METALORGANIC VAPOUR PHASE EPITAXIAL GROWTH AND INFRARED CHARACTERISATION OF InAsSb AND InAs ON InAs SUBSTRATES

TR Baisitse[1,2], JR Botha[2] and JAA Engelbrecht[2]

[1]CSIR-National Laser Centre, Pretoria

[2]Physics Department, Nelson Mandela Metropolitan University, Port Elizabeth

Nelson Mandela Metropolitan University

for tomorrow

CSIR

our future through science

Motivation

- Interest exists in III-V semiconducting materials (InAs, GaSb, InSb and related alloys) for the detection of infrared radiation
- Such materials could be used as alternatives for future infrared detectors and various sensing applications
- InAsSb is ideally suited for mid-infrared applications, since its band gap spans the wavelength range from 3 to 12 µm
- It can be combined epitaxially with GaSb for backside-illuminated detectors

Experimental – MOVPE growth

- Epilayers and ternary alloys were prepared by Metal Organic Vapour Phase Epitaxy (MOVPE) technique

- Substrates: GaAs (for electrical measurements)

  InAs (for minimal lattice-mismatch and optical characterisation)

Experimental - Characterisation

Layers were characterized by:

- Fourier Transform infrared (FTIR) reflectance spectroscopy
- Computer curve fitting techniques
- Hall effect measurements at 300 K

Nelson Mandela Metropolitan University

for tomorrow

our future through science

Simulation/Calculation of Reflectivity

- Interaction of radiation with a semiconductor

$$\varepsilon = (n + ik)^2 = \varepsilon^{/} + i\varepsilon^{//}$$

$$\varepsilon = \varepsilon_\infty \left[1 + \frac{\omega_L{}^2 - \omega_T{}^2}{\omega_T{}^2 - \omega^2 - i\omega\Gamma} - \frac{\omega_P{}^2}{\omega(\omega - i\gamma)} \right]$$

Nelson Mandela Metropolitan University
for tomorrow

CSIR
our future through science

Where

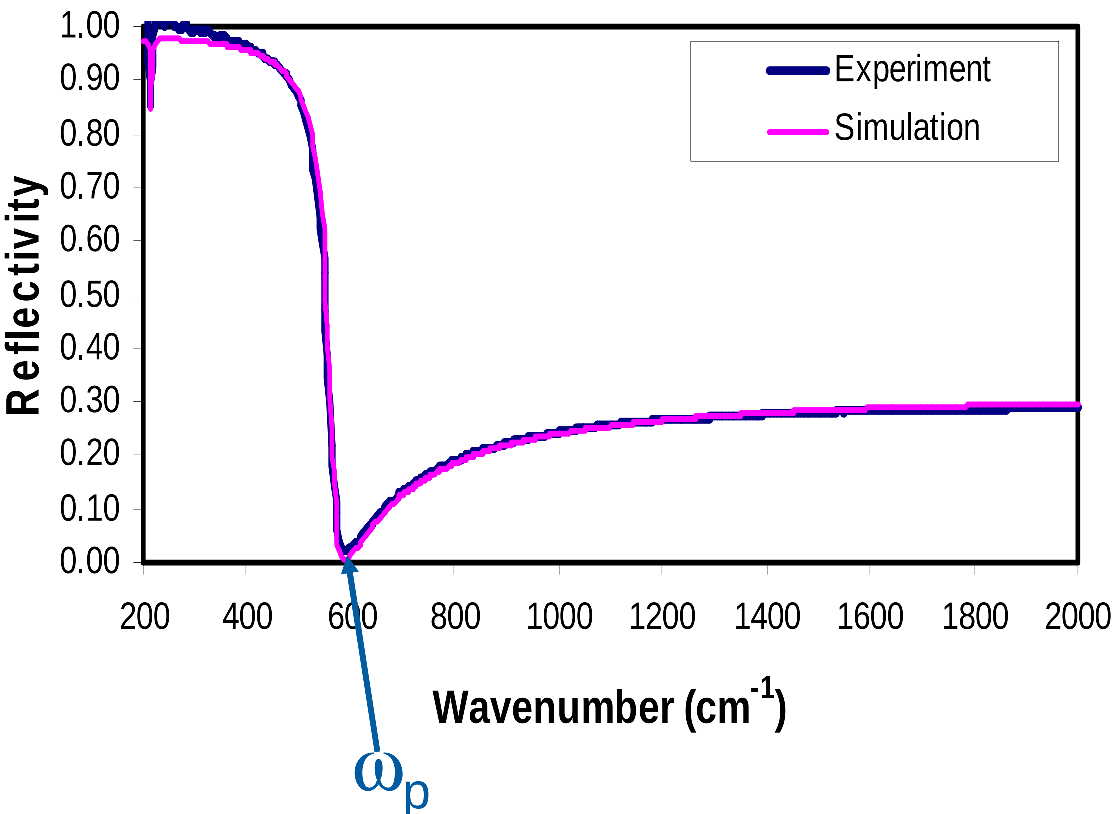
$$\omega_P{}^2 = \frac{4\pi Ne^2}{m^* \varepsilon_\infty} \qquad \gamma = \frac{e}{m^* \mu}$$

