliminates a difference in refractive index between the diffusing plate **734** and the display panel **22**. Note that ultraviolet rays are radiated through the diffusing plate **734**.

The reason why the diffusing plate **734** and the display panel **22** are bound together through Optical coupling liquid **735** such as gel is as follows: FIG. **75** is an explanatory diagram of the reason. FIG. **75(a)** is the case where the Optical coupling liquid **735** is not employed. The ultraviolet rays **183** incident on the diffusing plate **734** are scattered. The scattered rays emerge toward the display panel **22**. If the incident angle θ_1 to the display panel **22** is greater than a critical angle, the merging ray will be totally reflected according to Snell's law (ultraviolet ray **183a**). Therefore, unless the incident angle of the ultraviolet ray **183** to the display panel **22** is less than a critical angle, the ultraviolet ray will be reflected and make no contribution to phase separation of the mixed solution **315**.

On the other hand, as shown in FIG. **75**, on the incident surface of the display panel **22** a light shielding film, such as a light shielding film (BM) **202**, is often formed. If the incident angle of the ultraviolet ray to the display panel **22** is small, almost no ultraviolet ray will be incident on the A portion present under the light shielding film **202** (ultraviolet ray **202b**). If unpolymerized resin remains on the liquid crystal layer **21**, reliability in the display panel will be reduced. It is believed that the reason is that resin will be gradually set by the subsequent use of the display panel. In addition, separation between the counter substrate **11** and the liquid crystal layer **21** will be easily caused. It is believed that the reason is that the liquid crystal layer **21** and the counter substrate **11** are sufficiently pasted together by the resin component due to much amount of unpolymerised resin component.

As shown in FIG. **75(b)**, if the Optical coupling liquid **735** is present, the light diffusing plate **734** and the counter substrate **11** can be regarded as a single substrate. For this reason, as shown by the ultraviolet ray **183c**, the critical angle becomes small and the ultraviolet ray can go into the mixed solution **315** at a great angle. Therefore, even if the light shielding film **202** is formed, ultraviolet rays will be incident on the A portion and resin can be polymerized (phase-separated). Note that ultraviolet rays **183** are effectively collected by a lens **731**.

In the fabrication unit shown in FIG. **73**, the display panel **22** is mounted on the mounting base **738**. Also, the display panel **22** is held by the heater **739** at temperature at which a satisfactory phase separation condition is obtained. On the other hand, the space between the display panel **22** and the diffusing plate **734** is filled with the Optical coupling liquid **735**. Thereafter, the diffusing plate **734** is pressed from

above with a pressure of 0.8 to 1.6 kg/cm², thereby making the film thickness of the mixed solution **315** even. Note that the refractive index of the Optical coupling liquid **735** is 1.35 or more and 1.65 or less. It is preferable that the difference in refractive index between the Optical coupling liquid **735** and the counter substrate **11** be within 0.05. If the refractive index of the counter substrate **11** is 1.53, the refractive index of the Optical coupling liquid **735** is 1.48 or more and 1.58 or less. Ethylene glycol has a nearly proper refractive index, but it has many problems. For example, it needs to be washed later. An alcohol is slightly low in refractive index, but, since it naturally volatizes and evaporates, it is suitable material. Pure water is the desirable material for the Optical coupling liquid **735**. The reason for this is that it is inexpensive and only drying is required after ultraviolet rays have been radiated on the display panel **22**.

If the supply tube **732** is closed and then air or Optical coupling liquid **735** between the diffusing plate **734** and the display panel **22** is exhausted from the exhaust tube **733**, even pressure will be applied to the surface of the display panel **22**. If this force for exhaust is set to an appropriate value, a pressure of about 0.8 to 1.6 kg/cm² can be given.

Thereafter, ultraviolet rays **183** are radiated through the lens **731**. The lens **731** is a collective lens. The lens **731** also cuts ultraviolet rays having a wavelength of 350 nm or less and cuts infrared rays. The remaining rays are radiated on the display panel **22**.

Although ultraviolet rays are diffused (scattered) by the diffusing plate **734**, the Optical coupling liquid **735** may contain calcium fluoride powder and titan (Ti) powder to diffuse ultraviolet rays. In this case, the diffusing plate **734** can employ a normal transparent substrate.

If the phase separation of the mixed solution **315** is completed, the supply of the Optical coupling liquid **735** will be stopped and the Optical coupling liquid **735** will be exhausted. In addition, air is fed into the space between the diffusing plate **734** and the display panel **22**. Thereafter, the diffusing plate **734** is removed and the display panel **22** is taken out.

FIG. **74** illustrates a method which heats the display panel **22** to a required temperature by infrared rays instead of the heater **739**. On the exit side of the diffusing plate **734** an infrared ray reflecting plate or film **741** is arranged or formed.

The aforementioned infrared ray reflecting film **741** is expressed by a general equation M(1)xM(2)yInzO(x+3y/2+3z/2)−d. In the equation, M(1) represents at least either one element or the other of magnesium and zinc. M(2) represents at least either one element or the other of aluminum and gallium. The ratio of x:y is in a range of 0.2 to 1.8:1. The ratio of z:y is in a range of 0.4 to 1.4:1. The oxygen amount of loss d is in a range of 3×10^{-5} to 1×10−1 times (x+3y/2+3z/2). Among M(1), M(2) and indium, a portion of at least one kind of element is replaced with another element. For example, the element with which M(1) is replaced consists of an oxide whose valence is trivalence or more, and the elements with which M(2) and indium are replaced consist of an oxide whose valence is trivalence or more. Also, the infrared ray reflecting film **741** may be one which is formed with an interference film consisting of a dielectric multilayer film. On the other hand, on the back surface of the display panel **22** an ultraviolet ray reflecting plate or film **742** is arranged or formed. As an example, there is an interference film consisting of a dielectric multilayer film. However, there is a need to stack and form dielectric thin films consisting of hafnium dioxide (HfO_2) and silicon dioxide (SiO_2) in order to reduce absorption of ultraviolet rays.

Infrared rays **744** are generated by an infrared lamp and heat the display panel **22**. The infrared rays, transmitted through the display panel **22**, are reflected by the infrared ray reflecting film **741** and are again incident on the display panel **22**, thereby heating the display panel **22**. The temperature of the display panel is detected by a temperature sensor **745** attached to one end of the display panel **22**. Also, the Optical coupling liquid **735** to be supplied is heated to a proper value and supplied.

As previously described, the display panel **22** is warmed to a required value by infrared rays. Thereafter, the ultraviolet rays **183** are incident on the display panel **22** through the diffusing plate **734**. Since the ultraviolet ray reflecting film **742** is arranged on the back surface side of the display panel **22**, the ultraviolet rays **183** transmitted through the display panel **22** are again reflected by the aforementioned ultraviolet ray reflecting film **742** and phase-separate the mixed solution **315**. The rest constitution is the same as FIG. **73** and therefore a description thereof is omitted.

In the fabrication unit of the display panel of the present invention shown in FIG. **76**, a casing **762** is filled with Optical coupling liquid **735**, and a display panel **22** holding the mixed solution **315** is arranged within the Optical coupling liquid **735**. The display panel **22** is heated to a required temperature by heating and supplying the Optical coupling liquid **735**.

The display panel **22** is held by support members **761** within the casing **762** so that the Optical coupling liquid **735** can pass along the back side of the display panel **22**. On the interior surface of the casing **762** a reflecting plate **742** or a diffusing plate is arranged or formed.

At the time the display panel **22** has reached a predetermined temperature, the diffusing plate **743** is depressed, whereby the film thickness of the mixed solution **315** held between the support members **761** and the diffusing plate **743** is made even. The depression of the diffusing plate **743** can be realized by properly controlling the supply quantity of the Optical coupling liquid **315** from the supply tube **732** and the exhaust quantity of the Optical coupling liquid **315** from the exhaust tube **733**. If the exhaust quantity of the Optical coupling liquid **315** is greater than the supply quantity, pressure can be increased.

A description will hereinafter be made sequentially of the display panels in the other embodiments of the present invention. FIG. **35** is a sectional view of the display panel of the present invention. A protective film **153** consisting of an acrylic ultraviolet ray resin film is formed on a counter electrode **25**. The point differing from the constitution of FIG. **15** is that while the display panel **22** of FIG. **15** forms the color filter **151** on the counter electrode **25**, in the display panel **22** of FIG. **35** a color filter **151** is formed on a substrate **351**. In the construction of FIG. **35**, even if the color filter **151** consists of a dielectric color filter, it can be easily formed. There is no need to form TFTs **155** on the substrate **351**, and only the color filter **151** is formed. The reason for this is that there is no temperature limit of 450 to 600° C. when forming the color filter. A light shielding film **202** consisting of chrome (Cr) can be freely formed. The light shielding film **202** may be formed from sexivalent chrome, aluminum (Al), or titan (Ti) in addition to Cr. Also, it may be a light shielding film consisting of resin.

Of course the color filter may be made from resin material such as gelatin. Between the color filter **151** and the protective film **153**, sticking SiO_3 beads **161** with a diameter of 5 to 20 μm (trade name: SHINSHI sphere AB-8-13 μm manufactured by SHOKUBAI KASEI) are interposed as spacers **161**.

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The aforementioned beads **161** can stick if it is let alone at a temperature of 40° C. for 90 minutes. The reason why the beads **161** are thus employed is for preventing the color filter **151** and the protective film **153** from sticking together. Of course, if the color filter **151** and the protective film **153** stick together over the entire display surface, there will be no need to arrange the beads **161**. However, generally, if the beads **161** are not arranged, the color filter **151** and the protective film **153** will stick together at one point and be separated from each other at another point. This is because the color filter **151** or the protective film **153** has irregularities on the surface thereof. In addition, the reason is that the substrates **11** and **12** are warped. If a stuck portion and an unstuck portion are present, a refractive index distribution will occur and result in display unevenness.

If the diameter of the beads **161** is 5 μm or less, the beads **161** will be caught in the irregularities on the protective film **153** and a portion of each bead will be stuck in the irregularities. This will result in display unevenness. If the bead diameter is 20 μm or more, it will become large with respect to the size of a pixel and refract light. As a result, the beads are recognized as display images. Therefore, it is preferable that the diameter of the beads **161** should be 8 μm or more and 15 μm or less.

The protective film **153** is formed from ultraviolet ray resin. The protective film **153** also serves as an anti-reflection film. The reason for this is that the refractive index of ITO constituting the counter electrode **25** is high as 2.0 and the difference between it and the refractive index (1.0) of air (or vacuum) is too large. If the protective film **153** with a refractive index of 1.5 or so is formed on the ITO, inevitably the reflectance can be reduced. Note that the protective film **153** is not necessarily required structurally.

An inert gas, such as N$_2$, He, Ne, and H gases, is injected into the space between the color filter **151** and the protective film **153**. Particularly, nitrogen (N) gas is suitable one because it is stable. In addition, hydrogen (H) gas is suitable one because it has a high cooling effects and therefore can exhale heat out of the display panel. In this case the aforementioned gas is caused to flow. In the case where an inert gas is injected, the circumferential portion is sealed by a seal resin **361** to prevent leakage of the gas, as shown in FIG. **36**. There is another method which creates a vacuum state without injecting an inert gas.

As shown in FIG. **36**, on the surface of the color filter **151** another protective film **153**b may be formed. In addition, an air coat **211** is formed on the interface between the display panel **22** and air. Note that phase separation of the mixed solution **315** is performed before attaching the substrate **11**. After phase separation, the beads **161** are scattered in the atmosphere of an inert gas. Then, the substrate **11** and the array substrate **12** are stuck together and the circumferential portion is sealed by the seal resin **361**.

FIG. **37** is a sectional view of a display panel in another embodiment of the present invention. A color filter **151** and a light shielding film **202** are formed on a substrate **11**. On the color filter **151** a counter electrode **25** is formed. The counter electrode **25** and a PD liquid crystal layer **21** are pasted together by a transparent adhesive layer **371**.

A description will hereinafter be made of the fabrication method of the display panel of the present invention shown in FIG. **37**, referring to FIG. **39**. A mixed solution **315** is held between the array substrate **12** and a separation film **182**. The method of holding the mixed solution **315** may be either a drop method or a vacuum injection method. Thereafter, a pressure of 1 kg/cm^2 is applied to the separation film **182** to make the film thickness of the mixed solution **315** even, and

then ultraviolet rays are radiated on the separation film **182**. At this time, ultraviolet rays may also be radiated from the side of the array substrate **12**. In the case where the separation film **182** consists of resin film, usually it does not easily transmit ultraviolet rays, so a radiation quantity of about 2000 mJ/cm^2 is often required. Since this radiation quantity depends considerably upon the thickness of the separation film **182**, it is determined by experiment. In the case where the separation film **182** consists of a glass substrate, it transmits ultraviolet rays easily. In the case where the glass substrate consists of silica glass, it transmits ultraviolet rays most easily. In the case of soda glass, it does not easily transmit ultraviolet rays. In the case of a glass substrate, the radiation quantity of the ultraviolet rays also needs to be determined by experiment. In the case of **7059** manufactured by CORNING, the radiation quantity is greater than about 1000 mJ/cm^2 and less than 1500 mJ/cm^2.

For the ultraviolet rays that are radiated, a wavelength of 350 nm or less is cut. There is a need to completely cut a wavelength of at least 320 nm or less. The reason for this is for preventing the aforementioned liquid crystal from absorbing light having a wavelength of 350 nm or less, being dissolving, and from being degraded. It is a matter of course that radiation of ultraviolet rays may include visible light. The radiation of ultraviolet rays in the specification of the present invention means radiation of light which includes a range of ultraviolet rays. However, it is preferable that infrared rays should be cut. Particularly, it is preferable that a wavelength of 1.5 μm or more should be cut. If desired, it is preferable that a wavelength of 800 nm or more should be cut. Infrared rays are absorbed by the TFT **151** and the source signal line **15** and heat the signal line. For this reason, infrared rays will move the phase separation condition out of the range of a proper value.

Then, if the separation film **182** is peeled off, the state shown in FIG. **39**(b) will be obtained. After the separation film **182** is peeled off, the process of FIG. **39**(c) needs to be started immediately. Even if the PD liquid crystal **21** is a solid, there will be possibility that it will absorb water and be degraded, because a portion of the liquid crystal is exposed through the peeled portion. For this reason an unnecessary liquid crystal is washed off.

Then, the substrate **351**, formed with the color filter **151** and the counter electrode **25**, is pasted on the array substrate **12**, as shown in FIG. **39**(c). In this case, as shown in FIG. **39**(c), the beads **161** may be scattered. However, since the PD liquid crystal layer **21** is soft, there is the possibility that the beads **161** will be caught in the PD liquid crystal layer **21**.

In the case where the beads **161** are scattered, the mixed solution **315** is caused to be held in the space between the counter electrode **25** and the PD liquid crystal layer **21** by employing a capillary phenomenon. In this case the diameter of the beads **161** is 2 to 8 μm. Of course the mixed solution **315** may be held by a drop method. Thereafter, the counter substrate **11** is pressed from above, whereby the film thickness of the adhesive layer **371** becomes even. At this time, the beads **161** are caused to be caught in the PD liquid crystal layer **21**, and it is preferable that the adhesive layer **371** be made as thin as possible. Note that even if the beads **161** are not employed, the adhesive layer **371** can be formed extremely thin by a capillary phenomenon or a drop method. However, a sufficient examination on the method is required.

After formation of the adhesive layer **371**, a pressure of about 1 to 1.5 kg/cm^2 is applied on the counter substrate **11** from above. Therefore, an excess of the mixed solution **315** is exhausted. Thereafter, ultraviolet rays are radiated to

phase-separate the mixed solution **315**, thereby completing the display panel.

In the aforementioned embodiment, while the material of the adhesive layer **371** has employed the mixed solution **315**, the present invention is not limited to this, but it may employ acrylic ultraviolet ray setting resin. The adhesive layer **371** may also be formed from heat setting type epoxy resin.

In the case where the adhesive layer **371** is formed with the mixed solution **315**, the film thickness of the adhesive layer **371** does not matter, because the mixed solution **315** makes a contribution to light modulation. However, in the case where it is formed from ultraviolet ray (UV) setting resin, the ultraviolet ray setting resin causes voltage drop. For this reason it is important to make the adhesive layer **371** as thin as possible. In order to make it thin, pressure is applied between the counter substrate **11** and the array substrate **12**, and the adhesive layer is let alone for a while.

The film thickness of the adhesive layer **371** should be 5 μm or less when it is formed from the mixed solution **315**. In the case where it is formed from other materials, the film thickness should be at least 3 μm or less. Preferably, in the case of the mixed solution **315** the film thickness should be less than half of the film thickness of the PD liquid crystal layer **21**, and in the case of other materials, it should be less than ⅓. If the distance between the counter electrode **25** and the pixel electrode **14** becomes long, a voltage required for the liquid crystal layer to go to a transmitting state will become high.

FIG. **37** has showed the constitution where the counter substrate **11** having the counter electrode **25** and the color filter **151** formed thereon is pasted on the array substrate **12** having the PD liquid crystal layer **21** formed thereon. FIG. **38** shows the constitution where the substrate **351** having the color filter **151** formed thereon is pasted on the array substrate **12** having the PD liquid crystal layer **21** and the counter electrode **25** formed thereon. Note that the display panel shown in FIG. **38** is a reflection type display panel.

In the present invention it has been described that the display panel is of a transmission type. However, it is a matter of course that the technical idea of the present invention is also applicable to reflection type display panels. For example, if the pixel electrode **14** is formed with thin metal film such as aluminum (Al) film, the transmission type display panel will be a reflection type display panel.

In the display panel **22** shown in FIG. **38**, a switching device such as a TFT **155** is formed on the array substrate **12**, and a reflecting electrode **14a** is formed on the switching device. The reflecting electrode **14a** may be formed from metal material such as Al and Cr. Also, on the ITO electrode or metal electrode a dielectric mirror may be formed and constituted.

The aforementioned reflecting electrode **14a** and the drain terminal of the TFT **155** are electrically connected by a connecting portion **382**. An insulating layer **154** is formed so that the reflecting electrode **14a** and the TFT **155** do not short-circuit at a point other than the drain terminal. The insulating layer **154** is formed with inorganic material such as SiO₂, SiNx or organic material such as polyimide. In the case of polyimide, there is the advantage that thick film thickness can be formed easily and in a short time by coating it with a spinner. However, there is the disadvantage that a process of boring the connecting portion **382** is difficult to perform.

In the case where the reflecting electrode **14a** is formed with metal material, a surface contacting the liquid crystal layer **21** is made so that it becomes an electrode consisting of aluminum (Al). From the standpoint of the drain terminal

of the TFT **155** and ohm resistance it is preferable that the reflecting electrode **14a** have two-layer constitution consisting of titan (Ti) and aluminum (Al) or three-layer constitution consisting of Ti, Cr, and Al. To enhance the reflectance of the surface such as the Al surface, a thin film consisting of SiO₂ is formed on the surface such as the Al surface.

In the case where the reflecting electrode **14a** is formed with metal material, a light shielding film (light absorbing film) **381** is formed between adjacent reflecting electrodes **14a** to prevent incident light from going into the space between the reflecting electrodes **14a** and occuring the photoconductor phenomenon of the TFT **155**. The formation material of the light absorbing film is the same constituent material of the light shielding films **202** and **152**. In the formation method, the reflecting electrode **14a** is patterned and then resin material for the light absorbing film is applied over the entire surface. Thereafter, the surface is polished. This polishing makes the surface of the reflecting electrode **14a** as smooth as glass, and at the same time, the light absorbing film **381** remains only between adjacent reflecting electrodes **14a**. Note that the surface of the polished reflecting electrode **14a** is formed with a protective film, such as SiO₂ film, in order to prevent oxidation and the like.

It is not always beneficial to make the surface of the reflecting electrode **14a** into a glassy surface. For example, in the case where the display panel **22** is employed as a display for a portable information terminal, it is required to have a wide visual field angle. When a visual field angle is required, there is a need to form irregularities on the surface of the reflecting electrode **14a**. As a means of forming irregularities, there is a method of growing the crystal grain of the aluminum (Al) surface large. There is a method of performing a heat process on the Al surface. In addition, a PVA solution is applied to the surface of the reflecting electrode **14a**, thereby drying PVA. If done in this manner, microscopic irregularities will be produced on the surface. Thereafter, metal material for the reflecting electrode is deposited on the irregularities.

The fabrication method of the display panel of the present invention is similar to FIG. **39**. The point of difference is that the counter electrode **25** is formed on the PD liquid crystal layer **21** after formation of the PD liquid crystal layer **21**. The protective film **153** does not need to be formed. The array substrate **12** and the substrate **351** having the color filter formed **151** thereon are pasted together with the adhesive layer **371**.

Note that since the counter electrode **25** has already been formed on the PD liquid crystal layer **21**, the adhesive layer **371** will have no influence on a T-V curve even if the film thickness is thick. The beads **161** may be employed or need not be employed. However, if the beads **161** are employed, an even and proper cap can be made between the color filter **151** and the counter electrode **25**. For this reason, injection of the adhesive agent **371** becomes easy.

In the display panel shown in FIG. **19**, the color filter **151** is formed directly on the surface of the counter substrate **11**. The thickness t (mm) of the counter substrate **11** needs to meet the following equation when the diagonal line of a pixel is represented by d (mm).

$$20d \geqq t \qquad \text{[expression 19]}$$

Preferably,

$$10d \geqq t \qquad \text{[expression 20]}$$

where t is 0.1 mm or more. If thickness is 0.1 mm or less, the counter substrate will easily crack.

The reason for the aforementioned equation is that if the thickness t (mm) of the counter substrate is thick, a difference in diopter will occur and therefore the display screen will become difficult to see. As a result of examination, it has been found that a difference in diopter has influence on the pixel size (diagonal line) (mm). As a result of examination, the aforementioned equation has been obtained. In the case where the color filter 151 is a dielectric color filter, it is mechanically stable (scratches are difficult to occur). However, in the case of a resin color filter, it is not mechanically stable and therefore a protective film (not shown) consisting of acrylic ultraviolet ray setting resin is formed on the surface of the color filter 151. In addition, to prevent reflection of light at the surface of the color filter 151, it is preferable that the surface of the color filter 151 or the surface of the protective film should be formed with irregularities (i.e., the surface should be embossed). Since the reason for this has been described in FIG. 15, it is omitted.

In FIG. 19, although the color filter 151 is formed directly on the counter substrate 11, the present invention is not limited to this arrangement. For example, the color filter 151 may be formed on another substrate, which is arranged or glued so that the surface on which the color filter 151 is formed can contact the counter substrate 11. The array substrate 12 is pasted on the thin counter substrate 11 or the counter film serving as a substitute for the counter substrate 11. After a mixed solution has been held between the substrates 11 and 12, ultraviolet rays are radiated through the substrate 11, thereby phase-separating the mixed solution. Then, the filter substrate having the color filter 151 formed thereon is pasted on the counter substrate with a transparent adhesive agent or gluing agent (ultraviolet ray setting resin, epoxy resin, silicon resin, etc.). If constituted in this manner, ultraviolet rays can be sufficiently radiated on the mixed solution, whereby the mixed solution can be phase-separated satisfactorily. Since the PD liquid crystal layer is a solid, the counter substrate 11 will not be bent even if it is thin. In addition, when pasting the filter substrate and the counter substrate together, there is no possibility that the liquid crystal layer will warp due to pressure.

Note that the filter substrate may be glued or arranged on the side of the array substrate 12. In this constitution there is a need to form the array substrate 12 thin.

It is desirable that the thickness of the counter substrate 11 or array substrate 12 should be 0.6 mm or less. More desirably, it should be 0.3 mm or less. When the display panel shown in FIG. 19 is employed as a light valve for a projection type display, it is desirable that the optical system should be designed so that the F number of light incident on the display panel 22 is F 7 or more and F 15 or less. This design can realize high-contrast display and high-luminance display. The pixel may be of a reflection type.

The F number used herein is expressed as F=1/(2 sin θ). In other words, if the F number is prescribed, it will prescribe the spreading angle of the light which is incident on the liquid crystal display panel. If the spreading angle θ is large, incident light will enter an adjacent pixel. If the F number is too great, the optical length of an optical projection system will be too long and therefore the system size will be too large. If the F number is F 7 or more, light will be shut out by a light shielding film (BM) and there will be no possibility that R light, for example, will enter an adjacent green (G) pixel.

When the display panel of the present invention, such as that shown in FIG. 19, is employed as a light valve for a

projection type display, it is preferable that the display panel meet the following relation:

$$Fd/4 \leq t \leq Fd/2 \qquad \text{[expression 21]}$$

where d is the diagonal size (mm) of one pixel, t is the thickness (mm) of the counter substrate 11 or array substrate 12, and F is the F number of incident light. More preferably, the display panel meets the following relation:

$$Fd/3 \leq t \leq Fd/1.8 \qquad \text{[expression 22]}$$

The aforementioned constitution can realize a projection type display which is low in cost and high in luminance.

As shown in FIG. 58, if electromagnetic coupling is produced between the signal line 15 and the pixel electrode 14 and an electric force line 19 is generated, then liquid crystal molecules 20 will be oriented along the electric force line 19. For this reason, light escapes from the vicinity of the signal line 15, resulting in display contrast reduction.

In the embodiments of FIGS. 6 and 16, a low dielectric film is formed to suppress the occurrence of the electric force line 19 in the vicinity of the signal line 15. However, the low dielectric film is also a dielectric substance. For this reason the dielectric constant is 3 or more, so the suppression effect of the electric force line 19 is not perfect.

In FIG. 57 a PD liquid crystal 21 near a signal line 15 is removed. For this reason the dielectric constant of the peripheral portion of the signal line 15 is approximately 1. The PD liquid crystal layer 21 is formed on a pixel electrode 14. On the other hand, on the signal line 15 there is space 571, and a light shielding film 202 is formed on a counter electrode 25. The material for forming the light shielding film 202 employs, for example, Cr. In the space 571 an inert gas such as N_2, Ne, and He gases is injected. As an inert gas, particularly nitrogen (N_2) gas is preferable to be employed.

A description will hereinafter be made of the fabrication method of the display panel 22 shown in FIG. 57, referring to FIG. 59. FIG. 59 is an explanatory diagram of the fabrication method of the display panel 22 of the present invention. First, as shown in FIG. 59(a), a mixed solution 315 is held between a mask 181 formed with a light shielding film (light shielding pattern) 202 and an array substrate 12. The light shielding film (light shielding pattern) 202 is formed on a source signal line 15, a gate signal line, and a TFT 155. It is desirable that the light shielding film (light shielding pattern) 202 should be formed with aluminum (Al) or chrome (Cr). This is because the rate that it absorbs ultraviolet rays is small. Beads 161 are previously mixed with the mixed solution 315 so that a PD liquid crystal layer 21 has a predetermined film thickness. The beads 161 may be scattered. Thereafter, ultraviolet rays 183 are radiated through the mask 181.

The state after the process of FIG. 59(a) is shown in FIG. 60. Ultraviolet rays 183a are incident on the light shielding film (light shielding pattern) 202. For this reason the ultraviolet rays 183a are not incident on the mixed solution 315 but are reflected. An ultraviolet ray 183b is incident on the mixed solution 315. Therefore, the resin in the A portion of the mixed solution 315 does not polymerize and the resin in the B portion polymerizes, whereby the liquid crystal component and the resin component are phase-separated.

After ultraviolet rays 183 are radiated and then the mixed solution 315 is phase-separated, the mask 181 is removed. This state is shown in FIG. 59(c). Thereafter, unpolymerized mixed solution 315 is washed off. This is easily done by employing pure water. The unpolymerized portions A are washed off as shown in FIG. 59(c). For this reason, in the area where the light shielding film (light shielding pattern) 202 is formed above the signal line 15 and a TFT (not shown), space 571 is produced. Since the space 571 is air,

the dielectric constant is approximately 1. Therefore, the dielectric constant is low and an electric force line is difficult to occur.

Then, as shown in FIG. **59**(*d*), the counter substrate **11** having the light shielding film **202** formed thereon is pasted on the array substrate **21** in the presence of an inert gas. The adhesion is performed with ultraviolet ray setting resin.

In the fabrication method of FIG. **59**, the PD liquid crystal layer **21** is formed by employing the mask **181** which has the light shielding film (light shielding pattern) **202** formed thereon. This mask is also applicable to other fabrication methods. For example, the mask can be employed when light shielding films **202***a* are formed on a counter electrode **25**, as shown in FIG. **61**.

If ultraviolet rays are radiated to phase-separate the mixed solution **315**, the light shielding film **202***a* will absorb ultraviolet rays and generate heat, because it is usually formed from chrome (Cr). For this reason the mixed solution **315** in the peripheral portion of the light shielding film **202***a* is heated, and the average diameter of the PD liquid crystal layer **21** near the light shielding film (BM) is increased.

Then, ultraviolet rays are radiated on the mixed solution **315** by employing the mask **181** formed with the light shielding film (light shielding pattern) **202***b* having the same shape as the light shielding film **202***a*. The ultraviolet ray **183***a* is incident on the light shielding film (light shielding pattern) **202***b*. For this reason it is not incident on the light shielding film **202***a*. On the other hand, the ultraviolet ray **183***b* is incident on the mixed solution **315** without being shut out, and phase-separates the mixed solution **315** present on the pixel electrode **14**.

As described above, if ultraviolet rays are radiated on the mixed solution **315** by employing the mask **181** shown in FIG. **61**, the PD liquid crystal layer **21** can be satisfactorily formed even if the light shielding film **202** has been formed on the display panel.

In the aforementioned embodiment, the light shielding film (light shielding pattern) **202***b* has the same shape as the light shielding film **202***a*. However, in the case where ultraviolet rays are radiated through the mask **181** from the side of the array substrate **12**, it is a matter of course that the light shielding pattern of the mask **181** is made equal to the shape pattern of the source signal line **15**, gate signal line, and the TFT **155**.

In a display panel **22** shown in FIG. **62**, a color filter **151** is formed on a pixel electrode **14**. A red (R) color filter **151***a* is formed on a pixel electrode **14***a*. A green (G) color filter **151***b* is formed on a pixel electrode **14***b*. A blue (B) color filter **151***c* is formed on a pixel electrode **14***c*. In addition, the relation between the average diameter a of the PD liquid crystal **21***a* on the pixel electrode **14***a*, the average diameter b of the PD liquid crystal **21***b* on the pixel electrode **14***b*, and the average diameter c of the PD liquid crystal **21***c* on the pixel electrode **14***c* is made so as to be a>b≧c.

The reason is that the average diameters which can optimally modulate the wavelength of light are correlated with each other. If the wavelength of light becomes longer, there is a need to make the average diameter larger. In other words, the average diameter of the PD liquid crystal layer **21** which modulates B light is made smaller than that of the PD liquid crystal layer **21** which modulates R light.

FIG. **63** is an explanatory diagram of the fabrication method of the display panel of the present invention shown in FIG. **62**. As shown in FIG. **63**(*a*), the mask **181** is formed with an opening over the pixel electrode **14***c* which modulates B light. Then, a first mixed solution **315***a* is held between the mask **181** having the light shielding film (light

shielding pattern) **202***a* formed thereon and the array substrate **12**. Thereafter, ultraviolet rays **183***c* with a strength of c are radiated, thereby phase-separating the mixed solution **315***a* present under the opening of the mask **181**. Thereafter, the mask **181** is removed, and unpolymerized mixed solution **315***a* is washed off as shown in FIG. **63**(*b*).

Then, the aforementioned mask **181** is moved so that the opening thereof is positioned over the pixel electrode **14***b* which modulates G light. Likewise, a mixed solution **315***b* is held between the mask **181** and the array substrate **12**, and ultraviolet rays **183***b* with a strength of b are radiated. Thereafter, the mask **181** is removed, and unpolymerized mixed solution **315***b* is washed off as shown in FIG. **63**(*d*).

Then, the counter substrate **11** having the counter electrode **25** formed thereon and the array substrate **12** are pasted together, and between both substrates the mixed solution **315***c* is held. Thereafter, ultraviolet rays **183***c* with a strength of a are radiated, whereby the mixed solution **315***c* on the pixel electrode **14***a* which modulates R light is phase-separated.

The strength of the ultraviolet ray is made so as to be strength c<strength b<strength a. The average diameter changes nearly in proportion to the energy strength of ultraviolet rays per unit time. As the strength becomes stronger, the average diameter becomes smaller. Also, if the ratio between the liquid crystal component and the resin component of the mixed solution **315** is changed, the average diameter will change. Usually, as the content ratio of the liquid crystal component is increased, the average diameter becomes larger. As previously described, if the strength of the ultraviolet rays **183** and the ratio between the liquid crystal component and the resin component are changed by employing the mask **181**, the average diameter can be made so as to be optimum for the wavelength of each incident light which is modulated.

In FIG. **64** a transparent substrate **642**, formed with microlenses **641** as the mask **181**, is employed. On the transparent substrate **642** microlenses **641***a* and **641***b* are formed. The microlens **641***a* corresponds to a B pixel, and ultraviolet rays are incident on the A portion of the mixed solution **315**. The microlens **641***b* corresponds to a G pixel, and ultraviolet rays are incident on the B portion of the mixed solution **315**. The portion not formed with the microlenses **641** corresponds to a R pixel, and ultraviolet rays are incident on the C portion of the mixed solution **315**. In a plan view of the transparent substrate **642**, the microlenses **641** are arranged as shown in FIG. **65**.

Ultraviolet rays **183** are radiated on the mixed solution **315** through the transparent substrate **642**. With the operation of the microlens **641***a*, the A portion of the mixed solution **315** becomes strongest in strength of ultraviolet rays. The microlens **641***b* is longer in focal distance than the microlens **641***a*. For this reason the strength of ultraviolet rays **183** of the B portion of the mixed solution **315** becomes weaker than that of the A portion. The C portion of the mixed solution **315** becomes weakest, because there is no microlens and ultraviolet rays **183** are not collected.

The reason that although light is collected in the mixed solution **315** by the microlenses **641**, the mixed solution **315** on the pixel electrode **14** can be perfectly phase-separated is that the opening ratio of the pixel is low as about 50%. If incident light can be perfectly collected by the microlenses **641** and also the opening ratio of the pixel is 50%, the A portion can double the ultraviolet ray strength per unit area. In other words, if it is assumed that the strength of the ultraviolet ray of the C portion is 1, the mixed solution **315** on the pixel electrode **14** can be perfectly phase-separated even if the strength of the ultraviolet ray of the A portion is doubled.

