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Structuring The Energy Parameters Of Solar Cells

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Abstract *— What material the solar panels are made of affects its efficiency. This article explores what materials solar panels are made of and the effects of sunlight on panels.*

Keywords — solar energy; energy resources; the sun; irradiation; semiconductor materials

The influence of the solar energy the project starts to describe the energy situation nowadays. Energy is an issue that touches every person on the planet. At present in the world, especially in industrialized and emergent countries, energy has become vital for all the human beings. Accordingly the energy demand has been increasing dramatically in the last years.

Because of the greenhouse effect, environmental impact and the increasing cost of the fossil fuel-based energy sources, much more energy usage from renewable sources and more efficient utilization of conventional sources is becoming to be indispensable. The World Resource Institute estimates that 61.4% of global greenhouse emissions come from energy consumption. Thereby a solution that reduces these pollutants should include investment in the fields of renewable sources and energy efficiency in order to allow energy to play its role in the economy without endangering the environment. [1]

The increasing of the electricity price and the increasing of the environmental impact the world is suffering, solar energy may be considerably accepted one of the key solutions.

Solar energy is radiant light and heat coming from the solar radiation. It is a renewable source since the methods used to transform the solar energy into electricity don't produce any smoke or pollutants. However since the power generated by this source comes from the sunlight, it cannot be used during the night, and even during some days when the weather is completely cloudy, rainy, snowy or another natural factors. Solar energy can mainly be divided in two mainly sources; it can be exploited through the solar thermal and solar photovoltaic (PV) routes for various applications. The research has been focused on photovoltaics within the solar energy.

Solar photovoltaic modules are manufactured by semiconductor materials and they turn the radiant energy coming from the sun into direct current and therefore, electricity. The competitiveness of this field is increasing; in 2013, for the first time in more than a decade, solar was over all other renewable energy technologies in the sense of new generating capacity installed with an increase of 29 percent compared with 2012. [2] .Worldwide total PV installations represented 1.8 GW in 2000 and 71.1 GW in 2011 with a growth rate of 44%. [3].

This has led to a situation where the electricity from solar panels costs as much or is even cheaper than electricity purchased from the grid is within reach.

Nonetheless, solar power generation has still some problems as follows: the conversion efficiency of solar cells is lower, and the output power of photovoltaic (PV) array has great relationship with irradiation and temperature. [4]

Regardless the problems described above, one of the most important and critical problems on the photovoltaics field is the shadowing effect. Shaded conditions is sometimes inevitable because some parts of the photovoltaic system receives less intensity of sunlight due to several factors such as clouds, the time of the day, the season of the year or even shadows from neighboring objects. [5]

THE SUN AND ITS RADIATION

The sun is a hot atmosphere of gas heated by nuclear fusion reactions at its centre. Its diameter is about $1.39x10^9$ m and is, on the average $1.5x10^n$m from the earth. As seen from the earth, the sun rotates on its axis about once every 4 weeks. However it does not rotate as a solid body; the equator takes about 27 days and the Polar Regions take about 30 days for each rotation.

The energy produced in the interior of the solar sphere at temperatures of many millions of degrees must be transferred out to the surface and then be radiated into space. A succession of radiative and convective processes occur with successive emission, absorption and reradiation. In the subchapter below the different types of radiation that reaches the Earth's surface will be described.

COMPONENTS OF RADIATION

Solar radiation incident on the atmosphere from the direction of the sun is the solar extraterrestrial beam radiation. This radiation passing through the earth's atmosphere is attenuated, or reduced, by about 30%. Beneath the atmosphere, at the Earth's surface, the radiation that will be observable are:

- Beam Radiation. The solar radiation received from the sun without having been scattered by the atmosphere.

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- Diffuse Radiation. The solar radiation received from the sun after its direction has been changed by scattering by the atmosphere.

