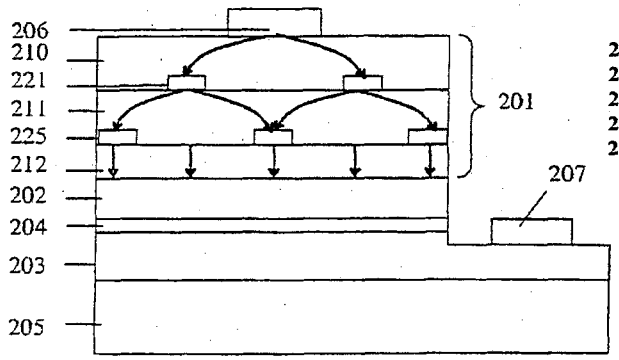


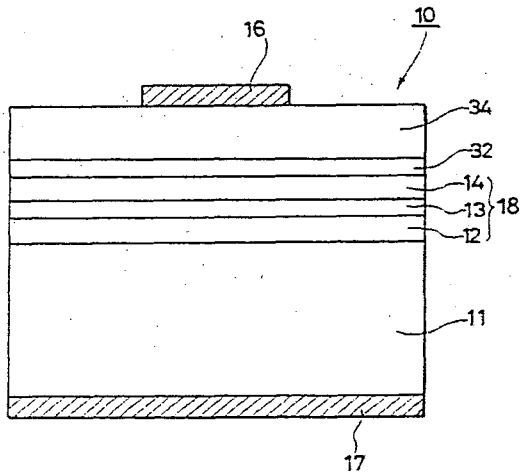
1. Transparent window layer
3. p-contact layer
4. Heavily doped layers as current spreading layer
5.p-doped cladding region
6.Active region
7.n-doped cladding region
8.n-doped contact layer
9.p-contact
10. n-contact

FIGURE 1 (Prior Art: US 7,026,653 B2)



202.p-type semiconductor material
203.n-type semiconductor material
204. Active region
205. Substrate (e.g. sapphire)
201.Transparent current spreading layer
210, 211 and 212. ITO
221 and 225.metallic pads for current spreading

FIGURE 2 (Prior Art: US 7,834,373 B2)



10.Light emitting device
11. n-type GaAs
12.n-type $(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$ cladding layer
13.$(Al_yGa_{1-y})_{0.51}In_{0.49}P$ ($0<y<0.7$) as active region
14.p-type $(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$ cladding layer
32.Undoped $Al_{0.7}Ga_{0.3}As$ as current spreading layer
34.p-type $Al_{0.7}Ga_{0.3}As$
16.p-electrode
17.n-electrode

FIGURE 3 (Prior Art: 5,600,158)

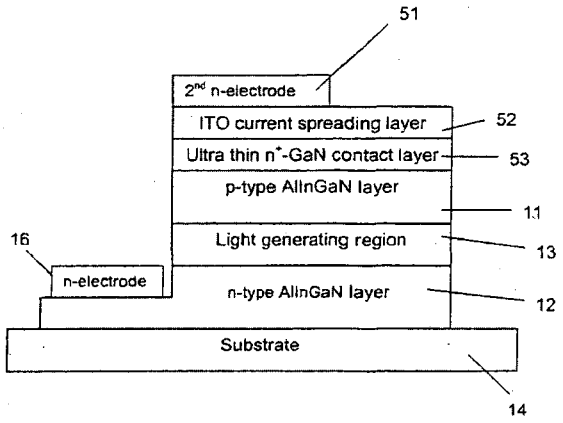


FIGURE 4

(Prior Art: US 2005/0173724 A1)

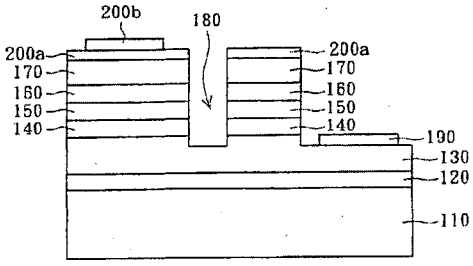


FIGURE 5A

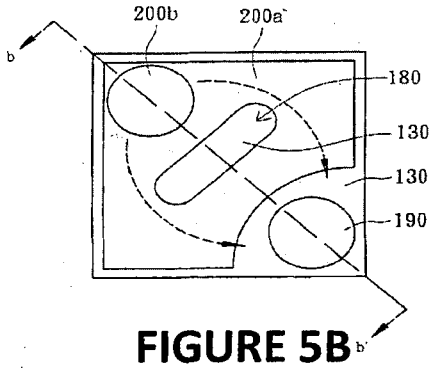
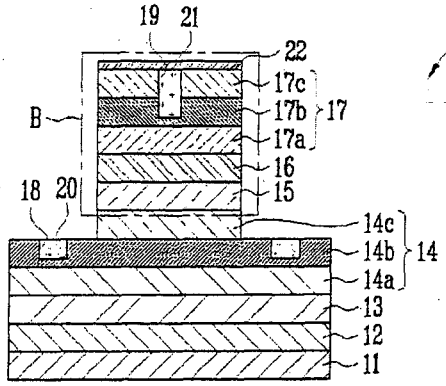


