AIP Applied Physics Letters

Absorption spectra of ZnSeZnS strainedlayer superlattices grown on (001) GaAs by molecular beam epitaxy

Aidong Shen, Hailong Wang, Zhijiang Wang, and Shaozhe Lü

Citation: Appl. Phys. Lett. **60**, 2640 (1992); doi: 10.1063/1.106880
View online: http://dx.doi.org/10.1063/1.106880
View Table of Contents: http://apl.aip.org/resource/1/APPLAB/v60/i21
Published by the American Institute of Physics.

Absorption spectra of ZnSe-ZnS strained-layer superlattices grown on (001) GaAs by molecular beam epitaxy

Aidong Shen, Hailong Wang, and Zhijiang Wang
Joint Laboratory for Quantum Optics, Shanghai Institute of Optics and Fine Mechanics, Academia Sinica, P.O. Box 800-216, Shanghai 201800, People's Republic of China

Shaozhe Lü
Laboratory of Excited State Processes, Changchun Institute of Physics, Academia Sinica, Changchun 130021, People's Republic of China

(Received 20 January 1992; accepted for publication 16 March 1992)

The absorption spectra of ZnSe-ZnS strained-layer superlattices were measured at temperatures ranging from 16 K to room temperature. Three excitonic absorption peaks corresponding to 1E-1HH, 1E-1LH, and 1E-3HH transitions were observed for the first time.

Wide band-gap II-VI compound semiconductors are useful materials for optoelectronic devices in the visible region. Superlattice and quantum-well (QW) structures based on these materials, such as ZnSe-ZnTe,[1–3] ZnSe-ZnS,[4–7] ZnSe-ZnSSe,[8] ZnSe-ZnMnSe,[9] and ZnSe-ZnCdSe (Refs. 10 and 11) heterostructures have been studied by many groups. Recently ZnSe-based laser diodes were also fabricated.[10,12] To realize the lasing action mechanism in the II-VI quantum wells, the study of optical absorption is very important.[13] Absorption measurements have been one of the main tools to study the exciton behavior in superlattice and quantum well structures since Dingle *et al.*[14] observed the exciton enhancement effect in GaAs-GaAlAs QWs. Yang *et al.*[15] reported their study on optical absorption of metalorganic chemical vapor deposition (MOCVD) grown ZnSe-ZnS SLSs, but no excited state was observed. In this letter, we report our measurements of the absorption in molecular-beam epitaxy (MBE) grown ZnSe-ZnS SLSs at temperatures ranging from 16 K to room temperature. Three excitonic absorption peaks corresponding to 1E-1HH, 1E-1LH, and 1E-3HH transitions were observed for the first time.

ZnSe-ZnS SLSs were grown on (001)-oriented GaAs substrate by a FWIII MBE system.[16] There was no intentional doping during the sample growth procedure. The crystalline quality was examined by *in situ* reflection high-energy electron diffraction (RHEED). The layer thickness was determined by x-ray diffraction and transmission electron spectroscopy (TEM) measurements. For optical transmission (absorption) measurement, the as-grown sample was glued upside down on a sapphire plate, which has good thermal conductivity, and the GaAs substrate was removed by a selective etchant. A white light lamp was used as light source. A double-grating GDM1000 monochromator and a R286 photomultiplier were used to receive and detect the transmission light.

Figure 1 is a typical absorption spectrum of a ZnSe-ZnS SLS at 16 K. Both the well and barrier width are 2.7 nm. The dashed line shows the corresponding photoluminescence (PL) spectrum. From the absorption spectrum we can see three exciton features which were attributed to 1E-1HH, 1E-1LH, and 1E-3HH transitions. The lattice mismatch between ZnSe and ZnS is very large ($\sim 5\%$), so in ZnSe-ZnS SLSs the energy separation between the $n=1$ heavy- and light-hole level is mainly caused by the strain effect.[17] Using Voisin's model,[18] we found that the strain-induced splitting of the light- and heavy-hole energy is about 140 meV. Taking into account the splitting caused by the quantum confinement effect, this result is well coincided with the experiment.

