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CHARACTERIZATION OF SOLAR CELLS ACQUIRED IN CHINA VIA ALI-EXPRESS

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***Summary**. In recent decades, society has begun to discuss problems associated with environmental and energy issues, with new energy sources based on non-renewable fossil fuels becoming the target of scientists and environmentalists. In this context, solar cells emerge as an alternative source with less polluting potential for energy generation at home or in plants. The most common and cheapest models of solar cells are based on polycrystalline silicon, however monocrystalline silicon models and even triple junction cells can be found on the market. Devices based on polycrystalline silicon have the advantage of being cheap and have relative efficiency (around 11%). In this context, this work aims to characterize a batch of polycrystalline silicon solar cells purchased through a virtual shopping website. Therefore, the secondary objectives were to obtain I x V curves of the solar cells and verify the standardization of the spectral response of the samples. The characterization of the solar cells was carried out using a solar simulator at the Photovoltaic Devices Laboratory of the National Institute for Space Research – INPE. It is expected to obtain standardized curves for the spectral response, as well as standardized IxV curves*.

***Keywords:** Characterization of solar cells; polycrystalline silicon; I x V curves; Standardization of solar cells.*

1. INTRODUCTION

The characterization of photovoltaic cells is an essential procedure in the field of solar energy. These cells, semiconductor devices that transform sunlight into electricity, are influenced by several factors that impact their efficiency and performance. Characterization consists of evaluating and measuring electrical, optical and structural properties to understand the behavior and improve the performance of cells. The efficiency of the solar cell, which represents the fraction of solar energy converted into electricity, is one of the main parameters evaluated during the characterization. It depends on parameters such as light absorption in the active layer of the cell, charge separation efficiency and ohmic resistance. Measurement and analysis techniques are employed to determine current efficiency and identify opportunities for improvement. In addition to efficiency, parameters such as short-circuit current, open-circuit voltage, maximum power current and maximum power voltage are important. Characteristic curves are used to relate cell voltage and current under different operating conditions. Characterization also involves analyzing the optical response, including absorption and transmission of light at different wavelengths, to determine the spectral range of greatest efficiency and identify losses due to inadequate reflection or absorption. In addition to electrical and optical properties, structural aspects, such as morphology and composition of materials, are considered in the characterization. Electron microscopy, spectroscopy and chemical analysis techniques are applied to understand the physical and chemical properties of materials, as well as identify possible defects or impurities. In summary, the characterization of photovoltaic cells plays a fundamental role in the development and improvement of the technology, providing an in-depth understanding of their properties and allowing the identification of strategies to increase efficiency and performance. With the continued advancement of solar energy as a clean and renewable source, the characterization of photovoltaic cells becomes increasingly crucial to drive technological innovations. It is important to use appropriate measurement systems to obtain the essential parameters of these cells. The objective of this work was to develop a study regarding the I x V curves and their spectral responses. Each type of radiometer has a specific sensor that operates in a particular wavelength range.

2. Methodology

In this study, twenty photovoltaic modules purchased in China through a shopping website were characterized. These samples were duly identified with the aim of recording their individual information, as exemplified in figure 1. The characterization stage began immediately after the identification of the solar panels. All work was conducted at the Solar Cell Laboratory (CELSOL) of the National Institute for Space Research (INPE).

At CELSOL, a solar simulator is available that is powered by a stabilized source. This simulator uses a high-pressure Xenon gas discharge lamp, with a power of 1000 W, to illuminate an area measuring 152x152 mm. It is capable of reproducing the AM0 or AM1.5G solar spectrum. Furthermore, the simulator has an ellipsoidal reflector, two mirrors positioned at 45º, an optical integrator, a shutter, a filter holder and a collimating lens. Fig.2 shows the simulator lamp together with the mirror. The system determines the parameters by the software “medicaoIxV.vi” which provides the Open circuit voltage, Short circuit current, Voltage at the maximum power point, Current at the maximum power point, Maximum power point, Form factor and efficiency of the board.

