14/12/2015

The Concept System of an Organic Solar Cell

A terminological resource for patent translators

By Giulia Mattoni, MTT, S.N. 15212326

Table of Contents

SECTION 1: INTRODUCTION

1.1 PREMISE

The field of Organic Electronics is a relatively new subject area: early research on the electrical behavior of organic materials was commenced in the 1960s. Photoconductive organic materials were then discovered in the 1970s. However, only after the announcement of conductive polymers in the late 1970s and of conjugated semiconductors and photoemission polymers in the 1980s a new impulse and interest in the field was generated. Nowadays electronics based on organic compounds has developed such that it can be considered a valid replacement of the conventional one. [1]
This project aims to compile a terminological resource for patent translators regarding this specialisation. The work consists of the creation of term records shaped on WIPO Pearl's requirements implemented through a collection of fragments, annotations and detailed information about the selected concepts. The purpose is to provide translators with a handy tool that can facilitate the understanding of both the terms and the complex surrounding context.

1.2 A SYNOPSIS OF THE SUBDOMAIN: ORGANIC PHOVOLTAICS (OPVs):

Predictions of limited fossil fuels and issues associated with their environmental impact have led to a rapid growth of research on photovoltaics (PVs) over the last 30 years. Solar cells have been widely considered as a next-generation clean and renewable energy resources to relieve the global energy crisis. Until recently, the majority of PVs were silicon-based conventional devices, in the last decade the dominance of these traditional solar cells is being challenged by the emergence of third-generation PV technologies, able to make noticeable leaps in power conversion efficiency. The progress is driven by two factors: the discovery of novel suitable materials and the design of more sophisticated device structures. [2]

Research led to the production of organic solar cells (OPVs), which are ensembles of planar layers - containing at least one organic semiconductor in the cell active region - performing the conversion of electromagnetic radiation into electrical charges [3]. The OPVs represent a valid alternative to conventional inorganic technologies due to a unique combination of advantages offered such as ultra-thin, lightweight flexibility and semitransparency features, multi-color options, free form factors, significantly lower production costs and lower environmental impact during manufacturing and operations. Nevertheless, limited efficiency level and lifetime represent crucial drawbacks that scientists are trying to overcome in order to improve this promising technology. [4]

Figure 1. OPV integrated in the membrane roofs and solar trees of the German Pavilion

Nowadays several industries are applying such pioneering technology on remarkable and innovative devices. This is what was showcased at the Expo 2015 in Milan (Italy), for instance. The German Pavilion presented an outstanding example of a self-sufficient energy installation through the integration of OPVs in the architecture of the building: solar cells were placed on the pavilion's membrane roofs to harvest energy during the day and then use it to illuminate the pavilion at night. [5]

1.3 CONCEPT SYSTEM

1.3.1 Premise

After selecting and collecting information about the Organic Photovoltaics subdomain, it was possible to further delimit the field of investigation, ending up with a concept system modelled on the concept of *organic solar cell*.
The terms included in the concept system outlined in this report are also strictly related to another big domain, namely Chemistry. The reason lies in the fact that Organic Photovoltaics is a branch of Electronics that deal with conductive molecules, a main subject of study of Chemistry.

1.3.2 Brief concepts overview

As above mentioned, ***organic solar cell (OSC)*** is the superordinate of the concept system. It is a multilayer photovoltaic device made with organic compounds, able to convert solar energy into electricity. This process is feasible due to the presence of an ***active layer,*** sandwiched between two electrodes. Such layer can present different configurations based on the type of junctions. In the particular case of the ***bilayer heterojunction*** the donor and acceptor layers are completely separated from each other. The ***buffer layer*** represents further stratification within the organic solar cell necessary to avoid direct contact between the active layer and the electrodes.

The active layer is made up of conjugated polymers. The ***conjugated polymer*** is usually the primary absorber of sunlight and hence is usually essential for the performance of the solar panel. The ***power conversion efficiency (PCE)*** is one of the most important measurements of an organic solar cell. It characterises the effectiveness of the OSC.
The characteristics of organic solar cells allowed the employment of a specific manufacturing technique called ***roll-to-roll process.*** It involves continuous processing of a flexible substrate as it is transferred between two moving rolls of material. This fast and innovative printing method is optimal for a large-scale production.
Recently a new subset of organic solar cells the so-called ***organic tandem solar cell*** appeared on the market. It consists of a junction of at least two solar cells vertically stacked. This peculiar architecture is very promising because it permits an increase in the power conversion efficiency of the organic photovoltaic device.

