FIG.1

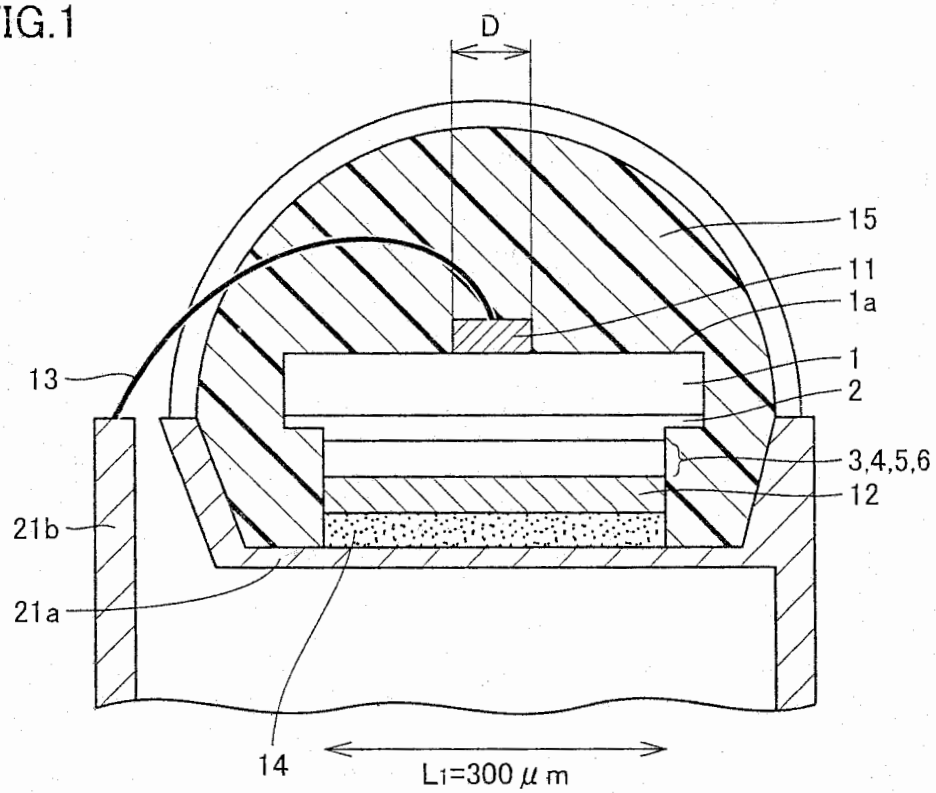


FIG.2

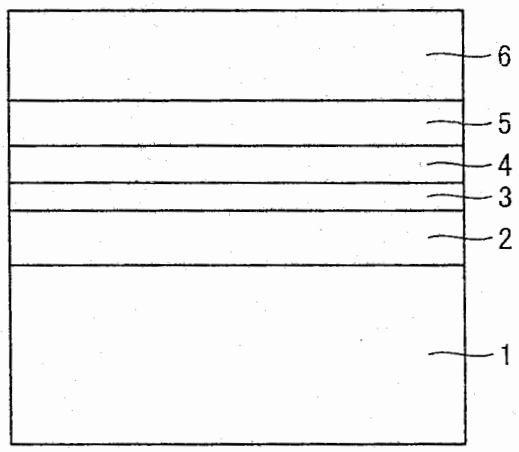


FIG.3

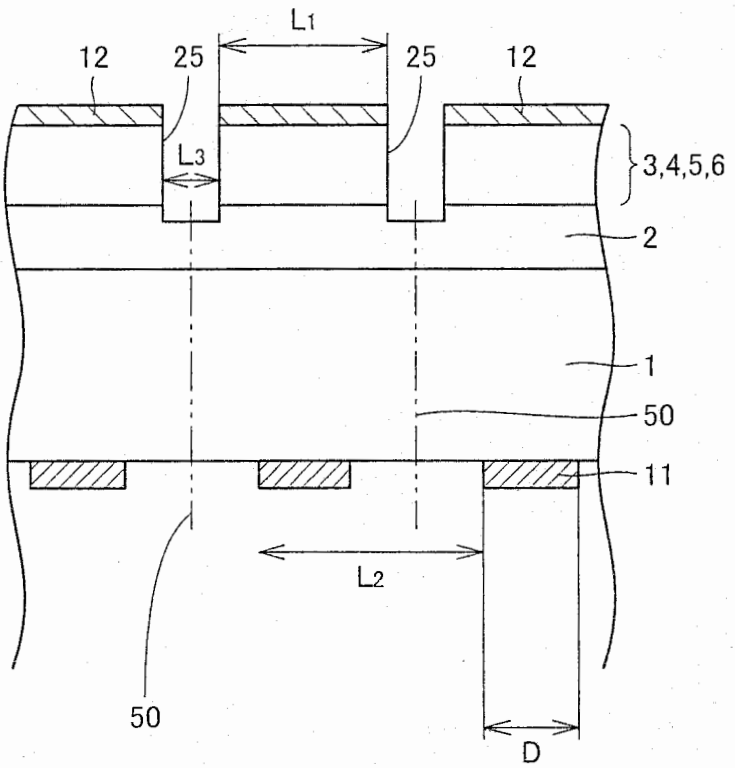


FIG.4

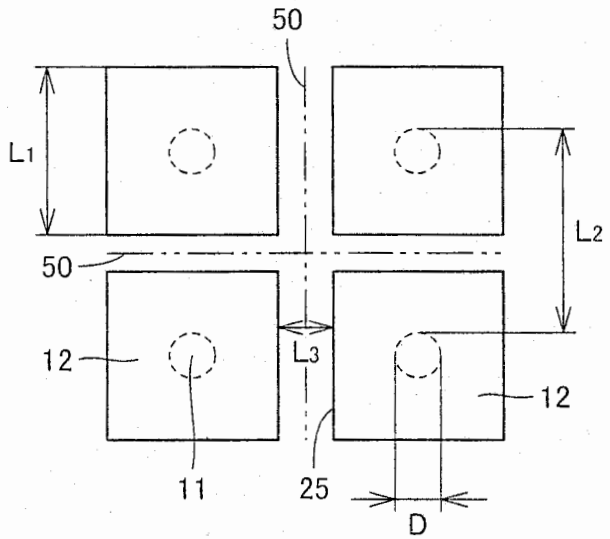


FIG.5

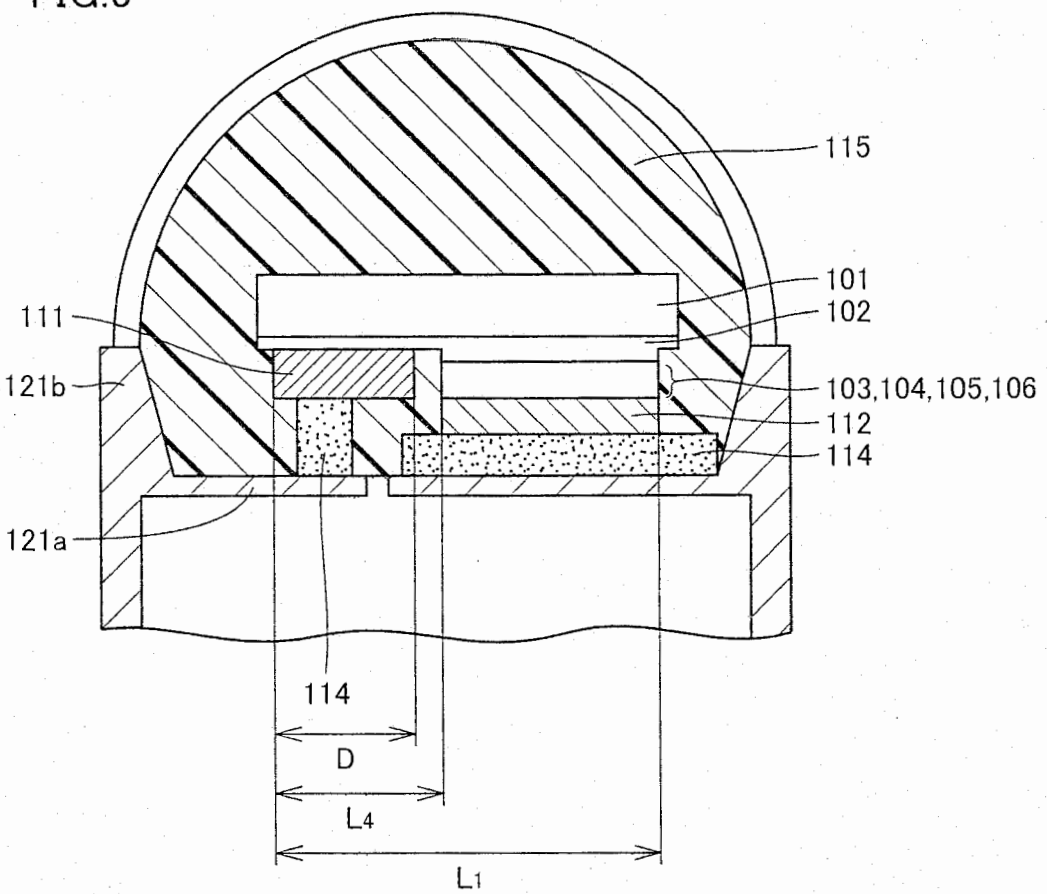

115
101
102
111
121b
103,104,105,106
112
114
121a
114
D
L4
L1

FIG.6

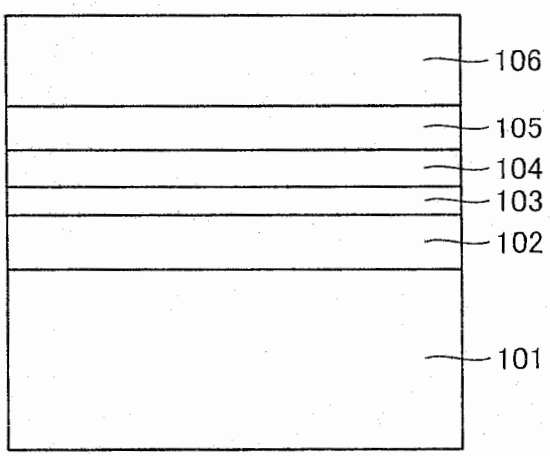

106
105
104
103
102
101

FIG.7

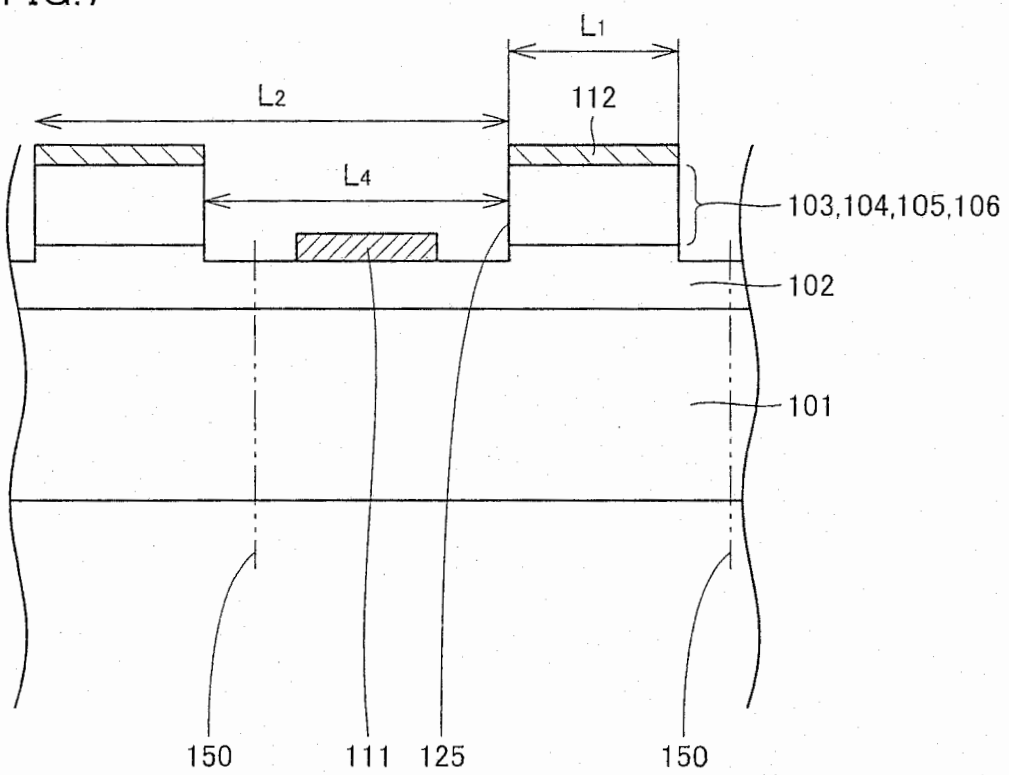

L1
L2
112
L4
103,104,105,106
102
101
150
111
125
150

FIG.8

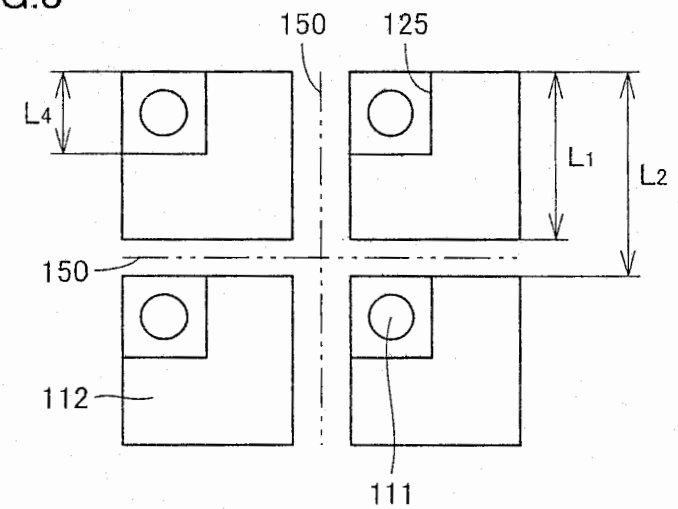

150
125
L4
L1
L2
150
112
111

FIG.9

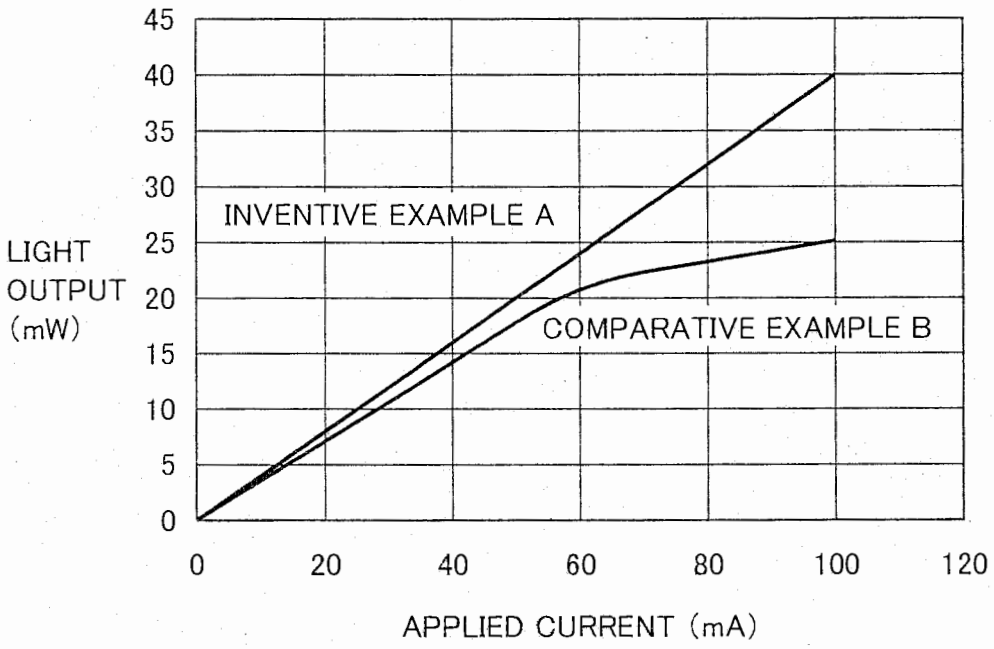

45
40
35
30
25
20
15
10
5
0
INVENTIVE EXAMPLE A
COMPARATIVE EXAMPLE B
LIGHT OUTPUT (mW)
0
20
40
60
80
100
120
APPLIED CURRENT (mA)

FIG.10

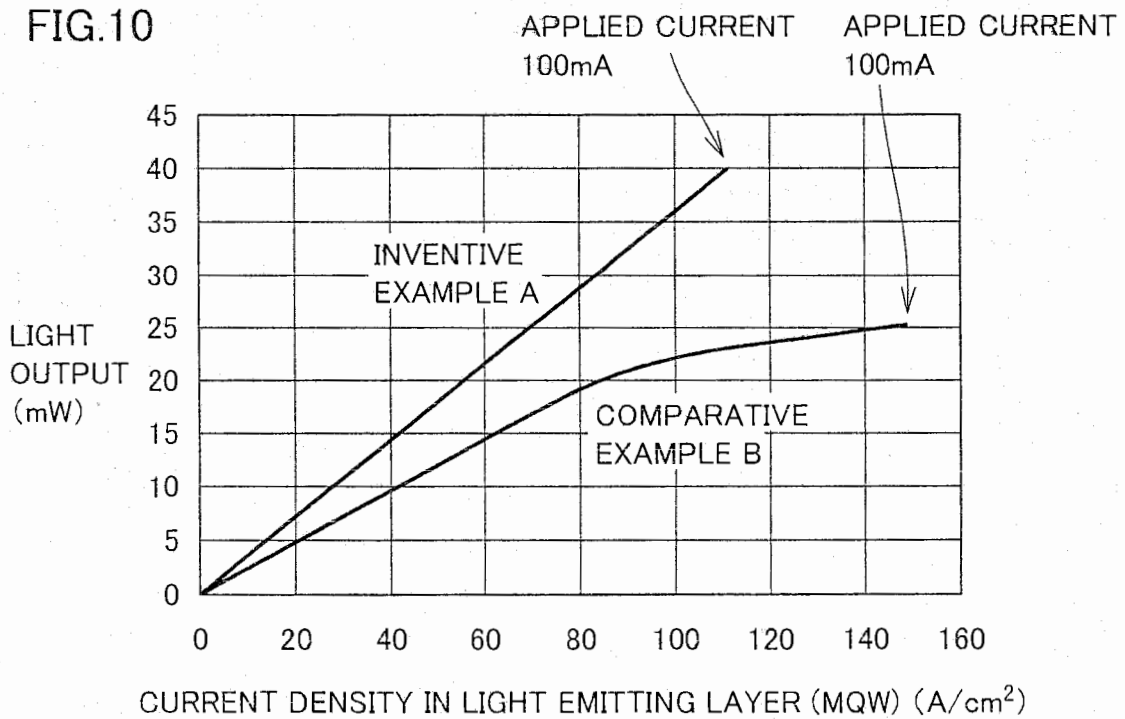

APPLIED CURRENT 100mA
APPLIED CURRENT 100mA
45
40
35
30
25
20
15
10
5
0
INVENTIVE EXAMPLE A
COMPARATIVE EXAMPLE B
LIGHT OUTPUT (mW)
0
20
40
60
80
100
120
140
160
CURRENT DENSITY IN LIGHT EMITTING LAYER (MQW) (A/cm2)

