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EXCITON ELECTROLUMINESCENCE OF ZnSe/ZnO STRUCTURES UNDER BIAXIAL STRESS*

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The strained ZnSe/ZnO structures grown on (111) ZnSe crystals by plasma oxidation was investigated by electro- and photoluminescence methods. The lines of heavy and light hole excitons under biaxial compressive stress are measured as a function of the temperature.

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Due to the lattice mismatch between the epilayer and the substrate in ZnSe/ZnO structures, it is crucial to know the limiting conditions leading to a pseudomorphic growth by the accommodation of the biaxial strains caused by difference in lattice constants and/or thermal expansion coefficients of the materials forming the heterostructure [1, 2]. Moreover, hydrostatic pressure decreases the lattice constant of the materials. The difference in the compressibility of ZnO from that of ZnSe generates under hydrostatic pressure a tensile strain which progressively compensates the lattice mismatch induced compressive strain. The valence band at the Γ point of the unstrained ZnSe crystals consists of a fourfold degenerate $P_{3/2}$ valence band ($J = 3/2$, $m_j = \pm 3/2$, $m_j = \pm 1/2$). Under biaxial compressive or tensile stress this valence band splits into a light-hole ($J = 3/2$, $m_j = \pm 1/2$) and a heavy-hole ($j = 3/2$, $m_j = \pm 3/2$) branches [3–5]. The trend in II–VI compounds is that the materials have a larger negative deformation potential as their lattice constants get smaller. It may be suspected that the deformation potential will get more negative as we apply pressure, since the average lattice constant gets smaller [3].

In addition, a situation similar to the pressure induced biaxial strain can occur for heterostructures where the thermal expansion coefficients for materials vary greatly. The lattice constants of constituent materials at each temperature must adjust each other.

In this paper, we present for the first time a study of the exciton emission of the strained ZnSe/ZnO structures as a function of the biaxial compressive or tensile stress and temperature using photo- and electroluminescence methods. These

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structures were grown on a n-type ZnSe substrates by plasma oxidation [6, 7]. The luminescence spectra of ZnSe crystals and ZnSe/ZnO structures made from these crystals were measured in the temperature range between 30 K and 300 K using the experimental technique described elsewhere [8]. It should be noted here that the radiative recombination in photo- and electroluminescence of ZnSe/ZnO heterostructure occurs at the insulator–semiconductor interface.

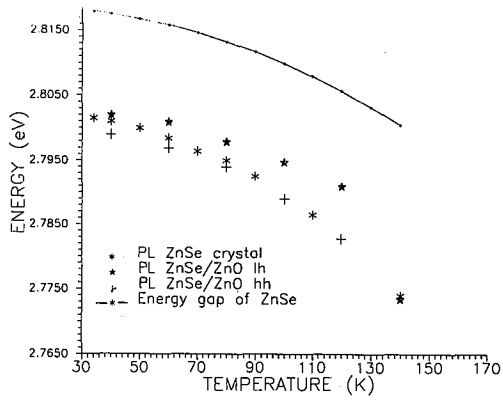

Fig. 1. The temperature variation of energetic position of exciton lines in ZnSe crystals and ZnO/ZnSe structures obtained from photoluminescence spectra.

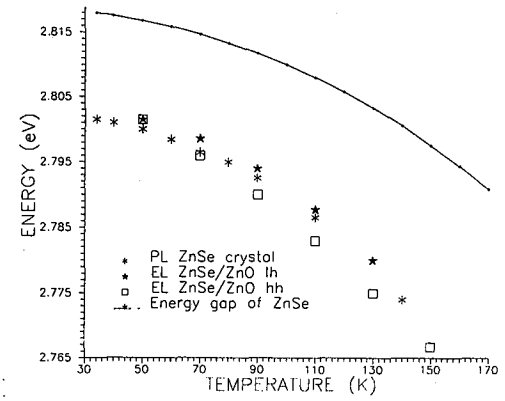

Fig. 2. Energetic position of exciton lines in electroluminescence of the ZnO/ZnSe structures versus temperature.

Figure 1 shows the variations of the energy position of the exciton lines of ZnSe crystals with and without ZnO layer obtained from measurements of photoluminescence spectra in conjunction with the energy band gap of ZnSe crystal without stress as a function of temperature. The energetic position of excitons obtained from electroluminescence versus temperature are presented in Fig. 2. One

can see from these figures that in photoluminescence spectra for the ZnSe crystal only one exciton line is observed in all measured ranges of temperature. This line is due to free exciton radiative recombination process. For ZnSe/ZnO structures this free exciton line splits into two components associated with the heavy- and light-hole valence band to conduction band transition [1]. This splitting is clearly seen in both photo- and electroluminescence in the temperature range between 50 K and 130 K. At higher temperatures this effect is merged probably because of the thermal broadening of exciton emission. At low temperature ($T < 50$ K), the free exciton line in the photo- and electroluminescence spectra of the ZnSe/ZnO structures due to the heavy-hole exciton occurs at an energy lower than that of the light-hole exciton. For higher temperatures, the biaxial strain in ZnSe at ZnSe/ZnO interface transforms from compression to tension ($T \approx 50$ K), and the light-hole line now occurs at the lower energy than the heavy-hole exciton. From Fig. 1 one can see that the energies of the free excitons in ZnSe crystals and ZnSe/ZnO structures are different. This difference is caused by existing both, the biaxial strain in epilayer due to accommodation of the lattice mismatching and the thermal strains due to the difference of the thermal coefficients between ZnSe crystal and ZnO epilayer [9, 10].

The present work demonstrates how externally applied hydrostatic pressure can be exploited in the context of characterizing the built-in strains in the constituent materials of the heterostructures.

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