1.3.3 Concept relations

The concept system outlined in this report consists of eight concepts: *organic solar cell, organic tandem solar cell, active layer, buffer layer, bilayer heterojunction, conjugated polymer, power conversion efficiency and roll-to-roll process.*
According to both the International Standard for Terminology Work ISO 704 (See Section 5.4) and the brief description of the concepts given above, it is possible to define the relations among these concepts as follow: **organic solar cell** is the *superordinate*, **organic tandem solar cell**, **active layer**, **buffer layer**, **bilayer heterojunction** and **conjugated polymer** are *subordinates*. These concepts are linked through *hierarchical relations*.
In detail, there is a *generic/specific relation* between organic solar cell and organic tandem solar cell; both active layer and buffer layer are components of the organic solar cell therefore the relation is *partitive*. The bilayer heterojunction is a type of internal configuration of the active layer consequently the relation is *generic/specific*. Conjugated polymers constitute the active layer, thus the relation is *partitive*. **Power conversion efficiency** and **roll-to-roll process** are both *associative concepts* relatively to the organic solar cell (associative relations).

1.4 EXISTING TERMINOLOGICAL RESOURCES FOR THE SUBDOMAIN

As this subject area is a relatively new object of study and research, the majority of the sources are available on the Internet, although with limitations on their accessibility. It was fundamental to combine different types of sources in order to have a satisfying idea of the big picture. Thus, the investigation began with the e-book *'Organic solar cells: An overview'* and the e-journal *'International Journal of Renewable and Sustainable Energy'*. In addition, the web article published by the *'Organic and Printed Electronics Association'* regarding the showcase of their novel OPVs device at Expo exhibition was helpful to understand the latest applications of the OPVs technology. After obtaining a first generic idea about the subject area, it was necessary to go into details in order to identify the terms to build up the concept system. Therefore, numerous patents, e-journals, e-books and doctoral thesis were consulted. In particular, the e-journals provided by '*The Royal Society of Chemistry'* represented an amazing resource. The University login credentials give free access to a great amount of up-to-date documents available for an online consultation.

1.5 CHALLENGES OF TERMINOLOGY PROJECT

One of the main problem I had to face for the realisation of this project was the shortage of textbooks available in the libraries. Therefore, I opted for online sources to find recent and up-to-date material, which also implied problems regarding both reliability and accessibility: the majority of e-books and e-journals were either just partially available or entirely not. In the latter case, significant fees were required in order to purchase and read the content.

Another problem I had to tackle was selecting untranslated concepts in WIPO term-base: assessing whether the terms represented good candidate in matter of giving sufficient scope for the research represented one of the most challenging stage of this assignment. In addition, being a layperson - due to my background oriented towards humanities - implied a considerable effort in the understanding of the subject itself, which is a domain belonging to both engineering and science. Finally, in order to improve an ineffective initial phase of work, I adopted a more fruitful approach. It was vital indeed to narrow down the vastness of information collected by delimitating the search to an interesting sub-domain. However, also at this stage of the work I encountered difficulties on finding fragments containing defining contexts for the terms that were part of approved reliable sources and originally written in English rather than other languages.

