FIG.1

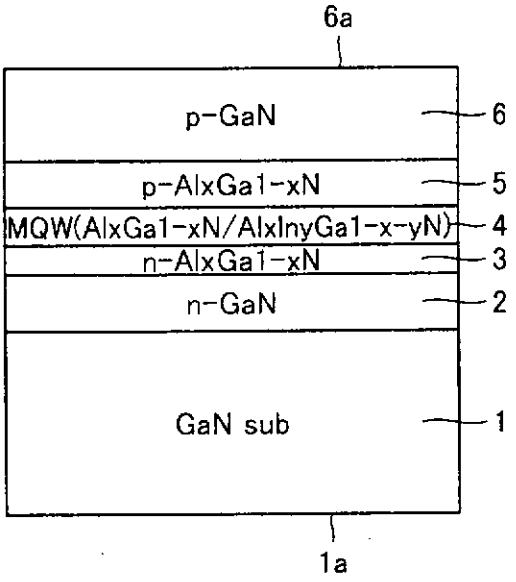

6a
p-GaN
6
p-AlxGa1-xN
5
MQW(AlxGa1-xN/AlxInyGa1-x-yN)
4
n-AlxGa1-xN
3
n-GaN
2
GaN sub
1
1a

FIG.2

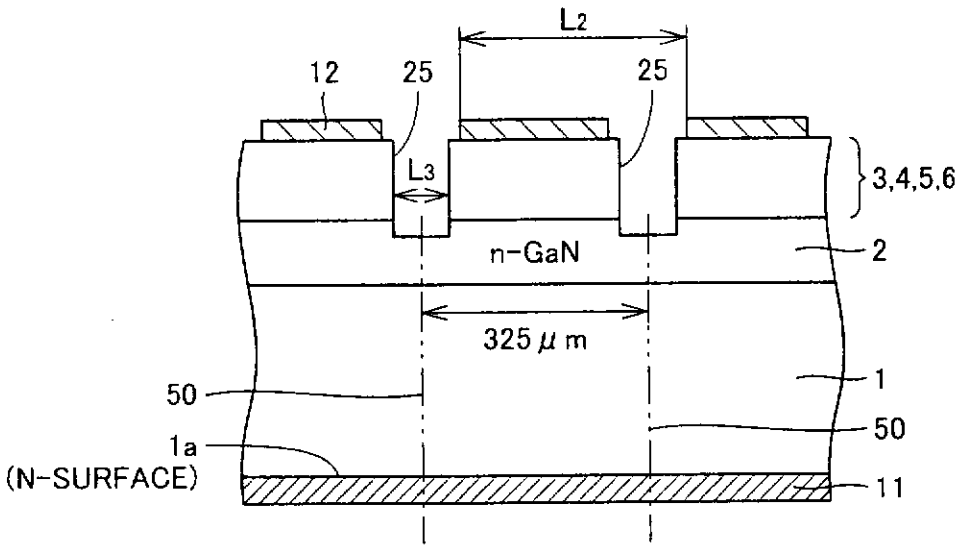

L2
12
25
25
L3
3,4,5,6
n-GaN
2
325 μm
50
1
50
1a
(N-SURFACE)
11

FIG.3

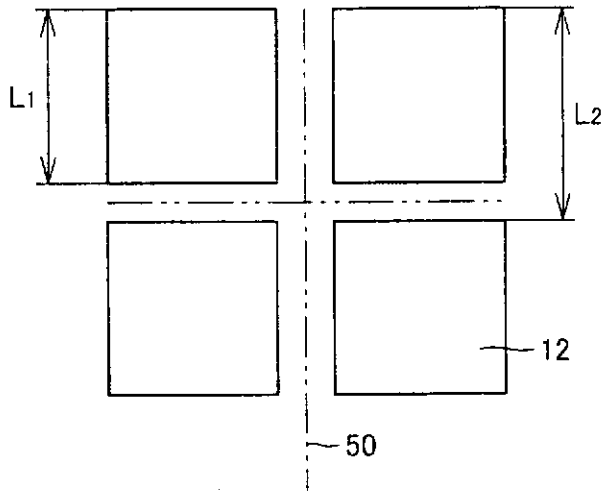


FIG.4

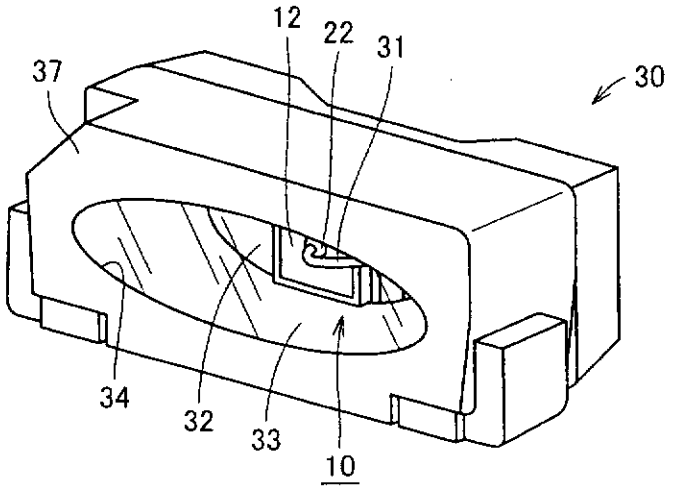


FIG.5

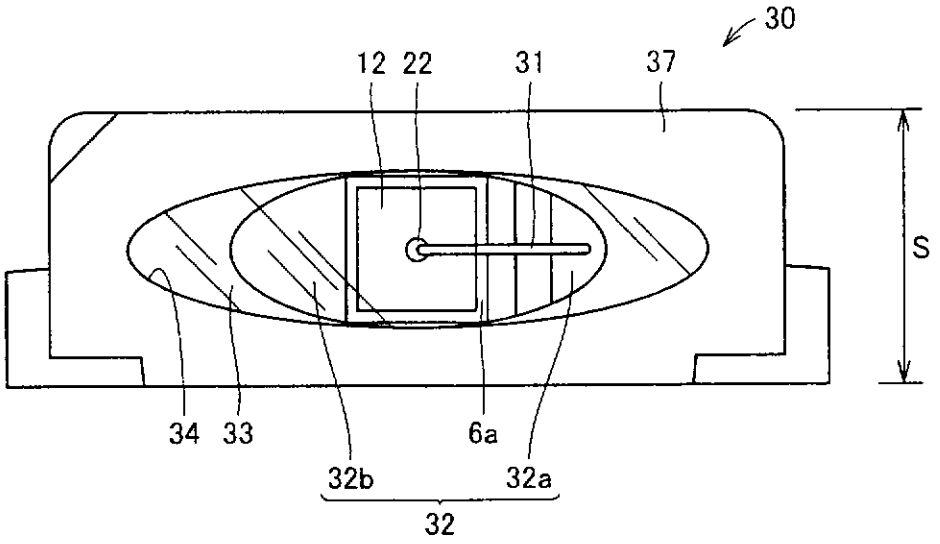

30
12
22
31
37
S
34
33
6a
32b
32a
32

FIG.6

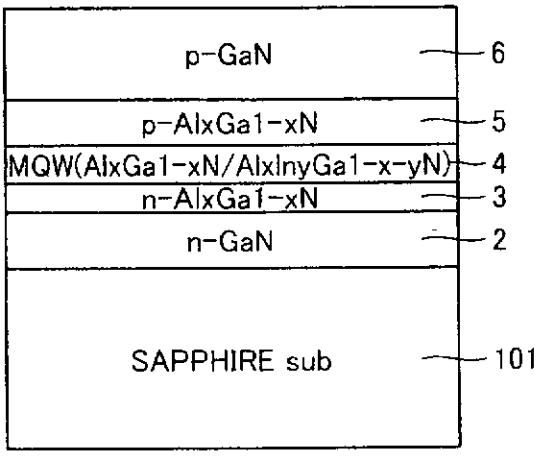

p-GaN
6
p-AlxGa1-xN
5
MQW(AlxGa1-xN/AlxInyGa1-x-yN)
4
n-AlxGa1-xN
3
n-GaN
2
SAPPHIRE sub
101

