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United States Patent [19]

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Edmond et al.

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[54] **BLUE LIGHT-EMITTING DIODE WITH HIGH EXTERNAL QUANTUM EFFICIENCY**

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[73] Assignee: **Cree Research, Inc., Durham, N.C.**

[21] Appl. No.: **81,668**

[22] Filed: **Jun. 23, 1993**

[51] Int. Cl.⁶ **H01L 33/00**

[52] U.S. Cl. **257/76; 257/77; 257/98; 257/99; 257/101; 257/103**

[58] Field of Search **257/76, 77, 91, 95, 257/98, 99, 101, 103, 102, 623**

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,918,497	4/1990	Edmond	357/17
5,027,168	6/1991	Edmond	357/17
5,063,421	11/1991	Suzuki et al.	257/77
5,187,547	2/1993	Niina et al.	257/77
5,243,204	9/1993	Suzuki et al.	257/77

FOREIGN PATENT DOCUMENTS

58-64074	4/1983	Japan	257/77
0221673	1/1990	Japan	257/77
0471278	3/1992	Japan	257/77
4112583	4/1992	Japan	257/77

OTHER PUBLICATIONS

K. H. Huang, et al., Twofold Efficiency Improvement in High Performance AlGaInP Light-Emitting Diodes

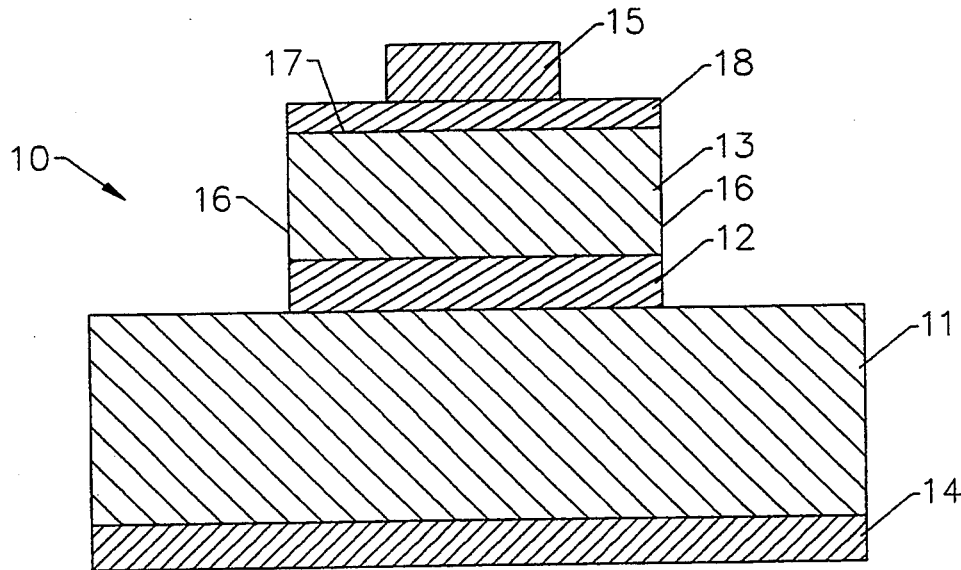
in the 555–620 nm Spectral Region Using a Thick GaP Window Layer, *Appl. Phys. Lett.*, vol. 61, No. 9, Aug. 1992, pp. 1045–1047.

Primary Examiner—William Mintel
Attorney, Agent, or Firm—Bell, Seltzer, Park & Gibson

[57] **ABSTRACT**

A light emitting diode is disclosed that emits light in the blue portion of the visible spectrum with high external quantum efficiency. The diode comprises a single crystal silicon carbide substrate having a first conductivity type, a first epitaxial layer of silicon carbide on the substrate and having the same conductivity type as the substrate, and a second epitaxial layer of silicon carbide on the first epitaxial layer and having the opposite conductivity type from the first layer. The first and second epitaxial layers forming a p-n junction, and the diode includes ohmic contacts for applying a potential difference across the p-n junction. The second epitaxial layer has side walls and a top surface that forms the top surface of the diode, and the second epitaxial layer has a thickness sufficient to increase the solid angle at which light emitted by the junction will radiate externally from the side walls, but less than the thickness at which internal absorption in said second layer would substantially reduce the light emitted from said top surface of the diode.

