[an error occurred while processing this directive]

发光学报
CHINESE JOURNAL OF LUMINESCENCE
中文核心期刊
主管：中国科学院
主办：中国科学院长春光学精密机械与物理研究
中国物理学会发光分会
主编：申德振

发光学报 2013, 34(10) 1300-1305 ISSN: 1000-7032 CN: 22-1116/O4

材料合成及性能

纤锌矿$Mg_xZn_{1-x}O/Mg_{0.3}Zn_{0.7}O$抛物量子阱中极化子能级

张国庆, 赵凤岐, 张晨宏

内蒙古师范大学 物理与电子信息学院, 内蒙古 呼和浩特 010022

PDF 下载 引用本文

摘要： 采用改进的Lee-Low-Pines(LLP)中间耦合方法研究纤锌矿$Mg_xZn_{1-x}O/Mg_{0.3}Zn_{0.7}O$抛物量子阱材料中的极化子能级,给出极化子基态能量、跃迁能量(第一激发态到基态)和不同支长波光学声子对电子态能级的贡献随量子阱宽度*d*的变化规律。理论计算中考虑了纤锌矿$Mg_xZn_{1-x}O/Mg_{0.3}Zn_{0.7}O$抛物量子阱材料中声子模的各向异性和介电常数、声子(类LO和类TO)频率等随空间坐标*Z*变化(SD)效应对极化子能量的影响。结果表明,$Mg_xZn_{1-x}O/Mg_{0.3}Zn_{0.7}O$抛物量子阱中电子与长波光学声子相互作用对极化子能级的移动很大,使得极化子能量明显降低。阱宽较小时,半空间长波光学声子对极化子能量的贡献较大,而定域长波光学声子的贡献较小;阱宽较大时,情况则正好相反。在*d*的变化范围内,电子与长波光学声子相互作用对极化子能级的移动(约67~79 meV)比$Al_xGa_{1-x}As/Al_{0.3}Ga_{0.7}As$抛物量子阱中的相应值(约1.8~3.2 meV)大得多。因此,讨论ZnO基量子阱中电子态问题时要考虑电子与长波光学声子的相互作用。

关键词： 抛物量子阱 电子-光学声子相互作用 极化子

Polaron Energy Level in Wurtzite $Mg_xZn_{1-x}O/Mg_{0.3}Zn_{0.7}O$ Parabolic Quantum Well

ZHANG Guo-qing, ZHAO Feng-qi, ZHANG Chen-hong

College of Physics and Electronic Information, Inner Mongolia Normal University, Hohhot 010022, China

Abstract: The energy levels of polaron in a wurtzite $Mg_xZn_{1-x}O/Mg_{0.3}Zn_{0.7}O$ parabolic quantum well are investigated by adopting a modified Lee-Low-Pines variational method. The ground state energy, the transition energy and the contributions of different branches of optical phonon modes to the ground state energy as functions of the well width *d* are given. The effects of the anisotropy of optical phonon modes(like-LO and like-TO)and the spatial dependence effective mass, dielectric constant, phonon frequency on energy levels are considered in theoretical calculation. The results indicate that the contributions of the electron-optical phonon interaction to polaron energy shift in $Mg_xZn_{1-x}O/Mg_{0.3}Zn_{0.7}O$ parabolic quantum well are very large, which make the energy of polaron reduce. For a narrower quantum well, the contributions of half-space optical phonon modes is large, and the contributions of the confined optical phonon modes is small, while for a wider one, the case is contrary. In the region of *d*, the contributions of the electron-optical phonon interaction to polaron energy shift in wurtzite $Mg_xZn_{1-x}O/Mg_{0.3}Zn_{0.7}O$ (about from 67 to 79 meV) are greater than that of $Al_xGa_{1-x}As/Al_{0.3}Ga_{0.7}N$ parabolic quantum well (about from 1.8 to 3.2 meV). Therefore, the electron-optical phonon interaction should be considered in studying electron state in ZnO based quantum well.