FIG.7

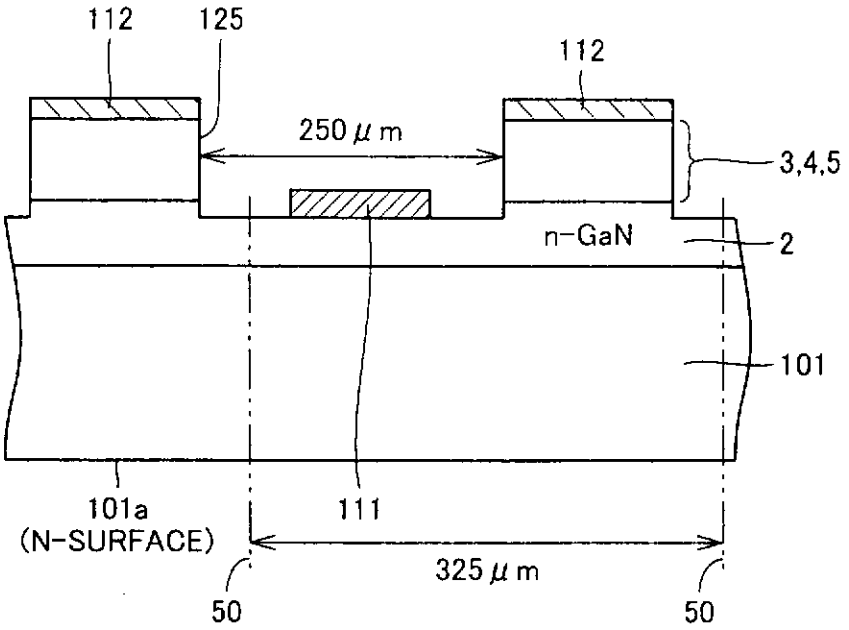

112
125
112
250 μ m
3,4,5
n-GaN
2
101
101a
(N-SURFACE)
111
325 μ m
50
50

FIG.8

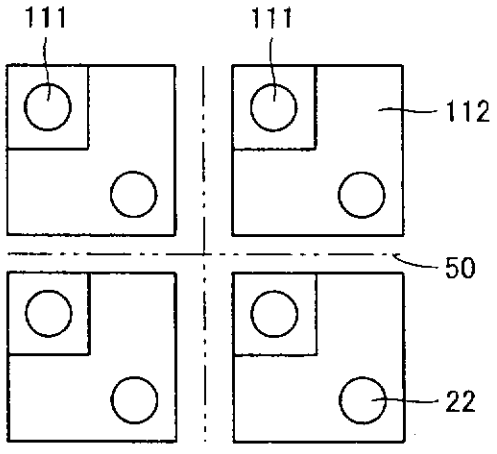

111
111
112
50
22

FIG.9

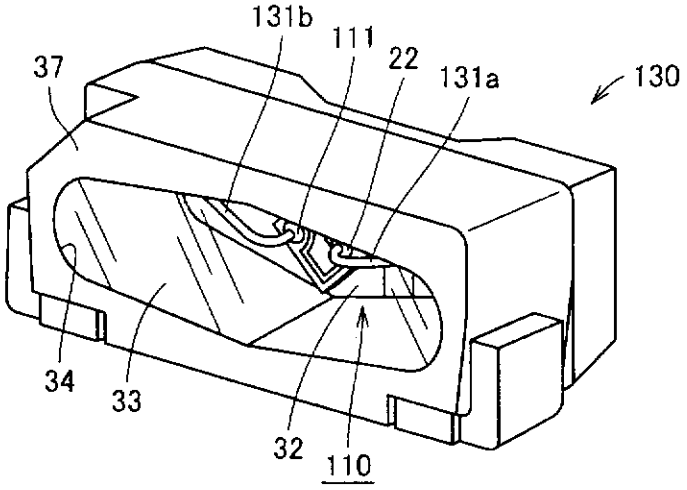

131b
111
22
131a
130
37
34
33
32
110

FIG.10

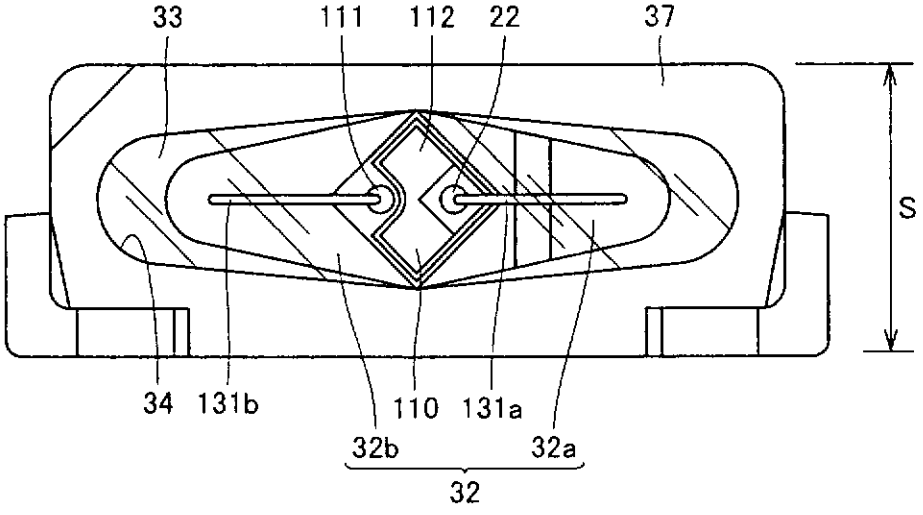

33
111
112
22
37
S
34
131b
110
131a
32b
32a
32

FIG.11

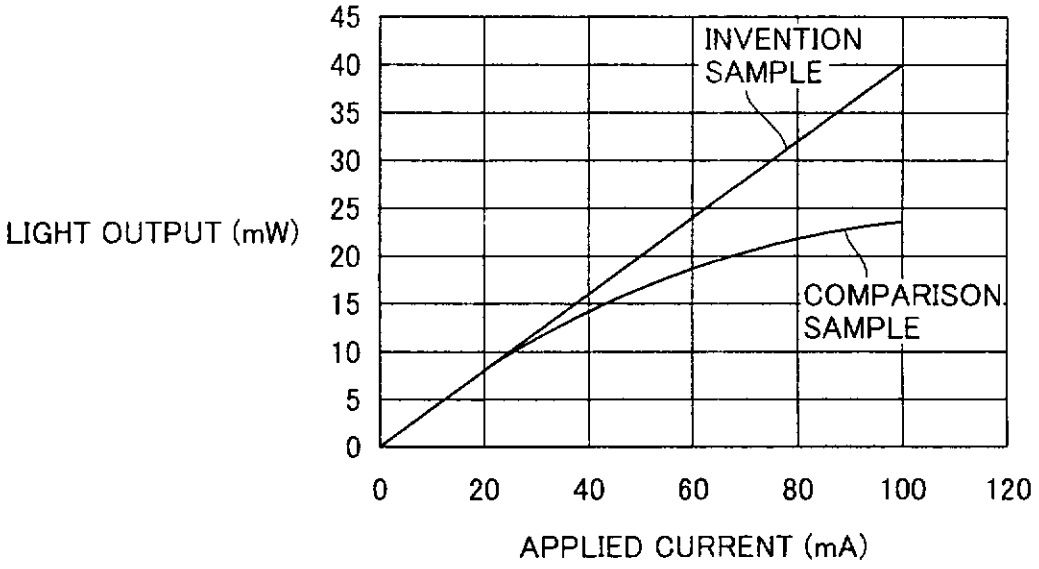

LIGHT OUTPUT (mW)
45
40
35
30
25
20
15
10
5
0
INVENTION SAMPLE
COMPARISON SAMPLE
0
20
40
60
80
100
120
APPLIED CURRENT (mA)

FIG.12

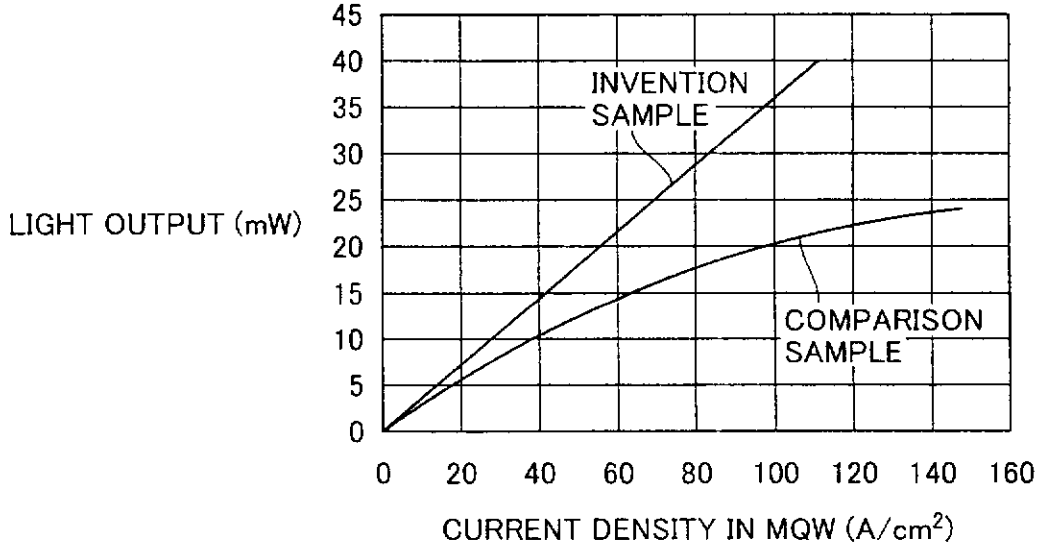

LIGHT OUTPUT (mW)
45
40
35
30
25
20
15
10
5
0
INVENTION SAMPLE
COMPARISON SAMPLE
0
20
40
60
80
100
120
140
160
CURRENT DENSITY IN MQW (A/cm2)

