FIG. 1

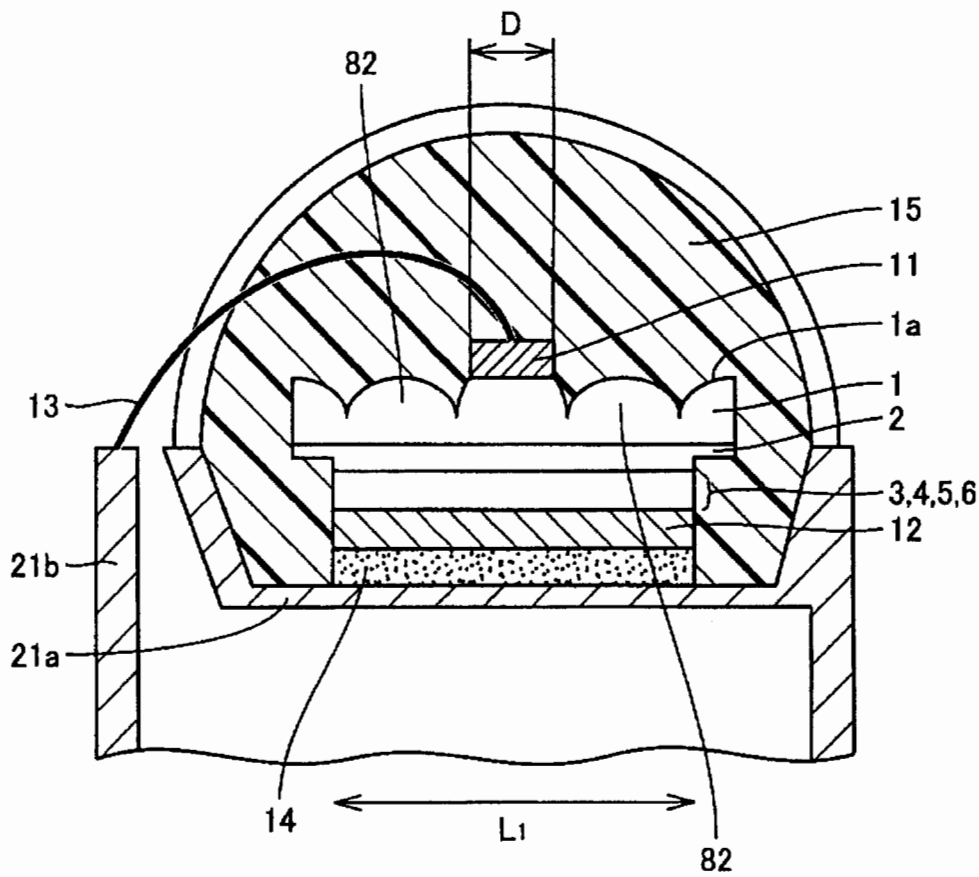


FIG. 2

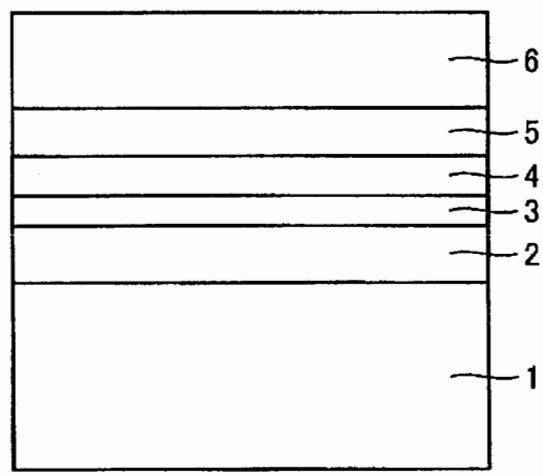


FIG. 3

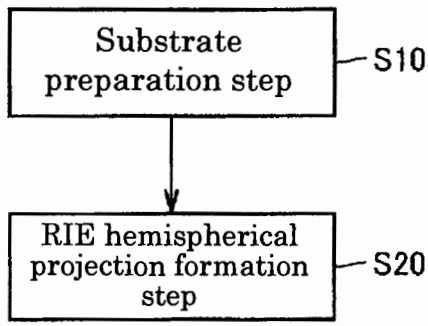

Substrate preparation step
S10
