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Room Temperature Exciton Absorption Peaks in $In_{1-x}Ga_xAs_yP_{1-y}$/InP Multiple Quantum Wells

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$In_{1-x}Ga_xAs_yP_{1-y}$/InP (x=0.47y) quantum wells (QWs) are basic structures for long-wavelength high-speed optical devices because, by controlling the composition, y, the ground state exciton energy can be tuned in the important wavelength range between 1.3 and 1.55 μm with the well width optimized[1]. However, sharp, intense exciton absorption peaks as observed in GaAs QW systems have not yet been observed at room temperature, except in ternary $In_{0.53}Ga_{0.47}As$ QWs (y=1.0)[2]. To obtain significant excitonic resonances, the QW interface must be as smooth as possible, since interface roughness causes inhomogeneities in the exciton energy level, resulting in broad absorption peaks.

In this work, we grew $In_{1-x}Ga_xAs_yP_{1-y}$/InP QWs by low-pressure metalorganic vapor phase epitaxy. The quality of the interfaces was investigated by 4.2 K photoluminescence (PL) spectra. We could obtain very smooth interfaces by lowering the growth temperature under 600 °C, and reducing the phosphine pressure in the growth of InP and the arsine pressure in the growth of InGaAsP. This suggests that the interface roughness is primarily caused by the thermodinamic exchange of phosphorous and arsenic atoms between the solid and vapor phase during the growth at interfaces. We report the high quality of the interfaces and an observation of a clear room temperature exciton absorption peak at 1.5 μm for the first time.

Figure 1 shows a typical 4.2 K PL spectrum of a QW structure containing six InGaAsP wells and a 1000 Å InGaAsP layer. The composition was y=0.9. The InP barrier width was 500 Å. Sharp PL peaks due to excitonic transitions were observed from the wells. The PL emission from the 10 Å and 25 Å wells split to doublets, indicating the presence of monolayer islands extending over areas of at least several thousands angstroms[3].

In Fig. 2, the full width at half maximum (FWHM) of the PL peaks of Fig. 1 is plotted by closed circles against the width of QWs. The linewidth increased as the well width decreased. Assuming that both interface roughness and composition fluctuation in the InGaAsP well primarily broaden the linewidth, the measured FWHM could be decomposed into the contribution of each structural imperfection. The line represents the FWHM caused by interface roughness. The open circles represent the narrowest FWHM reported in GaAs QW systems[4] and open triangles in InGaAs QWs[2]. It is found that the interfaces of the present QWs are as smooth as those of the other two QWs. To further improve the homogeneity of the exciton level, the magnitude of composition fluctuations must be reduced.

We grew a 20-period multiple QW structure with 100 Å wells and 100 Å barriers. The absorption spectrum at room temperature is shown in Fig. 3.

Resonance peaks due to heavy-hole excitons are clearly observed at 1.5 um over the step-like subband absorption continuum. This is the first observation of room temperature exciton absorption peaks in quaternary InGaAsP QWs.

In summary, $In_{1-x}Ga_xAs_yP_{1-y}/InP$ QWs with the composition of y=0.9 were grown by low-pressure metalorganic vapor phase epitaxy under the low growth tempearture below 600°C and the reduced group V gas pressure. The 4.2 K PL linewidth demonstrated the smoothness of the interfaces. As the result, we succeeded in obtaining a clear room temperature exciton absorption peak at 1.5 µm in multiple QWs for the first time.

References

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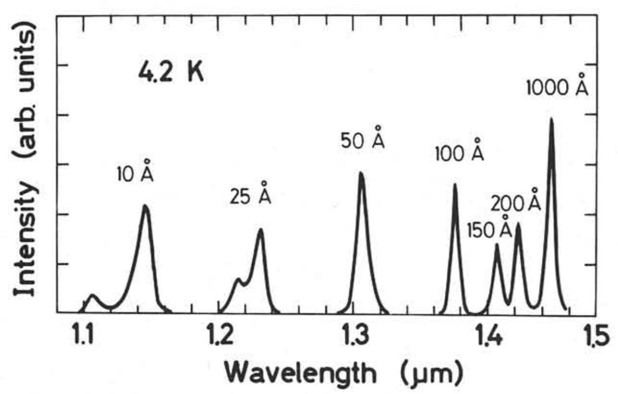

Fig.1 4.2K PL spectrum of a InGaAsP/InP QW structure.

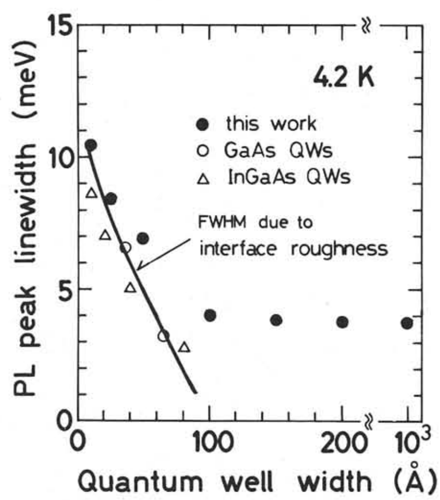

Fig.2 Plot of 4.2 K PL FWHM against the well width of QWs.

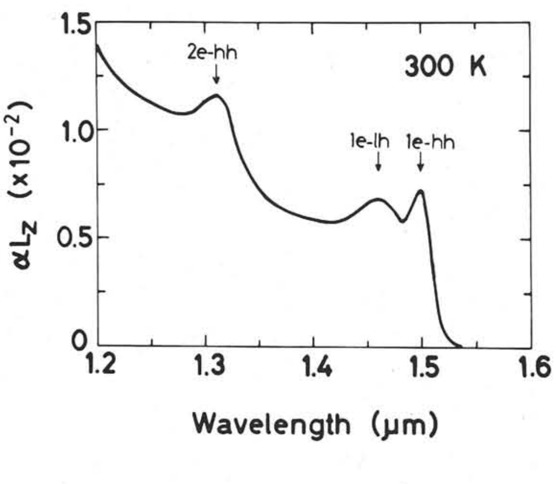

Fig.3 Room temperature absorption spectrum of InGaAsP/InP multiple QW.