FIG.13

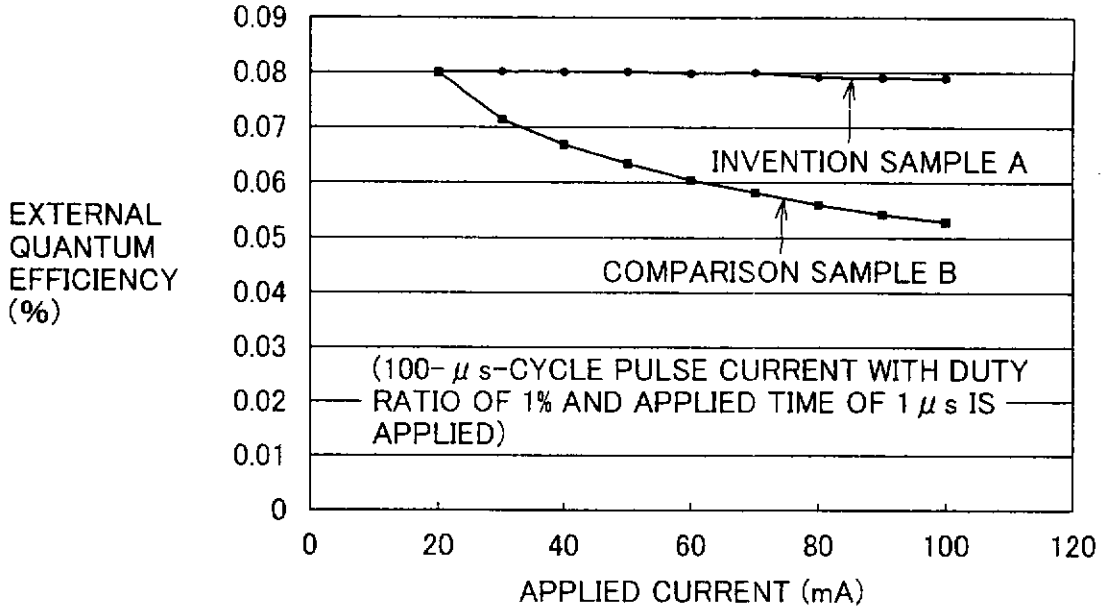

EXTERNAL QUANTUM EFFICIENCY (%)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
INVENTION SAMPLE A
COMPARISON SAMPLE B
(100-μs-CYCLE PULSE CURRENT WITH DUTY RATIO OF 1% AND APPLIED TIME OF 1μs IS APPLIED)
0
20
40
60
80
100
120
APPLIED CURRENT (mA)

FIG.14

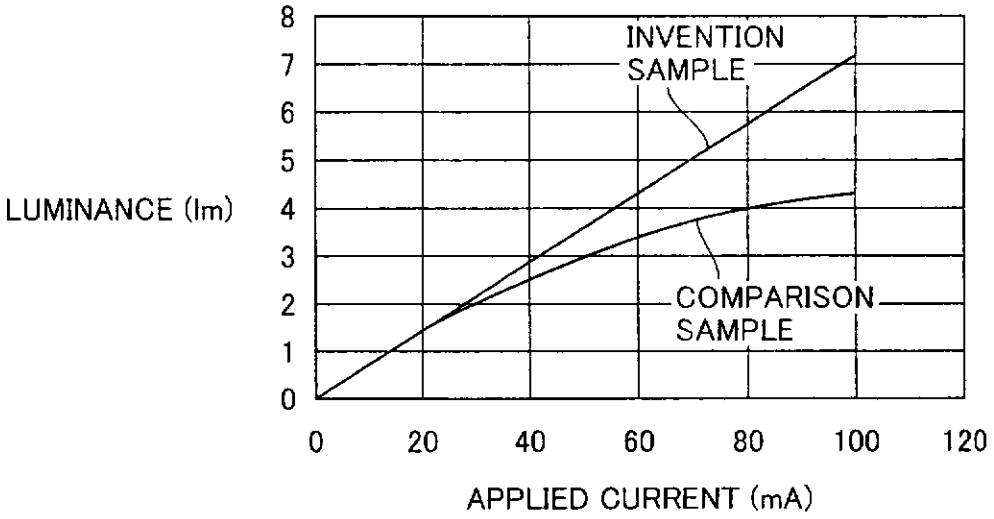

LUMINANCE (lm)
8
7
6
5
4
3
2
1
0
INVENTION SAMPLE
COMPARISON SAMPLE
0
20
40
60
80
100
120
APPLIED CURRENT (mA)

FIG.15

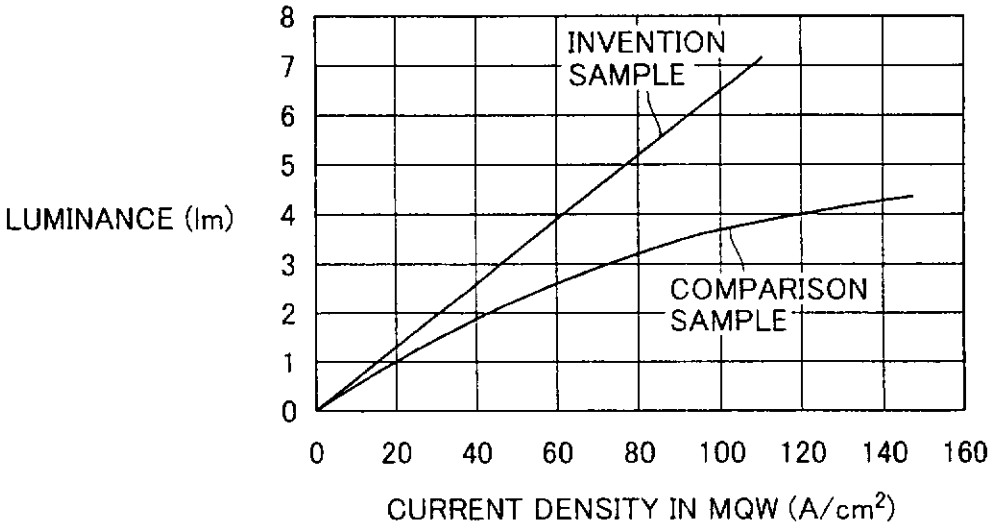

LUMINANCE (lm)
8
7
6
5
4
3
2
1
0
INVENTION SAMPLE
COMPARISON SAMPLE
0
20
40
60
80
100
120
140
160
CURRENT DENSITY IN MQW (A/cm2)