FIG.11

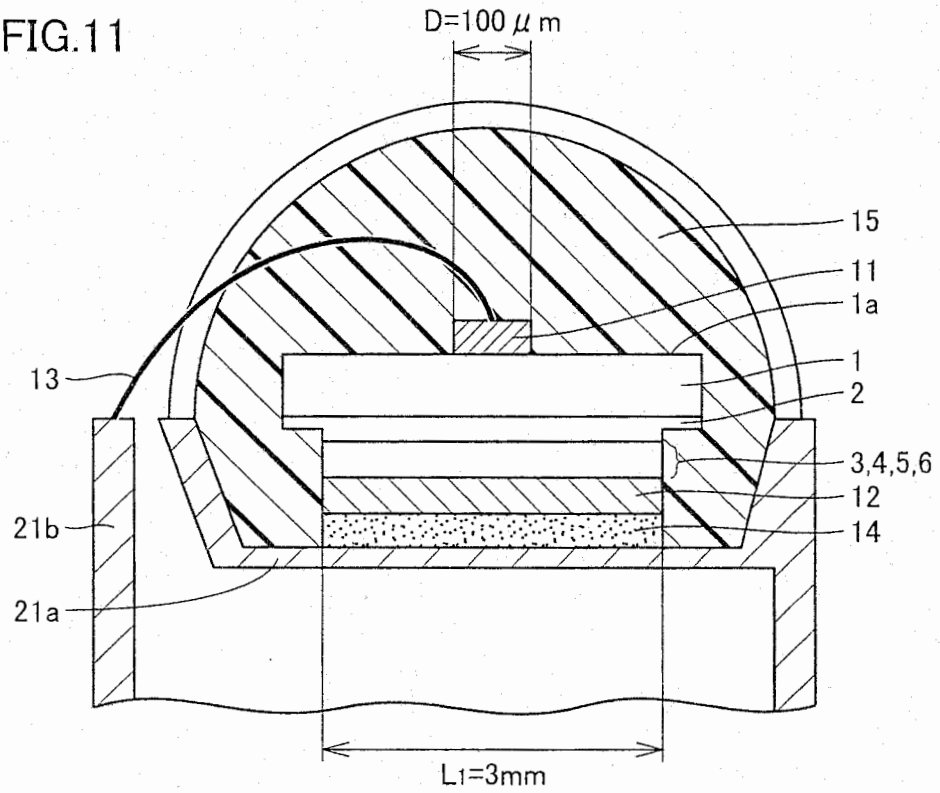

D=100 μm
15
11
1a
1
2
13
3,4,5,6
12
14
21b
21a
L1=3mm

FIG.12

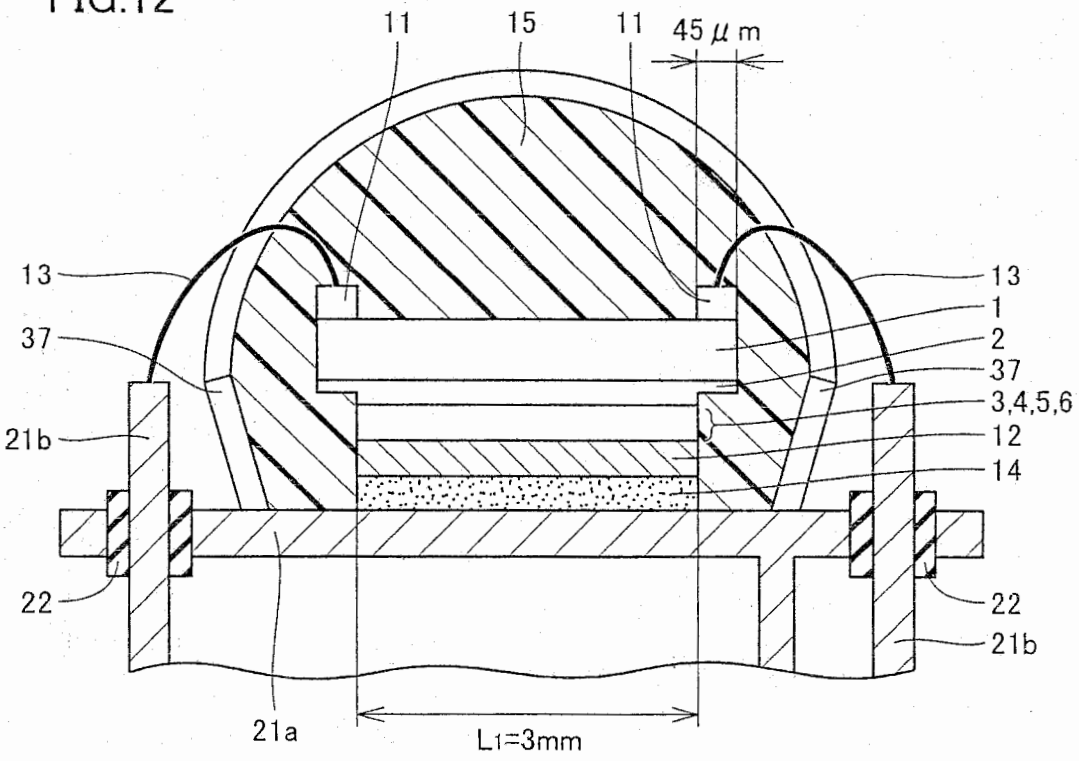

11
15
11
45 μm
13
13
1
37
2
37
3,4,5,6
21b
12
14
22
22
21b
21a
L1=3mm

FIG.13

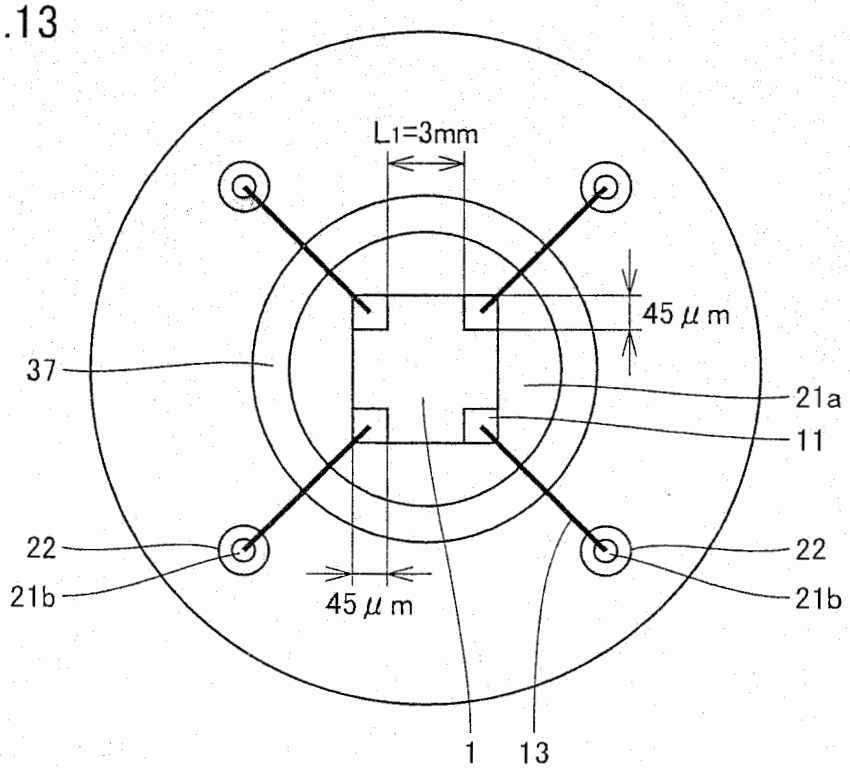

L1=3mm
45 μ m
37
21a
11
22
22
21b
21b
45 μ m
1
13

FIG.14

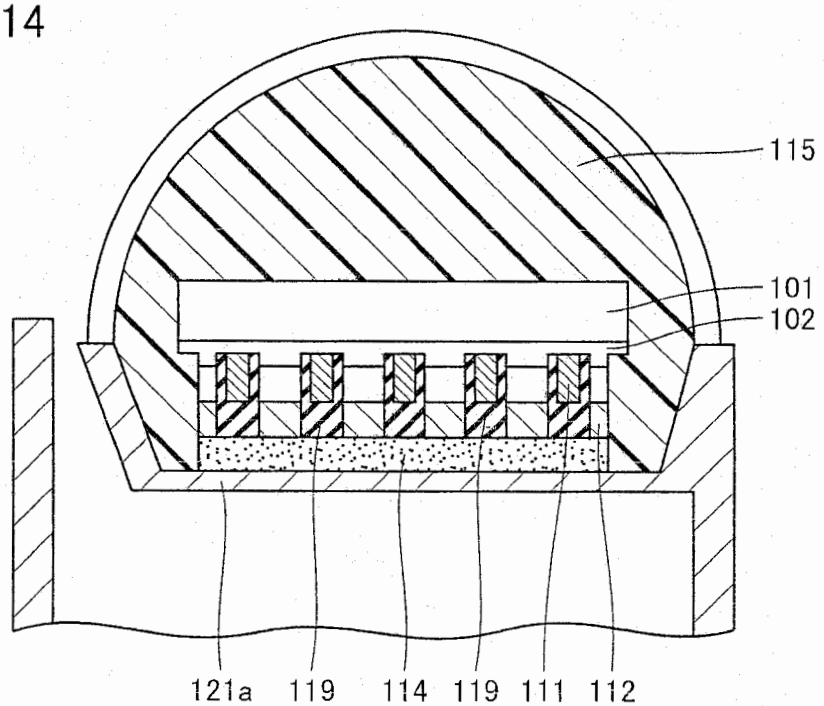

115
101
102
121a
119
114
119
111
112

FIG.15

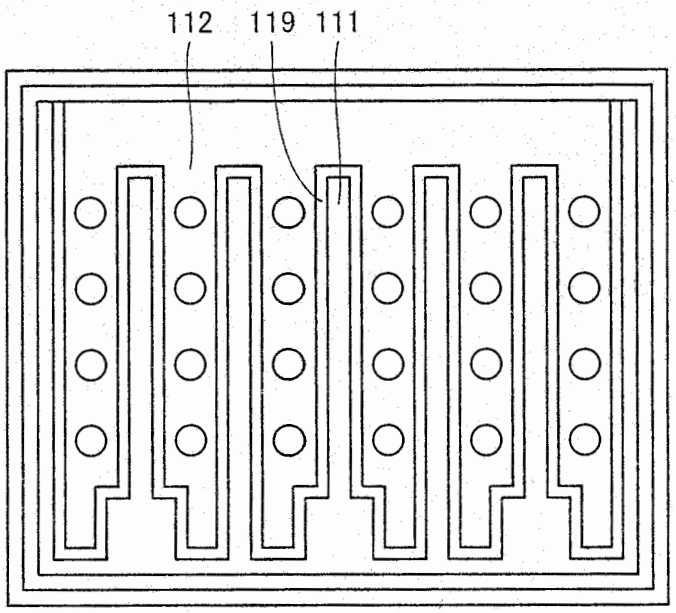


FIG.16

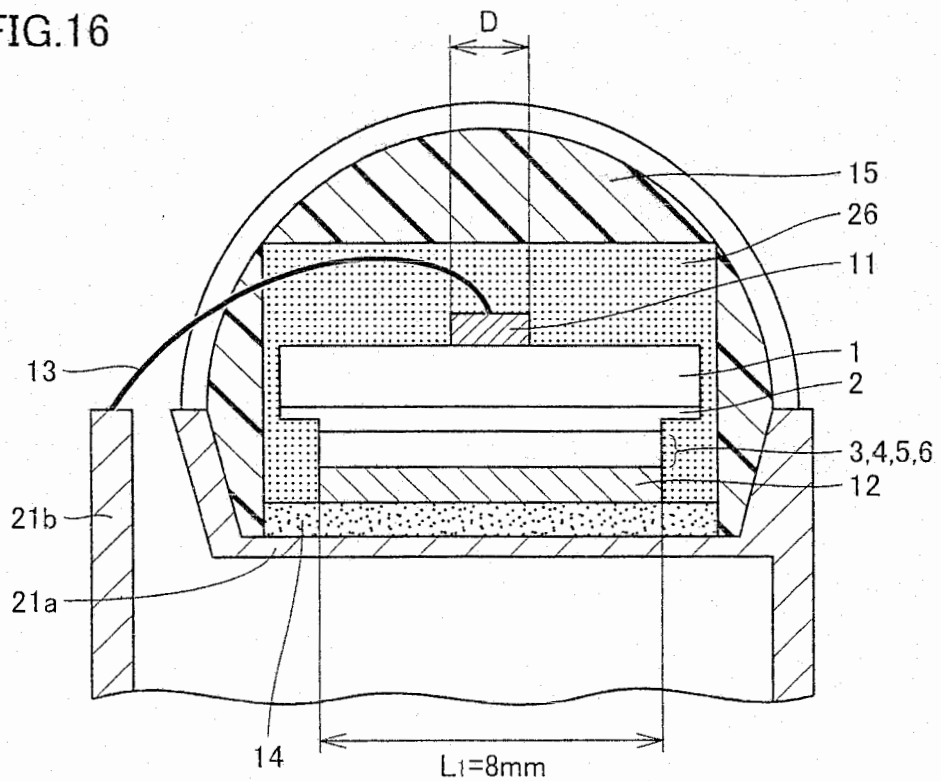


FIG.17

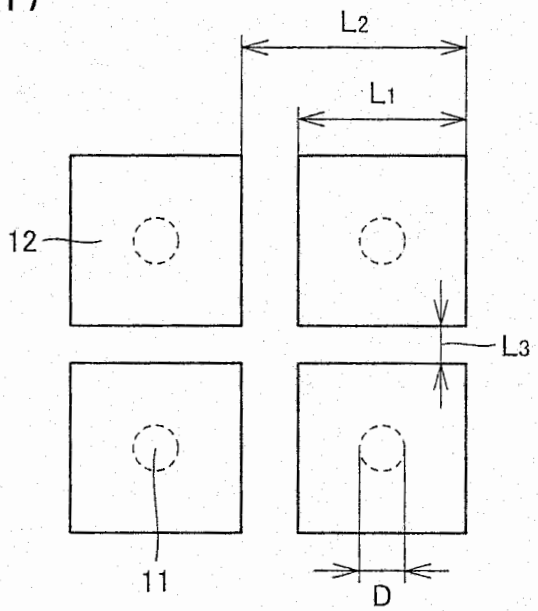


FIG.18

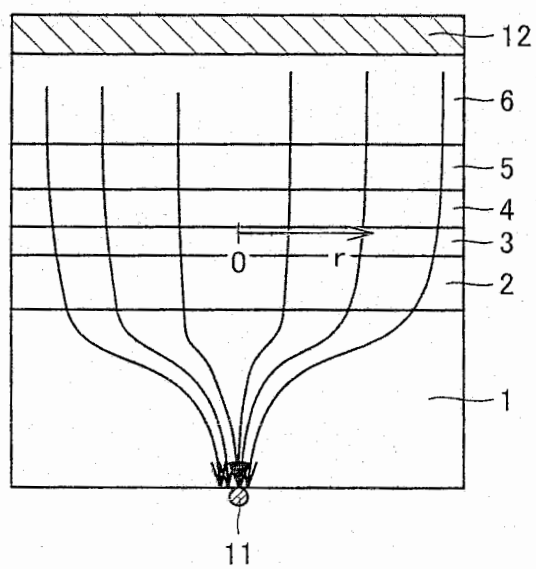


FIG.19

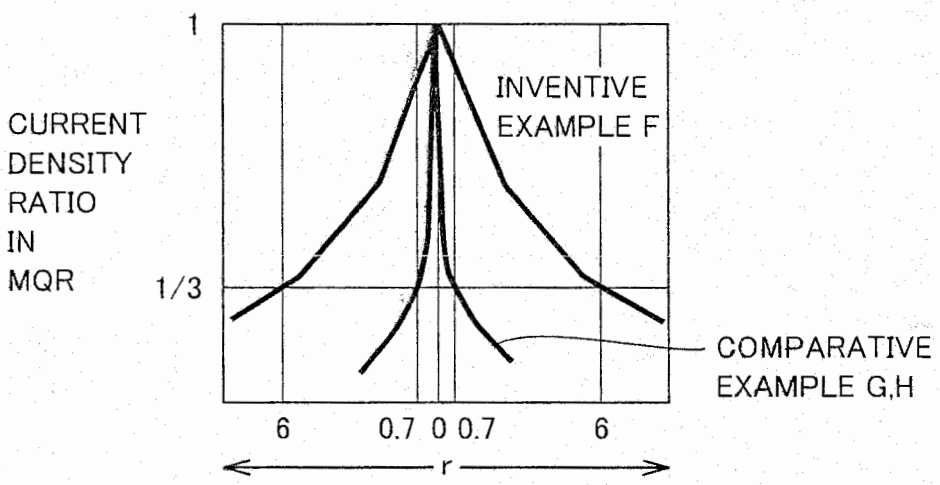

1
1/3
CURRENT DENSITY RATIO IN MQR
INVENTIVE EXAMPLE F
COMPARATIVE EXAMPLE G,H
6
0.7
0
0.7
6
r
DISTANCE r IN THE RADIAL DIRECTION FROM THE CENTER OF ACTIVE LAYER (MQW)(mm)
(CURRENT SPREAD DISTANCE)

FIG.20

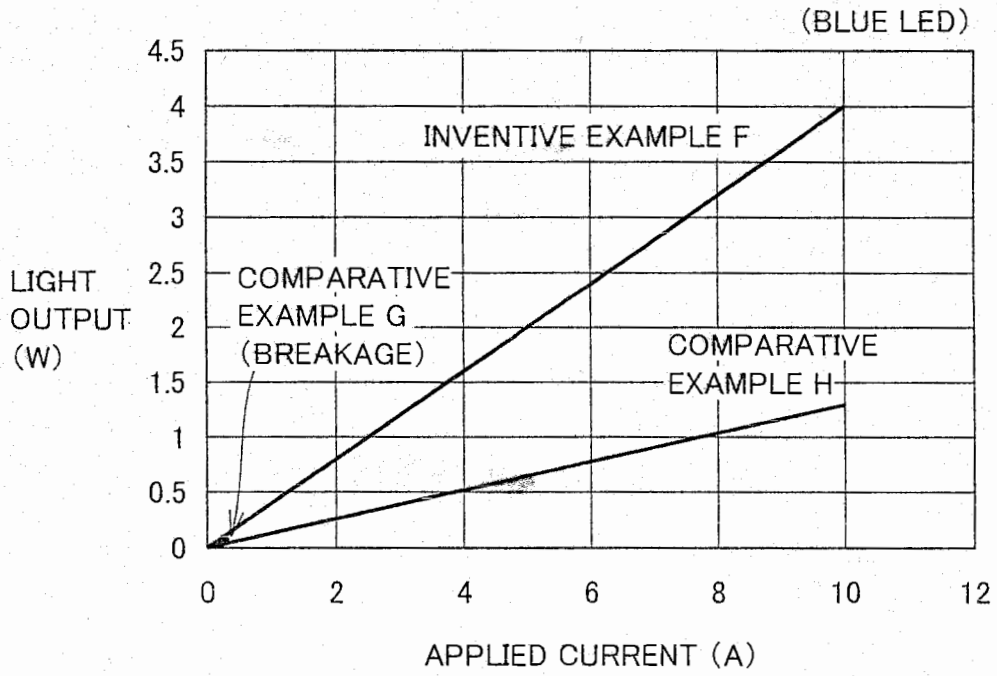

(BLUE LED)
LIGHT OUTPUT (W)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
INVENTIVE EXAMPLE F
COMPARATIVE EXAMPLE G (BREAKAGE)
COMPARATIVE EXAMPLE H
0
2
4
6
8
10
12
APPLIED CURRENT (A)