Figure 1. Identification of solar panels

Figure 2. CELSOL silicon solar cell IxV curve characterization system lamp

The second part of the analyzes consists of the spectral response, which is a fundamental aspect in the study and use of spectroradiometer equipment, radiation sources and voltage meters. This equipment plays important roles in different areas, such as atmospheric sciences, physics, chemistry and engineering.

A spectroradiometer is a device that measures the intensity of electromagnetic radiation at different wavelengths. It is capable of capturing and recording the spectral response of a radiation source or an object under analysis. Spectral response refers to the sensitivity of the spectroradiometer to different wavelengths of radiation.

The characterization of the spectral response of a spectroradiometer is carried out through a calibration process. This involves using known radiation sources, such as tungsten lamps or synchrotron radiation sources, which emit radiation at different wavelengths. The spectroradiometer's response to these radiation sources is measured and compared to known reference values in order to determine the performance and accuracy of the instrument at different wavelengths.

Furthermore, characterizing the spectral response may also involve consideration of factors such as non-linearity, temporal stability and correction of undesirable effects such as unwanted reflections or noise. These steps guarantee the reliability and precision of the measurements performed by the spectroradiometer.

As far as radiation sources are concerned, they play a crucial role in characterizing the spectral response. A radiation source is a device that emits electromagnetic energy at different wavelengths. Radiation sources can be calibrated and certified to provide a known and stable spectral distribution over time. These sources are used during the spectroradiometer calibration process, allowing its spectral response to be accurately determined.

Finally, the voltage meter is a device used to measure the difference in electrical potential between two points in a circuit. Although not directly related to the characterization of the spectral response, the voltage meter is frequently used to monitor and control the power supply to equipment, such as spectroradiometers and radiation sources.

A stable and accurate voltage is essential to guarantee the proper functioning of these devices and obtain reliable results during spectral measurements., and were carried out by mounting a system containing a light source, a monochromator and a data acquisition system on an optical table. . Figure 3 shows the specific equipment used. The light source emits electromagnetic radiation with different wavelengths from the monochromator. This, in turn, is responsible for selecting the desired wavelength and transmitting it towards the solar cell. The analyzes were carried out with wavelengths between 300 and 1100 nm, slit opening of 20 mm. A calibrated spectroradiometer, from Newport, was used to measure the radiation power for each wavelength specified in the monochromator, as shown in fig. 4 (T F Paes, (2012)).