FIGURE 5B

110. Substrate (e.g. sapphire)
120.Buffer layer (e.g. GaN, AlN)
130.First-polarity (AlxGa1-x)yIn1-yN
140.First-polarity (AlxGa1-x)yIn1-yN cladding layer
150.Active layer of AlxGa1-x)yIn1-yN
160.Second-polarity AlxGa1-x)yIn1-yN cladding layer
170.Highly doped contact layer for second polarity made of AlxGa1-x)yIn1-yN
200a.transparent electrode of second polarity
200b. Metal electrode pad of second polarity
180. Trench for current spreading

(Prior Art: US 6,781,147 B2)



11: Substrate
12: Buffer layer
13: GaN support layer
14: n-type electrode layer
14a: n-GaN layer
14b: n-type current spreading layer (AlGaN/GaN)
14c: n^+-GaN
15: Active layer
16: p-type cladding layer
17: p-type electrode layer
17a: p-GaN layer
17b: p-type current spreading layer (AlGaN/GaN)
17c: p-type barrier layer (p^+-GaN)
18 and 19: Trench
20 and 21: Metal contact layer
22: Transparent electrode layer
30: Light emitting diode

FIGURE 6

(Prior Art: US 7,998,771 B2)

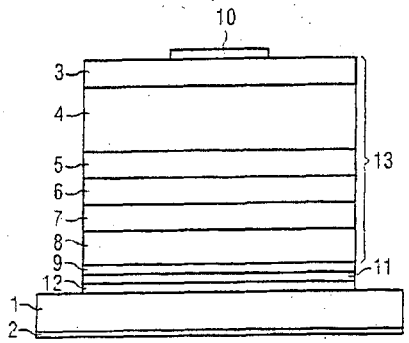


FIGURE 7A

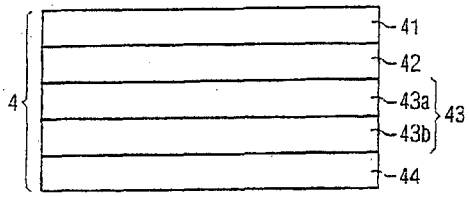


FIGURE 7B

1:Device carrier
2:Electrode
3:n-GaN layer
4:Current spreading layer
41:n-GaN
42:undoped GaN
43a:undoped AlGaN
43b:n-AlGaN
44:n-GaN
5:n-GaN
6:n-GaN
7:Acvtive region
8:p-GaN
9:p-electrode
10:n-electrode
11:TiWN
12:Connecting layer

(Prior Art: US 2011/0193057 A1)