- Reflectivity R of the material in terms of complex dielectric function

$$R = \frac{(n-1)^2 + k^2}{(n+1)^2 + k^2}$$

$$R = \left| \frac{\sqrt{\varepsilon} - 1}{\sqrt{\varepsilon} + 1} \right|^2$$

Results and discussion – FTIR spectrum of InAs substrate



Fit to the spectrum of InAs substrate yields :

- carrier concentration

  1.0×10^{18} cm^{-3}

- carrier mobility

  2.3×10^{4} $cm^{2} V^{-1} s^{-1}$

Nelson Mandela Metropolitan University
for tomorrow

CSIR
our future through science

Results and discussion – Hall measurements

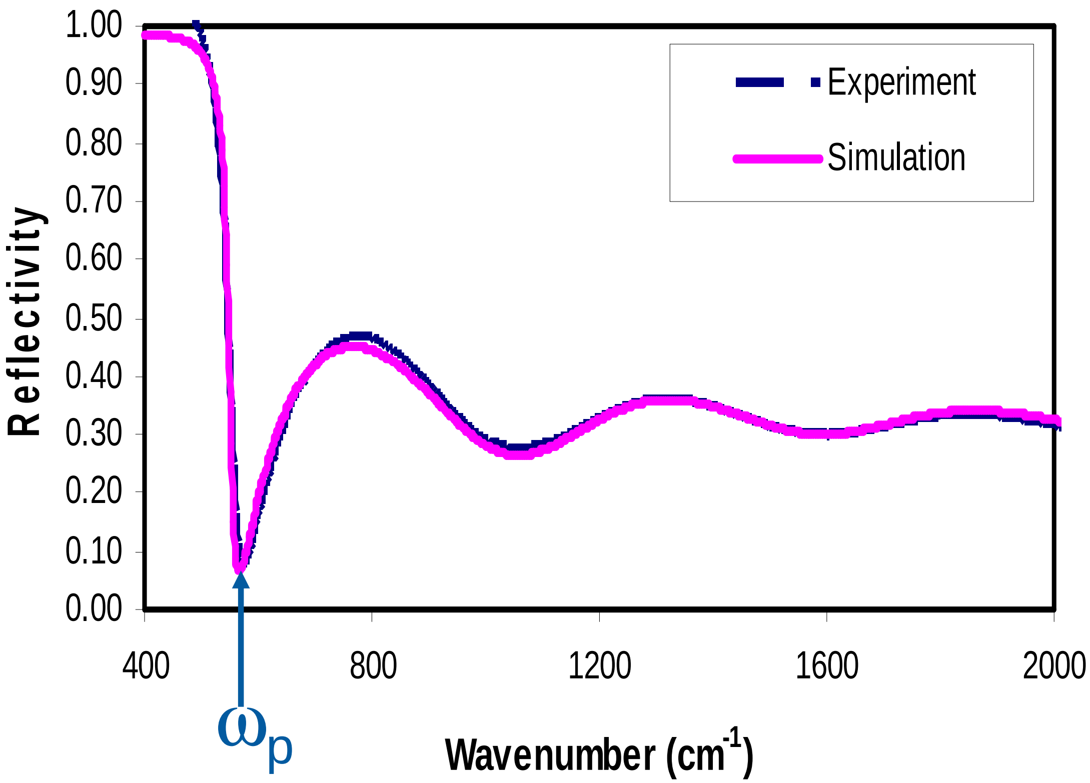
- Hall carrier concentration and mobility obtained from **InAs substrate** (300K)

$$n = 2.0 \times 10^{18}\ cm^{-3}$$

$$\mu = 0.9 \times 10^{4}\ cm^{2}\ V^{-1}\ s^{-1}$$

- Hall carrier concentration ~ twice the optical value
- Hall mobility ~ half the optical value

