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

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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, ZnSe-ZnS, ZnSe-ZnS-S, ZnSe-ZnMnSe, and ZnSe-ZnCdSe (Refs. 10 and 11) heterostructures have been studied by many groups. Recently ZnSe-based laser diodes were also fabricated. To realize the lasing action mechanism in the II-VI quantum wells, the study of optical absorption is very important. Absorption measurements have been one of the main tools to study the exciton behavior in superlattice and quantum well structures since Dingle et al. observed the exciton enhancement effect in GaAs-GaAlAs QWs. Yang et al. 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. 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 widths 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 (~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. Using Voisin's model, 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.

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.
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 $\Gamma(T) = \Gamma_0 + \Gamma_{LO}/[\exp(h\nu_{LO}/kT) - 1]$. The best fit is obtained for $\Gamma_{LO} = 77$ meV. Unlike the case in ZnSe-ZnCdSe QWs, in ZnSe-ZnS SLSs the $\Gamma_{LO}$ 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 1E-1HH absorption suggests a strong exciton-phonon interaction in the SLSs.

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