If the strength of the ultraviolet ray per unit area is changed, the average diameter will change. If the strength of the ultraviolet ray per unit area becomes strong, the average diameter will become small. From the aforementioned principles, if the curvature of the microlens **641** is changed to change light collecting efficiency, in the mixed solution **315** an optimum average diameter can be obtained according to pixels (R, G, and B) which modulate, even if the strengths of ultraviolet rays that are incident in the transparent substrate **642** are even per unit area.

The strength per unit area in the mixed solution **315** can be freely set if the size and focal distance (curvature) of the microlens **641** are changed. Also, the microlens **641** can be easily fabricated, if a metal mold is made and ultraviolet ray setting resin is injected into the metal mold and transferred.

As shown in FIG. **64**, in the case where ultraviolet rays are radiated through the microlens **641** from the side of the counter substrate **11**, the color filter **151** is formed on each pixel electrode **14**. In the case where ultraviolet rays are radiated through the microlens **641** from the side of the array substrate **12**, the color filter is formed on the counter electrode **11**.

As previously described, if the microlens **641** is employed, a display panel with average diameters optimum for R, G, and B wavelengths can be easily fabricated as shown in FIG. **62**.

FIG. **64** illustrates the case where color filters **151** are formed in mosaic form as shown in FIG. **65**. As shown in FIG. **66**(b), in the case where color filters **151** are formed in the form of stripes, microlenses **641** in the form of stripes are employed as shown in FIG. **66**(a). Although depending on focal distance, in FIG. **66** a microlens **641c** is caused to correspond to a B modulation pixel, a microlens **641d** to a G modulation pixel, and a portion having no microlens to a R modulation pixel, as an example.

In FIG. **64**, although the microlens **641** is not formed on the portion corresponding to a R pixel, microlenses **641a**, **641b**, and **641c** may be formed so that they correspond to R, G, and B pixels, as shown in FIG. **68**(b). Also, as shown in FIG. **68**(a), instead of the microlens **641** a fine prism **671** may be formed. In addition, the microlenses **641** are not necessarily formed on the surface of the transparent substrate **642** as irregularities. As shown in FIG. **67**(b), the microlenses **641** may be formed within the transparent substrate **642**, by employing an ion exchange technique. The fabrication method of the microlenses **641** by this technique has been put to practical use by Nippon Sheet Glass.

In FIG. **61**, the phase separation of the mixed solution **315** has been performed by forming the light shielding film (light shielding pattern) **202b** on the mask **181** so that ultraviolet rays are not radiated on the light shielding film **202b**. As shown in FIG. **69**, even if the microlenses **641** are employed instead of the mask **181**, the mixed solution **315** can be phase-separated satisfactorily without radiating ultraviolet rays on the light shielding film **202**.

Ultraviolet rays **183** incident on the transparent substrate **642** are collected by the microlenses **641** and therefore the ultraviolet rays are not incident on the light shielding films **202**. For this reason the light shielding film **202** does not absorb ultraviolet rays. Therefore, there is no possibility that the average diameter near the light shielding film **202** will be increased so that light can escape.

It is effective that the oblique line portion of FIG. **69** is filled with a Optical coupling agent **691**. The Optical coupling agent **691** can employ, for example, acrylic resin, water, alcohol, and ethylene glycol. Particularly, water is a suitable Optical coupling agent because it requires only

drying after it is processed. In the case where the microlens **641** is formed with ultraviolet ray setting resin, the refractive index is between 1.45 and 1.50. On the other hand, the refractive index of water is about 0.1 smaller than that of the microlens **641**. The thickness of the counter substrate **11** is between 0.8 and 1.1 mm. Therefore, the focal distance of the microlens **641** needs to be between 0.8 and 1.1 mm. However, if the convex portion of the microlens **641** is in contact with air, the difference in refractive index is too large and therefore the focal distance of the microlens **641** becomes extremely short. For this reason the focal point is within the counter substrate **11**. In this situation, the strength of an ultraviolet ray cannot be changed in the mixed solution **315**. In order to make the focal distance long, there is a need to enlarge the curvature R of the microlens, but there is a limit to manufacturing accuracy. The reason for this is that the curvature R becomes extremely large, the height of the microlens becomes low, and therefore, a required microlens cannot be made. The thickness of the counter substrate **11** is between 0.7 and 1.1 mm. Therefore, if pixel size is between 50 and 300 μm, the microlens **641** needs to have an extremely long focal distance. If the Optical coupling agent **691** is employed, a difference in refractive index will become small, and consequently, it is believed that a microlens with a long focal distance can be easily manufactured.

As shown in FIG. **69**, if the oblique line portion is filled with water (Optical coupling agent **691**), the difference in refractive index between the microlens and water in contact with the convex portion of the microlens will become small and therefore the focal distance will become long. Therefore, focal distance such that ultraviolet rays can pass just the light shielding film **202** can be easily realized. Also, the occurrence of the halation between the microlens **641** and the counter substrate **11** can be prevented. Since the optical path of incident light is refracted by the microlens **641**, the aforementioned halation prevention effect is also effective when the microlens **641** is formed by an ion exchange technique (refer to FIG. **67**(b)). In addition, in the case of FIG. **64**, it is a matter of course that it is effective that the space between the microlens **641** and the substrate is filled with the Optical coupling agent **691** such as water. It is a matter of course that the microlens may be replaced with the prism of FIG. **68**(a).

In FIG. **69** a description has been made of a method which satisfactorily phase-separates the mixed solution **315** present on the pixel electrode **14** by the microlenses **641**. In this method, the time for radiating ultraviolet rays is between about 30 and 90 seconds. Also, ultraviolet rays with a strength which can complete phase separation in the aforementioned radiating time are radiated.

If the phase separation method of the mixed solution is considered, for example, if the microlenses **641** are employed and also if the strength of ultraviolet rays is made proper and the radiating time for ultraviolet rays is more than 1 minute, then a density distribution between the resin component and the liquid component can be caused to occur on the pixel electrode **14**. This state is shown in FIG. **70**. The portion of the liquid crystal layer **21** having a great number of dotted lines represents a large amount of resin component. The refractive index of resin is lower than that of a liquid crystal. Therefore, the refractive index of the central portion of the pixel electrode **14** (central portion of the microlens) is low, and the refractive index becomes high toward the peripheral portion of the pixel electrode **14**.

If the central portion of the pixel electrode **14** has only a resin component and the peripheral portion has only a liquid crystal component, liquid crystal molecules can be oriented

along the resin component. If such a liquid crystal panel is employed alone or together with the polarizing plate **131**, a display panel with a wide visual field angle can be obtained.

It is considered that the reason is that since the strength of the ultraviolet ray at the focal portion of the microlens **641** is strong, the resin in the central portion begins to set, and pushes out the liquid crystal component in the central portion to the peripheral portion, pulling the resin component in the peripheral portion to the central portion.

In the aforementioned embodiment, while the distribution shown in FIG. **70** is formed with the employment of the microlens **641**, a similar display panel can be fabricated even if the mask **181** shown in FIG. **18** is employed. With the mask, ultraviolet rays are radiated on the central portion of the pixel electrode **14**. In addition, if voltage is applied to the pixel electrode **14** at the time of phase separation, orientation of liquid crystal molecules will be easily performed.

Therefore, as shown in FIG. **71**(*a*), incident light scatters in an "OFF state." It is believed that conceptually the scattering state is obtained by a combination of a concave lens **711** and an ordinary scattering mode, as shown in FIG. **71**(*c*). In other words, if a single pixel is observed, the refractive index is low at the central portion and high at the peripheral portion and therefore the pixel functions as the concave lens **711**. Incident light is also scattered by a waterdrop-like liquid crystal such as a normal PD liquid crystal layer. For this reason, the scattering characteristic of the "OFF state" is high by the amount of the concave lens effect. In the "ON state" of FIG. **71**(*b*), the refractive indexes of the liquid crystal layer **21** become even and therefore the liquid crystal layer **21** goes to a transparent state. Incident light, as it is, emerges from the liquid crystal layer **21**. From the aforementioned, the display panel of FIG. **70** can make display contrast high. When the display panel is employed as a direct display panel, it is believed that the effect of the high display contrast is also exhibited as the effect that a visual filed angle is enlarged.

The aforementioned description has been made of the constitution in which the mixed solution **315** is satisfactorily phase-separated by the microlenses **641**. However, in the fabrication process, it takes time to align the microlens **641** with the pixel electrode **14**. For this reason, the microlens substrate **642** may previously be formed integrally with the counter electrode **11** and/or the array substrate **12**. The phase separation of the mixed solution **315** can be satisfactorily performed if light is collected with the microlenses **641**. When the display panel is used as a light valve, the light rate of utilization can be made high, because light from a light emitting lamp can emerge from the display panel by the light collecting operation of the microlens **641** without being shut out by the TFT **155** and the light shielding film **202**.

It is also effective to form the microlens **641a** over the signal line **15** as shown in FIG. **73**. The ultraviolet ray **183b** that is incident on the microlens **641a** is strongly incident on the A portion on the signal line **15**. For this reason the average diameter of the liquid crystal layer **21** in the A portion becomes small. As a result, high scattering is obtained and a voltage required to produce a transmitting state is 10 (V) or more. For this reason the A portion is always in a scattering state. Ultraviolet ray **183a**, as it is, is incident on the pixel electrode **14**, whereby the liquid crystal layer **21** on the aforementioned pixel electrode **14** is optimally phase-separated.

In the aforementioned display panel of the present invention, while the PD liquid crystal layer **21** has been described as a single layer, the present invention is not limited to a single layer. For example, as shown in FIG. **40**,

liquid crystal layers **21a** and **21b** differing in the average diameter of the PD liquid crystal may be stacked with each other. As shown in FIG. **41**, a first PD liquid crystal layer **21a** may be formed between a first pixel electrode **14a** and a counter electrode **25**, and a second PD liquid crystal layer **21b** may be formed between a second pixel electrode **14b** and the counter electrode **25**. In addition, the present invention is not limited to an active matrix type display panel in which switching devices **155** are formed on pixel electrodes **14**, but may be a simple matrix type display panel in which pixels are formed with electrodes **421** in the form of stripes. As shown in FIG. **43**, the invention may be a display panel in which a counter electrode **25** is formed on liquid crystal layers **21a** and **21b** stacked with each other and which is not provided with the counter substarte **11**. As shown in FIG. **44**, it may be a display panel stacked with a liquid crystal layer **21a** containing a color which modulates Magenta light, a liquid crystal layer **21b** containing a color which modulates cyanogen light, and a liquid crystal layer **21c** containing a color which modulates yellow light. As shown in FIG. **45**, the present invention may be a display panel in which one layer is a TN liquid crystal layer **21b** and the other layer is a PD liquid crystal layer **21a**. In addition, the liquid crystal layer may be a ferroelectric liquid crystal layer, a cholestic liquid crystal layer, an STN liquid crystal layer, and a homeotropic liquid crystal layer.

Furthermore, the technical idea described in this specification of the present invention is also applicable to an optical write type display panel, a laser write type display panel, a heat write type display panel, a plasma display panel (PDP), a plasma address liquid crystal display (PALCD), an inorganic EL display panel, and an organic EL display panel.

FIGS. **40** and **41** show display panels in which the liquid crystal layer **21** is constituted by two layers, and the specific constitution is shown in FIG. **46**. FIG. **46** is a sectional view of the display panel of the present invention. Between a pixel electrode **14** and a common electrode **212** a first liquid crystal layer **21a** is held, and between the pixel electrode **14** and a counter electrode **25** a second liquid crystal layer **21b** is held. On a TFT **155** a light shielding film **152** or **202** is formed to prevent the occurrence of a photoconductor phenomenon. It is a matter of course that the composition and constitution (e.g., average particle diameter) of the liquid crystal layers **21a** and **21b** may be changed.

FIG. **49** is an equivalent circuit diagram of the display panel of FIG. **46**. As evident in FIG. **49**, the liquid crystal layers **21a** and **21b** are arranged with the pixel electrode **14** as a common electrode. The pixel electrode **14** is connected to the drain terminal of a TFT **155** through a connecting portion **382**. A common electrode **212** is a stripe-shaped electrode consisting of ITO. Outside the display area of the panel, the common electrode **212** is electrically connected to a counter electrode **25**.

FIG. **47** is a plan view of the array substrate **12**. The pixel electrodes **14** have been removed to make understanding of the substrate **12** easy. The common electrode **212** is an electrode common to all pixel electrodes **14**. It is preferable that the common electrode should be originally a flat face electrode (mat electrode), but, patterning of the common electrode is difficult because it crosses a gate signal line **471**. For this reason, in the present invention, an insulating film **154** is employed to maintain insulation between the common electrode and source signal lines **15**. The source signal lines **15** extend in the horizontal direction of each pixel and are electrically connected to another common electrode **212** at a point outside the display area. Furthermore, the source signal lines **15** are connected to the counter electrode **25** at

a point outside the display area. Note that the counter electrode **25** is a mat electrode consisting of ITO.

The place at which the common electrode **212** crosses the source signal lines **15** narrows the width of the common electrode **212**. This is for preventing a short circuit between the common electrode **212** and the source signal lines **15** and also reducing the parasitic capacity of the source signal line **15**. It is preferable that the width of the crossed portion should be less than ½ of pixel size. For example, if the vertical length of pixel size is 100 μm, the width of the crossed portion is reduced to less than 50 μm.

However, since the common electrode **212** is formed from ITO, the resistance value reaches 100 KΩ or more, when pixel size is 50 μm and panel size is about 3 inches. For this reason there is the problem that when voltage is written from the TFT **155** to the pixel electrode **14**, the electric potential of the common electrode **212** changes at the same time. As a countermeasure, in the present invention, a metal wire **471** consisting of metal material is formed on the common electrode **212**. The metal material employs, for example, chrome (Cr).

A sectional view along line AA' of FIG. **47** is shown in FIG. **48**. On the array substrate **12** an SiO$_2$ film (not shown) and the stripe-shaped common electrode **212** consisting of ITO are formed, and on the common electrode **212** the metal wire **471** is formed. **154** denotes an insulating film consisting of SiO$_2$, Ta$_2$O$_3$, TaOx, and SiNx. To prevent pinholes, the insulating film **154** is formed by performing a deposition process a plurality of times.

By forming storage capacitance between the common electrode **212** and the pixel electrode **14**, the potential on the pixel electrode **14** can be held for a one frame interval even if the OFF characteristic of the TFT **155** is not satisfactory. Particularly, in the case where the TFT has been formed by a low-temperature polysilicon technique, the OFF state of the TFT is not satisfactory (because leakage of light occurs in the OFF state), so formation of the common electrode **212** shown in FIG. **46** is useful. The constitution in which the common electrodes **212** in the form of stripes are formed from ITO in the row directions of pixels is not only specific to the display panel of FIG. **46** having two PD liquid crystal layers, but it is also useful for other liquid crystal display panels (e.g., a TN liquid crystal display panel, a PD liquid crystal display panel with a single liquid crystal layer, etc.).

In FIG. **46**, in the case where the liquid crystal layers **21**a and **21**b are formed with PD liquid crystals, it is preferable that the average particle diameters of the waterdrop-like liquid crystals or the average particle diameters of polymer networks should be different. It is also preferable that one of the liquid crystals contain a guest-host liquid crystal and also resin be colored. The liquid crystal layers **21**a and **21**b are not only formed by PD liquid crystals, but they may also be formed by TN liquid crystals as shown in FIG. **45**. In addition, it is a matter of course that the contents described in the aforementioned embodiment are applied to the display panel of FIG. **46**. For example, dielectric films are stacked on each of the electrodes **25** and **14** to obtain an antireflection effect, and an air coat is formed on an interface which contacts air.

FIG. **50** is an explanatory diagram for explaining the drive method of the display panel of FIG. **46**. At the first field (frame) a source driver circuit **491** outputs a positive-polarity video signal, and the video signal is passed through the source signal line **15** and the TFT **155** and written to the pixel electrodes **14**. On the other hand, the counter electrode **25** and the common electrode **212** are connected to ground.

If the positive-polarity video signal is written to the pixel electrodes **14**, electric fields shown by solid lines will be produced in the liquid crystal layers **21**a and **21**b as shown in FIG. **50**.

At the second frame next to the first frame, the driver circuit **491** outputs a negative-polarity video signal, and the video signal is written to the pixel electrodes **14**. Therefore, electric fields shown by dotted lines will be produced in the liquid crystal layers **21**a and **21**b. As described above, voltages different in signal polarity for each frame are written to the pixel, and an AC voltage is applied to the liquid crystal layer **21**.

Therefore, if voltage is applied to the pixel electrodes **14**, the two liquid crystal layers **21**a and **21**b will be light-modulated at the same time. In comparison with the conventional constitution in which only a single layer is light-modulated, the drive method is the same, but, if two liquid crystal layers are employed, the display contrast will be considerably enhanced.

A description will hereinafter be made of the fabrication method of the display panel of the present invention shown in FIG. **46**, referring to FIG. **51**. In FIG. **51**(a), a mixed solution **315** is coated on an array substrate **12** and held between a separation film **182** and the substrate **12**. The coating method employs, for example, a spinner method, a roller coater method, or a drop method. In the case where the mixed solution can be coated even by a spinner, it is obvious that there is no need to employ the separation film **182**.

Then, ultraviolet rays are radiated through the back surface of the array substrate **12**. The liquid crystal component in the mixed solution easily absorbs light having a wavelength of 370 to 390 nm, so there is the fear that the liquid crystal component will change its quality. Therefore, ultraviolet rays having a wavelength of more than 370 nm should be cut. Ultraviolet ray cut can be easily performed with a ultraviolet ray cut filter.

If ultraviolet rays are radiated through the back surface of the array substrate **12**, the ultraviolet rays will set the resin component of the mixed solution **315**, thereby phase-separating the liquid crystal component and the resin component from each other. However, the ultraviolet rays incident on the TFT **155** and the gate and source signal lines **15** (not shown) are shut out, so the resin component of the mixed solution **315** on these portions does not set.

Also, the common electrode **212** does not easily transmit ultraviolet rays, because it consists of ITO. For this reason, the mixed solution **315** on the common electrode **212** (indicated by B) shown in FIG. **51**(b) is different in the radiation quantity of the ultraviolet ray from the mixed solution on the portion (indicated by A) not formed with the common electrode **212**.

The average diameter of a waterdrop-like liquid crystal is usually small, if the radiation quantity of the ultraviolet ray per unit time is great, and vice versa. If this average diameter becomes small, it will become difficult for a liquid crystal to respond to an applied voltage. In the case where a PD liquid crystal is employed as the light modulating layer of a liquid crystal display panel, there is a need to cause the liquid crystal layer **21** to be in a light transmitting state by a voltage of less than a fixed value, and at the same time, there is a need to make the scattering characteristic highest by a voltage of less than a fixed value. These conditions are obtained by examining process conditions (strength of an ultraviolet ray, temperature of the mixed solution **315**, content ratio between the liquid crystal component and the resin component, film thickness of the liquid crystal layer **21**, etc.) Therefore, in FIG. **51**(a), the strength of ultraviolet rays is set so that the liquid crystal layer **21** (B range) on the common electrode **212** can make the scattering characteristic highest in a range in which voltage can be applied. On the other hand, since the liquid crystal layer **21** on the A portion

receives ultraviolet rays stronger than a proper value, the average diameter of the waterdrop-like liquid crystal becomes smaller than a proper value. However, this is beneficial. Since the liquid crystal layer 21 in the A range is not an effective range for image display, it is preferable that the liquid crystal layer 21 in the A range should not be operated by voltage applied to the pixel electrode 14 or common electrode 212. If the average diameter is small, the liquid crystal layer will not change an oriented state and will perform black display.

After radiation of ultraviolet rays, unpolymerized mixed solution 315 is washed off. Washing is performed with pure water or an alcohol. This washing causes the mixed solution 315 on the drain terminal of the TFT 155 to be washed off. Then, a pixel electrode 14 is formed on the liquid crystal layer 21a. The method of forming the pixel electrode 14 is easy because a PD liquid crystal is resin. The process of forming ITO on a resin color filter is well known in prior art. At the same time as formation of the pixel electrode 14a, the drain terminal of the TFT 155 and the pixel electrode 14 are connected together.

For example, when the liquid crystal layer 21a is thick, there are cases where difference in level occurs between the pixel electrode 14 and the drain terminal of the TFT 155. In such cases, in order to prevent the difference in level, metal or conductive material such as conductive paste is previously formed on the drain terminal of the TFT, and on that, the pixel electrode 14 is formed.

The constitution in which the liquid crystal layer 21 consists of two layers is also shown in a display panel shown in FIG. 52. In the constitution shown in the FIG. 52, a single counter electrode 25 and two liquid crystal layers 21a and 21b are formed between two array substrates.

As shown in FIG. 52, if two array substrates 12a and 12b are employed, the display panel can enhance display contrast, although it is a transmission type display panel.

In the constitution of FIG. 52, signals which are applied to the pixel electrodes 14a and 14b are controlled so that they have opposite polarities. For example, when a voltage of +6 V is applied to the pixel electrode 14b, a voltage of −6 V is applied to the pixel electrode 14a. In other words, a voltage of 6 V−(−6 V)=12 V can be applied to the liquid crystal layer. After one frame the polarity is reversed and an alternating signal is applied to the liquid crystal 21.

From the aforementioned, the constitution of FIG. 52 can apply voltage which is double a voltage applied to the pixel of a normal liquid crystal display panel. Therefore, since the film thickness of the liquid crystal can be made thick (double), display contrast can be enhanced.

The array substrates 12a and 12b can employ the same material. It is a matter of course that the array substrates 12a and 12b need to have opposite scanning directions of a source driver circuit. The counter electrode 25 may be replaced with the adhesive layer 371. The drive method is the same as the previous description. However, since there is not the counter electrode 25, loss will arise in voltage that is applied to the liquid crystal layer unless the timing at which voltage is applied to the pixel electrode 14a is the same as the pixel electrode 14b.

For the fabrication method of the liquid crystal display panel shown in FIG. 52, a description thereof will hereinafter be made with FIG. 53. First, the array substrate 12 and the mixed solution 315 are prepared (see FIG. 53(a)).

The mixed solution 315 is coated on the array substrate 12. As the coating method, there is a roller coater method and a spinner method. When the coating is performed, beads 161 for controlling the film thickness of the liquid crystal

layer 21 are scattered previously or coated at the same time as the mixed solution (see FIG. 53(b)).

Then, a separation film 182 or a substrate coated with fluororesin is superimposed on the mixed solution 315. At this time, it is superimposed little by little from the end of the array substrate 12 so that air does not enter. The state at that time is shown in FIG. 53(c). Then, pressure is applied on the separation film 182 from above. As the method, pressure is applied from the end of the separation film 182, preferably parallel to the source signal line 15 or gate signal line 472. In other words, pressure is applied along the signal line with a roller 312 or such. An excess of mixed solution 315 is pushed out (see 53(c)).

Then, ultraviolet rays are radiated, thereby polymerizing and setting (or phase-separating) the resin component present in the mixed solution 315. As described above, after resin has been polymerized (polymer 24), the separation film 182, etc. is peeld and removed. Since fluororesin is easily separated (or peeled), the separation film 182 can be easily separated from the liquid crystal layer 21. The state after the aforementioned process is shown in FIG. 53(d).

Another set of array substrate 12 (two array substrates) formed with a liquid crystal in the aforementioned procedure is fabricated. Then, either of the two array substrates is again coated extremely thin with the mixed solution 315. Next, the two array substrates are pasted together. Thereafter, ultraviolet rays are radiated once more. The mixed solution 315 last coated becomes an adhesive layer 371, and the two array substrates 12 is integrally formed into a single liquid crystal panel. Note that the adhesive layer may be an acrylic resin layer or an urethane resin layer.

Light incident on the PD liquid crystal layer 21 is scattered and causes halation. If the light with halation is incident on the driver circuit 541 (driver circuits 491, 492, etc.) of the liquid crystal panel, a photoconductor phenomenon will occur in the transistors constituting the aforementioned driver circuit, causing failure. This phenomenon frequently occurs in the case where the driver circuit is formed with a low-temperature polysilicon or high-temperature polysilicon technique.

Constitutions for preventing the photoconductor phenomenon of the driver circuit are shown in FIGS. 54, 55, and 56. FIG. 54 shows constitution formed with a light shielding film 542 on a driver circuit 541. The material of the light shielding film 542 may be metal material such as chrome (Cr), tantalum (Ta), and molybdenum (Mo), but, it is preferable that it should be a resin light shielding film which absorbs similar light as the light absorbing film 152. The reason for this is that the liquid crystal layer 21 absorbs irregularly reflected light and thereby can suppress hich is incident on the driver circuit 541. If it is a metallic light shielding film, light in the A direction can be perfectly shut out, but the halation light arising from the liquid crystal layer 21 will be reflected and conversely, it will be incident on the driver circuit 541. Even in a metal film, a composite layer (2-layer chrome) consisting of metal chrome and chrome oxide is low in reflectance and usable. In addition, a dielectric mirror consisting of a dielectric mutilayer film may be employed. The dielectric mirror is suitable because there is no absorption of light and no generation of heat.

It is advantageous to fill the driver circuit 541 and the vicinities with a light absorbing resin 551 as shown in FIG. 55 (resin light shielding film 152 of FIG. 16). Particularly, it is preferable that the light absorbing resin 551 adopt light setting resin. For example, it is ultraviolet ray setting type acrylic resin. When pasting the array substrate 12 and the counter substrate 11 together, the aforementioned light

absorbing resin **551** is dropped on the driver circuit **541**, and both substrates **11** and **12** are pasted together. Thereafter, the dropped resin is further set by radiating light on the light absorbing resin **551**. The light absorbing resin **551** has a function of preventing the incidence of light onto the driver circuit **541** and also sealing resin. Therefore, seal resin **361** of FIG. **55** may be omitted.

As shown in FIG. **56**, in the case where a driver circuit **541** is formed on the outer circumference beyond a counter substrate **11**, the driver circuit **541** is covered with light absorbing resin **551**.

In the aforementioned display panel of the present invention, while it has been described that the film thickness of the liquid crystal layer **21** is even, the present invention is not limited to this even thickness. For example, as shown in FIGS. **77** and **78**, the film thickness of the liquid crystal layer **21** on each pixel electrode **14** may be changed according to the wavelengths of R, G, and B lights which modulate. FIG. **77** shows constitution formed with pixel electrodes **14** on a substrate **12** varying its film thickness, and FIG. **78** shows constitution formed with a counter electrode **25** on a substrate **11** varying its film thickness. As resin **214** varying its film thickness, there is, for example, acrylic resin and urethane resin.

In the case where the PD liquid crystal modulates R light, it is preferable that the average diameter be relatively large (0.8 to 1.2 μm). When modulating B light, it is preferable that the average diameter be relatively small (0.6 to 1.0 μm). Also, if the average diameter is large, voltage required for drive will be reduced, and conversely, if it is small, the required voltage for drive will become high (in the case where the film thickness of the liquid crystal layer **21** is the same). In order to make the display contrast as R light is modulated and the display contrast as G or B light is modulated the same, it is necessary that the film thickness of the liquid crystal layer which modulate R light should be thicker than that of G or B light and that the average diameter of the liquid crystal layer which modulate R light should be larger than that of G or B light. If the film thickness of the liquid crystal layer for R light is thick and the average diameter is large, the voltage required to make the transmittance of the liquid crystal for R light equal to those of the liquid crystals for G light and B light will be the same.

From the aforementioned description, the film thickness of the liquid crystal layer **21a** on the pixel electrode **14a** which modulates R light is made thick and also the average diameter is made large. Conversely, the film thickness of the liquid crystal layers **21b** and **21c** on the pixel electrodes **14b** and **14c** which modulate G light and B light is made thin and also the average diameter is made small (compared with the R pixel).

The display panel which varies the film thickness of the color filter **151** in accordance with R, G, and B lights to vary the film thickness of the liquid crystal layer had been put to practical use by a TN liquid crystal display panel having a normally black mode. However, this had corresponded to the fact that the rotary polarization characteristic of a liquid crystal depends on a wavelength. Also, if the film thickness of the color filter is varied, the spectral distribution of light which is transmitted by the color filter will vary and this variation will become a problem. In the present invention, since the film thickness of a liquid crystal is varied by transparent resin **214** and also the counter electrode **25** and pixel electrode **14** are formed on the transparent resin **214**, the aforementioned problem will not arise. The color filter **151** is formed on a substrate on which the resin **214** is not formed.

In FIGS. **77** and **78**, a liquid crystal layer **21a** with thickest film thickness is used for R light. A liquid crystal layer **21c** with thinnest film thickness is used for B light. A liquid crystal layer **21b** with intermediate film thickness is used for G light. An insulating film **154** such as that shown in FIG. **16** is formed on the interface between a substrate and the liquid crystal layer **21**. In addition, a light shielding film **152** consisting of resin is formed on a TFT **155**, a signal line **15**, etc.

If a reflecting film **792** is formed on the surface of an array substrate **12** or counter substrate **11**, as shown in FIG. **79**, the display panel can be made a reflection type. It is preferable that the material of the reflecting film **792** should be aluminum (Al). On the surface of the Al film **792** contacting air, SiO_2 (not shown) is formed to prevent oxidation of the Al film. Alternatively, film or such(not shown) is formed so that the Al **792** film does not contact air directly.

Light is incident through the side of the color filter **151**. The incident light is reflected by the reflecting film **792**, and a portion of the reflected light is incident on the TFT **155**. To prevent light which is incident on the TFT **155**, a light shielding film **791** is formed on the back surface of the TFT **155**.

The light shielding film **791**, as shown in FIG. **80**, is formed with openings **341** so that they correspond to pixel electrodes **14**. In other words, the light shielding film **791** serves as a BM which protects light from the TFT, signal line **15**, and the vicinities. The light shielding film is formed from two layers of chrome consisting of chrome metal and chrome oxide. The reason for this is that if the reflectance of the light shielding film is high, a ghost image will occur on a display image. The light shielding film **791** may be formed with resin, but, if it is formed with resin, heat resisting property will become a problem.

FIG. **81** is a sectional view. An SiO_2 layer **811** with a thickness of about 0.1 μm is formed on an array substrate **12**. This is for preventing the dissolution of impurities from the array substrate **12**. On the SiO_2 layer **811** a light shielding film **791** is formed with chrome (Cr) or such. The film thickness of the light shielding film **791** is 0.1 μm (1000 angstroms). On the light shielding film **791** an insulating film **214** consisting of SiO_2 or SiNx is formed. The process of forming the insulating film **214** is performed a plurality of times to prevent the occurrence of pinholes. On the insulating film **214**, common electrodes **212** in the form of stripes (see FIG. **47**) are formed, and the common electrode **212** consists of ITO. Between a pixel electrode **14** and the common electrode **212** a dielectric film **812** consisting of SiO_2 or such is formed, and storage capacitance is formed with the pixel electrode **14** and the common electrode **212** as electric potential. In addition, on the interface between the pixel electrode **14** and a liquid crystal layer **21** an insulating film **154** consisting of polyimide is formed. This constitution having the light shielding film **791**, common electrodes **212** in the form of stripes, and the storage capacitance is also applicable to the other display panels of the present invention.

Note that as a rule, the described contents of the specification of the present invention can be mutually applied to the display panels, units, methods, etc. shown in the drawings. For example, the contents and constitution of FIG. **47** are also applicable to the display panel of FIG. **1**.

Also, when a layer for forming an optical image as a change in a light scattering state is employed as the light modulating layer **21** of the display panel of the present invention, for example, when a PD liquid crystal is employed as the light modulating layer, the light modulating

layer **21** needs to meet the following equation in a no-voltage applied state (light scattering state).

$$0.5 \leq \frac{\pi B}{E} \leq 3.0 \qquad \text{[expression 23]}$$

where E is the luminance of incident light on a small area of the light modulating layer **21**, B is the brightness of the small area measured in a direction normal to the substrate **21**, and π is the ratio of the circumference of a circle to its diameter.

In the above equation, if $\pi B/E \leq 0.5$, the scattering performance of the light modulating layer **21** and the display contrast can be made high. However, the drive voltage becomes high and the design of the driver circuit **541** becomes difficult. On the other hand, if $\pi B/E \geq 3.0$, the driver circuit design will become easy but the display contrast will become low. More preferably, the light modulating layer **21** needs to meet the following equation:

$$0.7 \leq \frac{\pi B}{E} \leq 2.0 \qquad \text{[expression 24]}$$

Also, in the case where the PD liquid crystal is employed as a light modulating layer, from the standpoint of improvements in the drive voltage and hysteresis characteristic it is preferable that the liquid crystal component of the PD liquid crystal employ tran fluororesin and the resin component employ a branch monomer. From the standpoint of making the responsibility of a liquid crystal fast, the viscosity C of the liquid crystal component and Δn need the following equations:

$$20(\text{cp}) \leq C \leq 50(\text{cp}) \qquad \text{[expression 25]}$$

$$0.23 \leq \Delta n \leq 0.3 \qquad \text{[expression 26]}$$

The viscosity of the liquid crystal employed in the PD liquid crystal display panel of the present invention is 27 cp and Δn is 0.27.

If the reflecting film **792** is smooth, the visual field angle will become narrow. For this reason it is difficult for the viewer (user) of the display panel **22** to view a display image. To solve this problem, it is preferable that the reflecting film **792** have irregularities on the surface thereof, as shown in FIG. **82**. The reflecting film **792** is formed on an irregularity film **821**. The irregularity film **821** is formed with light setting type acrylic resin, heat setting resin, polypropylene, polyester, polycarbonate, silicon rubber, etc. An embossed sheet **822** is arranged or bonded to the surface of the display panel **22** to prevent transfer of an outside scene onto the display panel. The embossed sheet **822** employs, for example, embossed polyester film. Note that the irregularity film **821** and the reflecting film **792** may be formed integrally and pasted on the array substrate **12**. For example, the reflecting film **792** may be formed on a sheet or substrate embossed on one surface, and stuck to the sheet or substrate **12** (or counter substrate **11**) with a Optical coupling layer, adhesive agent, or bonding agent. Also, even if the aforementioned sheet or substrate is only arranged, there will be a sufficient advantage.

