Modeling and Optimization of CIGS Solar Cell Module

1. Introduction

Solar cells manufactured from wafers of crystalline or polycrystalline silicon are today the dominant technology in the commercial market. Solar cells based on thin film semiconductor are another technology with great potential. One such technology is based on a compound of the elements copper, indium, gallium and selenium abbreviated Cu(in,Ga)Se2 or CIGS. Two advantages of this technology are the low material consumption and the high efficiency that has been demonstrated, which both make it economically competitive. The objective of this article is to simulate a CIGS Solar cell module taking into account electrical, optical and geometrical parameters in order to optimize his design.

2. Creation of the Structure

A CIGS solar cell is built up of a substrate glass, a back contact of molybdenum (Mo), a light absorbing layer of CIGS, a buffer layer of cadmium sulphide (CdS), a thin layer of resistive zinc oxide (ZnO) and a transparent front contact of aluminum doped zinc oxide (ZnO:Al). In a CIGS solar cell module several cells are connected in series. The interconnection part of the module is inactive (i.e no current is generated) whereas the cell itself is the active part of the module. We have created a fully parametrized input deck where the mesh is defined as a function of the geometrical parameters of the module and where key parameters like number of cells, cell width, material thicknesses, sheet resistance of the interconnection etc can be defined as variable for subsequent optimization. A CIGS solar cell module including 4 cells is shown in Figure 1.

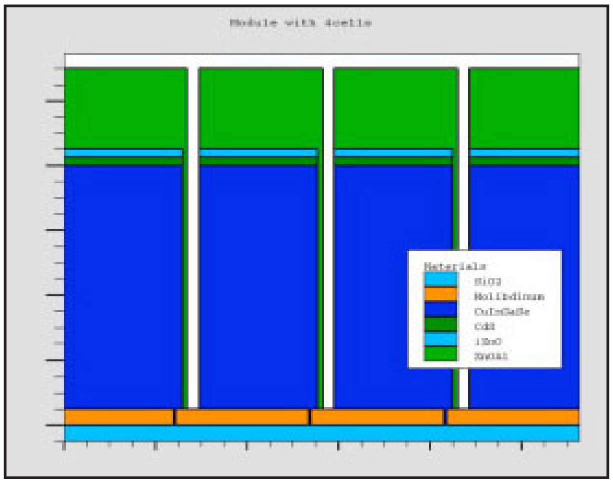

Figure 1: CIGS Solar cell module including 4 cell.

3. Simulation and Models

Simulation of a single cell was done first (Figure 2 and Figure 3) and the results were compared to experiment. All key figures of merit (Voc, Jsc, FF and EFF) compare very well with measurement (less than 2% error).

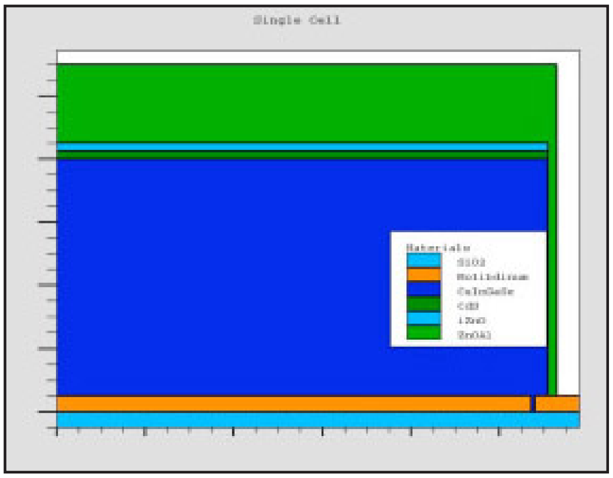

Figure 2: CIGS single solar cell structure.

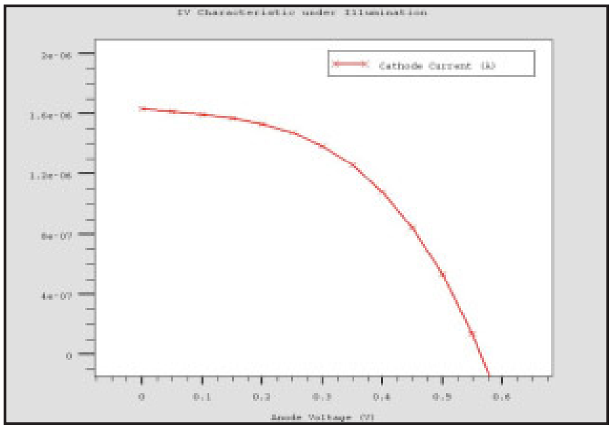

Figure 3: CIGS single solar cell IV curve.

Mini-modules with cell widths of 6mm, 4mm, 3mm, 2.35mm, 2mm, 1.3mm and 1.2mm were simulated. Figure 4 and Table 1 show simulation results of a module including 4 cells.

	Simulation
Voc (V)	3.04
Jsc (mA/cm2)	29.9
FF	0.65
EFF(%)	15

Table 1: Simulation result of CIGS module with 4 cells.