FIG.21

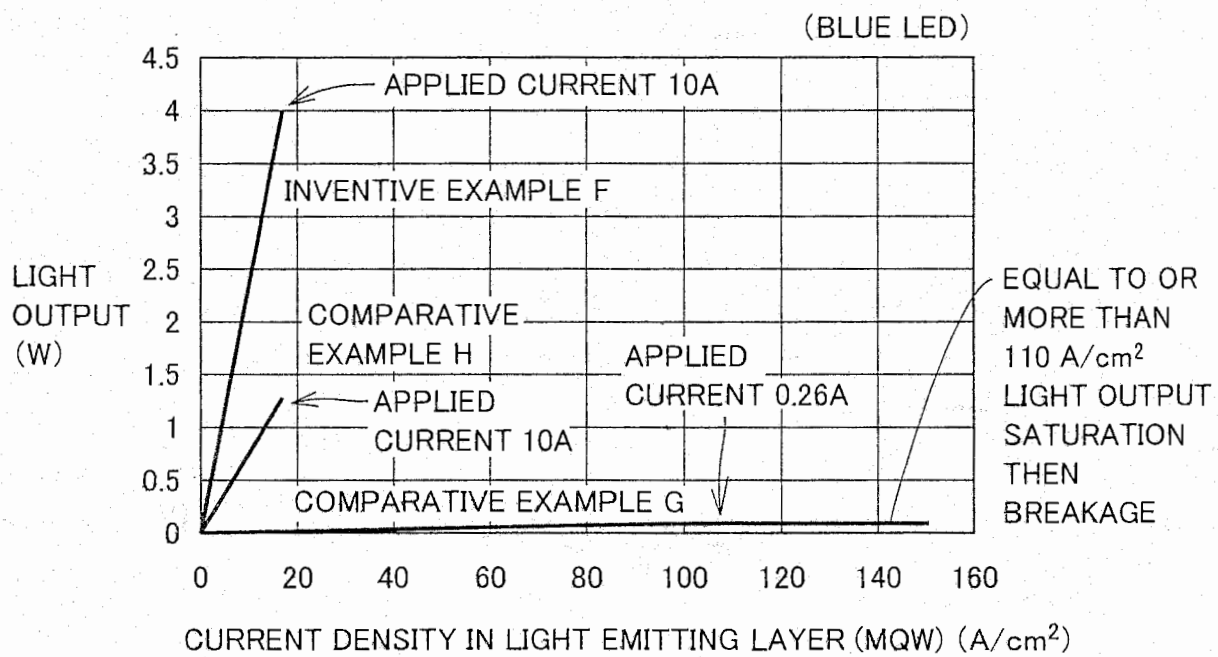

(BLUE LED)
LIGHT OUTPUT (W)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
APPLIED CURRENT 10A
INVENTIVE EXAMPLE F
COMPARATIVE EXAMPLE H
APPLIED CURRENT 10A
APPLIED CURRENT 0.26A
COMPARATIVE EXAMPLE G
EQUAL TO OR MORE THAN 110 A/cm2 LIGHT OUTPUT SATURATION THEN BREAKAGE
0
20
40
60
80
100
120
140
160
CURRENT DENSITY IN LIGHT EMITTING LAYER (MQW) (A/cm2)

FIG.22

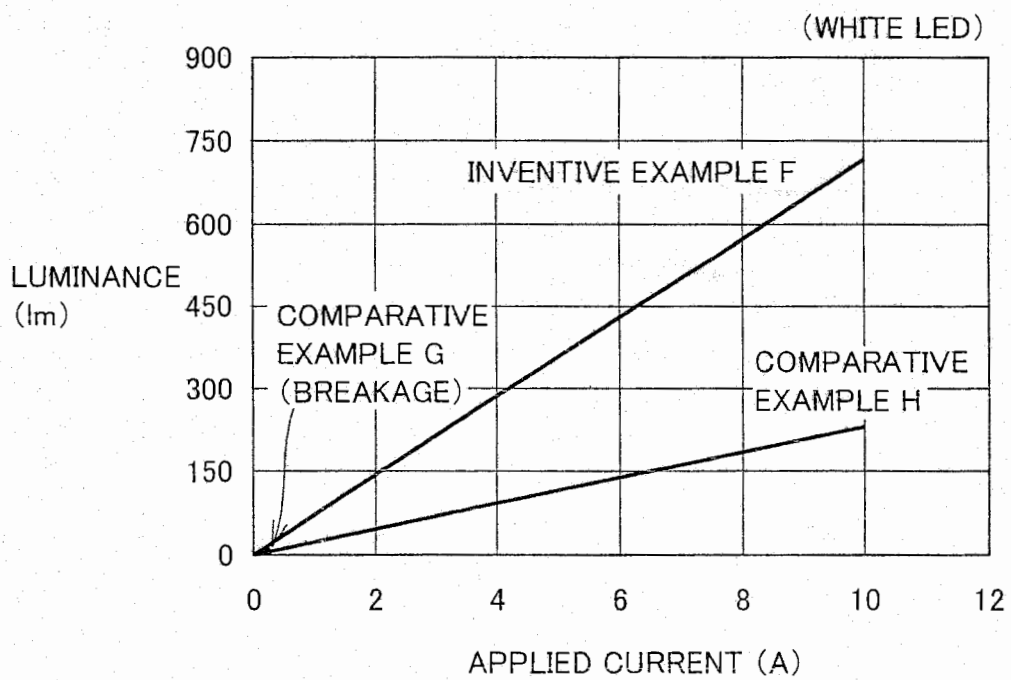

(WHITE LED)
LUMINANCE (lm)
900
750
600
450
300
150
0
INVENTIVE EXAMPLE F
COMPARATIVE EXAMPLE G (BREAKAGE)
COMPARATIVE EXAMPLE H
0
2
4
6
8
10
12
APPLIED CURRENT (A)

FIG.23

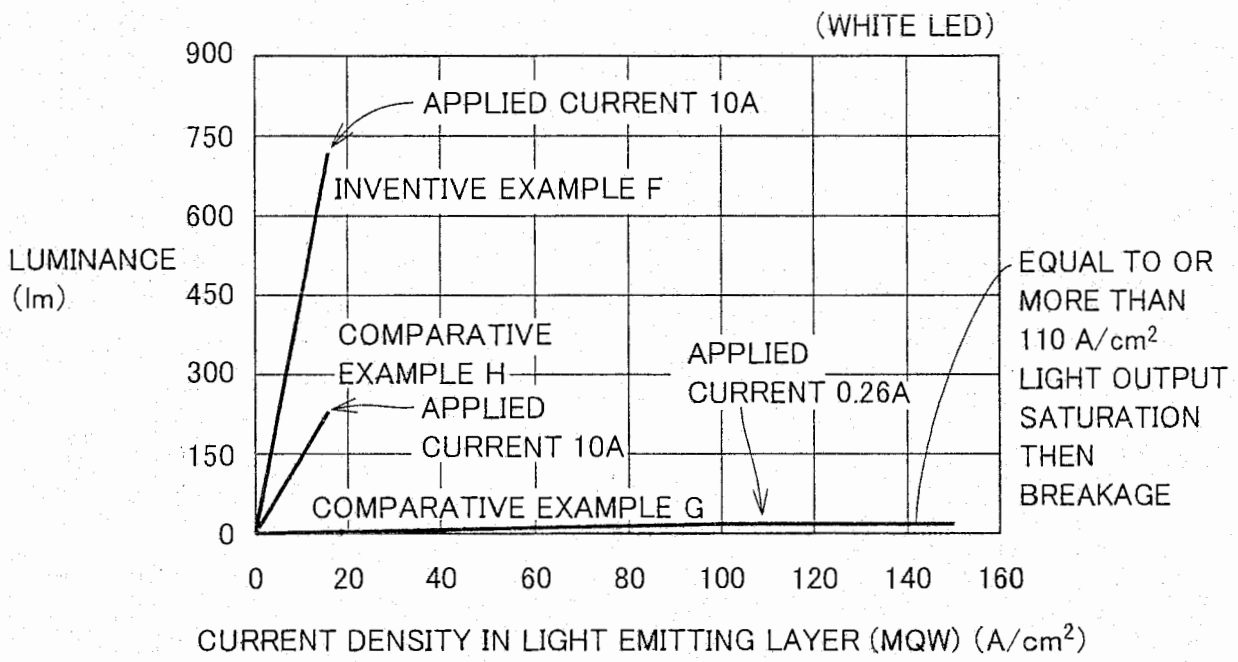

(WHITE LED)
900
750
600
450
300
150
0
LUMINANCE
(lm)
APPLIED CURRENT 10A
INVENTIVE EXAMPLE F
COMPARATIVE
EXAMPLE H
APPLIED
CURRENT 10A
COMPARATIVE EXAMPLE G
APPLIED
CURRENT 0.26A
EQUAL TO OR
MORE THAN
110 A/cm2
LIGHT OUTPUT
SATURATION
THEN
BREAKAGE
0
20
40
60
80
100
120
140
160
CURRENT DENSITY IN LIGHT EMITTING LAYER (MQW) (A/cm2)