FIG. **83** is an explanatory diagram of the fabrication method of the display panel of FIG. **82**. The mixed solution **315** is dropped on the array substrate **12** by a drop method (FIG. **83**(*a*)). On the mixed solution **315** the counter substrate **11** formed with the color filter **151** is placed, and the counter substrate **11** and the array substrate **12** are pressed so that the mixed solution **315** has a predetermined thickness.

Then, ultraviolet rays **183** are irradiated through the array substrate **12**, thereby phase-separating the mixed solution **315** (FIG. **83**(*b*)). Next, ultraviolet ray setting resin **831** is coated on the array substrate **12**. It is desirable that the coating should be performed by screen printing. Thereafter, ultraviolet rays **183** are irradiated, thereby setting the resin **831** (FIG. **83**(*c*)).

After setting, the resin **831** is pressed with a heated roller **312**, thereby forming fine irregularities on the resin **831** (FIG. **83**(*d*)). The roller **312** is formed with protrusions for transferring irregularities. Thereafter, the reflecting film **792** is formed by vaper deposition on the irregularity film **821**, thereby completing the panel **22**.

In the aforementioned fabrication method, although the ultraviolet ray setting resin **831** is coated and irregularities are formed on the coated resin with the roller **312**, there are other methods.

For example, there is a method in which a PVA solution diluted with water is coated on the array substrate **12** and irregularities are formed by evaporating water in the PVA solution. If the PVA solution is set, microscopic irregularities will appear on the surface. There is another method which coats paste containing microscopic glass or resin fibers, beads, etc. In the case where the paste has a shinning surface like silver paste, there is no need to form the reflecting film **792**. In other words, if the aforementioned paste is coated, the reflecting film **792** can be formed at the same time as the irregularity film **821**. Also, there is a method in which inorganic thin film such as SiO_2 or such is formed by vapor deposition and is patterned with a mask to form irregularities. Also, there is a similar method in which resist and ultraviolet ray setting resin are coated and then patterned with a mask to form irregularities. In addition, there is a method in which coated resin is chemically etched to form irregularities.

It is preferable that the difference in height between irregularities (difference between a concave portion and a convex portion) should be 0.5 μm or 5 μm or between 0.5 and 5 μm, particularly preferably 1 μm or 3 μm or between 1 μm and 3 μm. Also, it is preferable that the ratio between the flat portion (area with no irregularity) and the irregularity portion (area with irregularities) should be in a range from 1:1 to 1:3. If the height of the irregularities is low, transfer of a viewer's face or outside scene onto the display panel will occur. If the height is too high, the display brightness of the display panel will become low. Also, if the ratio of the irregularity portion is low, similarly the transfer of a viewer's face or outside scene onto the display panel will occur, and if it is high, the display brightness will become low. Thus, the aforementioned ratio is in an optimum range. Note that the aforementioned matters (formation method, constituent material, etc.) related to the irregularity film **821** are also applied to other display panels of the present invention.

FIG. **84** illustrates another fabrication method of the display panel of the present invention. ultraviolet ray setting resin **831** is coated on a substrate **181**, and irregularities are formed on the surface with a heated roller **312**. The substrate **181** formed with reflecting film **792** on the irregularity film **182** is pasted on a substrate **12** or **11** with an optical coupling layer **691**, as shown in FIG. **84**(*c*). The Optical coupling agent **691** is an acrylic transparent adhesive agent, ethylene glycol.

Note that there is a method which does not form the irregularity film **821**. This constitution is shown in FIG. **84**(*d*). On a substrate **181**, a reflecting film **792** is formed. The reflecting film **792** and a substrate **12** are pasted together through a light scattering layer **841**. The light scattering

layer **841** is one in which particles such as titan (Ti) are contained in a bonding agent. As another example, there is a solution or such in which two gel liquids different in refractive index are mixed together. Light incident on the light scattering layer **841** is scattered. For this reason, transfer of a viewer's face, etc. onto the display panel is suppressed.

The scattering characteristic of the light scattering layer **841** needs to meet the following equation:

$$1.0 \leq \frac{\pi B}{E} \leq 30.0 \qquad \text{[expression 27]}$$

where E is the luminance of incident light onto a small area of the light scattering layer **841**, B is the brightness of the small area measured in a direction normal to the substrate **181**, and π is the ratio of the circumference of a circle to its diameter.

More preferably, the scattering characteristic of the light scattering layer **841** needs to meet the following equation:

$$3.0 \leq \frac{\pi B}{E} < 20.0 \qquad \text{[expression 28]}$$

If a value of πB/E is small, the visual field angle will become wide, but the display brightness of the display panel will become low. If a value of πB/E is great, the display brightness will become high, but the visual field angle will become narrow, and consequently, a display image will become difficult to see.

In FIGS. **82**, **84**(*d*), etc., although the reflecting film **792** consists of aluminum (Al), it may be a two-layer chrome film consisting of chrome and chrome oxide. It may also be film containing carbon and titan (Ti) in resin. The reflecting film **792** containing carbon and Ti in resin serves as a light absorbing film rather than a reflecting film. In addition, while it has been described that the substrate **181** is pasted on the side of the array substrate **12**, the present invention is not limited to this, but it may be pasted on the side of the counter substrate **11**.

FIG. **85** is a sectional view of a display panel formed with an irregularity film **821** on a surface which contacts a liquid crystal layer **21**. In the case where the irregularity film **821** is formed on a surface which contacts the liquid crystal layer, the height of the irregularity film **821** is 2 μm or less, preferably 1.5 μm or less. The reason for this is that the irregularities on the irregularity film **821** change the thickness of the liquid crystal layer **21** and cause an unevenness in an electric field within the liquid crystal layer **21**. The other matters, related to the area between the flat portion having no irregularity and the irregularity portion having irregularities, fabrication method, etc., are similar to the aforementioned embodiments.

Even in the embodiment of FIG. **85** the reflecting film **792** is formed on the irregularity film **821**, and the color filter **151** is formed on the reflecting film **792**. The reflecting film **792** also serves as a counter electrode. Note that a counter electrode **25** consisting of ITO may be formed on the color filter **151**. The color filter **151** smoothes the irregularities on the irregularity film **821** and evens the thickness of the liquid crystal layer **21**. The color filter **151** is divided into red, blue, and green, or it is divided into magenta, yellow, and cyanogen.

In FIG. **85**, although the irregularity film **821** is formed, for the purpose of widening a visual field angle there is constitution in which a smooth reflecting film **792** is formed

and a diffusing agent (glass beads, Ti particles, etc.) is contained in a color filter **151** formed on the reflecting film **792**.

FIG. **86** is a sectional view of a display panel **22** with a pixel electrode formed as a reflecting electrode **14***b*. A TFT **155**, etc., are formed on an array substrate **12**, and an insulating film **154** consisting of photosensitive polyimide is formed on the TFT **155**. The polyimide film **154** is bored, and the reflecting electrode **14***b* and the drain terminal of the TFT **155** are connected together through a connecting portion **382**. The polyimide film **154** is formed with irregularities on the surface, and a buffering layer **861** is formed between the reflecting electrode **14***b* and the polyimide film **154** to enhance adhesion therebetween. As the buffering layer **861**, there is an SiO₂ layer or such. The reflecting electrode **14***b* is formed from a composite layer consisting of Ti, Al, and Cr a composite layer consisting of Al and Zr, or such. On the reflecting electrode **14***b*, a color filter **151** with a function of obtaining smoothness and performing color display is formed.

FIG. **87** is an explanatory diagram of the fabrication method of the display panel shown in FIG. **86**. The photosensitive polyimide **831** is coated on a substrate **12** formed with TFTs,etc. (FIG. **87**(*a*)). Then, light causing a light strength distribution to occur two-dimensionally by an interference effect is irradiated, thereby setting photosensitive polyimide. The polyimide **154** is contracted and irregularities are formed on the surface (FIG. **87**(*c*)). Thereafter, the connecting portion **382** is bored and the reflecting film **14***b* is formed.

In FIG. **87**, although irregularities are formed by irradiating light and polymerizing photosensitive polyimide, the present invention is not limited to this. For example, irregularities can be easily produced on a surface by performing mesh screen printing.

FIG. **88** illustrates irregularities formed on the surface of the reflecting electrode **14***b*. As a method of forming irregularities, there are a method which enlarge the particle shape of Al that is deposited, a method in which the crystal particle of Al₂O₃ is grown during vapor deposition and then the surface is coated with an Al film, etc.

The aforementioned reflection type display panel is one in which the pixel electrode **14** is formed with metal material. The display panel shown in FIG. **89** is one in which reflecting means is formed from a dielectric mirror **891**.

As shown in FIG. **89**, a TFT **155** is formed on an array substrate **12**. On the TFT **155** a light shielding film **152** is formed. The light shielding film **152** is employed to prevent the occurrence of a photoconductor phenomenon which is caused by light transmitted through the dielectric mirror **891**.

The drain terminal of the TFT **155** is connected with a pixel electrode **892** consisting of ITO. The pixel electrodes **892** are arranged in the form of a matrix and formed through an insulating film **154** so that they are not electrically connected to a portion other than the drain terminal of the TFT **155**. The insulating film **154** is formed with polyimide, SiO₂, SiNx, etc. On the ITO pixel electrode **892** a dielectric mirror **891** is formed. The dielectric mirror **891** is stacked regularly with 20 or more layers consisting of a high refractive index film and a low refractive index film. Since the band of light which is reflected by the dielectric mirror is narrow, the present invention employs stacked three dielectric mirrors with three wavelength bands: dielectric mirror for reflecting R light, dielectric mirror for reflecting G light, and dielectric mirror for reflecting B light.

The voltage output from the TFT **155** is transmitted to the pixel electrode **892**, and an electric field is produced

between the ITO electrode **892** and the counter electrode **25**. The liquid crystal layer on the pixel electrode **892** is caused to be in a scattering-transmitting state. Although the pixel electrode **892** consists of ITO, it may be formed from a polysilicon film. The thin polysilicon film is slightly colored light brown and has light transmittance. Particularly, it well transmits light with an infrared wavelength. The pixel electrode **892** may be formed from any material if it has light transmittance with respect to light having any of wavelengths.

If the color filter **151** is formed on the dielectric mirror **891** or counter electrode **25**, color display can be performed with a single display panel. The reflection type display panel can easily perform a countermeasure to heat radiation, if a radiating fin **921** is attached to the panel back surface with a silicon bonding agent **922** as shown in FIG. **92**.

While it has been described that the dielectric mirror **891** is formed on the ITO electrode (pixel electrode) **892**, an ITO electrode (pixel electrode) **892**a may be formed on the dielectric mirror **891**, as shown by a dotted line. In this case the dielectric mirror **891** is bored so that the pixel electrode **892** can be connected to the drain terminal of the TFT **155**.

Now, the defect inspection method,defect correction method, etc., of the display panel of the present invention will be described in sequence. FIG. **90** is an explanatory diagram of the inspection method of the liquid crystal display panel of the present invention shown in FIG. **89**. In the case where the liquid crystal display panel shown in FIG. **89** is formed on the silicon substrate **12**, the TFT **155**, etc., cannot be observed from the side of the substrate **12**. For this reason, a defective TFT **155**, etc., are observed from the side of the dielectric mirror **891**.

The observation is performed with an infrared camera **902**. The liquid crystal display panel of FIG. **89** employs the dielectric mirror **891**, and the pixel electrode **892** is formed with ITO or polysilicon material having light transmittance. The dielectric mirror **891** has a spectral characteristic which reflects visual light, but has light transmittance with respect to an infrared ray above red. ITO and polysilicon also have sufficient light transmittance with respect to an infrared ray. If the pixel electrode **892** is formed with metal material, then the TFT **155** will not be able to be observed with the infrared camera **901**.

Thus, the defect inspection method of the present invention is characterized in that an array substrate is observed with infrared rays. The observation means detection of a defective TFT **155**, a short-circuit of the pixel electrode **892**, detection of dust, etc. When a short-circuit defect occurs, a short-circuited portion is cut with a laser trimming unit **902**. Alternatively, the TFT **155** is destroyed with laser light and regarded as a black pixel defect. A white pixel defect is easy to see visually, while a black pixel defect is difficult to see. Therefore, the primary object of the point defect correction is to correct a white point defect to a black point defect.

As the laser trimming unit **902**, a YAG laser is a suitable one. The wavelength of the YAG laser is in an infrared area of 1.06 μm. The YAG laser transmits laser light through the pixel electrode **892** and can perform satisfactory cutting. The YAG laser radiates pulsed laser light. If laser light is irradiated at a time, the material of a cut portion will vaporize suddenly and therefore the dielectric mirror **891** will be destroyed. It is desirable that the frequency of the pulse should be between 100 Hz and 10 KHz, particularly between 200 Hz and 1 KHz. It is desirable that the mesial magnitude of the laser pulse should be between 20 and 500 ns, particularly between 50 and 200 ns. In addition, it is desirable that the number of pulses that are irradiated on a

single point should be between 2 and 10, particularly between 3 and 5. These must be obtained by experiment.

The aforementioned description has been made of the defect inspection method and defect correction method of the array substrate **12**. In FIGS. **91** and **93**, a description is made of the defect correction method and defect correction unit of the PD liquid crystal panel.

As previously described, a white point pixel defect is conspicuous as a pixel defect. In the case of a PD liquid crystal display panel, the white point pixel defect means the state in which voltage is continuously supplied to a pixel electrode. Therefore, if a white point pixel defect is changed to a black point pixel defect, it will become inconspicuous. As the method, there is a method which destroys the TFT **155** and a method in which the oriented state of liquid crystal molecules **20** will not be changed even if voltage is applied to the liquid crystal molecules on the pixel electrode **14**. In this embodiment, a description will first be made of a method in which liquid crystal molecules **20** will not operate even if voltage is applied to them.

In this embodiment, an excimer laser is employed as a light source, and an oscillating wavelength of 351 nm which is transmitted by a glass surface is employed as the oscillating wavelength of the excimer laser by using the sealed gas of the laser. First, the defect correction unit in this embodiment will be described.

The defect correction unit is provided with an excimer laser generator **901**a, as shown in FIG. **91**. An ultraviolet reflecting mirror **901**b, a mask **181**, a lens **901**c, a liquid crystal display panel **22**, and an XY stage **911** are arranged on the optical path of a laser beam **912** which is emitted from the excimer laser generator **901**a. The mask **181** is formed with a hole corresponding to the shape of a pixel **341**, as shown in FIG. **94**.

The laser beam **912** radiated from the excimer laser generator **901**a is reflected by the ultraviolet reflecting mirror **901**b and passes through the slit **341** of the mask **181**. The laser beam **912** is focused by the lens **901**c to a location on the liquid crystal display panel **22** which is corrected. The mask **181** has a rectangular slit, which corresponds to the pixel size of the liquid crystal display panel. On the other hand, the XY stage **911** can be positioned with a precision of 2 μm or less at the liquid crystal display panel and is positioned so that the focused laser beam **912** is irradiated on a pixel to be corrected. The spot size of the focused laser beam may be smaller than the pixel size. In the case the XY stage **911** is moved so that the laser beam is irradiated on a defect pixel area in sequence.

FIG. **93** is a diagram for explaining the defect correction method. It is desirable that the number of pulses of the laser beam **912** which is radiated from the excimer laser generator **901**a should be 2 or 20 or between 2 and 20, particularly 5 or 10 or between 5 and 10. It is desirable that the frequency of the pulse should be 0.1 Hz or 100 Hz or between 0.1 and 100 Hz, particularly 0.5 Hz or 10 Hz or between 0.5 and 10 Hz. It is desirable that the energy density should be 0.2 J/cm² or 1.5 J/cm² or between 0.2 and 1.5 J/cm², particularly 0.5 J/cm² or 1.0 J/cm² or between 0.5 and 1.0 J/cm².

If excimer laser light is irradiated, the liquid crystal molecule **20** will no longer be oriented. In other words, even if voltage is applied to the pixel electrode **14**, the liquid crystal will no longer operate and will maintain a normally scattering state (it will become a defective black pixel). The reason for this is that excimer laser light is laser light with a short wavelength and also the liquid crystal molecule **20** absorbs this laser light. In addition, a polymer **24** easily absorbs the laser light. For this reason the liquid crystal

molecule 20 and the polymer 24 change, and it is assumed that the liquid crystal layer is caused to be in a normally scattering state. It is also assumed that the heat generated by the laser light makes a contribution to the change.

If the aforementioned operation is performed by irradiating the laser light 912 on a white point pixel defect in sequence, correction of a detect in the liquid crystal display panel will be performed. The white point pixel defect can be detected by applying a signal which does not cause the liquid crystal layer 21 to be in a light transmitting state(for example, the signal is a drive signal which does not apply a video signal to the source signal line and which applies a signal synchronously repeating the ON voltage and OFF voltage of the TFT to the gate signal line alone). The detected white point pixel defect is previously stored in memory, and the XY stage 911 is sequentially controlled so that the defective pixel is in the irradiation range of the laser light. Of course, the XY stage 911 may be moved one point at a time and pulsed laser light may be irradiated, while an observer is sequentially detecting white point pixel defects with the state in which a signal which does not cause the liquid crystal layer to be in a light transmitting state is applied.

In the embodiment of FIGS. 91 and 93, although the laser light generator 901 employs an excimer laser light generator, the present invention is not limited to this excimer laser light generator. For example, it may employ a YAG laser light generator. In the case of YAG laser light, the wavelength is infrared and therefore it is believed that the possibility that the liquid crystal molecule 20 and the polymer 24 are changed by laser light is low. However, they can be changed by heating, and consequently, the liquid crystal on a defective pixel can be caused to be in a normally light scattering state.

In the case of YAG laser light, the pulse frequency exhibits a satisfactory result when it is 1 Hz or 1 KHz or between 1 Hz and 1 KHz, particularly 10 Hz or 100 Hz or between 10 Hz and 100 Hz. It is desirable that the mesial magnitude of the laser light should be 20 ns or 200 ns or between 20 and 200 ns. In addition, it is desirable that the number of pulses that are irradiated on a single pixel should be 1 or 10 or between 1 and 10, particularly 2 or 5 or between 2 and 5. If the irradiation period of the laser light is too long, it will have a thermal influence on the liquid crystal on a pixel adjacent to a defective pixel and therefore the liquid crystal molecule 20 on a normal pixel will no longer operate.

In addition, there is a method which further focuses the YAG laser light to directly destroy the TFT 155 and a method cuts off the TFT 155 and the pixel electrode 14 from each other. It is a matter of course that these methods are effective as a method which changes a white point pixel defect to a black point pixel defect.

In the case where the array substrate 12 consists of a glass substrate, it is also effective that the laser light is incident from the side of the array substrate 12. In this case the TFT 155 and the source signal line 15 serve as masks, and therefore even if the XY stage 911 is not precisely positioned, the liquid crystal layer on the pixel electrode 14 can be changed with reliability. Note that light from a xenon (Xe) lamp can be focused and employed instead of laser light. In addition, white laser, argon-gas laser, and Ne—He laser can be employed.

The aforementioned display panel of the present invention has its exceptions, but basically the color filter 151 is attached to the display panel. However, as shown in FIG. 95, color display can be performed with a single display panel

without attaching a color filter to the interior surface or exterior surface of the display panel.

In the display panel of FIG. 95, a color filter 151 is formed in correspondence with each microlens 641 of a microlens array 641. For example, an R color filter 151a is formed in correspondence with the microlens 641a. A G color filter 151b is formed in correspondence with the microlens 641b. A B color filter 151c is formed in correspondence with the microlens 641c.

The incident light on the microlens 614a is incident on the pixel electrode 14a. At this time, because the incident light is transmitted through the R color filter 151a, R (red) light is incident on the pixel electrode 14a. Similarly, the microlens 641b causes G (green) light to be incident on the pixel electrode 14b, and the microlens 641c causes B (blue) light to be incident on the pixel electrode 14c.

If constituted in the aforementioned manner, the display panel 22 can perform color display (without forming a color filter on the display panel) even if it is a monochromatic display panel. In the aforementioned description, although the microlens array 641 is arranged on the incident side of the display panel 22, the present invention is not limited to this arrangement. It is a matter of course that the microlens array 641 may be arranged on the exit side of the display panel 22. In addition, if a Optical coupling agent 691 is injected into the space between the microlens array 641 and the display panel 22, the positional offset between the microlens 641 and the pixel electrode 14 and the occurrence of halation can be suppressed. Thus, this arrangement is also a suitable one. In addition, in FIG. 95, although the microlens array is formed by ion exchange, it is a matter of course that the microlens array may be formed with a stamper (transfer type) or a metal mold. Also, it may be formed with an etching technique or a printing technique.

In FIG. 95, although the microlens 641 is formed on another substrate 642, it may be formed directly on the glass substrate of a display panel 22 as shown in FIG. 102. A microlens 641a colored red is formed at a position corresponding to a pixel electrode 14a. Likewise, a microlens 641b colored green is formed at a position corresponding to a pixel electrode 14b, and a microlens 641c colored blue is formed at a position corresponding to a pixel electrode 14c.

The microlens 641 is formed by containing colors in ultraviolet ray setting resin. A red (R) microlens is first formed with the stamper, and then a green (G) microlens is formed with the stamper. Finally, a blue (B) microlens is formed. If the three processes are performed in this manner, a display panel with R, G, and B microlenses can be fabricated as shown in FIG. 102.

In FIG. 102, although it has been illustrated that the microlens 641 is formed on the counter electrode 11, the present invention is not limited to this. It may be formed on the array substrate 12. In addition, the microlens does not need to be colored, and it is a matter of course that the color filter 151 may be formed on the counter substrate 11 and a colored transparent microlens formed at a position corresponding to the color filter 151.

FIG. 103 shows the substrates 11 and 12 of the display panel into which microlenses 641 are incorporated. In the constitution of FIG. 103, the directivity of light emerging from the display panel is maintained. The color filter 151 is formed on the interface between the substrate 11 (or 12) and air.

In FIG. 102, although the circular arc-shaped microlens is formed with a stamper (metal mold for transfer), it may be formed as a Fresnel lens 641c, as shown in FIG. 104. The Fresnel lens 641c is formed for each pixel as shown in FIG. 105.

FIG. **106** shows the constitution in which a reflecting film **962** formed on the back surface of a microlens sheet **1062** is arranged on the back surface of a display panel. Although the microlens sheet **1062** is not in the form of a Fresnel lens, as shown in FIG. **106**, it may be either the circular arc shape shown in FIG. **102** or the flat shape shown in FIG. **95**. Because the microlens **641** is arranged for the purpose of improving a visual field angle, it does not always need to be formed in correspondence with a single pixel. A single microlens may be arranged for a plurality of pixels.

In FIG. **106**, light is incident from the side of the counter substrate **11** and emerges from the pixel electrode **14**. The light emerging from the electrode **14** is reflected by a reflecting plate **962**, and the directivity is evened by the microlens **641**. The light emerges from the counter substrate **11** again.

1061 denotes a prism sheet such as that shown in FIG. **107**. A single prism sheet or a plurality of prism sheets is superimposed and used. The prism sheet narrows the directivity of light emerging from the panel surface and is employed so that the display surface can have high brightness. Note that a reflecting film **792** may be formed on the back surface of the prism sheet **1061**. As shown in FIG. **108**, it may be employed instead of the microlens sheet **1062** shown in FIG. **106**. In FIG. **106**, if the microlens sheet **1062** is formed by cutting a metal plate, the reflecting film **962** is not needed. The microlens **641** on the microlens sheet **1062** does not always need to be formed in correspondence with a single pixel electrode **14**. A single microlens **641** may be arranged for a plurality of pixel electrodes **14**.

As previously described, if the microlens sheet **1062** or prism sheet **1061** formed with the reflecting film **962** on one side is arranged or glued on one side of the display panel, a reflection type display panel **22** with a proper visual field angle can be constituted. Furthermore, if the prism sheet **1061** is arranged on the incident surface of the display panel, high brightness display can be realized.

If the PD liquid crystal layer is employed as a light modulating layer, the light rate of utilization can be enhanced. If the display panel is constituted as shown in FIG. **109**, the light rate of utilization can be further enhanced. In the constitution of FIG. **109**, a light guiding plate **1091** is stuck on the surface of the panel **22** with an adhesive layer **371**. However, the adhesive layer **371** is not required if the positional relation between the light guiding plate **1091** and the array substrate **12** is fixed (for example, mechanically).

As the adhesive layer **371**, there are silicon gel, a silicon adhesive agent, an epoxy adhesive agent, ultraviolet ray setting resin, a bonding agent, and heat setting resin. The adhesive agent is selected in view of the thermal stress and contraction ratio between the light guiding plate **1091** and the array substrate **12**.

The light guiding plate **1091** is formed with a reflecting film **1092** on the surface thereof. It is desirable that the material of the reflecting film **1092** should be silver (Ag). In addition, gold (Au), aluminum (Al), titan (Ti), and chrome (Cr) can be employed. In the case of Al and Ag, the surface is easily oxidized, so it is desirable that the surface should be formed with a protective film such as SiO_2 and TaO_x.

As a method of forming the reflecting film **1092**, there is a deposition method such as sputtering, an electrolytic plating method, and an electroless plating method. It is preferable that the light guiding plate **1091** should be formed from resin such as acrylic, polycarbonate, engineering plastic, and PVA from the side of cost and processability. In these resins, a hole for light guidance can be easily formed

by a molding technique using a metal mold. In the hole for light guidance, an opening **1094**b on the incident side is widened and an opening **1094**a on the exit side is narrowed. The opening **1094**a is made larger than or equal to the pixel electrode **14**.

The reflecting film **1092** is formed on the surface of the substrate in which the hole for light guidance is formed. A simplest method is to form it by an electroless plating technique. However, there is the disadvantage that the film is easily peeled.

In FIG. **109**, although it has been illustrated that the protective film **153** is formed on the counter electrode **25**, the present invention is not limited to this, but the counter substrate **11** may be arranged. In addition, in FIGS. **109** and **15** the protective film **153** may be replaced with a protective sheet such as plastic. In that case, the protective sheet (or a protective substrate) may be placed on the color filter **15** or pasted on it with an adhesive agent. The protective sheet and protective film **153** are generically called a protective layer.

FIG. **110** is a plan view seen from the opening **1094**b of the light guiding plate **1091**. The opening **1094**a is the same as the size of the pixel electrode **14**. In FIG. **110**, although the opening **1094**b is rectangular, it may be circular as shown in FIG. **111**.

As shown in FIG. **109**, incident light **1095** is reflected by the reflecting film **1092**. The reflected light **1095**a passes through the pixel electrode **14**. In other words, the reflected light becomes effective light for display. If the reflecting film **1092** is not present, the incident light **1095** will be light **1095**b, and the light **1095**b will be incident on the TFT **155**. For this reason, incident light does not pass through the pixel electrode **14**, so the light efficiency of utilization is reduced.

Thus, light is collected from the opening **1094**b toward the opening **1094**a and guided to the pixel electrode **14**. For this reason the light efficiency of utilization can be enhanced.

Although the reflecting surface **1092**b of FIG. **109** has a triangular cone shape, it may have a circular arc shape as shown in FIG. **112**. In addition, the light guiding plate **1091** itself may be formed with a reflecting material. For example, the opening **1094** may be formed in an aluminum plate. As another example, the opening **1094** may be filled with transparent resin **962**. The resin **962** employs, for example, silicon gel or ultraviolet ray setting resin. Also, it may be liquid such as ethylene glycol. In the case of liquid, the light reflecting surface of the light guiding plate is sealed, for example, with cover glass so that liquid does not leak.

The microlens **641** is made by a stamper or an ion exchange method, but it is high in cost and cannot be formed over a wide area.

FIG. **96** is a sectional view of the microlens of the present invention solving the aforementioned problem. In the microlens array shown in FIG. **96**, a protruding portion **961** is formed on film or a substrate **642** so that it corresponds to each pixel. A plan view of the protruding portion **961** is shown in FIG. **97**. The protruding portion **961** is formed by depositing inorganic film, exposing photosensitive acrylic resin, and developing. **962** denotes transparent resin film, which is formed by coating transparent resin film on the protruding portion **961** and then setting the coated resin film.

The material of the transparent resin film **962** is a polymeric compound having an acrylic base. An acrylic hard coating agent is exemplified. The resin component is 70 to 80%, and the viscosity is 0.15 to 0.2 Pa*S.

The microlens array shown in FIG. **96** is arranged near the array substrate **12** or counter substrate **11** and employed, as shown in FIG. **98**. In other words, it is employed in the same

way as the aforementioned microlens. If the reflecting film **792** is formed on the protruding portions **961**, as shown in FIG. **100**, it can be employed as a reflection type microlens. Also, it can be employed as the irregularity film **821** shown in FIG. **82**. If the protruding portion **961** is formed in the form of a line, a line microlens substrate such as that shown in FIG. **66** can also be constituted. If the height of the protruding portion **961** is varied, a microlens array with R, G, and B different in height, shown in FIG. **65**, can also be constituted. In addition, the irregularity portion **821** such as that shown in FIG. **85** can be formed with a similar technique.

FIG. **99** is an explanatory diagram of the fabrication method of the microlens array of the present invention. Transparent film **991** such as SiO$_2$ is formed on a substrate **181**, and on the film **991**, metal film **992** which becomes a mask is formed (FIG. **99**(a)). The metal film **992** is patterned (FIG. **99**(b)) and the film **991** is etched, thereby forming the protruding portions **961** (FIG. **99**(c)). Thereafter, acrylic hard coating agent is coated on the protruding portions **961** and dried for 10 min at room temperature. At this time, the coated coating agent is formed into a smooth irregularity shape by the surface tension between it and the protruding portions **961**. Then, ultraviolet rays are irradiated on the hard coating agent at a strength of 0.5 J/cm^2 with a high-pressure mercury lamp, and the polymeric compound of the hard coating agent is polymerized.

In FIG. **99**, although the protruding portions **961** are formed by etching inorganic film, the present invention is not limited to this. The protruding portions **961** may be formed by coating photosensitive acrylic resin on the substrate **181** and then irradiating light through a mask.

FIG. **96** shows the microlens sheet with convex lenses. As shown in FIG. **101**, if protruding portions **961**a are formed on the circumferential portion of the lens and then a transparent resin layer **962**a is formed on the protruding portions **961**a, a concave microlens sheet (substrate) can be fabricated.

While it has been described that the microlenses **641** and **962** are convex microlenses (Fresnel lenses), the present invention is not limited to convex lenses. The microlens or Fresnel lens may be changed to a concave lens, depending on the constitution of a display panel.

Light scattered by the liquid crystal layer **21** is reflected by the interface between the counter substrate **11** (or the array substrate **12**) and air and become reflected light **1095**a, and the reflected light **1095**a returns to the liquid crystal layer **21** again and is scattered (halation). This is called secondary scattered light. The secondary scattered light causes the display contrast of the PD liquid crystal display panel to be considerably reduced.

To prevent the occurrence of this secondary scattered light a transparent substrate **1131** is attached to at least either the array substrate **12** or the counter substrate **11**. The attachment of the transparent substrate **1131** is performed by optical coupling through a optical coupling layer **371**a. If the transparent substrate **1131** is attached, the aforementioned halation can be absorbed by a light absorbing film **1132** coated on the invalid area (that effective light for image display does not pass through) of the transparent substrate **1131**.

As the light absorbing film **1131**, there is black paint. The material of the light shielding film **152** can also be employed. Even structure with a polished and exposed surface also has the effect of the light absorbing film **1132**. These are believed to be included in the concept of the light absorbing film **1132**.

FIG. **113** shows the effect of the transparent substrate **1131**. As shown in FIG. **16**(a), a panel **22** is irradiated with a collimated beam of light, and the brightness of a light modulating layer **21** is measured from the exit side. The brightness B means brightness measured when the thickness t of a substrate on an exit side, i.e., the thickness of counter substrate+transparent substrate **1131** is extremely thin with respect to the diagonal length of an effective display area and also the light absorbing film **1132** is not present. Specifically, the thickness of a substrate on an exit side is 1 mm (t=1) when d=50 mm.

In FIG. **113**(b), the axis of ordinate represents brightness ratio (Be/B) and the axis of abscissa represents relative substrate thickness (t/d). From FIG. **113**(b) it is found that the brightness ratio (Be/B) becomes constant when t/d=0.3 and also a reduction in the ratio is great when t/d<0.3.

A small brightness ratio means high display contrast. According to FIG. **113**(b), it is found that a contrast enhancing effect is sufficient when t/d>0.25 to 0.3 and that the effect is in a practical range even when t/d=0.15 which is ½ of the relative substrate thickness (t/d). Therefore, it is preferable that t/d should be 0.15 or more when refractive index of a substrate n=1.52, particularly (t/d should be) 0.3 or more. The relation between thickness t and diagonal length d, therefore, needs to meet the following equation:

$$t \geq \frac{d}{8}\sqrt{n^2 - 1} \qquad \text{[expression 29]}$$

Note that the transparent substrate **1131** is not limited to a glass substrate. For example, it may be constituted by resin such as acrylic and polycarbonate. Also, if the transparent substrate **1131** is made into a concave lens **1131**b, the substrate thickness can be made thin. Furthermore, if the concave lens **1131**b is combined with a positive lens **1131**a, positive optical power and negative optical power can be cancelled out by the concave lens **1131** and positive lens **1131**a, and the combination can be apparently regarded as the transparent substrate **1131**. These examples are shown in FIG. **114**.

FIG. **54** has illustrated constitution formed with the light shielding film **542** on the counter substrate **11**.

FIG. **116** illustrates constitution formed with the light shielding film **542** on the back surface of the transparent substrate **1131** (or the concave lens **1131**b). A driver circuit **541** is formed on an array substrate **12** at the same time as a TFT **155** by employing a low-temperature polysilicon technique. Alternatively, a silicon chip is mounted on the array substrate **12** by a chip-on glass (COG) technique. On the other hand, the light shielding film **542** is formed or arranged on an invalid surface (that effective light for image display does not pass through) on the back surface of the transparent plate **1131**. The "light shielding film **542** is formed" is intended to mean that black resin or metal film is formed directly on the transparent substrate **1131** by a coating technique or a deposition technique. The "light shielding film **542** is arranged" is intended to mean that a metal plate is inserted. For the metal plate, black metal such as chrome oxide and sexivalent chrome is preferable to Al metal having a shinning surface. As the black paint, there is paint, acrylic resin, and resin **154** formed on a transistor.