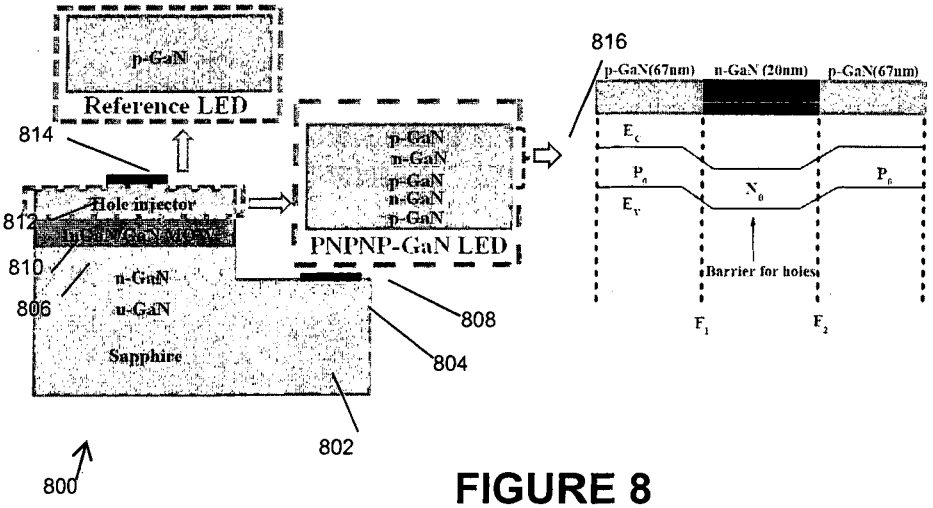


FIGURE 8

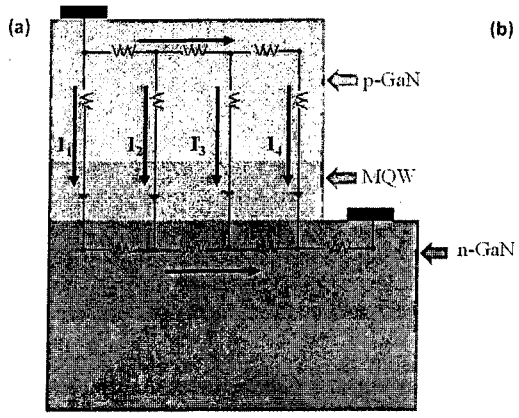


FIGURE 9A

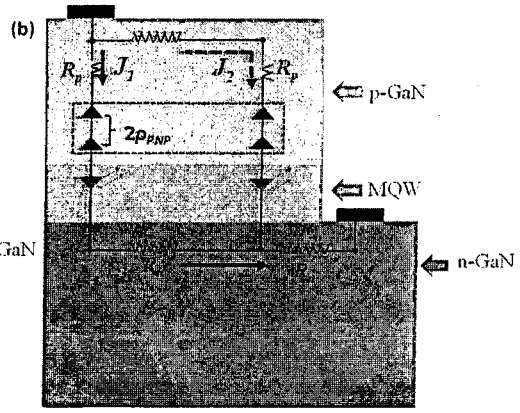


FIGURE 9B

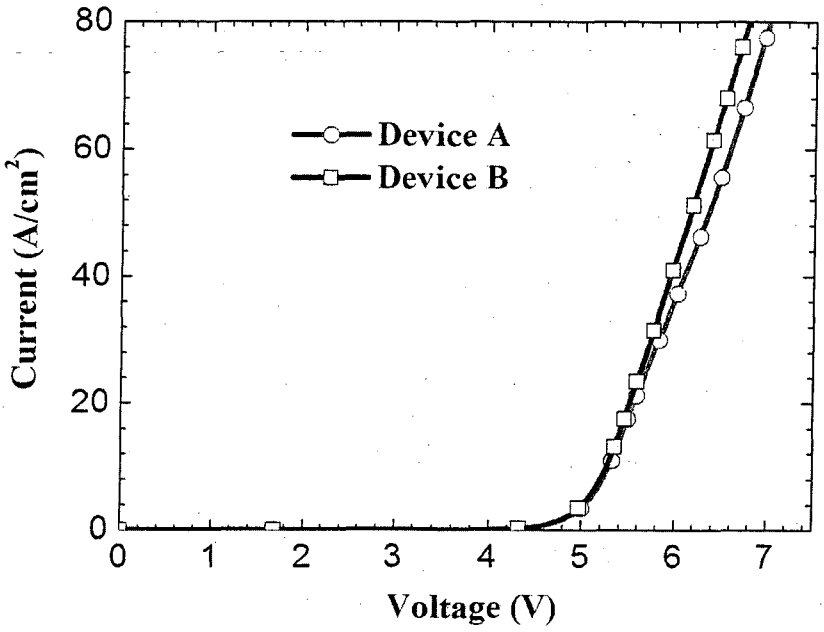


FIGURE 10A

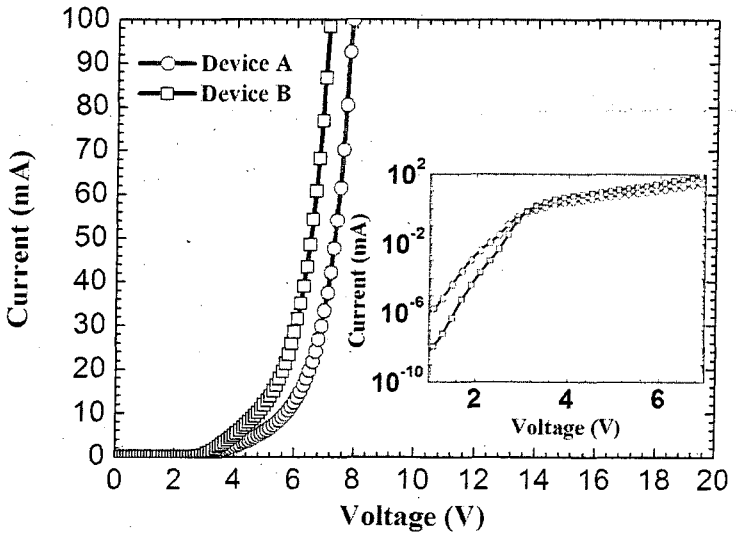
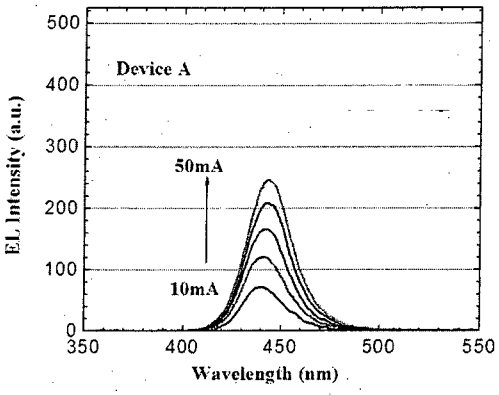