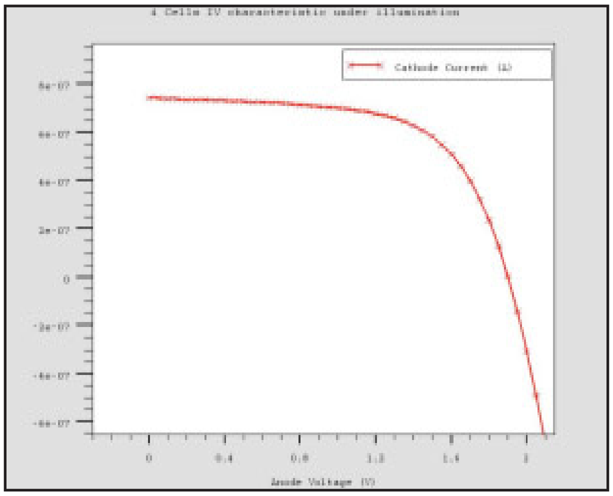

Figure 4: IV curve for a CIGS module including 4 cells.

Figure 5 shows comparison of IV curves of all the mini-modules, As expected Voc increases when width decreases (i.e number of cells in the module increases since the total width of the module was kept constant during the simulation) since the cells are in series. The short circuit current (Jsc) decreases when the cell width decreases mainly due to the fact that the active area decreases.

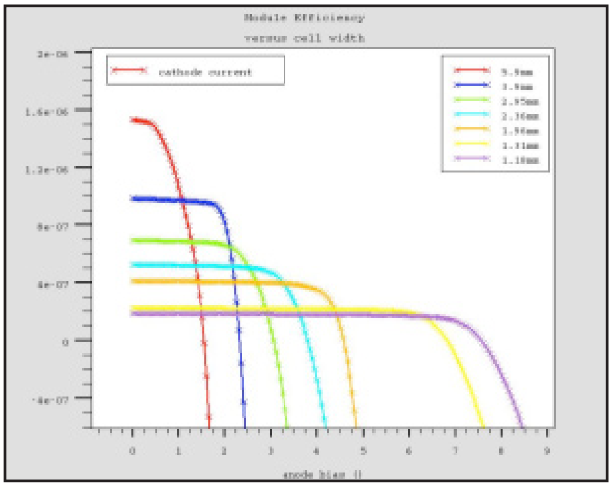

Figure 5: IV Characteristic versus number of cells in the module.

4. Cell width Optimization

Figure 6 shows Module efficiency versus cell width. A bell shape curve is clearly seen showing an optimum for the module efficiency versus cell width. The optimal cell width is found to be around 2.5mm to 3.5mm. Indeed there is a trade-off between maximizing absorption and minimizing resistance of the interconnection.

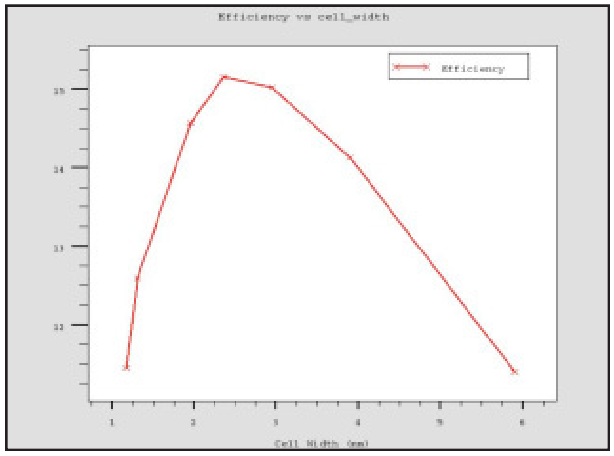

Figure 6: Module Efficiency versus number of cells in the module.

5. ZnO:Al Optimization

Simulation are performed to investigate how sheet resistance of the ZnO:Al influences the efficiency of the CIGS solar cell module. For each investigated cell width the mobility of the ZnO:Al layer is varied. Mobility is inversely proportional to sheet resistance. Figure 7 shows that module efficiency is higher when cell width is smaller only when ZnO:Al layer has a low mobility (high sheet resistance). When ZnO:Al layer has a high mobility (low sheet resistance) we have an opposite behavior. Figure 8 shows as well that module efficiency is less sensitive to sheet resistance for smaller cell width.

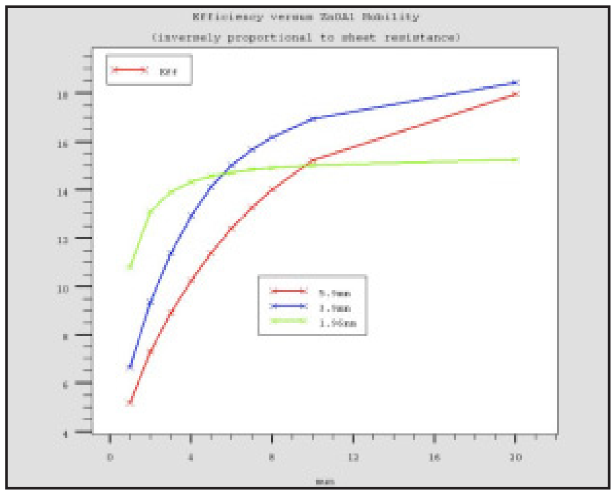

Figure 7: Module Efficiency versus ZnO:Al Mobility.

6. Conclusion

Accurate numerical simulations and optimization of CIGS module were demonstrated. A crucial part of the simulation was to describe correctly the optical and electrical part of the transparent front contact. It emphasis how important it is to do accurate TCAD simulation to analyze and optimize CIGS design.