SECTION 2: CASE FILES

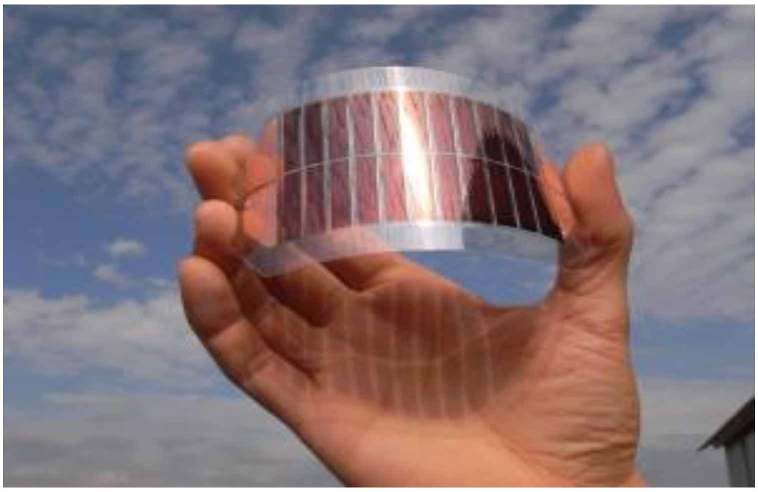
2.1 Premise

This section is conceived to implement the term records data. It contains a collection of fragments and images taken from a variety of sources for each of the 8 terms of the concept system of this report. The concepts are described through a *defining context* that “indicates essential characteristics of the object or shows the function that the object has or the effects that a process has, etc.” (Recommendation for work terminology). The choice of the fragments is justified by annotations containing related comments and explanations. The selected terms are in bold, whereas the relating terms included within the concept system are underlined (my emphasis).

2.2 CASE FILES

2.2.1 ORGANIC SOLAR CELL

2.2.1.1 Image



The picture taken from the e-journal ‘Science of Education Publishing’ [6] shows a third generation organic solar cell, flexible and ultra-thin.

2.2.1.2 Source of the term

The term **organic solar cell** emerges from the patent US9184392B2 “*Polymer and organic solar cell including same”. [7]*

2.2.1.3 Defining context

2.2.1.3.1 Preferred Context

A good defining context for the term has been found in the patent DE102010028945A1 [8]:

*"**Organic solar cells** consist of a series of thin layers (typically 1 nm to 1 micron) from organic materials, which are preferably vacuum deposited or spin-coated from a solution. The electrical contact can be effected by metal layers, transparent conductive oxides (TCOs) and / or transparent conductive polymer (PEDOT-PSS, PANI). A solar cell converts light energy into electrical energy. […] The advantages of organic over inorganic solar cells are primarily in the expected lower cost."*

2.2.1.3.2 Other Contexts

The following fragment provides an interesting contextualisation of the term and demonstrates its connection to other terms included in the concept system: [9]

*"Solar cells are devices which convert solar energy directly into electricity, and the most common material used for solar cells is silicon. Although silicon-based solar cells exhibit some of the highest <u>power conversion efficiencies</u>, they remain expensive because of the intensive processing techniques and the high cost of purified silicon. In this context, organic molecules are alternative candidates for solar cells because of their low cost and high processability. The most widely studied **organic solar cells** are polymer-based solar cells using <u>conjugated polymers.</u>"*

For analogue reasons the following section was taken from the e-journal 'Polymer Chemistry' [10]:

1.2 Working principles of organic solar cells

The typical structure of an organic solar cell is shown in Fig. 1. A hole transport layer, poly(3,4-ethylenedioxythiophene):poly (styrenesulfonate) (PEDOT:PSS), is spin-coated on top of the

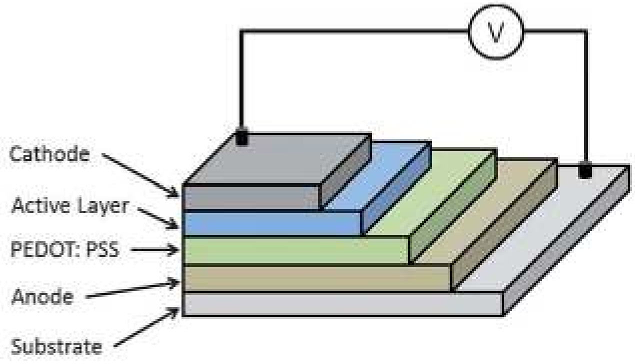


Fig. 1 Typical structure of an organic solar cell. PEDOT:PSS is spin-coated on top of the anode as a hole transport layer. The active layer is sandwiched between the cathode and the hole transport layer.

anode. The active layer comprising the donor and the acceptor is sandwiched between the cathode and the hole transport layer. The process for organic solar cells to convert sunlight into electricity is described as follows: The light-absorbing material with a bandgap in the visible region absorbs photons that excite the electrons from the ground state to the excited state, and bound electron-hole pairs (excitons) are created. The excitons diffuse to the donor–acceptor interface where excitons dissociate into free charge carriers after overcoming the binding energies. The free charge carriers transport to the respective electrodes under the internal electric fields, resulting in the generation of photocurrent.