RIE hemispherical projection formation step
S20

FIG. 4

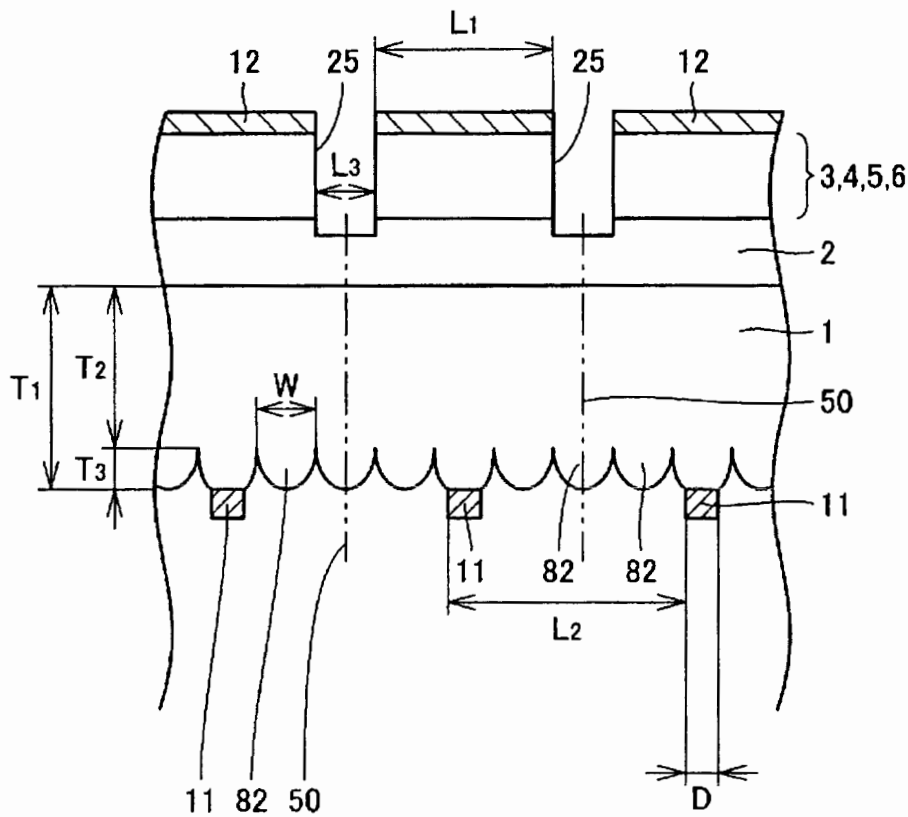

L1
12
25
25
12
L3
3,4,5,6
2
1
T1
T2
W
50
T3
11
11
82
82
L2
11
82
50
D

FIG. 5

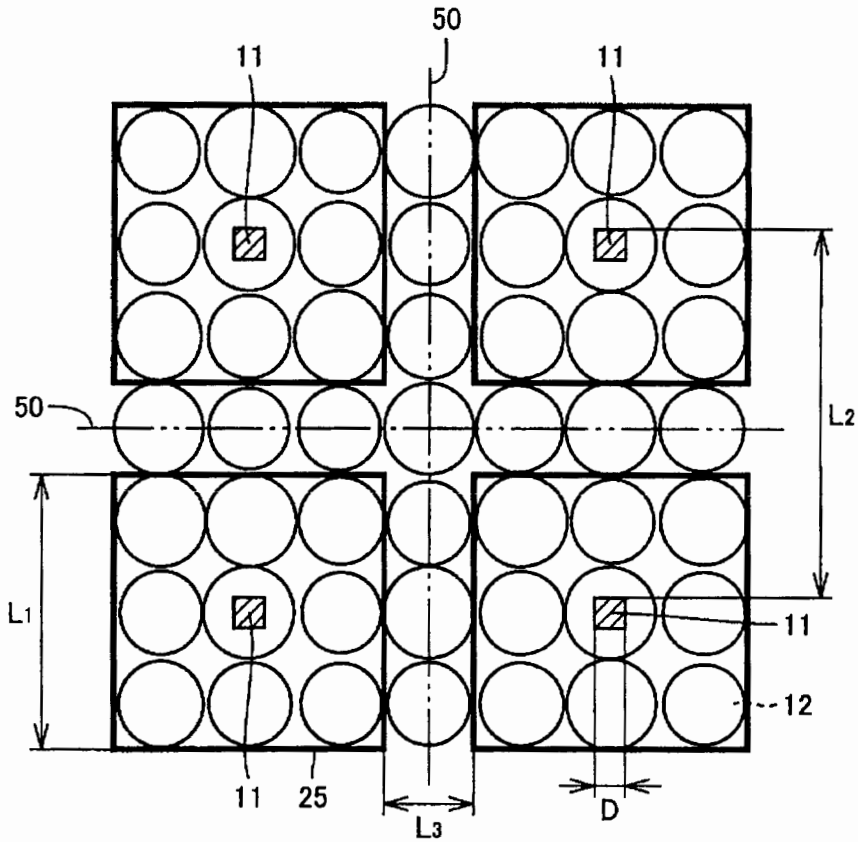

50
11
