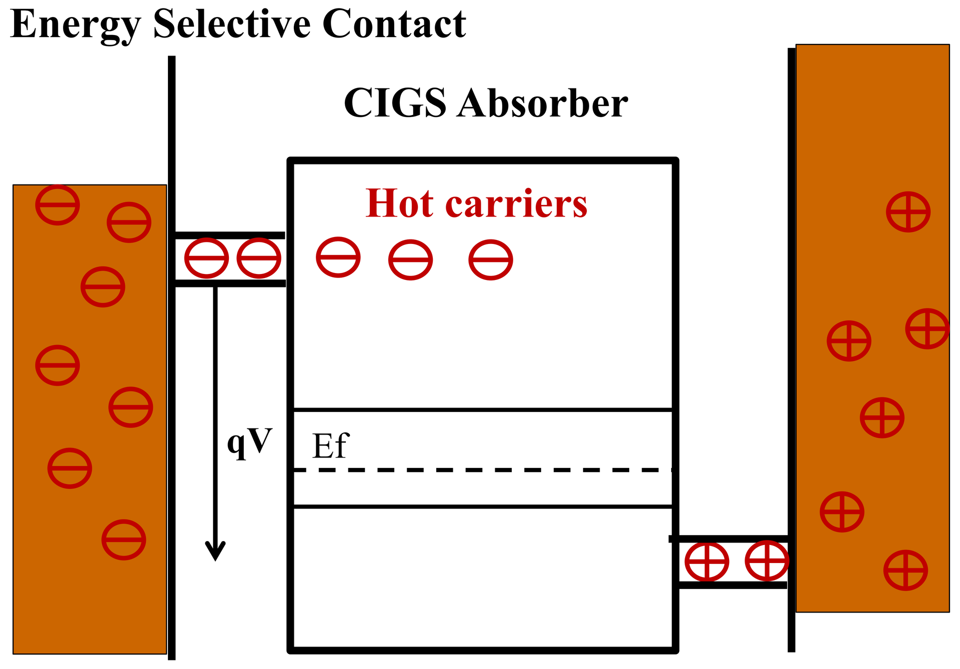
Development of Low Cost CIGS Thin Film Hot Carrier Solar Cells

Yige Hu[1], Gijs Bosman[1], and Tim Anderson[2]

Department of Electrical and Computer Engineering[1]
Department of Chemical Engineering[2]
University of Florida