FIG.16

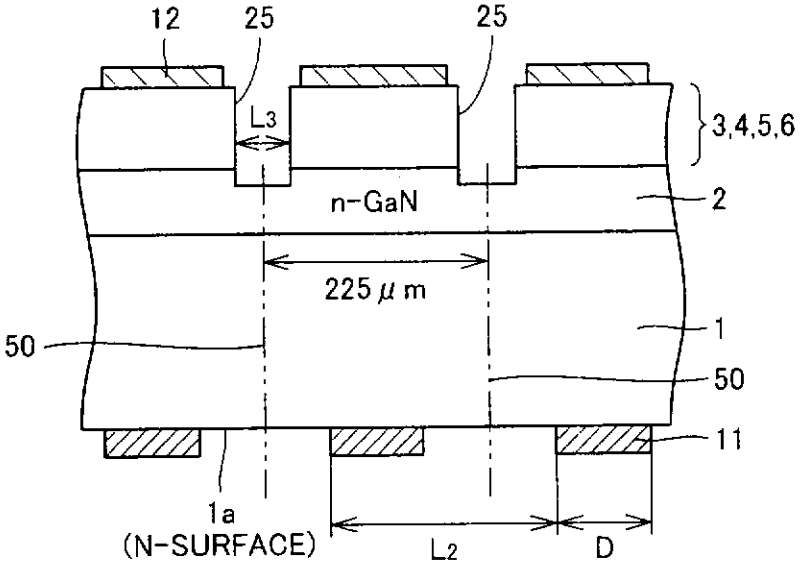

12
25
25
L3
3,4,5,6
n-GaN
2
225 μ m
1
50
50
11
1a
(N-SURFACE)
L2
D

FIG.17

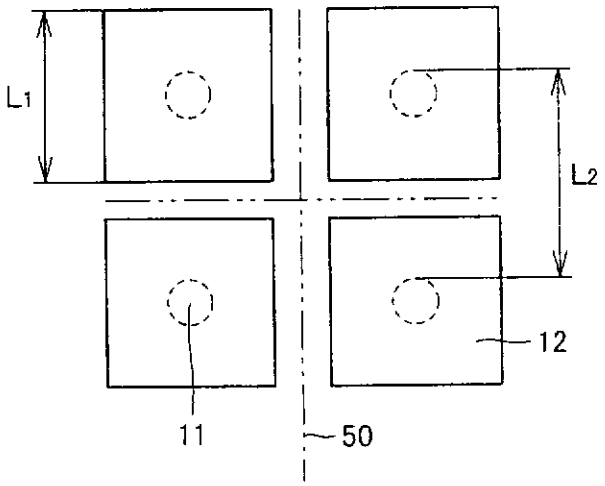

L1
L2
12
11
50

FIG.18

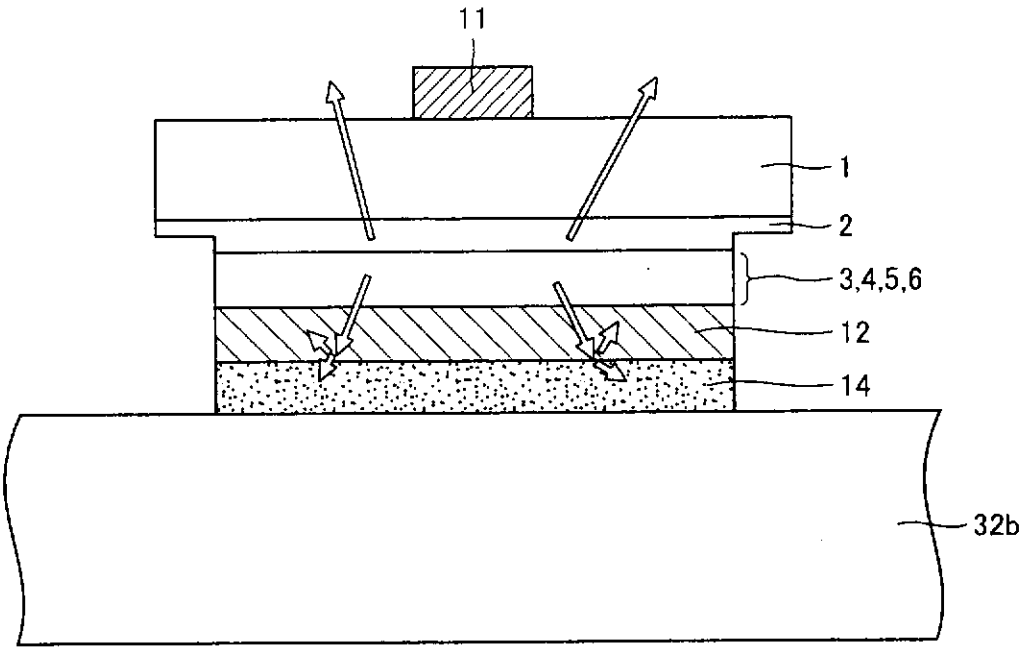


FIG.19

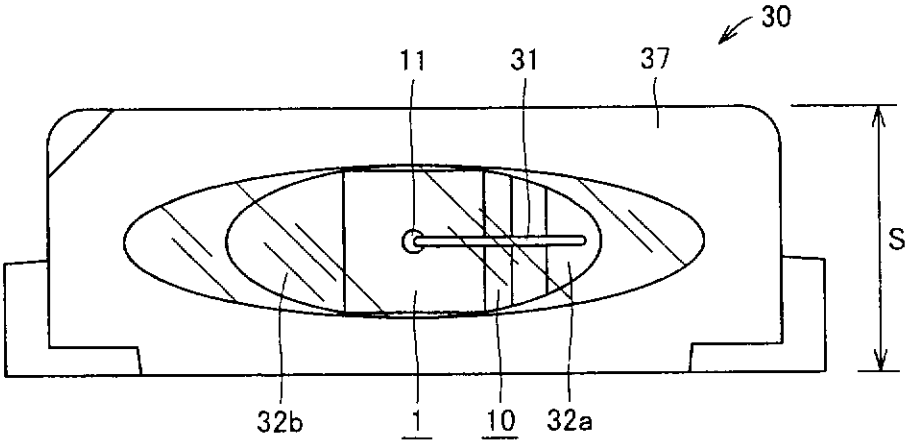


FIG.20

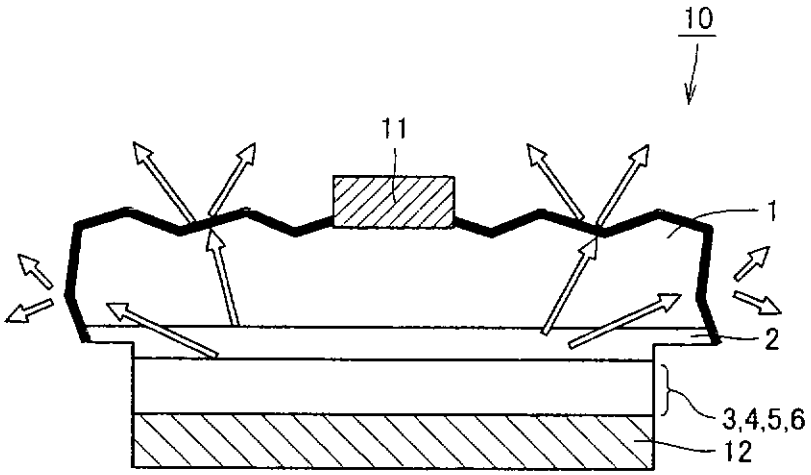


FIG.21

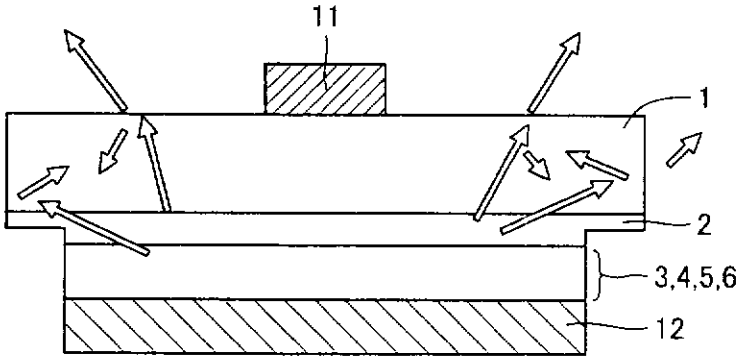


FIG.22

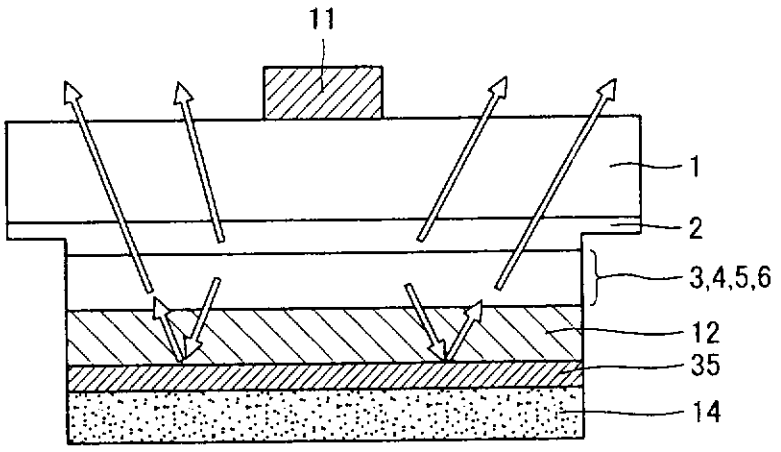


FIG.23

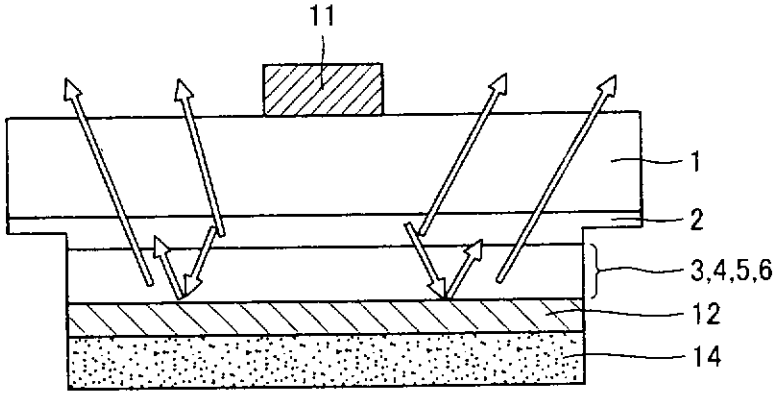


FIG.24A

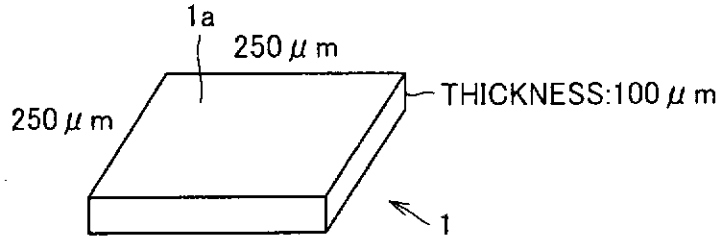


FIG.24B

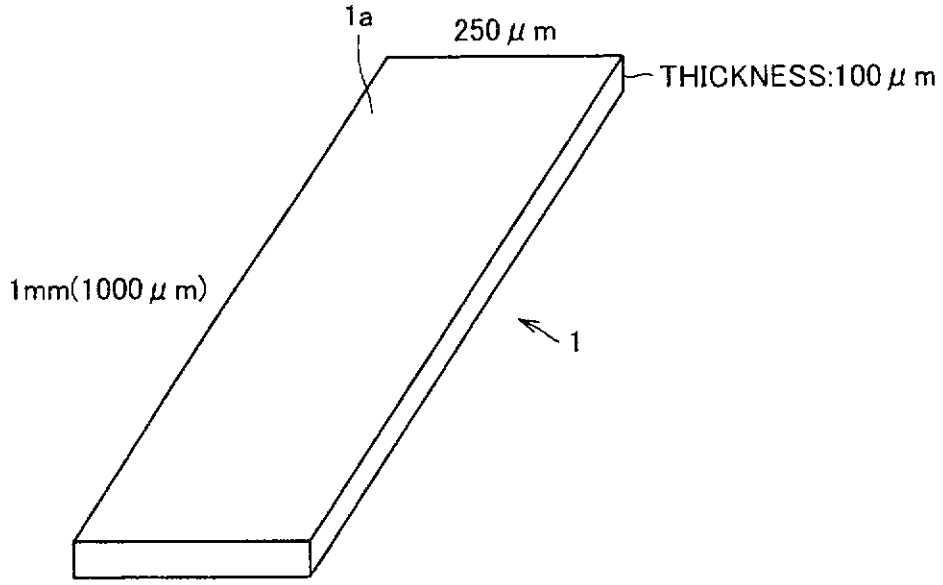


FIG.25

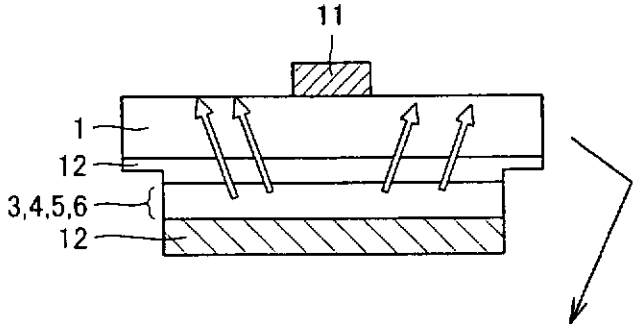


FIG.26

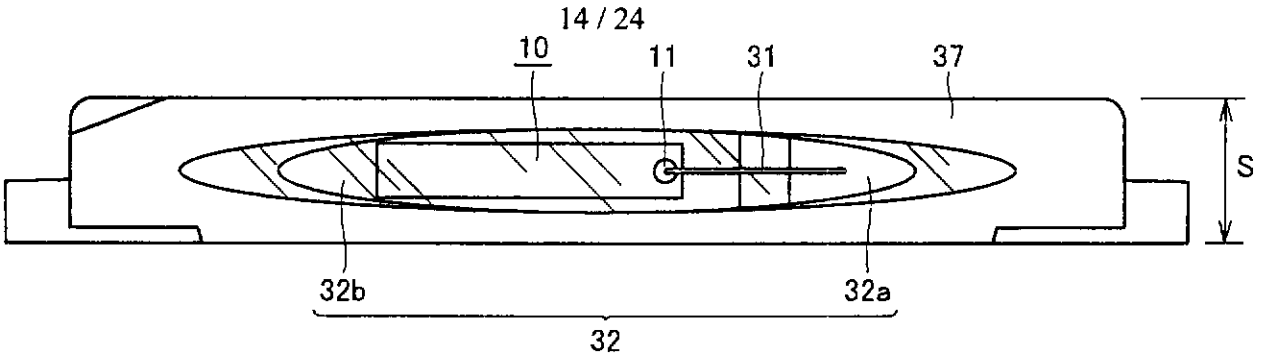