Figure 10B



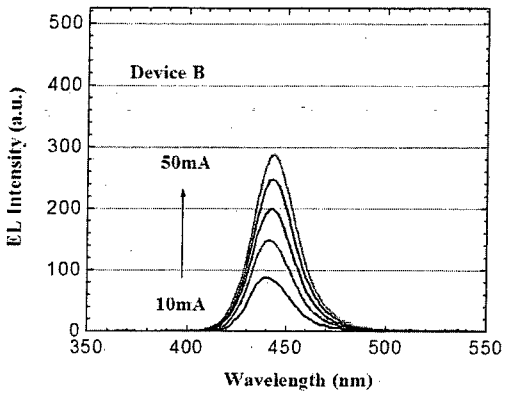


FIGURE 11A

FIGURE 11B

Device A: reference LED w/o transparent current spreading layer

Device B: PNP-LED w/o transparent current spreading layer

Current (mA)	Current density (A/cm^2)
10	8.16
20	16.33
30	24.49
40	32.65
50	40.82

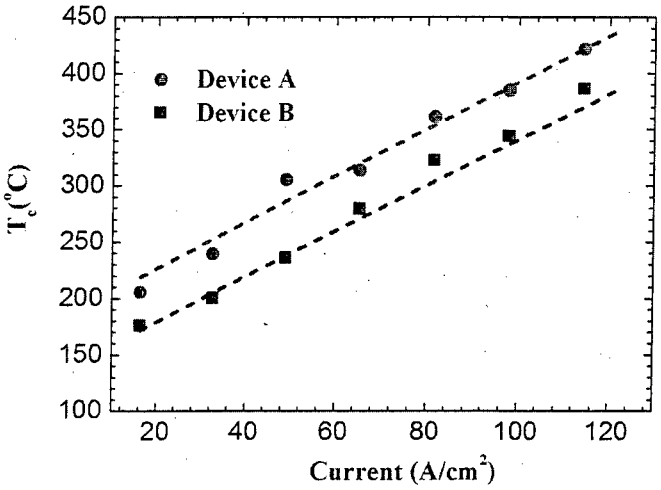
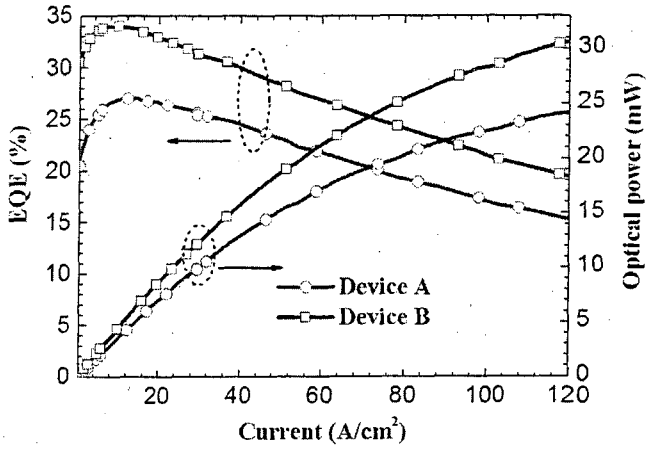


FIGURE 12

Device A: reference LED w/o transparent current spreading layer

Device B: PNP-LED w/o transparent current spreading layer

T_c: carrier temperature

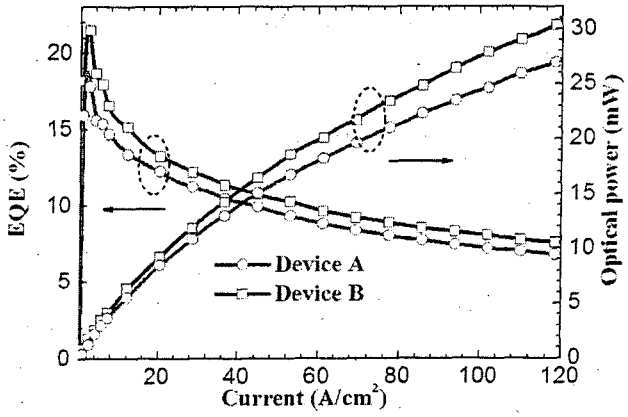


Current density (A/cm²)	Simulated power (mW)		Increment (%)
	Device A	Device B	
20	5.22	6.50	24.52
60	16.27	20.00	22.93
120	21.43	26.80	25.06

