EEE6212 “Semiconductor Materials” Practical Lab Assignment

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Introduction

- Discuss need for characterisation of epitaxial materials
- Focus on combination of photoluminescence and X-Ray diffraction
- Discuss both
- Introduce samples you will study
- How, where, when

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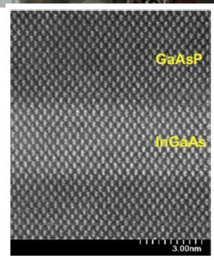
Motivation

- Advanced semiconductor structures are realised via epitaxial processes
- Structures have varying alloy compositions, doping, thickness (mono-layer precision)
- Need methods to characterise deposited materials
- In manufacturing – *non-destructive* characterisation is required
- PL and X-ray diffraction are a complementary set of methods



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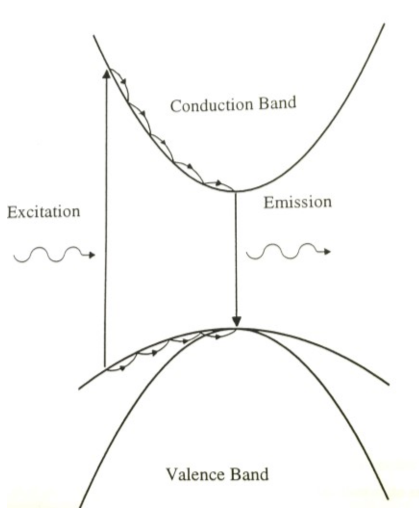
Photoluminescence (PL)

3 step process

Excitation – above band-gap light creates electrons and holes
Relaxation – electron (hole) relaxes to conduction band minimum (valence band maxima)
Emission – the electron and hole recombine through spontaneous emission

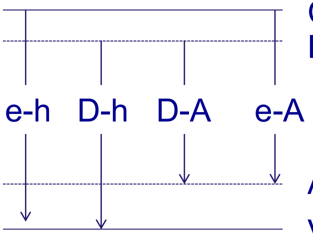
Provides a direct measure of the band-gap (caveats to this over the page!)



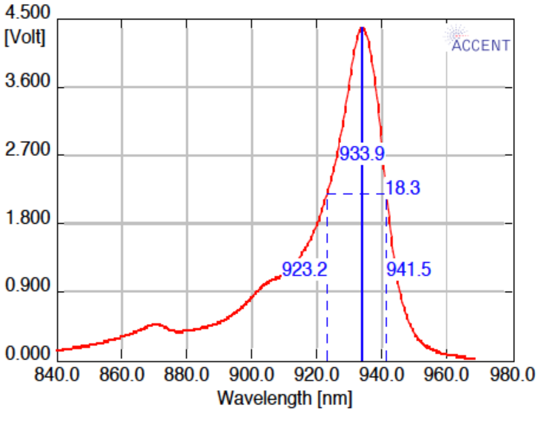
PL – Band-gap Caveats…..

Excitons ? Depending upon the band-gap and the temperature, excitons have a lower energy than the band-gap. At room temperature – not a problem for GaAs, InP.

Donors, Acceptor ?



Room Temperature Line-shape



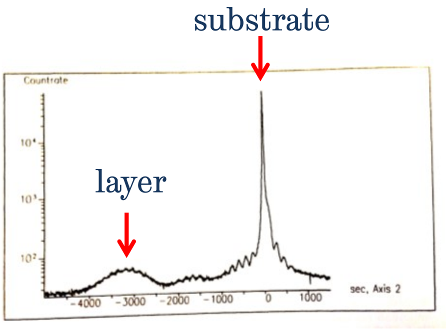
Lineshape is a convolution of Boltzmann Fn and Gaussian

(See http://dx.doi.org/10.1088/0268-1242/1/1/003)

Other features from other states (GaAs band-edge, higher order states in QW…)

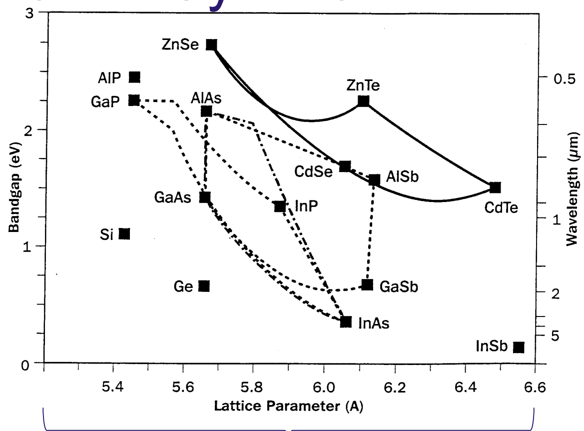
X-Ray Diffraction – Bulk

- See Lecture 7, XRD tells you many things about the deposited layers
- Critically – can provide a measure of the lattice constants in-plane and out-of plane and thicknesses/periodicities