FIG.24

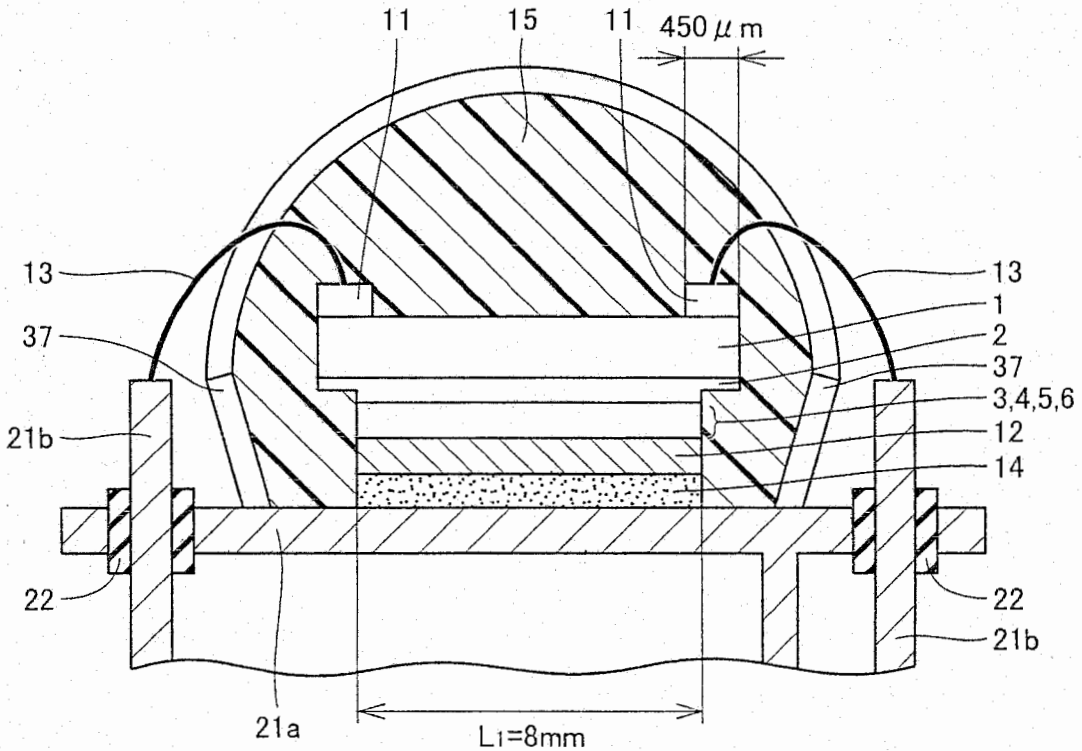

11
15
11
450 μm
13
37
21b
22
21a
L1=8mm
13
1
2
37
3,4,5,6
12
14
22
21b

FIG.25

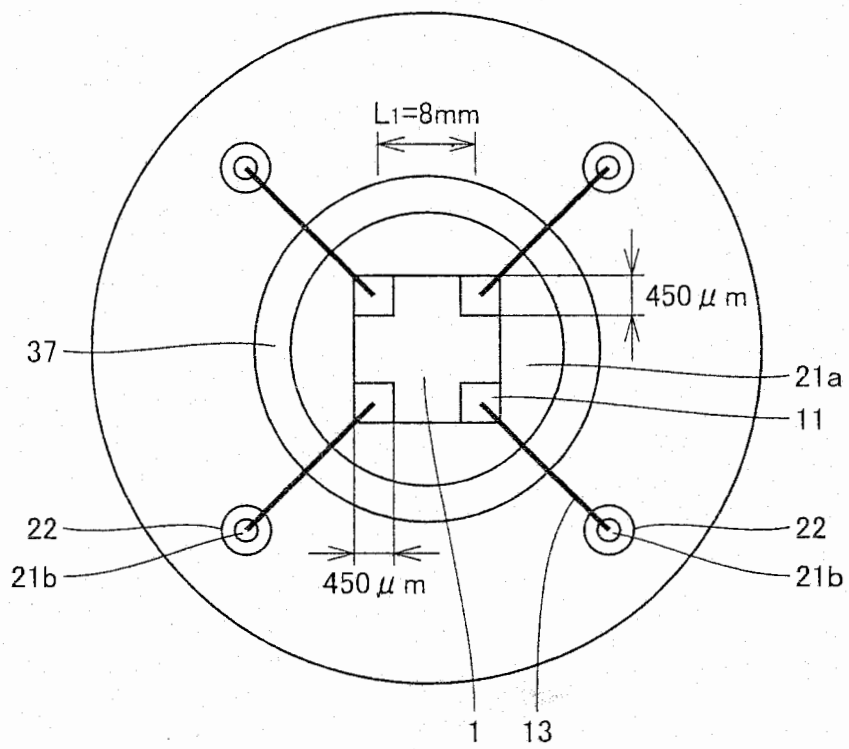


FIG.26

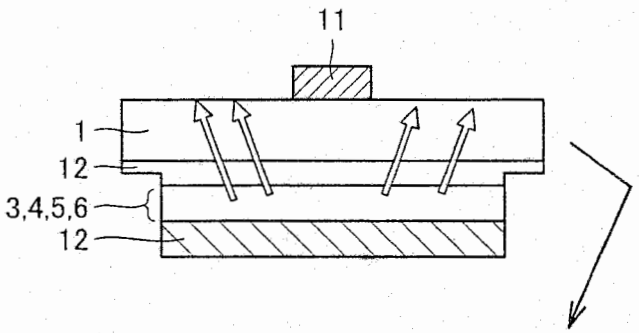


FIG.27

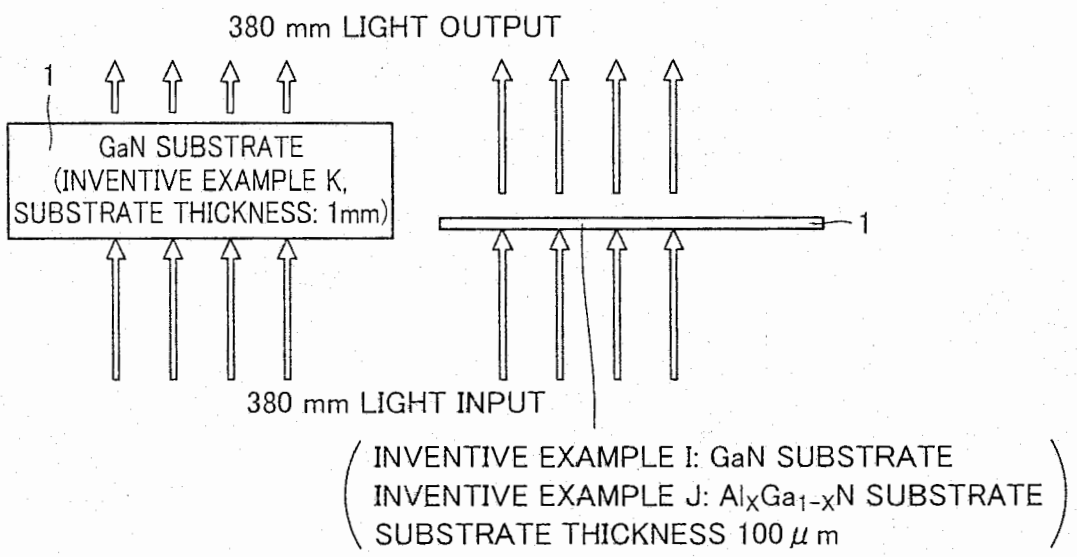

380 mm LIGHT OUTPUT
1
GaN SUBSTRATE
(INVENTIVE EXAMPLE K,
SUBSTRATE THICKNESS: 1mm)
1
380 mm LIGHT INPUT
INVENTIVE EXAMPLE I: GaN SUBSTRATE
INVENTIVE EXAMPLE J: AlXGa1-XN SUBSTRATE
SUBSTRATE THICKNESS 100 μm

FIG.28

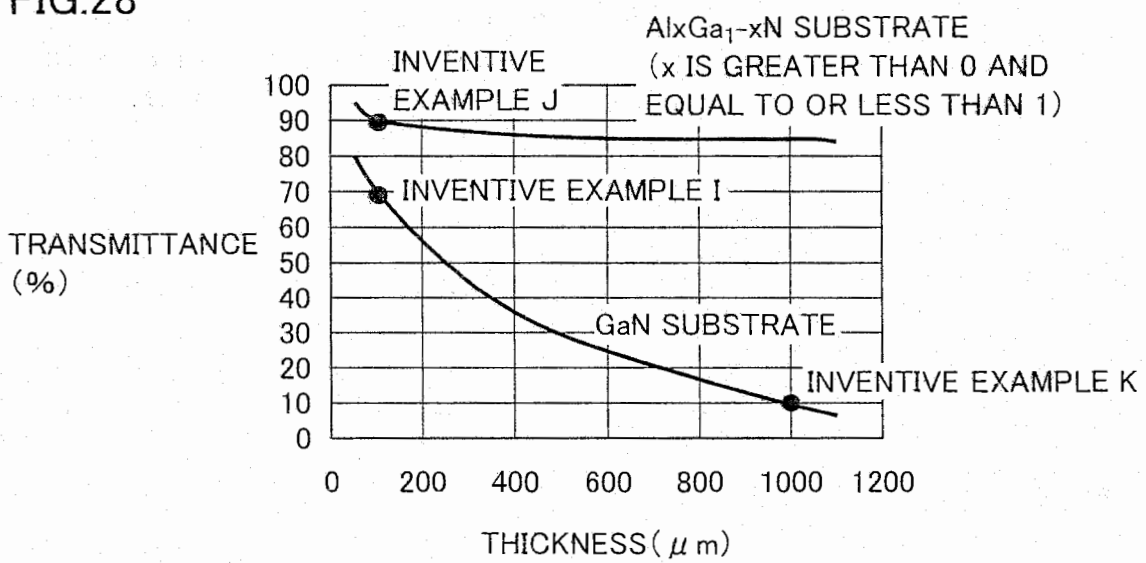

AlxGa1-xN SUBSTRATE
(x IS GREATER THAN 0 AND
EQUAL TO OR LESS THAN 1)
INVENTIVE
EXAMPLE J
INVENTIVE EXAMPLE I
GaN SUBSTRATE
INVENTIVE EXAMPLE K
TRANSMITTANCE
(%)
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
THICKNESS(μm)