Power conversion efficiency (PCE) is used to evaluate the performance of polymer solar cells.[5] The PCE of an organic solar cell is determined by the following equation:

$$PCE = (FF \times J_{sc} \times V_{oc})/P_{in} \qquad (1)$$

Additionally, the following fragment taken from the e-journal *'Science of Education Publishing' [11]* highlights other peculiarities of the device and contributes to render the definition more complete and detailed:

Organic solar cells can be distinguished by the production technique, the character of the materials and by the device design. The two main production techniques can be distinguished as either wet processing or thermal evaporation. Device architectures are single layer, bi layer hetero junction and bulk hetero junction, with the diffuse bi layer hetero junction as intermediate between the bi layer and the bulk hetero junction , Whereas the single layer comprises of only one active material, the other architectures are based on respectively two kinds of materials: electron donors (D) and electron acceptors (A).

2.2.1.3.3 Synonym Contexts

The head term presents a conspicuous variety of synonyms.

- **Organic photovoltaic solar cell/ Organic photovoltaic device**

"The principle of operation for an ***organic photovoltaic (OPV) device*** *is based on the conversion of incident electromagnetic radiation to electrical charges which may then be extracted at the electrodes. There are a number of processes which occur in order to achieve this and the OPV architecture is an ensemble of planar layers engineered to carry out these processes as efficiently as possible. Essentially the* ***OPV device*** *layered structure is tailored to accommodate the so-called active layer […].*

In summary the operation of an ***OPV*** *may be listed as follows:*

-Light is absorbed in the active layer creating an exciton

-The exciton diffuses to a dissociation site

-The exciton dissociates to a free electron and corresponding hole

-The free charge carriers are transported to the appropriate electron for extraction." [12]

- **Polymer solar cell**

"Polymer solar cells *have many intrinsic advantages, such as their light weight, flexibility, and low material and manufacturing costs." [13]*

- **Polymer-based solar cell**

"Recently, there has been tremendous progress in the development of polymer-based organic solar cells. ***Polymer-based solar cells*** *have attracted a great deal of attention because they have the potential to be efficient, inexpensive, and solution processable." [14]*

- **Plastic solar cell**

*"Although significant progress has been made, the efficiency of converting solar energy into electrical power obtained with **plastic solar cells** still does not warrant commercialization." [15]*

The last two fragments included in this case file have been chosen because both clearly proved how the terms listed above can be easily interchanged. The head term and most of its synonyms coexist in the same extract:

*"**Organic or plastic solar cells** use organic materials (carbon-compound based) mostly in the form of small molecules, dendrimers and polymers, to convert solar energy into electric energy. These semi conductive organic molecules have the ability to absorb light and induce the transport of electrical charges between the conduction band of the absorber to the conduction band of the acceptor molecule. There are various types of **organic photovoltaic cells (OPVs)**, including single layered and multilayered structured cells." [16]*

*"In addition to **organic (or polymer) solar cells**, another candidate that grew to dominate 3G PV technologies is dye or semiconductor sensitised (or mesoscopic) solar cells (DSSC)."* [17]

All the terms listed above are often substituted within the sources with their respectively acronyms.

2.2.1.4 Translated term

The term under investigation shows variation between Spanish and Latin American Spanish.

- **Célula solar orgánica**

  The following contextual fragment has been taken from a review called '*Revista Española de Fisica*': [18]

  "*La sucesión de pasos en la generación de electricidad en una **célula solar orgánica** sería, entonces: se absorbe un fotón en el polímero; el excitón emigra (se difunde) dentro del dominio del polímero hasta que alcanza una interfaz con el fulereno; entonces debido a la distinta afinidad electrónica y a la diferencia energética, el electrón salta al fulereno dejando el hueco en el polímero, es decir, se produce una transferencia de carga. Una vez se separa el excitón en cargas libres, éstas se transportan por dominios de cada uno de los materiales que percolan hasta ser recogidas en los contactos. Esta forma de funcionar establece un punto clave que desde* *entonces se ha mantenido se necesitan dos semiconductores para que la célula solar funcione, uno tipo p (o donante de electrones) y otro tipo n (o aceptor de electrones)."*