FIG.27B

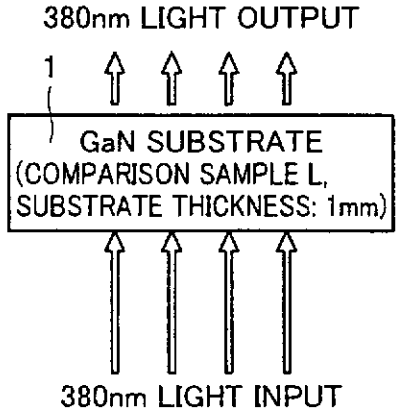


FIG.27A

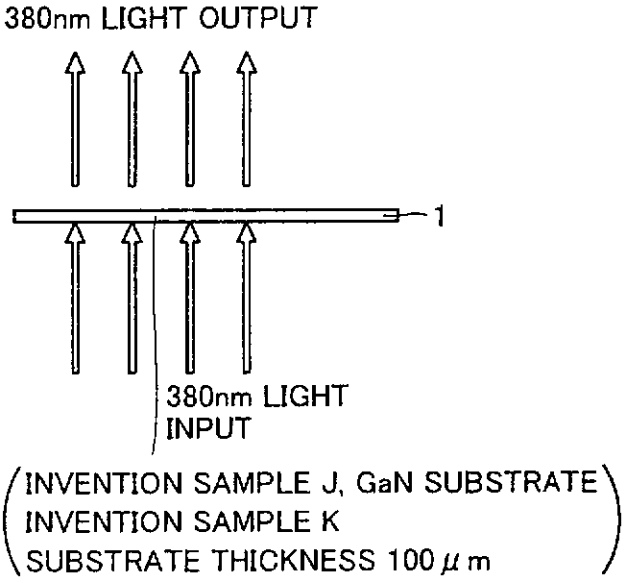


FIG.28

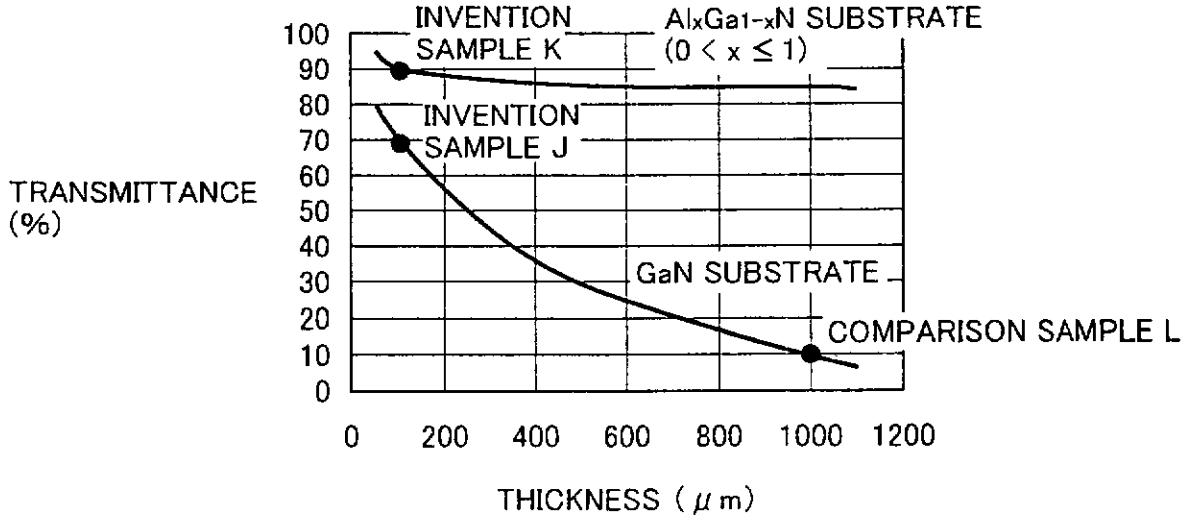


FIG.29

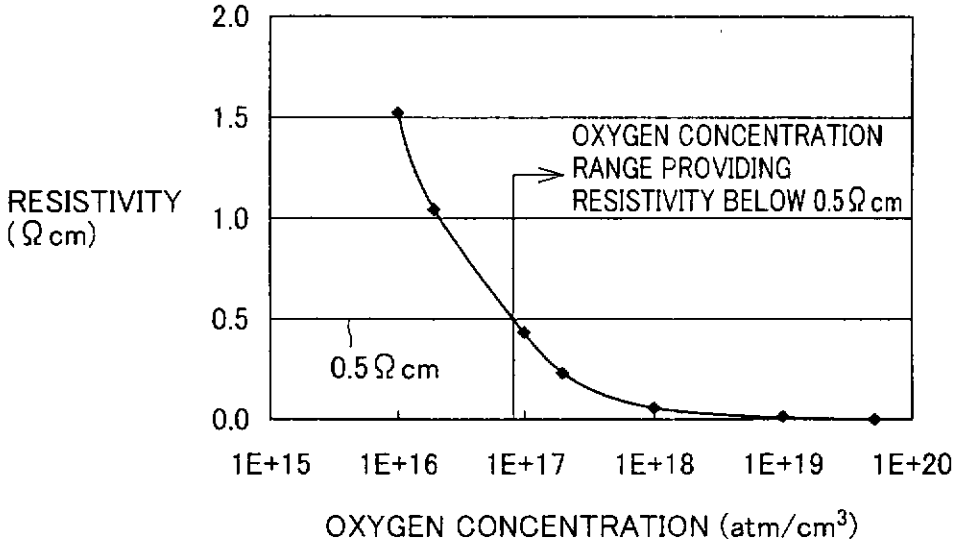

RESISTIVITY (Ω cm)
2.0
1.5
1.0
0.5
0.0
OXYGEN CONCENTRATION RANGE PROVIDING RESISTIVITY BELOW 0.5Ω cm
0.5Ω cm
1E+15
1E+16
1E+17
1E+18
1E+19
1E+20
OXYGEN CONCENTRATION (atm/cm3)

FIG.30

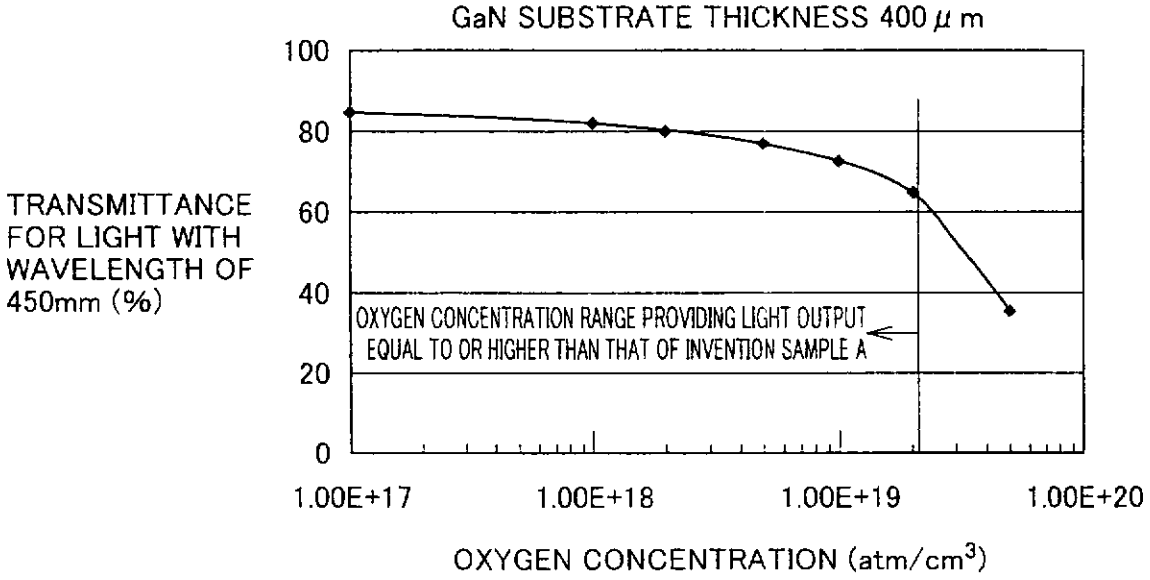

GaN SUBSTRATE THICKNESS 400μm
TRANSMITTANCE FOR LIGHT WITH WAVELENGTH OF 450mm (%)
100
80
60
40
20
0
OXYGEN CONCENTRATION RANGE PROVIDING LIGHT OUTPUT EQUAL TO OR HIGHER THAN THAT OF INVENTION SAMPLE A
1.00E+17
1.00E+18
1.00E+19
1.00E+20
OXYGEN CONCENTRATION (atm/cm3)