FIG.29

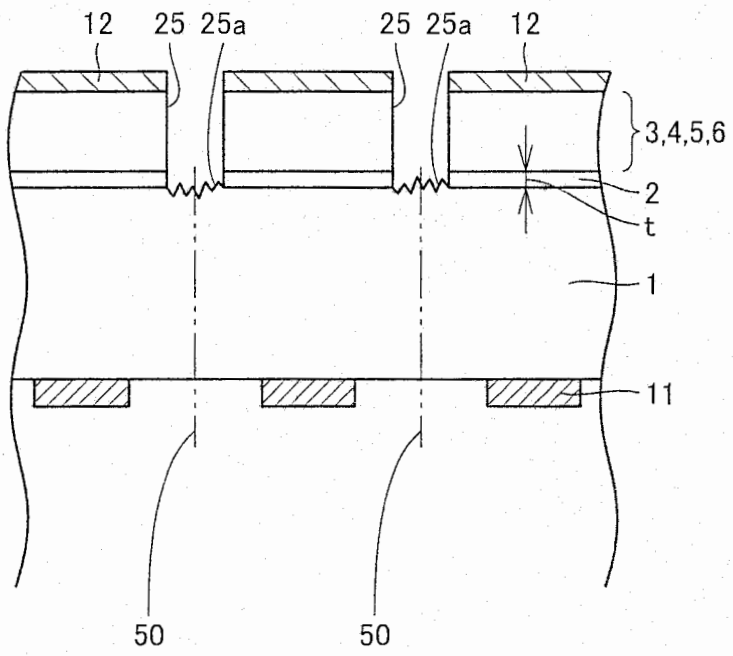

12
25
25a
25
25a
12
3,4,5,6
2
t
1
11
50
50

FIG.30

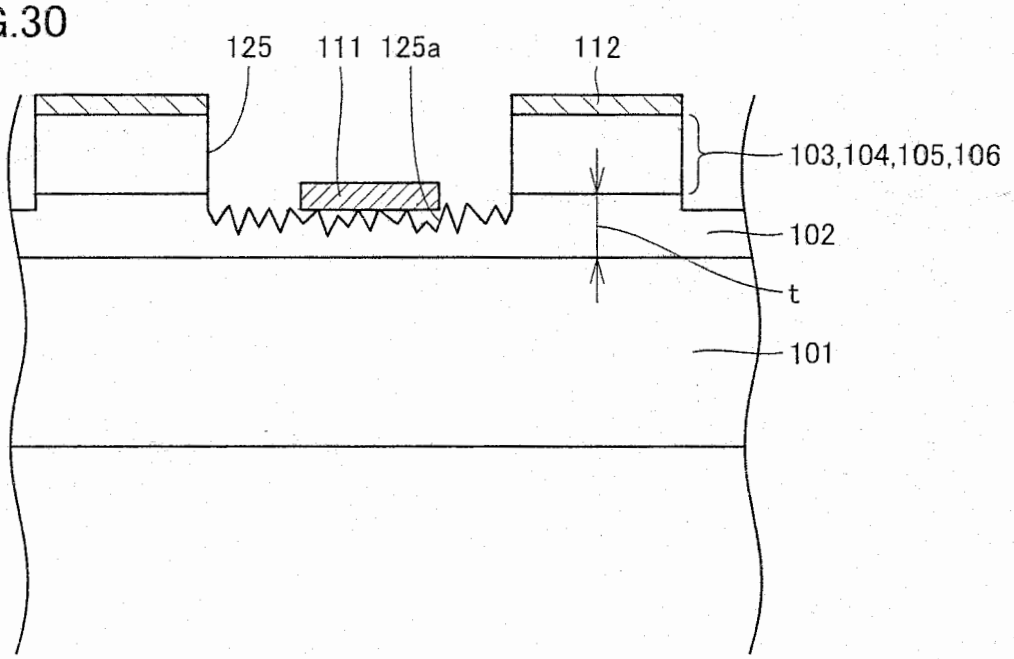

125
111
125a
112
103,104,105,106
102
t
101

FIG.31

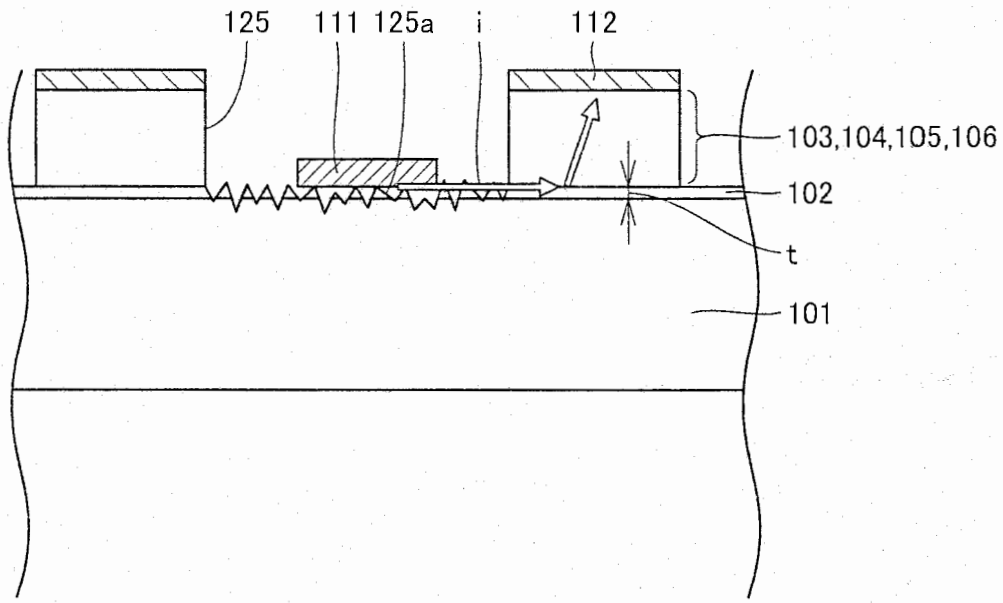

125
111
125a
i
112
103,104,105,106
102
t
101

FIG.32

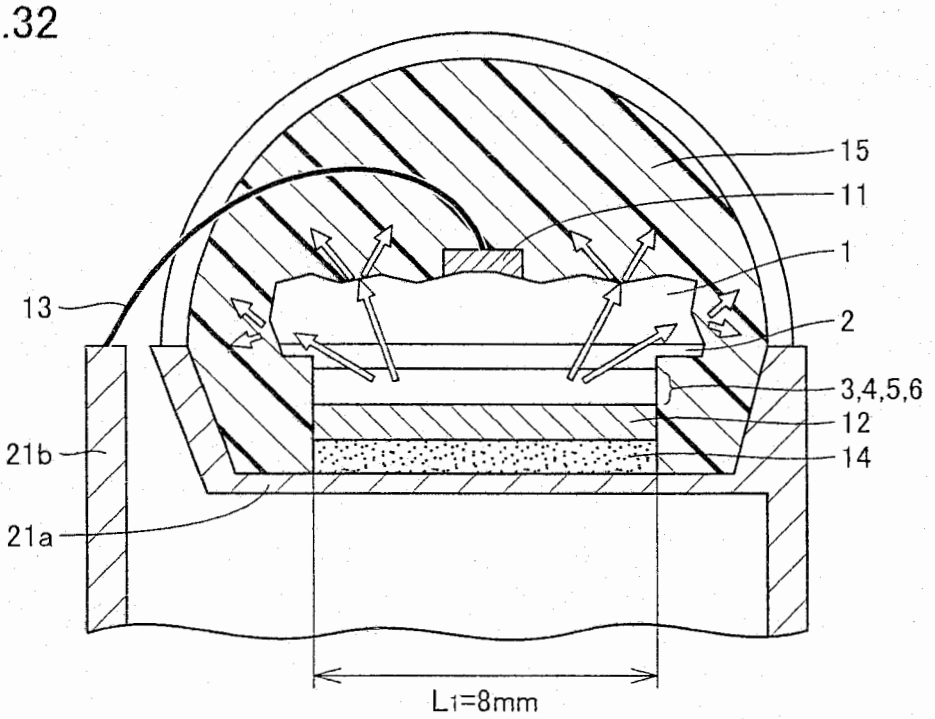

15
11
1
13
2
3,4,5,6
12
21b
14
21a
L1=8mm

FIG.33

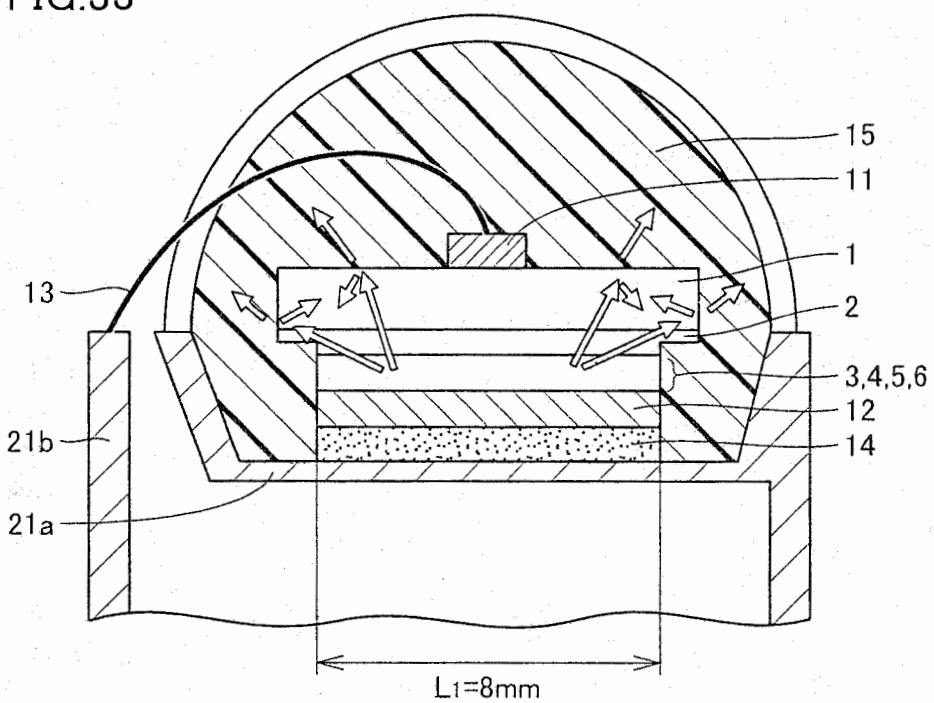


FIG.34

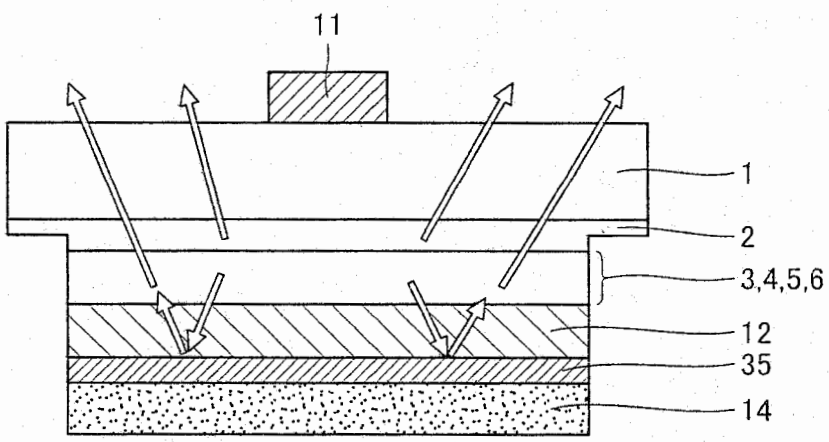


FIG.35

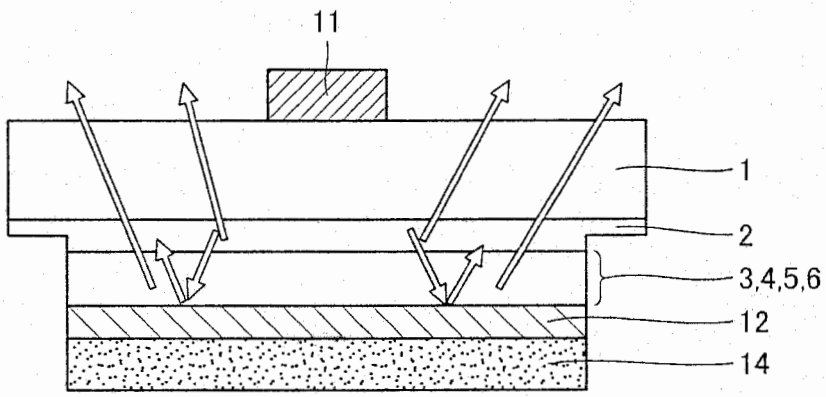


FIG.36

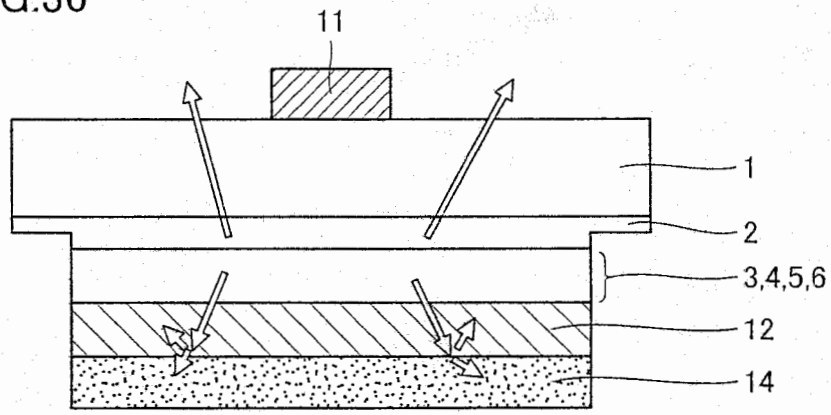


FIG.37

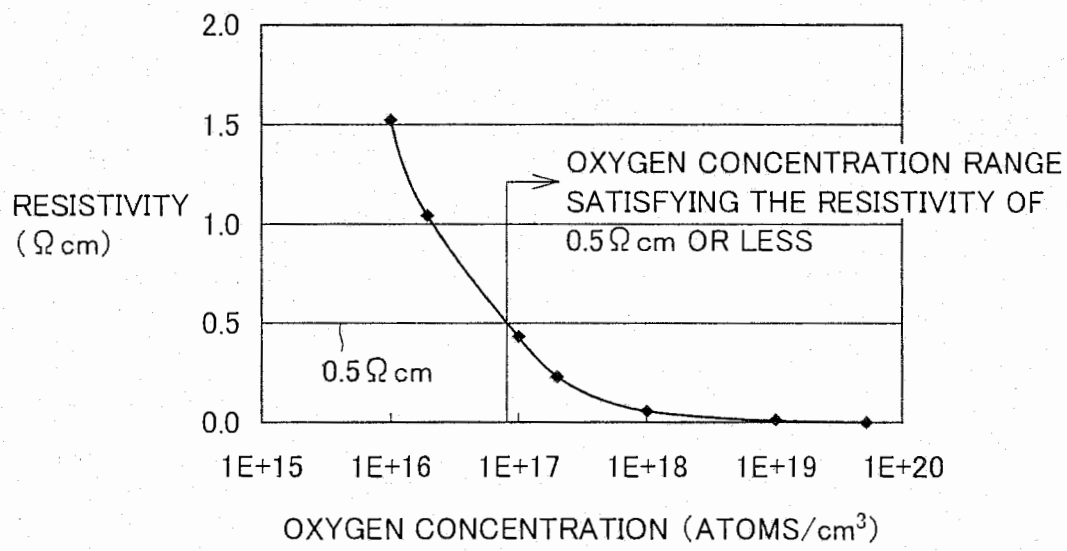

2.0
1.5
1.0
0.5
0.0
RESISTIVITY
(Ω cm)
OXYGEN CONCENTRATION RANGE
SATISFYING THE RESISTIVITY OF
0.5Ω cm OR LESS
0.5Ω cm
1E+15
1E+16
1E+17
1E+18
1E+19
1E+20
OXYGEN CONCENTRATION (ATOMS/cm3)

FIG.38

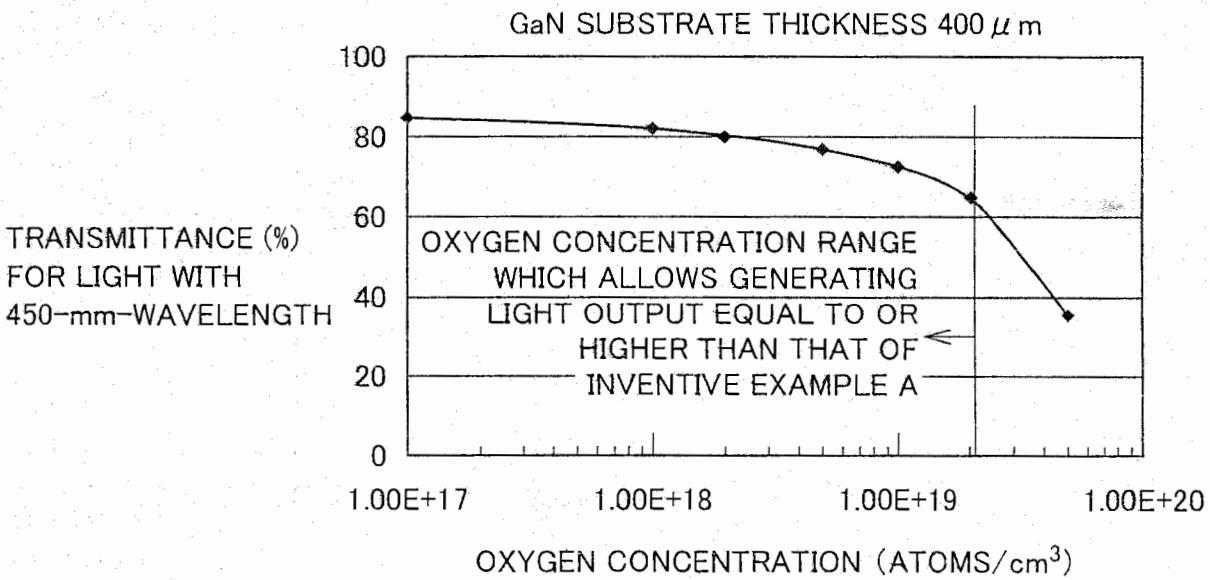

