光子学报 2013, 42(4) 409-416 DOI: 10.3788/gzxb20134204.0409 ISSN: 1004-4213 CN: 61-1235/O4

论文

顶端ZnO纳米结构对GaN基LED光提取效率的影响

李伟, 岳庆炀, 孔繁敏, 李康

山东大学 信息科学与工程学院, 济南 250100

摘要:

为了提高GaN基蓝光LED的光提取效率,本文建立了LED顶面分别铺设ZnO纳米柱和纳米锥结构的两种模型,利用时域有限差分法对两种模型进行仿真并对结果进行了比较.仿真结果表明,ZnO纳米结构的各项几何结构参量(包括排列周期*P*、高度*L*、宽度*W*以及斜率*k*等),对LED顶端光提取效率影响显著.仿真分别得到了两种结构的最佳模型,通过比较,LED顶面纳米柱和纳米锥结构对光提取效率的提高效果相近,其最佳提取效率分别增强至无任何结构时的2.5倍和2.3倍.同时,通过对各项参量扫描获得的对光提取效率的变化曲线进行了分析,并给出了相应相应的理论解释.这些模型优化和理论分析对实际的高性能GaN基LED的设计制造有着指导意义.

关键词: 发光二极管 ZnO纳米结构 光提取效率 时域有限差分

Influence of Surface ZnO Nano-structures on the Light Emitting Efficiency of GaN-based LED

LI Wei, YUE Qing-yang, KONG Fan-min, LI Kang

School of Information Science and Engineering, Shandong University, Jinan 250100, China

Abstract:

In order to improve the light emitting efficiency(LEE) of GaN-based blue LED, two LED models covered by ZnO nano-structures, including nano-rod and nano-cone structures, are simulated in the method of FDTD. The results of these simulations show that the light emitting efficiency of LED is varying regularly with the different nanostructures' geometric parameters (such as the period: *P*, the wide of bottom: *W*, and the length: *L*). The optimized model structure is obtained, and it is found that both ZnO nano-rod and nano-cone can bring obviously incensement (250% and 230%) on LEE. Besides, with the analysis on the variation curve, the influence of ZnO nano-structure and the reason of the optimization results are theoretically explained. These results provide a theoretical reference on the practical design and optimization of highly efficient GaN-based LED.

Keywords: Light emitting diodes ZnO nanorod structure Light emitting efficiency Finite-difference time-domain

收稿日期 2012-08-30 修回日期 2012-12-10 网络版发布日期

DOI: 10.3788/gzxb20134204.0409

基金项目:

国家重点基础研究发展计划(Nos.2009CB930503, 2009CB930501)和国家自然科学基金(No.61077043)资助

通讯作者:

作者简介:

参考文献:

[1] LIU Zhi-qiang, WANG Liang-chen. Analysis of light extraction efficiency for face-up and flip-chip GaN-based LED
[J]. Chinese Journal of Electron Devices, 2007, 30(3): 775-778. 刘志强, 王良辰. 正装、倒装结构GaN基LED提取效率分析

[J].电子器件, 2007, 30(3):775-778.

[2] CHEN Yi-xin, SHEN Guang-di, MENG Li-li, *et al.* Improved extraction efficiency of AlGaInP light emitting diodes by nano-scale surface roughness
[J]. Journal of Optoelectronics • Laser, 2011, 22(10): 1451-1454. 陈依新, 沈光地, 孟丽丽, 等. AlGaInP系LED的表面纳米级粗化以及光提取效率提高
[J].光电子.激光, 2011, 22(10):1451-1454.

[3] XIONG Wei-ping, FAN Guang-han, LI Qi. Improvement for the light extraction efficiency of light-emitting diodes
[J]. Acta Photonica Sinica, 2010, 39(11): 1956-1960. 熊伟平, 范广涵, 李琦. 提高LED光提取效率的研究
[J].光子学报,2010,39(11): 1956-1960.

[4] HSIAO S K, CHANG E Y, HSIAO Y L, *et al.* 460-nm InGaN-Based LEDs Grown on fully inclined hemisphere-shape-patterned sapphire substrate with submicrometer spacing
[J]. IEEE Photonics Technology Letters, 2009, 21(19): 1366-1368.