FIG.31

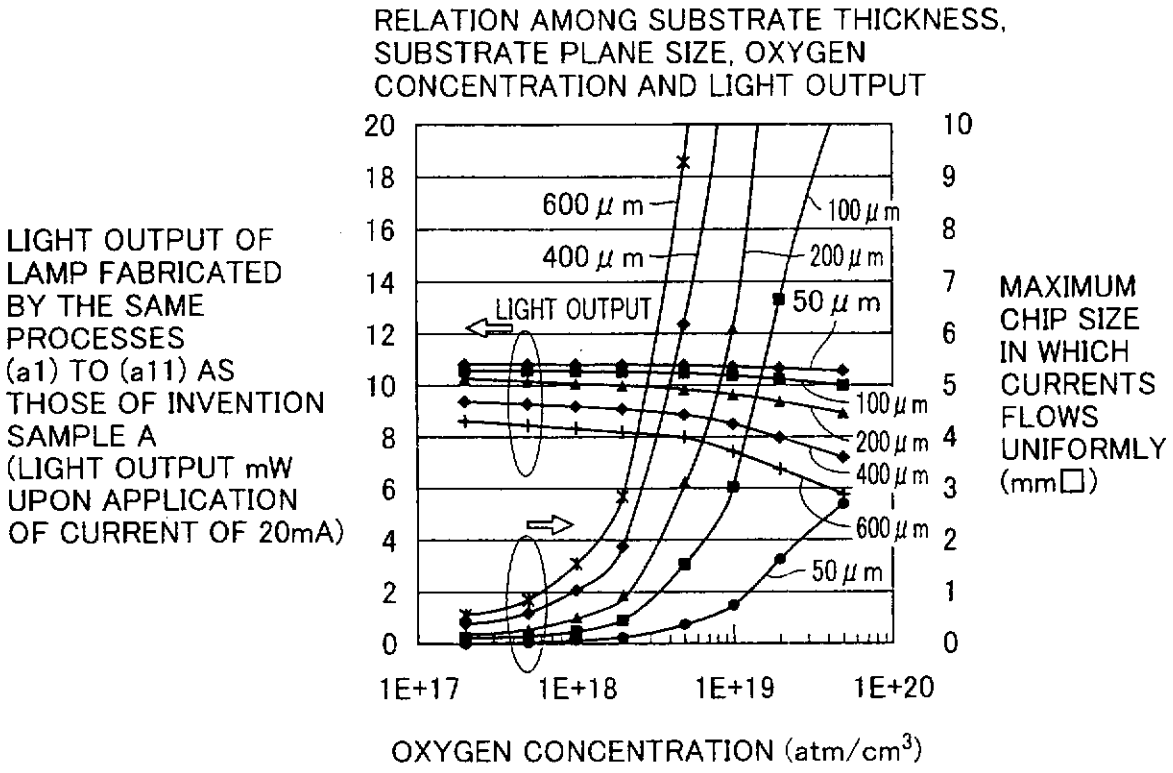

RELATION AMONG SUBSTRATE THICKNESS, SUBSTRATE PLANE SIZE, OXYGEN CONCENTRATION AND LIGHT OUTPUT
LIGHT OUTPUT OF LAMP FABRICATED BY THE SAME PROCESSES (a1) TO (a11) AS THOSE OF INVENTION SAMPLE A (LIGHT OUTPUT mW UPON APPLICATION OF CURRENT OF 20mA)
MAXIMUM CHIP SIZE IN WHICH CURRENTS FLOWS UNIFORMLY (mm□)
LIGHT OUTPUT
600 μm
400 μm
100 μm
200 μm
50 μm
OXYGEN CONCENTRATION (atm/cm3)
1E+17
1E+18
1E+19
1E+20

FIG.32

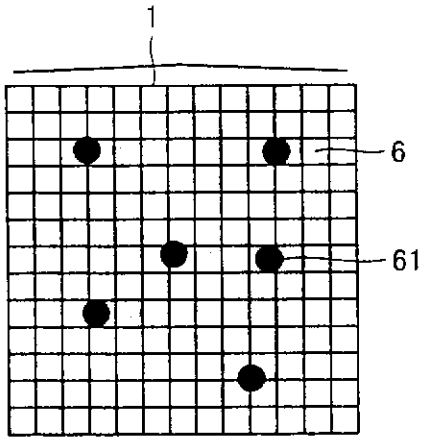

1
6
61

FIG.33

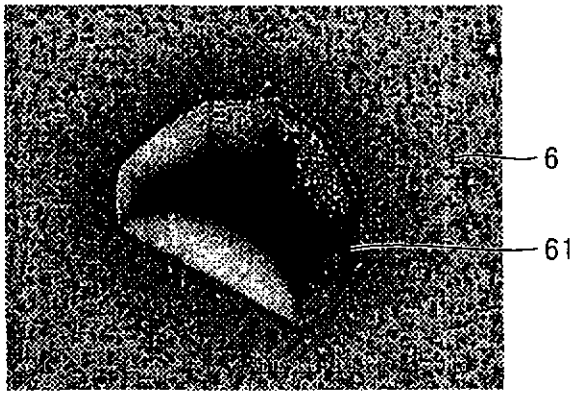
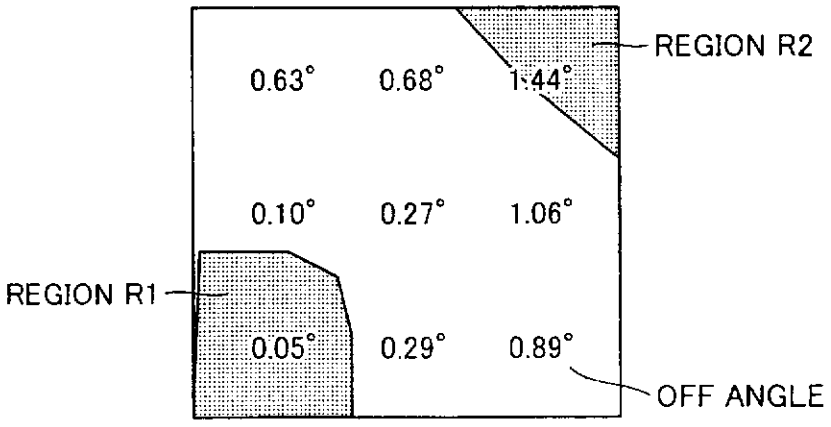


FIG.34



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

FIG.35

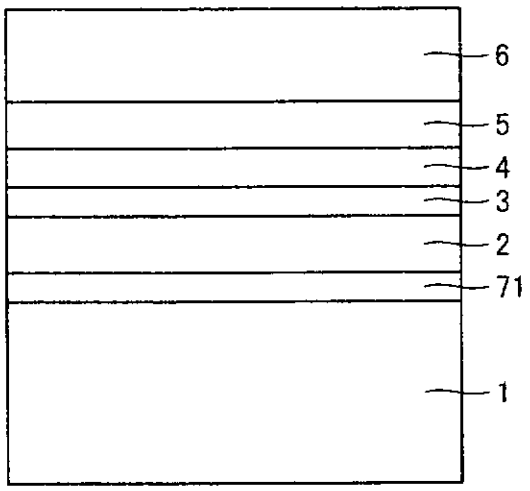

6
5
4
3
2
71
1

FIG.36

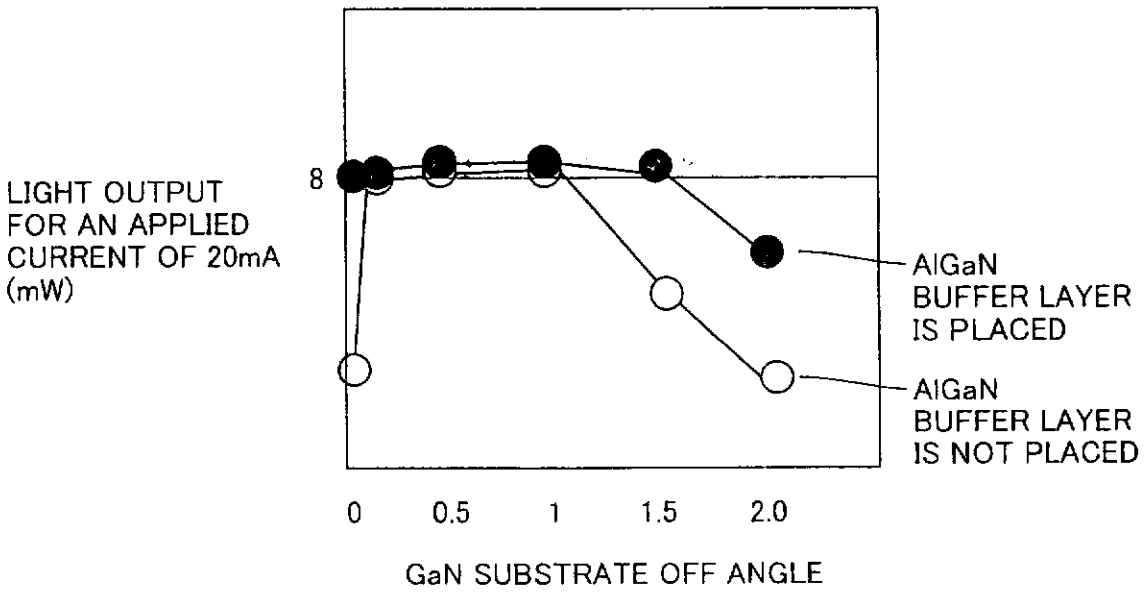

LIGHT OUTPUT FOR AN APPLIED CURRENT OF 20mA (mW)
8
AlGaN BUFFER LAYER IS PLACED
AlGaN BUFFER LAYER IS NOT PLACED
0
0.5
1
1.5
2.0
GaN SUBSTRATE OFF ANGLE