GaN SUBSTRATE THICKNESS 400 μm
100
80
60
40
20
0
TRANSMITTANCE (%)
FOR LIGHT WITH
450-mm-WAVELENGTH
OXYGEN CONCENTRATION RANGE
WHICH ALLOWS GENERATING
LIGHT OUTPUT EQUAL TO OR
HIGHER THAN THAT OF
INVENTIVE EXAMPLE A
1.00E+17
1.00E+18
1.00E+19
1.00E+20
OXYGEN CONCENTRATION (ATOMS/cm3)

FIG.39

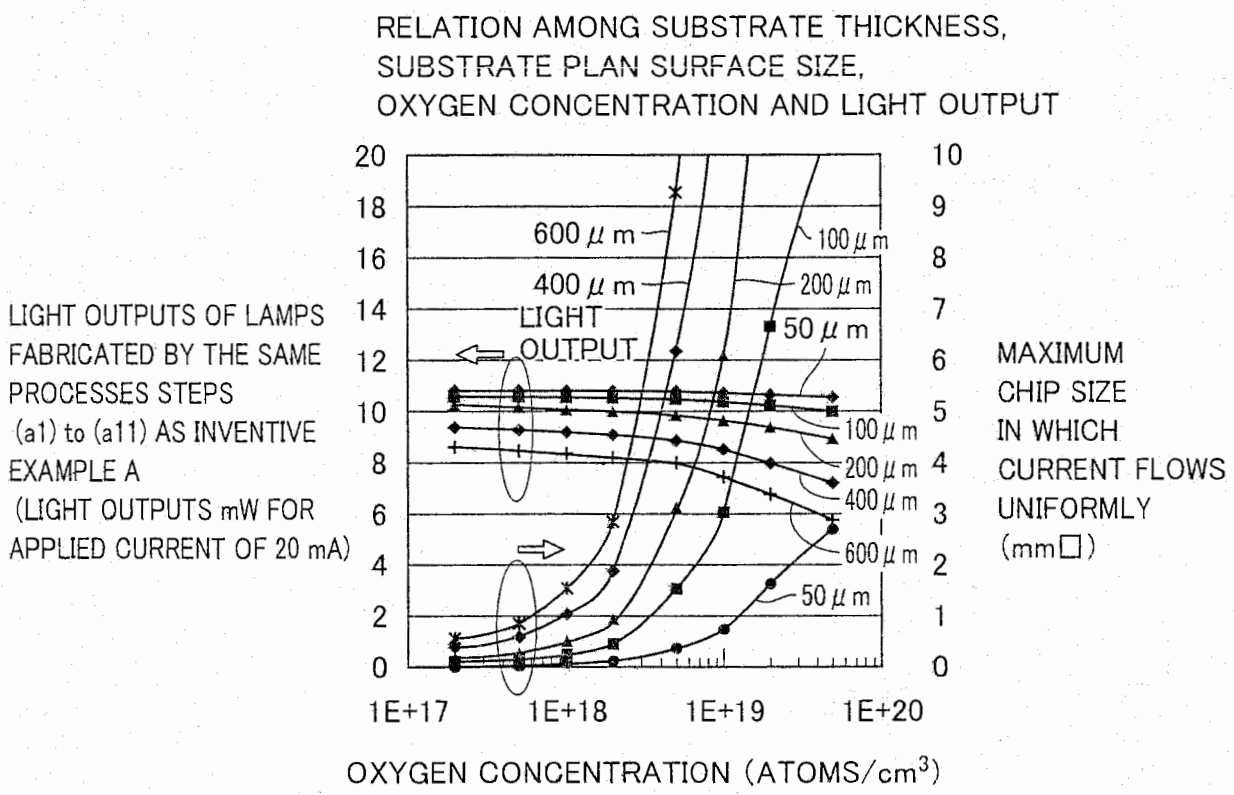

RELATION AMONG SUBSTRATE THICKNESS,
SUBSTRATE PLAN SURFACE SIZE,
OXYGEN CONCENTRATION AND LIGHT OUTPUT
LIGHT OUTPUTS OF LAMPS FABRICATED BY THE SAME PROCESSES STEPS (a1) to (a11) AS INVENTIVE EXAMPLE A (LIGHT OUTPUTS mW FOR APPLIED CURRENT OF 20 mA)
MAXIMUM CHIP SIZE IN WHICH CURRENT FLOWS UNIFORMLY (mm□)
600 μm
400 μm
100 μm
200 μm
50 μm
LIGHT OUTPUT
100 μm
200 μm
400 μm
600 μm
50 μm
20
18
16
14
12
10
8
6
4
2
0
10
9
8
7
6
5
4
3
2
1
0
1E+17
1E+18
1E+19
1E+20
OXYGEN CONCENTRATION (ATOMS/cm3)