[5] ZHANG Zhen-ming, LI Kang, KONG Fan-min, *et al.* Study on improving light emitting efficiency of led by using silver nanodisk array
[J]. Acta Optica Sinica, 2012, 32(4): 0423001-0423004. 张振明, 李康, 孔凡敏, 等. 采用银纳米圆盘阵列提高LED发光特性的研究
[J].光学学报, 2012, 32(4): 0423001-023004.

[6] GAO Hui, KONG Fan-min, LI Kang, *et al.* Structural optimization of gan blue light led with double layers of photonic crystals
[J]. Acta Physica Sinica, 2012, 61(12): 127807-127815. 高晖, 孔凡敏, 李康,等. 双层光子晶体氮化镓蓝光发光二极管结构优化的研究
[J].物理学报, 2012,61(12):127807-127815.

[7] YUE Qing-yang, KONG Fan-min, LI Kang, *et al.* Study on the light extraction efficiency of GaN-based light emitting diode by using the degects of the photonic crystals
[J]. Acta Physica Sinica, 2012, 61(20): 208502-208511. 岳庆炀, 孔凡敏, 李康,等. 基于缺陷光子晶体结构的GaN基发光二极管光提取效率的有关研究
[J].物理学报, 2012, 61(20):208502-208511.

[8] WANG Jing, WU Li-jun. A numerical study of influence of photonic crystals on the light extraction efficiency and far field radiation characteristics of light-emitting diode
[J]. Acta Photonica Sinica, 2010, 39(8): 1500-1508. 王靖, 吴立军.光子晶体发光二极管光抽取效率及远场辐射特性的数值研究
[J].光子学报, 2010, 39(8):1500-1508.

[9] YU Ren-yong, JIN Shang-zhong, LIANG Pei, *et al.* Monte Carlo simulation on leds graded-refractive-index-encapsulation
[J]. Acta Photonica Sinica, 2010, 39(12): 2200-2203. 余仁勇, 金尚忠, 梁培,等. LED梯度折射率封装结构的蒙特卡洛模拟
[J].光子学报, 2010,39(12): 2200-2203.

[10] LIN C L, CHEN P H, CHAN C H, *et al.* Light enhancement by the formation of an Al oxide honeycomb nanostructure on the n-GaN surface of thin-GaN light-emitting diodes
[J]. Applied Physics Letters, 2007, 90(24): 242106-242108.

[11] WANG Ya-wei, LIU Ren-jie, JIN Ji, *et al.* Dynamic relations between light extraction efficiency and characteristic parameters of gan-based led with double-grating structure

[J]. Acta Photonica Sinica, 2010, 39(7): 1208-1212. 王亚伟, 刘仁杰, 金骥, 等.基于双光栅结构下特征参量与GaN基LED光提取效率的动态关系
[J].光子学报,2010,39(7):1208-1212.

[12] OZGUR, HOFSTETTER U, MORKOC H. ZnO devices and applications: a review of current status and future prospects
[J]. Proceedings of the IEEE, 2010, 98(7): 1255-1268.

[13] ZHONG J, CHEN H, SARAF G, *et al.* Integrated ZnO nanotips on GaN light emitting diodes for enhanced emission efficiency
[J]. Appied Physics Leterst, 2007, 90(20): 203515-203517.

[14] CHEN Chih-han, CHANG Shoou-jinn, CHANG Sheng-po, *et al.* Fabrication of a white-light-emitting diode by doping gallium into zno nanowire on a p-gan substrate
[J]. The Journal of Physical Chemistry C, 2010, 114(29): 12422-12426.

[15] DAI K, SOH C B, CHUA S J, *et al.* Influence of the alignment of ZnO nanorod arrays on light extraction enhancement of GaN-based light-emitting diodes
[J]. Journal of Applied Physics, 2011, 109(8): 083110-083114.

[16] LIU Wen-de, GAN Zi-zhao. Analysis of the light extraction efficiency of light-emitting diodes with photonic crystals combined with the generalized Rouard method
[J]. Journal of Optical Society of America A, 2009, 26(2): 289-296.

[17] GAO Hui, KONG Fan-min, LI Kang, *et al.* Improving light extraction efficiency of GaN-based LEDs by $Al_xGa_{1-x}N$ confing layer and embedded photonic crystals
[J]. IEEE Journal of Selected Topics in Quantum Electronic, 2011, 99(1): 1-11.