Device A: reference LED w/o transparent current spreading layer

Device B: PNP-LED w/o transparent current spreading layer

FIGURE 13



Current density (A/cm²)	Experimental power (mW)		Increment (%)
	Device A	Device B	
20	8.49	9.23	8.72
60	18.21	20.07	10.21
120	26.97	30.35	12.53

Device A: reference LED w/o transparent current spreading layer

Device B: PNP-LED w/o transparent current spreading layer

FIGURE 14

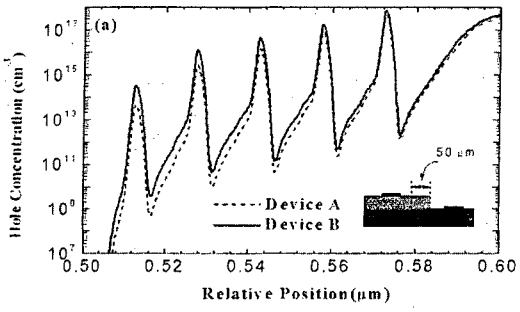


FIGURE 15A

Device A: reference LED w/o transparent current spreading layer

Device B: PNP-LED w/o transparent current spreading layer

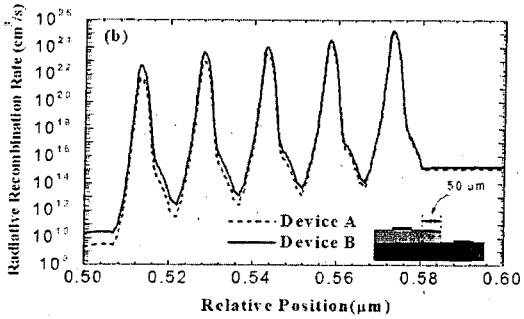


FIGURE 15B