FIG.40

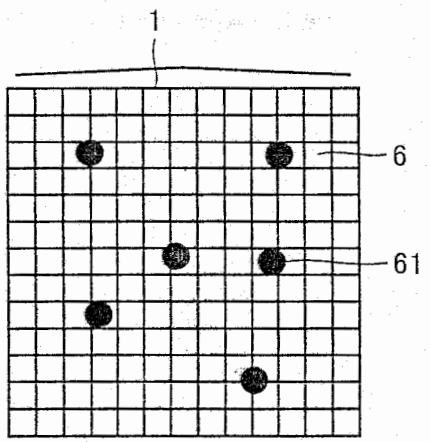

1
6
61

FIG.41

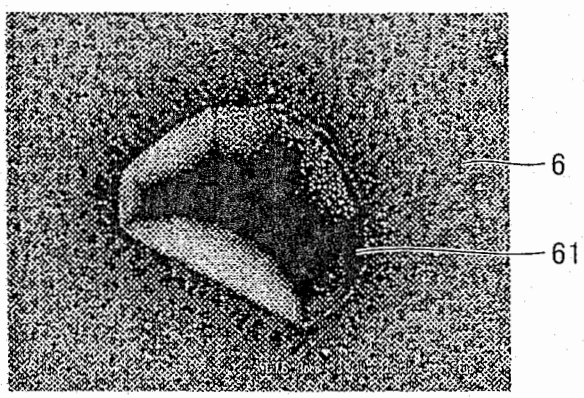
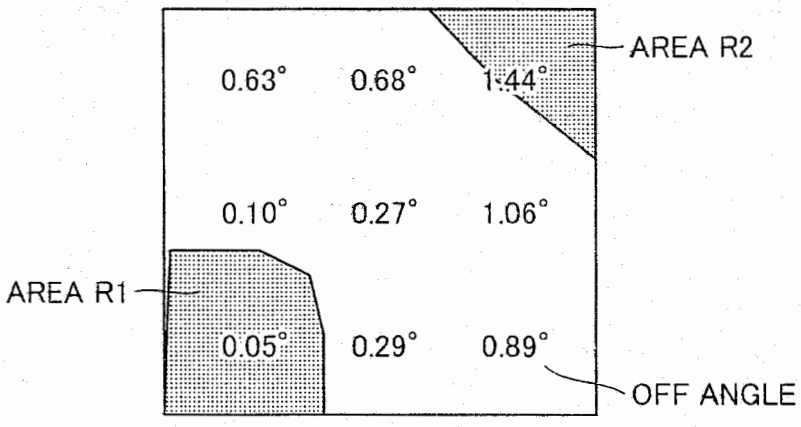


FIG.42



EXEMPLARY OFF ANGLE DISTRIBUTION
IN GaN SUBSTRATE (20mm × 20mm)

FIG.43

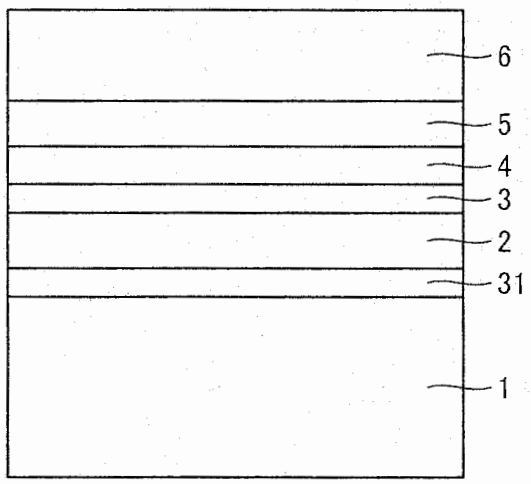

6
5
4
3
2
31
1

FIG.44

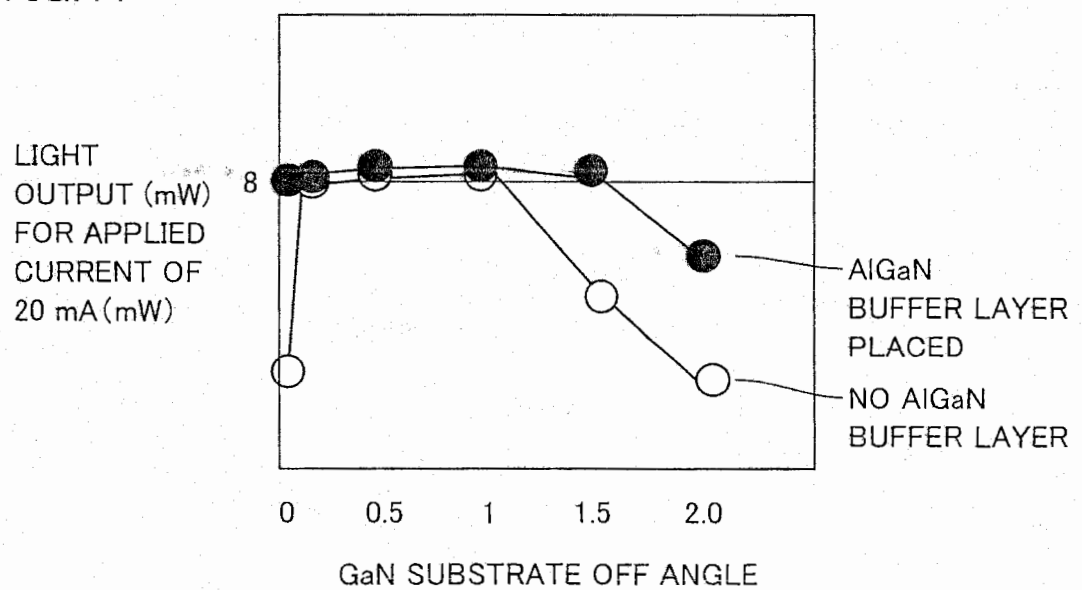

LIGHT OUTPUT (mW) FOR APPLIED CURRENT OF 20 mA (mW)
8
AlGaN BUFFER LAYER PLACED
NO AlGaN BUFFER LAYER
0
0.5
1
1.5
2.0
GaN SUBSTRATE OFF ANGLE