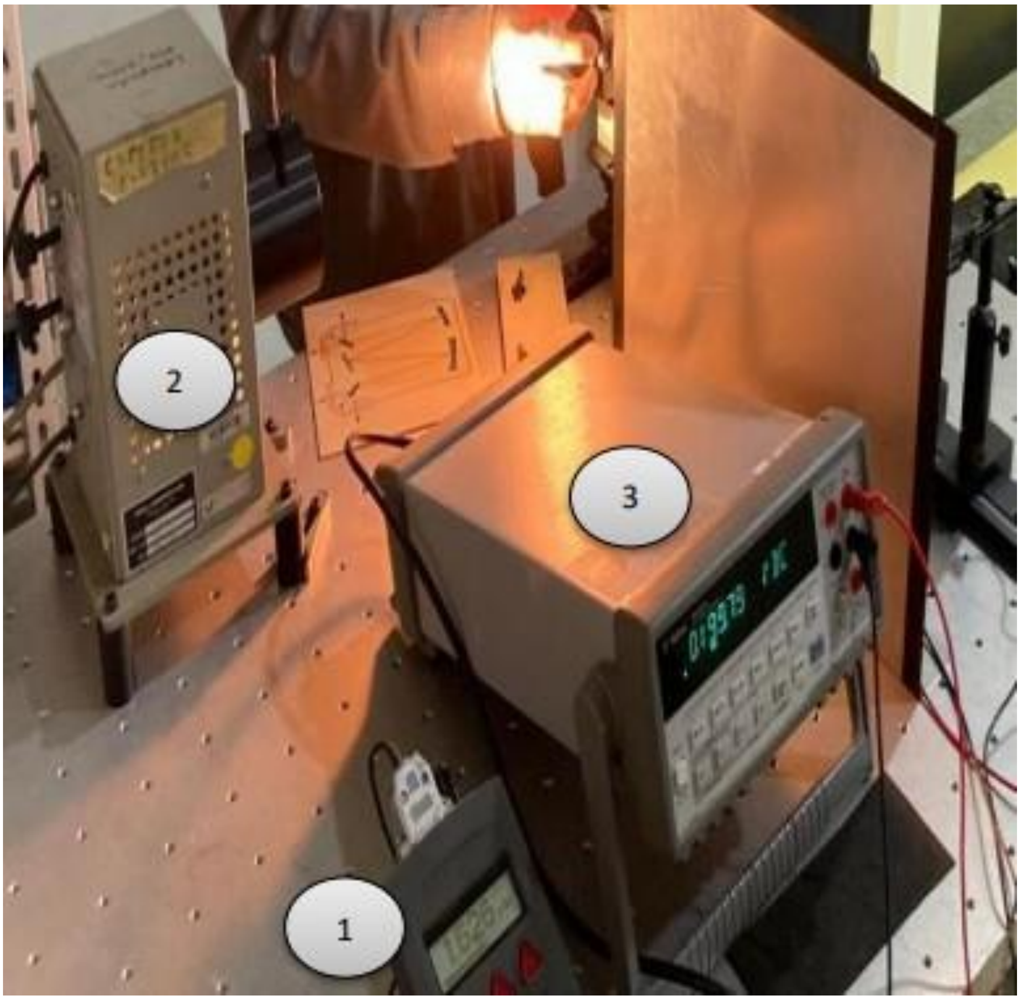


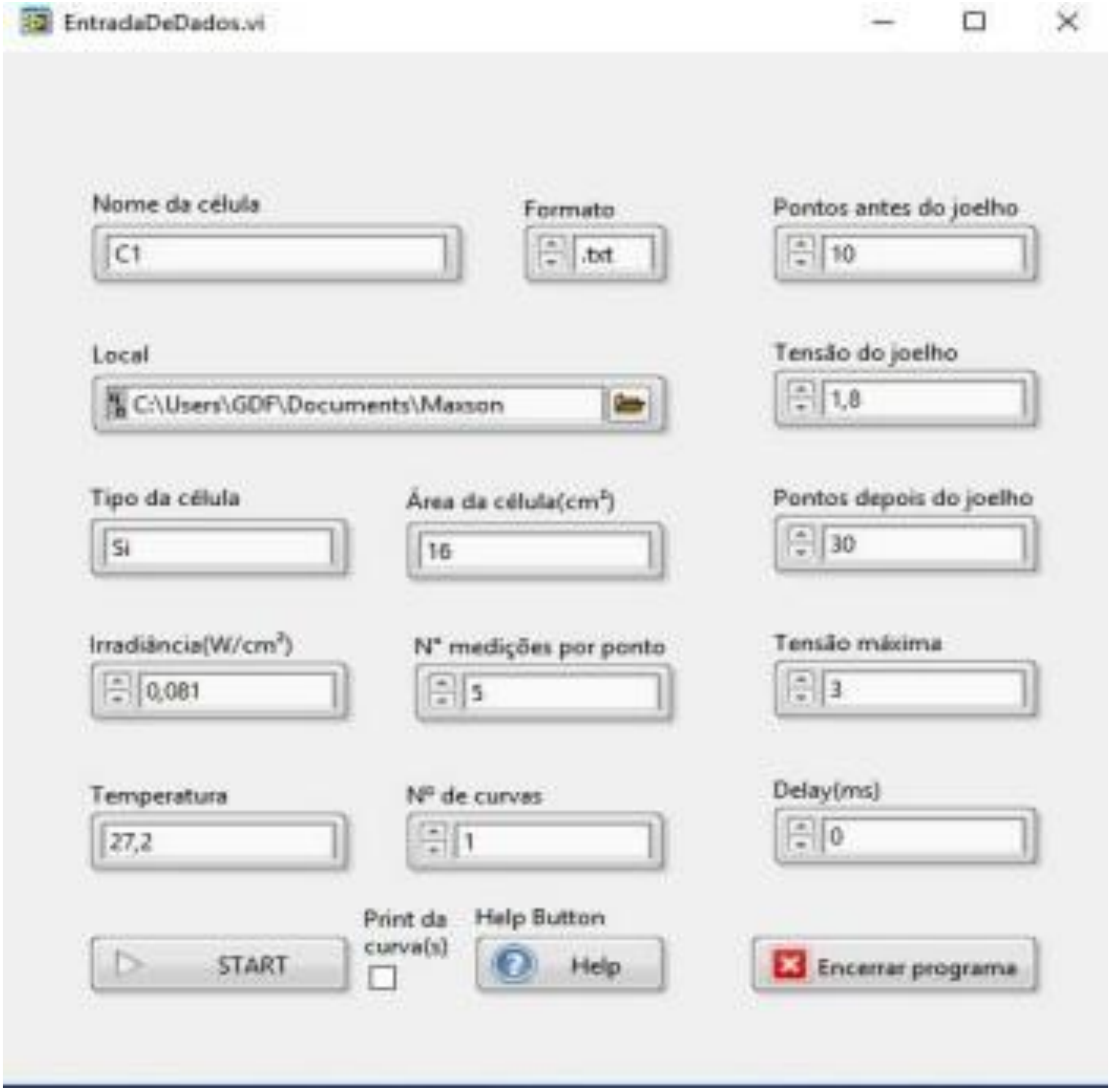
Figure 3. Photo of the spectral response (1 - spectroradiometer, 2 - power supply, 3 - voltage meter)

