光子学报 2012, (4) 485-492 DOI: 10.3788/gzxb20124104.0485 ISSN: 1004-4213 CN: 61-1235/O4

论文

应变纤锌矿GaN/A1$_{0.15}$Ga$_{0.85}$N柱形量子点的光学性质:流体静压力效应

郑冬梅,王宗篪

三明学院 物理与机电工程学院,福建 三明 365004

摘要:

在有效质量近似下,考虑强的内建电场和应变对材料参量的影响,变分研究了流体静压力对有限高势垒应变纤锌矿GaN/Al$_{0.15}$Ga$_{0.85}$N柱形量子点中重空穴激子的结合能、发光波长和电子空穴复合率的影响.数值结果表明,激子结合能和电子空穴复合率随流体静压力的增大而近线性增大,发光波长随流体静压力的增大而单调减小.在量子点尺寸较小的情况下,流体静压力对激子结合能和电子空穴复合率的影响更明显.由于应变效应,为了获得有效的电子-空穴复合过程,GaN量子点的高度必须小于5.5 nm.

关键词: 量子点 激子 流体静压力 应变

Optical Properties of Strained Wurtzite GaN/Al$_{0.15}$Ga$_{0.85}$N Cylindrical Quantum Dots: Effects of Hydrostatic Pressure

ZHENG Dong-mei, WANG Zong-chi

Department of Physics and Electromechanical Engineering, Sanming College, Sanming, Fujian 365004, China

Abstract:

Within the effective-mass approximation, the influences of hydrostatic pressure on the exciton binding energies, emission wavelengths and electron-hole recombination rates for a heavy-hole exciton in strained wurtzite (WZ) GaN/Al$_{0.15}$Ga$_{0.85}$N cylindrical quantum dot (QD) with finite potential barriers are investigated via a variational procedure, with considering the strong built-in electric field (BEF) effect and strain dependence of material parameters. Numerical results show that the exciton binding energies and electron-hole recombination rates both increase almost linearly, and the emission wavelengths are monotonically reduced with the increase of the applied hydrostatic pressure. The hydrostatic pressure has a remarkable influence on the exciton binding energy and electron-hole recombination rate for the QD with a small size. Furthermore, the height of GaN QDs must be less than 5.5 nm for an efficient electron-hole recombination process due to strain effects.

Keywords: Quantum dot Exciton Hydrostatic pressure Strain

收稿日期 2011-10-18 修回日期 2011-12-20 网络版发布日期

DOI: 10.3788/gzxb20124104.0485

基金项目:

The National Natural Science Foundation of China (No.11102100)

通讯作者:

作者简介:

参考文献:

[1] WU C W, BELL A, PONCE F A, *et al*. Growth of self-assembled GaN quantum dots via the vapor-liquid-solid mechanism[J]. *Applied Physics Letters*, 2002, 81(17): 3236-3238.
[2] KAWASAKI K, YAMAZAKI D, KINOSHITA A, *et al*. GaN quantum-dot formation by self-assembling droplet epitaxy and application to single-electron transistors[J]. *Applied Physics Letters*, 2001, 79(14): 2243-2245.
[3] RANJAN V, ALLAN G, PRIESTER C, *et al*. Self-consistent calculations of the optical properties of GaN dots[J]. *Physical Review B,* 2003, 68(11): 115305 (1-7).
[4] de RIINALDIS S, D'AMICO I, ROSSI F. Exciton-exciton interaction engineering in coupled GaN quantum dots[J]. *Applied Physics Letters*, 2002,81(22): 4236-4238.
[5] RAMVALL P, TANAKA S, NOMURA S, *et al*. Observation of confinement-dependent exciton binding energy of GaN quantum dots[J]. *Applied Physics Letters*, 1998, 73(8): 1104-1106.

扩展功能
本文信息
Supporting info
PDF(1263KB)
HTML
参考文献
服务与反馈
把本文推荐给朋友
加入我的书架
加入引用管理器
引用本文
Email Alert
文章反馈
浏览反馈信息
本文关键词相关文章
量子点
激子
流体静压力
应变
本文作者相关文章
郑冬梅
王宗篪

