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Growth and Temperature Dependent Photo - Luminescence of In GaAs QW

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Abstract: *In the present investigation InGaAs QW is grown by using molecular beam epitaxy (MBE) technique. The composition of Indium in the present investigation is 18%. The structural characterization is done by using High Resolution X-ray diffraction (HRXRD) method. In the present study we have used temperature dependent photoluminescence (PL) spectroscopy to study the optical characterization. It is found that the intensity and the bandgap decrease with increase in temperature. The elastic constants were determined by the Varshni's equation.*

Keywords: MBE, InGaAs, QW, HRXRD, PL, Varshni's equation.

1. Introduction

Optoelectronics based on very thin layers of semiconductor heterostructures, such as quantum wells (QWs), play an important role in many commercial applications. Recently Indium gallium arsenide (InGaAs) has been the focus of research interest. Currently InGaAs QW structures are used in opto electronic devices such as fiber optic communication [1], solar cell [2], infra red detectors [3] or lasers. The optical and mechanical properties of InGaAs can be varied by changing the ratio of In and Ga, $In_xGa_{1-x}As$.

For the production of semiconductor heterostructures various epitaxial methods are used like liquid phase epitaxy (LPE), chemical vapor deposition (CVD), metal organic chemical vapor deposition (MOCVD), molecular beam epitaxy (MBE), metal organic molecular beam epitaxy (MOMBE), vapor phase epitaxy (VPE) and metal organic vapor phase epitaxy (MOVPE). For our work, we have grown InGaAs epitaxial layers on commercially available GaAs substrates using molecular beam epitaxy Molecular beam epitaxy takes place in high vacuum or ultra high vacuum The most important aspect of MBE is the slow deposition rate (typically less than 1000 nm per hour), which allows the films to grow epitaxially.

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, non-destructive methods of analyzing semiconductor properties [5]. In the present study we have used photoluminescence (PL) spectroscopy.

2. Material and Method

The samples were grown using commercially available semi insulating GaAs substrate wafers. Each was loaded into the growth chamber of an all solid-source MBE machine DCA 450 model after being out gassed in the preparation chamber. A 270 nm GaAs buffer layer was grown at 580^0C after the removal of the native oxide layer under arsenic overpressure. This was followed by deposition of 10 nm InGaAs at a rate of 0.3 nm/s . The target indium composition was 18%.

The substrate was then taken up to 485^0C and 20 nm of GaAs was deposited, to form a cap layer. For the samples, the arsenic overpressure was kept at 7.4×10^{-12} torr during the period of InGaAs deposition, ramping up, and GaAs capping. Then the sample was cooled down rapidly and removed from the MBE growth chamber. RHEED pattern was recorded during the period of InGaAs deposition.

The structural properties of the samples were investigated by using a Philips X'pert MRD high resolution X-ray diffractometer (HRXRD) equipped with a four-crystal Ge (220) monochromator. For the PL measurement, the samples were mounted on a cold finger of a closed-cycle helium cryostat that allows varying the temperature from 10 to 300 K. For PL measurements a diode pumped solid-state (DPSS) laser (λ =532 nm) was used as the excitation source.

2.1 Theory/Calculations

2.1.1 XRD studies

The XRD pattern of $In_{0.18}Ga_{0.82}As$ is shown in figure 1.

The main features of the scanned profile are the substrate signal which is narrow and has the highest intensity, the InGaAs layer signal to the left of the substrate peak which is broad and has low intensity and the high frequency, low intensity pendellosung oscillations.. The appearance of the peak on the lower angle side of the substrate peak indicates the lattice expansion with InGaAs growth. It is seen from the plot that the simulated spectra are in agreement with the experimentally observed data.

Using the Vegard's law [6] $a_{InGaAs} = xa_{GaAs} + (1-x)a_{InAs}$ the lattice constant is found to be 5.7238 A^0.

2.1.2 Photoluminescence Studies

The temperature dependent PL spectra for InGaAs QW are shown in figure 2. In general, PL emission intensity increases with increase in the temperature. The most striking feature of the PL spectra is the distinct change from Gaussian-like to asymmetric line shape, induced by the increase in temperature. This suggests that there is an increased contribution from free carrier recombination with the increase in temperature [7]. The spectral peak positions were red shifted from 1.29 eV at 15 K to 1.22 eV at 300K. This red shift is due to the decreasing of the band gap with increase in temperature.

Temperature affects the properties of electronic systems in a number of fundamental ways. The most fundamental of properties is the energy band gap, Eg, which is affected by temperature according to the Varshni equation [8].

$$E_g(T) = E_g(0) - \frac{\propto T^2}{\beta + T}$$

Where Eg (0) is the band gap energy at absolute zero on the Kelvin scale in the given material, and α and β are material-specific constants. InGaAs QWs are shown in Fig. 1

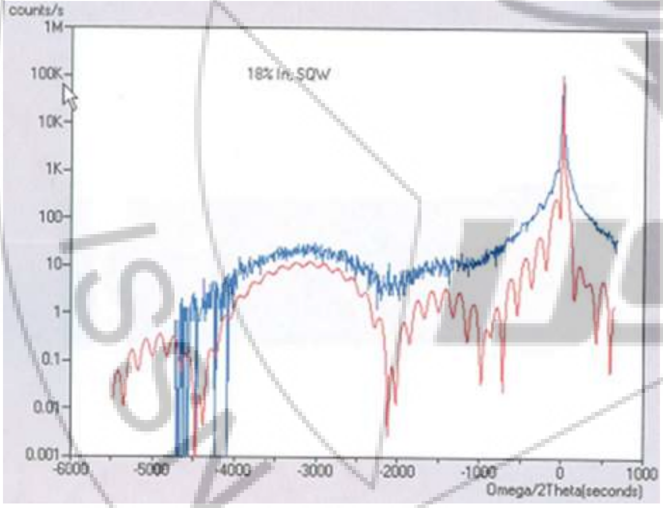

Figure 1: The XRD pattern of InGaAs Qw having 18% indium

The Figure 3 shows the curve fitted to the experimental results by using the empirical Varshni equation. The best fitting yields Eg(0) = 1.302 eV, α = 4.8 × 10^{-4} eV/K and β = 256 Kfor the InGaAs QW.