Figure 4. Monochromator wave length determination

3. RESULTS

3.1 Measurements of IxV curves

The characterizations of the solar cells were carried out using a solar simulator at the Photovoltaic Devices Laboratory of the National Institute for Space Research – INPE. To obtain the points on the IxV curve, the variable load source gradually increases the load resistance and records the voltage and current values measured by the multimeters on a computer. The software developed by CELSOL is responsible for recording these points in the computer and requires certain initial parameters for calculation, such as the area of the sensing element and the incident irradiance. Additionally, there are other fields in the program that can be filled in to provide more detailed information about the measurement, such as a reference name, the spectrum used, and the measurement temperature. As shown in figure 5.



Nome da célula
C1

Formato
.txt

Pontos antes do joelho
10

Local
C:\Users\GDF\Documents\Maxson

Tensão do joelho
1,8

Tipo da célula
Si

Área da célula(cm²)
16

Pontos depois do joelho
30

Irradiância(W/cm²)
0,081

Nº medições por ponto
5

Tensão máxima
3

Temperatura
27,2

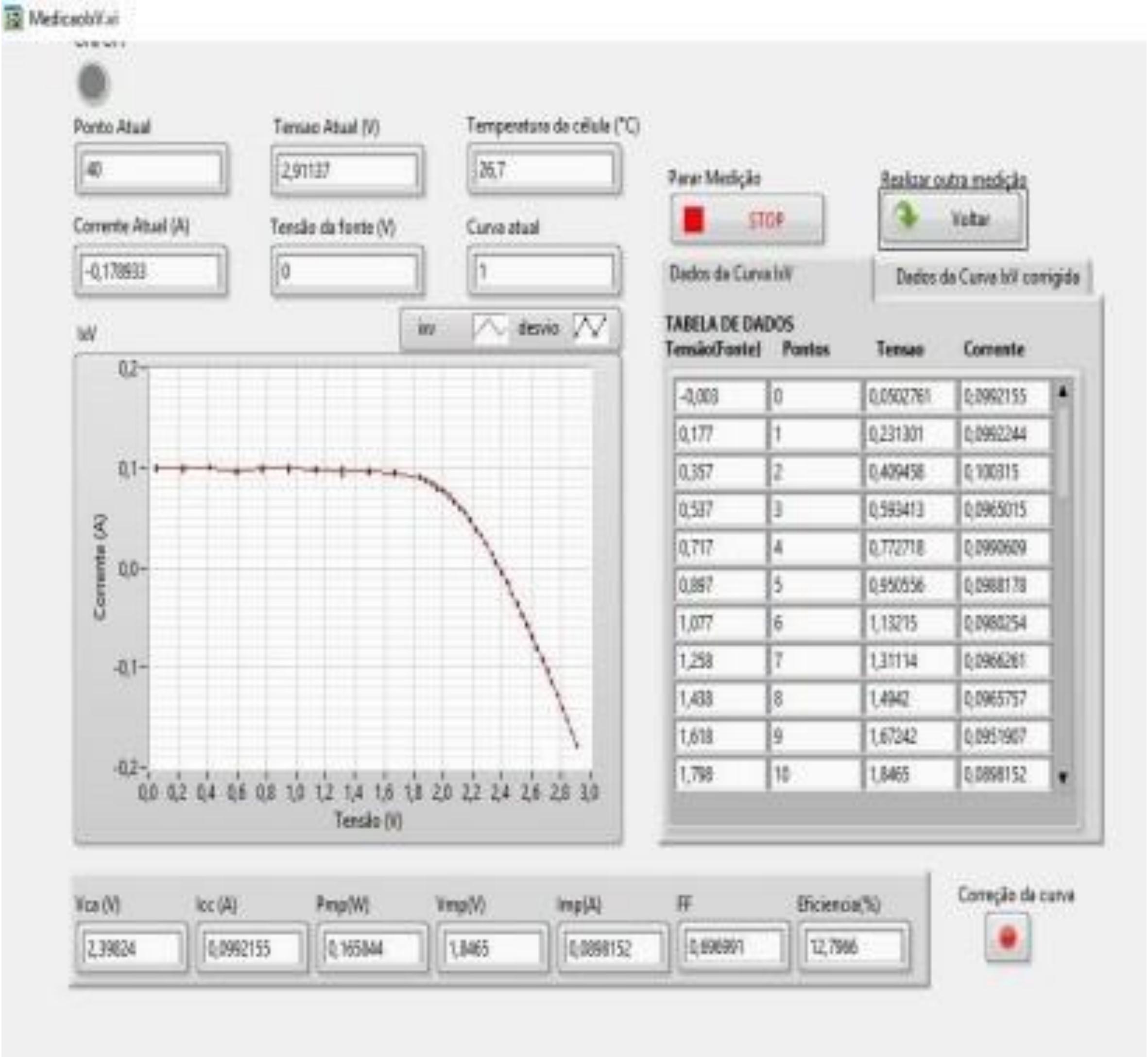
Nº de curvas
1

Delay(ms)
0

Print da curva(s)
☐

Figure 5. Solar simulator program interface.

Other information found in figure 4 includes the maximum voltage applied to the cell, the voltage variation steps before and after the inflection point in the curve. The number of points on the curve is determined by the variance and affects the resolution of the curve. After completing the measurement, the program generates a table of current in Amperes (I) with the respective voltage in Volts (V) and plots the IxV curve of the cell, as illustrated in figure 6. Based on the measured points and the parameters entered , the program calculates maximum power voltage, maximum power current, open circuit voltage, short circuit current, efficiency and form factor.



Ponto Atual: 40
Tensao Atual (V): 2,91137
Temperatura da célula (°C): 26,7
Corrente Atual (A): -0,178933
Tensão da fonte (V): 0
Curva atual: 1

TABELA DE DADOS

Tensão(Fonte)	Pontos	Tensao	Corrente
-0,003	0	0,0502761	0,0992155
0,177	1	0,231301	0,0992244
0,357	2	0,409458	0,100315
0,537	3	0,593413	0,0965015
0,717	4	0,772718	0,0990609
0,897	5	0,950556	0,0988178
1,077	6	1,13215	0,0980254
1,258	7	1,31114	0,0966261
1,438	8	1,4942	0,0965757
1,618	9	1,67242	0,0951907
1,798	10	1,8465	0,0898152

Vca (V)	Icc (A)	Pmp(W)	Vmp(V)	Imp(A)	FF	Eficiencia(%)
2,39024	0,0992155	0,165844	1,8465	0,0898152	0,696991	12,7986

Figure 6. Current and voltage curve generated by the solar simulator program

In the program graph, the short-circuit current is obtained by applying a small inverted potential difference at the device terminals by the reverse voltage source. This causes the voltmeter to register negative voltage values. This measurement method was used in all analyzed cells. The results obtained exceeded expectations. During the experiments in the solar simulator, it was found that 95 percent of the samples were working perfectly. After the analysis, the results revealed an average efficiency of 13% as shown in table 1 below.