Keywords: parabolic quantum well electron-optical phonon interaction polaron

收稿日期 2013-05-22 修回日期 2013-07-30 网络版发布日期

基金项目:

国家自然科学基金(11264027);内蒙古师范大学"十百千"人才培养工程基金(RCPY-2-2012-K-039)资助项目

通讯作者: 赵凤岐, E-mail: fqzhao@imnu.edu.cn

作者简介: 张国庆(1982-), 女, 山西晋城人, 主要从事凝聚态理论方面的研究。E-mail: zhangguoqing0602@163.com

作者Email: fqzhao@imnu.edu.cn

参考文献：

[1] Su S C, Lu Y M, Mei T. Fabrication and optical properties of ZnO/ZnMgO multiple quantumwells on m-sapphire substrates [J]. *Acta Phys. Sinica* (物理学报), 2011, 60(9):096801-1-4 (in Chinese).

[2] Nomura K, Ohta H, Ueda K, *et al.* Thin-film transistor fabricated in single-crystalline transparent oxide semiconductor [J]. *Science,* 2003, 300(5623):1269-1272.

[3] Ozgur U, Alivov Y I, Liu C, *et al.* A comprehensive review of ZnO materials and devices [J]. *J. Appl. Phys.,* 2005, 98(4):041301-403.

[4] Bagnall D M, Chen Y F, Zhu Z, *et al.* High temperature excitonic stimulated emission from ZnO epitaxial layers [J]. *Appl. Phys. Lett.,* 1998, 73(8):1038-1041.

[5] Liu H X, Zhou S M, Li S Z, *et al.* Growth of ZnO microrod array films and their optical properties [J]. *Acta Phys. Sinica* (物理学报), 2006, 55(3):1398-1401 (in Chinese).

[6] Lee B C, Kim K V, Stroscio M A. Electron-optical-phonon scattering in wurtzite crystals [J]. *Phys. Rev.* B.1997,56(3):997-1000

本刊中的类似文章

1. 导带弯曲对有限深GaN/$Ga_{1-x}Al_xN$球形量束缚极化子的影响及其压力效应[J]. 2013(9): 1128-1134
2. 量子棒中强耦合杂质束缚极化子的振动频率2011,32(1): 27-32
3. 极化子效应对非对称量子阱中光吸收系数的[J]. 2010,31(4): 467-472
4. ZnSe/ZnS抛物量子阱中激子的极化子效应2010,31(3): 348-352
5. 半导体量子点中极化子的跃迁能量[J]. 20(4): 525-528
6. 极化子效应对ZnS/CdSe量子点三阶极化率响[J]. 2009,30(4): 535-540
7. 磁场中量子点内弱耦合磁极化子基态束缚能度依赖性[J]. 2009,30(2): 152-156
8. 二维声学极化子的基态能量和有效质量[J]. 2008,29(4): 670-674
9. 非对称量子点中弱耦合极化子的相互作用能2008,29(4): 723-726
10. 库仑场对非对称量子点中强耦合极化子声子数的影响[J]. 2008,29(3): 547-550
11. 半导体量子阱中弱耦合磁极化子的性质(英2008,29(2): 215-220
12. 磁场对非对称量子点中束缚磁极化子性质的[J]. 2008,29(2): 243-247
13. 量子线中强耦合极化子的温度效应[J]. 20(2): 238-242
14. 非对称量子点中弱耦合束缚极化子的性质[2008,29(1): 15-18
15. 纤锌矿GaN/$Al_xGa_{1-x}N$量子阱中极化子能2008,29(1): 10-14
16. 声子色散对抛物量子点中极化子基态能量的[J]. 2008,29(1): 5-9
17. 极性晶体膜中的束缚极化子的有效质量[J]. 2007,28(6): 827-831
18. 非对称量子点中磁极化子的声子平均数[J]. 2007,28(6): 847-852
19. 磁场和库仑场对抛物量子点中弱耦合极化子态性质的影响[J]. 2007,28(6): 832-83(
20. 抛物量子点中极化子的温度依赖性[J]. 20(5): 647-650

[7] Zhang B P, Binh N T, Wakatsuki K, *et al.* Growth of ZnO/MgZnO quantum wells on sapphire substrates and observation of the two-dimensional confinement effect [J]. *Appl. Phys. Lett.,* 2007, 86(3):032105-1-3.