11
50
L2
L1
11
12
11
25
L3
D

FIG. 6

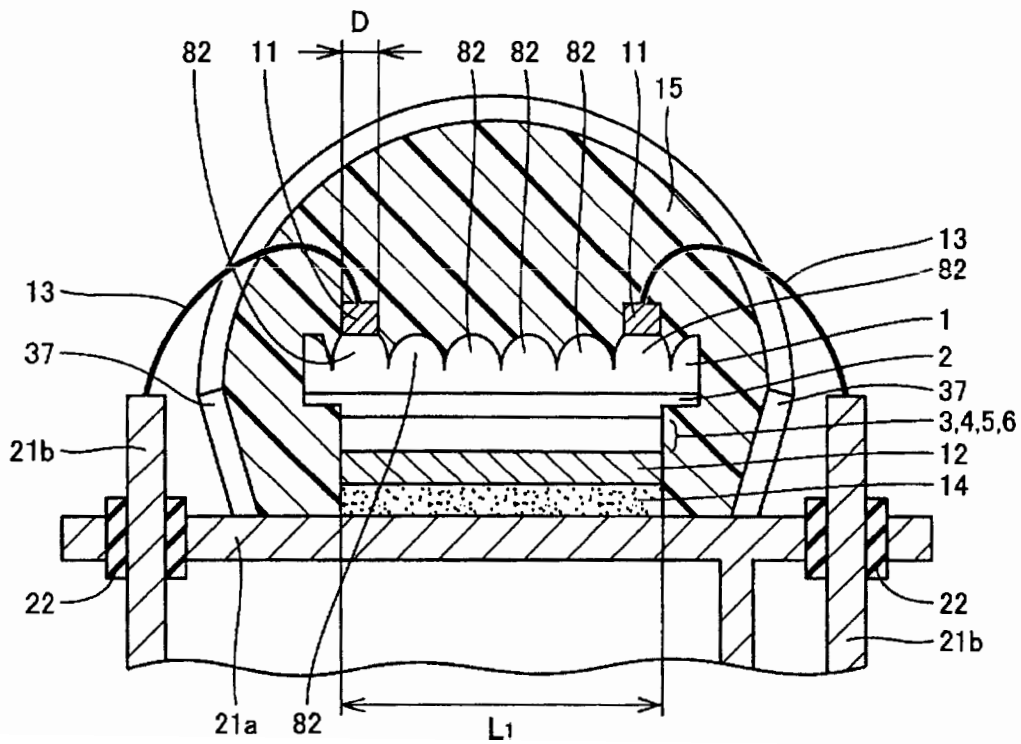

D
82
11
82
82
82
11
15
13
82
13
1
37
2
37
3,4,5,6
21b
12
14
22
22
21b
21a
82
L1

FIG. 7

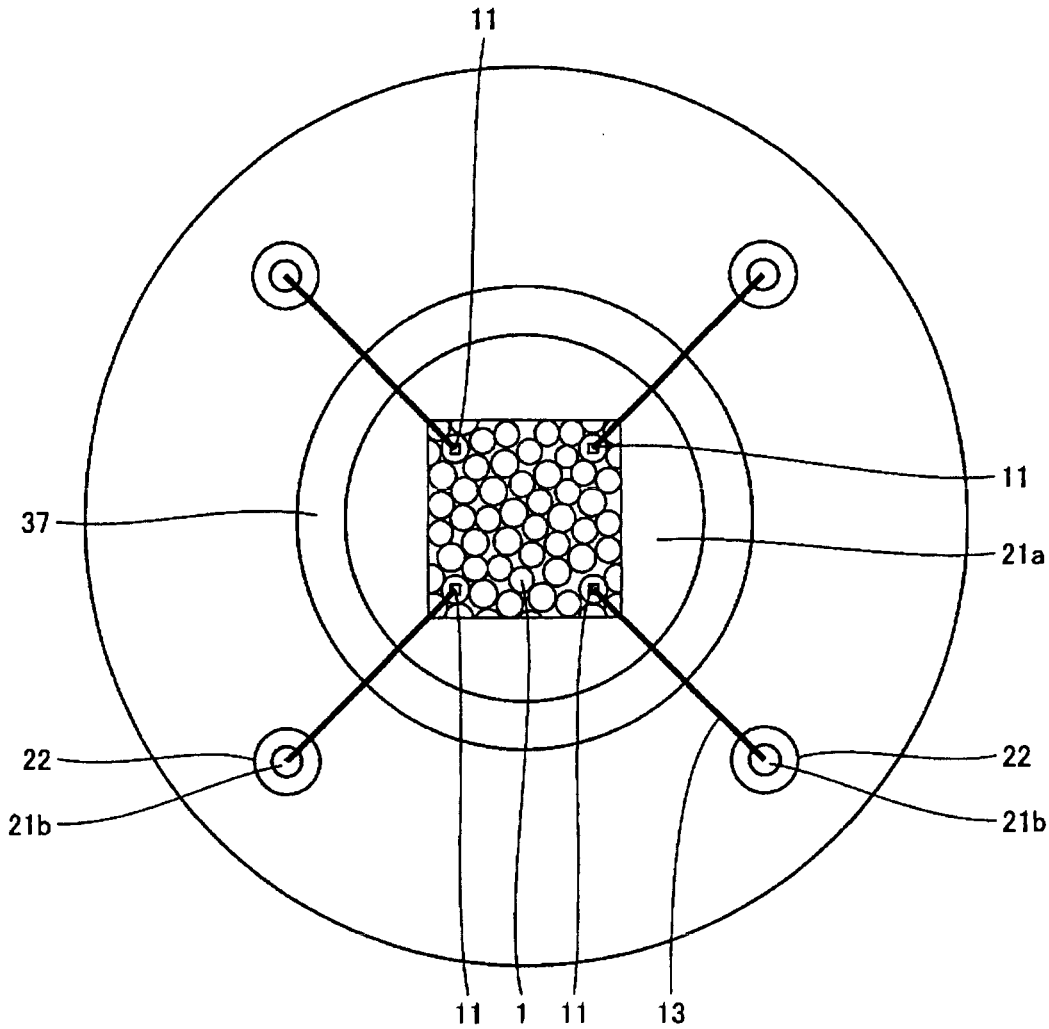