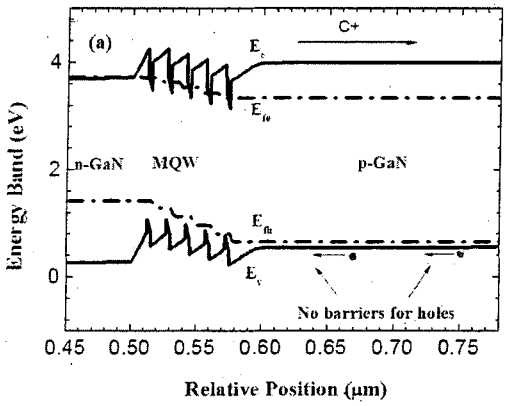


FIGURE 16A

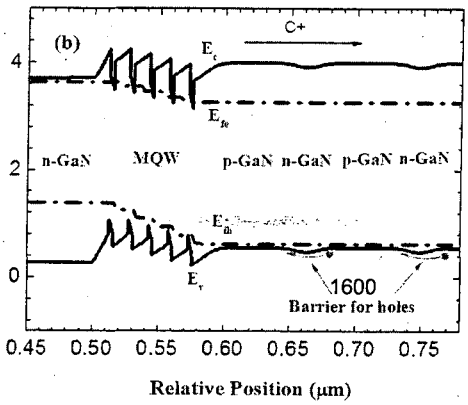


FIGURE 16B

Device A: reference LED w/o transparent current spreading layer

Device B: PNP-LED w/o transparent current spreading layer

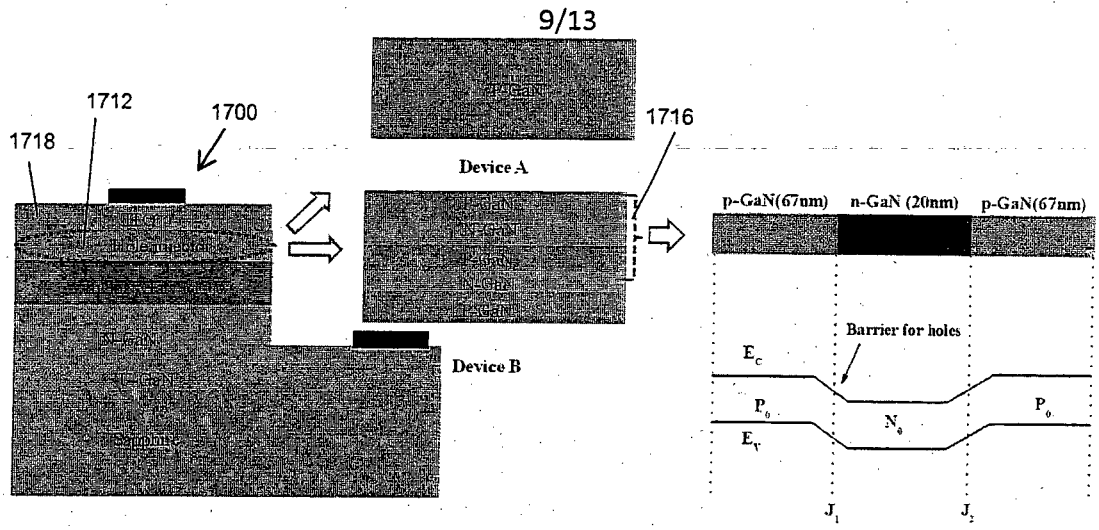


FIGURE 17

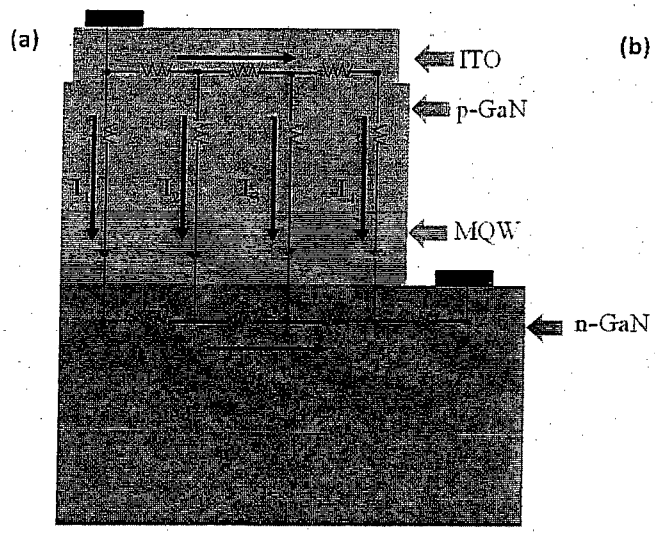


FIGURE 18A

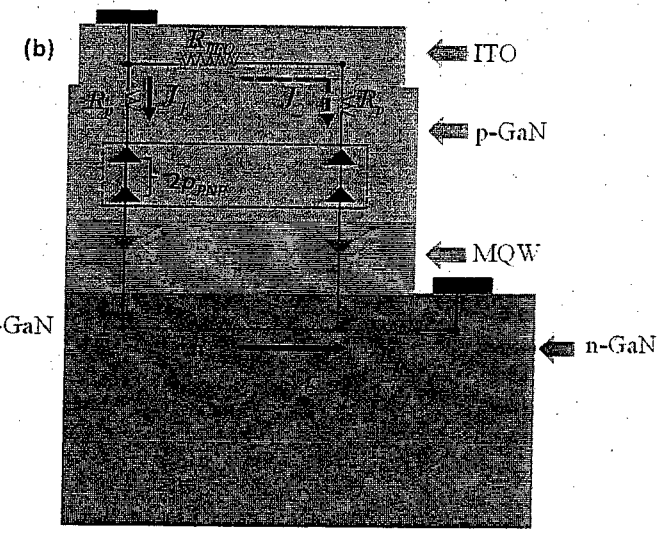


FIGURE 18B

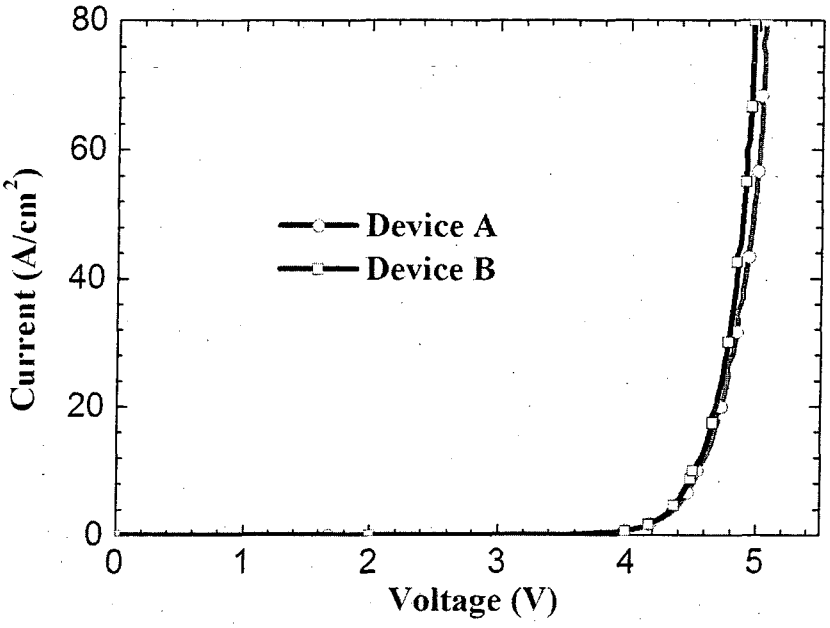


Figure 19A

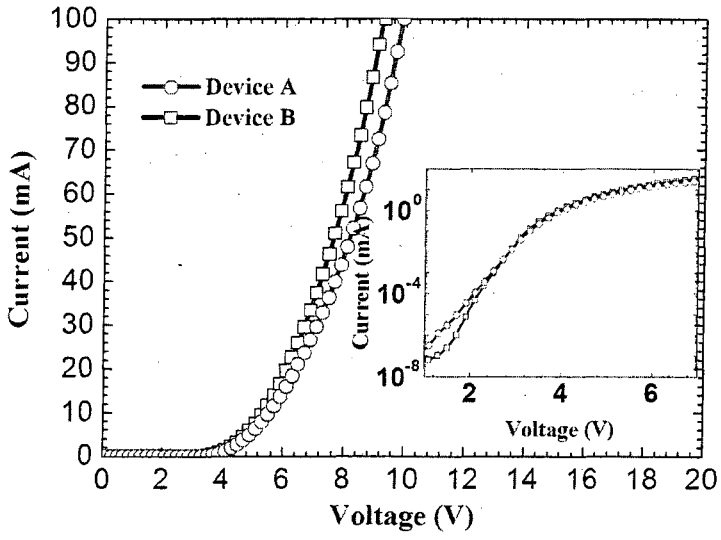


Figure 19B

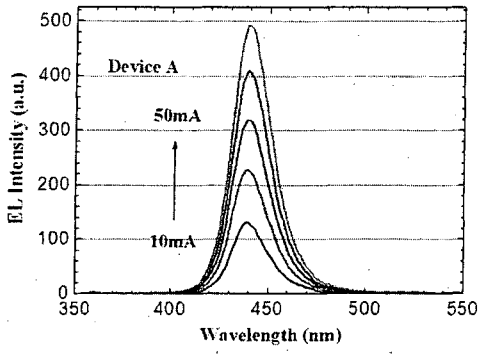


FIGURE 20A

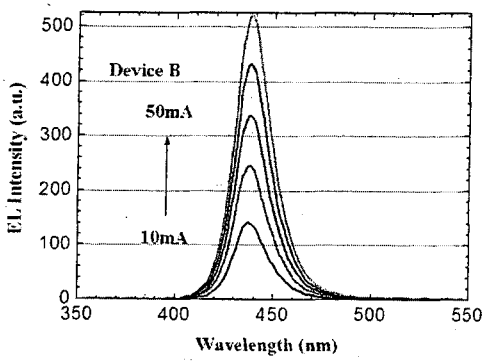


FIGURE 20B

Device A: reference LED with ITO as current spreading layer

