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Organic Photovoltaic Cells: The Future of Solar Energy

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Abstract

The technology related to photovoltaic organic cells consists in the use of semiconductor polymers to generate electricity from sunlight. This technology is relatively new, but it has a promising field of development and application. Characteristics such as malleability and lightness guarantee the versatility necessary to replace, in a few years, the current crystalline silicon panels. Currently, the technology is in the process of research and testing to optimize its efficiency and useful life, in addition to the search for materials that can be economically viable for large-scale production. In this context, it is important to spread the word and show the future perspectives of the segment, so that more enthusiasts and researchers become interested in improving the methods of obtaining it.

Keywords: photovoltaic organic cells, polymers, electrical energy.

INTRODUCTION

In recent years, the efforts of the most diverse sectors of society have been notorious for reducing environmental impacts caused by indiscriminate use of

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fossil fuels. In this scenario, clean and renewable energy sources have gained more and more space as an ecologically sustainable development alternative.

In Brazil, according to data from the Agência Nacional de Energia Elétrica - ANEEL[1], about 57% of the energy generated in the country comes from hydroelectric power plants, which despite being considered a clean energy source and having a low cost of generation , require a large and complex structure for their operation, usually far from the large centers and with dams that interfere directly and indirectly in the fauna, flora and villages close to them[2]. Furthermore, the hydroelectric generation is strongly affected by the seasonality of the rains, which entails a scenario of unpredictability and significant increases in the electric energy tariff due to compensatory policies to defray the high cost of generating thermoelectric plants[3].

Among the possible sources of renewable energy, solar energy emerges as one of the most prominent sustainable alternatives to diversify the Brazilian energy matrix and reduce dependence on hydroelectric power plants. According to consolidated data from the National Energy Balance[4], which annually synthesizes information from the country's energy sector, there was an increase of 187.1% in the generation of photovoltaic energy between the years 2019 and 2020.

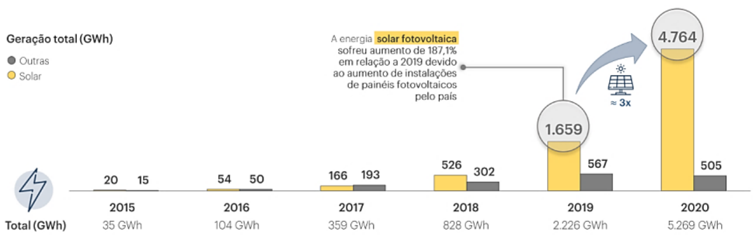

Figure 1. Growth of solar generation over the years.

Source: EPE[4]

The exponential increase in solar power generation in recent years is mainly due to the cheapening and popularization of segment-related equipment, a factor that has coincided with successive and substantial increases in the electricity tariff supplied by the distributors.

Currently, the crystalline silicon photovoltaic panels, which have had significant efficiency gains in recent years and are economically more accessible, have dominated the solar energy market as the main photogenerator unit. However, a relatively new technology and with a large and promising potential of applicability are the organic photovoltaic cells, or simply OPV (organic photovoltaic) cells.

OPV cells are considered the third generation of solar cells, and mostly correspond to organic polymers with photovoltaic properties. In summary, this technology results in a flexible, lightweight and semitransparent plastic material capable of generating electricity from the incidence of sunlight[5]. It should be noted that the cell is organic due to the molecular composition of its polymer raw material, which formed essentially by carbon atoms connections.

Figure 2. Pelolastic photovoltaic organic cell.
Source: InfinityPV[6]

In the course of this article, concepts, methods of obtaining, operating principles, present prospects and future challenges will be presented with the objective of contextualizing, informing and disseminating the technology related to organic photovoltaic cells.

METHOD OF OBTAINING

The basic structure of an organic solar cell is assembled in the form layers, composed of a transparent electrode (anode), a photosensitive semiconductive polymer (active layer) and a metal electrode (cathode)[7].

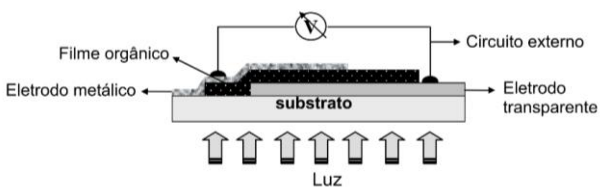

Figure 3. Organic solar cell with monolayer structure.
Source: CANESTRARO, Carla Daniele[8]

According to the incidence of photons from the electromagnetic radiation emitted by sunlight passes through the transparent material and reaches the photosensitive polymer layer, the synthesis of excitons occurs, which are electron / gap linked by Coulombian interaction forces. As the dissociation of excitons occurs, free loads are collected by the electrodes, creating an intrinsic electrical potential on the device. The metal electrode, in addition to collecting the photogenerated gaps, also reflects the photons not absorbed by the active layer, enabling the process to be redone[9].

As a result of the strong electrostatic connection of excitons and its rapid dissociation, the monolayer structure has a low efficiency in the conversion of energy. However, the yield can be significantly increased by distinctly adding two semiconductor organic materials in the active region, a donor and other electron acceptor. This heterojunction can be in bilayers (Figure 4.a) or in volume (Figure 4.b).

