원자섞임처리한 InGaAs/InGaAsP 양자우물의 PL 스펙트럼 특성

PL spectra of disorderd InGaAs/InGaAsP quantum wells

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Quantum Well Disordering (QWD) has drawn a considerable attention in recent years[1-3] due to its wide applicability to optoelectronic devices. QWD allows modification of the shape of QW in selected regions, hence it modifies the subband energies in conduction and valance bands[4]. This leads to changes in optical properties such as band gap, absorption coefficient and refractive index. Thus such disordering in selected areas enables monolithic integration of various optoelectronic devices such as lasers, EA/EO modulators, waveguides and optical amplifiers. In this paper, we investigate the quantum well disordering effects on photoluminescence spectra by using experimental measurements and theoretical analysis[5].

The disordering profile of 1.55Q InGaAs/InGaAsP quantum wells lattice-matched to InP was controlled by choice of cap layer materials and diffusion time as well as diffusion temperature. The cap layer materials chosen were InP, InGaAs, and InGaAsP with silicon nitride or silicon dioxide on them, respectively. The diffusion temperature was 750 °C and the diffusion time was varied up to 16 min. The largest PL peak shift observed was 120 meV when the cap layer was InP under silicon nitride. Figure 1 shows the actual epilayer structure and the measured PL spectra. The structure consists of an 7nm thick $In_{0.53}Ga_{0.47}As$ layer sandwiched between thick $In_{0.76}Ga_{0.24}As_{0.51}P_{0.49}$ barriers. After the disordering the concentration of the interdiffused atoms across the QW structure is assumed to have an error function distribution. The disordering process in InGaAs/InGaAsP studied here is more complicated than the disordering of lattice matched InGaAs/GaAs or AlGaAs/GaAs QW structures. Disordering in the latter case is only due to the interdiffusion of group III (In, Ga) atoms, whereas in the present case interdiffusion can occur for both group III and group V (As, P) atoms.

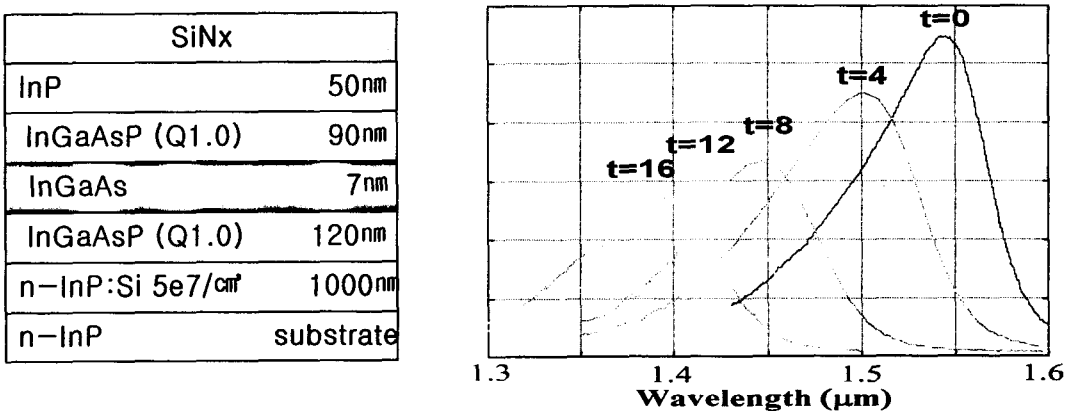
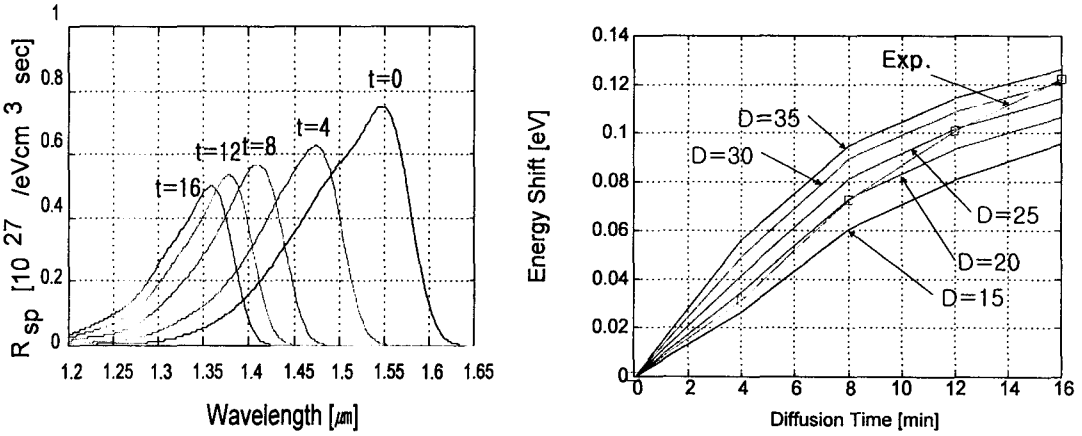


Figure 1. Epilayer structure(in the left side) and the measured PL spectra(in the right side). The indicated times represent the diffusion time in minute.

When we have different diffusion constants for group III and group V atoms, the k factor can be defined as $k=\sqrt{D_V \cdot t}/\sqrt{D_{III} \cdot t}$ where D_V and D_{III} denote the diffusion constants and t the diffusion time[6]. The PL spectra have been calculated for various k factor values and diffusion constants as well as diffusion times taking the strain, valence band intermixing, and the exciton binding energy into account. Figure 2(a) shows the resulting PL spectra. The PL peak energy shifts due to the quantum well disordering effect have also been plotted in Figure 2(b) and are compared with the experimental data. The best agreement between experimental and calculated spectra was for k=1.5 and D_{III}=25Å^2/min. The squares indicate the experimental data. The extracted material parameters such as the k factor and diffusion constants will play an important role in designing and fabricating optoelectronic devices. For more accurate analysis, however, one needs to include other secondary effects such as bandgap renormalization and multi-subband exciton trial functions.



(a) (b)

Figure 2. (a) Calculated PL spectra at various diffusion times. (b) Calculated PL peak energy shifts at various diffusion times and diffusion constants. The best agreement between experimental and calculated spectra was for k=1.5 and D_{III}=25Å^2/min. The squares indicate the experimental data.

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