The characterization of the spectral response results in similar curves for all analyses, as shown in fig. 7. Despite the characteristic plots, the samples revealed an abrupt drop in response near the 450nm wavelength. This drop is seen in all samples analyzed, and the hypothesis is that there is total absorption or reflection of this wavelength by the anti-reflective layer. Already in fig. 8 the offset is removed and it is possible to see how the curve behaves, so it is noticeable that there is a constancy in the graph, different from the previous graph where there is a different peak from which the spectral response is known.

Table 1. Cell efficiency.

Células	Eficiência
C1	12,796614
C2	12,158984
C3	13,274166
C4	13,636271
C5	13,087450
C6	13,232126
C7	13,749892
C8	13,630206
C9	11,686208
C10	13,226899
C11	13,058874
C12	13,789057
C13	13,351332
C14	12,345513
C15	12,822590
C16	13,877171
C17	13,421676
C18	13,554055
C19	13,407452
C20	13,085734
Média	13,159614

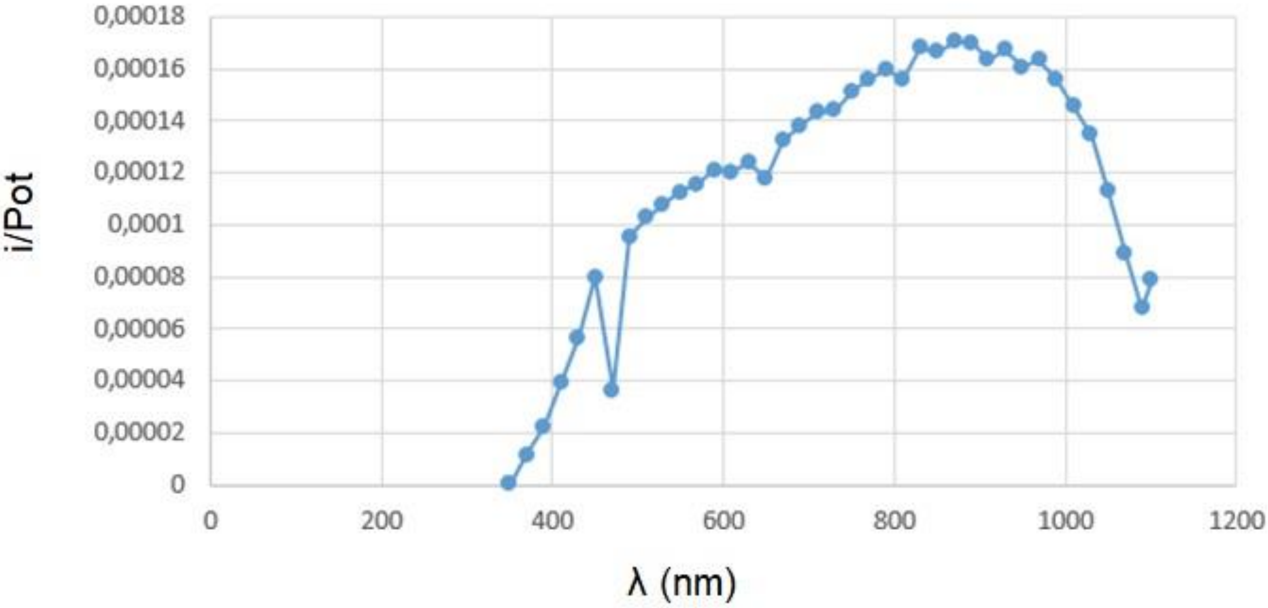


Figure 7. Expectral response characteristic of the analyzed samples.

