Increasing the dot density in quantum dot infrared photodetectors via antimony mediated dot formation

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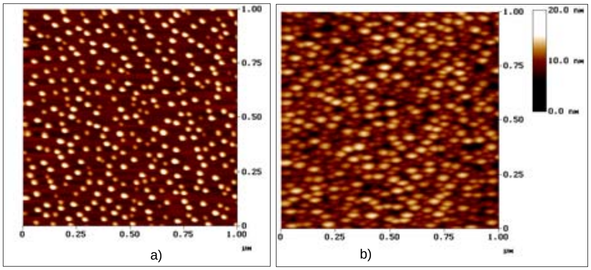
Motivation

- One of the key factors limiting the performance levels of QDIPs relative to quantum well infrared photodetectors (QWIPs) is the ~10x lower intraband absorption strength for a single layer of QDs compared to a single QW.
- Main reason for the lower absorption: In-plane QD density limits the number of absorbing electrons to a few $10^{10}cm^{-2}$ in a QDIP, compared with a few $10^{11}cm^{-2}$ in a typical QWIP.
- We address this issue by depositing a thin layer of GaSb just prior to the InAs QD growth [1] as a method towards the realisation of the potential benefits of QDIPs, including longer excited lifetimes (higher responsivity) and normal incidence operation.

Atomic force microscopy (AFM) of Sb-mediated grown structures

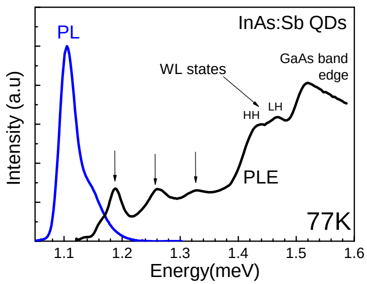


AFM images of :a) Standard In/GaAs dots, b) InAs on GaSb/GaAs dots

Increase in dot density from typically **~3x10^{10}cm^{-1}** to **~6x10^{10}cm^{-1}** for Sb pre-deposition before growth of wetting layer

Photoluminescence

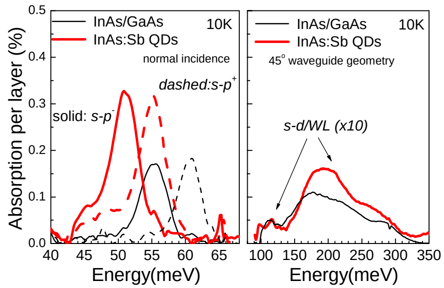
- QD energy configuration not altered with incorporation of antimony
- PL&PLE and intraband absorption studies can be used to estimate valence band energy levels



Photoluminescence and photoluminescence excitation for InAs in GaSb/GaAs dots

Intraband Absorption

- Red-shift between InAs/GaAs and InAs on GaSb/GaAs dots within the range of 48-60meV-(typical for standard QD structures, depending on growth parameters)
- Absorption per layer of **~15%** for *s-d* and *s-WL* transitions, and **35%** for normal incidence absorption from *s-p* state

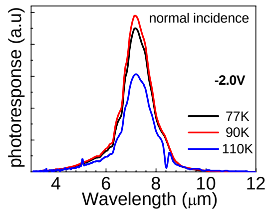


Absorption per layer for *s-p* and *s-d* and *s-WL* states for samples with and without antimony

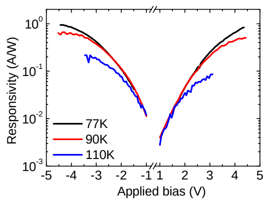
- Conduction band structure unaltered, unlike other approaches for producing high QD densities which lead to formation of coalesced QDs or quantum dashes [2]
- Low energy shoulder of *s-p$^-$* peak attributed to effect of bimodal distribution for the Sb-sample

DWELL QDIP with GaSb

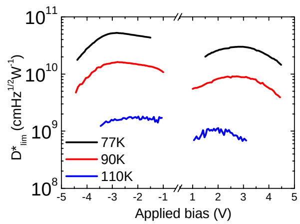
- Above technique applied for the fabrication of a quantum dots-in-a-well (DWELL) infrared photodetector
- narrow photoresponse at **~8µm** up to temperatures of **110K**
- Responsivity of **1A/W** at **77K** scaling down to only 0.12A/W at 110K



Spectral response of DWELL infrared detector with GaSb



Responsivity of DWELL detector with GaSb



*Detectivity of **5x10^{10}cmHz$^{1/2}$W^{-1} at 77K***

Incorporating Sb in DWELL QDIPs is a very promising technique for high performance detectors

related work published in Applied Physics Letters, ***P. Aivaliotis et al*, *APL 91,013503 (2007)***

[1]. Y. Sun et al, J. Applied Physics **97**, 053503, 2005
[2]. Heedon Hwang et al, Appl. Phys. Lett. Vol 85 (26), 2004