FIG. 8

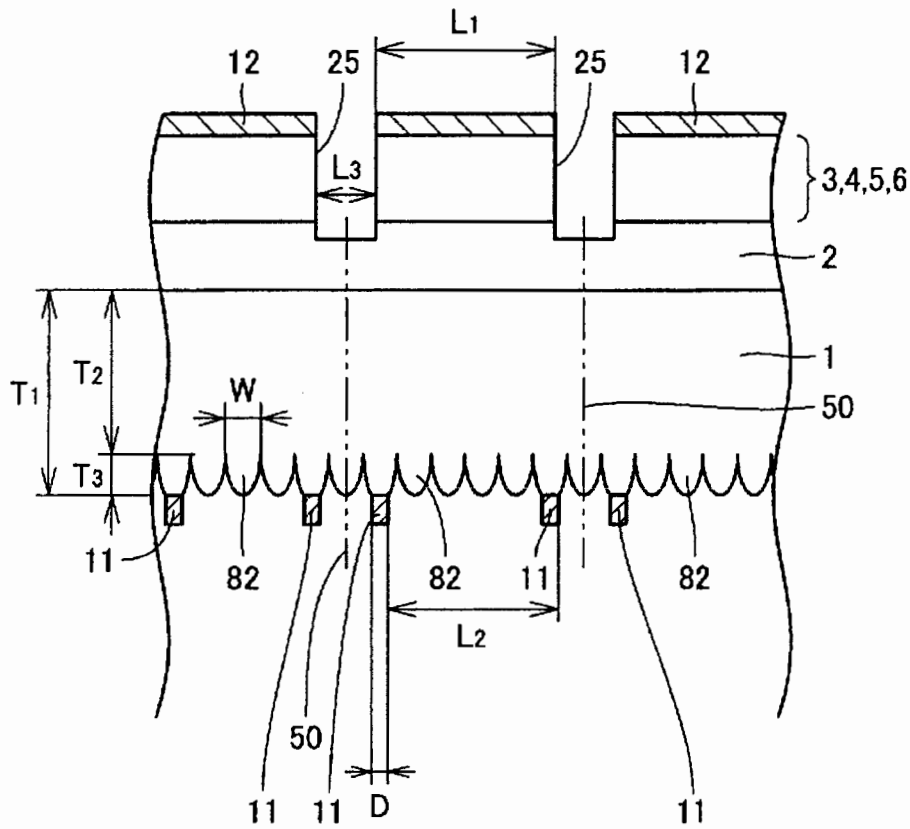

L1
12
25
25
12
L3
3,4,5,6
2
1
50
T1
T2
T3
W
11
82
82
11
82
L2
50
11
11
D
11

FIG. 9

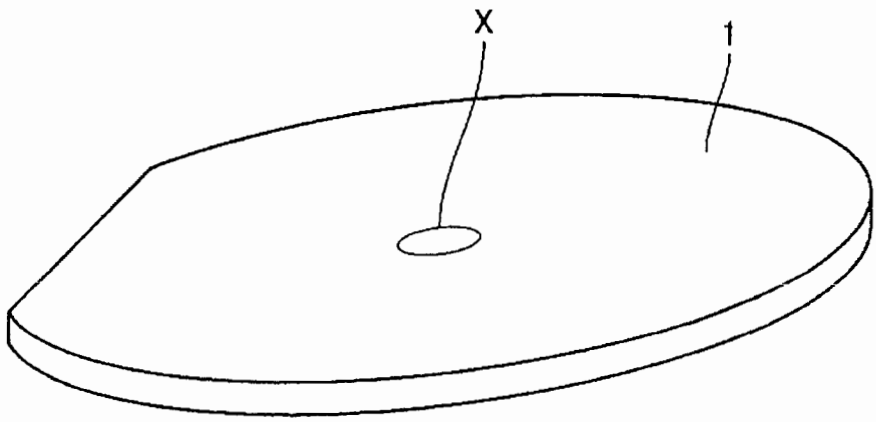

X
1

FIG. 10