FIG.45

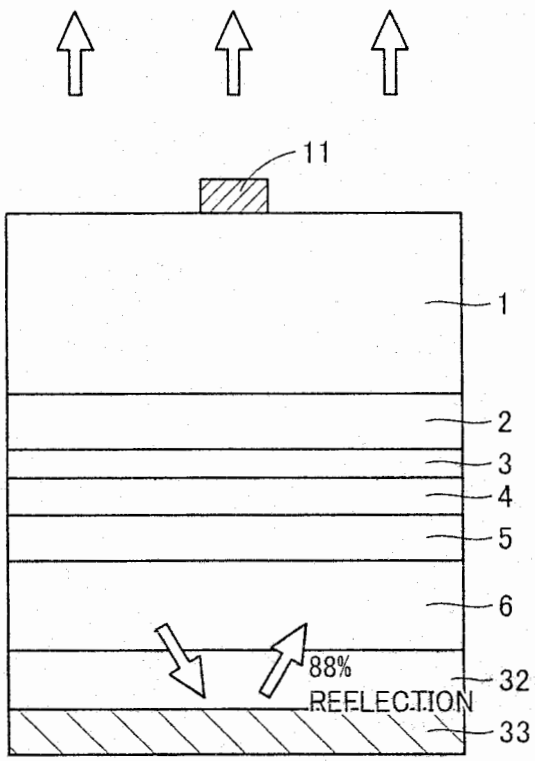


FIG.46

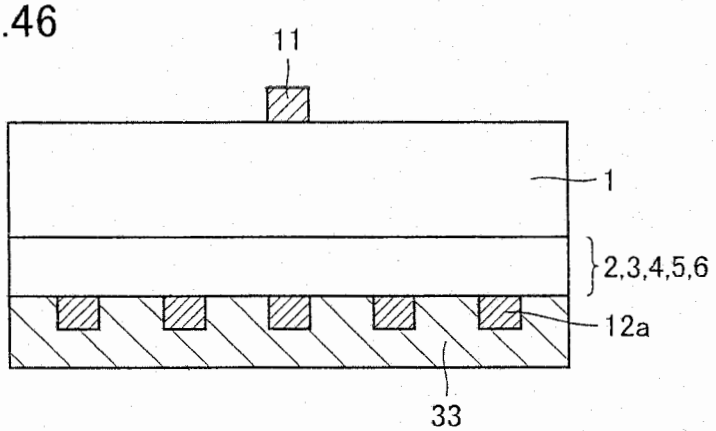


FIG.47

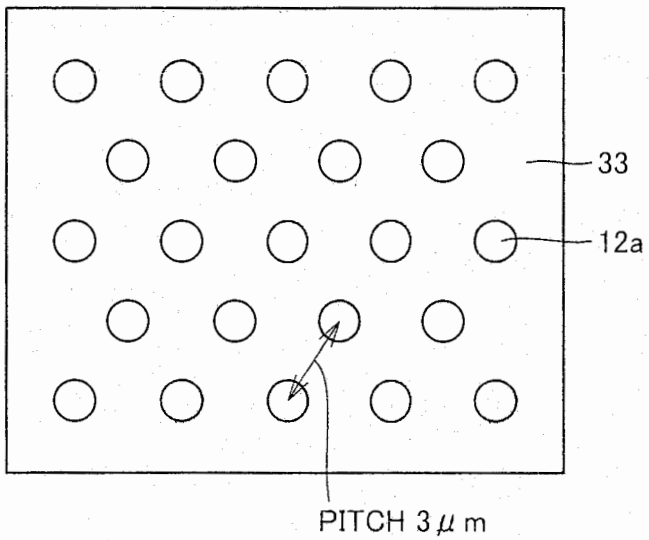


FIG.48

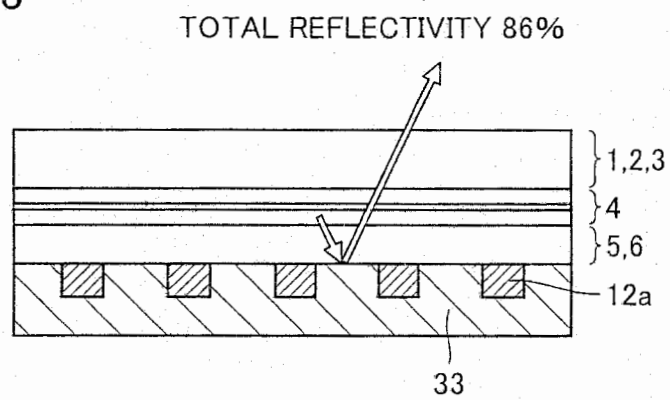


FIG.49

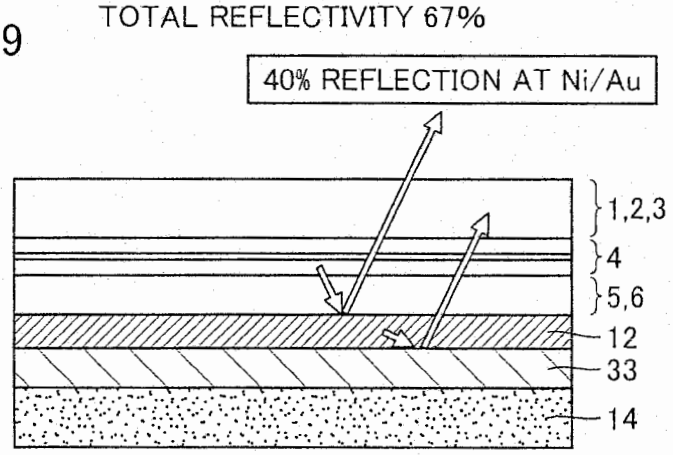


FIG.50

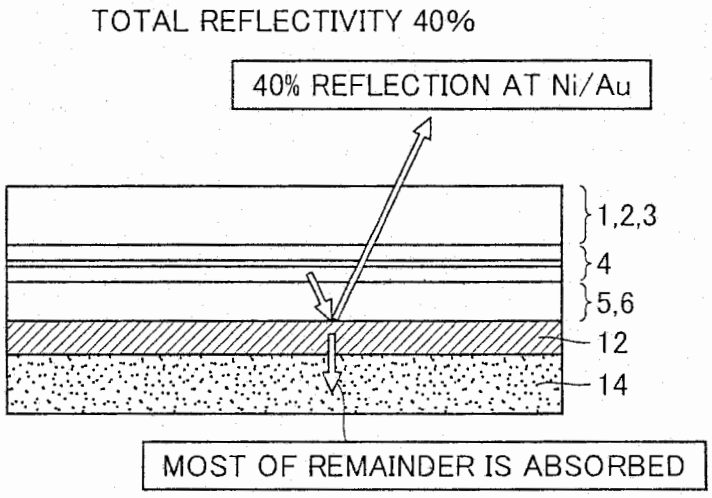


FIG.51

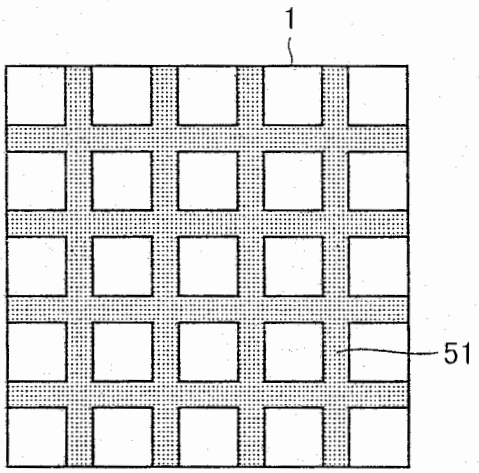


FIG.52

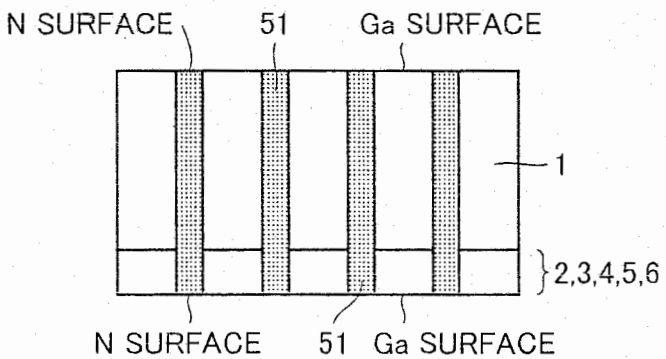


FIG.53

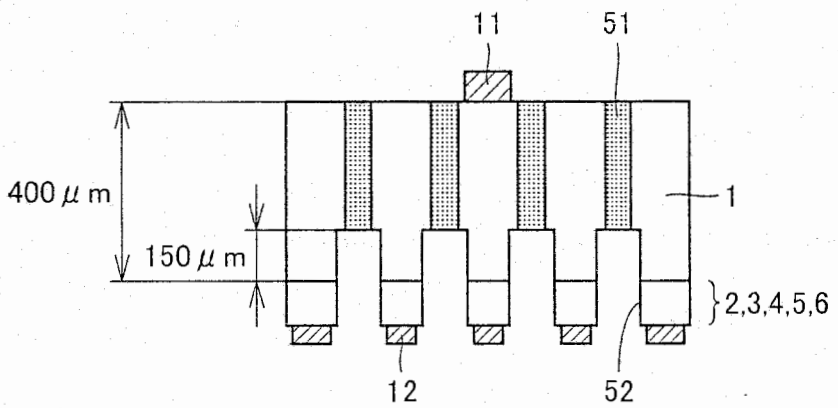


FIG.54

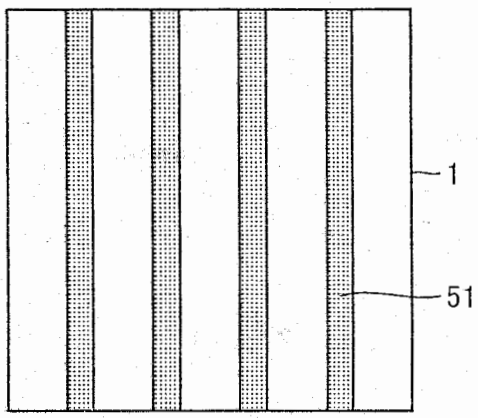


FIG.55

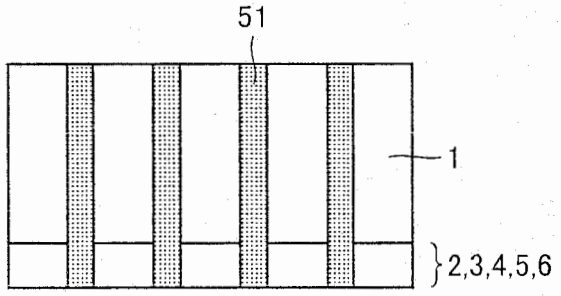


FIG.56

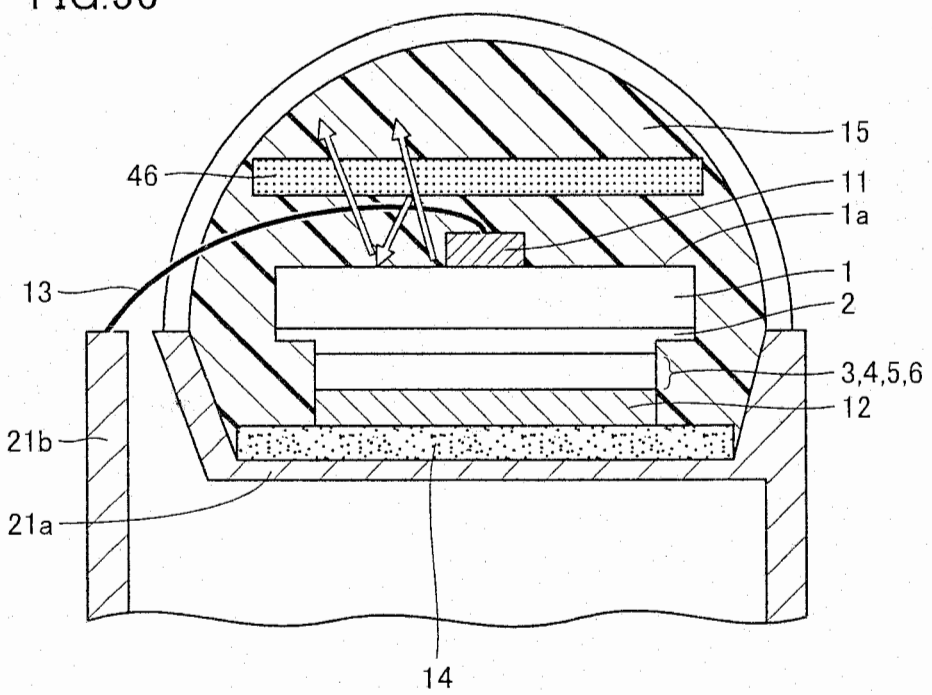

15
46
11
1a
13
1
2
3,4,5,6
12
21b
21a
14

FIG.57

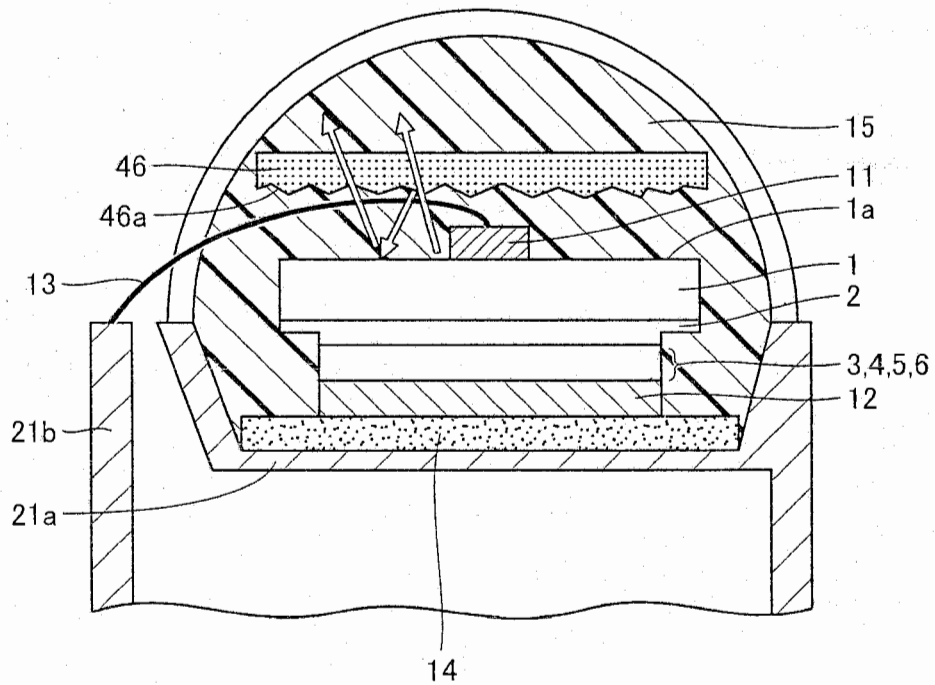

15
46
11
46a
1a
13
1
2
3,4,5,6
12
21b
21a
14

FIG.58

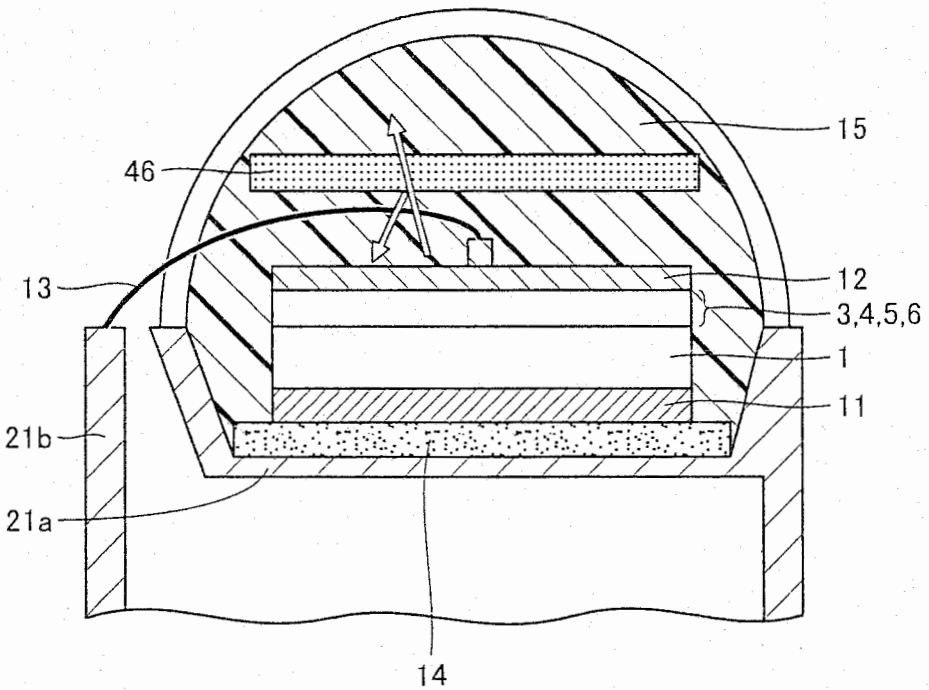
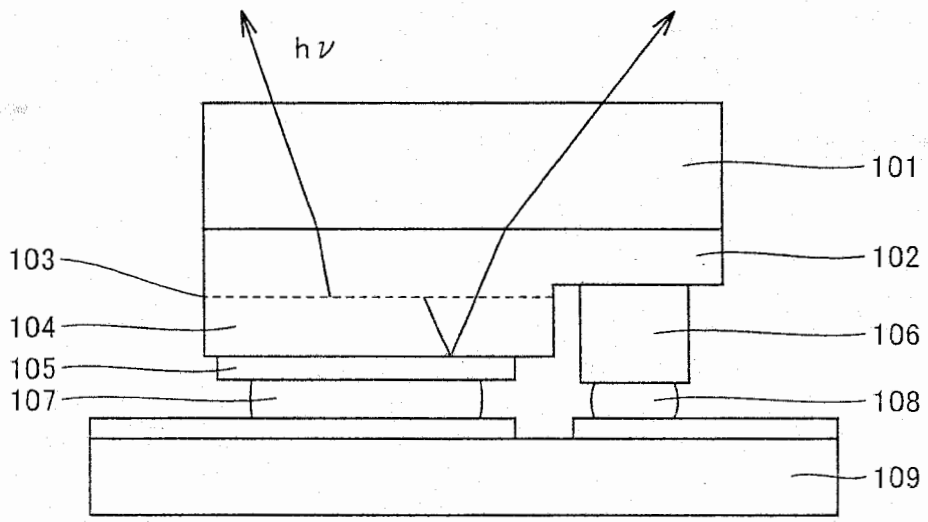

15
46
13
12
3,4,5,6
1
11
21b
21a
14

FIG.59


hν
101
103
102
104
106
105
107
108
109