53 Claims, 5 Drawing Sheets



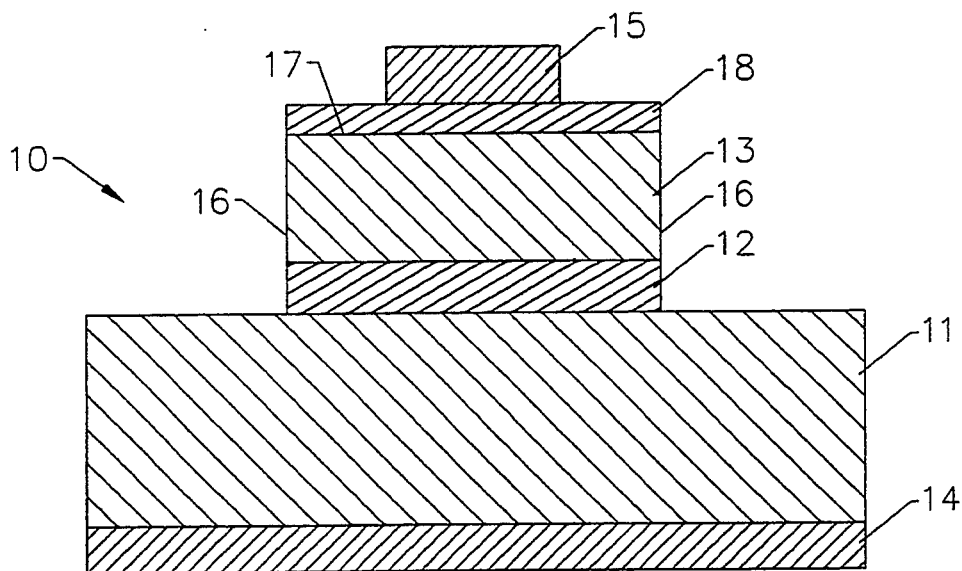


FIG. 1.

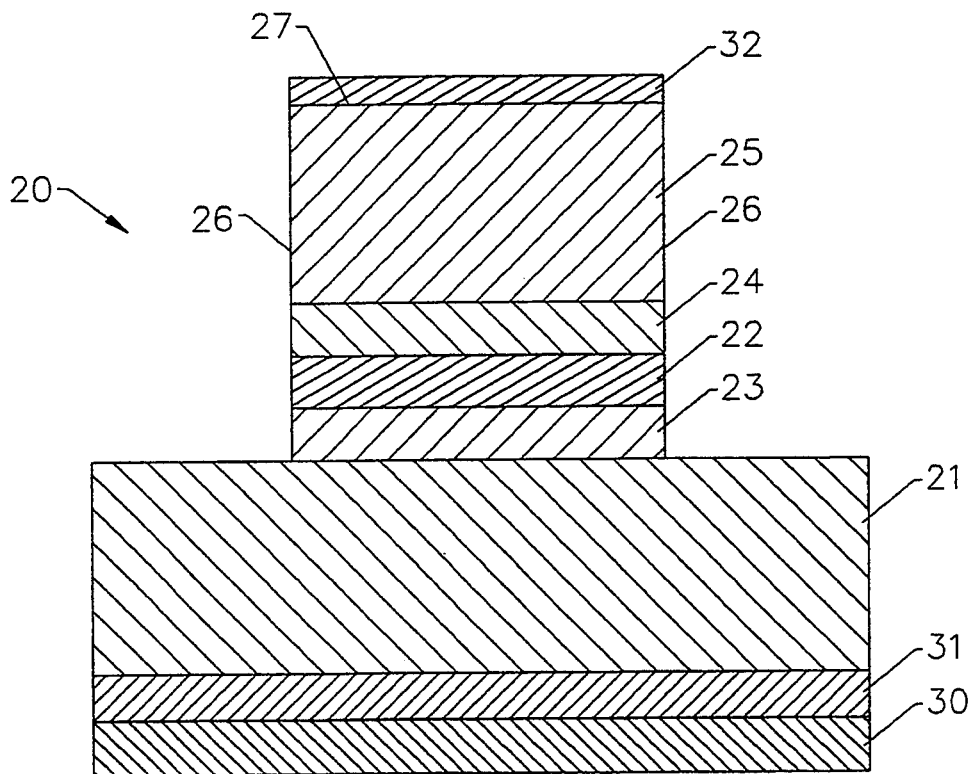


FIG. 2.