Device B: PNP-LED with ITO as current spreading layer

Current (mA)	Current density (A/cm²)
10	8.16
20	16.33
30	24.49
40	32.65
50	40.82

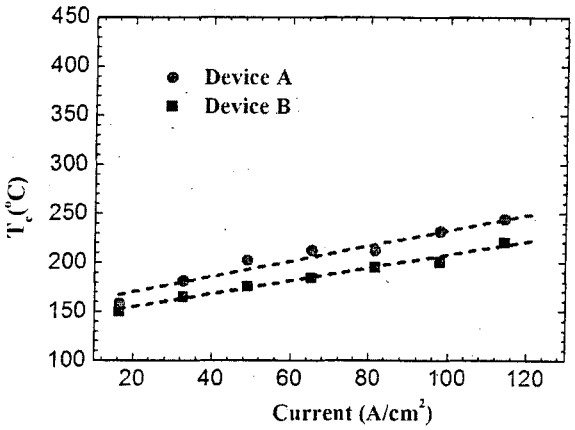


FIGURE 21

Device A: reference LED with ITO as current spreading layer

Device B: PNP-LED with ITO as current spreading layer

T_c: carrier temperature

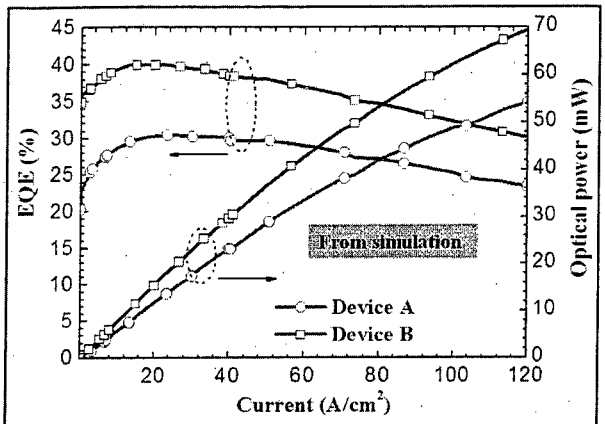


FIGURE 22

Device A: reference LED with ITO as current spreading layer

Device B: PNP-LED with ITO as current spreading layer

Current density (A/cm²)	Simulated power (mW)		Increment (%)
	Device A	Device B	
20	11.67	15.38	31.80
60	33.46	42.78	27.85
120	54.23	69.60	28.34