[18] ZHAO Jia, LI Kang, KONG Fan-min, *et al.* Enhancement of blue light emission using surface plasmons coupling with quantum wells
[J].Progress In Electromagnetics Research, 2010, 108(17): 293-306.

[19] 葛德彪, 闫玉波. 电磁波时域有限差分方法
[M].西安:西安电子科技大学出版社, 2002.

[20] WIESMANN C. Nano-structured LEDs-light extraction mechanisms and applications. University Regensburg, 2009, 3: 1-105.

[21] KONG Fan-min, LIU Xin, LI Kang, *et al.* Analysis of planar optical waveguide structures with the pml-fdtd method
[J]. Journal of Optoelectronics Laser, 2003, 14(4): 352-354. 孔凡敏, 刘新, 李康,等. PML-FDTD法在分析平面光波导结构中的应用
[J].光电子激光, 2003,14(4):352-354.

[22] MATIOLI E N, WEISBUCH C. Impact of photonic crystals on LED light extraction efficiency: approaches and limits to vertical structure designs
[J]. Journal of Physics D-Applied Physics, 2010, 43(5): 3540005.

本刊中的类似文章

1. 丁坤, 饶海波, 宋继荣.感光性树脂应用于发光二极管平面自适应封装技术[J]. 光子学报, 2012,(6): 664-667
2. 谢东华;何晓东;佟传平;于海霞;冯金顺.

[J]. 光子学报, 2007,36(3): 434-438
3. 王建永;李庆武;赵长青.旋转体时域有限差分法的另一推导方法和单向波方程吸收边界条件[J]. 光子学报, 2007,36(1): 148-151
4. 朱志宏;叶卫民;季家镕;袁晓东;曾淳.用三维并行时域有限差分算法研究光子晶体薄板W3波导传输特性[J]. 光子学报, 2006,35(6): 815-818
5. 严俊;王宗宝;王克逸;周绍详.光学微球腔的壳层结构研究[J]. 光子学报, 2006,35(2): 197-200
6. 王慧琴 刘正东 冷新丽.光在二维无序介质中的动态传播过程[J]. 光子学报, 2009,38(3): 709-712
7. 巴晓艳;张桂才;李永兵;王巍.SLD光谱调制对光纤陀螺性能的影响[J]. 光子学报, 2006,35(5): 680-683
8. 蔡纯 肖金标 张明德 孙小菡 .基于系统辨识的平面光波导谐振腔滤波器仿真实验研究[J]. 光子学报, 2007,36(4): 667-671
9. 李岩;郑瑞生;冯玉春;刘颂豪;牛憨笨.一种发光二极管模型中无序光子晶体对光输出影响的研究[J]. 光子学报, 2006,35(6): 902-905
10. 贺锋涛; 张东玲; 白永林; 冯晓强; 侯洵.固体浸没透镜出射光场偏振特性研究[J]. 光子学报, 2005,34(2): 276-279
11. 杨振宇;朱大庆;赵茗;曹明翠.纳米孔隙聚合物光学薄膜透过率谱线的数值计算[J]. 光子学报, 2005,34(4): 582-585
12. 胡宝晶,黄铭,张剑龙,彭金辉.光波辐射下正多边形异向介质柱聚焦特性分析[J]. 光子学报, 2009,38(5): 1264-1267
13. 申屠伟进;蔡纯;戴劲草;张明德;孙小菡.平面光波导器件时域有限差分束传输法分析中边界和初始条件的处理[J]. 光子学报, 2005,34(4): 537-541
14. 沈伟东;王建浦;陈海星;李海峰;刘旭;顾培夫.基于MEMS的波长可调谐微腔有机发光二极管的设计[J]. 光子学报, 2004,33(2): 155-158
15. 田进寿;许蓓蕾;王俊峰;周军兰;郭宝平.一种基于碳纳米管场发射的发光二极管[J]. 光子学报, 2004,33(9): 1148-1150

文章评论 (请注意:本站实行文责自负, 请不要发表与学术无关的内容!评论内容不代表本站观点.)

反馈人		邮箱地址	
反馈标题		验证码	1889
反馈内			