PL and X-Ray - Bulk

PL



X-Ray Diffraction

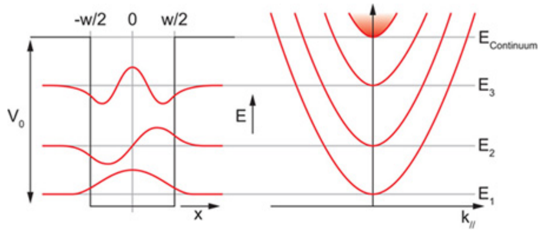
(See http://www.ioffe.ru/SVA/NSM/Semicond/ for lattice parameter and Room Temperature bandgap information)

The Quantum Well

(We will do this in more detail later…)

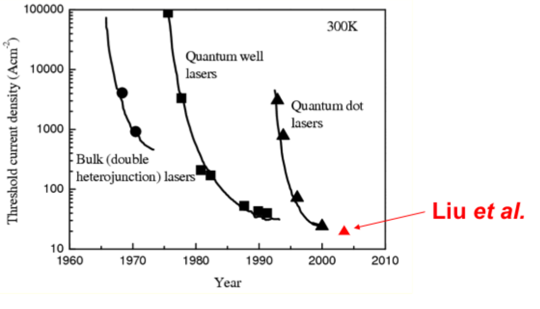
QW - Semiconductor structure which creates a potential on the length scale of the De Broglie wavelength of the electron

-Lowest energy state no longer from band-edge
-Quantum confinement Energy depends upon depth and width of quantum well



QW – Why care?

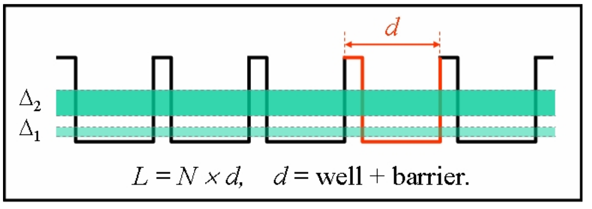
- At the heart of every semiconductor laser
- Many transistors enabled by QWs
- State-of-the-art solar cells…



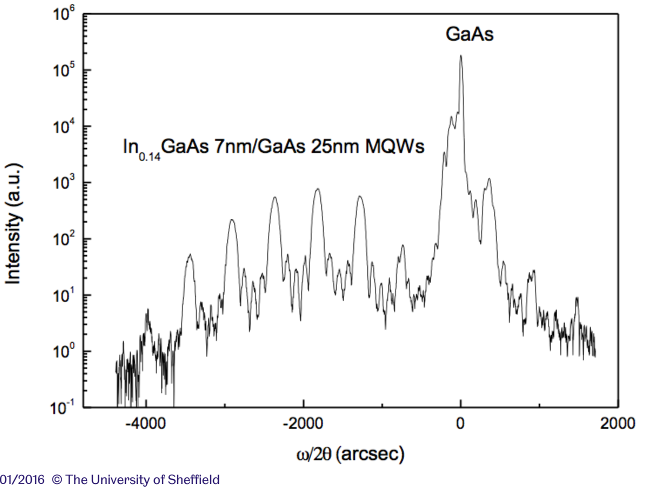
n.b. The Term "Superlattice"

- Crystallography – multiple layers A/B/A/B……

- Quantum mechanics – analogous to a crystal lattice – short period quantum well with



Example X-Ray Diffraction



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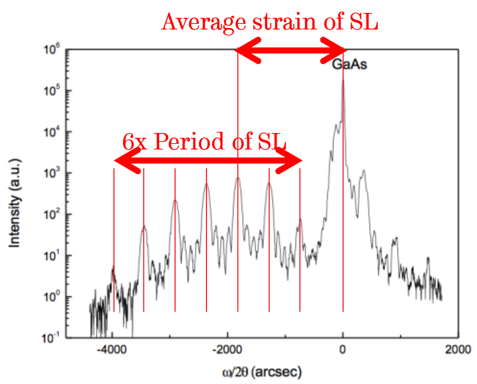
Superlattice - X-Ray



Substrate peak

Zero-order peak – addition of Bragg reflections from A and B components of superlattice. Average composition of A + B layers can be obtained by differentiation of Bragg's law.