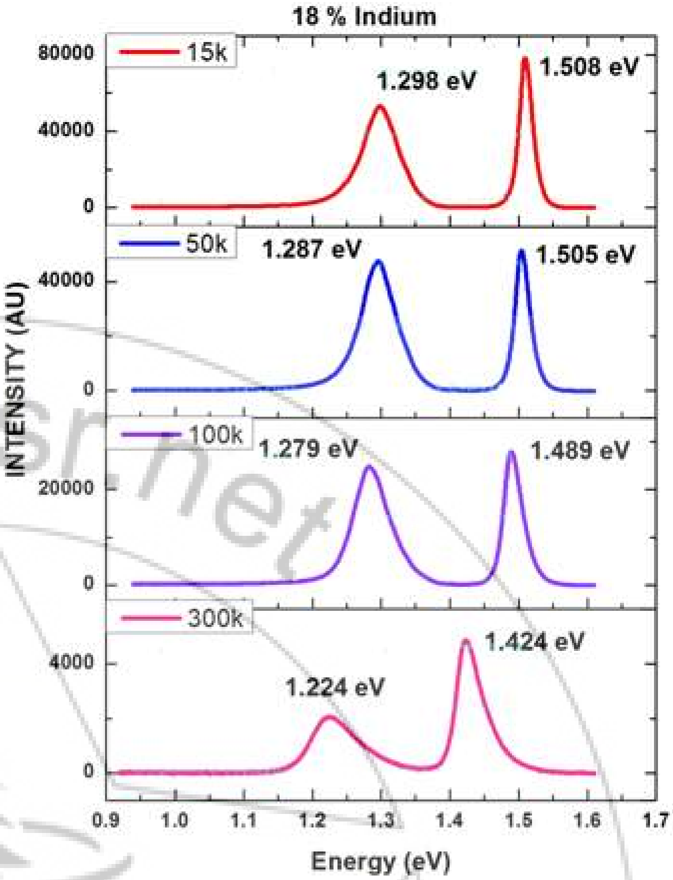

Figure 2: The temperature dependent PL Spectra

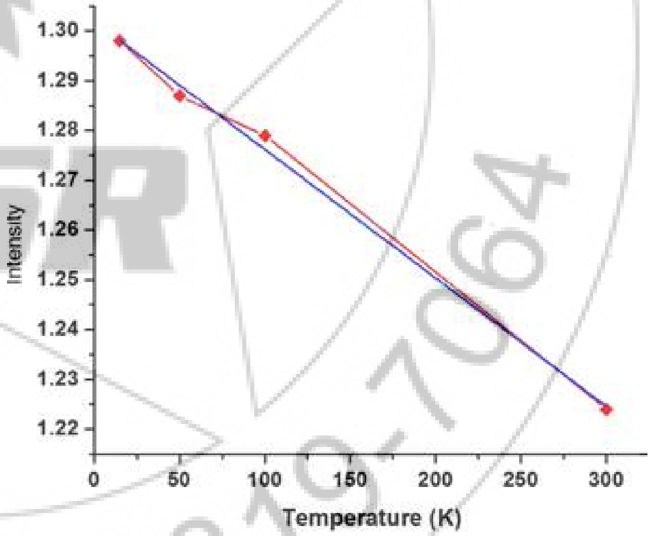

Figure 3: PL intensity as Function of Temperature

3. Conclusion

$In_{0.18}Ga_{0.82}As$ QW structures have been grown by molecular beam epitaxy. The HRXRD spectra shows a high intensity narrow substrate peak and a broad InGaAs layer peak of low intensity to the left of substrate peak. The InGaAs QW is also 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 temperature increases the intensity goes on decreasing. The bandgap also decreases with increase in temperature.

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References

[1] Devaux F, Chelles S, Ougazzaden A, Mircea A, Harmand J C, Electroabsorption modulators for high-bit-rate optical communications: a comparison of strained InGaAs/InAlAs and InGaAsP MQW, Semiconductor Science and technology 10(7),1995,pp.887-901
[2] Raisky O Y, Wang W B, Alfano R R, Reynolds C L, Stampone Jr D V, Focht M W In1-xGaxAs1-yPy/InP multiple quantum well solar cell structures, Journal of Applied Physics 84(10), 1998, pp. 5790-4
[3] Levine B F,Quantum well infrared photodtectors, Journal of Applied Physics 74(8), 1993 pp. R1-81.
[4] B.M. Arora, Sandip Ghosh, Shouvik Datta, Shailendra Kumar Materials Science in Semiconductor Processing 4 (2001) 489–495
[5] Y. F. Chen, J. L. Shen, and L. Y. Lin; J. Appl. Phys. 73 (9); 4555-4559.
[6] A. R. Denton and N. W. Ashcroft Phys. Rev. A **43**, 3161
[7] LiFang Xu, D. Patel, and C. S. Menoni Applied Physics Letters 89, 171112, 2006
[8] D. Wolpert and P. Ampadu,Managing Temperature Effects in NanoscaleAdaptive Systems, Springer Science+Business Media, LLC 2012