Direct incident light is shut out by a casing **1161**a. Between the driver circuit **541** and the casing **1161**a, space is provided for air-cooling heat generated by the driver circuit **541**. The casing **1161** is fabricated by a sheeting technique or a plastic molding technique.

The casing **1161**b is a lower lid, which is caught on an indent portion of the transparent substrate **1131** and held.

The casing 1161b is formed with a hole through which the transparent substrate 1131 is inserted. The transparent substrate 1131 and the array substrate 12 are stuck together through a Optical coupling layer 371.

When a light valve is assembled, the transparent substrate (or the concave lens) 1131 is first inserted into the lower lid (casing) 1161b. Then, the Optical coupling layer 371, sufficiently given a bubble removing process, is dropped. Thereafter, the liquid crystal display panel 22 is inserted and then stuck on the transparent substrate 1131. Finally, an upper lid (casing) 1161a is fitted on the lower lid 1161b through a flange portion 1162. As occasion demands, a glass substrate 642 formed with an antireflection film 211 is stuck through a Optical coupling layer (not shown). Note that another antireflection film 211 should be formed on a contacted surface between the transparent substrate 1131 and air.

If the transparent substrate 1131 is colored and made into an optical filter, there is an advantage. The colored optical filter is easily realizable by forming the transparent substrate,1131 with acrylic resin and then coloring the acrylic resin with a pigment. If the transparent substrate 1131 is colored, the color purity of light emerging from the liquid crystal display panel 22 can be enhanced and the color reproducibility of a projected image can be made sufficient.

In FIG. 116, although the transparent substrate 1131 is formed with resin or glass, it can also be realized by injecting gel or liquid 1172 into the casing 1161a. On the interior surface or exterior surface of the casing 1161a, a light absorbing film 1132 is formed or arranged. The casing 1161a is fitted on a counter substrate 11, and an adhesive agent 371a is applied to the contacted portion between the casing 1161a and the counter substrate 11 so that liquid 1171 does not leak from the contacted portion. An array substrate 12 is stuck on a casing (lower lid) 1161b with the adhesive agent 371b.

After the adhesive agent 371a has been set, liquid or gel 1172 is injected into the casing 1161a. The liquid or gel 1172 employs, for example, ethylene glycol, methyl salicylate, silicon gel, or epoxy resin. It is desirable that the refractive index should be 1.42 or more. The reason for this is that since the refractive index of a glass substrate such as the counter substrate 11 is 1.52, a difference in refractive index between the gel 1172 and the glass substrate is made within 0.1. If the difference is 0.1 or more, light will be reflected between the counter substrate 11 and the gel 1172. The gel 1172 maybe colored. The reason for this is that the colored gel can reduce the band width of light modulated at the liquid crystal display panel 22 and enhance the color purity of a display image. After the injection of the gel 1172, a glass substrate 1171 is fitted and sealed with an adhesive agent 371c.

Since the gel 1172 has fluidity, it is suitable for transfer of heat produced by the liquid crystal display panel 22. In other words, it makes a contribution to the cooling of the liquid crystal display panel 22. In addition, since the gel 1172 is light in weight compared with glass or resin, it makes a contribution to a reduction in the weight of a light valve. In the case of a large light valve, the constitution of FIG. 117 becomes inexpensive compared with the case where transparent substrate 1131 is formed with glass. In addition, the constitution shown in FIG. 117 can reduce the weight of the light valve.

As shown in FIG. 115, if a radiating fin 921 is attached to an invalid area on a transparent substrate 1131, heat can be effectively radiated from the light absorbing film 1132. The radiating fin 921 is attached to the transparent substrate 1131 with an adhesive agent 922.

In the case where the liquid crystal display panel 22 of the present invention is employed as a light valve for a projection type display, it is preferable that light should be incident from the side of the array substrate 12 (see FIG. 118). The light incident on the liquid crystal layer 21 scatters, gives rise to halation, and produces heat. As a consequence, there is the fear that incident light will degrade the liquid crystal display panel 22. The opening ratio of the liquid crystal display panel is usually about 50%, although it depends on panel size and the number of pixels. If light is incident from the side of the array substrate 12, only light corresponding to the amount of the opening ratio will be incident on the liquid crystal layer 21 and the rest light will be reflected by the source signal line 15. For this reason the aforementioned halation is reduced and therefore display contrast is enhanced.

A description will hereinafter be made of the drive method of the driver circuit and display panel of the present invention, but, before that, a description will be made of the fabrication method of the array substrate. First, the glass substrate 12 is given a US washing/washing/MS/rinsing process. Then, the glass substrate is covered with an undercoat of $SiO_2=200$ nm by AP-CVD. Thereafter, a film of chrome (Cr) is deposited to a thickness of 1000 angstroms and patterned, thereby forming a metal light-shielding film 791. In addition to the Cr film, aluminum (Al) and titan (Ti) can also be employed. On the upper layer of this metal light-shielding film 791 a recording film 214 is formed, and a TFT 155 is formed. Also, common electrodes 212 in the form of stripes are formed. The metal light-shielding film 791 serves as a light shielding film for external light. In the case where the liquid crystal display panel of the present invention is employed as a light valve, the metal light-shielding film 791 also serves as a light shielding film for shutting out light which is incident from a metal halide lamp. Furthermore, on the light shielding film an insulating film 791 of $SiO_2=200$ to 300 nm is formed, and thereafter, a film of a-Si:H=85 nm is formed by AP-CVD. Thereafter, an AS process is performed. Silicon is etched with RIE, resist is removed with an O_2-asher, and dehydrogenation is performed for 90 min at a temperature of 450° with LP-CVD.

Next, crystallization is performed with an excimer laser. The condition is 290/390 mJ/cm^2.

Thereafter, a gate insulating film of $SiO_2=85$ nm is formed by AP-CVD, and a gate metal of Ta=200 nm is formed by M-SP. Thereafter, a doping process, etc. are performed, thereby completing the array substrate 12.

FIG. 119 is a constitution diagram of the drive circuit of the liquid crystal display panel of the present invention. A gate driver circuit 492 outputs an ON voltage V_{on}, which operates a TFT T_{ij} (where i and j are integers) and an OFF voltage V_{off} which non-operates a TFT T_{ij}. On the other hand, a source driver circuit 491 sequentially transfers data applied to a HDATA terminal by a clock signal applied to a CLK terminal. Data is output from a terminal d_j (where j is an integer), which outputs a positive logic signal (high level signal). The high level signal causes the switch SW_j of a switch circuit 1192 to be closed, and a video signal applied to a SIG terminal is applied to a source signal line S_j (where j is an integer). A signal applied to the source signal line S_j is charged in a capacitor 1193 formed on the signal line. The charged capacity is held for one horizontal scanning period (1 H period).

The TFT T_{ij} writes voltage to a liquid crystal layer 21 and an additional capacitor 1194, based on the ON voltage applied to a gate signal line G_i (where i is an integer). One terminal of the liquid crystal layer 21 is a pixel electrode 14,

and the other terminal is a counter =electrode **25**. One terminal of the additional capacitor **1194** is the pixel electrode **14**, and the other terminal is a common electrode **212**. A common electrode **354** is an electrode common to all additional capacitors **1194**. The common electrode **354** is over the array substrate **12** and formed on the lower layer of the pixel electrode **14**. Note that the common electrodes **212** are not limited only to ITO electrodes in the form of stripes. For example, they may be in the form of a mat electrode.

If a logic high signal is applied to a CNT terminal, the outputs of OR circuits **1191** will go to a high level and all switches SW of the switch circuits **1192** will be closed. The voltage applied on the SIG signal terminal is applied to all source signal lines. The signal on the CNT terminal is high only for a predetermined period (one horizontal scanning period).

To describe the drive method of the display panel of the present invention, a description thereof will hereinafter be made employing FIGS. **119** and **120**. In FIG. **120** a conventional video signal **1** represents a video signal that is applied to the SIG terminal. The amplitude value of the video signal **1** is previously adjusted with an amplifier or a gamma circuit so that it corresponds to the electro-optical characteristic curve of the liquid crystal layer **21**, and the adjusted video signal **1** is input to the SIG terminal. Therefore, when the amplitude of the video signal **1** reaches the maximum value, the transmittance T reaches the maximum value (see FIG. **122**).

The CNT signal is a logic signal that is input to the CNT terminal. The CNT signal is in a high level state for a predetermined time corresponding to the back porch portion of a video signal in the blanking period of the video signal. A video signal **2** is one which is input to the SIG terminal of the drive circuit of the liquid crystal display panel of the present invention. As with the video signal **1**, the amplitude value of the video signal **2** is adjusted to a predetermined value by an amplifier and a gamma circuit.

The video signal **2** is one in which a pulse having a pulse width longer than that of the CNT signal and also having an amplitude of the height h of the time of the back porch portion in the blanking period is superimposed to the back porch portion. This pulse will hereinafter be referred to as a superimposed pulse. The height h is determined by the value of the video signal within the image display period S in the scanning period.

The timing and width of the superimposed pulse may be the same width and timing as the CNT signal, but it is preferable that the width of the superimposed pulse should be wider than the CNT signal in correspondence with the characteristic speed and operation of the switch SW of the switching circuit **1192**. The amplitude value h of the super-imposed pulse is written to all source signal lines for the period of the back porch portion by the CNT signal and is charged to signal line capacitors.

It is preferable that the height h of the superimposed pulse should be an average value of amplitude values during image display period S (in which there is video signal data that is image-displayed on a liquid crystal display). The reason for this will be given below. Note that the aforementioned average value is an average value which is obtained in consideration of the T-V characteristic. For example, if an applied voltage is less than the rise voltage of a liquid crystal, the transmittance of the liquid crystal will not change. In consideration of the transmittance of the liquid crystal, the aforementioned average value is an average value of the transmittance.

Now, assume that a voltage of average value h is written to all source signal line S_j during back porch period and also

the amplitude value h is 50. Also, the maximum value of the amplitude value within the image display period S is assumed to be 80 and the minimum value is assumed to be 30. In addition, assume that there is a need to write an amplitude of 50 to the source signal line S_1, an amplitude of 80 to the source signal line S_2, and an amplitude of 30 to the source signal line S_3. The video signal applied to the SIG terminal is written to the source signal lines in sequence by the clock signal applied to the source driver circuit **491**. A voltage of 50 has already been written to the source signal line S_1. In the case where voltage is newly applied, the signal line capacitor **1193**a does not need to be again charged, because there is a voltage of 50. Since the source signal line S_2 needs to write a voltage of 80, an electric charge of difference (80–50=30) between 80 and the voltage already written is written to the signal line capacitor **1193**b. Since the source signal line S_3 needs to write a voltage of 30, an electric charge of difference (50–30=20) between 30 and the voltage already written is written to the signal line capacitor **1193**c. Note that since the voltages of 30 and 50 are temporarily determined to make a description easy, it is necessary that they should be considered to be originally voltages required for transmittance 30% and transmittance 50%.

From the aforementioned description, an amount of electric charge required to be again charged to the source signal line S_i can be reduced. This is equivalent to lengthening the time for a TFT to write voltage to the pixel electrode **14**. Particularly, in a point sequence method shown in FIG. **119** (in which a sample and hold operation is performed in sequence on source signal lines), the reduction in the amount of electric charge is effective because the pixel on the right edge can ensure only the back porch period in the blanking period. Note that all of the present liquid crystal display panels fabricated by high-temperature polysilicon and low-temperature polysilicon techniques employ the point sequence method.

In the case where the CNT terminal of the present invention is not present, the amplitude voltage during the previous one horizontal scanning period has been written to each source signal line. If it is assumed that a voltage of 100 has been written to all source signal lines, the source signal line S_1 needs to be charged with an electric charge of 100–50=50. The source signal line S_2 needs to be charged with an electric charge of 100–80=20 again, and the source signal line S3 needs to be charged with an electric charge of 100–30 =70 again. In FIG. **120**, in the case of 1-field inverting drive (in which the polarity of a signal to be applied to a source signal line is inverted at 1-field intervals) or 1-H inverting drive (in which the polarity of a signal to be applied to a source signal line is inverted at 1-horizontal-scan intervals), the amount of an electric charge to be written is further increased. The reason for this is that a voltage with an opposite polarity has been written before one horizontal scanning period. For example, if it is assumed that a voltage of –100 (which means a negative polarity) has been written to source signal lines, the source signal lines S_1, S_2, and S_3 will need to be again charged with electric charges of 50–(–100)=150, 80–(–100)=180, and 30–(–100)=130, respectively.

The amplitude value h of the superimposed pulse in a video signal is obtained from amplitude data within the next image display period S. Therefore, as shown in FIG. **120**, if the amplitude value is small like the (n+1)st line, the height h of the superimposed pulse will become small, and if the amplitude value is great like the (n+2)nd line, the height will become high.

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FIG. **121** shows a block diagram of a circuit which computes the height h of the superimposed pulse. The video signal **1** is converted to digital data by an A/D conversion circuit **1211**. The digital data is temporarily stored in line memory **1212**. Of course, it may be stored in field memory. At the same time, data within the image display period S are added by an arithmetic circuit **1213**. After addition, an average value is computed based on the number of sampled data, thereby computing the amplitude data of the superimposed pulse. Then, in consideration of the T-V characteristic of a liquid crystal, the computed amplitude data is added to the data temporarily stored in the line memory. The processed data is converted to the video signal **2** by a D/A conversion circuit **1214**.

While it has been described that the amplitude data of the superimposed pulse is digitally computed by the arithmetic circuit **1213**, the present invention is not limited to this. The amplitude value of the superimposed pulse may be analogically computed by smoothing the amplitude values present within the image display period S with a capacitor. For example, the video signal **1** is delayed by about **1** horizontal scanning period with a delay line circuit, and this delayed video signal and the amplitude pulse of the superimposed pulse may be added together by an operational amplifier.

In FIG. **120**, although the amplitude value h of the superimposed pulse is computed from an average value in the image display period S, it is theoretically computed. In practice, it depends on the output impedance, suction current, and sweep-out current characteristics of the switching circuit **1192**, According to experiment, a satisfactory result is obtained when the amplitude value h is greater than the average value. However, if it is too great, floating of a black display level will occur, i.e., the transmittance of a black level will become high. According to experiment, it is preferable that the amplitude value of the superimposed pulse should be about 1.2 to 1.4% times an average value in the image display period S.

FIG. **122** shows the transmittance-voltage T-V characteristic curve of a liquid crystal. The case where the drive method of the present invention is applied is represented by a dotted line and a conventional case by a solid line. If the drive method of the present invention is carried out, the gradient of the T-V characteristic curve will become great. In other words, even if voltage to be applied to a pixel is small, the transmittance T can be made high. Therefore, since the film thickness of the liquid crystal **21** can be thickened by the amount of reduction, the display contrast is enhanced.

FIG. **123**(*b*) shows the waveform of the video signal **2** at the time of 1-field (1-F) inverting drive, and FIG. **123**(*c*) shows the waveform of the video signal **2** at the time of 1-H inverting drive. The polarity of the superimposed pulse and the characteristic of the video signal are inverted.

The aforementioned description has been made of a normally black (NB) mode in which black display is performed when no voltage is applied to a pixel. In the case of a normally white (NW) mode in which white display is performed when no voltage is applied to a pixel, the display state needs to be inverted. In the NW mode, black display is performed in the state in which voltage is applied to a pixel, and white display is performed in the state of non-application of voltage. Since only the display state is changed, it is a matter of course that the drive method of the present invention is applicable to a liquid crystal display with an NW mode., etc.

In the case of a PD liquid crystal display, if the liquid crystal layer **21** is thickened, the scattering characteristic will become high and therefore the display contrast can be

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enhanced. However, a drive voltage to be applied to a pixel is also increased. Therefore, in order to enhance display contrast, the driver circuit **541** needs to be constituted so that high voltage can be applied to a pixel.

FIG. **124** is a constitution diagram of the liquid crystal display panel of the present invention. The driver circuit is mainly depicted. An odd source signal line is connected to a source driver circuit **491***a* and an even source signal line to a source driver circuit **491***b*. The source driver circuits **491***a* and **491***b* output video signals to the source signal lines so that the polarities are opposite to each other. Now, suppose that a positive polarity image signal is represented by "+" and a negative polarity image signal by "−". In addition, the source driver circuit **491** switches the polarity of a video signal at 1-H intervals. If done in this manner, the image display state will be obtained as shown in FIG. **129**. An image signal with a polarity opposite to adjacent pixels is written to a pixel **1291***a*. If done in the aforementioned manner, the parasitic capacity between the pixel electrode **14** and the source signal line **15** will be reduced and satisfactory image display with less occurrence of flickers can be realized.

In order to raise voltage which is applied to the pixel electrode **14**, there is a need to raise a drive voltage (source voltage) for each of the drivers **491** to **492**. However, if voltage to be applied is too high, blockage will occur in data transfer which is performed by the shift register of each driver, or reliability will be reduced by generation of heat.

Now, assume that the amplitude values of a video signal which is applied to the pixel electrode **14** are +V and −V (0 V is the electric potential of the counter electrode). The power source +V1 for the source driver circuit **491** needs to be +V, and the GND1 needs to be −V. Also, the voltage V_{on} which is applied to the gate signal line G_i needs to be +V +1 (V), and V_{off} needs to be −V −3 (V). 1 (V) is the ON operation margin of the TFT **155**, and −3 (V) is the OFF operation margin of the TFT **155**. Therefore, the voltage V3 for the buffer circuit **1241** of the gate driver **492** needs to be V_{on}, and the GND3 needs to be V_{off}. It is preferable that the voltage on the gate driver circuit **492** be made as low as possible. V2 is taken to be V1, and GND2 is taken to be GND1. Note that there is a need to anticipate that V1, V2, V3, GND1, and GND2 will have a small margin of 0.5 to 1.5 (V).

The characteristic of the present invention resides in the gate driver **492**. In other words, the present invention is characterized in that the power source mainly employed for the shift registers of the gate driver **492** is separated from the power source for the gate buffer circuit **1241**. The absolute value of the voltage on the gate buffer circuit **1241** is greater than that of the shift register of the gate driver. Therefore, the characteristic of the present invention resides in that heat, which is generated by the shift register of the gate driver **492** which operates at high speeds, is reduced and also the voltage of the gate buffer **1241** is raised so that high voltage can be applied to the gate signal line G_i. Note that even if the GND3 of the gate buffer **1241** and the GND2 of the gate driver circuit **492** are shared with each other, practically there will be no problem.

The present invention is also characterized in that the number of operational clocks of the source driver circuit **491** is reduced to ½ by alternately pulling out source signal lines in opposite directions, like as cross-stitch, with the two source drivers **491***a* and **491***b*. If done in this way, satisfactory image display with no flicker can be realized as shown in FIG. **129**. Note that the buffer **1192** has a function of increasing a write current which is applied to the source signal line **15**.

In order to further raise voltage which is applied to the pixel electrode **14**, a signal which is applied to the counter electrode **25** is inverted at 1-H intervals. In this case, the polarities of the output signals of the source drivers **491**a and **492**a are made the same, and also the polarity of a video signal is inverted at 1-H intervals.

The drive method of the display panel of the present invention will hereinafter be described referring to FIGS. **132** and **133**. In FIG. **132**, a one-dotted line represents an applied signal to the counter electrode **25**. A solid line represents an input signal to the source driver circuit **491**, and a dotted line represents the signal center of the input signal to the source driver circuit **491**. The display image **1311** on the display panel is shown in FIG. **131**. That is, the image is constituted by step display which is black display on the left side and white display on the right side. The display mode is an NB mode. The polarities of signals to pixels are shown in FIG. **129**. After 1 field (1 frame) the signal polarity of each pixel **1291** is inverted.

As evident in FIG. **132**, a rectangular waveform is applied to the counter electrode **25** and inverted at 1-H intervals. The input waveform to the source driver circuit **491** is also inverted at 1-H intervals. At this time, the polarity of the signal to the counter electrode **25** and the polarity of the video signal (solid line) are opposite polarities. In other words, when the signal polarity of the counter electrode is "+", the polarity of the video signal is "−", and when the signal polarity of the counter electrode is "−", the polarity of the video signal is "+". The maximum value V_o of an applied signal to the counter electrode **25** from the signal center (strictly speaking, pedestal level of the video signal) needs to be less than a rise voltage of V_a. If $V_o \geqq V_a$, black display cannot be performed.

If the aforementioned operation is shown with an equivalent circuit, it will be as shown in FIG. **128**. Assume that rectangular waveforms (e.g., +4 (V) and −4 (V)are output. i.e., V_a=4(V)) are output from a signal generating circuit **1281** to a common electrode **212** and a counter electrode **25**. On other hand, the source driver circuit **491** outputs video signals (e.g., −6 (V) and +6 (V)).

During 1H period shown in FIG. **128**(a), +4 (V) is applied to the counter electrode **25**, etc. and the video signal 6 (V) from the source driver circuit **491** is applied to the pixel electrode **14** through the TFT **155**. Therefore, a voltage of 6 (V)−(−4 (V))=10 (V) is applied to the liquid crystal layer **21**. During the next 1H period shown in FIG. **128**(b), −4 (V) is applied to the counter electrode **25**, etc. and 6 (V) is applied to the pixel electrode **14**. Therefore, a voltage of −4 (V)−(6 (V))=−10 (V) is applied to the liquid crystal layer **21**. If the during is performed in this manner, the effective value of voltage which can be applied to the liquid crystal layer **21** can be raised and the film thickness of the liquid crystal layer **21** may be thickened correspondingly. Therefore, the display contrast can be enhanced.

However, there is a little problem. In FIG. **132**, although it has been described that V_o needs to be less than a rise voltage of V_a, the transmittance of the PD liquid crystal display panel is gradually increased between θ (V) and V_a. Therefore, in the vicinity V_a, satisfactory black display cannot be realized.

Hence, as shown in FIG. **133**, when an applied signal waveform to the counter electrode is high (+), an input signal waveform to the source driver circuit is also raised in a direction of +. The voltage that is applied to the liquid crystal layer **21** is a difference in electric potential between the counter electrode **25** and the pixel electrode **14**. If the applied signal waveform (voltage) to the counter electrode is

+4 (V) and also the input signal waveform to the source driver circuit (i.e., voltage that is applied to the pixel electrode **14**) is +4 (V), no voltage will be applied to the liquid crystal layer **21** and the pixel will become black. Conversely, if the voltage to the counter electrode is +4 (V) and also the voltage to the pixel electrode **14** is 0 (V), a voltage of +4 (V)−0 (V)=4 (V) will be applied to the liquid crystal layer.

FIG. **133** realizes the aforementioned drive method. At the same time a rectangular waveform being inverted at 1-H intervals is applied to the counter electrode, the voltage (signal) that is applied to the pixel electrode **14** is output to source signal lines by the source driver circuit **491** with the voltage applied to the counter electrode **25** as reference. In the drive method of FIG. **132**, the polarity of an applied voltage to the counter electrode **25** and the polarity of an applied voltage to the pixel electrode **14** are opposite polarities with respect to a signal center represented by a dotted line. In the drive method of FIG. **133**, the case of the same polarity takes place.

The drive method of FIG. **133** is a drive method which includes the case where voltage is applied to the pixel electrode **14** with the electric potential of the counter electrode **25** as reference (0 V),and also the voltage polarity of the counter electrode **25** and the voltage polarity of the pixel electrode **14** are the same polarity voltage with respect to the center (indicated by a dotted line) of an applied waveform to the counter electrode **25**.

The advantage of the drive method of FIG. **133** will be easily understandable if the amplitude value of an video signal that is output from the source driver **491** to the source signal line **15** is compared.

In FIG. **132** the amplitude value is V_{s1}, while in FIG. **133** it is V_{s2}. Since there is a relation of $V_{s1} > V_{s2}$, adopting the drive method of FIG. **133** is more advantageous than adopting the drive method of FIG. **132**, because the power source voltage for the source driver circuit **491** can be reduced low.

A circuit for realizing the drive method of FIG. **133** is conceptually shown in FIG. **134**. An image signal is supplied to the base of a transistor Q_1. The negative polarity image signal is output to the collector of the transistor, and the positive polarity image signal is output to the emitter. The DC components of the two positive and negative image signals are cut by capacitors C. On the other hand, a DC voltage that is supplied (clamped) from an analog switch **1341**b to one end of each capacitor C is produced by a variable resistor, and the absolute values of the positive and negative polarity clamp voltages are the same. If this clamp voltage is produced with the electric potential of the counter electrode **25** as reference, the waveform of FIG. **133** can be easily produced. The positive and negative polarities of the image signal is inverted at 1H intervals by the analog switch **1341**a and is output to a source signal line **15**.

Where a projection type display is constituted by three liquid crystal display panels fabricated with a high-temperature or low-temperature polysilicon technique, there is one problem. The reason for this is that the scanning direction of the source driver circuit **491** or gate drive circuit **492** of one liquid crystal display panel needs to be opposite to the other liquid crystal display panels.

For example, as shown in FIG. **137**, the scanning direction of gate drive circuit **492** of the liquid crystal display panel **22**b needs to be opposite to the scanning directions of the gate driver circuits **492** of the other liquid crystal display panels in FIG. **180**. This is because an image is inverted upside down by a dichroic mirror (DM) **1161**. In order to superimpose the projected images of three liquid crystal

display panels with each other on the screen, the image of one liquid crystal display panel needs to be inverted. The constitution of FIG. **180** is referred to as a vertical developed constitution. On the other hand, in another constitution (horizontal developed constitution), as shown in FIG. **136**, the scanning direction of the source drive circuit **491** of the liquid crystal display panel **22**b needs to be opposite to the scanning directions of the other liquid crystal display panels.

However, in the liquid crystal display panel fabricated with a high-temperature or low-temperature polysilicon technique, since the driver circuit needs to be formed on a single substrate at the same time as pixels and TFTS, it is difficult to form a complicated driver circuit which has a horizontally inverting function or a vertically inverting function. In addition, because the mobility of transistors is low as 100 or less, an inverting circuit is structurally complicated.

The present invention previously forms at least either one or the other of the source driver circuits **491**a and **491**b differing in the scanning direction from each other and at least either one or the other of the gate driver circuits **492**a and **492**b differing in the scanning direction from each other, as shown in FIG. **135**. For example, in the horizontal developed constitution, the liquid crystal display panel **22**b cuts off the gate driver circuit **492**b from the gate signal lines at line d–d' and also cuts off the source driver circuit **491**a from the source signal lines at line a–a'. This can be easily realized by employing a laser trimming technique or an etching technique. In the horizontal developed constitution, since the scanning directions of the gate driver circuits of three liquid crystal display panels **22** are the same, it is a matter of course that there is no need to form the gate driver circuit **492**b from the beginning. In the other liquid crystal display panels **22**a and **22**c, the gate driver circuit **492**a is cut off from the gate signal lines at line c–c' and also the source driver circuit **491**b is cut off from the source signal lines at line b–b'.

In the vertical developed constitution, the source driver circuit **491**a of each of three liquid crystal display panels **22** is cut off from the source signal lines at line a–a', and the gate driver circuit **492**b of the liquid crystal display panels is cut off from the gate signal lines at line c–c'. In the other liquid crystal display panels **22**a and **22**c, the gate driver circuit **492**b is cut off from the gate signal lines at line d–d'.

As described above, the gate driver circuits **492** or source driver circuits **491** whose scanning directions are different from each other are formed on the liquid crystal display panels, and one gate driver circuit and one source driver circuit are cut off. Therefore, if one kind of liquid crystal display panel is fabricated, a projection type display with the constitution of FIG. **180** can be easily constituted.

A liquid crystal display panel usually has three color pixels:R, G, and B(or alternatively, cyanogen, magenta, red, blue, or yellow). As shown in FIGS. **129** and **130**, voltages differing in polarity from each other are applied to adjacent pixels for flicker reduction.

A display panel of FIG. **138** has pixels having brightness (W) in addition to R, G, and B pixels. The W pixel performs black-and-white brightness display. A composite image signal is divided into Y and C signals, and this Y signal is employed as brightness (W). On the other hand, R, G, and B are applied to pixels by the C signal.

A display panel employing a PD liquid crystal can realize high-brightness display, but even higher brightness display is desired. On the other hand, an image with high brightness shows a tendency to reduce human's color discriminating ability.

The display panel of the present invention of FIG. **138** employs a PD liquid crystal in the liquid crystal layer. The display panel also has R, G, and B pixels having color filters and W pixels having no filter(Of course, the W pixel may have a transparent resin filter in order to make the film thickness of the liquid crystal **21** equal to the film thickness of the other pixels (R, G, and B)). When performing high brightness display, the W pixel is caused to be in a light transmitting state, and when performing low brightness display, the W pixel is caused to be in an OFF state.

The output of the source driver circuit **491** causes transfer gates (TG) **1192**, an analog switch, to be in an ON state in sequence. First, TG **1192**R1, **1192**G1, **1192**B1, and **1192**W1 are turned on at the same time. Then, the aforementioned TG go to an OFF state and also transfer gates **1192**R2, **1192**G2, **1192**B2, and **1192**W2 go to an ON state. In the next step, the aforementioned TG go to an OFF state and also TG **1192**R3, **1192**G3, **1192**B3, and **1192**W3 go to an ON state. In this manner, a group of 47 TG is sequentially turned.

The operating clock of the source driver circuit **491** needs to perform high-speed operation because it is a horizontal operating clock. In addition, the wiring resistance of the signal lines (SIG-W, SIG-R, SIG-G, and SIG-B) formed within the display panel is high. For this reason, the polarities of image signals that are applied to the display panel during 1H period are caused to be the same. Inverting signal polarity during 1-H period is impossible from the relation of time constants.

However, in liquid crystal display panels there is a need to invert the polarities of adjacent pixels from the standpoint of flicker reduction. In the present invention, there are four kinds of pixels: R, G, B, and W, and four signal lines SIG-R, SIG-G, SIG-B, and SIG-W are provided in correspondence with the four pixels. Now, suppose that for the polarities of image signals that are applied to signal lines during a certain horizontal period (1H period), SIG-R is –polarity, SIG-G is +polarity, SIG-B is –polarity , and SIG-W is +polarity. In the next 1H period, +polarity is applied to SIG-R, –polarity to SIG-G, and +polarity to SIG-B, and this operation is repeated.

If the appling to the pixels is performed in the aforementioned manner, polarities can be applied to pixels so that they differ from each other between adjacent pixels, like as –+–+–+, at the first row, as shown in FIG. **139**(b). Although pixels **1291**a and **1291**e have the same polarity voltage, voltages alternately differing in polarity can be applied like as –+–+–+ . . . At the second row, +–+–+– . . . can be applied. If the display panel is driven in this manner, there will be no flicker and the influence of the parasitic capacitance between the pixel electrode **14** and the signal line **15** can be reduced. Therefore, the liquid crystal layer **21** with high transmittance can be obtained with low voltage.

If pixels are constituted by three color R, G, and B and signal lines are constituted by three signal lines SIG-R, SIG-G, and SIG-B corresponding to the pixels, pixel polarities will be +–++–++–++– . . . as shown in FIG. **139**(a) and therefore polarities cannot be applied so that they differ from each other between adjacent pixels.

In the present invention, since the pixcels are constituted by four color R, G, B and W and four signal lines corresponding to the four color pixels, the polarity of voltage that is applied to pixel electrodes **14** adjacent in a horizontal direction can be inverted as shown in FIG. **139**(b). For this reason, parasitic capacitance can be reduced, the transmittance of the liquid crystal layer can be enhanced, and furthermore, the occurrence of a flicker can be eliminated. Note that if the number of color pixels is even, polarities can

be alternately inverted. For example, there is the case where pixels are constituted by two colors, R and G and the case where pixels are constituted by 6 colors, R, G, B, W, cyanogen, and yellow. In addition, there is the case where pixels are constituted by three colors R, G, and B, R is divided into two parts, and there are two signal lines corresponding to the two parts (in other words, there are four signal lines in total). This case also corresponds to the drive method and constitution of the present invention.

In the drive method of FIG. **139**(*a*), voltage polarity is applied in the row direction along "++–++–++–." In the next frame (field), voltage polarity is applied along "––+––+––+ ." Also, opposite polarities are applied for each line (e.g., at the first row, voltage polarity are applied along "++–++–++–," and at the second row, the opposite voltage polarity is applied along "––+––+––+.") In FIG. **139**(*a*), the colors of the color filters are three colors (odd), R, G, and B. However, if opposite signal polarities are applied for each row in the aforementioned manner, the occurrence of a flicker can be reduced. Thus, a drive method which applies signal polarity along "–++–++" at a certain pixel row and also applies the opposite signal polarity along "+––+––" at the previous row is also an important invention. In other words, the polarities of two adjacent pixels are the same. The opposite polarity signal is applied to a pixel adjacent to the two adjacent pixels, and opposite polarities are applied for each field. This drive method can considerably reduce the occurrence of a flicker. In addition, the colors of pixels may be three primary colors (R, G, and B). Therefore, the drive method shown in FIG. **139** is also an effective method for flicker reduction. This method also reduce the gradient of brightness.

Although it has been described that pixel colors are R, G, B, and W, black or magenta may be employed instead of W. In addition, the color arrangement of the pixels may be arrangement shown in FIGS. **140**(*a*) and **140**(*b*).

The color arrangedment of the pixels of FIG. **138** are arranged in the form of stripes. In the present invention, it is clear that even pixel arrangement shown in FIGS. **140**(*a*) and **140**(*b*) can exhibit similar advantages.

In FIG. **124** it has been illustrated that the output of the source driver **491** is connected directly to the gate of the analog switch **1192**. In practice, as shown in FIG. **125**, the output of the shift register of the source driver **491** is connected to inverters **1251** of multiple stages, and the outputs of the inverters **1251** of the final stage are connected to the gate of the analog switch **1192**.

The inverter is constituted by a p-channel MOS transistor and an n-channel MOS transistor. When the analog switch **1192** is constituted by a single n-channel MOS transistor, there are cases where it is constituted by n-channel and p-channel MOS transistors as shown in FIG. **126**. Particularly, the analog switch **1192** of FIG. **126** is called a transfer gate (TG).

The design of the ability of the analog switch **1192** which writes a signal to a source signal line is important. If the writing ability is insufficient, the transmittance of the liquid crystal layer will be unsatisfactory. Conversely, if the size of the analog switch **1192** is too large, the size of the driver circuit will become large and the dissipation power will be increased. Also, the fabrication yield of the driver circuit is reduced.

