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Optical properties of $In_xGa_{1-x}As$ quantum Wells Grown by Molecular Beam Epitaxial Technique

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Abstract

The samples were grown on (001)-oriented GaAs substrates using molecular beam epitaxy system. The effect of change in the percentage of indium on the optical properties of $In_xGa_{1-x}As$ quantum well structures is investigated using the temperature-dependent photoluminescence from 15 K to 300 K and Raman spectroscopy.The temperature-dependent integrated photoluminescence intensities of the samples reveal that the photoluminescence intensity is significantly enhanced by about 27 times at 15 K with respect to that at 300 K.

Keywords: $In_xGa_{1-x}As$, quantum wells, photoluminescence, Raman spectroscopy.

1. Introduction

Optoelectronics based on very thin layers of semiconductor heterostructures, such as quantum wells (QWs), play an important role in many commercial applications. Currently InGaAs QW structures are used in opto electronic devices such as fiber optic communication [1], solar cell [2], infrared detectors [3] or lasers.Semiconductor quantum structures are in common usage for optoelectronics as well as high-speed electronics. Electronic energy levels of quantum structures are important structural parameters because of their dependence on size, composition, strain, etc. A number of spectroscopic techniques photoluminescence (PL), photoluminescence excitation (PLE), and absorption have been in use to probe the electronic transitions. [4]

Luminescence techniques belong to the most sensitive, nondestructive methods of analyzing semiconductor properties [5].

2. Experimental Detail

All the samples were grown on (001)-oriented GaAs substrates using molecular beam epitaxy system DCA 450 model. As shown in the Fig. (1), the growth of $In_xGa_{1-x}As$ QW samples started with a GaAs buffer grown at 580^0 C followed by a 10-nm-thick In_xGa_{1-x} As (where x = 0.18) layer grown at 485^0 C. Finally, a 20-nm-thick GaAs cap layer were grown at 485 ^{0}C.

The PL spectra were measured by using a laser (λ =514 nm) as the excitation source. The Raman spectroscopy was done using RENISHAW INVIA Raman microscope RE-04.

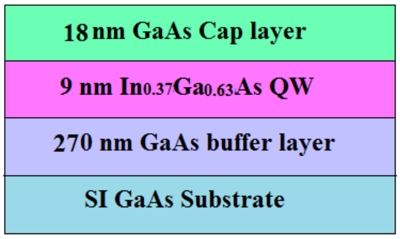
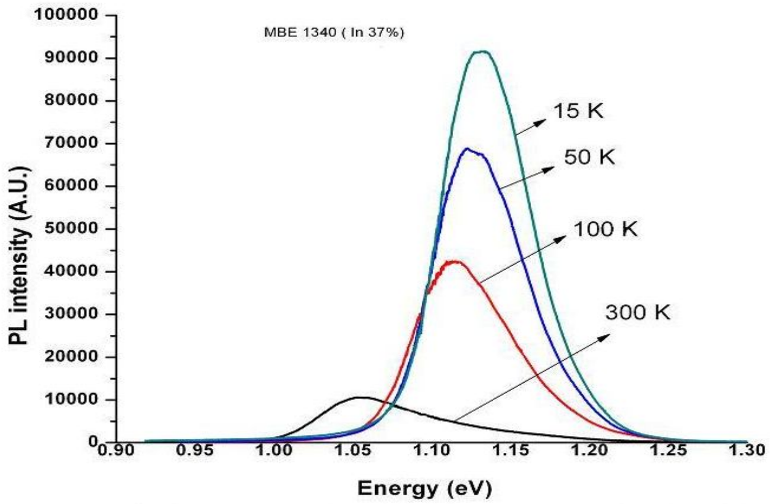


Fig. 1: The schematic structure of the sample.

3. Results and Discussion

The temperature-dependent PL spectra were carefully measured from 15 K to 300 K as shown in Fig. (2). For each sample at a specific temperature, one peak is observed.



The temperature dependent PL spectra for InGaAs QWs

Fig. 2

The temperature-dependent PL peak energies of the samples show quite similar behavior in the whole temperature range from 15 K to 300 K. The temperature-dependent integrated photoluminescence intensities of the samples reveal that the photoluminescence intensity is significantly enhanced by about 24 times at 15 K with respect to that at 300 K for sample MBE 1338 (Indium 18%); about 20 times at 15 K with respect to that at 300 K for sample MBE 1344 (Indium 09%) and about 9 times at 15 K with respect to that at 300 K for sample MBE 1340 (Indium 37%). In all the 3 samples there is a red shift of about 81meV.

Fig. (3) shows the concentration dependence of PL spectrum. It is observed that as the concentration of indium in $In_xGa_{1-x}As$ increases the intensity goes on increasing and there is a red shift of about 300 meV for the spectra at temperatures 15 K and 100 K. It is observed that there is no intensity peak for the indium concentration 9% at 300 K. There is a shift of about 170 meV between the other two concentrations (18 and 37 %) at 300 K.