Therefore, the total sum of the beam and the diffuse solar radiation on a surface is called Total Solar Radiation. The components of the solar radiation can be observed in the figure below:

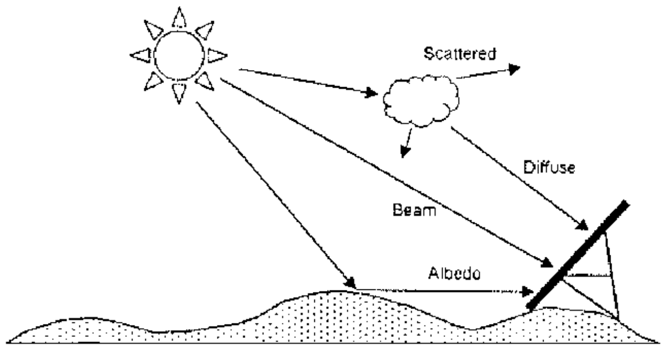

FIGURE 1 COMPONENTS OF SOLAR RADIATION

SEMICONDUCTORS

Solar cells are manufactured from semiconductor materials. This type of materials acts as insulators at low temperatures but as conductors when energy or heat is available. So far, most solar cells are made by silicon-based, since this is the most mature technology. However, other materials are under active investigation and may supersede silicon in the long term. [6]

The electrical properties of semiconductors can be explained using two different theories:

1. At low temperatures, the bonds joining the silicon atoms are intact, so the silicon acts as an insulator. However, at higher temperatures, some of these bonds are broken and two processes can be taken place; electrons from the broken bond are able to move, and the ones from the neighboring bonds can also move to the broken bond, allowing the broken bond to propagate as if it had a positive charge. This phenomenon is called the bond model.

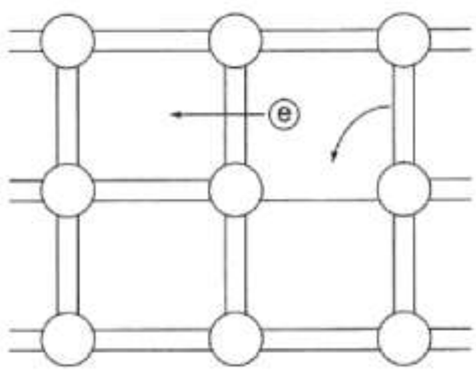

FIGURE 2 SCHEMATIC REPRESENTATION OF COVALENT BONDS IN A SILICON CRYSTAL LATTICE

2. The band model. The electrons in covalent bonds have energies corresponding to those in the valence band. In the conduction band the electrons are free. The minimum energy needed to release an electron from a covalent bond to the conduction band it's called the forbidden gap. The holes remaining conduct in the opposite direction in the valence band, as described for the bond model.

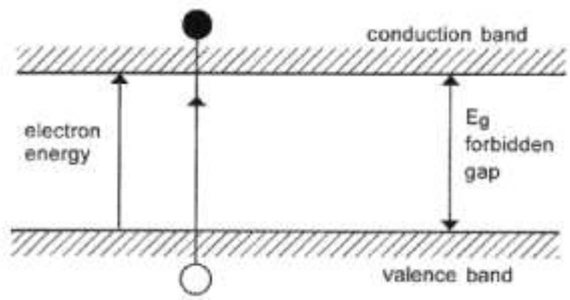

FIGURE 3 SCHEMATIC OF THE ENERGY BANDS FOR ELECTRONS IN A SOLID

SEMICONDUCTOR TYPES

There are three mainly types of semiconductor materials used for solar cells; crystalline, multicrystalline and amorphous semiconductors. The research of these material is focused on silicon matter.Crystalline silicon. In this case the atoms are arranged in a regular pattern. Since the careful and slow manufacturing processes, this material is the most expensive one.

1. Multicrystalline or polycrystalline silicon. Regions of crystalline Si separated by 'grain boundaries', where bounding is irregular. It is cheaper to produce since the techniques are less critical.