FIG.37

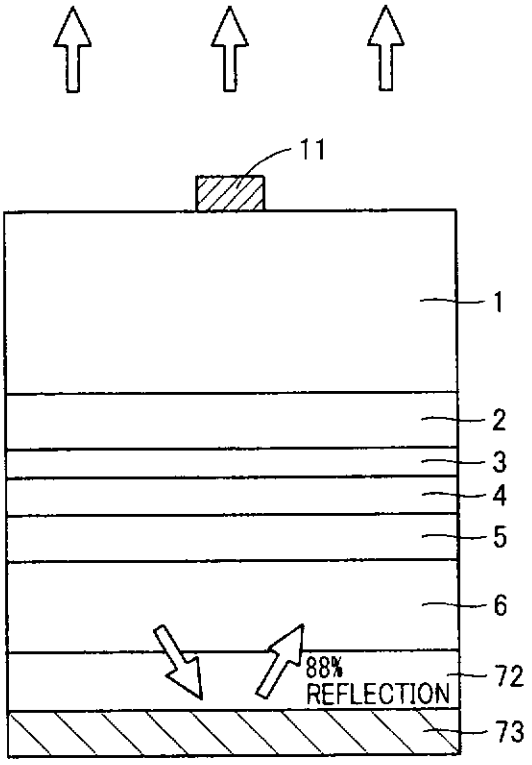


FIG.38

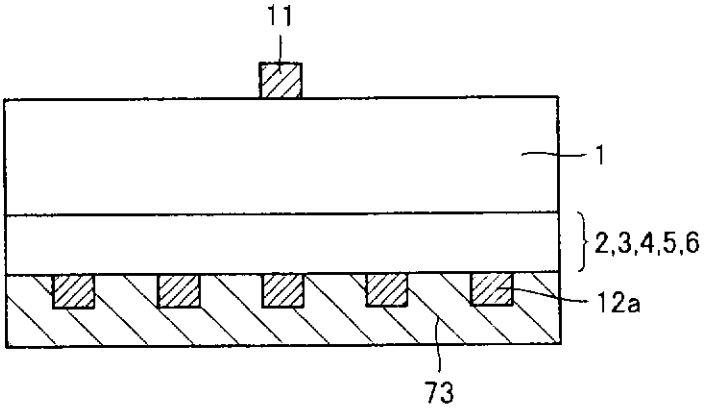


FIG.39

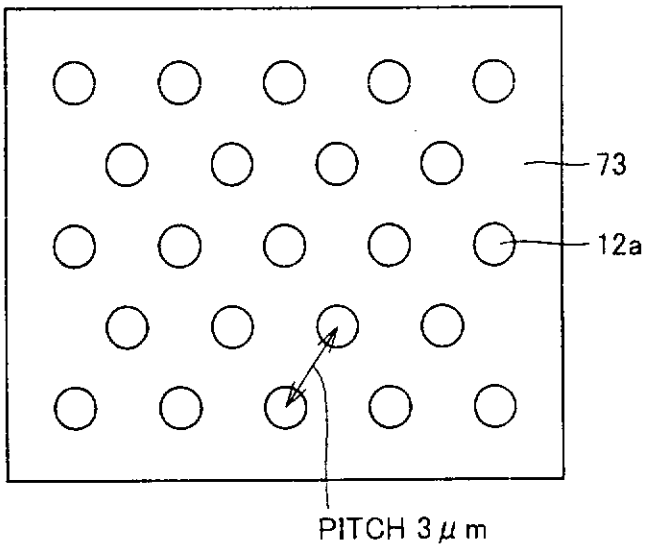


FIG.40

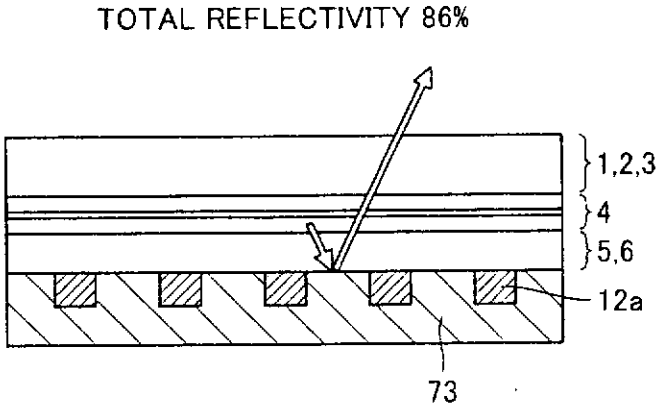


FIG.41

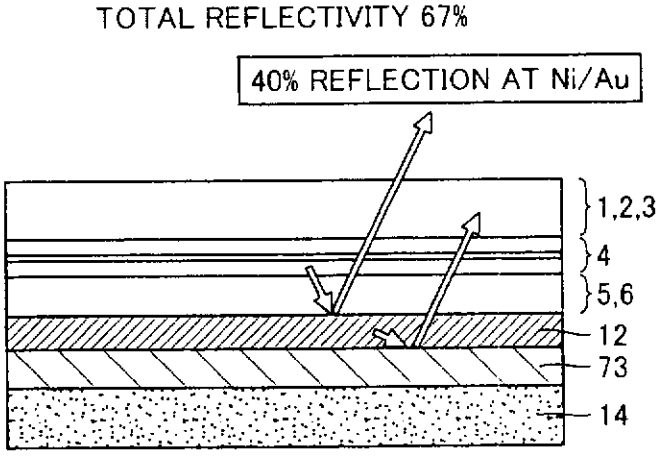


FIG.42

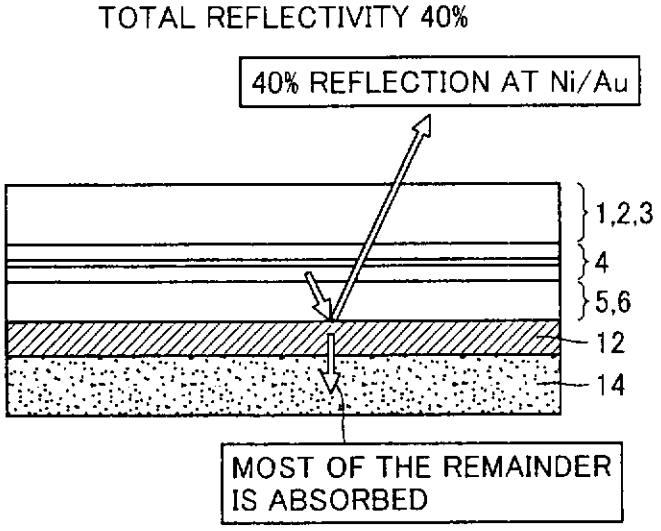


FIG.43

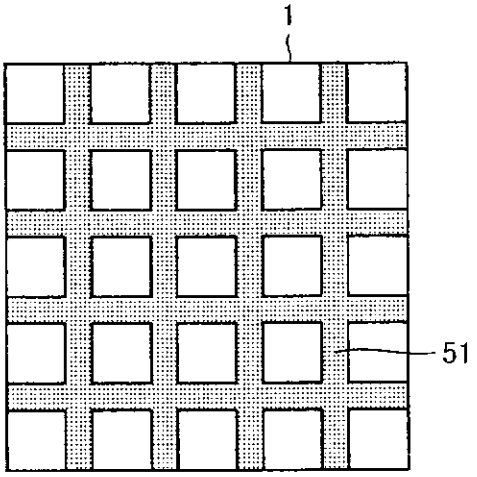


FIG.44

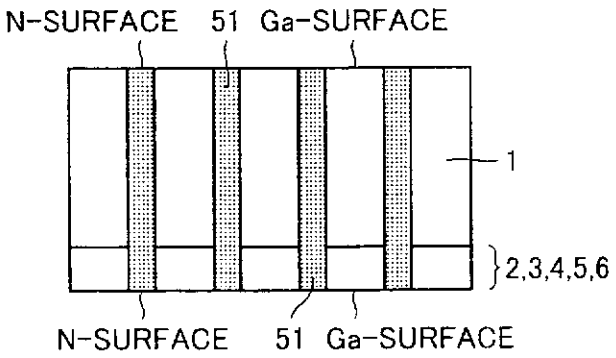


FIG.45

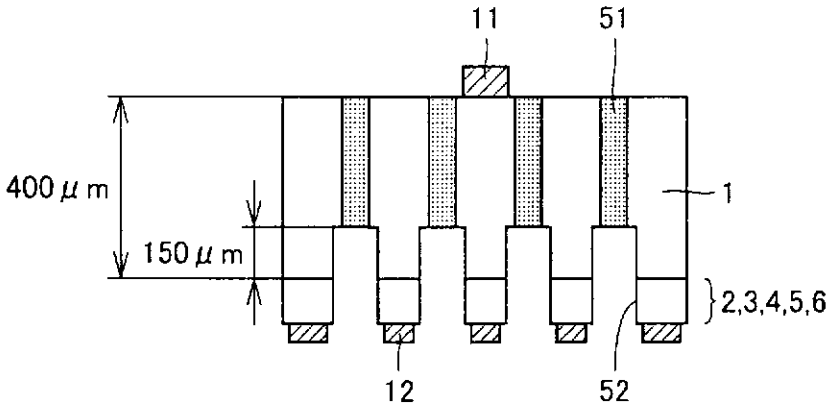


FIG.46