As a result of examination, there is a need to meet the following relation:

$$10D \leq \frac{W}{L} \leq 50D \qquad \text{[expression 30]}$$

where D (inch) is the diagonal length of the effective display area on the liquid crystal display panel, L (μm) is the length of the gate of the p-channel transistor of the transfer gate **1192**, and W (μm) is the width of the gate.

Preferably, the design is made so as to meet the following equation:

$$15D \leq \frac{W}{L} \leq 40D \qquad \text{[expression 31]}$$

When the mobility of the p-channel transistor is expressed by "μp (cm^2/V*sec)," there is a need to meet the following relation. The mobility μp (cm^2/V*sec) assumes, for example, 50 or 30.

$$\frac{200D}{\mu p} \leq \frac{W}{L} \leq \frac{1200D}{\mu p} \qquad \text{[expression 32]}$$

Preferably, there is a need to meet the following relation:

$$\frac{300D}{\mu p} \leq \frac{W}{L} \leq \frac{1000D}{\mu p} \qquad \text{[expression 33]}$$

It is preferable that a value of W should be 100 (μm) or more.

As previously described, the output terminal of the shift register circuit of the driver circuit **491** is connected to the inverters **1251** of multiple stages, and the outputs of the inverters **1251**b and **1251**c of the final stage are connected to TG **1192** (see FIG. **126**(*b*)). If there are a number of inverter stages, a characteristic difference between inverters **1251** will be cumulated (or accumulated) and difference will occur in the transfer time from the shift register to TG (fluctuation in delayed time). For example, in an extreme case, TG **1292R1** in FIG. **138** is turned on after 1.0 μsec (since a pulse was output from the shift register), while TG **1292G1** is turned on after 1.5 μsec. Therefore, it is preferable that the number of inverters between the shift register and TG should be small, but the width (W) of TG is very large and it is impossible for the inverter (NAND) constituting the shift register to directly drive TG. For this reason a number of inverter stages are required. However, for example, if the ratio between the magnitude of W$_2$/L$_2$ of the inverter **1251**d of FIG. **126**(*b*) and the magnitude of W$_1$/L$_1$ of the inverter **1251**b, the delayed time will become long and the inverter characteristic will undergo a great fluctuation.

FIG. **228** shows the relation between delayed time fluctuation (represented by a dotted line) and delayed time ratio (represented by a solid line). The axis of abscissa represents (W$_{n-1}$/L$_{n-1}$)/(W$_n$/L$_n$). For example, if the L of the inverters **1251**b and **1251**d of FIG. **126**(*b*) are the same and 2W$_2$=W$_1$, (W$_1$/L$_1$)/(W$_2$/L$_2$)=0.5. In FIG. **228**, delayed time ratio is 1 when (W$_{n-1}$/L$_{n-1}$)/(W$_n$/L$_n$)=0.5. Similarly, delayed time fluctuation is 1 when (W$_{n-1}$/L$_{n-1}$)/(W$_n$/L$_n$)=0.5.

In FIG. **228**, an increase in (W$_{n-1}$/L$_{n-1}$)/(W$_n$/L$_n$) shows that the number of the connected stages of the inverters **1251** is increased and delayed time fluctuation becomes great. A reduction in (W$_{n-1}$/L$_{n-1}$)/(W$_n$/L$_n$) shows that the delayed time between the inverters **1251** of two adjacent stages becomes long. For this graph it is desirable that the delayed time ratio and the delayed time fluctuation be within 2.

Therefore, there is a need to meet the following condition:

$$0.25 \leq \frac{\dfrac{W_{n-1}}{L_{n-1}}}{\dfrac{W_n}{L_n}} \leq 0.75 \qquad \text{[expression 34]}$$

In addition, the ratio between the magnitude of W/L (W_p/L_p) of the p-channel of each inverter **1251** and the magnitude of W/L (W_s/L_s) of the n-channel needs to meet the following relation:

$$0.4 \leq \frac{\dfrac{W_3}{L_3}}{\dfrac{W_p}{L_p}} \leq 0.8 \qquad \text{[expression 35]}$$

Furthermore, if the number of stages m of the inverter **1251** between the output terminal of the shift register and TG **1192** meets the following equation, the fluctuation in the delayed time will be reduced.

$$3 \leq m \leq 8 \qquad \text{[expression 36]}$$

There is a problem with mobility μ. If the mobility μ_n of an n-channel transistor is small, the sizes of a TG and an inverter will become large and the dissipation power will be increased. Also, an area on which a driver circuit is formed is enlarged. For this reason the panel size is enlarged. If the mobility μ_n is great, characteristic degradation in a transistor will be easily caused. Therefore, it is preferable that mobility μ_n meet the following range:

$$50 \leq \mu_n \leq 150 \qquad \text{[expression 37]}$$

In addition, the throughrate of a clock signal within the shift register **491** is set to less than 500 V/μsec. If the throughrate is high, an n-channel transistor will undergo severe degradation.

In FIG. 126, while it has been described that the output of the shift register is connected to the inverters **1251** of multiple stages, the inverters may be replaced with NAND circuits. The aforementioned ratio W/L is also true in this case. It is desirable that the transistor adopt a low doping drain (LDD) structure. In addition, it is preferable that the matters relating to the design values of W and L, described in this specification, should be applied to display panels fabricated with a low-temperature polysilicon technique.

A description will hereinafter be made of an embodiment of a projection type display of the present invention in reference to the drawings. The constitution of a projection type display in a first embodiment of the present invention is shown in FIG. **141**. **1411** is a light source as light generation means, **1412** a color purity enhancement filter, and **1415** a projection lens as projection means.

The light source **1411** is constituted by a discharge lamp **1411a**, a concave mirror **1411b**, an ultraviolet-ray and infrared-ray (UVIR) cut filter **1411c**. The discharge lamp **1411a** is constituted by a metal halide lamp, and dysprosium (Dy) and neodymium (Nd) are enclosed within the light emitting tube. The emission spectrum is shown in FIG. **147**. As evident in FIG. **147**, in the spectral distribution of light emitted by the metal halide lamp, a great number of continuous emission spectra by dysprosium (Dy) and neodymium (Nd) and a bright line spectrum by mercury are present together. The concave mirror **1411b** is formed with glass or ceramic material, and a dielectric film for reflecting

visual light and also transmitting infrared light is deposited on the reflecting surface. The visual light, contained in light emitted from the lamp **1411a**, is reflected by the reflecting surface of the concave mirror **1411b**, and the reflected light becomes a nearly collimated light. The nearly collimated light from the concave mirror **1141b** is passed through the UVIR filter **1411c**, and consequently, infrared light and ultraviolet light are removed.

The discharge lamp **1411a** means a lamp having a discharge phenomenon, such as an ultrahigh pressure (UHP) mercury lamp, a high pressure mercury lamp, a metal halide (MH) lamp, a sodium lamp, a halogen lamp, and a xenon (Xe) lamp. In a wide sense, it also means a krypton lamp, an LED lamp, and a tungsten lamp. It is preferable that the projection type display of the present invention employ a UHP lamp or an MH lamp.

In UHP lamps or metal halide lamps, arc length means the distance between electrodes which generate an arc. In halogen lamps, arc length means an effective filament length, particularly the length of an area of more than 20% of the maximum brightness. In xenon lamps, arc length means the diameter of a light emitting valve of more than 20% of the maximum brightness, preferably the diameter of a light emitting valve of more than 50%. Where a UHP lamp and a metal halide lamp are of a DC lamp type, there is a preferable case where about 60 to 80% of the distance between electrodes which generate an arc is regarded as arc length.

In a projection type display employing a PD liquid crystal display panel as a light valve, the lamp **1411a** is selected so that a relation of D/L>1 be met. In the relation of D/L, D is the arc length of the discharge lamp and L is the diagonal length of the display area of the display panel. It is preferably that a relation of D/L>1.6 be met. As the value of D/L becomes greater, light collecting efficiency becomes higher and high brightness display can be realized. However, if the value is too great, panel size will become large compared with lamp size and system size will be too large. Therefore, it is preferable that D/L be 2.5 or less.

In FIG. 141, although the color filter **151** is arranged on the side of the light source, the present invention is not limited to this arrangement. For example, it is a matter of course that the color filter may be arranged on the side of a screen (not shown). If the color filter **151** is arranged on the screen side, a degradation in the color filter can be reduced, because there is no possibility that it will directly absorb light emitted from the light source. Particularly, this arrangement should be applied to the case where the color filter is formed with resin such as gelatin. Where the color filter consists of an optical interference film, there is almost no possibility that the interference film will absorb light, and it reflects unnecessary light. For this reason, in the case where the color filter **151** is formed with an optical interference film, it is preferable that the color filter **151** be arranged on the side of a light source. The reason for this is as follows: Since there is no possibility that unnecessary light will enter the liquid crystal layer **21**, there is no possibility that the liquid crystal display panel **22** will be heated. Therefore, halation is difficult to occur within the liquid crystal layer **21** and display contrast is enhanced.

A description will hereinafter be made of the color purity enhancement filter **1412** employed in the projection type display of the present invention. FIG. 142 shows an enlarged model diagram of the color purity enhancement filter **1412** of the first embodiment. **1422** is a first dielectric multilayer film and **1423** a second dielectric multilayer film.

The first dielectric multilayer film **1422** and the second dielectric multilayer film **1423** are formed on both sides of

a glass substrate **642**. The first dielectric multilayer film **1422** is constituted by **12** layers of alternations of low refractive index (1.46) SiO_2 layers **1424a** to **1424f** and high refractive index (2.30) TiO_2 layers **1425a** to **1425f**. The optical film thickness of the SiO_2 layer **1424a** is 0.188 λ_Y (λ_Y=577 nm). The optical film thickness of the SiO_2 layers **1424b** to **1424f** is 0.375 λ_Y. The optical film thickness of the TiO_2 layers **1425a** to **1425f** is 1.125 λ_Y. Similarly, the second dielectric multilayer film **1423** is constituted by **12** layers of alternations of low refractive index SiO_2 layers **1424g** to **1424l** and high refractive index TiO_2 layers **1425g** to **1425f**. The optical film thickness of the SiO_2 layer **1424** is 0.313 λ_C (λ_C=490 nm). The optical film thickness of the SiO_2 layers **1424g** to **1424k** is 0.625 λ_C. The optical film thickness of the TiO_2 layers **1425g** to **1425l** is 1.875 λ_C.

FIG. **144** shows the spectral transmittance of the color purity enhancement filter **1412**. The first dielectric multilayer film **1422** reflects 90% or more of yellow light (half value width: about 550 to 600 nm) at a peak wavelength. The second dielectric multilayer film **1423** reflects 90% or more of cyanogen light (half value width: about 475 to 505 nm) at a peak wavelength. Only three primary colors, red, green, and blue show high transmittance.

Note that if the difference in refractive index between a high refractive index layer and a low refractive index layer is made small, the half value width of a reflection wavelength area can be further narrowed.

FIG. **143** shows an enlarged model diagram of the color purity enhancement filter **1412** of a second embodiment. **1432** is a first dielectric multilayer film and **1433** a second dielectric multilayer film.

The first dielectric multilayer film **1432** and the second dielectric multilayer film **1433** are formed on both sides of a glass substrate **181**. The first dielectric multilayer film **1432** is constituted by 16 layers of alternations of low refractive index (1.62) Al_2O_3 layers **1434a** to **1434h** and high refractive index (2.30) TiO_2 layers **1435a** to **1435h**. The optical film thickness of the Al_2O_3 layer **1434a** is 0.188 λ_Y (λ_Y=577 nm). The optical film thickness of the Al_2O_3 layers **1434b** to **1434h** is 0.375 λ_Y. The optical film thickness of the TiO_2 layers **1435a** to **1435h** is 1.125 λ_Y. Likewise, the second dielectric multilayer film **1433** is constituted by 16 layers of alternations of low refractive index Al_2O_3 layers **1434i** to **1434p** and high refractive index TiO_2 layers **1435i** to **1435p**. The optical film thickness of the Al_2O_3 layer **1434p** is 0.313 λ_C (λ_C=490 nm). The optical film thickness of the Al_2O_3 layers **1434i** to **1434o** is 0.625 λ_C. The optical film thickness of the TiO_2 layers **1435i** to **1435p** is 1.875 λ_C.

FIG. **145** shows the spectral transmittance of the color purity enhancement filter **1412**. The first dielectric multilayer film **1432** reflects 90% or more of yellow light (half value width: about 555 to 595 nm) at a peak wavelength. The second dielectric multilayer film **1433** reflects 90% or more of cyanogen light (half value width: about 480 to 500 nm) at a peak wavelength. Only three primary colors, red, green, and blue show high transmittance.

In the first and second embodiments shown in FIGS. **142** and **143**, the first and second dielectric multilayer films are formed on both sides of a glass substrate, respectively. However, even if two kinds of dielectric multilayer films are superimposed and formed on one side of the glass substrate, similar performance will be obtained. However, there are a great number of continuous layers on one side, and consequently, when there is the fear that a crack will occur in the dielectric multilayer film surface due to internal stress produced in the multilayer film, it is preferable that a great number of layers be formed on both sides of a glass substrate.

Even if the film thicknesses of the high refractive index layer and the low refractive index layer are thicker than 1.875 λ_C and 0.625 λ_C employed in the aforementioned embodiments where cyanogen light is reflected, high reflectance will be periodically obtained. In practice, this case is unsuitable because if film thickness per one layer becomes thicker than the film thickness employed in the aforementioned embodiments, there will be the danger that a crack will occur.

Also, the absolute value of the reflectance at a peak wavelength can be made high if the number of dielectric multilayer films is increased.

In the aforementioned embodiments, although SiO_2 or Al_2O_3 is employed as a low refractive index layer and TiO_2 as a high refractive index layer, MgF_2 may be employed as a low refractive index layer and ZnS, CeO_2, $ZrTiO_4$, HfO_2, Ta_2O_5, and ZrO_2 as a high refractive index layer.

Furthermore, as in the second embodiment, in the case where the difference in refractive index between a high refractive index layer and a low refractive index layer is small, if the absolute value of reflectance at a peak wavelength is attempted to be made high, there will be a need to increase the number of dielectric multilayer films, and depending on the number of films, there will be the fear that a crack will occur. In this case, the high refractive index layer can be constituted by a combination of TiO_2 and ZnS whose refractive indexes are nearly the same and which has the property that the directions of internal stresses cancel out each other. The refractive indexes of the TiO_2 and ZnS layers are nearly 2.30. In the TiO_2 layer, tensile stress is produced, and in the ZnS layer, compression stress is produced. Therefore, for example, if the layers in the high refractive index multilayer film are respectively constituted by three layers consisting of TiO_2, ZnS, and TiO_2 and also the film thickness is divided into three parts, the internal stress in the entire multilayer film can be alleviated.

As evident in the aforementioned description, in the dielectric multilayer film constitution where an optical film thickness per one layer is $\lambda/4$ (λ: reflection peak wavelength), as shown in FIG. **146**, a color filter in which a half value width is narrow (50 nm or less) in a high reflection area is unrealizable.

On the other hand, if the optical film thickness ratio between the low refractive index film and high refractive index film of a multilayer film is 1: X (X>1) and also X is increased, the half value width can be slightly narrowed. However, as the film thickness ratio becomes greater, a balance of stress is lost between the low refractive index film and the high refractive index film by the internal stresses produced in the films, and consequently, there is the fear that a crack will occur in the multilayer film surface. Hence, it is desirable that the optical film thickness ratio between the low refractive index film and the high refractive index film should be 1:3 or less. However, in this condition alone, the half value width is insufficient to reflect only yellow light or cyanogen light.

This kind of interference filter has the spectral performance that in addition to reflection peak at wavelength λ, reflection peaks appear periodically on a shorter wavelength side than wavelength λ. The interference filter further has the characteristic that the half value width is narrowed if cycles superimpose each other. Hence, these periodic reflection peaks with a narrow half-value width are utilized, and they are shifted to the center wavelength of yellow light or cyanogen light. Specifically, the thickness of the aforementioned alternate multilayer film, in which the optical film thickness ratio between the low refractive index film and the

high refractive index film is 1:3, is relatively thickened. It is desirable that the second cycle be shifted to realize less than half value width 50 nm corresponding to yellow light. Also, it is desirable that the third cycle be shifted to realize less than half value width 40 nm corresponding to cyanogen light.

In the case of yellow light reflection, the optical film thickness of a multilayer film is relatively increased by approximately 1.5 times, the thickness of the low refractive index layer is 0.375λ, and the thickness of the high refractive index layer is 1.125λ. In the case of cyanogen light reflection, the optical film thickness of a multilayer film is relatively increased by approximately 2.5 times, the thickness of the low refractive index layer is 0.625λ, and the thickness of the high refractive index layer is 1.875λ.

The reflection peaks are also present in the fourth cycle and the cycles thereafter, but, since the thickness of the multilayer film becomes considerably thick, it is unsuitable from the viewpoint of reliability.

Attention given here is that in the color purity enhancement filter 1412, λ_Y=577 nm. The metal halide lamp shown in FIG. 147 shows a strong emission spectrum at a wavelength of 577 nm. This spectrum is caused by a mercury atom. The wavelength of 577 nm corresponds to the band of yellow light. Therefore, if light with a wavelength of 577 nm cannot be cut sufficiently, the hue of an image projected on a screen cannot be made satisfactorily.

The emission spectrum at a wavelength of 490 nm is caused by neodymium (Nd). Although the spectral characteristic of FIG. 147 does not show a strong peak value at a wavelength of 490 nm, a strong emission spectrum occurs depending on an amount of addition of neodymium (Nd). A metal halide lamp containing dysprosium (Dy) and neodymium (Nd) is satisfactory in spectral characteristic and long in life. However, the emission spectra of yellow light and cyanogen light are strong.

The color purity enhancement filter 1412 of the present invention is characterized in that the emission spectra at wavelengths of 490 nm and 577 nm can be cut sufficiently and also the half value widths at the cut bands are narrow as about 50 nm. In this sense, when the color purity enhancement filter 1412 is combined with a metal halide lamp and employed, there is a synergistic effect.

Nearly collimated light from the light source 1411a is incident on the color purity enhancement filter 1412. The color purity enhancement filter 1412 transmits only three primary light components whose purity is high in accordance with the spectral characteristic shown in FIG. 144 or 145. The light, transmitted through the color purity enhancement filter 1412, is transmitted through a field lens 1413 and incident on a display panel 22 of the present invention. The field lens 1413 is employed to direct the light being transmitted through the circumferential portion of the liquid crystal display panel 22 to a projection lens 1415. The light incident on the display panel 22 modulates incident light as a change in transmittance in accordance with a video signal, and a color image is formed on a screen (not shown). The focusing adjustment of a projected image is performed by moving the projection lens 1415 along an optical axis 1416.

For the projected images of red, green, and blue pixels on the screen, the spectral characteristics are shown in FIGS. 149(a), (b), and (c). A dotted line represents a spectral characteristic obtained only by the color filter 151, and a solid line represents a spectral characteristic improved by the color purity enhancement filter 1412 added to the optical path. It is found that the use of the color purity enhancement filter 1412 reduces the light band component which is

believed to be causative of color purity degradation. It is also found that all red, green, blue components have become narrow compared with the light transmittance band of the color filter 151. FIG. 148 shows a spectral characteristic distribution obtained when light components transmitted through the R, G, and B color filters 151 are synthesized. Since cyanogen light and yellow light are cut by the color purity enhancement filter 1412, the spectral characteristic distribution of the metal halide lamp 1411a shown in FIG. 147 becomes a spectral characteristic distribution of FIG. 148.

FIG. 150 shows the color reproducibility (solid line) of the projection type display of the present invention arranging the color purity enhancement filter 1412 in the optical path 1416. It is found that the color reproduction range of the present invention has been widened compared with conventional constitution having only the color filter 151 (dotted line).

If the color purity enhancement filter 1412 removes unnecessary light components from light emitted from the light source 1411, a quantity of light which is absorbed by the color filter 151 formed within the liquid crystal display panel 22 can be reduced. Therefore, the amount of heat that is generated by unnecessary light absorbed by the color filter 151 can be reduced, whereby a degradation in the color filter 151 can be suppressed.

FIG. 151 shows the constitution of a projection type display in another embodiment of the present invention. Light emerging from a lamp 1411a is focused by a concave mirror 1411b, and ultraviolet light and infrared light are removed by a UVIR cut filter 1411c. The emitted light from the light source 1411 is transmitted through a color purity enhancement filter 1412, a field lens 1413, a display panel 22 of the present invention, and a transparent plate 1131 in the recited order and is incident on a projection lens 1415. The color purity enhancement filter 1412 removes the light component in a band which is believed to be causative of color purity degradation in accordance with the spectral characteristic distribution shown in FIG. 144 or 145. The transparent plate 1131 is optically coupled to the exit side of the PD liquid crystal display panel 22 by a Optical coupling agent 371. An ineffective area of the transparent plate 1131 is coated with black paint 1132. 211 denotes an antireflection film (air coat) for preventing the reflection of light emerging from the exit side of the display panel 22.

The pupil of the projection lens 1415 is sized so that when a pixel on the screen center of the liquid crystal display panel 22 is in a transparent state, about 90% of a light quantity emitted from that pixel in all directions can be incident. The field lens 1413 is employed so that the circumferential portion of a projected image does not become dark, by refracting light being transmitted through the circumferential portion of the display area of the liquid crystal display panel 22 inwardly and then directing the refracted light to the pupil of the projection lens 1415. The focusing adjustment of the projected image is performed by moving the projection lens 1415 along an optical axis 1416.

On the liquid crystal display panel 22 an optical image is formed as the change of a light scattering state in accordance with a video signal. Among the light emitted from the pixels, the projection lens 1415 receives the light contained in a certain solid angle. If the scattering state of the light emitted from the pixels changes, the light quantity contained in the solid angle will change. Therefore, the optical image, formed as the change of a light scattering state on the liquid crystal display panel 22, is converted to the change of illuminance on a screen 1501. In this manner, the optical

image formed on the liquid crystal display panel **22** is enlarged and projected on the screen **1501** by the projection lens **1415**. This embodiment can also improve color reproducibility by the same operation as the aforementioned embodiment with the use of the color purity enhancement filter **142**. The matters, related to the determination of the reflection light band of the color purity enhancement filter **142** based on the spectral characteristic distribution of the metal halide lamp **1419a**, are the same as or similar to the aforementioned embodiments.

FIG. **152** shows a variation of FIG. **151**. The variation is the same constitution as FIG. **151** except for a flat-concave lens **1131b** arranged on the exit side of the liquid crystal display panel **22**.

In the state in which the projection lens **1415** is combined with the flat-concave lens **1131b**, the optical image on the liquid crystal layer **21** is projected onto the screen **1501**. Since the light emerging from the concave surface of the flat-concave lens **1131b** needs to be incident on the projection lens **1415**, converged light needs to be incident on the liquid crystal display panel **22**. The focusing adjustment of the projected image is performed by moving the projection lens **1415** along an optical axis **1416**.

Light emitted from a light source **1411** is incident on the PD liquid crystal display panel **22** through a color purity enhancement filter **1412** and a field lens **1413**. Black paint **1132** coated on the side surface of the flat-concave lens **1131b** and an antireflection film **211** deposited on the concave surface of the flat-concave lens **1131b** show the same operation as the aforementioned embodiment and enhance the contrast of the projected image.

Color display is realizable by employing the projection type display shown in FIG. **141** or **151**. However, since the overall length of the projection type display is long, it is unhandy to carry. FIGS. **153** and **154** are explanatory diagrams of a projection type display which has solved the aforementioned problem. FIG. **153** is an explanatory diagram of the state when it is used. FIG. **154** is an explanatory diagram of the state when it is carried. The reason why the overall length can be shortened as shown in FIG. **154** is that large space is provided between a projection lens **1415** and a panel **22** and between the panel **22** and a light emitting lamp **1411a**.

A casing **1535** is constituted by three casing portions: a casing portion **1535c** mounted with the projection lens **1415**, a casing portion **1535b** mounted with the panel **22**, and a casing portion **1535a** mounted with a lamp. When the display is carried, the overall length can be shortened by housing the casing portions **1535a** and **1535c** into the casing portion **1535b** as shown in FIG. **154**.

Field lenses **1413b** and **1413c** are arranged before and after the panel **22**, and these are mounted in a mounting portion **1537**. **1534b** is a fan for cooling the panel. **1536** is a portion on which a printed board, such a circuit for converting a composite signal to R, G, and B component signals and a circuit for generating a pulse to control the panel, is arranged. The panel **22** is arranged so that it is slightly slanted at an angle of 2° to 8°. The reason for this is that when an image is projected onto an upper screen obliquely provided with respect to the panel, the image is formed satisfactorily (trapezoidal strain correction).

The projection lens **1415** is a zoom lens, and the focusing adjustment of the lens **1415** is performed by a lens drive portion **1536**. **1533** is a control button, and a video input switching button, a picture/contrast adjustment switch, a zoom/focus adjustment switch, and a power on-off switch are arranged on the control box. The control button **1533** can

be removed from the casing portion **1535c** and used as a remote control button.

The control button **1533** includes a movement control button for moving the lamp **1411a**. The lamp **1411a** is mounted on a position adjustment table **1531** that can be moved in X and Y directions. If the movement control button is operated, the lamp **1411a** will be moved longitudinally and laterally. The reason that such a movement control button is arranged is that since the casing **1535** of the projection type display of the present invention is divided into three portions, the lamp **1411a** is easily offset from the optical axis between the lamp **1411a** and the projection lens **1415**. To cope with the optical axis offset, the position of the lamp **1411a** is aligned with the optical axis by the position adjustment table **1531**.

When a PD liquid crystal display panel is employed as the display panel **22**, the effective F number of the projection lens **1415** is between 7 and 10. Also, the F number of an illuminating light beam and the F number of the projection lens are nearly the same. Between the projection lens **1415** and the display panel **22** a color purity enhancement filter **1412** is arranged.

1532 is a power source for the lamp **1411a**. The lamp **1411a** employs an ultrahigh-pressure (UHP) mercury lamp. The lamp power is between 100 and 150 W. **1534a** is a lamp cooling fan.

The cooling fan **1534b** suctions the air inside the casing **1535**, and the cooling fan **1534a** exhausts air outside the casing **1535**. Thus, the casing **1535** is constructed so that air cools the panel **22**, then cools the lamp, and is exhausted outside.

In the state in which the casing is contracted as shown in FIG. **154**, the switch for turning on the power source is not operated. The reason for this is that if the lamp **1411a** is lit in the state of FIG. **154**, an air path for the cooling fans cannot be formed and therefore the display panel **22** will be damaged. To detect whether or not the power source can be turned on (whether or not the casing has been contracted), switches **1539** are provided for detecting contact between the casing portions **1535a** and **1535b** and contact between the casing portions **1535c** and **1535b**. With these switches **1539**, it is detected whether or not the casing is in the state of FIG. **153**.

In the projection type display of FIG. **154**, the detection of whether or not the casing portions **1535a** and **1535c** have been moved from the casing portion **1535b** to predetermined positions (at which projection can be performed) is performed by mechanical relay switches, push switches, conductive rubber switches, light detecting switches, or Hall elements. The outputs from these switches **1539** (**1539a** to **1539d** in FIG. **154**) are processed by a microcomputer. The microcomputer controls the power source switch, based on a result of processing.

Until the light output of the lamp **1411a** assumes a sufficient value after it has been lit, a video signal is not applied to the display panel **22**, and a voice signal is not output either. The reason for this is that noise is easily contained in the voice signal during the brightness rise time of the lamp **1411a** and is easily contained in the video signal as well. For this reason, after the lamp has been lit, the microcomputer operates a timer, and the voice signal is output after a predetermined period.

In the aforementioned description, the screen **1501** and the projector are separated from each other. If the aforementioned projection type display is arranged as an optical block **1551** within a cabinet **1535**, as shown in FIG. **155**, a rear type projector can be constituted. The rear type projector is

one in which the screen **1501** and a projection portion (projection type display) are integrally formed with each other, and it is called a projection TV.

Light emitted from the projection type display (optical block **1551**) is reflected by mirrors **1552**a and **1552**b and is directed to the screen **1501**. The screen **1501** is a transmission type screen, and a Fresnel lens and a lenticular lens are pasted together.

As shown in FIG. **156**, if a mirror **1552** is arranged within a projection lens **1415** and also an optical block **1551** is horizontally arranged, the depth can be shortened. Therefore, a compact rear type projector can be constituted. The constitution where a mirror is arranged within an integrally formed projection lens **1415** and also an optical path is bent at an angle of 90° is effective particularly in rear projectors.

In the aforementioned embodiments, the liquid crystal display panel is of a transmission type.

Therefore, the projection type display panel is also of a transmission type. It is also easy to constitute a reflection type display. The light valve which is employed in the reflection type display employs a reflection type liquid crystal display. As an example of the reflection type display, the pixel electrode **14** shown in FIG. **19** is formed from aluminum (Al) as a reflecting electrode. In the case of reflection type display panels, light is incident through the counter electrode **25** and again emerges from the counter electrode **25**. Therefore, the transparent plate **1131**a is optically connected to the side of the substrate **11**.

A description will hereinafter be made of the reflection type projection display. FIG. **157** shows a constitution diagram of the reflection type projection display.

A projection lens **1415** is constituted by a first lens group **1415**a on the side of a liquid crystal display panel **22** and a second lens group **1415**b on the side of a screen **1501**. Between the first lens group **1415**a and the second lens group **1415**b a piano mirror **1552** is arranged. Scattered light emerging from a pixel on the screen center of the liquid crystal display panel **22** is transmitted through the first lens group **1415**a. Then, about 50% of the transmitted light is incident on the piano mirror **1552**, and the remaining light is incident on the second lens group **1415**b. The normal line of the reflecting surface of the piano mirror **1552** is inclined at an angle of 45° to the optical axis **1416** of the projection lens **1415**. For the light from the light source **1411**, cyanogen light and yellow light are cut by a color purity enhancement filter **1412**. Then, the aforementioned light is reflected by the plano mirror **1552** and is transmitted through the first lens group **1415**a.

The transmitted light is reflected by the liquid crystal display panel **22** and arrives at the screen **1501** through the first lens group **1415**a and the second lens group **1415**b. The projection lens **1415** is constituted by a telecentric lens so that light emerging from the center of the lens aperture toward the liquid crystal display panel **22** is nearly perpendicularly incident on the liquid crystal layer **21**.

FIG. **158** is a constitution diagram of a projection type display employing a polarization beam splitter (hereinafter referred to as a PBS). Light emitted from a light source **1411** is reflected by a color purity enhancement filter **1412**. At this time, the light component other than cyanogen and yellow bands is reflected. The reflected light is incident on the PBS **1581** and S-polarized light is reflected at a light separating surface **1582**. The reflected light is incident on a reflection type liquid crystal display panel **22**. The panel **22** modulates the incident light, based on a video signal. The modulated light is transmitted through the PBS **1581** and a projection

lens **1415**. The transmitted light is reflected by a plano mirror **1552** and is projected onto a screen **1501**.

In the aforementioned embodiments, the color purity of a projected image is improved by the color purity enhancement filter **1412**. In FIG. **159** the color purity is improved by a dichroic prism **1591**.

Light emitted from a light source **1411** is separated into three primary light components (R, G, and B) by the interfaces **1582**a and **1582**b of a dichroic prism **1591**a. The separated light components are reflected by mirrors **1552**a and **1552**b and are transmitted trough a lens **1592**. The transmitted light components are again synthesized by the interfaces **1582**c and **1582**d of a dichroic mirror **1591**b. The synthesized light is transmitted through a lens **1413**b. The transmitted light is modulated by a display panel **22** and is projected onto a projection lens **1415**.

Since cyanogen light and yellow light from a light emitting lamp **1411**a are cut, band cut filters **1594**a and **1594**b are arranged in an optical path. The band cut filters are of a light absorption type, and absorbed light is converted to heat. However, since the band cut filter does not reflect light as in a dielectric mirror, it does not cause halation. For this reason there is no occurrence of a ghost image. Since the band cut filter **1594** cuts unnecessary band light, the light incident on the display panel **22** becomes three satisfactory primary colors. For this reason the color purity of a projected image can be enhanced.

A lens plate **1592** is made by forming a plurality of Fresnel lenses **1593** on a single acrylic plate. The Fresnel lenses **1593**a and **1593**c function as relay lenses. A plurality of lenses **1593** are formed on the single lens plate **1592**, and this lens plate **1592** is arranged in a plurality of optical paths (e.g., optical paths of R, G, and B). The distance between lenses **1593** (e.g., distance between lenses **1593**a and **1593**b) on the lens plate **1592** is precisely made. In a conventional projection type display, separate relay lenses are arranged in a plurality of optical paths (optical paths of R, G, and B), respectively. For this reason, the individual lenses need to be positioned respectively and therefore it takes time for positioning. In the present invention, since a plurality of lenses **1593** are formed on a single lens plate **1592**, a plurality of lenses in optical paths can be positioned at the same time by positioning the lens plate **1592**.

The lens plate **1592** can be easily fabricated by stamping transparent resin such as acrylic and polycarbonate.

As shown in FIG. **160**, the lens **1593** may be a circular arc lens (**1593**a, **1593**b, and **1593**c). Also, as shown in FIG. **160**, instead of the band cut filter **1594** the mirrors **1552**a and **1552**b may be employed as dichroic mirrors **1611**a and **1611**b. The dichroic mirror **1611** transmits unnecessary light (cyanogen light and yellow light) and reflects necessary light path at an angle of 90°.

FIG. **161** shows an embodiment in which two lenses **1593**a and **1593**b are formed on a lens plate **1592**. The lens **1593**a is arranged in a first optical path and the lens **1593**b is arranged in a second optical path. The dichroic mirror **1611**a reflects light in the range of R light, as shown in FIG. **162**(a). The dichroic mirror **1611**b reflects light in the range of G light and G light, as shown in FIG. **162**(b). Therefore, since yellow light in the range of a band k shown in FIG. **162** is cut, the color purity of a projected image can be improved.

In the aforementioned embodiment, a sheet of display panel is employed and the color filter **151** is formed on the display panel **22**, thereby performing color display. The method of the present invention, which constitutes a projection type display by forming a plurality of lenses **1593** on a single lens plate **1592** and then arranging the lenses **1593**

in different optical paths, is also applicable to a projection type display having a plurality of display panels.