Device A: reference LED with ITO as current spreading layer

Device B: PNP-LED with ITO as as current spreading layer

Current density (A/cm²)	Simulated power (mW)		Increment (%)
	Device A	Device B	
20	5.22	15.38	194.63
60	16.27	42.78	162.94
120	21.43	69.60	224.78

Device A: reference LED w/o ITO as current spreading layer

Device B: PNP-LED with ITO as current spreading layer

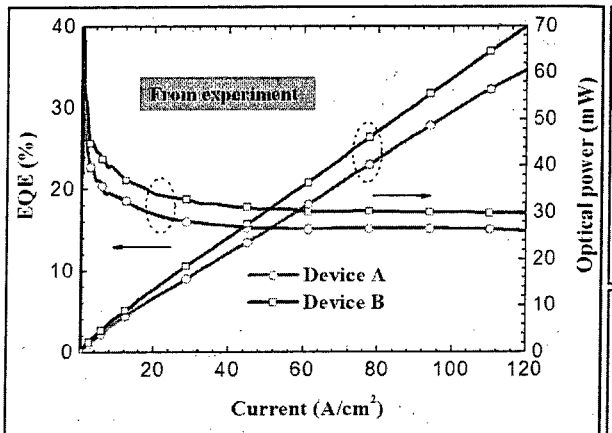


FIGURE 23

Device A: reference LED with ITO as current spreading layer

Device B: PNP-LED with ITO as current spreading layer

Current density (A/cm²)	Experimental power (mW)		Increment (%)
	Device A	Device B	
20	11.87	13.70	15.42
60	31.71	36.36	14.66
120	60.68	70.27	15.80

Device A: reference LED with ITO as current spreading layer

Device B: PNP-LED with ITO as as current spreading layer

Current density (A/cm²)	Experimental power (mW)		Increment (%)
	Device A	Device B	
20	8.49	13.70	61.14
60	18.21	36.36	99.67
120	26.97	70.27	160.55

Device A: reference LED w/o ITO as current spreading layer

Device B: PNP-LED with ITO as current spreading layer

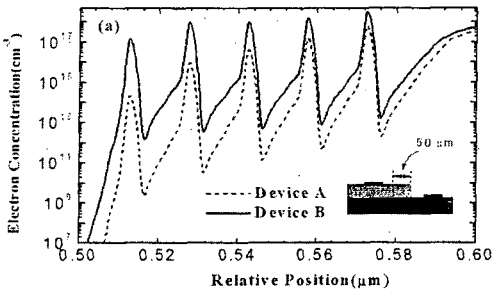


FIGURE 24A

Device A: reference LED with ITO as current spreading layer

Device B: PNP-LED with ITO as current spreading layer

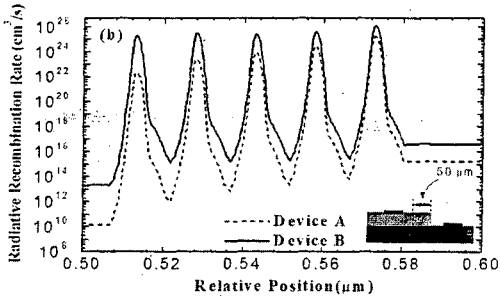


FIGURE 24B

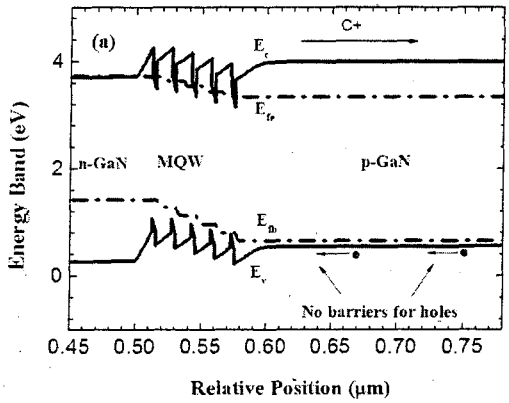


FIGURE 25A

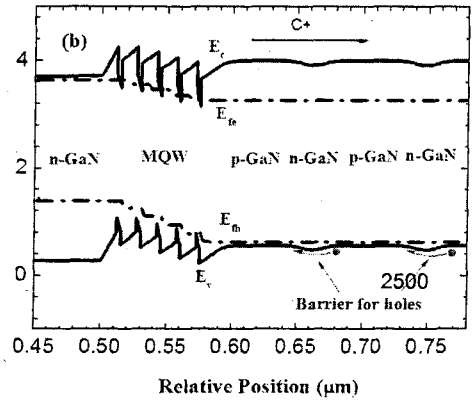


FIGURE 25B

Device A: reference LED with ITO as current spreading layer

Device B: PNP-LED with ITO as current spreading layer