[8] Park S H. Exciton binding energies in wurtzite ZnO/MgZnO quantum well with spontaneous and piezoelectric polarizations [J]. *J. Korean Phys. Soc.,* 2007, 51(4):1404-1408.

[9] Makino T, Chia C H, Tuan T, *et al.* Room-temperature luminescence of excitons in ZnO/(Mg,Zn)O multiple quantum wells on lattice-matched substrates [J]. *Appl. Phys. Lett.,* 2000, 77(7):975-977.

[10] Gruber T, Kirchner C, Kling R, *et al.* ZnMgO epilayers and ZnO-ZnMgO quantum wells for optoelectronic applications in the blue and UV spectral region [J]. *Appl. Phys. Lett.,* 2004, 84(26):5359-5361.

[11] Makino T, Tuan N T, Sun H D, *et al.* Temperature dependence of near ultraviolet photoluminescence in ZnO/(Mg,Zn)O multiple quantum wells [J]. *Appl. Phys. Lett.,* 2001, 78(14):1979-1981.

[12] Bretagnon T, Lefebvre P, Guillet T, *et al.* Barrier composition dependence of the internal electric field in ZnO/$Zn_{1-x}Mg_xO$ quantum wells [J]. *Appl. Phys. Lett.,* 2007, 90(20):201912-1-3.

[13] Furno E, Chiaria S, Penna M, *et al.* Electronic and optical properties of $Mg_xZn_{1-x}O$ and $Be_xZn_{1-x}O$ quantum wells [J]. *J. Elect. Mater.,* 2010, 39(3):936-944.

[14] Ohtomo A, Tamura K, Kawasaki M, *et al.* Room-temperature stimulated emission of excitons in ZnO/(Mg,Zn)O superlattices [J]. *Appl. Phys. Lett.,* 2000, 77(14):2204-2206.

[15] Xia Y, Brault J, Nemoz M, *et al.* Optical properties of *a*-plane(Al, Ga)N/GaN multiple quantum wells grown on strain engineered $Zn_{1-x}Mg_xO$ layers by molecular beam epitaxy [J]. *Appl. Phys. Lett.,* 2011, 99(15):261910-261912.

[16] St lzel M, Kupper J, Brandt M, *et al.* Electronic and optical properties of ZnO/(Mg, Zn)O quantum wells with and without a distinct quantum-confined Stark effect [J]. *J. Appl. Phys.,* 2012, 111(6):063701-1-10.

[17] Fan W J, Xia J B, Agus P A, *et al.* Band parameters and electronic structures of wurtzite ZnO and ZnO/MgZnO quantum wells [J]. *J. Appl. Phys.,* 2006, 99(1):013702-1-4.

[18] Coli G, Bajaj K K. Excitonic transitions in ZnO/MgZnO quantum well heterostructures [J]. *Appl. Phys. Lett.,* 2001, 78(18):2861-2863.

[19] Lange M, Kupper J, Dietrich C P, *et al.* Exciton localization and phonon sidebands in polar ZnO/MgZnO quantum wells [J]. *Phys. Rev.* B.2012, 86(4):045318-1

[20] Morhain C, Bretagnon T, Lefebvre P, *et al.* Internal electric field in wurtzite ZnO/$Zn_{078}Mg_{0.22}O$ quantum wells [J].. *Phys. Rev.* B.2005, 72(24):241305-1

[21] Weston L, Cui X Y, Delley B, *et al.* Band offsets and polarization effects in wurtzite ZnO/$Mg_{025}Zn_{0.75}O$ superlattices from first principles [J].. *Phys. Rev.* B.2012, 86(20):205322-1

[22] Lee B C, Kim K W, Stroscio M A, *et al.* Optical-phonon confinement and scattering in wurtzite heterostructures [J]. *Phys. Rev.* B.1998, 58(8):4860-4865

[23] Komirenko S M, Kim K W, Stroscio M A, *et al.* Energy-dependent electron scattering *via* interaction with optical phonons in wurtzite crystals and quantum wells [J]. *Phys. Rev.* B.2000, 61(3):2034-2040