EEE3037 Nanotechnology Coursework

6420013

1 Quantum Engineering Design

1.1 Structure Design

In order to design a quantum well which emits light of wavelength 1.55μm, a well material must be chosen such that an interband electron transition emits photons of this wavelength.

This band gap energy can be found from the equation

$$E = hf$$

When considering photons, f can be substituted with

$$f = \frac{c}{\lambda}$$

In order to find the E in terms of wavelength

$$E = \frac{hc}{\lambda}$$

Returning to the specifications, this allows 1.55μm to be expressed as 1.28x10^{-19} J or approximately 0.8 eV.

This energy value will be the same as the total band gap for the well from the first hole energy level to the first electron enery level, shown as

$$\Sigma E_g = E_{1h} + E_g + E_{1e} \approx 0.8eV$$

see figure 1.

E_g should be the dominant term in this equation and as such in investigating suitable materials, the bulk band gap should be close to but lower than 0.8eV.

None of the binary III-V Indium based alloys have bulk band gaps in a suitable range, as such ternary alloys were investigated.

Indium Gallium Arsenide ($In_xGa_{(1-x)}As$) as a well material with Indium Phosphide (InP) as a barrier material would provide a suitable combination assuming that a composition ratio x could be found that satisfied the two conditions of having the required bulk band gap and being lattice matched. A common ratio in industry is $In_{0.53}Ga_{0.47}As$ and as such this was tested first.

1.1.1 Lattice Match

Lattice matching is the process of ensuring that two crystalline structures are of similar dimensions in order to decrease strain at the interface between the two materials. This is particularly important for quantum wells formed through epitaxial growth as strain introduced between such thin layers can cause defects ultimately negatively affecting it's electronic properties.

The lattice constants between the barrier and well materials should be as close as is deemed acceptable for the application. The lattice constants for the prospective materials are shown in table 1.

In order to compute a compound lattice constant for InGaAs, Vegard's law can be applied. Vegard's law provides an approximation for the lattice constant of a solid solution by finding the weighted average the individual lattice constants by composition ratio and is given by:

$$\alpha_{A_{(1-x)}B_x} = (1-x)\alpha_A + x\alpha_B$$

Applying this to the prospective well material gives the following,

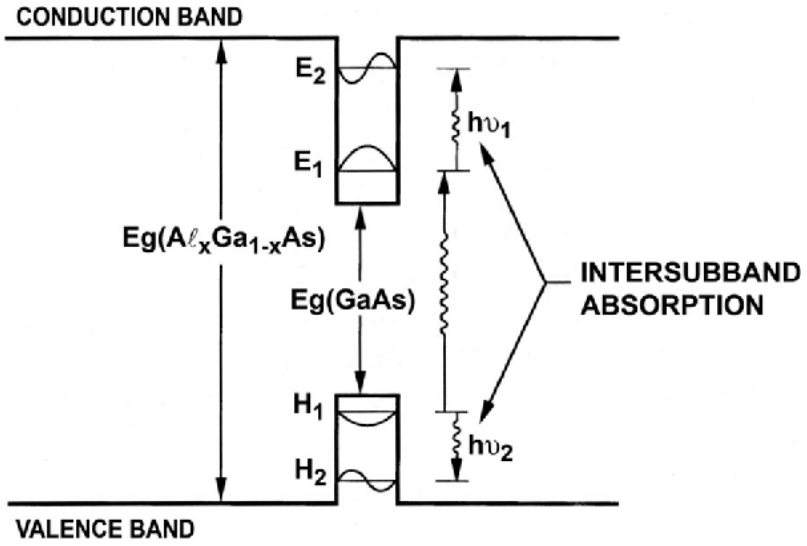

Figure 1: Band structure of an AlGaAs/GaAs/AlGaAs quantum well including discrete energy levels [1]

Material	Lattice Constant, α (Å)
InAs	6.0583
GaAs	5.6532
InP	5.8687

Table 1: Lattice constants for prospective well and barrier materials [2]

$$\alpha_{In_{0.53}Ga_{0.47}As} = 0.53 \cdot 6.0583 + 0.47 \cdot 5.6532 = 5.8679$$

This shows that to 4 significant figures the composition of InGaAs is lattice matched to InP to within 0.001Å which is sufficient for this application.

1.1.2 Band Gap

1.2 Probability Plot

1.3 Probability Intervals

2 Application of Nanomaterials

References

[1] S. D. Gunapala, S. V. Bandara, J. K. Liu, J. M. Mumolo, S. B. Rafol, D. Z. Ting, A. Soibel, and C. Hill, "Quantum well infrared photodetector technology and applications", eng, *IEEE Journal of Selected Topics in Quantum Electronics*, vol. 20, no. 6, pp. 154,165, 2014-11, ISSN: 1077-260X.

[2] *Nsm archive - physical properties of semiconductors*. [Online]. Available: `http://matprop.ru/`.