Satellite peaks –spacing determined by periodicity of superlattice

(See http://dx.doi.org/10.1109/COMMAD.2000.1022929)

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Your Test Samples

Surface

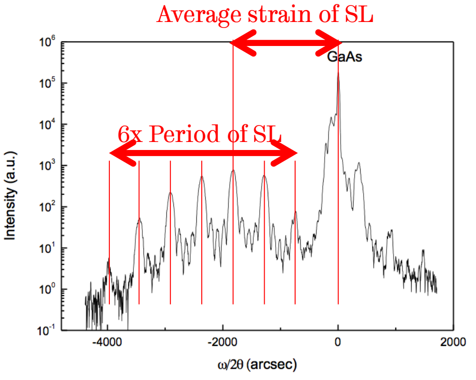
Repeats	Thickness	Thickness tolerance	Material	Material tolerance	Doping type	Doping level	Doping tolerance
1	20.0 nm		GaAs		Undoped	0.0 cm $^{-3}$	
1	50.0 nm		$Al_{(0.3)}$ $Ga_{(0.7)}$ As		Undoped	0.0 cm $^{-3}$	
1	25.0 nm		GaAs		Undoped	0.0 cm $^{-3}$	
5	25.0 nm		GaAs		Undoped	0.0 cm $^{-3}$	
5	8.0 nm		$In_{(0.12)}$ $Ga_{(0.88)}$ As		Undoped	0.0 cm $^{-3}$	
1	50.0 nm		GaAs		Undoped	0.0 cm $^{-3}$	
1	50.0 nm		$Al_{(0.3)}$ $Ga_{(0.7)}$ As		Undoped	0.0	
1	200.0 nm		GaAs		Undoped	0.0	
1	1.0 nm		-		Undoped	0.0	

Various [In], thicknesses

Substrate

Note that it is common in growth sheets for the layer order to be reversed (growth has to start at the substrate and finish at the surface!)

Your Experiment…



Substrate peak

Satellite peaks –spacing will change as QW width is varied

Zero-order peak – As period changes, so average strain of SL changes

What You Will Do

- Before the practical
  - Read all the paperwork and attempt the questions on the sheet
  - The demonstrator may send you home if this is not done satisfactorily!
- Measure X-Ray diffraction curve for your wafers
  - Deduce the period of your superlattice (assumption that GaAs growth rate doesn't change)
  - Deduce the indium composition of your QW
  - Explore reasons for the shape of the curve
- Measure PL spectrum of your wafers
  - Discuss the form of the spectrum
  - Knowing the indium composition, determine the quantum well width
- Write a report
  - Describe background of Molecular Beam Epitaxy, PL measurement, X-Ray diffraction, and your measurements

When, Where?

- Experiments will take ~2 hours in the Nano-Science Cleanrooms, North Campus

Monday	February 8th	3:15 PM – 5:30 PM	Group 1
Tuesday	February 9th	3:15 PM – 5:30 PM	Group 2
Wednesday	February 10th	9:15 AM – 11:30 AM	Group 3
Friday	February 12th	11:15 AM – 1:30 PM	Group 4
Monday	February 15th	3:15 PM – 5:30 PM	Group 5
Tuesday	February 16th	3:15 PM – 5:30 PM	Group 6

- Check your timetables as soon as possible for any clashes with other module lectures. If so contact me promptly to try and rearrange!!

- DON'T BE LATE….Be in reception at Centre for Nanoscience and Technology at this time….You are advised not to wear a skirt!

How?

- You take the data as a team and have a good long think….
- We will provide a pro-forma template which forms the back-bone of your report and prompt some questions
- You need to describe the experimental procedures, plot graphs (please spend time to do this professionally), process data, draw conclusions and speculate on the interpretation of your data
- The report is worth 25% of the module marks
- Be aware of plagiarism rules and regs…..
- TurnItIn is very efficient…..Don't be a fool….
- ……Good luck!

Lectures in Semester 2

- This practical class *replaces* the EEE6212 lectures for weeks 1 and 2 of Semester 2

- Thus there are **no** EEE6212 lectures on
  - Monday Feb 8th 3pm
  - Wednesday Feb 10th 1pm
  - Monday Feb 15th 3pm
  - Wednesday Feb 17th 1pm

- The first EEE6212 lecture of Semester 2 will be on Monday Feb 22nd at 3pm (Mappin LT10)

Links

http://dx.doi.org/10.1088/0268-1242/1/1/003

http://www.ioffe.ru/SVA/NSM/Semicond/

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