UNIVERSITY OF FLORIDA

Development of Low Cost Low Cost CIGS Thin Film Hot Carrier Solar Cells

PI: Gijs Bosman, Yige Hu (Ph.D.)

Description: Our study is focused on hot carrier solar cells for cell conversion efficiency improvement in a low cost, high throughput CIGS system. The rapid thermalization loss of hot photoexited carriers interacting with the lattice can potentially be reduced through phonon engineering in the absorber layer; the subsequent extraction of the hot carriers may be realized through device engineering of energy selective contacts.

Budget: $450,000
Universities: UF

Progress Summary

Our research for this period was focused on modeling energy selective contacts to collect the hot carriers generated in the solar cell absorber without energy loss and prevent cold carriers from the contacts to flow into the hot absorber. The proposed contact configuration borrows a structure used to increase the responsivity of photodetectors and has a double barrier quantum well (DBQW) configuration, which consists of ultrathin barriers on either side of a quantum well as depicted in figure 1. This is a resonant tunneling structure where the transmission probability goes towards one within the resonant energy band and falls towards zero outside the band. The energy range is optimized to match the most likely energy of the hot carriers, so that existing carriers will be collected as quickly and efficiently as possible and cold carriers from the contact are prevented to flow into the absorber. The key is to select an appropriate materials system.

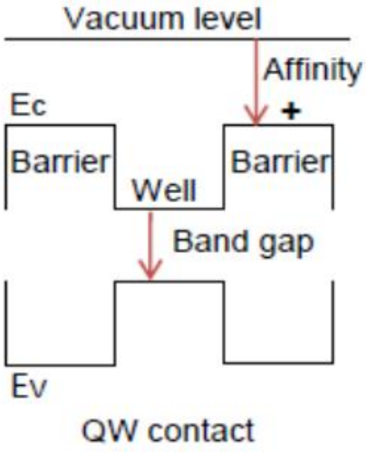

Figure 1. Band diagram of double barrier quantum well contact

Of the materials considered, AlN is a very good candidate for adapting to the CIGS absorber, as the material is used in a number of applications requiring very thin films. Furthermore, the high bandgap of AlN and the thin layer of the well material make it transparent for photon transport. Two reasonable well material candidates for the QW are $CuGaSe_2$ and GaN. $CuGaSe_2$ is compatible with the absorber and also has a high electron affinity to form a suitable well between two AlN cladding films. GaN has a wider band gap (3.4 eV) then CGS and thus more transparent. GaN also shows a type I band alignment with AlN with the valence and conduction band offsets about equal.

Preliminary simulations were performed on a $AlN/CuGaSe_2/AlN$ structure for selected thicknesses (see Figure 2). The simulated electron transmission probability is shown in the Figure 2(a) and (b). Calculations performed as a function of barrier and well widths result in different resonant band locations. In Figure 2(a), the thickness of the AlN barrier is 4nm and the thickness of $CuGaSe_2$ well is 2nm. Seven resonant bands appear for electrons with energies ranging from 0 to 3 eV. In Figure 2(b), the thickness of the AlN and $CuGaSe_2$ layers are 2nm and 4nm, respectively. There are still seven resonant bands for incident energies ranging from 0 to 3 eV. More resonant bands, however, are located below 2 eV. The resonant bands located above 2eV are narrower and better separated. Hence, tuning the DBQW structure gives desirable energy selections for the hot carrier solar cell domain of operation. The hole transmission probability of the respective AlN DBQW contacts are shown in Figures 2(c) and (d). The energy selection property is not obvious for holes because the barrier potentials for holes are small. Also the relatively heavy mass of the holes works to reduce the resonance. Candidates for hole ESCs will still have to be identified. The results of above simulation are encouraging and simulations will be performed using GaN as the QW material.