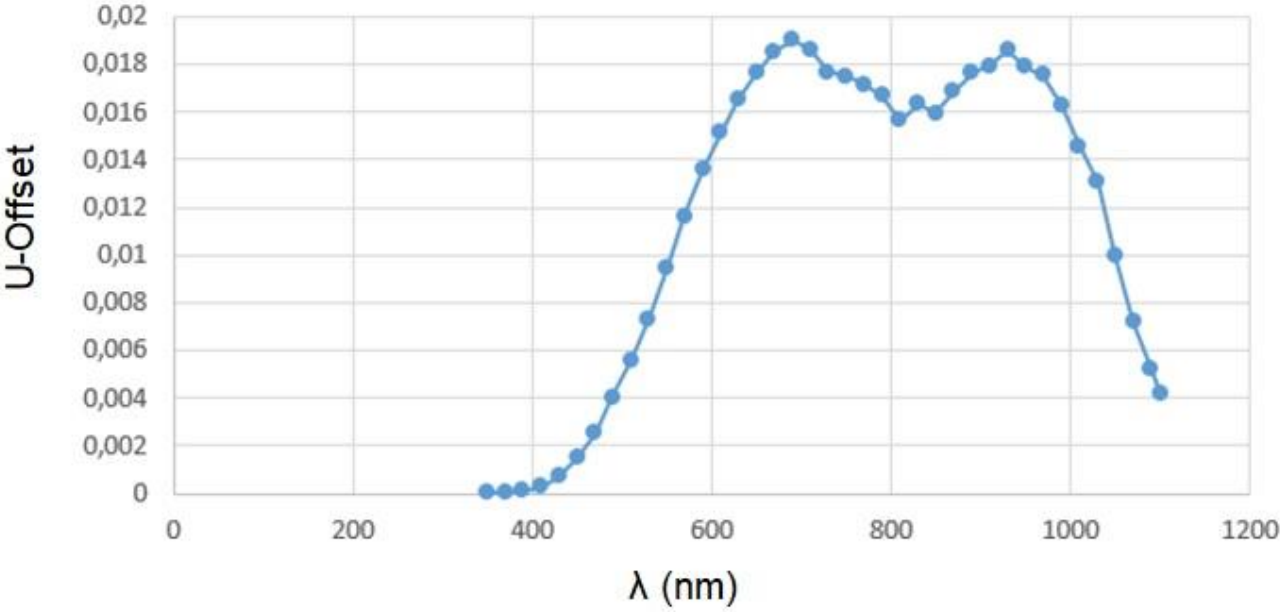


Figure 8. U-offset by wavelength (nm)

4. FINAL CONSIDERATIONS

It can be concluded that the characterization of polycrystalline silicon solar cells is an essential step in the development and improvement of photovoltaic technology. By analyzing the IxV (current-voltage) curves and the spectral response of solar cells, it is possible to obtain important information about the performance and efficiency of these devices.

Analyzes of the polycrystalline silicon solar cells analyzed, the results revealed an average efficiency of 13%, furthermore, it is encouraging to note that approximately 95% of the solar cells are functioning correctly. This means that the vast majority of cells in a solar panel are fully functioning, allowing solar energy to be efficiently captured and converted into electricity. Exceeding initial expectations. However, an abrupt drop in the spectral response was observed near the wavelength of 450 nm, which may indicate absorption or total reflection in this wavelength range.

These results highlight the importance of characterizing polycrystalline silicon solar cells to evaluate their performance and identify possible improvements. Understanding the electrical and optical properties of these devices is fundamental to driving technological advances in the area of photovoltaic solar energy and promoting the development of clean and renewable energy sources..

5. REFERENCES

France; System for spectral characterization of photovoltaic devices; IV Brazilian solar energy congress and V Latin American conference of ISES – Sao Paulo, September/2012

T. F. Paes; Sensor Element Characterization Systems for Photovoltaic Radiometers; master's thesis, National Institute for Space Research – INPE/LAS, February/2012.