



# Use of polymer Poly(N-vinylcarbazole) for photovoltaic applications

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## Abstract

The objective of this article is to demonstrate that the Poly(N-vinylcarbazole) – PVK doped with lithium perchlorate (LiClO<sub>4</sub>) can transform solar energy to electrical energy. To achieve that a solar cell has been constructed “(glass structure/ITO/a-Si:H (p)/polymer PVK/ $\mu$ -Si:H (n)/Al)” with the PVK working as active layer. This work proposed had had the objective to research, develop, construct and characterize this device, analyzing its electrical and optical characteristics, efficiency and other topics related to its development and construction process.

Keywords: PVK, solar cell, photovoltaic effect

## 1. Introduction

Sun gives every year 10.000 times the demand of energy consumption of the planet, and it is the most promising energy source. Having that in mind, it is deduced that one should take advantage of this large amount of available energy. The main characteristics of solar radiation are:

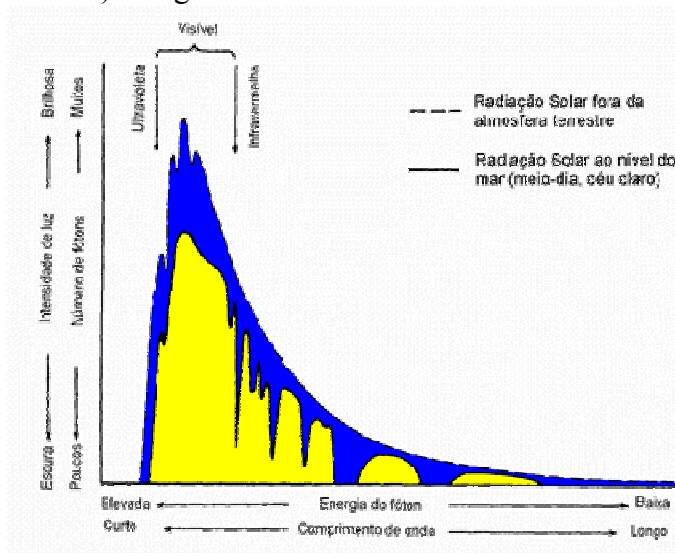
- Intensity;
- Spectral distribution;
- Angular distribution.

Solar cells are photovoltaic devices that transform solar energy to electrical energy. Currently the photovoltaic cells available in the market are inorganic and made of:

- Monocrystalline silicon;
- Polycrystalline silicon;
- Amorphous silicon.

This work use a mixture of inorganic and organic to obtain the same effect where PVK is the active layer, absorbing the radiation and transform in electrical current. The polymers, specially the poly(N-vinylcarbazole) - PVK is made from the synthesis of N-vinylcarbazole along with two initiators BPO and TEMPO, and doped with lithium perchlorate, that gives a molecular mass of 50.000 g/mol. The resulting material is a transparent thermoplastic, good stability thermal and chemical, that since it has been discovered, it has been used due to its good characteristics:

- Vitreous transition temperature (T<sub>g</sub>) 189°C (do not dismantle before 300°C);
- High refractive (1,69);
- Soluble in ordinary solvents (Benzene, Toluene or Chloroform);
- Electrical conductor when exposed to sun light.



## 2. Theoretical concepts

### 2.1 Electrical properties

The electrical and optical properties of a crystal solid, as conductivity and optical and absorption are directly linked to its structure of energy stripes. A crystal net is a periodic arrangement of atoms, mathematically described in terms of Bravais net and a base (KP theory and effective mass) where each base can be made of one or more atoms, which each one generate a peak in the distribution of net potential.

When two semiconductors of different gaps are put together, one above the other, (forming a heterostructure– figure 2), the difference of energy between the gaps is divided into the conduction band ( $\Delta E_c$ ) and valence band ( $\Delta E_v$ ). This way it creates a discontinuity in the stripes of extremities in the interface of the two materials, and a profile of potential energy for electrons (BC) and holes (BV) has the shape of steps.

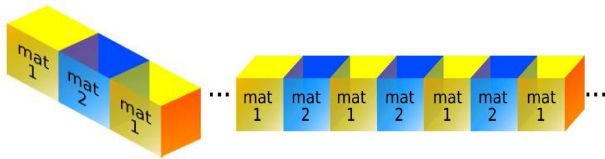


Figure 2 – Heterostructures.

If the materials are disposed alternately, it is possible to construct a potential profile of well shape, depending of the gap of the the material in between, forming a heterostructure.

To apply heterostructures in photo detectors, the ideal situation is that the material shows an indirect gap, the top of BC and bottom of BV.

The gap is defined for its chemical composition that allows tuning its energy between the maximum and minimum value of the materials gap that composed its material.

### 2.2 Basic parameters of solar cells

The solar cells produces a current proportional to the radiation incident ( $I_L$ ), as shown in the equivalent electric circuit in figures 3 and 4, where the current source represents the energy photo conversion, the diode PIN represents the

junction between the materials,  $R_{sh}$  represents the resistances between the materials,  $R_s$  represents the boundaries leakage effect that occurs over the surface of the device, and  $R_c$  is the charge itself.