[6] TANAKA S, LEE J S, RAMVALL P, *et al*. A UV light-emitting diode incorporating GaN quantum dots[J]. *Japanese Journal of Applied Physics*, 2003, 42(8A): L885-L887.
[7] RAMVALL P, RIBLET P, NOMURA S, *et al*. Optical properties of GaN quantum dots[J]. *Journal of Applied Physics*, 2000, 87(8): 3883-3890.
[8] LITVINOV V I. Optical transitions and gain in group-III nitride quantum wells[J]. *Journal of Applied Physics*, 2000, 88(10): 5814 -5819.
[9] WAN S P, XIA J B, CHANG K. Effects of piezoelectricity and spontaneous polarization on electronic and optical properties of wurtzite III-V nitride quantum wells[J]. *Journal of Applied Physics*, 2001, 90 (12): 6210-6216.
[10] FONOBEROV V A, BALANDIN A A. Excitonic properties of strained wurtzite and zinc-blende GaN/$Al_xGa_{1-x}N$ quantum dots[J]. *Journal of Applied Physics*, 2003, 94(11): 7178-7186.
[11] FONOBEROV V A, POKATILOV E P, BALANDIN A A. Interplay of confinement, strain, and piezoelectric effects in the optical spectrum of GaN quantum dots[J]. *Journal of Nanoscience and Nanotechnology*, 2003, 3(3): 253-256.
[12] de RINALDIS S, AMICO I D, ROSSI F. Intrinsic electric field effects on few-particle interactions in coupled GaN quantum dots[J]. *Physical Review B*, 2004, 69(23): 235316(1-9).
[13] DAI Xian-qi, HUANG Feng-zhen, SHI Jun-jie. Exciton states in strained GaN/$A1_xGa_{1-x}N$ quantum dot [J]. *Journal of Functional Materials*, 2006, 37(1): 130-135.
[14] WEI Shu-yi, ZHAO Xu, WU Hua-rui, *et al*. Influence of built-in electric field on luminescent properties of self-formed single GaN/$Al_xGa_{1-x}N$ quantum dots[J]. *Chinese Journal of Liquid Crystals and Displays*, 2006, 21(2): 139-144.
[15] WAGNER J M, BECHSTEDT F. Pressure dependence of the dielectric and lattice-dynamical properties of GaN and AlN[J]. *Physical Review B*, 2000, 62(7): 4526-4534.
[16] GO I A R, SIEGLE H, SYASSEN K, *et al*. Effect of pressure on optical phonon modes and transverse effective charges in GaN and AlN[J]. *Physical Review B*, 2001, 64(3): 035205(1-6).
[17] EPKOWSKI S P, TEISSEYRE H, SUSKI T, *et al*. Piezoelectric field and its influence on the pressure behavior of the light emission from GaN/AlGaN strained quantum wells[J]. *Applied Physics Letters*, 2001, 79(10): 1483-1485.
[18] HA S H, BAN S L. Binding energies of excitons in a strained wurtzite GaN/AlGaN quantum well influenced by screening and hydrostatic pressure[J]. *Journal of Physics: Condensed Matter*, 2008, 20(8): 085218(1-7).
[19] LIU Fu-ti, ZHANG Shu-hua, GAO Zeng-hui. The optical property of GaN under high pressure[J]. *Journal of Shandong University (Natural Science)*, 2010, 45(1): 69-72.
[20] XIA C X, WEI S Y, ZHAO X. Built-in electric field effect on hydrogenic impurity in wurtzite GaN/AlGaN quantum dot[J]. *Applied Surface Science*, 2007, 253: 5345-5348.
[21] SHI J J, GAN Z Z. Effects of piezoelectricity and spontaneous polarization on localized excitons in self-formed InGaN quantum dots[J]. *Journal of Applied Physics*, 2003, 94(1): 407-415.
[22] SZAFRAN B, BEDNAREK S, ADAMOWSKI J. Parity symmetry and energy spectrum of excitons in coupled self-assembled quantum dots[J]. *Physical Review B*, 2001, 64(12): 125301(1-10).
[23] CHRISTENSEN N E, GORCZYCA I. Optical and structural properties of III-V nitrides under pressure [J]. *Physical Review B*, 1994, 50(7): 4397-4415.
[24] WAGNER M, BECHSTEDT F. Properties of strained wurtzite GaN and AlN: *Ab* initio studies[J]. *Physical Review B*, 2002, 66(11): 115202(1-20).
[25] PERLIN P, MATTOS L, SHAPIRO N A, *et al*. Reduction of the energy gap pressure coefficient of GaN due to the constraining presence of the sapphire substrate[J]. *Journal of Applied Physics*, 1999, 85(4): 2385-2389.
[26] XIA C X, ZENG Z P, WEI S Y. Effects of applied electric field and hydrostatic pressure on donor impurity states in cylindrical GaN/AlN quantum dot[J]. Journal of Applied Physics, *2010, 107: 014305(1-5).*
[27] ZHANG Ming, BAN Shi-liang. Stark effect of donor impurity states in strained heterojunctions under pressure[J]. Acta Physica Sinica, 2008, 57(7): 4459-4465.
[28] VASCHENKO G, PATEL D, MENONI C S, *et al*. Significant strain dependence of piezoelectric constants in $In_xGa_{1-x}N$/GaN quantum wells[J]. *Physical Review B*, 2001, 64(24): 241308(1-10).
[29] RAIGOZA N, DUQUE CA, PORRAS-MONTENEGRO N, *et al*. Correlated electron hole transition energies in quantum-well wires: Effects of hydrostatic pressure[J]. *Physica B*, 2006, 371(1): 153-157.
[30] VURGAFTMAN I, MEYER J R, RAM-MOHAN L R. Band parameters for III-V compound semiconductors and their alloys[J]. *Journal of Applied Physics*, 2001, 89(11): 5815-5873.
[31] PARK S H, CHUANG S L. Comparison of zinc-blende and wurtzite GaN semiconductors with spontaneous polarization and piezoelectric field effects[J]. *Journal of Applied Physics*, 2000, 87(1): 353-364.
[32] BERNARDINI F, FIORENTINI V, VANDERBILT D. Spontaneous polarization and piezoelectric constants of III-V nitrides[J]. *Physical Review B*, 1997, 56(16): R10024-R10027.
[33] WEI S H, ZUNGER A. Predicted band-gap pressure coefficient of all diamond and zinc-blende semiconductors: chemical trends[J]. *Physical Review B*, 1999, 60(8): 5404-5411.