FIG. **163** is a constitution diagram showing a lens plate **1592** arranged on a projection type display employing a display panel **22** which has three R, G, and B display areas.

Light emitted from a light emitting lamp **1411a** is separated into R, G, and B light components by dichroic mirrors **1611a** and **1611b**. The separated light components are transmitted trough the lenses **1593** of a lens plate **1592** and incident on the display areas **1631a**, **1631b**, and **1631c** of the display panel **22**. The light modulated by the display area **1631** is transmitted through the dichroic mirrors **1611a** and **1611b**. At this time, unnecessary light is cut and the color purity is enhanced. The transmitted light components are synthesized to a single optical path by the dichroic mirrors **1611c** and **1611d**. The synthesized light is projected onto a projection lens **1415**.

In FIG. **163**, the optical paths of R light and B light differ in optical path length from the optical path of G light. In other words, the optical path lengths of R light and B light are longer than that of G light. For this reason the focal distances of the lenses **1593a** and **1593c** are different from that of the lens **1593b**.

FIG. **163** is a constitution diagram showing a display panel having three display areas for modulating R light, G light, and B light, the display panel being employed as a light valve. However, as shown in FIG. **164**, it is a matter of course that the technical idea of the lens plate **1592** of the present invention is also applicable to a projection type display having three panels, a display panel **22a** for modulating R light, a display panel **22b** for modulating G light, and a display panel **22c** for modulating B light.

In projection type displays (liquid crystal projectors), a growing high-brightness display tendency has been seen in recent years. For this reason the output of the lamp **1411a** is increasing. Therefore, a great quantity of light is incident on the display panel **22a**, and the display panel and polarizing plate are heated and degraded. To cool the polarizing plate and display panel **22**, air cooling is presently being performed by cooling fans. However, there is a limit to the cooling power of the cooling fan. If the speed of the cooling fan is increased to enhance the cooling power, the rotational sound will be increased.

The present invention performs hydrogen cooling on a display panel **22**, as shown in FIG. **165**. As an example, the range of a dotted line shown in FIG. **164** is enclosed by a casing **1651**, and within the casing **1651**, a display panel **22**, a polarizing plate (not shown), and a dichroic prism (dichroic mirror) **1591** are disposed. The casing **1651** is filled with hydrogen. The casing is formed from transparent resin or glass. The area that light is transmitted through is formed with an air coat **211** for preventing interface reflection.

The heat transfer rate and surface heat transfer rate of hydrogen are 6.69 times and 1.35 times those of air and are thus great. For this reason, since the cooling effect of hydrogen is great, it can sufficiently cool the display panel **22**. In addition, because the density of hydrogen is 7% of air and thus light, loss of wind is reduced and efficiency is enhanced. Therefore, the sound of the cooling fan can be reduced. Furthermore, hydrogen is inactive compared with air, so the occurrence of display panel degradation is low.

If the display panel **22** is arranged within the casing **1651** and also the casing **1651** is sealed, there will be no possibility that dust will adhere to the surface of the display panel. In addition, if the cooling fan **1534** is arranged within the casing **1651**, there will be no possibility that the sound of the

cooling fan will leak outside. Note that FIG. **166** is a top view of the casing **1651**.

At least the display panel **22** is arranged within the casing **1651**. The cooling fan **1534** blows wind to a radiating plate **921**. Heat generated within the casing **1534** is radiated outside the casing **1651** by the radiating plate **921**. The cooling fan constantly circulates hydrogen within the casing **1651**, and the circulated hydrogen cools the display panel **22**. For this reason a temperature distribution will not occur in the display panel **22**.

In FIG. **165**(*a*), although the cooling fan **1534** is arranged within the casing **1651**, it is also effective to arrange a Peltier device (electronic cooling device) as shown in FIG. **165**(*b*). The Peltier device can easily perform the temperature control of the casing by controlling an amount of current which flows through the device. Also, if current is caused to flow through the Peltier device in the opposite direction, air (hydrogen) within the casing can be warmed. Furthermore, the casing can be easily sealed because there is no moving portion. The heat removed from the casing by the Peltier device is transferred directly to the radiating plate **921** and exhausted outside the casing **1651**. The Peltier device **1652** does not require a cooling fan and there is no occurrence of noise. If air is blown to the radiating plate **921** extending outside the casing **1651** by a cooling fan, the cooling power can be further enhanced.

In FIG. **164**, while it has been illustrated that the display panel portion is enclosed by he casing **1651** and cooled, the present invention is not limited to this arrangement. It is effective that the lamp **1411** is enclosed with the casing **1651** and cooled. In addition, it is effective that the entire projection type display is sealed and cooled with hydrogen.

In FIGS. **164** and **165**(*a*), (*b*), although the casing **1651** is filled with hydrogen to cool the display panel **22**, sulfur hexafluoride (SF_6) and helium may be employed.

The display panel **22** may be a reflection type display panel. As a reflection type display panel, there is a digital micromirror device (DMD) developed by Texas Instrument (TI). The display panel is cooled from the back surface with a Peltier device (electronic cooling device) and also hydrogen is circulated between the prism **1591** and the display panel **22** to cool the display panel. Also, the entire display panel may be cooled with hydrogen. In addition, the display panel may be an organic EL display panel, an inorganic EL display panel, a TN display panel, a guest-host liquid crystal display panel, an STN display panel, a homeotropic mode type display panel, a heat write type display panel, an LED display panel, an optical write type display panel, a laser write type display panel, or a ferroelectric liquid crystal display panel.

Hydrogen cooling is also effective in the case of the cooling of the rotary filter **1414**. Particularly, hydrogen cooling is effective in the case where a polarizing plate is formed in the rotary filter **1414** and the case where a light absorption type filter (e.g., color filters for R light, G light, and B light) is formed. The reason for this is that the rotary filter **1414** absorbs light from a lamp and generates heat. If the rotary filter **1414** is cooled with hydrogen, heat can be efficiently radiated from the rotary filter **1414**.

The prism **1591** may be a prism for a CCD (see FIG. **201**). It may also be replaced with a dichroic mirror. In addition, the entire casing **1535** of FIG. **153** may be filled with hydrogen and cooled without employing the casing **1651**.

In FIGS. **165**(*a*) and (*b*), the display panel is cooled with hydrogen. Instead of hydrogen, silicon oil, water, or freon fluid may be employed. This method is shown in FIGS. **167** and **168**. As shown in FIG. **168**, a display panel **22** is

arranged within a casing **1651***a*, which is in turn filled with cooling liquid **1682** such as ethylene glycol and silicon oil. The cooling liquid **1682** absorbs heat from the display panel **22** and cools it. The casing **1651***a* is arranged so as to surround a prism **1591**.

The casing **1651***a* is connected to a casing **1651***b*, and the casings are filled with nitrogen gas **1681** on the upper surface of the cooling liquid **1682** to prevent oxidation of the cooling liquid **1682**. The reason that there is space in the upper portion of the cooling liquid **1682** is that the cooling liquid **1682** varies in volume, depending on temperature. The casing **1651***b* is divided into two chambers B and C, which are filled with silicon oil. The liquid in the chambers B and C differs from the cooling liquid in the chamber A of the casing **1651***a* and serves as seal liquid **1683** which prevents contact between the air and the cooling liquid in the chamber A. Thus, the seal liquid **1683** and the nitrogen gas **1681** prevent the oxidization of the cooling liquid **1682** and the occurrence of slag(impurities). FIG. **167** is a sectional view taken along line A–A' of FIG. **168**.

In FIG. **168** the casing **1651***b* is filled with the seal liquid **1683**, but, if the upper portion of the cooling liquid **1682** is formed with a conservator film, the casing **1651***b* is not required. Also, if a moisture absorbent such as active alumina is put into the cooling liquid **1682**, it will absorb moisture from the cooling liquid **1682** and can prevent degradation of the cooling liquid **1682**. In addition, if the cooling liquid is circulated by a pump, the cooling power can be further enhanced.

A display panel employing a PD liquid crystal layer as a light modulating layer can realize high brightness display, but there is a problem with the PD liquid crystal display panel. The problem is that a hysteresis characteristic occurs at low temperature. If hysteresis occurs, image baking will arise. The hysteresis occurs easily when panel temperature is less than 10° C.

When the display panel **22** is employed as the light valve of a projection type display, it is heated in a short time after a lamp is lit. For this reason the temperature of the panel **22** rises and no hysteresis will occur. However, when room temperature is low (less than 10° C.) and immediately after a lamp is lit, there is the problem that hysteresis will occur.

FIG. **169** is an explanatory diagram of a display panel of the present invention carrying out a measure to counter hysteresis. A counter substrate **11** is mounted on an array substrate **12** so that it is offset from the array substrate **12**. On the counter substrate **11** a wire **1693** is formed. The wire **1693** is formed as the same time as formation of a chrome (Cr) film which becomes a light shielding film (BM). It may be formed from silver paste. At this time, the wire **1693** is formed so that the resistance thereof is lower than the sheet resistance of ITO of a counter electrode **25**.

On one end of the wire **1693** a connecting point **1694** is formed from paste. A lead wire **1695** extends from the connecting point **1694**. The lead wire **1695** is connected to an AC power supply **1691**. If a switch **1692** is closed, current will flow between wires **1693***a* and **1693***b*.

On the other hand, the array substrate **12** is formed with a source drive circuit **491** and a gate drive circuit **492**. The aforementioned wire **1693** and the drive circuits are formed at positions where they do not contact each other. Also, the wire **1693** is formed outside seal resin **361**.

If the switch **1692** is closed, current will flow between wires **1693***a* and **1693***b*. The current flows through ITO serving the counter electrode **25**. The ITO has a relatively high resistance value, so if current flows through the ITO, Joule heat will be generated. The generated heat causes the

temperature of the liquid crystal layer **21** to rise. Since the PD liquid crystal layer **21** is heated to more than 10° C., no hysteresis will occur.

The switch **1692** interlocks with a power switch for the projection type display, a temperature sensor **745** (see FIG. **74**) for detecting the temperature of the display panel, and a microcomputer (timer) for counting time that has passed since the power switch is turned on. When the power switch is turned on and also the temperature of the display panel **22** shows a predetermined value (e.g., less than 10° C.), the switch **1692** is closed and current flows through the counter electrode **25**. However, even if the liquid crystal layer **21** reaches more than a predetermined temperature (e.g., 10° C.), the temperature of the display panel will not rise at once. In that case, the timer of the microcomputer judges that the liquid crystal layer **21** has already reached more than a predetermined value, thereby opening the switch **1692**.

When current is flowing through the counter electrode **25**, there are cases where the display image on the display panel becomes unstable (e.g., brightness inclination appears or there is a large amount of noise). Therefore, when current is flowing through the counter electrode **25**, image display is not performed. The period is short and usually about 10 sec.

If a lamp **1411***a* is lit, the panel **22** is already heated by light from the lamp and there is no possibility that hysteresis occurs again. Conversely, the cooling fan needs to be turned on to cool the display panel.

Thus, if current flows directly through the counter electrode **25**, the PD liquid crystal layer **21** can be directly heated. For this reason a measure to counter hysteresis can be performed quickly. It is desirable that current which flows through the wire **1693** can be adjusted according to the output of the temperature sensor **745**. For example, if the output of the temperature sensor **745** is –10° C., a current of 3 A will flow through the wire **1693**. If it is +10° C., a current of 1 A will flow.

As an example of the temperature sensor **745**, there is a thermoelectric thermometer employing a thermocouple, a resistance thermometer utilizing the fact that the resistance rate of a semiconductor depends on temperature, a radiation thermometer, an optical altimeter, a bimetal thermometer, and a photoelectric pyrometer.

In FIG. **169**, a measure to counter hysteresis is carried out with the panel **22**. FIG. **170** is an explanatory diagram of the case where a measure to counter hysteresis is carried out with an optical system. It is a matter of course that both countermeasures shown in FIGS. **169** and **170** may be carried out at the same time.

On the exit side of a lamp **1411** an ultraviolet-ray and infrared-ray (UVIR) cut filter is usually arranged. The UVIR cut filter is usually constituted by a single cut filter. The arrangement shown in FIG. **170** is provided with a single ultraviolet-ray (UV) cut filter **1701** and a single infrared-ray (IR) cut filter **1702**.

When the lamp **1411***a* is lit, the IR cut filter **1702** has been removed from an optical path **1416** (i.e., it is held at a position of **1702***a*). At this time, the display panel **22** is heated by the radiation heat of infrared light emitted from the lamp **1411***a*. For this reason the display panel **22** is warmed at once and reaches more than 10° C., so there is no occurrence of hysteresis. If the display panel **22** is heated to a predetermined temperature, the IR cut filter **1702** is inserted in the optical path **1416** (at a position of **1702***b*). The timing at which the cut filter is inserted in the optical path is detected with the temperature sensor **745**. The IR cut filter **1702** may be forcibly inserted in the optical path after a predetermined time that has passed since the lamp is lit.

However, in the case where the output of the temperature sensor **745** is higher than a predetermined temperature (e.g.,, 30° C.) when power is turned on, the IR cut filter **1702** is inserted in the optical path **1416** immediately after the lamp is lit. The reason f or this is that the display panel **22** is overheated and degraded.

It is effective that as occasion demands, an infrared-ray absorption filter **1703** is attached to the incident side or exit side of the display panel **22**. The reason for this is that the filter **1703** absorbs infrared light emitted from the lamp **1411***a* and heats the display panel **22** quickly to the temperature where hysteresis does not occur.

Structure such as that shown in FIG. **171** can facilitate the aforementioned insertion and removal of the IR cut filter **1702** for the optical path. The IR cut filter **1702** is attached to a motor **1711** which rotates through 90°. Immediately after a lamp **1411***a* is lit, the IR cut filter **1702** is held at a position indicated by a dotted line. If a predetermined time has passed after the lamp **1411***a* is lit, or if the display panel **22** reaches a predetermined temperature, the motor **1711** is rotated through 90° so that the IR cut filter **1702** is inserted in an optical path **1416** (solid line position). At this time, the IR cut filter **1702** is stopped by a damper **1712** for preventing overshoot. If constituted in the aforementioned manner, a measure to counter hysteresis can be easily performed.

Although the aforementioned projection type display of the present invention employs a single display panel **22**, two display panels **22** may be employed. The constitution diagram is shown in FIG. **172**.

White light emitted from a light source **1411** is transmitted through a color purity enhancement filter **1412**. At this time, cyanogen light and yellow light are cut. The light from the filter **1412** is separated into P-polarized light and S-polarized light by a polarization beam splitter (PBS) **1581***a*. The S-polarized light is reflected by the PBS **1581***a* and is turned at an angle of 90° by a mirror **1552***b*. The S-polarized light is transmitted through a field lens **1413***b* and incident on a liquid crystal display panel **22***b*. The P-polarized light transmitted through the PBS **1581***a* is likewise turned at an angle of 90° by a mirror **1552***a*. The P-polarized light is transmitted through a field lens **1413***a* and incident on a liquid crystal display panel **22***a*. The liquid crystal display panels **22***a* and **22***b* modulate the P-polarized light and the S-polarized light, respectively. The P-polarized light and the S-polarized light are synthesized together by a PBS **1581***b*. The synthesized light is projected on an enlarged scale onto a screen (not shown) by a projection lens **1415**.

As shown in FIG. **173**, the projection type display may have two light sources **1411**. In this case the PBS **1581***a* of FIG. **172** is not required.

A further description will hereinafter be made of the projection type display of the present invention. First, a supplementary description will be made of the liquid crystal display panels **22** having the transverse electric field wire **17** shown in FIG. **1**. These display panels are characterized in that they have satisfactory scattering performance with respect to predetermined polarized light. As shown in FIG. **3**(*b*), if the liquid crystal molecule **20** is oriented by the electric field **19**, the refractive index of the liquid crystal molecule **20** will be n_e with respect to polarized light in a direction of aa'. For this reason a strong refractive index mismatch between the liquid crystal molecule **20** and the resin component **24** occurs and therefore the liquid crystal layer scatters strongly. Therefore, if the polarized light in the direction of aa' is incident on the liquid crystal display panel of the present invention, the display contrast can be enhanced.

As an example of the arrangement of the polarizing plate (polarization axis), there is constitution shown in FIGS. **13** and **14**. Basically, the transverse electric field generation direction **133** and the polarization axis **132** are aligned with each other. In FIGS. **13**(*a*) and **14**(*a*), polarization means (e.g., the polarizing plate **131**, the polarization beam splitter (PBS), etc.) are arranged on the incident side and exit side of the liquid crystal display panel **22**. In FIGS. **13**(*b*), **13**(*c*), **14**(*b*), and **14**(*c*), polarization means is arranged on either one or the other of the incident and exit sides of the liquid crystal display panel **22**.

FIG. **174** is a constitution diagram of a projection type display of the present invention. Unnecessary parts for explanation are not given. The curvature of a concave mirror **1411***b* is designed to a proper value in accordance with the arc length of a lamp **1411***a* and a projection lens **1415**. In a projection type display employing the PD liquid crystal display panel **22** as a light valve, since the F number of the projection lens **1415** is large, it is preferable that the concave mirror be constituted by an elliptical mirror. A dichroic mirror **1611***a* reflects red (R) light (RDM) and a dichroic mirror **1611***b* reflects green (G) light (GDM).

Light emitted from the light emitting lamp **1411***a* is transmitted through an ultraviolet-ray and infrared-ray (UVIR) cut filter **1411***c*. At this time, ultraviolet light and infrared light are cut. The light from the filter **1411***c* is incident on a polarization beam splitter (PBS) **1581**. The polarization axis **132** of light (P-polarized light or S-polarized light) which passes through the light separating surface **1582** of the PBS **1581** is aligned with the transverse electric field generation direction **133** of the display panel **22**. The light reflected by the light separating surface **1582** is reflected by a mirror **1552***a*. Then, the polarization axis B2 is rotated 90° by a half-wave plate **1741** and is emitted from the half-wave plate **1741**. On the incident side of the projection lens **1415**, polarization means (polarizing plate **131** or PBS) is arranged. The polarization axis **132** of the polarization means is nearly aligned with the polarization axis **132** emitted from the half-wave plate **1741**.

The light emitted from the PBS **1581** is divided into R, G, and B light by dichroic mirrors **1611***a* and **1611***b*. The R light, G light, and B light are modulated by display panels **22** respectively arranged in the optical paths of R, G, and B light. The modulated R light, G light, and B light are synthesized by dichroic mirrors **1611***c* and **1611***d*. The synthesized light is projected on an enlarged scale onto a screen (not shown) by a projection lens **1415**.

Thus, in the projection type display of the present invention, if the display panel **22** of the present invention is employed and also polarized light is incident on the display panel **22**, satisfactory display contrast can be realized. Note that practical display contrast is sufficiently realizable without the polarizing plate **131**.

FIG. **175** is a constitution diagram of a projection type display in another embodiment of the present invention. Light emitted from a light emitting lamp **1411***a* is separated into P-polarized light and S-polarized light by a polarization beam splitter (PBS) **1581**. Now, suppose that the light transmitted through the light separating surface **1582** of the PBS is P-polarized light and the reflected light is S-polarized light. The P-polarized light is transmitted through an R filter **1751***a*, and only R light passes through the filter. On the other hand, the S-polarized light adjusts the optical path lengths of the liquid crystal display panels **22***a* and **22***b* by a relay lens **1413**. The S-polarized light is reflected by a mirror **1552***a*, and only B light is transmitted through a B filter **1751***b*. The R light is incident on a liquid crystal

display panel 22a, and the B light is incident on a liquid crystal display panel 22b. In the case where the half-wave plate 1741 is arranged on the exit side of the PBS 1581, the transverse electric field generation directions 133 of the liquid crystal display panels 22a and 22b may be the same. However, in the case where there is no half-wave plate, the transverse electric field generation directions 133 are different 90° from each other. For example, in the liquid crystal display panel 22a, the transverse electric field wire 17 is formed parallel to the gate signal line, and in the liquid crystal display panel 22b, the transverse electric field wire 17 is formed parallel to the source signal line 15. Also, in the constitution of FIG. 10, even if the polarization directions of incident light components are different from each other, the same display contrast can be maintained high.

The light modulated by the display panel 22 is reflected by a mirror 1522 and is incident on a reflection type prism 1752. As an example of the reflection type prism 1752, a reflecting mirror is formed on an isosceles triangular prism. The light reflected by the prism 1752 is incident on the polarizing plate 131 and is projected on an enlarged scale onto a screen 1501 by a projection lens 1415.

The display panel 22a modulates red light, and the image is projected onto the screen 1501. On the other hand, the display panel 22b modulates blue light, and the image is projected onto the screen 1501. Therefore, the two red and blue images are displayed on the screen 1501. If these images are viewed with eyeglasses having a red filter on one lens and a blue filter on the other, three-dimensional display can be viewed. Of course, it is necessary that a video input to the display panel 22a and a video input to the display panel 22b should be set so that a three-dimensional image is obtained when photographed with a camera.

In the case where the filter 1751 is not present, a color filter may be mounted on the liquid crystal display panel 22. In the case where the half-wave plate 1741 is not present, three-dimensional color display can be observed with eyeglasses in which polarization axes are different 90° between the right and left lenses.

In the aforementioned projection type display, polarization means is arranged on the incident side of the liquid crystal display panel 22 so that polarized light is incident on the panel 22. However, it is a matter of course that practical image display is sufficiently realizable without the polarization means. These embodiments will hereinafter be described in sequence.

FIG. 176 is a constitution diagram of a projection type display of the present invention. 1611a is a dichroic mirror (BDM) for reflecting B light, 1611b is a dichroic mirror (GDM) for reflecting G light, and 1611c is a dichroic mirror (RDM) for reflecting R light. The arrangement of the dichroic mirrors 1611a to 1611c is not limited to the order shown in FIG. 176. It is a matter of course that the last RDM 1611c may be replaced with a total reflection mirror.

The film thickness of the liquid crystal layer 21 of the liquid crystal display panel 22c for modulating R light is constituted so that it is thicker than the film thicknesses of the liquid crystal layers 21 of the liquid crystal display panels 22a and 22b for modulating G light and B light. Also, depending on the wavelength of light to be modulated, the average particle diameter of the waterdrop-like liquid crystal or the average hole diameter of the polymer network is varied. If the wavelength of light to be modulated becomes longer, the aforementioned average particle diameter or average hole diameter is enlarged. The reason for this is that a longer wavelength shows the tendency that a scattering characteristic is reduced and therefore contrast becomes low.

This should hold in the aforementioned embodiments. 1415 is a projection lens and 1762 is an aperture as a lens aperture. The aperture 1762 is illustrated to explain the operation of the projection type display. Since the aperture 1762 prescribes the focused angle of the optical projection system, it is considered to be included in the function of the optical projection system. In other words, if the F value of the optical projection system is great, the diameter of the aperture 1762 can be considered to be small. To obtain high contrast display, it is preferable that the F value of the optical projection system be great. However, if it becomes great, the brightness of white display will be reduced. Specifically, the aperture is not employed, but the function of the aperture 1762 is included in the function of the projection lens 1415.

FIG. 177 shows a perspective view of the arrangement shown in FIG. 176. 1771 is a field lens. Unnecessary parts for explanation, such as relay lens 1761, are not given. If the optical system of FIG. 177 is arranged as an optical block 1551 in the cabinet 1535 shown in FIG. 155, a projection TV can be constituted.

A description will hereinafter be described of the operation of the projection type display of the present invention. Since modulation systems for R, G, and B light are nearly the same, a description will be made of the modulation system for B light.

White light is emitted from the light source 1411, and the B light component of the white light is reflected by the BDM 1611a. This B light is incident on the liquid crystal display panel 22a. The light scattered by the liquid crystal display panel 22a is shut out by the aperture 1762a. Conversely, collimated light, or light within a predetermined angle is passed through the aperture 1762a. Modulated light is projected on an enlarged scale onto the screen 1501 by the projection lens 1415a. In the aforementioned manner, the B light component of an image is displayed on the screen 1501. Similarly, the liquid crystal display panel 22b modulates the G light component, and the liquid crystal display panel 22c modulates the R light component, whereby a color image is displayed on the screen 1501.

In FIG. 176, three liquid crystal display panels 22 are employed. As shown in FIG. 163 or 178, if a single liquid crystal display panel with three display areas is employed, the projection type display can be made structurally simple.

The liquid crystal display panel 22 shown in FIG. 163 or 178 has three display areas (B, G, and R) on a single array substrate 12. In other words, it has three display areas formed with pixel electrodes in the form of a matrix. As shown in FIG. 178, three counter substrates 11 may be employed. Alternatively, a single counter substrate 11 may be employed with respect to three display areas. Gate source drive circuits 492 are formed or arranged on the left side of the display area B and on the right side of the display area R. Source drive circuits 491 are formed or arranged with respect to the display areas, respectively.

The gate drive circuit 492a is connected to an odd-numbered gate signal line, and an even-numbered gate signal line is connected to the gate drive circuit 492b. The gate signal lines 492 connected in this manner can prevent a horizontal brightness fluctuation in a display image which is caused by the delay of signals to the gate signal lines 492. The horizontal brightness fluctuation occurs because the voltage near the output of the gate drive circuit 492 and the voltage on the signal line end differ from each other due to the resistance of the gate signal line when viewed at a certain time. In the arrangement of FIG. 178, although there is the possibility that brightness fluctuation in the form of a comb will occur in the R and B display areas, there is no possibility that the brightness fluctuation is visually recognized.

FIG. **179** is a constitution diagram of a projection type display employing the liquid crystal display panel of FIG. **178** as a light valve. This constitution can shorten the distance k between the display areas shown in FIG. **178** and reduce the size of the optical block. In addition, since three display areas can be positioned at the same time, focusing adjustment can be performed at high speeds.

Although FIGS. **176** and **179** show a method of enlarging and projecting an image on the screen **1501** by three projection lens **1415**. There is a method of enlarging and projecting an image on the screen **1501** by a single projection lens **1415**. The constitution diagram is shown in FIG. **180**.

For making explanation easy, **22***b* denotes a liquid crystal display panel which displays an image of G light. **22***a* denoted a liquid crystal display panel which displays an image of R light, and **22***c* denotes a liquid crystal display panel which displays an image of B light. A light source **1411** and the position in which a display panel **22** is disposed are separated by a separation wall **1801**. This is for preventing the degradation of the display panel due to heat generated by the light source **1411**. A dichroic mirror **1611***a* reflects R light and transmits G light and B light. A dichroic mirror **1611***b* reflects G light and B light. A dichroic mirror **1611***c* transmits R light and reflects G light. A dichroic mirror **1611***d* transmits R light and G light and reflects B light.

Light emitted from light generation means **1411***a* is reflected by a total reflection mirror **1552***a* and is varied in direction. The optical path of the reflected light is separated into three optical paths of R.G.B lights by the dichroic mirrors **1611***a* and **1611***b*. R light is incident on a field lens **1771***a*, G light is incident on a field lens **1771***b*, and B light is incident on a field lens **1771***c*. Each field lens **1771** focuses each light and directs the focused light to each liquid crystal display panel. The liquid crystal display panel **22** varies the orientation of the liquid crystal **21** in accordance with a video signal, thereby modulating light. The thus modulated R light, G light, and B light are synthesized by dichroic mirrors **1611***c* and **1611***d* and are enlarged and projected onto a screen **1501** by a projection lens **1415**.

FIG. **181** is a constitution diagram of an embodiment of a reflection type projection display. To make explanation easy, a liquid crystal display panel for modulating R light is represented by **22***a*, a liquid crystal display panel for modulating G light by **22***b*, and a liquid crystal display panel for modulating B light is represented by **22***c*.

In FIG. **181** a dichroic mirror **1611** serves as a color synthesizing system and a color separating system. White light emitted from a light source is turned by a plano mirror **1552** and is incident on the first group **1415***b* of a projection lens **1415**. The half value of the band of an ultraviolet-ray and infrared-ray (UVIR) cut filter **1411***c* is 430 to 690 nm. The band of light will hereinafter be expressed by a half value. A dichroic mirror **1611***a* reflects R light and transmits B light and G light. The reflected R light is band limited by a dichroic mirror **1611***c* and is incident on the liquid crystal display panel **22***a*. The band of the incident R light is assumed to be 600 to 690 nm. On the other hand, a dichroic mirror **1611***b* reflects B light and transmits G light. The reflected B light is incident on the liquid crystal display panel **22***b*, and the R light is incident on the liquid crystal display panel **22***a*. The band of the incident B light is 430 to 490 nm. The band of the incident G light is 510 to 570 nm. These light bands are also true of other projection type displays of the present invention. Each liquid crystal display panel **22** forms an optical image as the change of the

scattering state in accordance with a video signal. The optical images formed by the liquid crystal display panels **22***a*, **22***b*, and **22***c* are color synthesized by the dichroic mirrors **1611**. The synthesized image is incident on the projection lens **1415** and projected on an enlarged scale onto a screen **1501**.

The dichroic mirror **1611** functions a filter which reflects (or transmits) light of a specific wavelength. For example, the dichroic mirror **1611***b* reflects light of a specific wavelength when light from the light source **1411** is incident on the liquid crystal display panel **22***b*, and also reflects light of a specific wavelength when light reflected by the liquid crystal display panel **22***b* is incident on the projection lens **1415**.

A single dichroic mirror **1611** reflects light twice when it is incident on and emerges from the liquid crystal display panel **22**. In the constitution of FIG. **181**, the wavelength band of light is limited twice by a single dichroic mirror **1611**. In other words, the dichroic mirror **1611** serves as a secondary filter. As compared with the dichroic mirror **1611** of FIG. **180**, the cut-off characteristic of limiting the band of light is conspicuous. For this reason, there is no overlap in the bands of light incident on the liquid crystal display panel **22**. Therefore, color reproducibility becomes satisfactory and high-quality image display can be realized.

In addition, since the dichroic mirror **1611** has both a color separating function and a color synthesizing function, a reduction in the size of the projection type display can be realized.

In the reflection type projection display panel of the present invention shown in FIG. **181**, attention must be given to the direction of light incident on the light separating surface and the direction of light emerging from the light separating surface. Specifically, the constitution of FIG. **181** needs to be arranged as shown in FIG. **182**. In other words, the constitution of FIG. **181** is merely shown for making illustration and explanation easy. The reason why the constitution of FIGS. **181** should be arranged as shown in FIG. **182** is as follows:

In the case of the constitution shown in FIG. **181**, the optical axis **1811***a* of the light arriving from the light source **1411** at the liquid crystal display panel **22** differs in the angle of light incident on the dichroic mirror **1611** from the optical axis **1811***b* of the light going from the liquid crystal display panel **22** to the screen **1501** through the projection lens **1415**. The dichroic mirror **1611** is formed by depositing a dielectric multilayer film on a glass substrate and transmits or reflects light having a specific wavelength band. This type of dichroic mirror **1611** has the property that the spectral characteristic is shifted due to incident light angle dependency. Therefore, as shown in FIG. **181**, when the optical axis **1811***a* and the optical axis **1811***b* are incident at different angles, the spectral characteristic for color separation and the spectral characteristic for color synthesis differs from each other, it is difficult to obtain a projected image with a desired color purity.

In the case of the constitution of FIG. **182**, the optical axis **1811***a* of the light going from the light source **1411** and the optical axis **1811***b* of the light going from the Liquid crystal display panel **22** to the projection lens **1415** are symmetrical with respect to a plane including both the center normal line of the liquid crystal display panel **22** and the center normal line of the light separating surface of the dichroic mirror **1611**. Therefore, the incident angles to the light separating surface can be made equal to each other. Therefore, since the spectral characteristic after color separation and the spectral characteristic after color synthesis are the same, a projection image displayed on the screen **1501** can obtain a desired color purity.

As evident in the aforementioned description, the advantage of the projection type display of FIG. **182** is that color purity is satisfactory when a reflection type liquid crystal display panel utilizing natural light is employed and that display of a projected image can be easily realized with excellent color evenness.

The dichroic mirrors **1611***a* and **1611***b* are formed by depositing a dielectric multilayer film on a glass substrate, the dielectric multilayer film consisting of low refractive index layers and high refractive index layers alternately stacked with one another. Both the color separating surface and the color synthesizing surface are arranged at an angle of 45° to the light modulating layers **21** of the liquid crystal display panels **22***a*, **22***b*, and **22***c*.

Light emitted from a lamp **1411***a* is reflected by a cold mirror **1552***a* and a mirror **1552** and is incident on dichroic mirrors **1611***a* and **1611***b* in sequence. The light incident on the dichroic mirrors **1611***a* and **1611***b* is separated into three primary color light: R, G, and B light. The R light, G light, and B light are incident on three corresponding liquid crystal display panels **22***a*, **22***b*, and **22***c*. The reflected light is again incident on the dichroic mirrors **1611***a* and **1611***b*. The R light, G light, and B light are synthesized by the dichroic mirrors **1611***a* and **1611***b*. The synthesized light is transmitted through an aperture and then is projected on an enlarged scale onto the screen **1501** by the projection lens **1415**.

In the light incident on the liquid crystal display panels **22***a*, **22***b*, and **22***c*, the light incident on a pixel being in a scattering state is scattered. The greater part of the scattered light is shut out by the aperture of the projection lens **1415** or the interior wall of a lens barrel (not shown) and is obtained as black display. On the other hand, light incident on a pixel being in a non-scattering state is regularly reflected. The regularly reflected light is transmitted through the aperture of the projection lens **1415** and a lens group constituting the projection lens **1415** and arrives at the screen **1501** as white display. In this manner, the optical images, modulated as a scattering mode and a non-scattering mode on the liquid crystal display panels **22***a*, **22***b*, and **22***c*, are displayed onto the screen **1501** as a projected image.

In the constitution of FIG. **182**, the plane including both the optical axis **1811***a* of the light emitted from the light source **1415** and the optical axis **1811***b* of the light reflected by the liquid crystal display panel **22** is arranged perpendicular to the plane including both the center normal line of the liquid crystal display panel **22** and the center normal lines of the dichroic mirrors **1611***a* and **1611***b*. Therefore, the plane including the optical axis **1811***a* and the optical axis **1811***b* forms an angle of 45° with the color separating and synthesizing surfaces of the dichroic mirrors **1611***a* and **1611***b*. Therefore, both the light emitted from the light source and the light reflected by the liquid crystal display panel are incident on the dichroic mirrors **1611***a* and **1611***b* at angle of 45°.