Results and discussion – FTIR spectra of InAs layer on InAs substrate



- Simulation yields for layer

  $n = 3.1 \times 10^{15}\ cm^{-3}$

  $\mu = 2.9 \times 10^{4}\ cm^{2}\ V^{-1}\ s^{-1}$

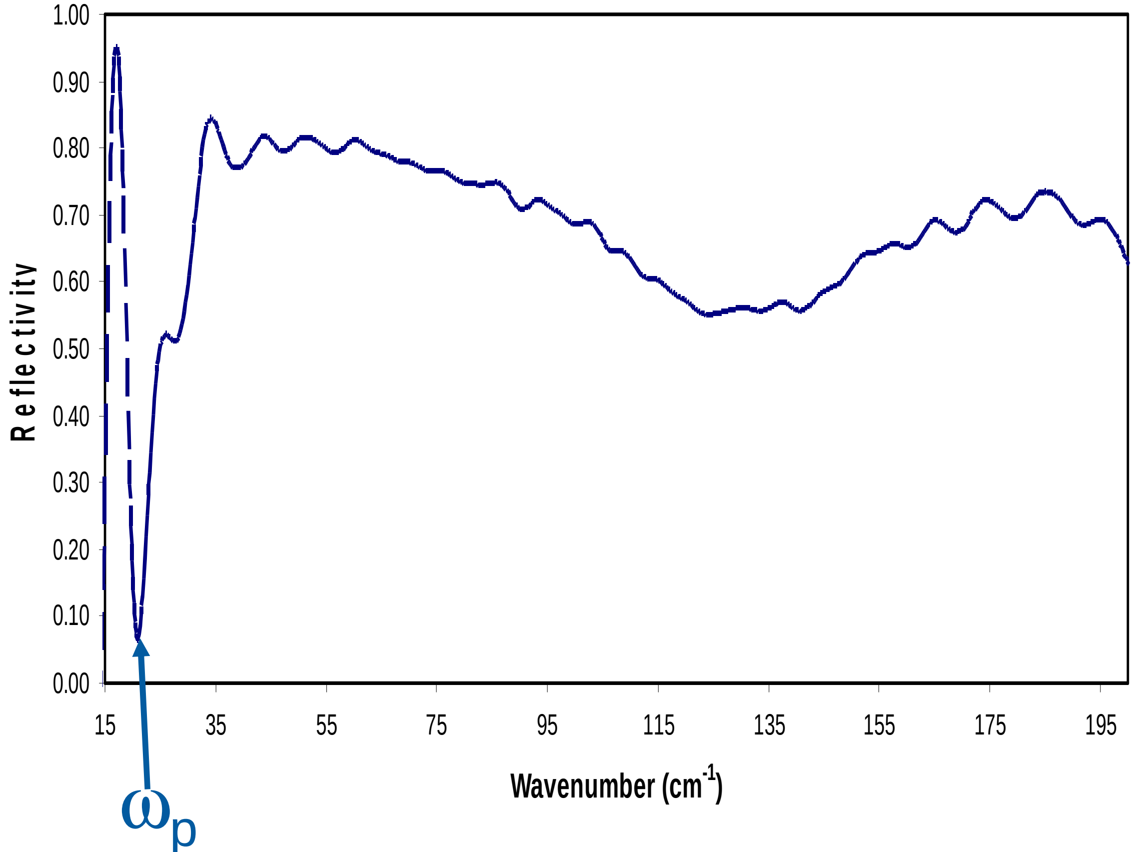
  thickness 2.6 µm

- For substrate

  $n = 1.0 \times 10^{18}\ cm^{-3}$

  $\mu = 2.7 \times 10^{4}\ cm^{2}\ V^{-1}\ s^{-1}$

Resonance plasma frequency of InAs layer on InAs substrate

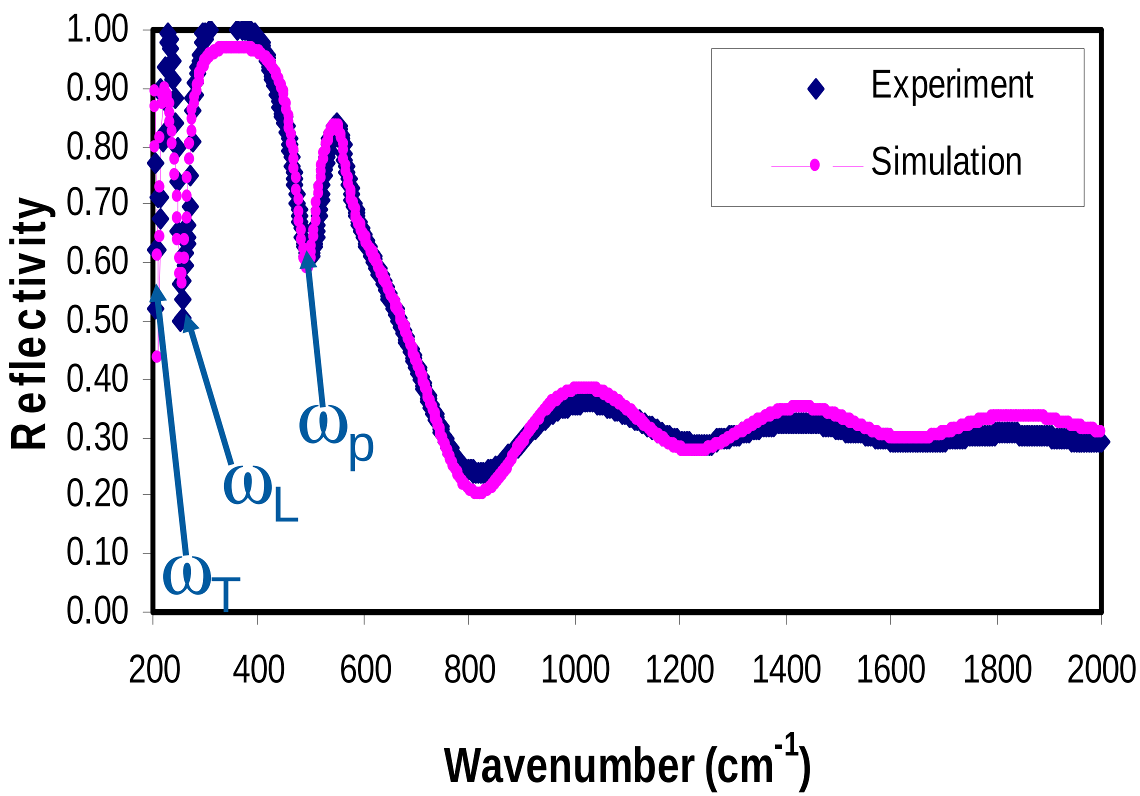


- ω_p (**simulated**) = 20 cm^{-1}
- ω_p (**measured**) = 21 cm^{-1}

Nelson Mandela Metropolitan University
for tomorrow

CSIR
our future through science

Results and discussion – FTIR spectra of InAsSb layer on InAs substrate



- Simulation yields for layer
  $n = 1.9 \times 10^{15}\ cm^{-3}$
  $\mu = 7.1 \times 10^{4}\ cm^{2}\ V^{-1}\ s^{-1}$
  thickness 3.4 µm
- For substrate
  $n = 1.0 \times 10^{18}\ cm^{-3}$
  $\mu = 2.0 \times 10^{4}\ cm^{2}\ V^{-1}\ s^{-1}$

Nelson Mandela Metropolitan University
for tomorrow

CSIR
our future through science

Results and discussion – comparison of optical and electrical data

Sample	Simulation		Measured/Expected	
	$n(cm^{-3})$	$\mu(cm^2\,V^{-1}\,s^{-1})$	$n(cm^{-3})$	$\mu(cm^2\,V^{-1}\,s^{-1})$
InAs sub	1.0×10^{18}	2.3×10^{4}	2.0×10^{18}	0.9×10^{4}
(InAs/InAs)				
