Basics of Solar Cell Theory

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Solar cells are currently the most promising candidate for providing the next generation of secure, sustainable and affordable energy source. Besides the obvious advantages solar cells bring on the table, such as energy independence and pollutant reduction, they also come with very interesting physics as a package deal. In the basic physics of solar cells one can find basic quantum mechanical concepts such as black body theory and basic semi-conductor physics along with material design such as thin film solar cells. In my presentation I will focus mainly on the basic principles behind the function of solar cells starting with the photovoltaic effect, the effect that is the basis for the generation of charge carriers. Those charge carriers, which are basically electron-hole pairs, are separated by a built in asymmetry in the solar cell and electrons are fed into a circuit generating current. [1]

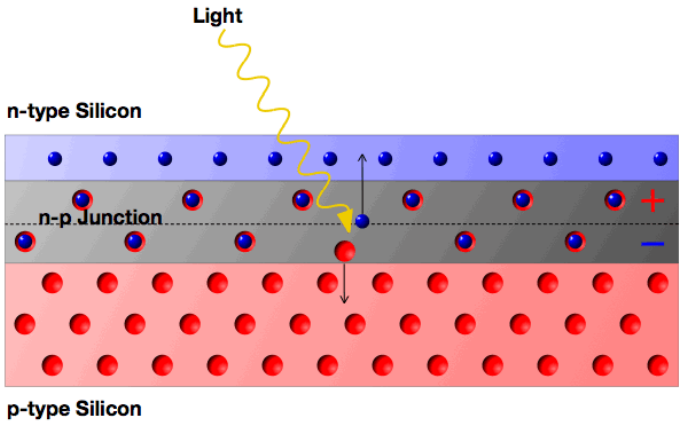

Figure 1 Schematic representation of the photovoltaic effect in a p-n junction (pveducation.org)

The electronic behavior of a solar cell is understood by modeling it with an equivalent electronic circuit, which is useful to extract the basic relations for voltage and current generated from a solar cell under illumination. The power losses that exist in real solar cells are modeled as resistances in series and parallel to the solar cell. [2]

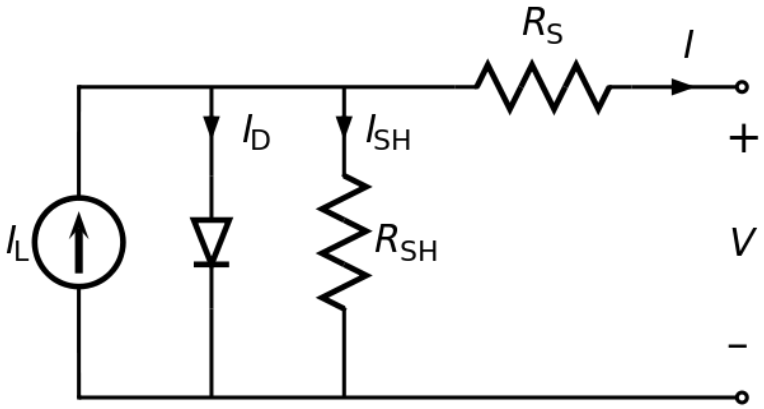

Figure 2 Equivalent circuit of a photovoltaic cell (source: Energies 2014, 7(7), 4098-4115)

Furthermore, I will talk about the electron-hole recombination in solar cells, which limits the efficiency of the cell, and the theoretical thermodynamic limit of a single junction solar cell as set by Shockley and Queisser [3]. The efficiency limit is set by the so called detailed balance principle which simply has to do with the fact that the solar cell exchanges thermal radiation with its surroundings, reducing the efficiency. Along with that and other considerations having to do with the band gap of the material, the solar spectrum etc. they obtain that for a single junction solar cell the following graph (figure 3).

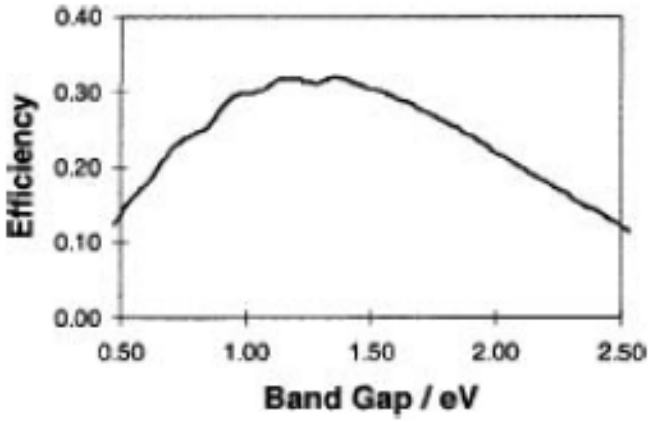

Figure 3 Solar cell efficiency as a function of the energy band gap [1]

References

[1] Nelson J., ”The Physics of Solar Cells”, Imperial College Press,(2003).
[2] Lorenzo E., “Solar Electricity: Engineering of Photovoltaic Systems”, Progensa, (1994)
[3] Shockley W.,Quiesser H., Journal of Applied Physics 1961 32:3, 510-519