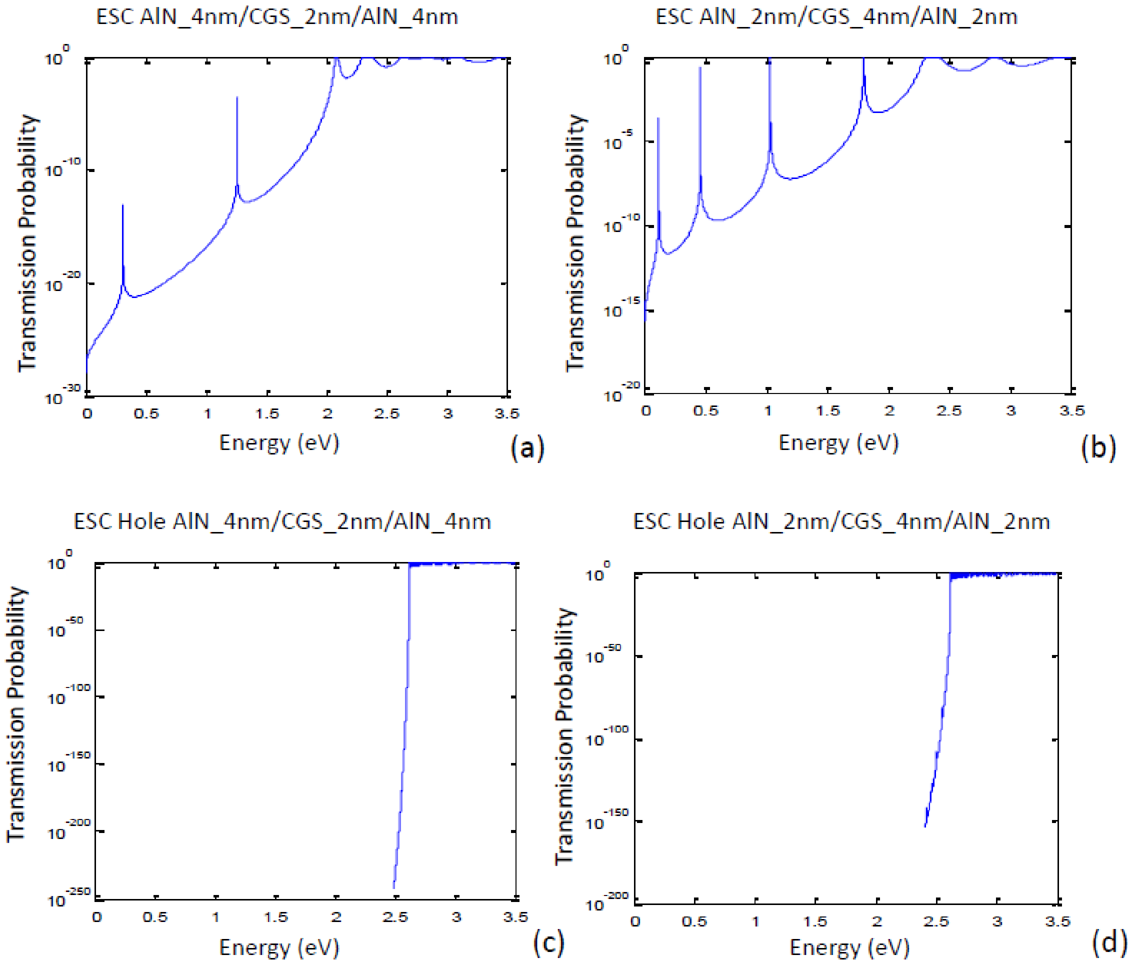

Figure 2. Transmission probability of an AlN DBQW contact: (a)electron transmission probability of AlN/CGS/AlN DBQW with 4nm AlN and 2nm CGS layers, (b)electron transmission probability of AlN/CGS/AlN DBQW with 2nm AlN and 4nm CGS layers, (c)hole transmission probability of AlN/CGS/AlN DBQW with 4nm AlN and 2nm CGS layers, and (d)hole transmission probability of AlN/CGS/AlN DBQW with 2nm AlN and 4nm CGS layers.