Layer	3.1×10^{15} ! 4.4×10^{15}	2.9×10^{4}	** 1.7×10^{15}	** 2.1×10^{4}
Substrate	1.0×10^{18}	2.7×10^{4}	2.0×10^{18}	0.9×10^{4}
(InAsSb/InAs)				
Layer	1.9×10^{15}	7.2×10^{4}	** 9.7×10^{15}	** 2.1×10^{4}
Substrate	1.0×10^{18}	2.0×10^{4}	2.0×10^{18}	0.9×10^{4}

! From direct measurement of ω_P

** Simulation of magnetic field-dependent Hall measurements on similar layers

Nelson Mandela Metropolitan University
for tomorrow

CSIR our future through science

Conclusion

- Reasonable correlation between optical and electrical results
- Differences between carrier concentrations for substrate within supplier specifications
- Differences in mobility will depend on mechanisms of carrier scattering

For polycrystalline material [Journal of Electronic Materials, Vol. 35, No.4, 2006]

- Electrically – scattering in bulk and at grain boundaries
- Optically – bulk scattering only, since electrons displaced over a short distance

Present films are **single crystalline**, however → discrepancies need further investigation

Acknowledgments

I would like to acknowledge NRF and National Laser Centre for financial support

I am also thankful to Dr. A. Forbes, Mr. G Katumba for their support, and useful discussions with / input from L Botha and P Shamba

Nelson Mandela Metropolitan University

for tomorrow

CSIR

our future through science