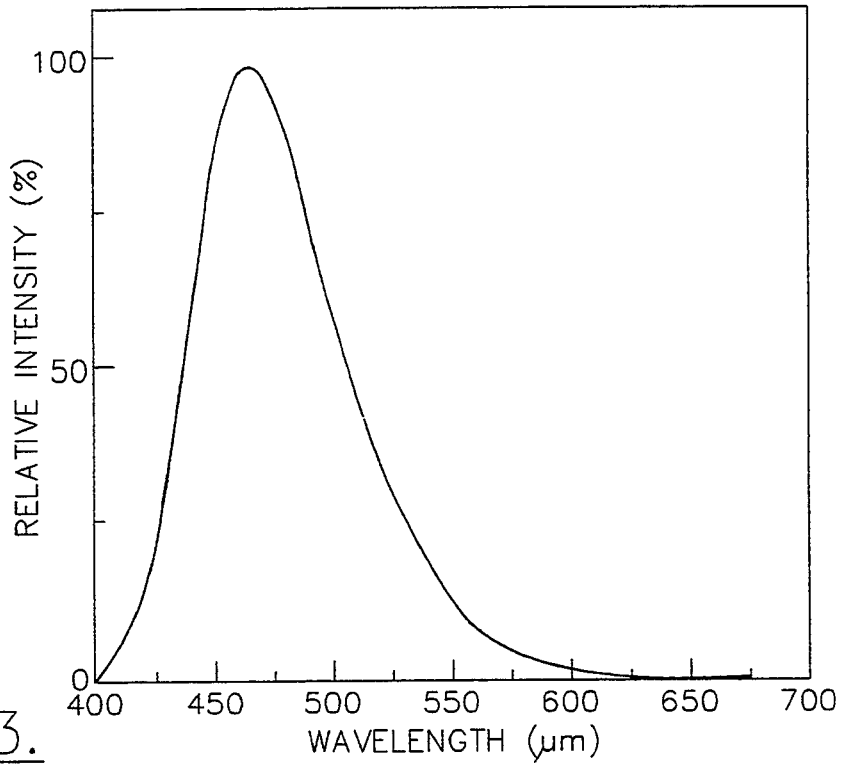


FIG. 3.

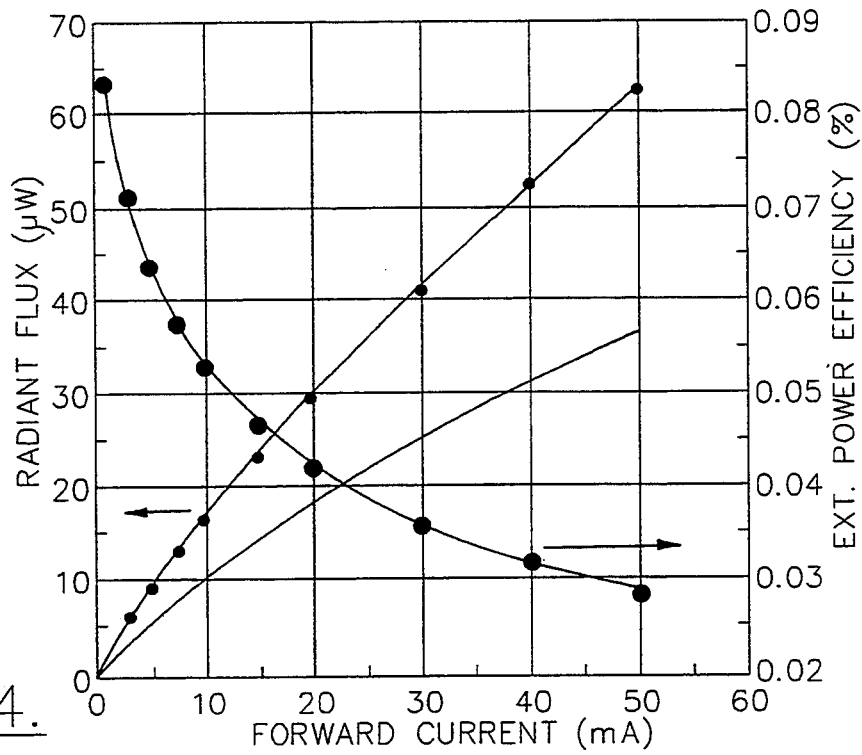


FIG. 4.