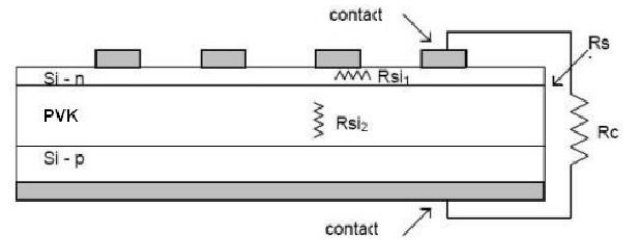


Figure 3 – Cut cross in a solar cell

### 2.3 Junction PIN (p + PVK + n)

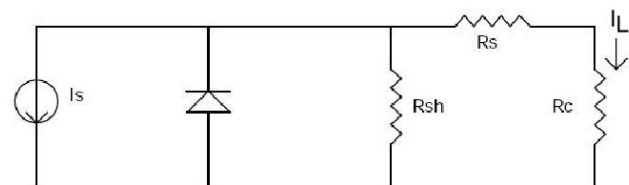


Figure 4 – Circuit equivalent of a solar cell

The junctions between the different materials divide the potential between the poles through the opposed electric fields, creating internal electrical field. The incidence of light through the glass base direct in the polymeric material, generate pairs of electron-holes, and its separated from this field and using a resistance  $R_c$ , begins the conduct process, i.e., transforms light energy to electrical energy, as shown in figure 5.

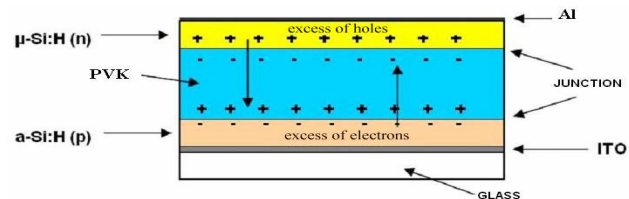


Figure 5 – Internal electrical field.

## 3. Process for manufacturing

The device has been constructed from an structure that is able to sustain the glass base, containing a transparent and electrically conductor layer of tin oxide dumped with indium (ITO), as shown in figure 6.

The first step is to put a layer of an inorganic material of amorphous silicon hydrogenated

dumped with boron (a-Si:H (p)), over an oxide conductor of electricity (ITO), through a reactor using the plasma enhanced chemical vapor deposition “PECVD” method. This reactor is composed of a deposition chamber, a gas flow control system (MFM – mass flow meters), vacuum system (cleaning  $\sim 10^{-6}$  torr and process about  $\sim 10$  mtorr) with rotary pumps and a temperature control of the substrate. The deposition starts on the gas phase which the molecules of the gases (  $\text{SiH}_4$  – silane,  $\text{B}_2\text{H}_6$  – diborane,  $\text{H}_2$  – Hydrogen) are broken by a “plasma” of high radiofrequency resulting in a solid material that deposite over the substrate (glass, ITO, polymer metal, etc.). This process was conducted in a temperature of  $200^\circ\text{C}$ , and the layer has a thickness of 20 nm, which is responsible for the gathering of electrons generated on the polymer.

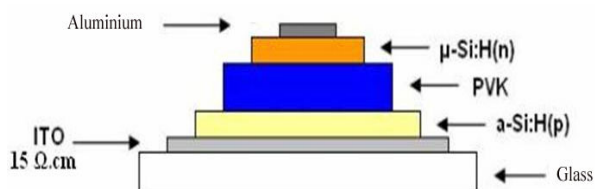


Figure 6 – Structure of the device manufactured

The second step was to deposite the polymer PVK synthesized, already prepared in liquid solution (chloroform), using the casting method with a rotation of 2000 rpm in a environment temperature exposed to the weather for 30 s, obtaining a thickness of  $1,6 \mu\text{m}$ , forming a thin layer above the amorphous silicon.

The third step was to put over the polymer layer a material of microcrystalline silicon hydrogenated dumped with phosphorus ( $\mu\text{-Si:H (n)}$ ) through the PECVD in a temperature up to  $100^\circ\text{C}$ , giving a thickness of 50nm, responsible for the gathering of gaps produced in the polymeric material.

Finally, a layer of aluminum was evaporated through the thermal metallization over the  $\mu\text{-Si:H (n)}$  layer forming the contact and the solar cell of glass structure ITO/a-Si:H (p)/PVK/ $\mu\text{-Si:H (n)}$ /Al. On the figure 7 it is possible to see the device constructed.