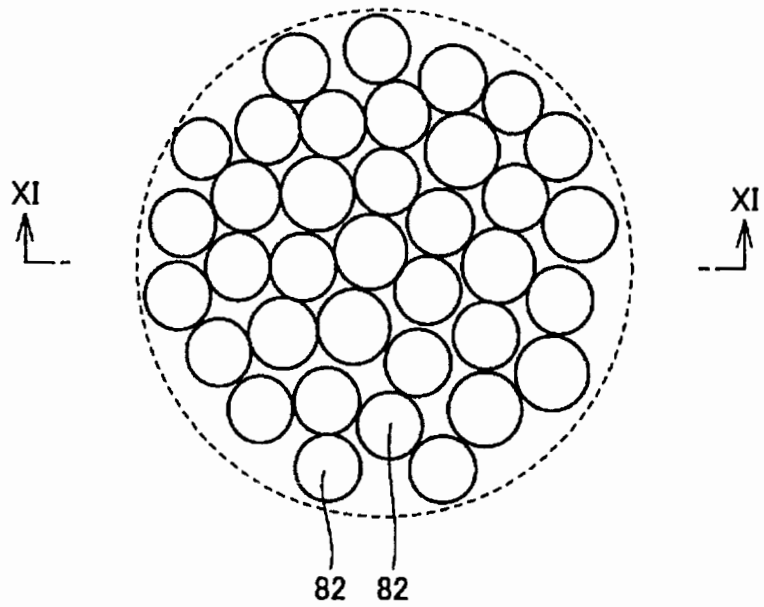


FIG. 11

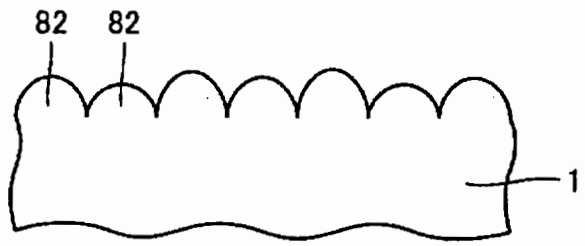


FIG. 12

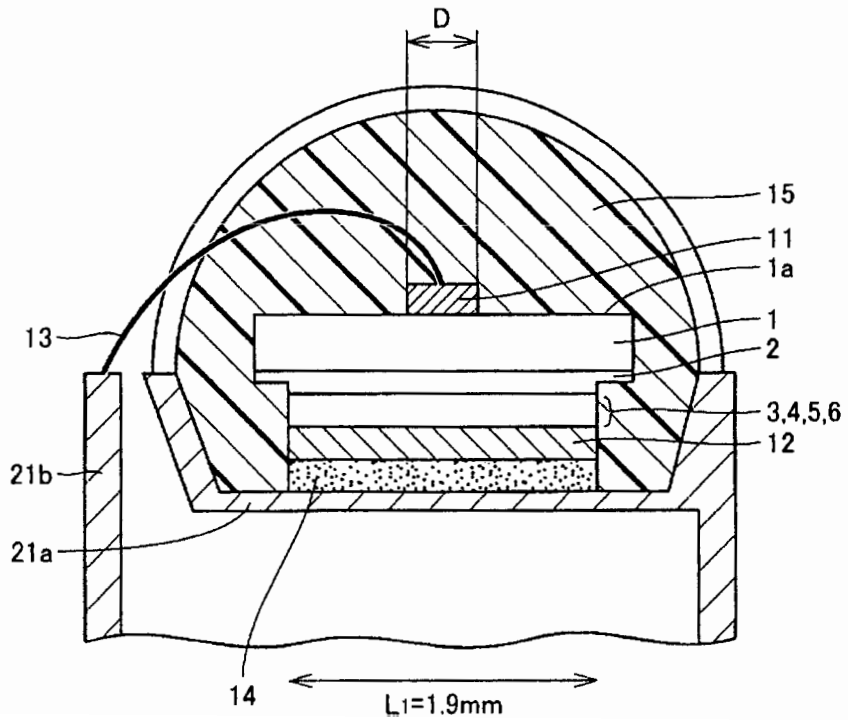


FIG. 13

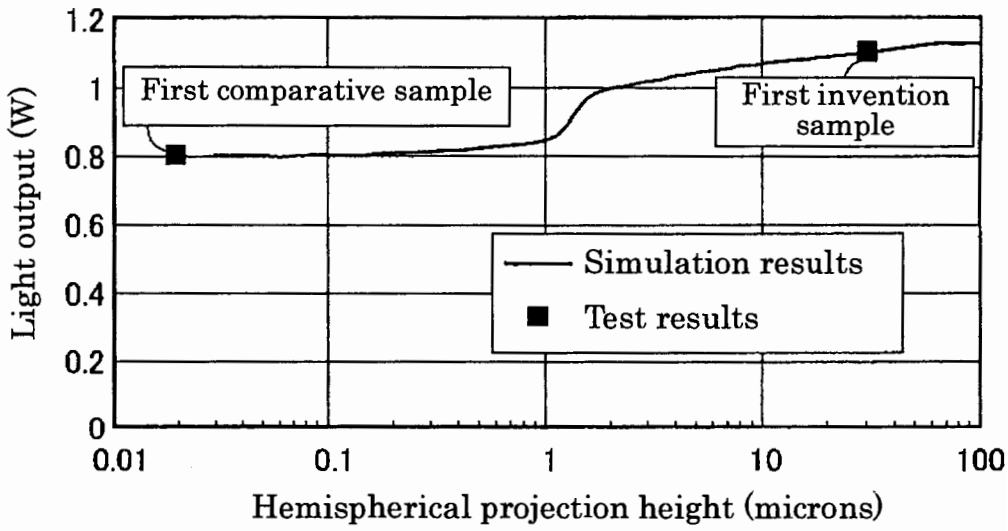

1.2
1
0.8
0.6