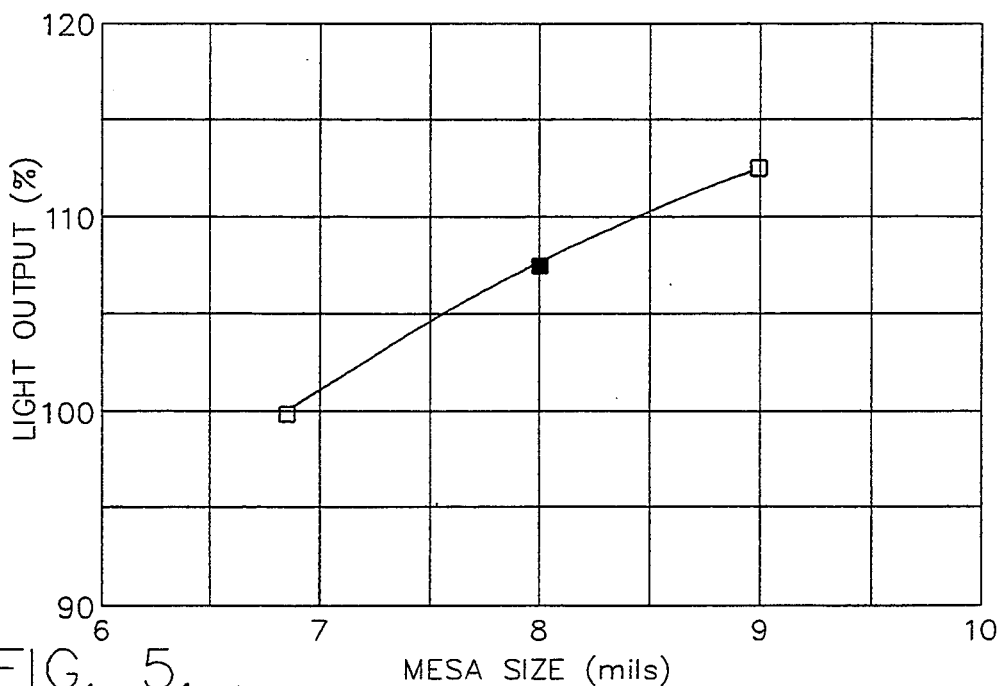


FIG. 5.

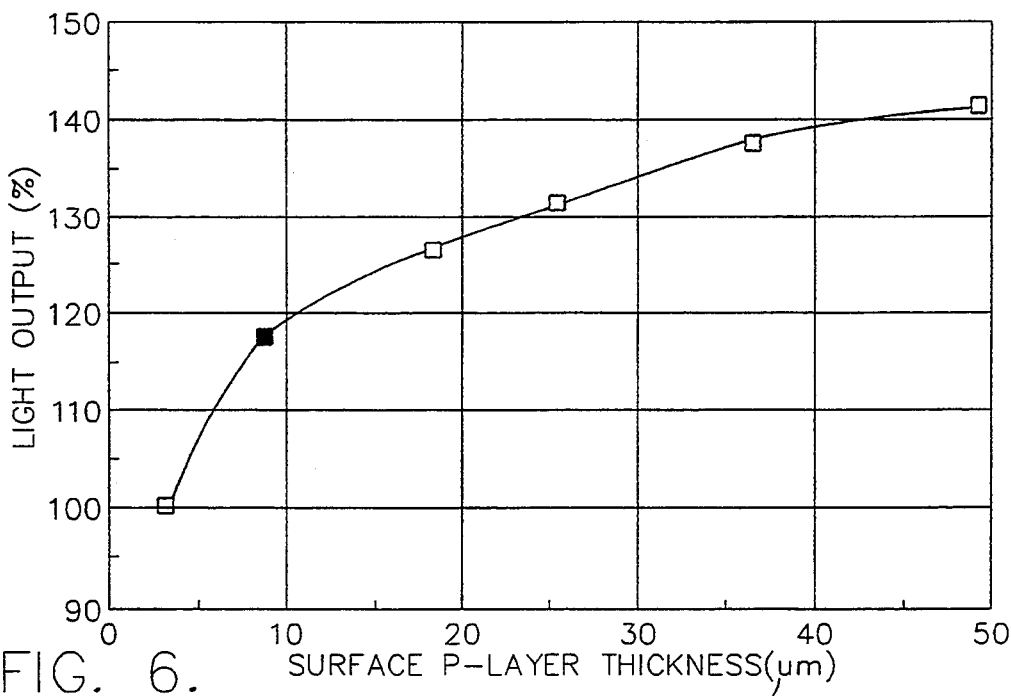


FIG. 6.