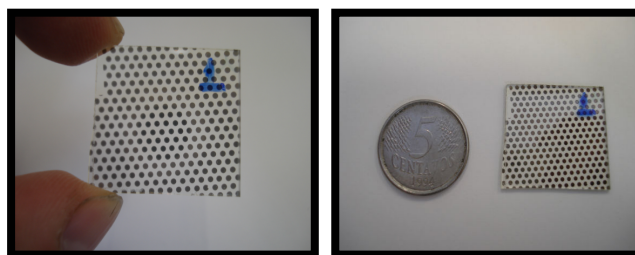


Figure 7 – Manufactured device

#### 4. Electrical characterization

To electrical characterization the device, a measure instrument HP 4145 (Semiconductor Parameter Analyzer) was used to obtain and visualize the main parameters. The sample was exposed to many light conditions (dark and illumination AM 1,5 conditions), so it was possible to extract different curves in a way that its behavior could be researched. The lamp used to send the light was the type ELH 300W, allowing to be controlled by a variac. From that point, curves IxV (figure 8) were extracted, and the mounting scheme and measures is shown in figure 7.

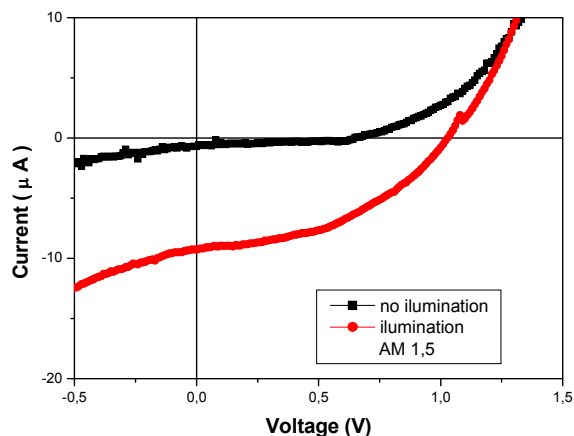


Figure 7 – Current versus Voltage under dark and illuminated (AM 1,5) conditions.

The incident power was calculated through a default cell of silicon calibrated from the “LME of Polytechnic School USP ( $100 \text{ mW/cm}^2$  under AM 1.5). After the characterization, it was noticed that the device presented a efficiency of 0.13% of energy absorbed to the energy photo generated and the fill factor  $\text{FF} = 0,43$ .

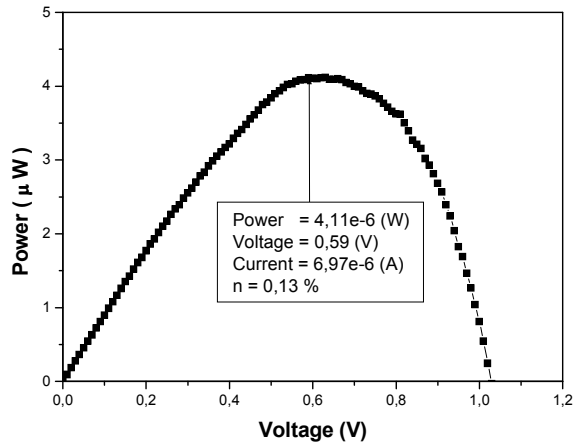


Figure 8 – Power curve of the solar cell.

During the characterization of the photovoltaic cell, it was necessary to measure spectral responses, what, in few words, measure in which wave length the photovoltaic effect is more efficient but its not possible because the current is very low and the system can not measure perfectly.

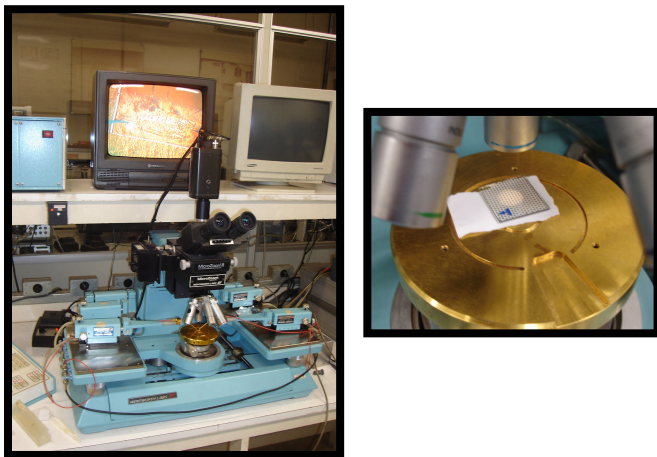


Figure 9 – Characterization of the device

## 5. Conclusion

The structure discussed here by presented an easy construction, though basing on the research presented, it is concluded that the polymer PVK dumped with lithium perchlorate didn't present satisfactory conversion of light energy in electrical energy, showing low conductivity due to the characteristics of the material itself, and so to the fact that during the deposition of the silicon dumped with phosphorus layer, through the

PECVD above the polymeric material in the third step of construction, where the plasma ended up degrading the polymer changing the structure and the results of efficiency in the photo conversion. Although the here by experiment has the objective of researching, the point was to develop a cell with a different material through an easy structure, with an easy control of the process and low operational cost. Remarking the possibility of knowing new structures able to take advantage of the photovoltaic effect of the polymeric material as the active layer in the conversion of electrical energy. The society has an option, mainly on knowledge field, which can be implemented in the future.

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