0.4
0.2
0
Light output (W)
First comparative sample
First invention sample
Simulation results
Test results
0.01
0.1
1
10
100
Hemispherical projection height (microns)

FIG. 14

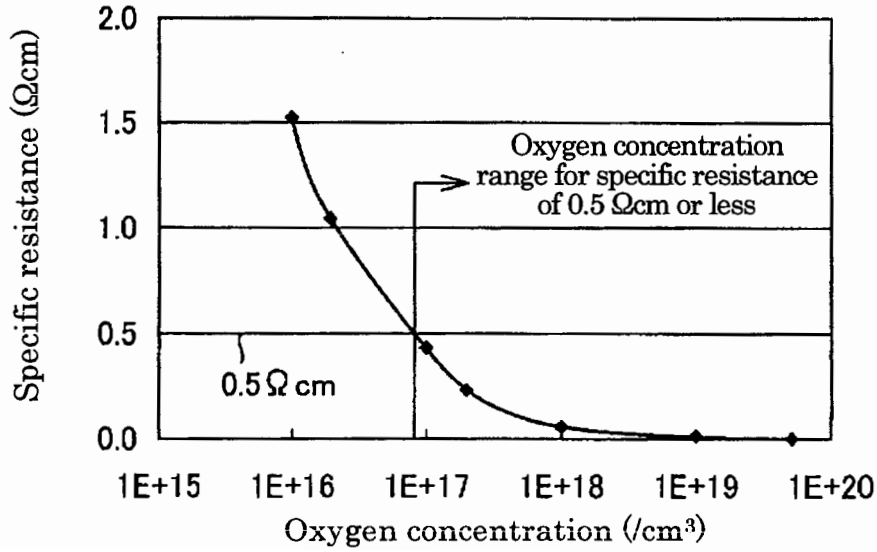

2.0
1.5
1.0
0.5
0.0
Specific resistance (Ωcm)
Oxygen concentration range for specific resistance of 0.5 Ωcm or less
0.5 Ω cm
1E+15
1E+16
1E+17
1E+18
1E+19
1E+20
Oxygen concentration (/cm3)