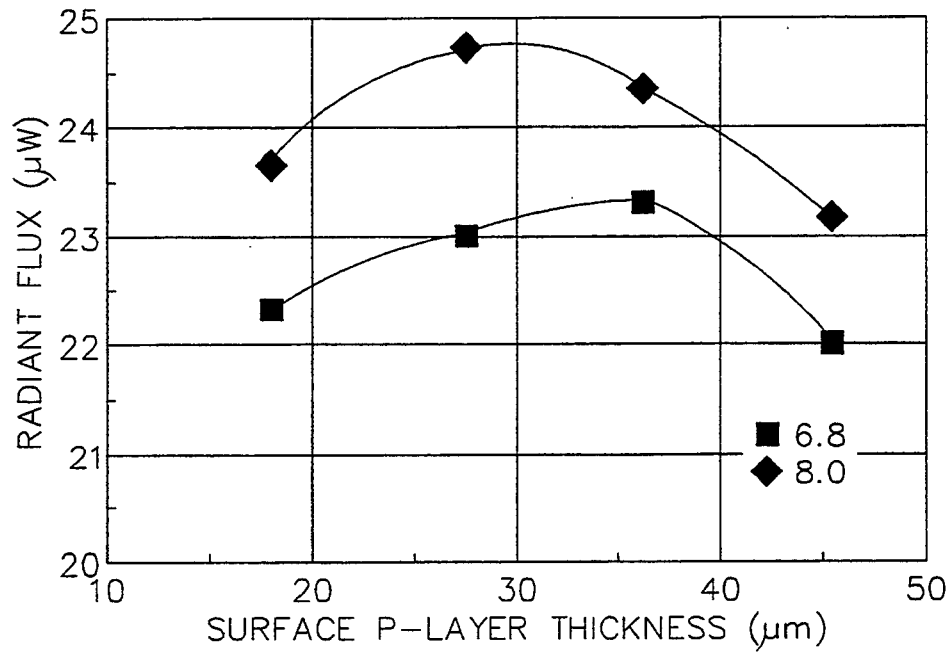


FIG. 7.

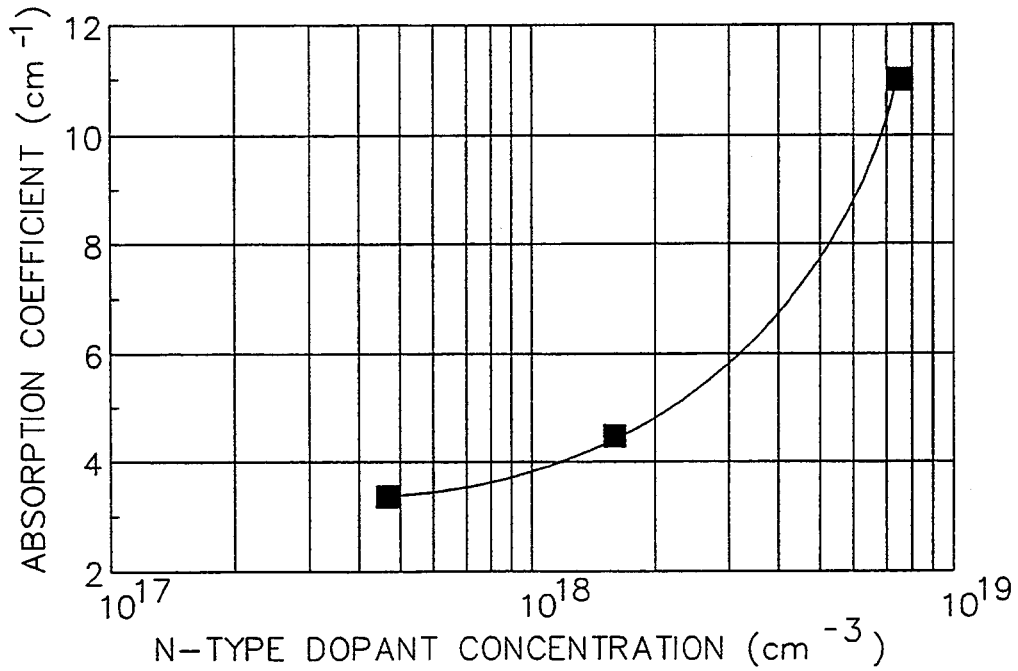


FIG. 8.

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