The spectral transmittances of the dichroic mirrors **1611***a* and **1611***b* are shown in FIGS. **183**(*a*) and (*b*). FIG. **183**(*a*) shows spectral transmittance in the case where light is incident on the dichroic mirror **1611***a* at an angle of 45°. The dichroic mirror **1611***a* is of the type which reflects R light and transmits G and B light. FIG. **183**(*b*) shows spectral transmittance in the case where light is incident on the dichroic mirror **1611***b* at an angle of 45°. The dichroic mirror **1611***b* is of the type which reflects B light and transmits G light.

According to this embodiment, the spectral characteristic for color separation and the spectral characteristic for color synthesis are the same. Therefore, the spectral characteris-

tics shown in FIGS. **183**(*a*) and (*b*), as they are, can be reflected on a projected image.

For comparison, a description will hereinafter be made of the case where a display is constituted as shown in FIG. **183** by employing the same dichroic mirror as the embodiment of FIG. **183**. If it is assumed that the optical axis **1811***a* of the light going from the light source to the liquid crystal display panel **22** (hereinafter referred to as illumination light) is incident on the liquid crystal display panel **22** at an angle of 5°, the optical axis **1811***a* of the illumination light and the optical axis **1811***b* of the light going from the liquid crystal panel **22** to the screen (hereinafter referred to as projection light) form an angle of 10°. The incident angle of the illumination light to the dichroic mirrors **1611***a* and **1611***b* is 40°, and the incident angle of the projection light to the dichroic mirrors **1611***a* and **1611***b* is 50°. The spectral transmittance in the case of incident angle 40° and the spectral transmittance in the case of incident angle 50° are shown in FIGS. **184**(*a*) and (*b*). FIG. **184**(*a*) shows the spectral transmittance of the dichroic mirror **1611***a* and FIG. **184**(*b*) the spectral transmittance of the dichroic mirror **1611***b*. In the figures, a solid line represents the case where the incident angle of light is 40° and a dotted line the case where the incident angle of light is 50°. From FIGS. **184**(*a*) and (*b*) it is found that the spectral characteristic of the illumination light and the spectral characteristic of the projection light differ considerably from each other due to incident angle dependency and therefore it is difficult to obtain a desired color purity without reducing light efficiency of utilization.

Similarly, the technical idea that the incident angles of the projection light and illumination light to the dichroic mirror **1611** are taken into consideration, as it is, is applicable to other reflection type projection displays. It is a matter of course that the technical idea is also applicable in the case where a dichroic prism to be described later is employed.

FIG. **185** is a block diagram of a projection type display which performs color separation and color synthesis by employing a dichroic prism **1591**. The dichroic prism **1591** has two light separating surfaces **1582***a* and **1582***b*. The light separating surfaces **1582** separate white light into R, G, and B light. Liquid crystal display panels **22** are mounted on the dichroic prism **1591**through optical coupling layers **371**. In other words, the liquid crystal display panel **22** is optically coupled to the dichroic prism **1591** by the optical coupling layer **371**. The ineffective area of the prism **1591** (that effective light for image display does not pass through) is coated with a light absorbing film **1132**.

Assume in FIG. **185** that a liquid crystal display panel **22***c* modulates R light and a light separating surface **1852***a* reflects R light. Incident light is reflected at the light reflecting surface **1582***a* and is incident on the light modulating layer **21** of a liquid crystal display panel **22***a*. The light incident on the light modulating layer **21** is scattered according to the magnitude of voltage applied to a pixel electrode **14**. The light not scattered is again reflected at the light separating surface **1852***a* and becomes outgoing light. The greater part of the scattered light is incident on a light absorbing film **1132** formed on the ineffective area of the prism **1591** and is absorbed. In this manner, the greater part of light scattered at the liquid crystal layer **21** is absorbed by the light absorbing film **1132**. Therefore, there is no possibility that scattered light becomes outgoing light. Since the operations of the liquid crystal display panels **22***c* and **22***b* are the same as the liquid crystal display panel **22***a*, a description thereof is not given.

Note that the light absorbing film **1132** is formed with the same material as the light shielding film **152** formed on the

TFT **155**. Also, a black pigment, or a pigment and dyes in the relation of a complementary color to the light modulated by the liquid crystal display panel **22** may be coated. Also, the ineffective area may be roughened so that it is in a slightly opaque state. In addition, a black plate may be pasted.

The constitution, in which the liquid crystal display panel **22** is optically coupled to the prism **1591** and also a light absorbing film is formed or arranged on the ineffective area of the prism **1591**, is also applicable to constitution of FIG. **71**.

FIG. **187** shows the constitution in which liquid crystal display panels **22**a and **22**b are optically coupled to a prism **1591**a and also a liquid crystal display panel **22**c is optically coupled to a triangular prism **1591**c.

If a dichroic mirror is employed in an image forming system, it is difficult to position the dichroic mirror in a case because the dichroic mirror **1611** is flat in shape. A slight inclination in the dichroic mirror **1611** causes the positional offset between three optical images formed on the display panels **22** to occur on a screen. Also, a change with the passage of time (warp, etc.) will easily come to occur. In addition, the positional offset between three images formed on display panels **22** will easily come to occur. In the constitution of FIG. **187**, a change with the passage of time is difficult to occur and the position of a formed image can be easily adjusted. If the light scattered at the liquid crystal display panel **22** is absorbed by the light absorbing film **1132** formed on the surface of prism **1591**, the return of light to the liquid crystal layer **21** and the occurrence of secondary scattered light can be prevented. This effect is the same as FIG. **185** and therefore a description thereof is not given. It is a matter of course that if the display panel **22** and the prism **1591** is constituted as a single optical component, an adjustment process can be considerably shortened without adjusting the position of the liquid crystal display panel **22**.

The illumination system of FIGS. **187** and **188** is constituted with a relay lens **1871**. Also, a concave mirror **1411**b employs an elliptical mirror. If done in this way, the F value of illumination light can be raised =and display contrast can be enhanced.

In FIG. **188**, three liquid crystal display panels **22** are attached to an L-shaped prism **1591**. In comparison with the constitution of FIG. **187**, only a single prism is required. In addition, adjustment of a formed image is easy and the position adjustment of the liquid crystal display panel **22** is entirely unnecessary. Since the light absorbing film **1132** can be formed over a wide range, the occurrence of secondary scattered light is low and extremely satisfactory display contract can be realized.

A description will next be made of a method which further enhances display contrast, while maintaining high brightness display in a projection type display. FIG. **189** shows a first embodiment for realizing the aforementioned method. A projection lens **1415** is constituted by a front lens group **1891**b and a rear lens group **1891**a. An output lens **1897** and the rear lens group **1891**b cause lens apertures **1896** and **1898** to be conjugate with each other.

An input lens array **1894** is constituted by disposing a plurality of input lenses **1899** in two-dimensional form. An example of the constitution is shown in FIG. **190**. Ten input lenses **1899** with a rectangular opening are disposed so as to be inscribed in a true circle. The ten input lenses **1899** are flat-convex lenses with the same opening shape, and the ratio between the long side and short side of the rectangular opening is 4:3.

Similarly, a central lens array **1895** is constituted by disposing a plurality of central lenses **1900** in two-

dimensional form. The central lenses **1900** correspond in number to the input lenses **1899** and have the same opening as the input lens **1899**. The central lenses **1900** are disposed in the same way as the input lens array **1894**.

The illumination procedure in the projection type display will be described. Light emitted from the illuminant **1892** of a metal halide lamp **1411**a is reflected by a parabolic mirror **1411**b. The reflected light goes nearly parallel to an optical axis **1416** and is incident on the input lens array **1894**. Since the sectional form of light emitted from the parabolic mirror **1411**b generally forms a true circle, the input lens array **1894** is constituted so that the total sum of openings of the input lenses **1899** are inscribed in the true circle. The light transmitted through the input lens array **1894** is divided into partial light beams corresponding in number to the input lenses **1899**. The partial light beams illuminate the display area of a PD liquid crystal display panel **22**.

The light transmitted through the input lens **1899** is guided to the corresponding central lens **1900** and collected. The opening of each central lens **1900** is provided with a secondary illuminant (e.g., **1901**A and **1901**B shown in FIG. **189**). A plurality of secondary illuminants **1901** formed on the central lens array **1895** is schematically shown in FIG. **191** by way of an example. Each central lens **1900** effectively transmits its corresponding light to the display area of the PD liquid crystal display panel **22**. Specifically, the real image **1893** of an object (e.g., **1902**A and **1902**B shown in FIG. **189**) on the principal plane of a corresponding input lens **1899** is formed near the display area of the liquid crystal display panel **22**. In this case, the central lenses **1900** are suitably eccentric to each other so that a plurality of images are superimposed and form a single real image **1893**.

According to the aforementioned constitution, the display area of the PD liquid crystal display panel **22** and the opening of each input lens **1899** nealy are conjugate with each other. Therefore, if the opening of the input lens **1899** is formed into a shape similar to the display area of the PD liquid crystal display panel **22**, the section of illumination light will be adjusted to the display area, whereby loss of light can be suppressed. Therefore, it is preferable that the input lens array **1894** shown in FIG. **190** be combined with the PD liquid crystal display panel **22** which displays an image having an aspect ratio of 4:3 corresponding to NTSC.

Light, emitted from a concave mirror such as a parabolic mirror, generally has a relatively great brightness fluctuation. If light with a great brightness fluctuation, as it is, is transmitted and illuminates the PD liquid crystal display panel **22**, an evenness in the brightness of a projected image will be reduced. If only an area with relatively even brightness is illuminated, light not utilized will be increased and therefore light efficiency of utilization will be reduced. On the other hand, the projection type display of the present invention has the advantage that high light efficiency of utilization can be obtained and also a projected image with an excellent evenness in brightness can be obtained. The reasons will hereinafter be described.

The input lens array **1894** divides light having a great brightness fluctuation into a plurality of partial light beams. The brightness fluctuation of each partial light beam on the opening of the input lens **1899** is small compared with the brightness of the section of a light beam before division. The central lenses **1895** enlarge partial light beams having less brightness fluctuation to a suitable size. The enlarged partial light beams are superimposed on the PD liquid crystal display panel **22**. Therefore, satisfactory illumination with even brightness can be realized.

Since the total sum of openings of the input lenses **1899** are inscribed in the cross section of an incident light beam,

the loss of light at the input lens array **1894** is small. In addition, since the opening of each central lens **1900** is sufficiently larger than the secondary illuminant **1901**, the loss of light at the central lens array **1895** is small. Furthermore, because the section of light incident on the PD liquid crystal display panel **22** is adjusted to the shape of the display area, the loss of light at the PD liquid crystal display panel **22** is small. Therefore, the greater part of light emitted from the illuminant **1892** is reflected by the parabolic mirror **1411***b* and arrives at the projection lens **1415** through the input lens array **1894**, central lens array **1895**, output lens **1897**, and the PD liquid crystal display panel **22**. Therefore, if the loss of light at the projection lens **1415** is suppressed, high light efficiency of utilization can be realized and a projected image with an excellent evenness and the brightness can be obtained.

Incidentally, since a plurality of secondary illuminants **1901** are dispersedly formed on the central lens array **1895**, the effective F number of illumination light in this case needs to be determined from an angle of irradiation converted equivalently from the total area of the secondary illuminants **1901**. On the other hand, the converging angle of light, emitted from the liquid crystal display panel **22** at the greatest angle to the optical axis **1416**, becomes a value greater than this equivalent angle of irradiation. Therefore, in order to suppress loss of light, the effective F number of the projection lens **1415** needs to be made smaller than the effective F number of illumination light. Because this reduces the contrast of a projected image in the case of a PD liquid crystal display panel, there is a problem.

On the other hand, in the projection type display of this embodiment, the opening on the side of illumination light and the opening on the side of the projection lens **1415** can be made in a necessary and minimum size without increasing loss of light by the lens apertures **1896** and **1898**, and consequently, contrast reduction can be suppressed. Specifically, the lens aperture **1896** on the side of illumination light is formed into a shape such as that shown in FIG. **192** in accordance with the effective areas of the secondary illuminants **1901** dispersedly formed. A broken line represents the opening of each central lens **1900** of FIG. **191**. Also, since the real image of the secondary illuminant **1901** is formed on the opening of the lens aperture **1898** present on the side of the projection lens **1415**, the shape of the opening of the lens aperture **1898** is made equal to that of the lens aperture **1896**. Therefore, since light transmitted through the lens aperture **1896** passes through the lens aperture **1898**, high light efficiency of utilization can be realized. At the same time, the projection lens **1415** provides a necessary and minimum opening necessary for illumination light, so a display image with high contrast can be realized. As a consequence, a projected image with brightness and high quality can be provided, so great advantages are obtainable.

In the projection type display of the present invention, the input lens array **1894**, the central lens array **1895**, the lens aperture **1896**, and the lens aperture **1898** are even better if they are constituted as follows: FIG. **193** shows the constitution of the central lens array **1895** in this case. In general, the size of the secondary illuminant **1901** will become larger if the position of the input lens **1899** approaches the optical axis. Therefore, the openings of the central lenses **1900** do not always need to be the same. It will be sufficient if the opening of the central lens **1900** has a necessary and sufficient size with respect to the secondary illuminant **1901**. If the central lens array **1895** is constituted so that a plurality of central lenses **1900** with openings effectively different

from each other are condensed and disposed, there is an advantage of reducing the total sum of the opening areas. The input lens array **1895** which is combined with the central lens array **1899** is constituted in the same manner as that shown in FIG. **192**. The input lenses **1899** are suitably eccentric to each other, and the secondary illuminant **1901** is formed in the opening center of the corresponding central lens **1900**.

In this case, a lens aperture **1898** with an opening shape shown in FIG. **194** is employed instead of the lens aperture **1896** provided on the illumination light side. Likewise, the lens aperture with an opening shape shown in FIG. **194** is employed instead of the lens aperture **1898** provided on the projection lens side. This arrangement has the advantages that there is no loss of light, also the aperture diameter of the central lens array **1895** can be reduced, and the lens diameter of the projection lens **1415** can be reduced.

As previously described, the projection type display of this embodiment has even greater advantages in the case where a plurality of secondary illuminants are dispersedly formed to illuminate the display panel **22**. Even if the projection lens **1415** whose maximum converging angle is great is employed, a necessary and minimum opening with respect to light emerging from the display panel **22** can be provided, because a plurality of openings are dispersedly formed in a lens aperture. As a result, this embodiment can obtain a projected image having brightness and high contrast.

FIG. **199** shows a modification of the projection type display shown in FIG. **189** and is a constitution diagram of a projection type display which performs full color display with three PD liquid crystal display panels **22**. For the following embodiment, a difference with the first embodiment will mainly be described. In FIG. **198**, three PD liquid crystal display panels **22** corresponding to three primary colors are employed. A parabolic mirror **1411***b*, an input lens array **1894**, a central lens array **1895**, and an output lens **1897** are the same as those shown in FIG. **189**. The display areas of the PD liquid crystal display panels **22***a*, **22***b*, and **22***c* are illuminated in the same procedure as FIG. **189**. In this embodiment, illumination light is divided into three primary color light components by a dichroic mirror **1611***a*, a dichroic mirror **1611***b*, and a piano mirror **1552***b*. The three primary color light components are guided to the corresponding PD liquid crystal display panels **22**.

In accordance with an external video signal, optical images corresponding to three primary colors are formed on the display areas of the PD liquid crystal display panels **22**, respectively. A projection lens **1415** is constituted by a front lens group **1891***b* and a rear lens group **1891***a* and projects, on an enlarged scale, the optical images of three primary colors onto a screen **1501**. The optical paths of the optical images are synthesized to a single optical path by a dichroic mirror **1611***c*, a dichroic mirror **1611***d*, and a plano mirror **1552***c*. As a result, a projected image with full colors is obtained.

A lens aperture **1896** on the illumination light side and a lens aperture **1898** on the projection lens side are the same as those shown in FIG. **189** and employed for the same purpose. The output lens **1897** and the rear lens **1891***b* are positioned so the lens apertures **1896** and **1898** are conjugate with each other. Since the operation is the same as the aforementioned description, a description thereof is not given.

A flat-concave lens **1311***b* is coupled by a transparent adhesive agent to the exit side of the PD liquid crystal display panel **22** with the concave surface directed to the exit

side. A light absorbing film **1132** is coated on the side surface of the flat-concave lens **1311***b*, and an antireflection film is deposited on the concave surface. The flat-concave lens **1311***b* is formed from acrylic resin by a molding process. In the molding process, since the same lens can be made with a metal mold, better productivity is obtained.

A positive lens **1311***a* is arranged in close proximity to the exit side of the concave lens **1311***b*. The radius of curvature of the convex surface of the positive lens **1311***a* is equal to that of the concave surface of the concave lens **1311***b*. A thin air gap is equiped between the convex surfaces of both lens. Both surfaces of the positive lens **1311***a* are deposited with an antireflection film as in the flat-concave lens **1311***b*. With a combination of the concave lens **1311***b* and the positive lens **1311***a*, an optical image on the liquid crystal layer **21** is projected onto the screen **1501** by the projection lens **1415**. The focusing adjustment of a projected image is performed by moving the projection lens **1415** along an optical axis **1416**.

The optical characteristic of the PD liquid crystal display panel **22** does not strongly depend on the incident angle of light as compared with a TN liquid crystal display, but, in the case where the incident angle is too great, the optical path length of light being passed through the liquid crystal layer **21** becomes longer and therefore the scattering characteristic varies. In other words, if the incident angle of light to the PD liquid crystal display panel **22** varies depending on a place on the panel **22**, the image quality of a projected image will become uneven. On the other hand, if the radius of curvature of the concave surface of the concave lens **1311***b* is attempted to be reduced, it is necessary that converging light with a great converging angle should be incident on the PD liquid crystal display panel **22** or the effective diameter of the projection lens **1415** should be increased. The former has the disadvantage that a projected image becomes uneven in quality, because image quality is not even depending on a place on the PD liquid crystal display panel **22**. The latter has the disadvantage that an increase in the size of the projection lens **1415** results in high cost. In the case where the scattering characteristic of the PD liquid crystal display panel **22** is strongly dependent on an incident angle, if the concave lens **1311***b* and the positive lens **1311***a* are combined together as shown in FIGS. **198** and **199**, nearly collimated light can be incident on the PD liquid crystal display panel **22** without increasing the size of the projection lens **1415**, and consequently, an evenness in the image quality of a projected image is easily assured.

In FIGS. **198** and **199**, the transparent type liquid crystal display panel **22** is employed as a light valve. The technical idea of enhancing display contrast with the lens aperture **1896** of FIG. **189** is also applicable to a reflection type projection display. An example thereof is shown in FIG. **200**.

FIG. **200** shows an embodiment in which a reflection type PD liquid crystal display panel is applied as a light valve. Note that the concave lens **1311***b* is not limited to the shape of a concave lens. For example, it may be flat in shape.

In the reflection type projection display, a lens aperture **1898** is arranged so as to correspond to the upper half portion of a projection lens **1415**. The lower half portion of the projection lens **1415** is employed for the optical path of incident light. The rest constitution has already been described in the aforementioned embodiments and therefore a description thereof is not given.

FIG. **201** shows the constitution where a prism **2011** is employed in an optical system for color separation and color synthesis. Since the constitution of the prism of FIG. **201** has been adopted in the CCD portion of a business video

camera, a description thereof is omitted. Although the display panel **22** employs a PD liquid crystal display panel, it may be a digital micromirror device (DMD) developed by Texas Instrument.

A further description will be made of a projection type display having the lens arrays **1894**, **1895**, **1896**, and **1898** of FIGS. **189**, **198**, and **200**. A projection type display such as this is called a discrete opening display.

FIG. **195** is a graph showing the relation between a scattering gain G with a PD liquid crystal display panel and a drive voltage V for maintaining transmittance to more than 90%. The scattering gain G is expressed by the following equation:

$$G = \frac{\pi B}{E} \qquad \text{[expression 38]}$$

where E is the illuminance of the light incidence surface of the light modulating layer **21** obtained when light is irradiated on the PD liquid crystal display panel, B is the brightness of the light modulating layer measured from the light exit surface (or light incidence surface) in the normal direction of the light modulating layer, and π is the ratio of the circumference of a circle to its diameter.

A smaller scattering gain G shows a better scattering characteristic, and high contrast display can be performed. However, as shown in FIG. **195**, the drive voltage also becomes high. Conversely, if the scattering gain G is great, the drive voltage (V) will become low, but display contrast will also become low. The drive voltage (V) considerably relates to the design of the driver circuit **541**, particularly the source driver circuit **491**. The maximum value of the drive voltage (absolute value of voltage applied to the pixel electrode **14**) is believed to be 10 (V) considering the withstand voltage of the driver circuit. When the drive voltage is 10 (V), the scattering gain G is 0.7 to 0.8. If the scattering gain G is low, the drive voltage will become low and a problem with the driver design will be eliminated. However, display contrast becomes considerably worse. As described later, the scattering gain G needs to be 3 or less. Therefore, the scattering gain of the PD liquid crystal display panel needs to meet the following equation:

$$0.5 \leq G \leq 3.0 \qquad \text{[expression 39]}$$

It is preferable that the scattering gain G meet the following equation:

$$0.7 \leq G \leq 2.0 \qquad \text{[expression 40]}$$

In a discrete opening display, when the diagonal length of the display area of the display panel **22** is represented by D (inch) and the arc length of the light emitting lamp **1411***a* by L (mm), the relation of the effective F number of an optimum projection lens is shown in FIG. **196**. This F number is a value when the rate of utilization of the pupil of a projection lens becomes maximum (optimum). In other words, it is a value when the projected light beam on a screen begins to reduce, while the arc length of a certain lamp and the F number of a projection lens are gradually raised. As shown in FIG. **196**, as a value of D/L is increased, the F number of a projection lens becomes great. As the F number becomes small, display contrast is reduced. On the other hand, if the F number becomes great, optical path length will become long and the projection type display will become too large. As one standard, F number should be between 5 and 12.

FIG. **197** shows the relation between D/L and display contrast. Scattering gain G as a variable is 0.7, 1, 2, and 3.

In the case of a projection television, the display contrast needs to be 150 or more. To obtain a contrast of 150, in a graph of FIG. 197, D/L is 1.0 when scattering gain G=0.7 to 0.9. The F number at that time is 5 in a graph of FIG. 196. When the scattering gain is low (G=2 to 3), D/L is 2.0 in a graph of FIG. 197. The F number at that time is 12 in a graph of FIG. 196.

In other words, considering the drive voltage of the liquid crystal layer 21, the design of the driver 491, the design of the projection lens, and the system size, in a discrete opening display the F number needs to meet the following condition:

$$5 \leq F \leq 12 \qquad \text{[expression 41]}$$

Considering the effective diagonal length D (inch) and the effective arc length L (mm), the F number needs to meet the following condition:

$$1.0 \leq \frac{D}{L} \leq 2.0 \qquad \text{[expression 42]}$$

As shown in FIG. 197, display contrast is a function of scattering gain. Considering the scattering gain G, an necessary relation with F number needs to meet the following equation:

$$\frac{3DG}{2L} \leq F \leq \frac{4DG}{L} \qquad \text{[expression 43]}$$

If the aforementioned relations are met, a discrete opening display can realize satisfactory image display.

If a projected image is displayed in a bright room by a projection type display, the contrast will be reduced by external light. In that case it will be sufficient if a polarization screen **2031** is employed in a screen **1501**. The polarization screen **1501** is formed by pasting a reflecting sheet to the back surface of a polarizing plate.

In order to perform satisfactory image display by the polarization screen, the polarization axis **132** of the polarization screen **2031** needs to be aligned with the polarization axis **132** of light to be projected.

Hence, as shown in FIG. **141**, in the projection type display of the present invention, a polarizing plate is arranged between the screen **2031** (object onto which light is projected) and the display panel **22**. In FIG. **141**, the polarizing plate is indicated by a dotted line **1414a** or **1414b**. This polarization means is provisionally called a rotary filter **1414**.

FIG. **202** shows a plan view of the rotary filter **1414**. The rotary filter **1414** is constituted so that it is rotatable on a center of rotation **2023**, and a range of about ¼ is cut away. On the surface a polarizing plate **131** is pasted. The polarization axis **132** of the polarizing plate **131** has a direction shown in FIG. **202**. A dotted line represents a range that light emitted from the display panel **22** passes through the projection lens **1415**. This range is called a light transmission range.

The direction of the polarization axis **132b** of the polarization screen **2031** is not always constant. There are cases where the direction varies depending on products. For example, as shown in FIG. **203**, there are cases where the polarization axis **132b** is arranged in a vertical direction. As shown in FIG. **204**, there are cases where the polarization axis **132b** is arranged in a horizontal direction. As shown in FIG. **205**, there are cases where the polarization axis **132b** is arranged in an oblique direction.

As shown in FIG. **203**, when the polarization axis **132b** of the polarization screen **2031a** is arranged in a vertical

direction, the rotary filter **1414** is rotated so that the polarization axis **132a** of the light transmission range **2022** is in the vertical direction. The rotary filter **1414** may be rotated manually,, or automatically with a motor. As shown in FIG. **204**, when the polarization axis **132b** of the polarization screen **2031a** is arranged in a horizontal direction, the rotary filter **1414** is rotated so that the polarization axis **132a** of the light transmission range **2022** is in the horizontal direction. As shown in FIG. **205**, when the polarization axis **132b** of the polarization screen **2031a** is arranged in an oblique direction, the rotary filter **1414** is rotated so that the polarization axis **132a** of the light transmission range **2022** is in the oblique direction.

Thus, in the projection type display of the present invention, if the rotary filter **1414** is rotated, the polarization axis **132a** of the light transmission range **2022** can be aligned with the polarization axes **132b** of all polarization screens **2031**. As shown in FIG. **206**, when a screen **1501** is not a polarization screen (when it has no polarization axis), or when contrast is not required but bright image display is required, the cutout of the rotary filter **1414** not formed with a polarizing plate is employed as a light transmission range **2022**. Since the light transmittance of the polarizing plate is about 40%, more than twice high-brightness display can be performed, by arranging the rotary filter **1414** as shown in FIG. **206**.

FIG. **207** shows another embodiment of the rotary filter **1414**. In the rotary filter **1414** shown in FIG. **207**, the half portion has a polarizing plate pasted thereon, the ¼ portion has no polarizing plate, and the remaining ¼ portion has a correction filter **2072** pasted thereon.

The correction filter **2072** is inserted in an optical path in accordance with the color of light emitted from a lamp **1411a**. When a metal halide lamp is employed as the light emitting lamp **1411a** of a projection type display, the correction filter **2072** is employed as a correction filter for reducing G light. In other words, it is employed as a correction filter for narrowing the band of G light. When a projection type display is employed as a data projector, color reproducibility does not matter but brightness is required. However, when a video image is displayed, color reproducibility becomes a problem. Hence, when displaying a video image, the correction filter **2072** is inserted and arranged in an optical path.

The metal halide lamp **1411a** usually has a great rate of G light, as shown in a spectral distribution of FIG. **147**. In the case where it is employed as a data projector, there will be no problem even if an image is greenish. However, in the case of a video image, there is a need to reduce G light. The correction filter **2072** is employed as a filter for reducing G light. The correction filter **2072** can be easily fabricated with resin or glass containing a color. It may also be formed from a dielectric multilayer film. While the color purity of a display image can also be corrected by a video signal which is applied to the display panel **22**, circuit cost is increased. If it can be changed by the correction filter **2072**, the change can be easily performed and cost will also become cheap.

If the light transmission range **2022** is in a C area, the polarization axis **132** is in a vertical direction. If it is in a D area, the polarization axis **132** is in a horizontal direction. Also, if the light transmission range **2022** is in a B area, a bright image suitable for a data projector can be displayed. If the light transmission range **2022** is in an A area, color is corrected and optimum color reproducibility suitable for a video image is obtained. While the rotary filter **1414** is rotated on the rotational center **2023**, it does not necessarily need to be rotated. For example, a polarizing plate or a

correction filter may be constituted so that it can be inserted at the position 1414a or 1414b of FIG. 141 indicated by a dot line. In other words, a polarizing plate or correction filter 2072 may be constituted so that it can be inserted in the optical axis 1416 as needed. In the case where the light emitting lamp 1411a consists of a halogen lamp, it is a matter of course that the correction filter 2072 shown in FIG. 207 is employed as a filter for reducing red light, because there is a great rate of red light.

FIG. 208(a) shows a plan view of a rotary filter 1414 according to another embodiment, and FIG. 280(b) is a sectional view of the rotary filter 1414. The rotary filter 1414 consists of four areas A, B, C, and D having a polarizing sheet 131 pasted thereon and an area E formed with a light shielding film 2081.

The light shielding film 2081 is formed on a transparent substrate 2082. As the light shielding film 2081, there is a black color, a metal sheet, or a thin metal film. The aforementioned polarizing sheet 131 is pasted onto the light shielding film 2081. Note that the light shielding film 2081 and the light polarizing sheet 131 may be arranged in reverse order.

The rotary filter 1414 rotates through 90° at an interval of one field (one frame). In other words, the polarization axis 132 of the light transmission range 2022 is changed 90° in synchronization with one field (one frame). FIG. 209 shows an explanatory diagram of the operation of the projection type display of the present invention. An observer views an image present on the screen 1501 with polarization eyeglasses 2091 where the polarization axes of the left and right lenses are different 90°. Note that the screen 1501 is not a polarization screen.

As shown in FIG. 209(a), if the rotary filter 1414 is rotated and the polarization axis 132 is caused to be in a vertical direction at the first field (first frame), then a display image on the screen 1501 will be seen only on the right eye. At this time, the display panel 22 displays a display image for the right eye. At the second field (frame) next to the first field (frame), the rotary filter 1414 is rotated as shown in FIG. 209(b), and if the polarization axis 132 is caused to be in a horizontal direction, then a display image on the screen 1501 will be seen only on the left eye. At this time, the display panel 22 displays a display image for the left eye.

As described above, if the rotation of the rotary filer 1414 is synchronized with the display image of the display panel 22, the eyes of an observer will see a display image, switching the left eye and the right eye. If the display image is a three-dimensional image, the observer can perform stereoscopic vision.

Note that a light shielding film 2081 is employed to hide an image when the left eye and the right eye are switched. When no obstacle occurs in display, of course the light shielding film 2081 does not need to be formed.

It is specific to the PD liquid crystal display panel 22 that the direction of the polarization axis 132 can be varied by rotation of the rotary filer 1414 in the aforementioned manner. The reason for this is that the PD liquid crystal display panel 22 is a display panel which modulates natural light. In the case of a TN liquid crystal display panel, the polarizing sheet 131 is indispensable for light modulation, so there is no possibility that the polarization axis 132 on the polarizing sheet 131 on the exit side is rotated.

In the aforementioned embodiment, the rotary filter 1414 is arranged between the screen (onto which light is projected) and the display panel 22. However, the rotary filter 1414 may be arranged on the incident side of the display panel 22. The reason for this is that if the liquid

crystal layer 21 of the display panel is in a light transmitting state when polarized light is incident on the display panel 22, the state of polarization is maintained. However, in the scattering state, since a polarization state is not maintained, sometimes there is effect reduction, but there is no practical problem. The reason for this is that a pixel performs black display in a scattering state. In white display, a polarization state is maintained, so an image with high display contrast can be displayed on the polarization screen 2031. Satisfactory three-dimensional display can also be performed. Therefore, the rotary filter (means of rotating a polarization axis) is arranged between the exit end of the lamp 1411b and the screen.

In FIG. 208, although the rotary filter 1414 is rotated on the rotational center 2023 and also the light transmission range 2022 is arranged above the rotational center 2023, the present invention is not limited to this arrangement. As shown in FIG. 222, it is a matter of course that the light transmission range 2022 may be arranged with the rotational center 2023 as center. As the rotary filter 1414 is rotated 90°, the direction of the polarization axis 132 is changed 90°. In this case, although the light shielding film 2081 can not be formed as shown in FIG. 208, the size of the rotary filter 1414 is reduced, whereby saving of space can be realized.

In FIGS. 203 and 208, while the rotary filter 1414 is employed to vary the direction of the polarization axis 132 which is incident on the screen, the present invention is not limited to this arrangement. As shown in FIG. 227, it may be replaced with a TN liquid crystal display panel 22a. A polarizing sheet or a polarization beam splitter is arranged on the exit side of the display panel 22a so that polarized light is incident on the TN liquid crystal display panel 22a. The TN liquid crystal display panel 22a rotates the polarization axis through 90° by applying voltage. Therefore, if the TN liquid crystal display panel 22a is switched between a voltage applied state and a no-voltage applied state, the polarization axis can be varied 90°. As described above, if the direction of the polarization axis of the TN liquid crystal display panel 22a is automatically or manually switched at one field (frame), it can be aligned with the direction of the polarization axis 132 of the polarization screen 2031. In addition, three-dimensional display can be realized. The TN liquid crystal display panel 22a of FIG. 227 does not need to form pixel electrodes. It will suffice if a TN liquid crystal is interposed between two electrodes. The TN liquid crystal display panel 22 may be replaced with a PLZT display panel.

In the aforementioned embodiment, while a description has been made of a projection type display which is employed in a transmission type display panel, the present invention is also applicable to a reflection type. In this case, the rotary filter 1414 is arranged on the incident side of the reflection type display panel.

Furthermore, in the aforementioned embodiment, although the rotary filter 1414 is rotated or the TN liquid crystal display panel 22a is employed to rotate or vary the direction of the polarization axis, it is a matter of course that the same advantage will be obtainable even if the aforementioned device is fixed and also the screen 2031 is rotated.

Also, although it has been described that the rotary filter 1414 is manually rotated, it is a matter of course that it may be rotated with a motor. The rotary filter 1414 does not always need to be rotated on the rotational center 2023. The rotary filter 1414 may be fitted into a rotatable circular frame (not shown).

In addition, it is beneficial if the rotational angle is previously set and the light transmission range 2022 is previously set so that it is caused to be in the state of FIG.

203 if button **1** is depressed, in the state of FIG. **204** if button **2** is depressed, and also in the state of FIG. **206** if button **3** is depressed.