本刊中的类似文章

1．彭保进;张敏;廖延彪;赖淑蓉;匡武;贺晓霞.在－50℃~+150℃大温度范围下用FBG测材料　的三维热膨胀系数[J]. 光子学报, 2005,34(10): 1501-1505

2．廖毅 饶云江 胡永明 李景义 .低成本长周期光纤光栅传感系统[J]. 光子学报, 2007,36(4): 702-705

3．张纪梅 许世超 宋秀云 代昭 孙波 姚翠翠.CdTe,核　壳型CdTe/CdS及CdTe/ZnS量子点的合成及表征[J]. 光子学报, 2009,38(4): 905-910

4．童凯;汪梅婷;李志全.光纤Bragg光栅应变测量中啁啾特性的研究[J]. 光子学报, 2006,35(6): 877-880

5．颜国君;陈光德;邱复生;Zhaoyan;Fan.氮化铝薄膜的光学性能[J]. 光子学报, 2006,35(2): 221-223

6．罗志徽;贺俊芳;汪敏强;张苏娟;彭延湘.

$ZnSe/SiO_2$半导体量子点玻璃的光谱特性

[J]. 光子学报, 2007,36(3): 471-475

7．朱慧群;丁瑞钦;胡怡.氢对GaAs薄膜的钝化作用[J]. 光子学报, 2006,35(8): 1194-1198

8．冯德全 乔学光 王宏亮 周红 罗小东 刘颖刚.大范围光纤Bragg光栅压力传感器增敏实验研究[J]. 光子学报, 2007,36(7): 1273-1276

9．谭敏峰;朱四荣;宋显辉;李卓球.安装偏差对光纤布喇格光栅应变测量的影响[J]. 光子学报, 2006,35(9): 1354-1357

10．于秀娟;余有龙;张　敏;廖延彪;赖淑蓉.铜片封装光纤光栅传感器的应变和温度传感特性研究[J]. 光子学报, 2006,35(9): 1325-1328

11．杨军;刘志海;裴雅鹏;苑立波.双涂层光纤应变传感器的理论与实验研究[J]. 光子学报, 2006,35(6): 842-845

12．袁艳红;侯洵;白晋涛.紫外光激发下氧化锌纳米线的发光特性研究[J]. 光子学报, 2006,35(3): 373-376

13．佟艳群;符欲梅;陈伟民;朱永;陈雨森;梁大开.光纤法珀应变传感器并联复用实验研究[J]. 光子学报, 2005,34(10): 1506-1509

14．李景义;饶云江;牛永昌;聂玲.基于新型长周期光纤光栅的低成本应变传感系统[J]. 光子学报, 2005,34(3): 431-433

15．姚鸣;朱卡的;袁晓忠;蒋逸文;吴卓杰.强耦合激子-声子系统中的三阶非线性光学系数的理论计算[J]. 光子学报, 2005,34(10): 1480-1484

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	9803
反馈内			

Copyright 2008 by 光子学报