- **Celda solar orgánica**

The term has been encountered in the Doctoral thesis "Espectroscopia de absorción transitoria como instrumento de investigación en fotovoltaica orgánica: estudios de generación de carga en la mezcla activa de celdas solares, caso de estudio: fluorinacion de polímero": [19]

*"Las **celdas solares orgánicas** usan semiconductores de carbono para los procesos de absorción, generación y transporte de cargas, las cuales se colectan finalmente en los electrodos metálicos. El reto principal de usar materiales orgánicosse centra en la generación eficiente de cargasa pesar de sus constantes dieléctricas bajas, comparadas con las de los materiales inorgánicos, en los que la generación de cargas libres sucede es inmediata. Una constante dieléctrica pequeña produce la formación de "excitones" es decir, especies excitadas de pseudo-cargas que aun interaccionan fuertemente, en los que la carga positiva remanente en el HOMO (orbital molecular ocupado de mayor energía) interacciona con el electrón que ha sido promovido por la acción de un fotón al LUMO (orbital molecular desocupado de menor energía) todo esto provocando la deformación de los alrededores.*

2.2.2 ORGANIC TANDEM SOLAR CELL

2.2.2.1 Image

The image shows the multilayer structure of an organic tandem solar cell.

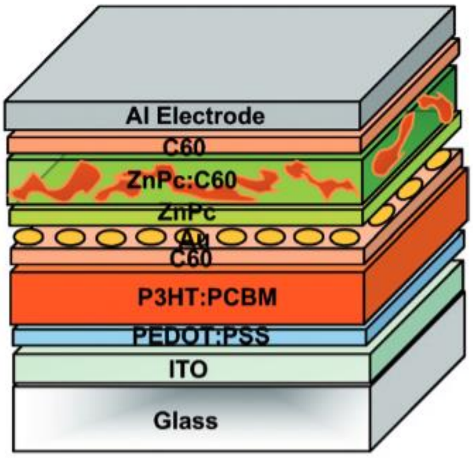


Fig. 15 Schematic structure of the tandem organic solar cell realized by Dennler *et al.*[42] comprising of two sub-cells with complementary absorption spectra.

2.2.2.2 Source of the term

The term **organic tandem solar cell** has been encountered within *'Chemistry Society Review'. [20]*

2.2.2.3 Defining context

2.2.2.3.1 Preferred context

A good definition of the term is also contained in the article above mentioned taken from '*Chemistry Society Review':*

*"Two or even more OPV cells can be stacked on top of each other to form a **tandem OPV** structure, which enables one to resolve two limiting factors existing intrinsically among organic semiconductor molecules: poor charge carrier mobility and a narrow light absorption range."*

2.2.2.3.2 Other contexts

The following three fragments are gathered together as they all pinpoint the intrinsic nature of an organic tandem solar cell, which is the result of the junction of two distinct solar cells:

*"One of the approaches to improve the absorption is stacking two or more organic solar cells with different absorption characteristics in so-called **tandem solar cells**". [21]*

*"The limitations of single junction photovoltaics can be overcome using **tandem solar cells** where in two or more single cells absorbing in a complementary wavelength range are stacked together." [22]*

Source [23]

In order to produce organic tandem solar cells employing solution processing, serious engineering challenges have to be met. Multiple layers have to be cast on top of each other, and because casting a further layer from solution dissolves the underneath layer it is something that has to be avoided. Researchers have developed several approaches to circumvent this intrinsic problem. These comprise employing sophisticated material sequences soluble in incompatible solvents or applying one or more layers by vacuum deposition methods.

2.2.2.3.3 Synonym contexts

'Organic tandem solar cells' term presents a variety of synonyms. The one that shows a considerable number of occurrences is **polymer tandem solar cells.** Here the contextual fragment that provides an example of usage implemented by a further definition:

*"**Polymer tandem solar cells**, where two or more single junction cells that absorb in different wavelength range are connected in tandem, are being explored to overcome the limitations of single junction cells." [24]*

In addition, **double junction polymer solar cell**, **multi-layer polymer solar cell** and **organic photovoltaic multicells** have been encountered during the research.