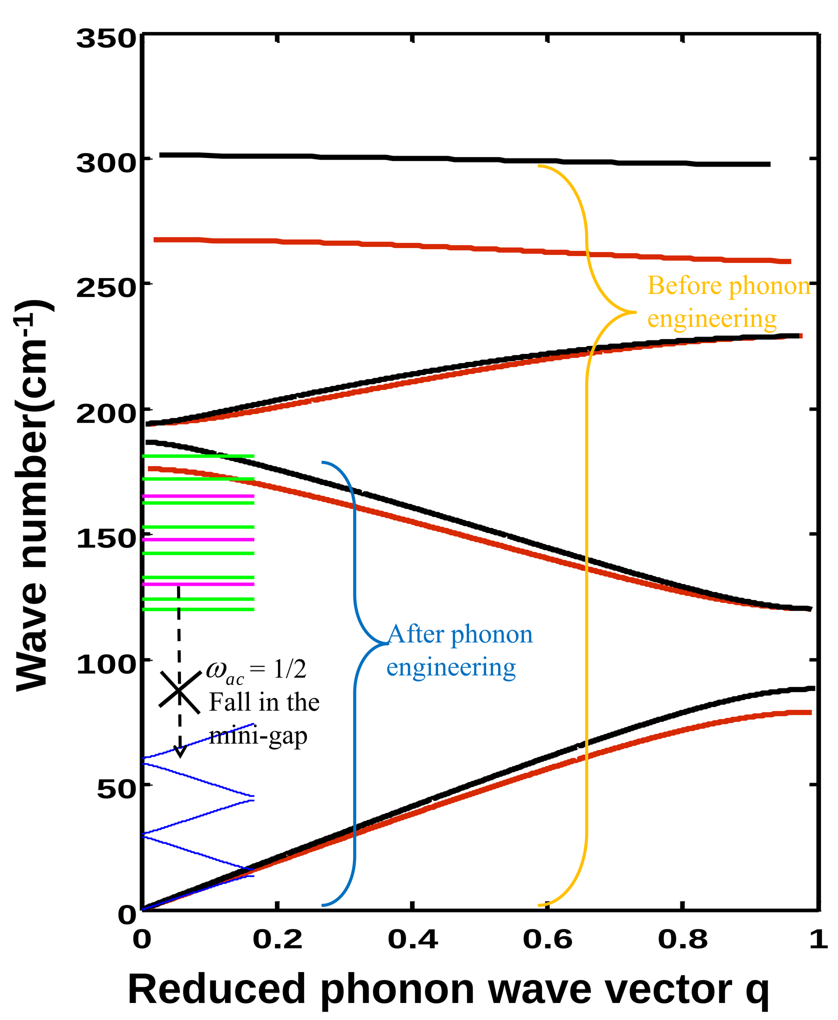
Introdution



Hot carrier solar cell offers enhanced efficiency by

- Slowing carrier thermalisation in the absorber material.
- Extract carriers at selective energies so that carrier energy is not lost to the cold contacts.

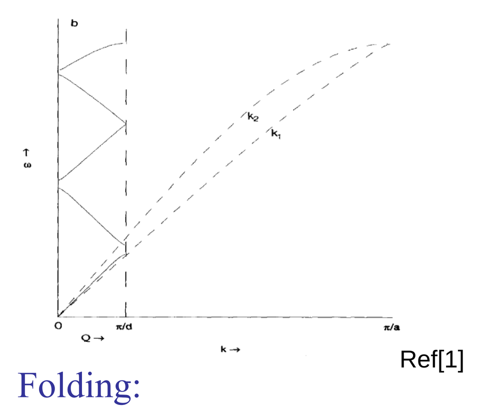
Slowing Thermalisation



Black Solid lines represent the CGS bulk phonon dispersion curve; red solid lines represent the CIS bulk phonon dispersion curve. The green, purple, and blue lines are the phonon dispersion curves for a repeating nano-structure of 1 atomic layer of CIS over 2 atomic layer of CGS.

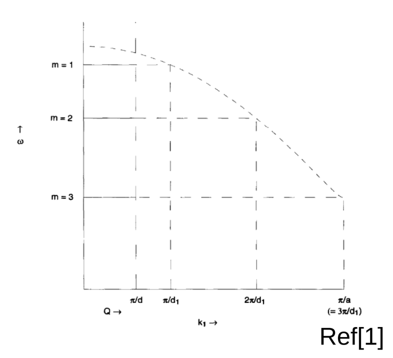
•Phonon engineering

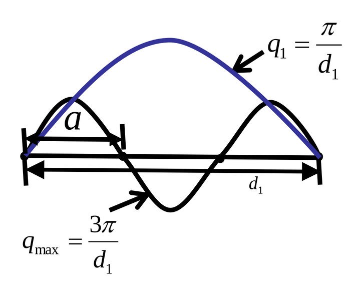
- Hot-phonon bottleneck effect – reabsorption of hot phonons
  Emission of optical phonons builds up a hot non-equilibrium population.
  This hot optical phonon population reheats the electron population, thus slowing carrier cooling.
- Klemens mechanism – An optical phonon decays into two equal energy acoustic phonons: LTO→2LA(only).
- Block Klemens scattering, reduce the thermalisation of the hot carriers.
- Improve open circuit voltage, enhance cell efficiency, lower the cost



Folding:

- The bulk dispersion curve is folded back into the reduced Brillouin zone, an "average" k is used.
- If the superlattiece structure is engineered correctly, the mini-gaps can be arranged to block the Klemens mechanism





Confined optic-phonon dispersion curves(solid line) within a superlattice reduced Brillouin zone 0<Q< /d, compared with the bulk dispersion curve(dashed π curve). In the example the layer thickness is 3 lattice units.

