

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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Sample Structure

In _{0.53} Ga _{0.47} As (N _{DC})	Cap: 5000 Å
In _{0.52} Al _{0.48} As	Barrier: L _{OB} Å
AlAs	Barrier: L _{IB} Å
In _x Ga _{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	

MQWs x 15

Parameters	Sample No.	
	1723	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

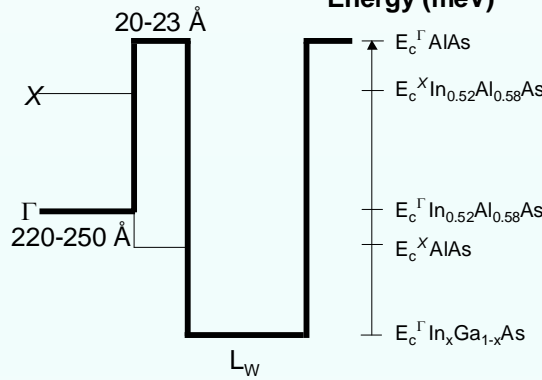
Introduction

- 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.

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	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 ^Γ + 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

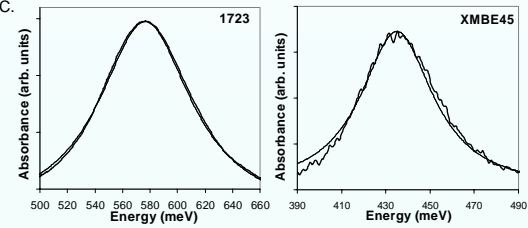


Modelled generic Γ (thick line) and X (thin line) conduction band edge profile of the samples.

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.

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

Samples parameters.

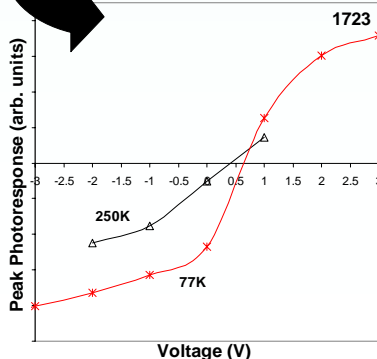
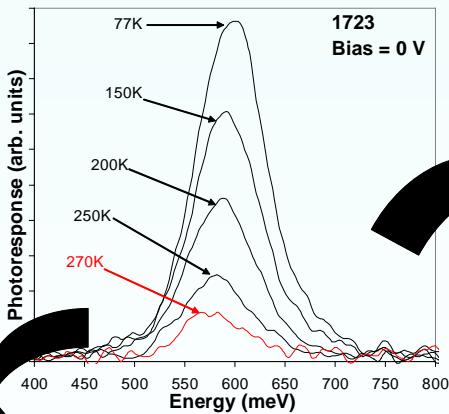
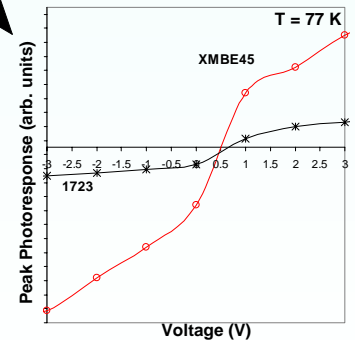
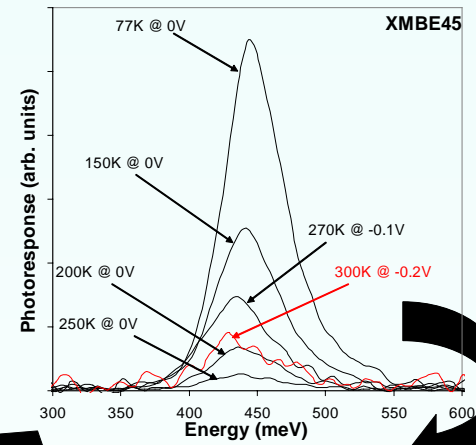


- Measured 300 K (thick line) and Lorentzian fit (thin line) absorbance spectrum for samples 1723 and XMBE45.
- The observed peak energies of 435 meV and 576.5 meV and are in excellent agreement with the calculated values of 433 meV and 572 meV for samples XMBE45 and 1723, respectively.
- The corresponding 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].

Optimised 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
 - $\Delta E_c \sim 675$ meV and $I_a^A \sim 304$ meV for sample 1723.
 - $\Delta E_c \sim 627$ meV and $I_a^A \sim 361$ 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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