FIG. **223** is a block diagram when a rotary filter **1414** is applied to a view finder. A rotary filter **1414** such as that shown in FIG. **222** is arranged at the A or B position between the eye **2231** of an observer and a display panel **22**. As previously described, in the case where a polarization state is maintained, the rotary filter **1414** may be arranged between a light source **2181** and the display panel **22**.

Polarizing eyeglasses **2091** (or a polarizing plate) is arranged between the eye **2231** of an observer and the rotary filter **1414**. If the rotation of the rotary filter **1414** and the display image of the display panel **22** are synchronized with each other, the observer can view a three-dimensional image.

Although the embodiment of FIG. **223** employs the lamp-shaped light source **2181**, a surface light source **2241** may be employed as shown in FIG. **224**. The surface light source **2241** emits light from the surface thereof by the principles of fluorescence. It is manufactured, for example, by Sanyo Electric. Also, a bar-shaped fluorescent tube may be arranged within a box and a light scattering plate arranged on the light exit surface. In addition, the rotary filter **1414** may employ that shown in FIG. **202** or **207**. If the correction filter **2072** is detachable from an optical axis, the color correction of a display image can also be performed. In that case it will be sufficient if color glass can be inserted in an optical axis instead of the rotary filter **1414** shown in FIG. **202**, FIG. **207**, or FIG. **222**. The color glass employs one sold by HOYA or Shiguma Khoki.

Although the rotary filter **1414** is arranged on the light exit side of the display panel **22**, the present invention is not limited to this arrangement. For example, it may be arranged between the light source **1411** and the display panel **22**, or directly behind the light source **1411**. Since the rotary filter **1414** is employed to narrow the wavelength band of light or polarized light in the optical path **1414**, it can exhibit its effect even if it is arranged at any position in the optical path **1416**.

In the case where the concave mirror **1411**b of the light source **1411** is large in size, if the rotary filter **1414** is arranged directly behind the light source **1411** (e.g. at a position indicated by a dot line **1414**c in FIG. **141**), there is the advantage that the size of the optical system is reduced. The concave mirror **1411**b becomes large in size when the diagonal length of the display area of the display panel **22** is smaller than the diameter of the concave mirror **1411**b.

The rotary filter **1414** is relatively large in size (wide in area). When the concave mirror **1411**b is large in size, if the rotary filter is arranged directly behind the exit side of the concave mirror **1411**b, the rotary filter **1414** will not be a hindrance and therefore the optical system can be made compact. To prevent the rotary filter **1414** from being heated, it is preferable that an infrared-ray cut filter should be arranged on the light incidence side of the rotary filter **1414**, or an infrared-ray reflecting film consisting of a dielectric multilayer film should be formed on the back surface of the rotary filter **1414**.

The rotary filter **1414** may be coated with three primary colors (R, G, and B) in addition to those shown in FIGS. **202, 207**, and **208**. If this rotary filter of three primary colors is employed, color display can be realized by driving a single monochromatic display panel in time-division. The RGB filter may be formed with a dielectric multilayer film. Since a dielectric multilayer film does not absorb light, there is no possibility that it will be heated and therefore it is a

suitable material. Also, a correction filter **2072** is preferred to be formed with dielectric multilayer.

Note that if the light shield film (BM) **202** of the display panel is likewise formed with a dielectric multilayer film, it will not absorb incident light. For this reason, the case where the display panel is heated is reduced, and consequently, light with even stronger strength is incident on the display panel. As a result, the projection type display of the present invention can realized high brightness display. Also, the color filter consisting of a dielectric multilayer film may be constituted by forming a dielectric multilayer film on a glass substrate for each R, G, and B, cutting into a predetermined shape, and by pasting it on a transparent disc such as polycarbonate.

The rotary filter **1414** can be constituted even if it is of a reflection type. For example, it can be fabricated by coating a circular aluminum disc with a color filter consisting of R, G, and B (or cyanogen, magenta, and yellow).

It is preferable that the surface of the rotary filter **1414** be given an electrostatic prevention process to prevent the occurrence of static electricity. For example, the surface is covered with resin containing a number of hydraphilic groups. Also, the rotary filter **1414** is formed with irregularities on an area that effective light for display does not pass through. This is for reducing friction between the rotary filter **1414** and air. This employs the principle that the flight distance of a golf ball can be extended if the surface of the ball is formed with irregularity.

The display panel of the present invention is not adoptable only in the light valve of a projection type display, but it is also adoptable, for example, in a display employed in a video camera it is called a view finder . A description will hereinafter be made of an embodiment where the display panel **22** of the present invention is adopted as the light valve of a view finder.

FIG. **218** shows a perspective view of the view finder of the present invention. FIG. **219** shows a sectional view of FIG. **218**. A condenser lens **2183** and a display panel **22** are arranged interiorly of a body **2186**. An eyepiece **2185** is arranged interiorly of an eyepiece ring **2184**. **2181** denotes a light source employing a fluorescent tube. Light radiated by the light source (fluorescent tube) **2181** is emitted from the center hole **2189** of an aperture **2182** which is a light shielding plate. Since the body **2186** and the eyepiece ring **2184** absorb unnecessary light, the interior surfaces are painted black or a dark color. The light source **2181** which is a fluorescent tube may employ a light-emitting diode (LED) or a fluorescent device (VFD). Also, it can employ a surface light source. On the incident side or exit side of the display panel **22** a polarizing plate **131** may be arranged.

As an example, the diagonal length D of the display area of the display panel **22** is about 18 mm, the effective diameter of the condenser lens **2183** is 20 mm, and the focal distance is 15 mm. The condenser lens **2183** is a flat-convex lens, and the flat side is directed to the side of the light emitting device **2181**. Note that the condenser lens **2183** and the eyepiece **2185** may be replaced with Fresnel lenses. If Fresnel lenses are employed, the view finder can be reduced in volume and weight.

Light radiated at a wide solid angle from the light source (light emitting device) **2181** is converted to nearly collimated light having narrow directivity by the condenser lens **2183** and is incident on the side of the counter substrate of the display panel **22**. An observer brings his eyes into close contact with an eyepiece rubber **2187** and views a display image on the display panel **22**. In other words, the position of the pupils of the observer is nearly fixed. When it is

assumed that all pixels of the display panel **22** cause light to go straight, the condenser lens **2183** is positioned so that the light, radiated from the light source (light emitting device) **2181** and incident on the effective area of the condenser lens **2183**, is transmitted through the eyepiece **2185** and incident on the pupils of the observer. In this manner, the observer can zoom and view a small display image on the display panel **22**.

In the view finder, since the position of the pupils of the observer is nearly fixed by the eyepiece rubber **2187**, the light source arranged on the back side may be narrow in directivity. In a conventional view finder employing a light box which employs a bar-shaped fluorescent tube as a light source, only light traveling from an area of nearly the same size as the display area of the display panel at a small solid angle in a certain direction is utilized and light traveling in the other directions is not utilized. In other words, the light rate of utilization is very low.

The present invention employs a light source whose illuminant is small, and light radiated at a wide solid angle from the illuminant is nearly collimated by the condenser lens **2183**. The light emerging from the condenser lens **2183** becomes narrow in directivity. If the visual point of an observer is fixed, even the aforementioned light having narrow directivity can be sufficiently used in the view finder. If the size of the illuminant is small, inevitably the consumption power will be reduced. Thus, the view finder of the present invention makes use of the fact that an observer fixes its visual point and views a display image. Although a direct liquid crystal display panel usually requires a certain visual field angle, a view finder will serve its purpose if a display image can be satisfactory observed in a predetermined direction. Note that the view finder and video camera of the present invention are both fixed to a video camera (not shown) by a mounting bracket **2188**.

If the insertion degree of the eyepiece ring **2183** into the body **2186** is adjusted, focusing adjustment can be performed according to the eye sight of an observer. Since the position of the eyes of the observer is fixed by the eyepiece rubber **2187**, there is little possibility that the visual point position will be moved during use of the view finder. If the visual point is fixed, the observer can view a satisfactory image even if the directivity of light to the liquid crystal display panel **22** is narrow. To view an even better image, the direction in which light is radiated from the light source (light emitting device) **2181** needs to be moved in an optimum direction.

FIG. **220** is a sectional view of a fluorescent tube according to an embodiment of the light source (light emitting device) **2181** employed in the view finder of the present invention. As shown in FIG. **220**, the fluorescent tube has a miniature lamp shape as its exterior appearance. **2201** denotes a casing consisting of glass, and the diameter is 2.4 to 10 mm. **2203** denotes a filament. If a voltage of about 4 to 8 V is applied to the filament **2203**, it will be heated. **2204** is an anode, and the applied DC voltage is about 15 to 25 V. The anode voltage accelerates electrons emitted by heating the filament **2203**. The casing **2201** has mercury molecules (not shown) enclosed therein, and if the aforementioned accelerated electrons impinge on mercury molecules, ultraviolet rays will be emitted. These ultraviolet rays excite an illuminant **2202**, which in turn emits visual light. As such an illuminant (light emitting device) **2181**, there is a fluorescent tube (Lunar light 05 series) manufactured by Minipairo Electric. Also, there is a 2.4-mm-diameter light source manufactured by Tohoku Electronics.

The light source is driven by a pulsed signal so that a quantity of light to be radiated can be adjusted. The frequency of the pulsed signal is 30 Hz or more, preferably 60 Hz or more. If a pulsed voltage signal is applied to the anode **2204**, the emission quantity can be varied in proportion to the pulse width.

As shown in FIG. **220**(*b*), if a light shielding film **2205** is formed on the casing **2201**, the light radiating area of the illuminant **2181** will be reduced. Therefore, this illuminant will not require an aperture (light shielding plate) **2182** such as that shown in FIG. **219**.

The lamp **2181** of FIG. **220** is a hot-cathode light emitting tube. For this reason, the brightness will be reduced if outside temperature is low. As a measure to counter brightness reduction, it is preferable that the casing **2201** consist of two layers, an inner casing **2201***a* and an outer casing **2201***b*, as shown in FIG. **221**. The space between the inner and outer casings **2201***a* and **2201***b* forms a layer of air or a vacuum. The lamp is mounted on a substrate **2211** through a rubber connector **2212**. The connector **2212** is fitted in a hole formed in the substrate **2211**. The terminals of the lamp are soldered to the substrate **2111**.

As described above, the view finder of the present invention efficiently focuses the light emitted at a wide solid angle from the light emitting body having a small light source (light emitting device) **2181** by the condenser lens **2183**. Therefore, the consumption power of the light source can be considerably reduced in comparison with the case where a back light consisting of a surface light source employing a fluorescent tube is employed.

In FIG. **219**, although the display panel **22** of the present invention is applied to a view finder, it is also applicable to a video monitor as shown in FIG. **225**. FIG. **225** shows a sectional view of the video monitor.

Light emitted from a light source (light emitting lamp) **2181** is transmitted through an aperture **2182**. The transmitted light is reflected by a mirror **1552** and is directed to a display panel **22**. The reason why light is reflected by the mirror **1552** is for shortening the depth of the video monitor. The reflected light is incident on a Fresnel lens **2183** which is a condenser lens, and it is nearly collimated by the lens. The nearly collimated light is incident on the display panel **22**, which in turn modulates the incident light in accordance with a video signal. The display panel **22** has a transparent substrate **1311** mounted thereon to prevent the occurrence of secondary scattered light, thereby enhancing display contrast.

The display panel of the present invention is also applicable to a direct vision type display. The direct vision type display is shown in FIG. **226**. White light radiated from a bar-shaped fluorescent tube **2262** is reflected by a reflecting sheet **2263**, or it is incident directly on a light guiding plate **2261**. As an example of the reflecting sheet **2263**, there is polyester film deposited with silver. The relation between the thickness d_2 of the light guiding plate **2261** and the diameter d_1 of the fluorescent tube **2262** is $d_2 > 2d_1$ and $3d_2 < 4d_1$. In this range, the quantity of incident light on the light guiding plate **2261** is increased and the light rate of utilization is raised.

The surface of the light guiding plate **2261** is formed with diffusing points. Light incident on the diffusing points is emitted from the light guiding plate **2261**. On the light guiding plate **2261** a prism sheet **1061** is arranged. Two prism sheets may be arranged. The prism sheet **1061** has a function of narrowing the directivity of light.

Polarizing plates **131***a* and **131***b* are arranged on the incident side and exit side of the display panel **22** so that they cross each other. In other words, the polarization axes **132***a* and **132***b* of the polarizing plates **132***a* and **132***b* are

arranged so as to cross each other. The display panel 22 employs a PD liquid crystal display panel and displays an image in a normally white mode.

A description will next be made of the fact that a dynamic image on a liquid crystal display panel becomes dim while displaying.

As a cause of degrading an image displayed by a liquid crystal projector, there is a phenomenon that a screen becomes dim while displaying a dynamic image. This cause is considered as follows:

1. The response time of a liquid crystal is slow.

2. Memory holds an electric charge on a pixel all during a 1-field (1-frame) period.

For the response time of a liquid crystal in the aforementioned item 1, the rise time+fall time of a TN liquid or a PD liquid crystal is about 30 msec (when panel temperature is 30° C. or more). If a 1-frame period is ⅟₆₀=16 msec, the response time of the liquid crystal will follow sufficiently. The aforementioned item 2 becomes a problem. A CRT writes data by an electronic beam and makes peak brightness high, thereby performing display for the remaining time. For this reason, black-and-white display is clear, the responsibility is fast, and there is no problem with high quality display. On the other hand, a liquid crystal hold a certain brightness all during a 1-frame period and displays an image with an average brightness. For this reason the response time is felt to be slow during a display of dynamic image.

FIG. 216 is a block diagram used to explain a circuit which improves response time during dynamic-image display. Conceptually, a black screen is displayed between the display periods of a first image and a second image. The display method is conceptually shown in FIG. 215. Although a letter of F is displayed on a screen for making explanation easy, actually a natural image is displayed.

As shown in FIG. 215(a), an image F is first displayed from the upper portion of a screen 1613. FIG. 215(b) shows the state as the display of the image F is ended. Then, as shown in FIG. 215(c), black display is performed from the upper portion of the screen (display area or display image) 1631. FIG. 215(d) shows the state when the black display is ended. In other words, image display (natural image) and black display are alternately performed. Note that for the method of driving the liquid crystal display panel 22, a 1-H inverting drive method or a 1-column inverting method is a suitable one, because there is no occurrence of cross talk.

If the ratio between a period A for performing image display and a period B for performing black display is 1:1, circuit constitution will become simple and the design of X and Y driver circuits will also become easy. In other words, image signals held in memory are read out at double speed and then they are sequentially written to the liquid crystal display panel 22. The aforementioned ratio is not limited to 1:1. It is a matter of course that the black display period B may be shortened. Also, while black display is performed on the liquid crystal display panel 22 during the black display period, the present invention is not limited to this. For example, dark level (gray color or middle level) display or white display may be performed. Such display will hereinafter be referred to as raster display. In addition, a natural image with a reduced brightness may be displayed.

As shown in FIG. 216, a video signal SIG is converted to digital data by an A/D conversion circuit 2161 and held in the storage means of F memory (field memory or frame memory) 2162. On the other hand, a raster-display setting circuit 2163 sets the display brightness level of the black display period B. The raster-display setting circuit 2163 outputs a natural image as needed. A double-speed read

circuit 2164 reads out data from the F memory 2162 at the first half (image display period A) of the first frame (field) period and then writes an image to the liquid crystal display panel 22 at double speed. Based on a value set by the raster-display setting circuit 2163, raster display is performed on the liquid crystal display panel 22 at the second half (black display period B) of the first frame period.

In FIG. 215, although natural image display and black display are alternately performed, natural images and black images may be displayed one by one, or a plurality of horizontal lines at a time. A single horizontal line or a set of a plurality of horizontal lines will hereinafter be referred to as a display line set. For example, in FIG. 217(a), raster display is performed. That is, natural images are displayed from the upper portion of the screen by display line sets and also black images are displayed by display line sets indicated by oblique lines. This display line set will be referred to as a black line set. FIG. 217(b) shows the state when writing of one screen is ended. In FIG. 217(c), a black line set is written from the upper portion of the screen and then natural images are written to a display line set. This operation is performed in sequence, and writing of one screen is ended in FIG. 217(d).

Even in the aforementioned drive method of FIG. 217, black display (raster display) is performed in the frame (field) next to a natural image and therefore the responsibility of a dynamic image is improved. Particularly, in interlace scanning display (e.g., NTSC), if a display line set is regarded as a single horizontal line, the drive method of FIG. 217 can be easily realized. In other words, a signal supplied in an interlace scanning fashion is written at double speed to the display panel and then black display is written at a line next to natural image display. This operation is repeatedly performed.

The drive method and drive circuit shown in FIGS. 215 through 217 have been described with regard to the liquid crystal display panel 22. However, the present invention is not limited to the panel 22 but is applicable to all dot matrix display panels. The dot matrix display panel holds the brightness of a pixel during a constant period (frame or field period). Of course, this holding includes holding in a constant state as in the liquid crystal display panel 22. In addition, holding a certain brightness on a pixel by average pulse modulation (e.g., PWM modulation) during a 1-frame or 1-field period is believed to be included in the technical idea of the present invention. The reason for this is that the holding method performs a predetermined display by a combination of pulses and differs a CRT method in which display is performed by peak brightness. Since a predetermined brightness is displayed during a 1-frame period by pulse drive (e.g., PWM modulation), it is believed that an electric charge is held on a pixel.

Therefore, the drive method of the present invention is technically applicable to a reflection type digital micromirror device (DMD and DLP) developed by Texas Instrument and a plasma display (PDP). In addition, it is applicable to an organic EL display, an LED display, an inorganic EL display, a fluorescent tube, and a FED. If these dot matrix displays (other than a CRT method employing an electric gun) employ the drive method of the present invention, the response time during dynamic-image display is improved. Furthermore, the technique of the present invention is also applicable to a flat CRT (CFP) developed by Matsushita Electronic.

The aforementioned dynamic-image dimming is also improved by the constitution shown in FIG. 210. 2101 denotes a drum-shaped(cylindrical) object. Within the drum

2101 a display panel 22 is arranged. The drum 2101 rotates on a rotational center 2023 in a direction of arrow. The drum 2101 is formed with light shielding portions 2102 and light transmitting portions 2103, which are alternately arranged. Incident light travels along an optical axis 1416 and is modulated by the display panel 22. The modulated light is projected onto a screen by a projection lens 1415. Lenses 1413 are arranged so that a display image on the display panel 22 is projected onto the screen.

FIG. 211 shows the drum 2101 viewed from the side of the projection lens 1415. As the drum 2101 is rotated, the light shielding portion 2102 of the drum 2101 shuts out a display image (screen) 1631. FIG. 211(a) shows the state as the upper portion of the display image 1631 is shut out by the light shielding portion 2102. FIG. 211(b) shows the state as almost all of the screen 1631 is shut out by the light shielding portion 2102.

A further description will be made in reference to FIG. 212. It is assumed for simplicity that a letter of "F" is displayed at the first frame and a letter of "A" is displayed at the next frame. Assume that in FIG. 212(a) a letter of "F" has completely been displayed and then it has been projected on the screen by the projection lens 1415. In other words, light is passing through the light transmitting portion 2103 of the drum 2101. As the drum 2101 is rotated, the screen 1631 is shut out by the light shielding portion 2102 from the upper portion as shown in FIG. 212(b). At this time, a letter of "A" is written to the display panel 22 from the upper portion of the screen. In other word, the next frame is displayed on the display panel in synchronization with the speed at which the light shielding portion 2102 is rotated. In the state of FIG. 212(d), the screen is completely shut out by the light shielding portion 2102 and also a letter of "A" is displayed. Then, as the light shielding portion 2102 is rotated, the letter "A" is displayed.

From the aforementioned description, 1 frame (field) is displayed by a set of the light shielding portion 2102 and the light transmitting portion 2103. Therefore, if the area of the light shielding portion 2102 is the same as the light transmitting portion 2103, an image will be displayed for half a 1-field period. Note that the area ratio between the light shielding portion 2102 and the light transmitting portion 2103 does not need to be 1:1. If the area of the light shielding portion is reduced, the brightness of a projected image will be raised. However, dynamic-image dimming becomes difficult to be improved.

The brightness of point B on the screen in FIG. 212 is indicated by a dotted line in FIG. 213. In other words, it becomes dark in the light shielding portion and becomes light in the light transmitting portion. That is, brightness of the point B repeats light-darkness-light-darkness. If the drum 2101 is not present, constant brightness will be obtained as shown by a solid line.

If light and darkness are repeated in the aforementioned manner, peak brightness display can be falsely expressed as in a CRT and therefore it is believed that dynamic-picture dimming is improved.

It is a matter of course that this embodiment, as with the embodiment of FIG. 216, is also applicable to other display panels.

The method of shutting out an image from the upper portion of a screen and also displaying an image from the upper portion one after another can be realized by a display panel shown in FIG. 214.

The display panel of FIG. 214 is constituted by liquid crystal layers 21a and 21b. The liquid crystal layer 21a is interposed between a pixel electrode 14 and a counter

electrode. The liquid crystal layer 21b is interposed between the counter electrode and electrodes 421 in the form of stripes. Each of the stripes-shaped electrode 421 corresponds to one line of pixel electrodes 14. The liquid crystal layer 2 1a displays a natural image by active matrix drive, while the liquid crystal layer 21b performs simple matrix drive. If voltage is applied to the stripes-shaped electrodes 421, the PD liquid crystal layer 21 will be caused to be in a light transmitting state. If no voltage is applied, the PD liquid crystal layer 21 will be caused to be in a scattering state and will perform black display. When an image on the liquid crystal layer 21a is displayed, the liquid crystal layer 21b is caused to be in a scattering state. If the stripe-shaped electrodes 421 are scanned, it is clear that the image shown in FIG. 212 can be displayed. Therefore, dynamic-picture dimming can be improved.

In FIG. 214, although the liquid crystal layer 21b for performing a light shielding operation and the liquid crystal layer 21a for performing image display are formed on a single liquid crystal panel, the present invention is not limited to this arrangement. For example, a display panel 22a having a liquid crystal layer 21 for performing a light shielding operation and a display panel 22b having a liquid crystal layer 21 for performing image display are fabricated, and the two display panels 22a and 22b are pasted together or arranged in close proximity to each other. In this manner, the image display method of FIG. 212 can be realized.

FIG. 214 shows the liquid crystal panel 22 which has a plurality of liquid crystal layers 21 consisting of a PD liquid crystal layer 21b and another liquid crystal layer 21a (e.g., a TN liquid crystal layer). Note that the liquid crystal layer 21a may be a PD liquid crystal layer. Although this display panel is effective as a light valve, the present invention is not limited to the light valve. The liquid crystal panel can also be employed as a direct vision display panel.

The display panel 22 of FIG. 214 is a display panel which has two liquid crystal layers, an active matrix display panel (liquid crystal layer 21a) and a simple matrix display panel (liquid crystal layer 21b). The simple matrix display panel is a display panel provided with electrodes in the form of stripes and displays an 8-segment number and a simple symbol such as ○ and x.

In FIG. 214, while only the counter electrode 25 is formed between the liquid crystal layers 21a and 21b, the present invention is not limited to this arrangement. The counter electrode 25 may be formed on a substrate formed from glass or resin. In the display panel of the present invention, the liquid crystal layers 21a and 21b are arranged between the array substrate 11, the substrate 25 formed with a counter electrode, and the substrate 12.

When voltage is applied to pixels arranged in the form of a matrix, the liquid crystal layer 21a displays an image. The liquid crystal layer 21b displays numbers and symbols. When the liquid crystal layer is in a scattering state, the numbers and symbols are displayed white. Also, if voltage is applied, the upper liquid crystal layer will become transparent and the image on the lower liquid crystal layer 21a will be directly seen. In other words, in the display panel of FIG. 214, superimposed images can be seen by the two liquid crystal layers. For example, a TV dynamic image displayed on the liquid crystal 21a is covered with smoke by the liquid crystal layer 21b. 8 segments can be employed to display time white (of course, time may be colored). In addition, mosaic display can be performed on a portion of display.

It is a matter of course that the drive methods shown in FIGS. 120, 215, 217, and 216 are applicable to the projection

type display, direct vision display panel (device), and view finder of the present invention. If they are applied, dynamic-image responsibility will be improved and high-quality image display can be performed.

As described above, the matters described in the specification of the present invention are applied mutually. For example, the display panels of FIGS. 1 and 15 are combined together. The constitution of FIG. 112 is applied to FIG. 1. The fabrication methods of FIGS. 74 and 76 are applied as a method of fabricating the display panels of FIGS. 1 and 15. The display panel of the present invention is applied to the projection type display of the present invention. The driver circuits described in FIGS. 124, 125, and 126 are applied to the display panels of FIGS. 1, 15, 27, and 28. The matters related to the arrangement of the polarizing plate of FIG. 13 are applied to the displays of FIGS. 153, 164, 219, and 226. The display panel of the present invention is employed in the display of FIG. 226. The display panel of the present invention is applied to a view finder.

In FIG. 84(d) the light scattering layer 841 may contain material which absorbs black or light, such as paints, pigments, and dyes. If these are contained, black in a display image will sink and therefore high quality display will be obtained.

Also, instead of containing paints, pigments, and dyes, these may be coated or deposited on the surface of the substrate 642 or 12. Chrome oxide such as sexivalent chrome may be deposited. The substrate surface may be chemically processed to form irregularities on the surface. These constitutions can also enlarge a visual field angle. In addition, black in a display image can be displayed more black, and high-quality display can be realized.

Similarly, even if the irregularity film 821 of FIG. 82 and the transparent resin film 962 of FIG. 112 contain titan powder or contain the aforementioned dyes and pigments, the same advantages will be obtainable.

Also, if the microlens 641, prism 671, or optical coupling agent 691, shown in FIGS. 68 and 69, is colored with dyes or pigments, the band of incident light onto the mixed solution 315 can be limited and therefore satisfactory phase separation can be performed.

In the microlens arrays of FIGS. 96, 100 and 101, the transparent resin film 962 may employ polyvinyl alcohol (PVA). In addition, it may employ thermosetting type epoxy resin, 2-solution setting type resin (resin for a principal agent and a setting initiator), and silicon resin. Among these resins, the transparent resin film 962 employs resin whose transmittance is high and whose contraction ratio is relatively high during setting.

The microlens substrate 642 (e.g., FIG. 95) may be arranged on the exit side of the display panel.

In the Fresnel lenses 641c and 641 and prism sheet 1061 shown in FIGS. 105 and 106, a single Fresnel lens 641c or 641 may be arranged for a plurality of pixels. To improve a visual field angle, a single Fresnel lens 641c or 641 may be arranged over the entire display area of the display panel 22. If the direction of incident light onto the display panel is suitably aligned with the position of the eyes of an observer, an image on the display panel 22 can be satisfactorily observed. Although the microlens substrate 642 and Fresnel lenses 641c and 641 differ in shape, they have the same function.

In the Fresnel lenses 641c and 641 and prism sheet 1061 shown in FIGS. 106 and 108, it is preferable that the flat side be directed to the display panel. The reflectance of incident light onto the aforementioned lenses is reduced, and irregular reflection of light is suppressed. As a result, high-quality

display can be realized. Also, it is preferable that the surface of the aforementioned substrate 642, microlens, or prism should be formed with an antireflection film.

As an example, the antireflection film is constituted by a low refractive index layer, the layer being stacked with fluorine-contained polymer particles whose average particle diameter is in a range of 5 to 200 nm and also being formed with microvoids between particles. Also, there is a photo-setting resin whose refractive index is 1.35 to 1.45. In addition, the antireflection film may be formed from a dielectric multilayer film.

While it has been described that the PD liquid crystal is mainly employed as the liquid crystal layer 21 of the transmission display panel or reflection display panel of the present invention, the invention is not limited to this. It may be an STN liquid crystal, a TN liquid crystal, a guest-host liquid crystal, a ferroelectric liquid crystal, a homeotropic liquid crystal, a liquid crystal which has comb electrode constitution and performs light modulation by varying the angle of orientation of a liquid crystal molecule in a horizontal direction (fabricated by Hitachi), and a plasma address liquid crystal (fabricated by Sony). Also, depending on the constitution of a display panel, the PD liquid crystal is applicable to an organic EL display panel, an inorganic EL display panel, a plasma display panel, and an LED display panel. The same may be said of the projection type display, the view finder, the direct vision display, the fabrication method, the drive method, and the drive unit.

The Fresnel lens (or a microlens) 641 may be a concave lens or a convex lens. The lens is set so that it is suitable to the position at which an observer sees. Also, the Fresnel lens 641 of FIG. 106 may be a reflection type Fresnel lens. The reflection type Fresnel lens is formed by processing a metal plate.

In FIG. 95, although the color filter 151 is arranged on the exit side of the microlens 641, it may arranged on the incident side. In other words, light emitted from the color filter 151 is transmitted through the microlens 641 and incident on the liquid crystal display panel. The microlens 641 may be of a semicylindrical type. A colored microlens 641 and the color filter 151 may be formed integrally with each other.

In the specification of the present invention, in consideration of a display panel having no pixel electrode, a pixel electrode itself has been described, for example, as a pixel electrode 14, and a pixel in a wide sense, including a type having no pixel electrode, has been described, for example, as a pixel 14.

As evident in the aforementioned description, the present invention has the advantage that display contrast can be even further enhanced in comparison with prior art.

In the display panel of the present invention, since the color filter is formed after the phase separation of the liquid crystal layer, the phase separation of the PD liquid crystal layer can be performed under an optimum condition, and satisfactory display contrast can be realized. Since the color filter is formed under the pixel electrode 14, ultraviolet rays can be irradiated through the counter electrode 25 and therefore the PD liquid crystal layer can be phase-separated satisfactorily.

Since space is formed between the pixel electrodes 14, electromagnetic coupling can be prevented between the signal line 15 and the pixel electrode 14 and there is no occurrence of light escape from the peripheral portion of the pixel electrode. As a result, satisfactory display contract can be realized.

Since the phase separation of the PD liquid crystal layer is performed with a microlens or a mask, a PD liquid crystal

layer with an average diameter optimum to the wavelengths of R, G, and B light to be modulated can be formed in the unit of a pixel.

In the projection type display of the present invention, since the display panel of the present invention is employed as a light valve, high display contrast can be realized. Also, since the liquid crystal layer is heated when temperature is low, there is no occurrence of hysteresis. In addition, since the rotary filter is rotated in synchronization with a video signal, three-dimensional display can be realized.

As evident in the aforementioned description, the present invention has the advantage that display contrast can be even further enhanced in comparison with prior art.

The display panel of the present invention also has the advantage that satisfactory display contrast can be realized. Furthermore, the present invention has the advantage that the phase separation of the PD liquid crystal layer can be satisfactorily performed.

The present invention has the advantage that a PD liquid crystal layer with an average diameter optimum to the wavelengths of R, G, and B light to be modulated can be formed in the unit of a pixel.

The projection type display of the present invention has the advantage that high display contrast can be realized. The present invention has the advantage that there is no occurrence of hysteresis. The present =invention has the advantage that three-dimensional display can be realized. Finally, the present invention has the advantage that high brightness display can be realized.

What is claimed is:

1. A display panel comprising:

a first substrate formed with pixels in the form of a matrix;

a second substrate formed with a counter electrode; and

a color filter formed or arranged on a surface of at least either said first substrate or said second substrate, the surface contacting air;

wherein the following relation is met:

$$20d \geq t$$

where t is the thickness of the substrate formed with said color filter and d is the diagonal length of said pixel.

2. A display panel comprising:

a first electrode substrate;

a second electrode substrate;

a PD liquid crystal layer interposed between said first and second electrode substrates;

a third substrate or sheet having a light reflecting function; and

a light scattering layer;

wherein said third substrate or sheet is arranged through said second electrode substrate and said light scattering layer, and the following condition is met:

$$3 \leq \frac{\pi B}{E} \leq 20$$

where E is the luminance of a small area of said light scattering layer on which light is incident, B is brightness measured in a normal direction of said light scattering layer, and π is the ratio of the circumference of a circle to its diameter.

*   *   *   *   *

专利名称(译)	液晶显示面板包括用于控制入射光的遮光膜		
公开(公告)号	US6628355	公开(公告)日	2003-09-30
申请号	US09/697991	申请日	2000-10-27
申请(专利权)人(译)	松下电器产业有限公司.		
当前申请(专利权)人(译)	松下电器产业有限公司.		
[标]发明人	TAKAHARA HIROSHI		
发明人	TAKAHARA, HIROSHI		
IPC分类号	G02F1/13 G02F1/1334 G02F1/1335 G09G3/36 H04N9/31 G02F1/1333 G02F1/1347 G02F1/1362 G02F1/1343 G02F1/1368 G02F1/133 G02F1/136		
CPC分类号	G02F1/1334 G02F1/133526 G09G3/3648 H04N9/3105 H04N9/3144 H04N9/3167 H04N9/3197 G02F1/133345 G02F1/133553 G02F1/134363 G02F1/13454 G02F1/1347 G02F1/136259 G02F1/1368 G02F2001/133521 G02F2201/34 G02F2202/104 G09G3/3614 G09G3/3655 G09G2300/0434 G09G2310/0283		
优先权	1997175744 1997-07-01 JP 1996336777 1996-12-17 JP 1997082595 1997-04-01 JP		
外部链接	Espacenet USPTO		

摘要(译)

阵列基板12形成有矩阵形式的像素电极14。像素电极14连接到薄膜晶体管155.薄膜晶体管155形成有遮光膜152，遮光膜152由树脂组成，用于防止光进入薄膜晶体管155.聚合物分散液晶层21是插入在对电极25和像素电极14之间。基板11形成有具有红色（R），绿色（G）和蓝色（B）的滤色器151。滤色器151由电介质多层膜或有机材料形成。对电极25形成在滤色器155上方，并且对电极25和液晶层21通过粘合层371接合在一起。


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11 :  COUNTER SUBSTRATE
12 :  ARRAY SUBSTRATE
14 :  PIXEL ELECTRODE
15 :  SOURCE SIGNAL LINE
16 :  LOW DIELECTRIC FILM
17 :  TRANSVERSE ELECTRIC FIELD WIRE
18 :  LIGHT SHIELDING FILM
19 :  ELECTRIC FORCE LINE
20 :  LIQUID CRYSTAL MOLECULE
21 :  LIQUID CRYSTAL LAYER
22 :  LIQUID CRYSTAL DISPLAY
25 :  COUNTER ELECTRODE
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