Amorphous silicon. It can be produced more cheaply than polysilicon, since there is no long- range order in the structural arrangement of the atoms, resulting in areas within the material containing unsatisfied bonds.

ABSORPTION OF LIGHT

When the light drops into semiconductor material, photons with energy Eph greater than the forbidden gap, Eg, interact with electrons in covalent bonds, using up their energy to break bonds and create electron-hole pairs, which can then circulate independently. The next figure shows how electron wanders off due to the energy of the photons. It will explained in the next part how solar cells produces a voltage and a current flows through a solar cell.

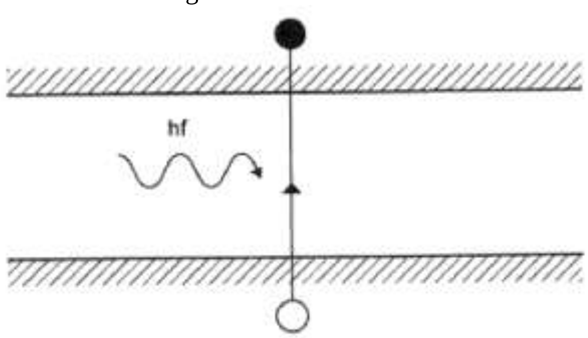

FIGURE 4 THE CREATION OF ELECTRON-HOLE PAIRS WHEN ILLUMINATED WITH LIGHT OF ENERGY EPH = HF WHERE EPH>EG

SOLAR CELLS AND P-N JUNCTIONS

A solar cell is a photodiode made by joining the p-type and n-type silicon.

To understand how it works is better to know how P-type and N-type silicon works. A brief explanation may be when p-type and n-type silicon are joined this phenomenon is called P-N junction. It can be observed in the figures below

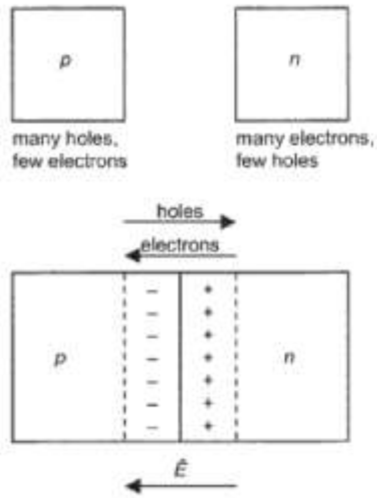

FIGURE 5 P-N JUNCTION OF DIFFERENT PART OF THE SEMICONDUCTOR

The p-type has an excess of holes but few electrons and the n-type has many electrons but few holes. When the two different semiconductors are joined, and the light is switched on as it has been showed before the electrons in the n-type flow to the p-type semiconductor, and meanwhile the holes flow from the p-type to the n-type. An electric field is built up to stop this flow created and therefore a voltage will be built in. Since this electric field is not large enough to stop the flow of electrons and holes a current is produced.

BEHAVIOUR OF SOLAR CELLS

The characteristic curve represent all of the combinations of current and voltage at which the module or cell can be operated or loaded. Normally simple in shape, these curves actually provide the most complete measure of the health and capacity of a PV module or array, providing much more information than traditional electrical test methods [9]

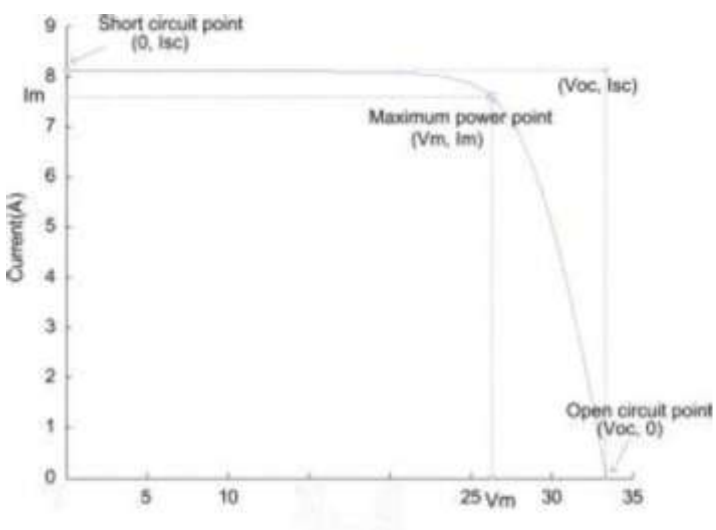

FIGURE 6 CHARACTERISTIC I-V AND POWER CURVES OF A SOLAR CELL

Here two different parameters have to be introduced:

