A Strain-compensated Mid-infrared Quantum Well Photodetector Operating at Zero Bias up to 250K and in Photoconductive Mode up to 300K

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Introduction

- We report on two strain-compensated $AlAs/In_xGa_{1-x}As/AlAs/In_{0.52}Al_{0.48}As$ double barrier quantum well infrared photodetectors operating up to 270 K at zero bias and in photoconductive mode up to 300 K.
- These structures take advantage of strain balancing due to the opposing strain of AlAs and InGaAs layers relative to the InP substrate [1].
- The wavelength of operation for the two samples is 2.1 μm (590 meV) for 1723 and 2.9 μm (428 meV) for XMBE45.

Sample Structure

	Layer	
	$In_{0.53}Ga_{0.47}As$ (N_{DC})	Cap: 5000 Å
	$In_{0.52}Al_{0.48}As$	Barrier: L_{OB} Å
MQWs x 15	AlAs	Barrier: L_{IB} Å
	$In_XGa_{1-X}As$ (N_{DW})	QW: L_W Å
	AlAs	Barrier: L_{IB} Å
	$In_{0.52}Al_{0.48}As$	Barrier: L_{OB} Å
	$In_{0.53}Ga_{0.47}As$ (N_{DC})	Buffer: 5000 Å
	InP:Fe	

Generic schematic epitaxial layer of the samples structure. The samples were grown by MBE at a growth temperature of 420^0C.

Parameters	Sample No. 1723	Sample No. XMBE45
QW thickness (L_W) Å	30	45
Indium composition (x) %	84	75
Well doping density (N_{DW}) cm^{-3}	$3x10^{18}$	$2x10^{18}$
Contact doping density (N_{DC}) cm^{-3}	$1.5x10^{19}$	$5x10^{18}$
Outer barrier thickness (L_{OB}) Å	230	250
Inner barrier thickness (L_{IB}) Å	23	20
Average net strain per period %	-1.3	-1

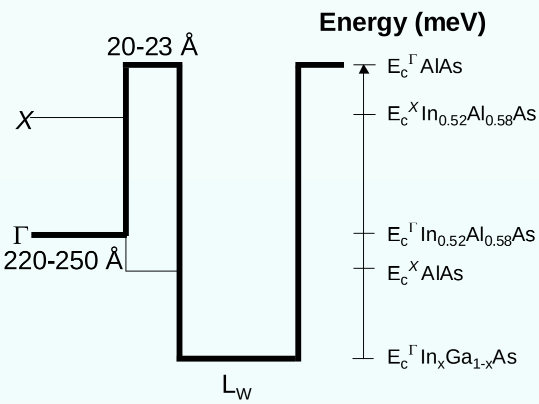
Samples parameters.

Modelling

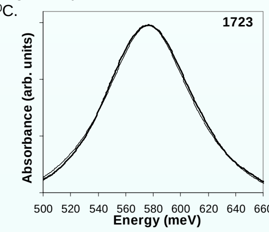
- 3 Band Approximation Kane (*k.p*) model [2].
- Takes into account the effect of strain and bulk band nonparabolicity.
- Gives good approximation to the energy levels in the well.

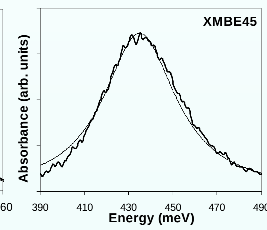
Energy/conduction band potential levels (meV)	Sample No. 1723	Sample No. XMBE45
E_1^{Γ}	301	211
E_2^{Γ}	873	644
E_3^{Γ}	1434	1123
E_1^{X}	705	678
E_2^{X}	908	915
$E_1^{\Gamma} + E_F$	371	266
E_c^{Γ} $In_{0.52}Ga_{0.48}As$	675	627
E_c^{X} $In_{0.52}Ga_{0.48}As$	1201	1153
E_c^{Γ} AlAs	1472	1430
E_c^{X} AlAs	624	580

Modelled subband energy levels in the Γ band for the samples. All the energy levels are relative to the bottom of the Γ conduction band of the InGaAs QW layer.