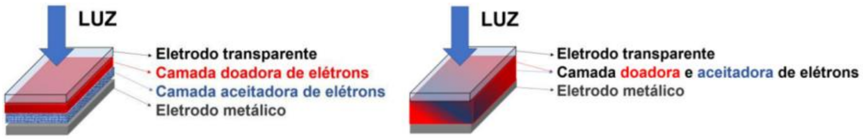

Figure 4. a) heterojunction in bilayer. (b) heterocunction in volume.
Source: MENEZES, Luana Cristina Wouk de.[9]

The distinction between these two methods consists of the organizational arrangement of donor and acceptors materials. In heterojunction in bilayer, the arrangement is done at perfectly distinct levels. In the case of heterojunction in volume, the combination is done without a defined order, which allows to increase the thickness of the active layer without the diffusion levels of excitons be compromised. Thus, a better absorption of light is possible.

Factors such as open circuit voltage (maximum voltage value) and the short-circuit current influence directly in the current flow[10].

The acceptor material acts by optimizing the capture and transport of electrons, which, consequently, increases the flow of photocurrent originated by the dissociation of excitons. The fullerene carbon allotrope (C_{60}) has been widely used for this purpose. However, this molecule has little stability in the face of environmental changes, such as increased temperature and humidity, as well as being susceptible to degradation and poorly soluble for the application of heterojunction in volume.

In the quest for synthesizing new materials to improve this process, the Federal University of Paraná (UFPR), through the Department of Physics, has developed in partnership with educational institutions of Sweden, research combining several polymeric nanocomposites. As in the case with the tests carried out with non-halogenated solvent o-methylanisole (O-MA) to process heterojunction based on the PTB7-th donor and ITIC acceptor, which have shown encouraging results for the production of OPV cells on a large scale[11].

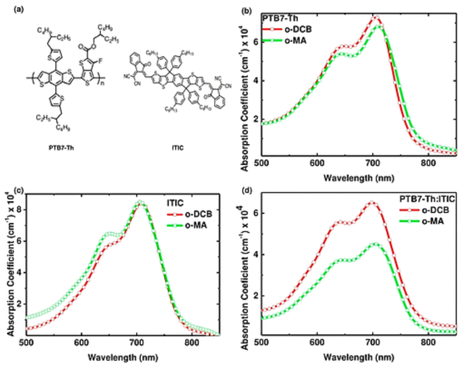

Figure 5. Luminous absorption coefficient PTB7-Th e ITIC
Source: MENEZES, Luana Cristina Wouk de et al[12]

RESULTS AND DISCUSSION

OPV technology combines the characteristics of malleability, lightness, and mechanical resistance of polymers with the electrical properties of photovoltaic devices[8].

As a result of the versatility of its characteristics, OPV cells can be used in numerous applications, especially in situations where robust and heavy silicon panels are not structurally viable, such as building glazing, architectural monuments with angular contours, automobiles, aircraft, among others.

In addition, OPV technology can be associated with the Internet of things (IoT), giving autonomy to sensors and portable devices by providing energy directly integrated to them[13].

Figure 6. Practical examples of the use of OPVs cells.
Source: MaterialDistrict[14]

In Brazil, the technology has been developed and implemented in a pioneering way by the Swiss company CSEM, which has a headquarter in Belo Horizonte. CSEM Brasil Research and Innovation Center is currently a global reference in nanotechnology and already produces, on an industrial scale, organic solar cells that reach up to 11% efficiency[15].

It is already possible to find CSEM Brasil projects associated with renowned brands, such as the solar roof prototype developed for the Fiat vehicle manufacturer and the use of solar films on the facades of the administrative offices of Grupo Energisa[16, 17].

Another company that has gained prominence in the segment is Sunew, which integrates OPV cells to power complementary electrical systems for trucks, such as GPS tracking, electronic locks and cargo refrigeration systems[18].

The manufacturing process on a commercial scale of organic solar cells is done through the roll-to-roll deposition, which consists of a sequential substrate printing mechanism, allowing the manufacture to make cells in different sizes, shapes and colors[19].

Laboratory tests with small samples and under favorable environmental conditions already reach about 18% efficiency in the conversion of luminous energy into electricity. The great challenge is to maintain this efficiency in larger cells and exposed to climatic conditions. For this, research is required to find combinations of materials that capture a larger spectral band of visible light, and which allied to this, are resistant and economically viable[20].

In this way, it is necessary to disseminate and encourage studies and research related to the topic, so that new materials and construction processes are tested and developed. In addition, the popularization and dissemination of the OPV panels already available on the market is essential to reduce the cost of large-scale production.

CONCLUSION

Through the information presented in this article, it is possible to verify that photovoltaic solar cells represent the future of solar energy, and as soon as studies related to engineering of matters and physical phenomena such as optics manage to mitigate the barriers of efficiency and productivity, this technology will be present in everyday life, whether in architectural structures or in portable electronic devices.

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