The 1E-3HH exciton peak was identified using effective infinite-well model. Contrary to what one would expect from envelope wave-function overlap integrals, this peak is nearly as strong as that of the 1E-1HH. This is still not recognized by the authors.

In the experiment, no excited states above 2E-nHH were observed. This may be owing to the fact that the conduction-band offset in ZnSe-ZnS SLS is very small[8] (Fig. 2), and the $n=2$ electrons are no longer confined particles. The 1E-2HH and 1E-2LH transitions are forbidden by the selection rules.

The three exciton features can be well resolved up to room temperature. Figure 3 shows the temperature dependence of the three peak energies. As the temperature in-

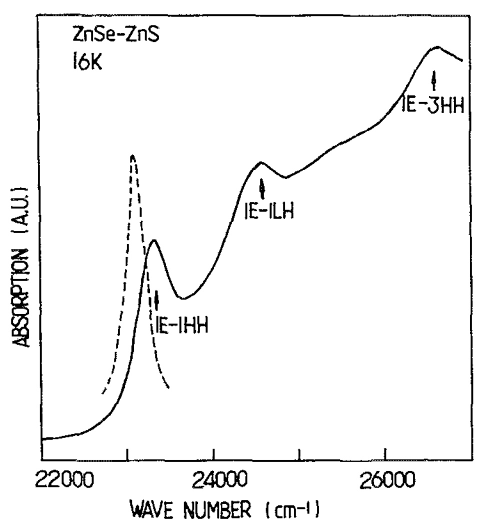

FIG. 1. A typical absorption spectrum of a ZnSe-ZnS (2.7 nm, 2.7 nm) strained-layer superlattice at 16 K. The dashed line shows the corresponding photoluminescence spectrum.

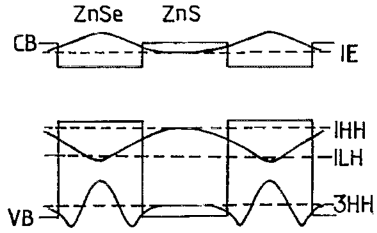

FIG. 2. Schematic representation of the band structure in ZnSe-ZnS SLS. For simplicity, the 1LH wave function and the $n=2$ hole levels are not shown in the figure.

creases, the peak energy shifts monotonically to the lower energy. Figure 4 shows the linewidth of the 1E-1HH exciton absorption versus temperature, where the solid line is the fitted line using the equation $\Gamma(T)=\Gamma_0+\Gamma_{LO}/[\exp(\hbar\omega_{LO}/kT)-1]$. The best fit is obtained for $\Gamma_{LO}=77$ meV. Unlike the case in ZnSe-ZnCdSe QWs,[13] in ZnSe-ZnS SLSs the Γ_{LO} is larger than that in bulk ZnSe (60 meV). This means that in ZnSe-ZnS SLSs the exciton-phonon interaction is rather strong.

In summary, we have measured the optical absorption spectra of MBE-grown ZnSe-ZnS SLSs. Three exciton features corresponding to 1E-1HH, 1E-1LH, and 1E-3HH transitions can be clearly resolved up to room temperature. The study on the temperature-dependent linewidth of the

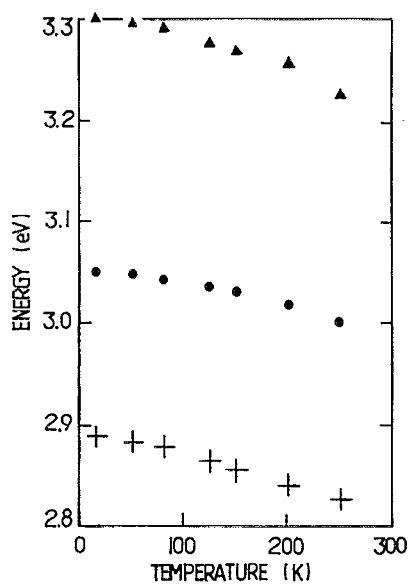

FIG. 3. Temperature dependence of the three exciton energies. (+) 1E-1HH exciton. (●) 1E-1LH exciton. (▲) 1E-3HH exciton.