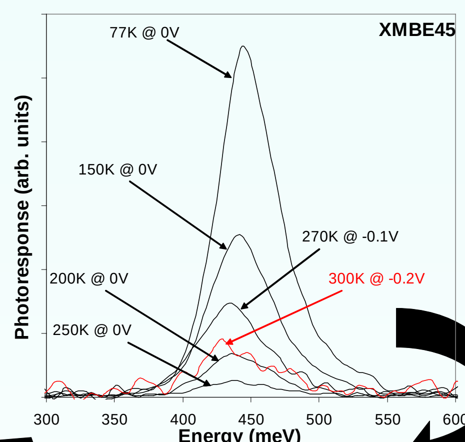


Modelled generic Γ (thick line) and X (thin line) conduction band edge profile of the samples.



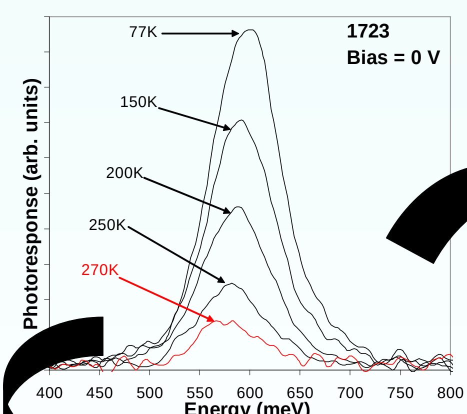


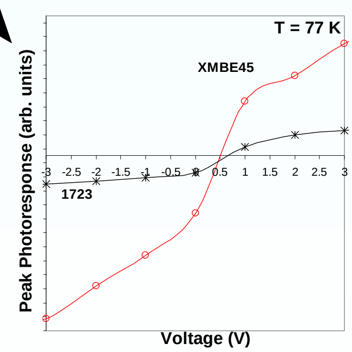
- Measured 300 K (thick line) and Lorentzian fit (thin line) absorbance spectrum for samples 1723 and XMBE45.
- The observed peak energies of 435 meV and 576.5 meV and are in excellent agreement with the calculated values of 433 meV and 572 meV for samples XMBE45 and 1723, respectively.
- The corresponding spectral width $\Delta\lambda/\lambda_p$ of 9.2% and 14.2% is in the expected range for a bound-to-bound and bound-to-quasibound transitions [3].



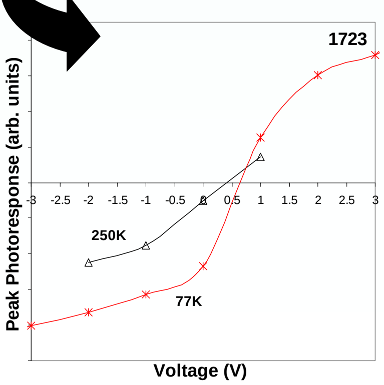
Optimsed Structure

- Zero bias photoresponse up to 250 K.
- Photoresponse up to 300 K at -0.2 V.
- Photoresponse decreases initially with increasing positive bias.
- Photoresponse is higher as compared to 1723 for all applied biases and temperatures





- Zero bias photoresponse at 270 K.
- 77 K to 250 K photoresponse increases with increasing negative bias.
- Photoresponse decreases initially with increasing positive bias.



Summary

- QWIPs capable of operation up to 270 K at zero bias and up to 300 K at -0.2 V.
- The observed peaks energies are in good agreement with our modelled values.
- The higher operating temperature due to the large band offset and dark current activation energy
  - ΔE_C ~ 675 meV and I_d^A ~ 304 meV for sample 1723.
  - ΔE_C ~ 627 meV and I_d^A ~ 361 meV for sample XMBE45.
- These results show that we can potentially make use of strain to cover a wide range of mid-Infrared spectrum.
- Further optimisation of this design should lead to improve performance at higher temperature.

References

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