Hot Carrier Solar Cells: A New Approach

D. K. Ferry[1], I. R. Sellers[2], V. R. Whiteside[2], H. Esmaeilpour[2], M. B. Santos[2]
[1]*School of Electrical, Computer, and Energy Engineering*
Arizona State University, Tempe, AZ 85287-5706 USA
[2]*Department of Physics and Astronomy, University of Oklahoma, Norman, OK 73019*
Ferry@asu.edu

Hot carrier solar cells have been of interest as third generation cells since the work of Ross and Nozik [1]. In this approach, use of a structure which decreases the emission of phonons by the energetic photo-carriers, thus reducing their heat loss to the lattice, and use of an energy selective barrier which allows only the hot carriers to be transferred to the contacts of the device [2,3]. Unfortunately, this approach has been shown to lead to very low efficiency cells [4]. In most of these discussions, only the lowest valleys of the conduction band are considered, and higher lying satellite valleys are ignored. Thus, no account of using the higher valleys as metastable levels to maintain the hot carrier properties is considered. Since the scattering rate to the satellite valleys is generally much larger than that for intravalley phonon emission, the standard approach disregards an obvious method of maintaining the hot carrier properties of the photo-electrons. In this paper, I will describe how the use of the entire band structure for the absorber material can be used to give realistic, and conservative, estimates of achieving higher efficiencies for HCSC. We consider a *p-n* junction solar cell constructed with a heavily-doped p^+ layer followed by an n^- layer. The heavily-doped *p*-layer and lightly-doped *n*-layer assures that nearly all the depletion width of the junction is in the *n*-layer. We want the *n*-layer to be thinner than the depletion width, so that the electric field extends through this layer to a collector. A semi-infinite (in energy) collector is used; e.g., collection of only the hot carriers is achieved by a heterojunction with the collector layer having a larger band gap. When the photo-electrons transition from the absorber layer to the collector layer, a very large fraction of their kinetic energy is converted into potential energy of the band offset arising from the larger bandgap of the collector layer. The greatly reduced kinetic energy in this latter layer cannot emit large numbers of intravalley phonons and this further prevents significant energy loss by this mechanism. Here we use InAlAs for the absorber and AlAsSb for the other two layers, both lattice matched to InAs. We also discuss using InGaAs as the absorber for its greater solar collection efficiency.

[1] R. T. Ross and A. J. Nozik, J. Appl. Phys. **53**, 3813 (1982).
[2] H. Esmalelour *et al.,* Prog. Photovolt. Res. Appl. **24**, 591 (2016).
[3] J. A. R. Dimmock *et al.,* J. Opt. **18**, 074003 (2016),
[4] A. P. Kirk and M. V. Fischetti, Phys. Rev. B **86**, 165206 (2012).

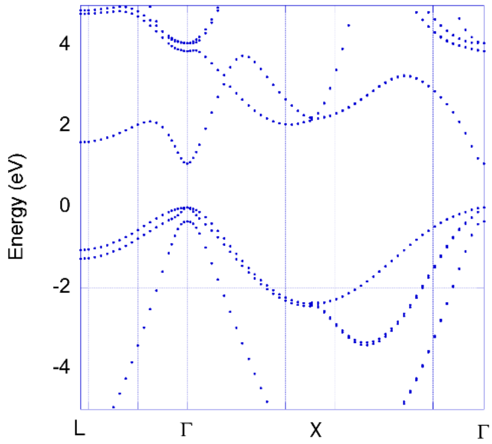

Fig.1: Band structure of $In_{0.65}Al_{0.35}As$ using non-local EPM with spin-orbing interaction included..

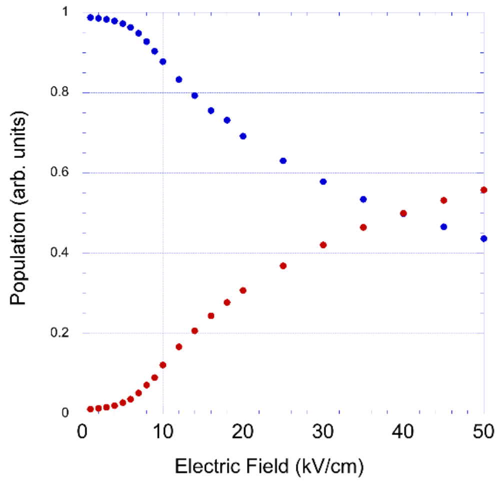

Fig.4: Population of the Γ and L valleys as a function of the electric field under continuous solar illumination.

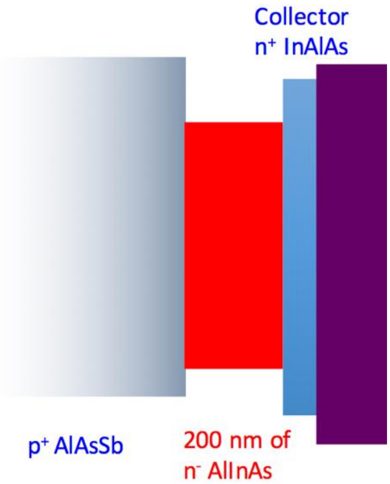

Fig.2: Structure of porposed HCSC..

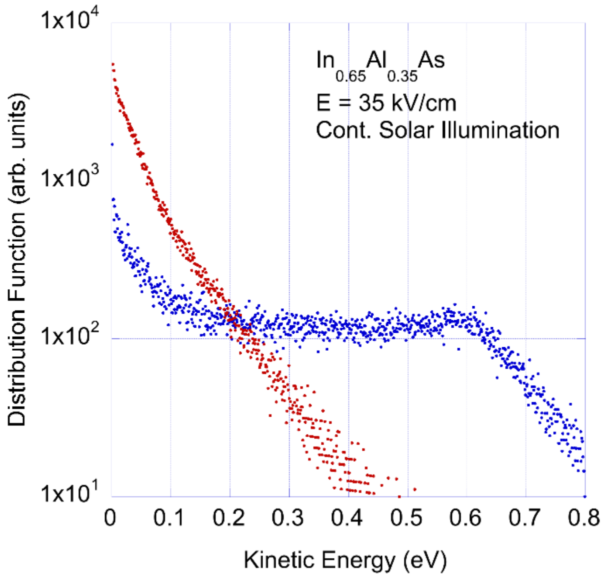

Fig.5 Carrier distribution function in the Γ and L valleys for an electric field of 35 kV/cm and continuous solar radiation.

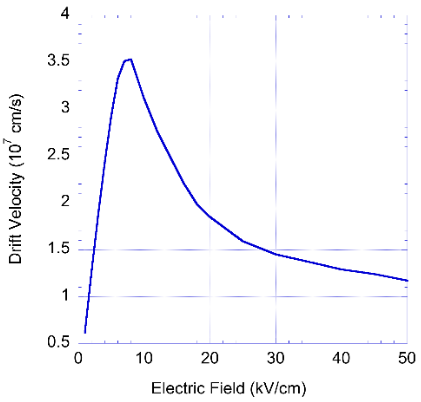

Fig.3: Drift velocity as a function of electric field when the material is continuously illuminated by solar radiation.