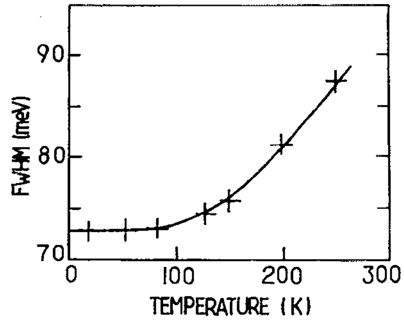

FIG. 4. Temperature dependence of the linewidth of the 1E-1HH exciton absorption peak. The solid line is the fitted line.

1E-1HH absorption suggests a strong exciton-phonon interaction in the SLSs.

The authors are very grateful to Dr. J. Cui, Y. L. Chen, Dr. L. Xu, and Professor S. H. Huang for their helpful discussions.

[1] H. Fujiyasu and K. Mochizuki, J. Appl. Phys. **57**, 2960 (1985).
[2] M. Kobayashi, N. Mino, H. Katagiri, R. Kimura, M. Konagai, and K. Takahashi, Appl. Phys. Lett. **48**, 296 (1986); J. Appl. Phys. **60**, 773 (1986).
[3] A. Shen, J. Cui, Y. Chen, L. Xu, and H. Wang, Chin. J. Semicond. **12**, 583 (1991).
[4] T. Yokogawa, M. Ogura, and T. Kajiwara, Appl. Phys. Lett. **49**, 1702 (1986).
[5] Y. Kawakami, T. Taguchi, and A. Hiraki, J. Cryst. Growth **93**, 714 (1988).
[6] H. Kuwabara, H. Fujiyasu, H. Shimizu, A. Sasaki, and S. Yamada, J. Cryst. Growth **72**, 299 (1985).
[7] A. Taike, N. Teraguchi, M. Konagai, and K. Takahashi, Jpn. J. Appl. Phys. **26**, L989 (1987).
[8] K. Shahazad, D. J. Olego, C. G. van de Walle, and D. A. Cammack, J. Lumin. **46**, 109 (1990).
[9] L. A. Kolodziejski, R. L. Gunshor, T. C. Bonsett, R. Venkatasubramanian, S. Datta, R. B. Bylsma, W. M. Becker, and N. Otsuka, Appl. Phys. Lett. **47**, 169 (1985).
[10] M. A. Haase, J. Qiu, J. M. DePuydt, and H. Cheng, Appl. Phys. Lett. **59**, 1272 (1991).
[11] H. Jeon, J. Ding, A. V. Nurmikko, H. Luo, N. Samarth, and J. K. Furdyna, Appl. Phys. Lett. **59**, 1293 (1991).
[12] W. Xie, D. C. Grillo, M. Kobayashi, R. L. Gunshor, G. C. Hau, N. Otsuka, H. Jeon, J. Ding, and A. V. Nurmikko, presented at the 5th International Conference on II-VI Compounds, Okayama, Japan, September, 1991.
[13] J. Ding, N. Pelekanos, A. V. Nurmikko, H. Luo, N. Samarth, and J. Furdyna, Appl. Phys. Lett. **57**, 2885 (1990).
[14] R. Dingle, W. Wiegmann, and C. H. Henry, Phys. Rev. Lett. **33**, 827 (1974).
[15] F. Yang, P. J. Parbrook, B. Henderson, K. P. O'Donnel, P. J. Wright, and B. Cockayne, Appl. Phys. Lett. **59**, 2142 (1991).
[16] A. Shen, J. Cui, H. Wang, and Z. Wang, SPIE **1519**, 656 (1991).
[17] A. Shen, J. Cui, Y. Chen, H. Wang, and A. Li, J. Cryst. Growth **111**, 807 (1991).
[18] P. Voisin, Surf. Sci. **168**, 546 (1986).