Confinement:

- Standing wave, not propagated
- Different , big mismatch, not propagated

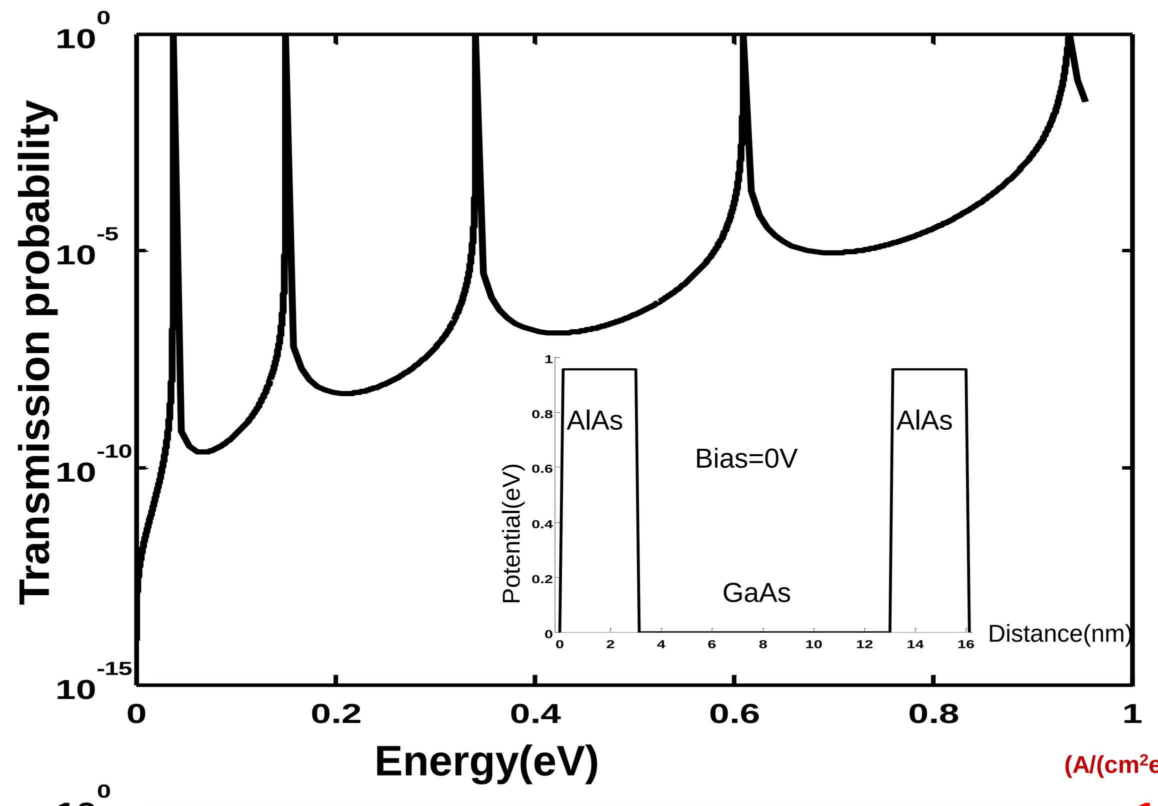
Energy Selective Contact

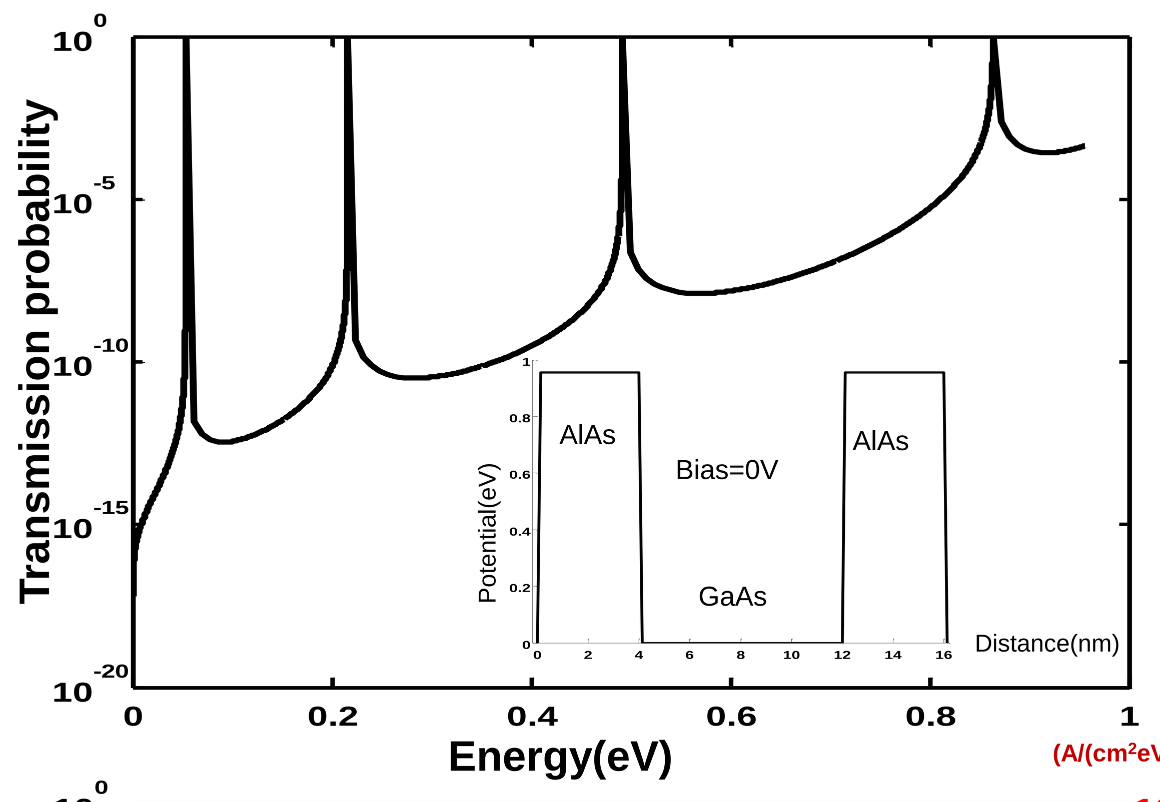
•Electrical engineering

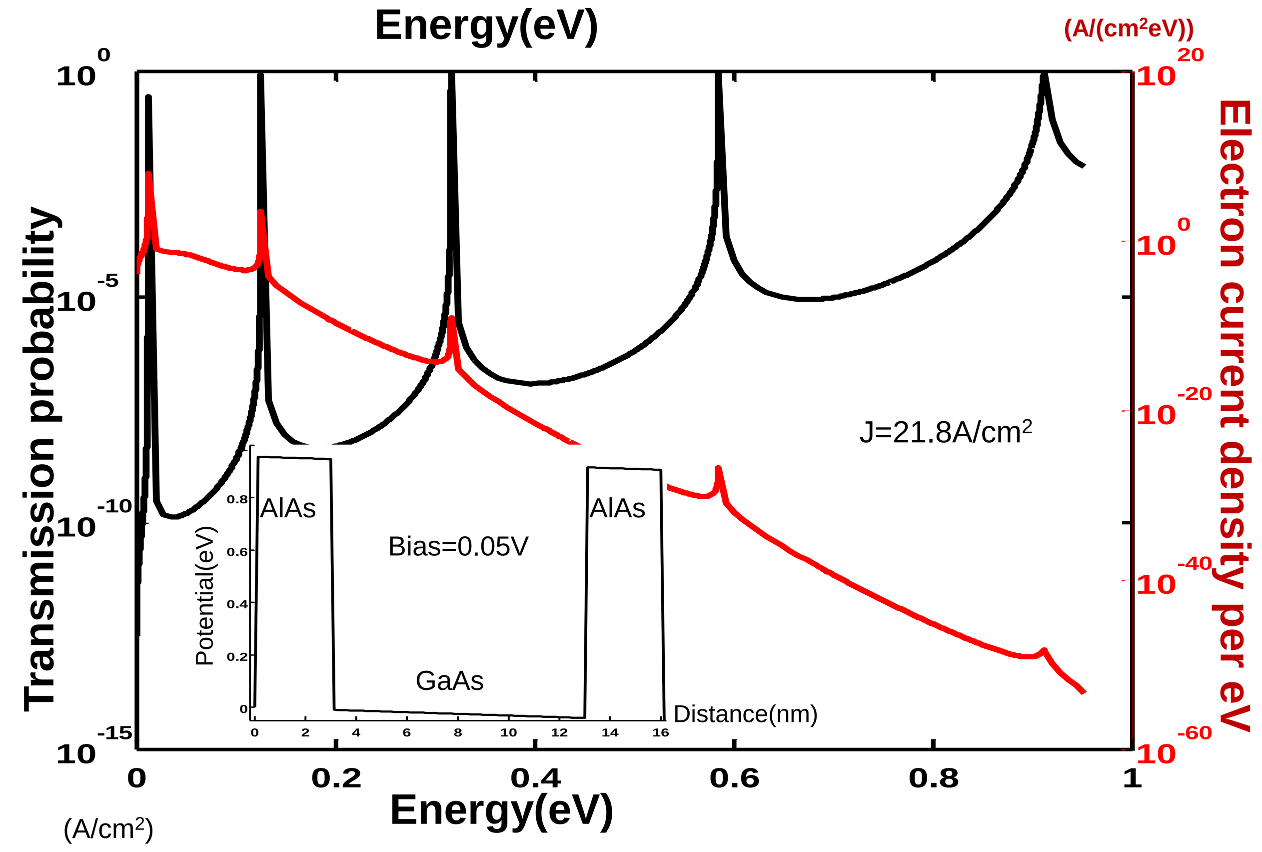
- Contact was required to be very thin so that carriers are collected before they interacted with the lattice.
- The device design should allowe collection of carriers at an optimal energy range. Carriers having energies outside this range were rejected to prevent scattering loss.
- Energy selective contact—quantum mechanical tunneling is used, only carriers with optimal energy are collected ref[3],[4].
- Enhance Auger process to utilize cold carriers