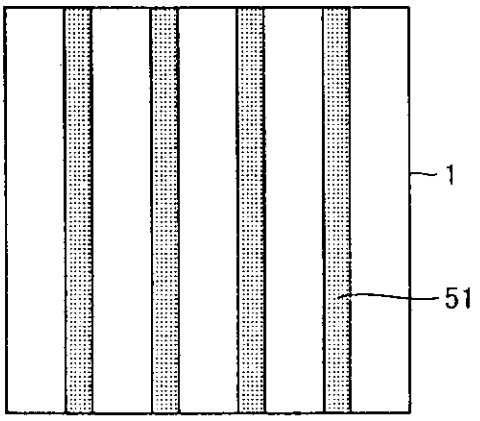


FIG.47

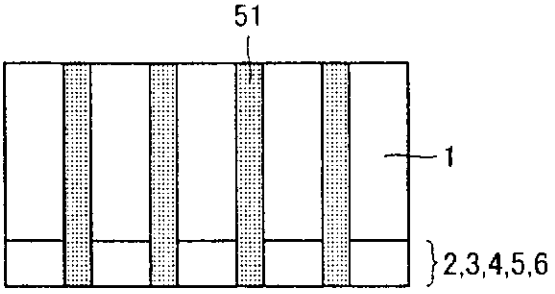


FIG.48

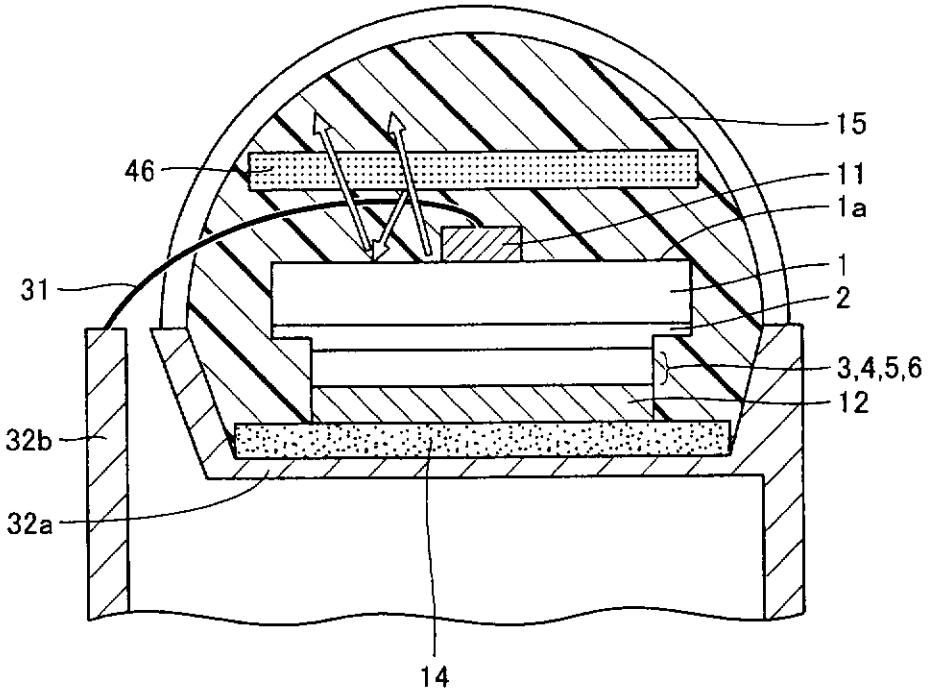

15
46
11
1a
1
31
2
3,4,5,6
12
32b
32a
14

FIG.49

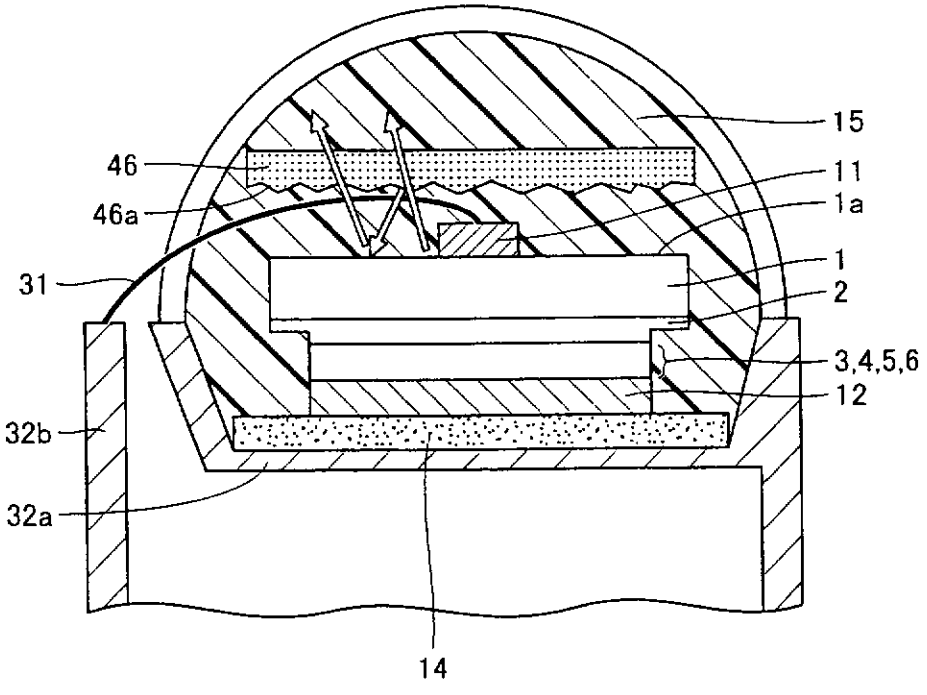

15
46
11
46a
1a
1
31
2
3,4,5,6
12
32b
32a
14

FIG.50

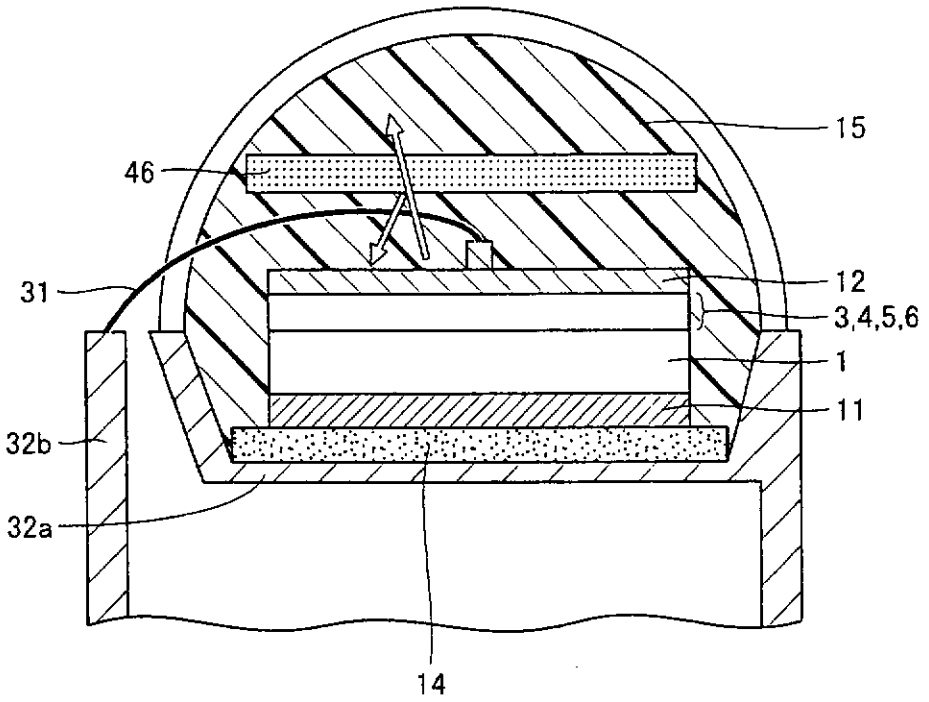
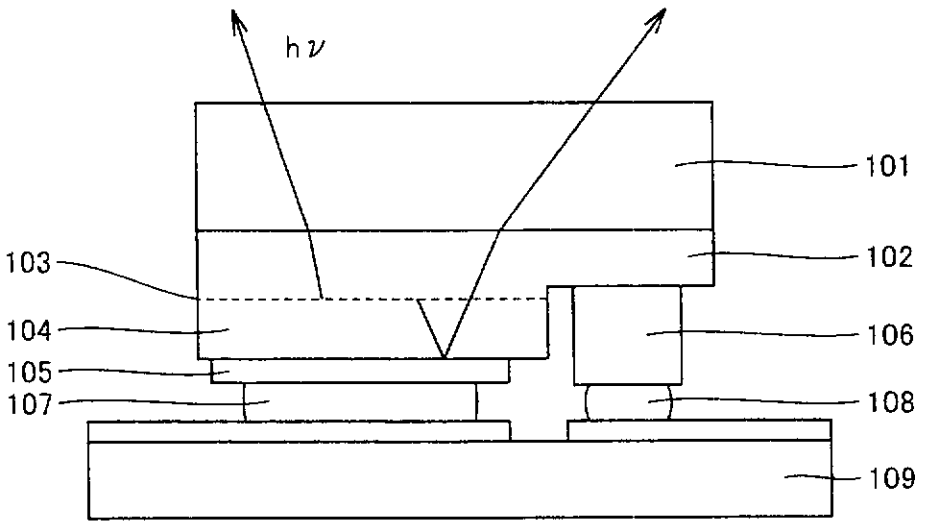

15
46
12
31
3,4,5,6
1
11
32b
32a
14

FIG.51


hν
101
103
102
104
106
105
107
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109