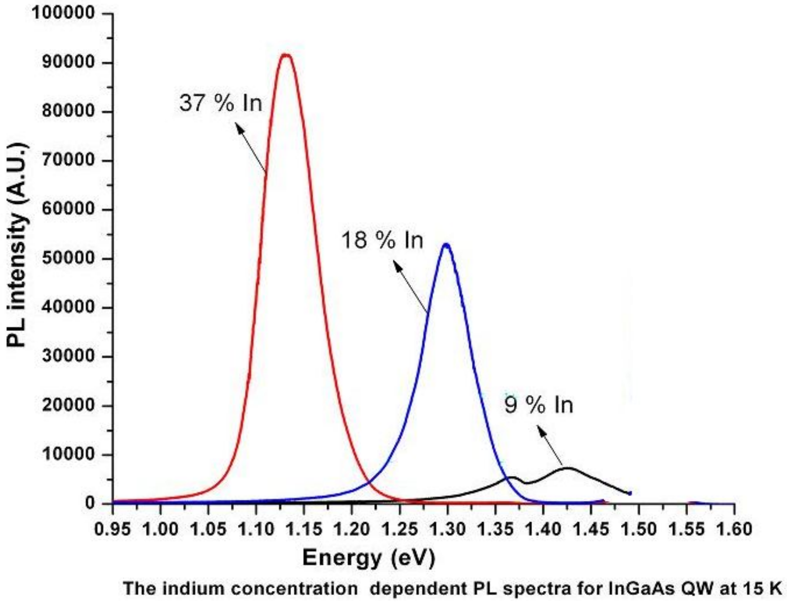


Fig. 3

The samples investigated by PL were studied then by Ra-man scattering technique. The Raman spectrum for the samples is shown in Fig. (4).

The spectra have been recorded at room temperature for indium contents 10 %, 18%, 30 % and 37%. The Raman spectra for the sample show a strong line at 292.6 cm^{-1}corresponding to scattering by longitudinal-optical LO GaAs phonons. There is also a weaker line at 268.527 cm^{-1} corresponding to scattering by transverse-optical TO GaAs phonons.It is observed that as there is no change in the thickness of the QW (~ 10 nm) there is no horizontal shift in the spectrum. But it is observed that as the

Indium percentage goes on increasing there is a vertical shift. i.e the intensity of the weaker peak goes on decreasing with the increase in percentage of Indium content.

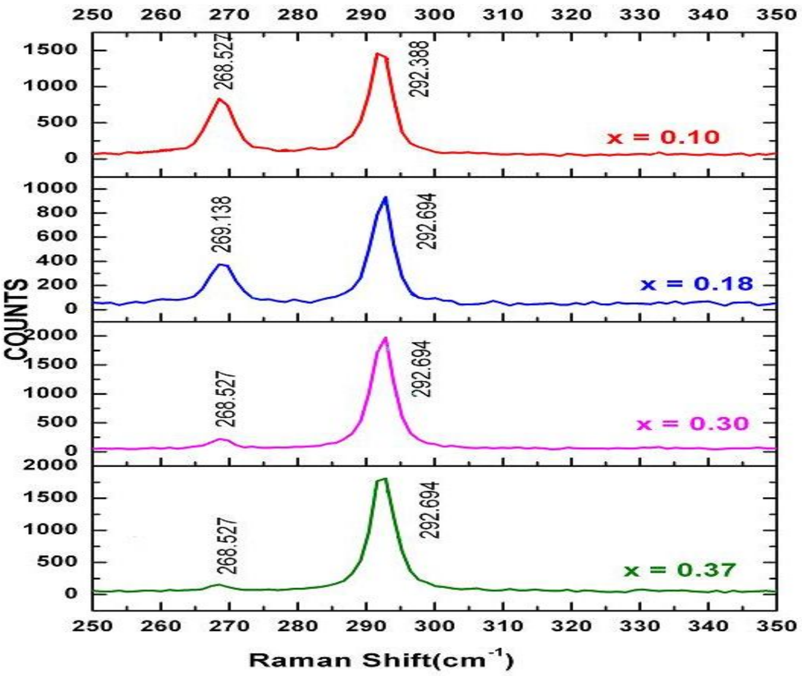


Fig. 4

Table I: Observed and reported Raman peaks for a InGaAs QW

Peak	**Observed energy cm^{-1}**	**Closest Reported Energy cm^{-1}**	**Phonon mode**	**Designation**
1	292.64	292	GaAs like	LO $In_{0.37}Ga_{0.63}$ As
2	268.527	266.3	GaAs like	TO $In_{0.37}Ga_{0.63}$ As

The reported value of peak is taken from the paper as mentioned in reference paper [6] and peak two from reference paper [7].

4. Conclusion

In conclusion, $In_xGa_{1-x}As$ QW structures have been grown by molecular beam epitaxy and investigated by temperature-dependent PL measurements from 15 K to 300 K. The temperature-dependent integrated photoluminescence intensities of the samples reveal that the photoluminescence intensity is significantly enhanced. It is observed that as the concentration of indium in $In_xGa_{1-x}As$ increases the intensity goes on increasing. The Raman spectra for the sample show a strong line at 292.6 cm−1corresponding to scattering by longitudinal-optical LO GaAs phonons. There is also a weaker line at 268.527 cm^{-1} corresponding to scattering by transverse-optical TOGaAs phonons.

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