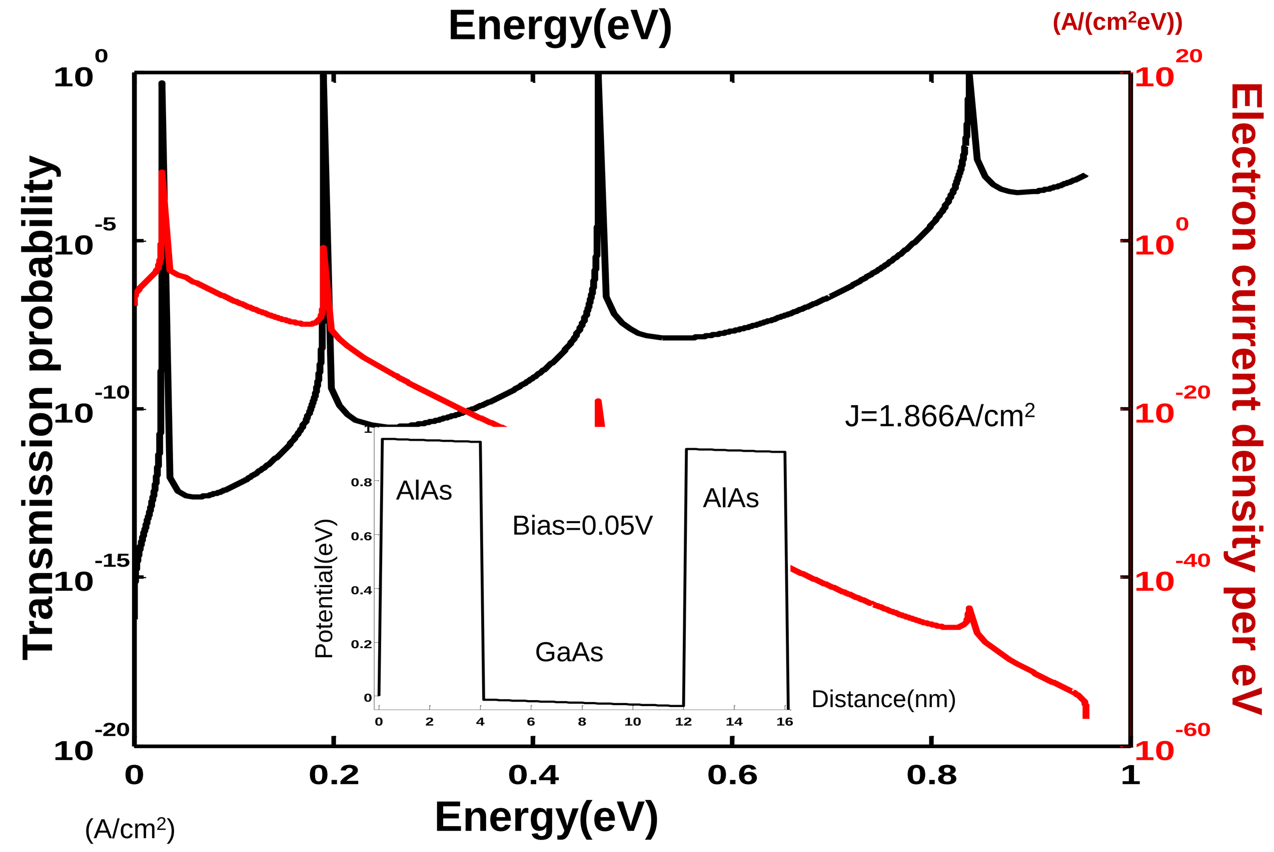
•Bandgap engineering

- Reduce recombination rate

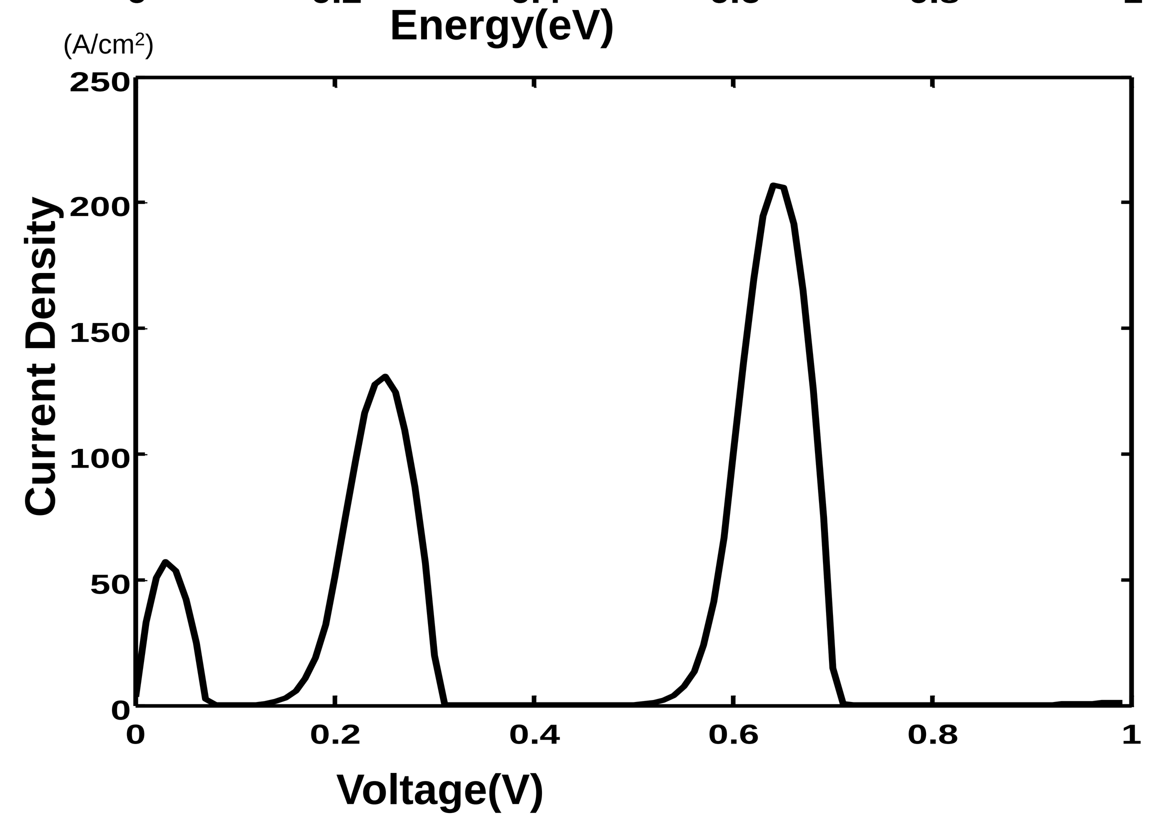


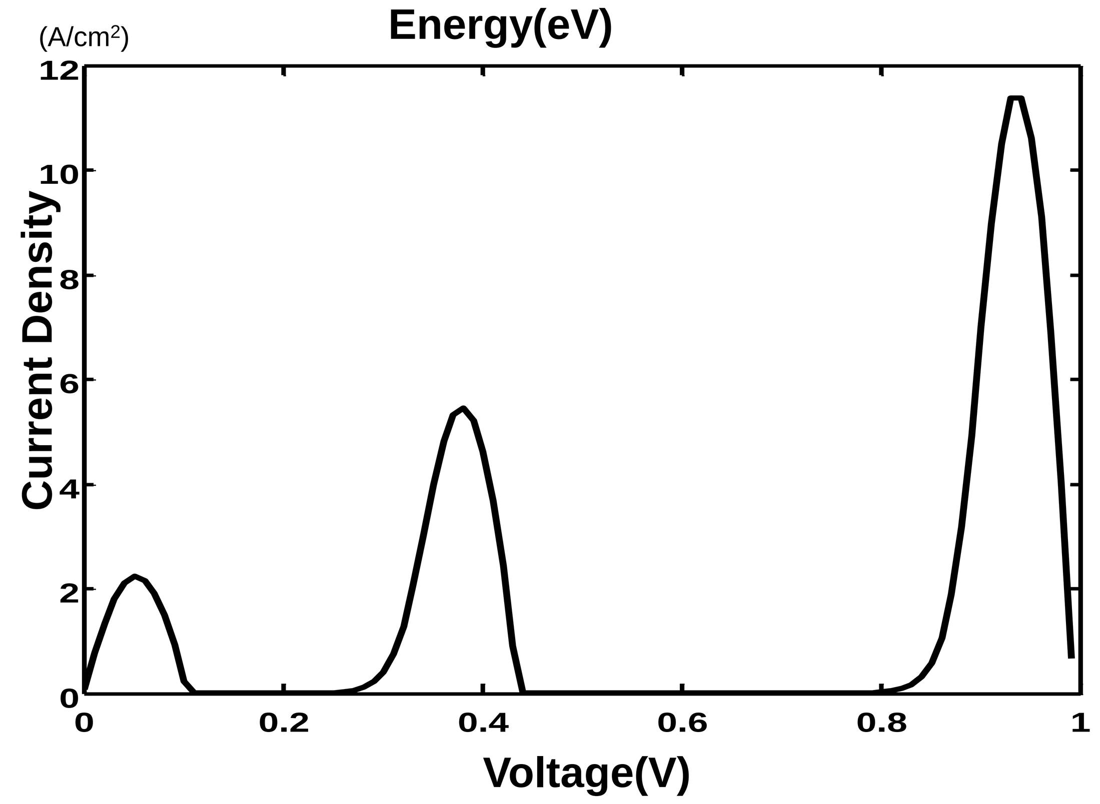






Simulated J-V curve on the left is of quantum well device featuring 3nm AlAs barriers and 10nm GaAs well. J-V curve on the right is of 4nm AlAs barriers and 8nm GaAs well.





Reference

[1]:T. Dumelow, T.J. Parker, S.R.P. Smith and D.R. Tilley, "Far-infrared spectroscopy of phonons and plasmons in semiconductor superlattices", Surface Science Reports 17 (1993) 151-212.
[2]: S. Tamura, D.C. Hurley and J.P. Wolfe, Acoustic-phonon propagation in superlattice", Physical review B 38(2) 1427-1449
[3]: C.Flynn, D. Konig, M.A. Green and G. Conibeer, "Modelling of metal-insulator-semiconductor devices featuring a silicon quantum well", Physica E 42 (9) 2211-2217.
[4]: Y. Ando and T. Itoh, "Calculation of transmission tunneling current across arbitrary potential barriers", J. Appl. Phys. 61(4) 1497-1502.

Future work

1. Phonon life time experiament. Extract phonon life to validate simulation results with experimental data
2. Find proper Energy Selective Contact material fitting CIGS hot solar cell.