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- Short circuit current Isc . Is the maximum current, given when voltage is 0.
- Open circuit voltage Voc. Is the maximum voltage, given at zero current.

There is also a relevant point, MPP is the maximum power point, therefore the point where the product of Vmp*Imp is at its maximum value.

Another important parameter is the fill factor (FF) is the ratio between Pmax and Isc*Voc. It gives an information about the quality of the solar cell, if it increases so do the quality of the solar cell

PARASITIC RESISTANCES

However this curve describes the case of an ideal solar cell. An ideal solar cell is modeled by a current source, representing the photo-generated current IL, in parallel with a diode, representing the p-n junction of a solar cell. In a real solar cell, there exist other effects. Two of these extrinsic effects include: 1) current leaks proportional to the terminal voltage of a solar cell characterized by a parallel resistance Rsh and 2) losses of semiconductor itself and of the metal contacts with the semiconductor characterized by a series resistance Rs [11]

The electrical disposition of those resistances as well as the model of a solar cell can be observed in the following image:

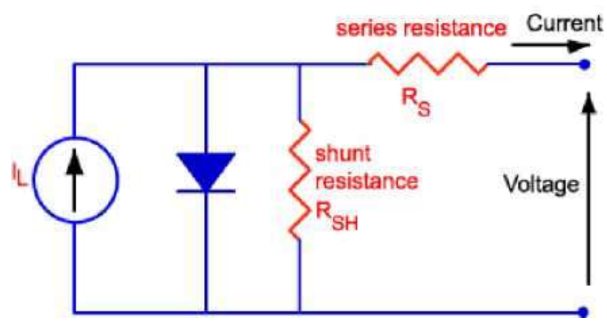

FIGURE 7 DIFFERENT PARASITIC RESISTANCE IN A SOLAR CELL

It can be seen the impact of the resistances in the IV curve below;

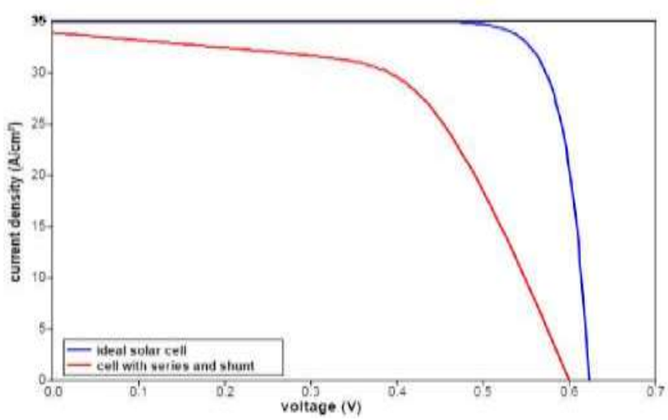

FIGURE 8 INFLUENCE OF PARASITIC RESISTANCES IN A SOLAR CELL.

In this case $R_s = \mathbf{4.2\ \Pi * }\ cm^2$ **and** $R_{sh} = \mathbf{135.5\ \Pi *}\ cm^2$ The results for the cell with no parasitic resistances are: Voc = 0.623 V; Isc= 35 mA/cm^2 and the FF=0.83**.** However, the results for the real cell are: Voc = 0.601 V; Isc= 33.9 mA/cm^2 and the FF=0.58.

So, it has shown how the parasitic resistances drops the output of a solar cell.

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