FIG. 15

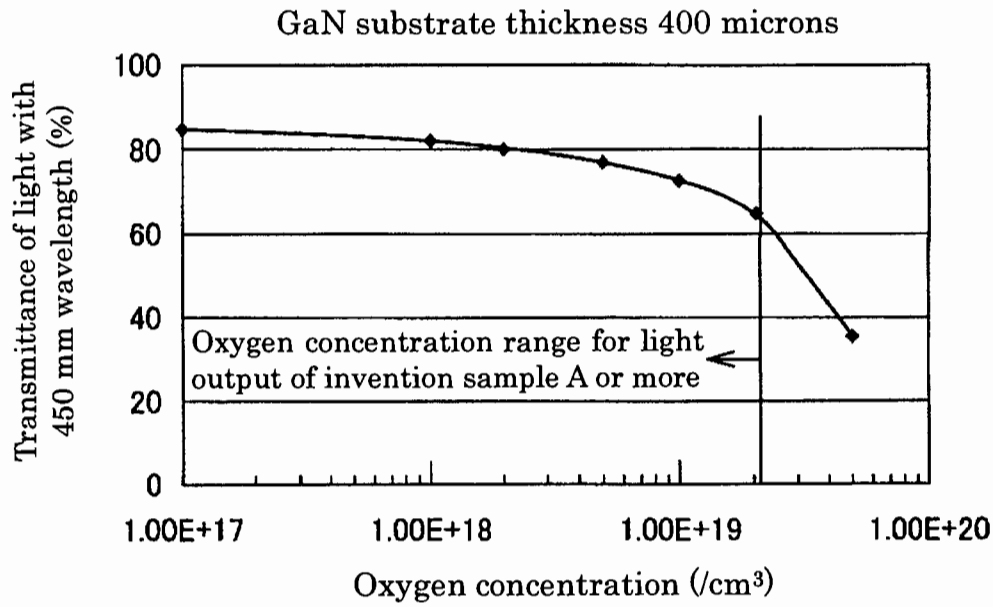
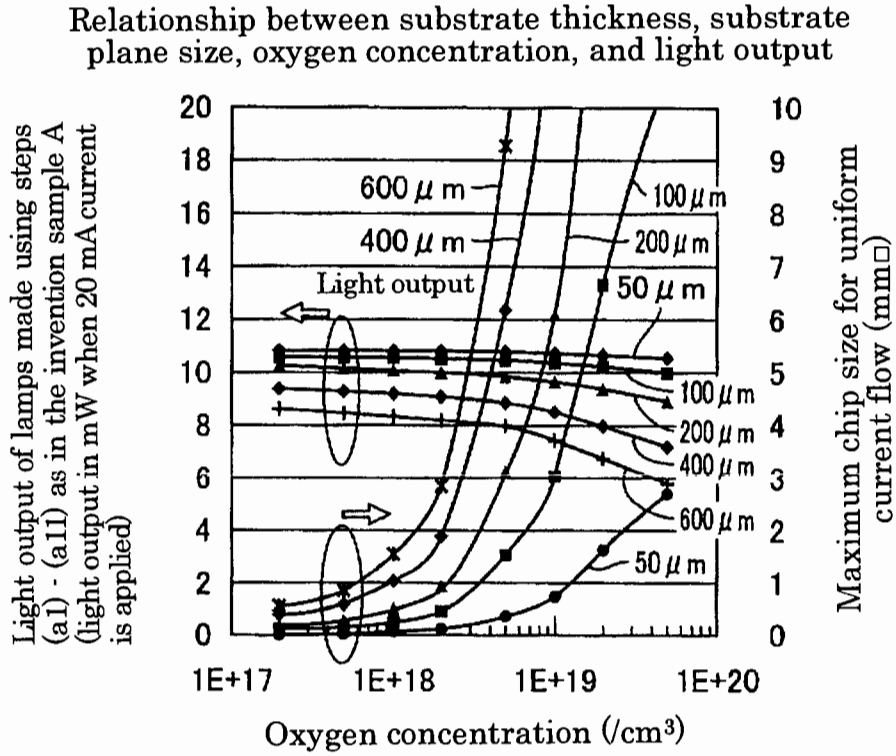

GaN substrate thickness 400 microns
Transmittance of light with 450 mm wavelength (%)
100
80
60
40
20
0
Oxygen concentration range for light output of invention sample A or more
1.00E+17
1.00E+18
1.00E+19
1.00E+20
Oxygen concentration (/cm3)

FIG. 16


Relationship between substrate thickness, substrate plane size, oxygen concentration, and light output
Light output of lamps made using steps (a1) - (a11) as in the invention sample A (light output in mW when 20 mA current is applied)
Maximum chip size for uniform current flow (mm□)
600 μm
400 μm
Light output
100 μm
200 μm
50 μm
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 (/cm3)