2.2.2.4 Translated term

The Spanish equivalent, i.e. **célula solar orgánica tandem**, shows several hits. However, since it was impossible to find good defining contexts citing the exact term under investigation, I opted for a fragment that describes an organic solar cell with a particular mention of the tandem architecture, although without an explicit citation of the term.
The following is an extract taken from the Master's thesis '*Utilización de polímeros de bajo band-gap en células fotovoltaicas*': [25]

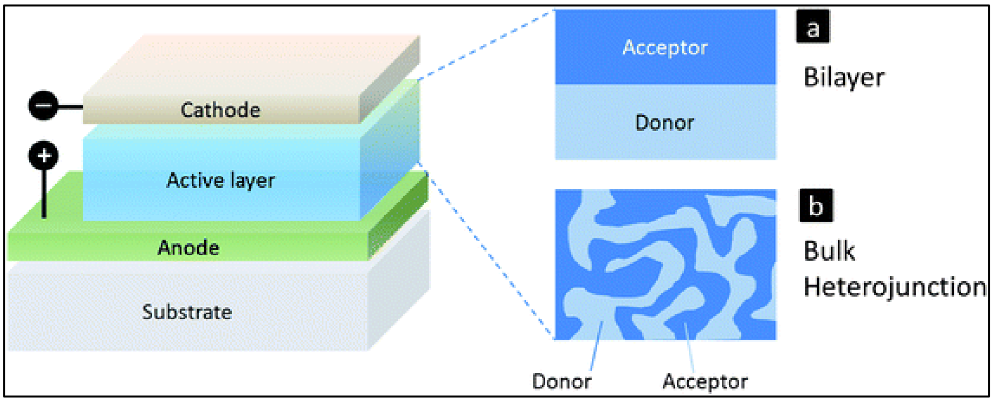
*"Desde que se fabricó la primera célula solar orgánica, muchos han sido los avances que se han realizado con el objetivo de mejorar la eficiencia de la conversión de potencia. Entre ellos pueden citarse la generación múltiple de excitones, el empleo de nanomateriales como las perovskitas o nuevas arquitecturas como la tándem. El concepto de **célula tándem**, en la que dos o más células solares con ventanas de absorción complementarias se encuentran superpuestas y conectadas (en serie o en paralelo), es uno de los avances más prometedores para solucionar uno de los problemas*

más relevantes de las OSCs: la pérdida de fotocorriente o corriente de cortocircuito, ISC, debido a una baja absorción de fotones."

2.2.3. ACTIVE LAYER

2.2.3.1 Image

The image taken from '*Energy and Environmental Science*' [26] shows the structure of an organic solar cell, focusing in particular on the active layer and its composition.



2.2.3.2 Source of the term

The term **active layer** was encountered in the patent WO2015171689 '*Functional interlayers of fullerene derivatives and applications in organic solar cells*'. [27]

2.2.3.3 Defining context

2.2.3.3.1 Preferred Context

The most approachable and clarifying context is given by the '*International Journal of Molecular Science',* which defines what an **active layer** is on the basis of its composition:

"*Organic solar cell **active layers** consist of two organic semiconductors, one serving as an electron donor and the other as an electron acceptor*." [28]

Subsequently a detailed explanation of the process that takes place in the layer is described:

"*Absorption of a photon leads to the generation of an exciton, a short-lived bound electron-hole pair. Due to the high binding energy of excitons in organic semiconductors, the exciton cannot dissociate unless it diffuses to a donor–acceptor interface, where it is energetically favorable to separate into* *free charges. For the charges to be collected, the electron must travel through the acceptor to the cathode while the hole must travel through the donor to the anode." [29]*

2.2.3.3.2 Other Contexts

By consulting other sources, it was possible to verify the reliability of the definition. The following fragments prove their concordance in meaning with the main source and also add further characterisations and features related to the **active layer**.

Source 1: PhD Thesis "*New Architectures and Designs for Organic Photovoltaics* "(Nigel John Alley): [30]

"*The so-called* ***active layer*** *typically comprises of one or more semiconductor materials which are either made up of organic materials that are solution processed or small molecular systems, which may be physically deposited by vapor deposition"* (Nigel John Alley).

Additionally, in the same source:

> The morphology of the active layer is defined by the arrangement (shape, size, location) of the donor and acceptor materials. The fabrication processes employed to deposit the active layer do not yield identical morphologies but rather on average tend to yield similar device performance given the same processing conditions (spin-speed, solvent annealing time, oven temperatures). The active layer may be considered as a disordered structure relying on the particular alignment of polymers and molecules separated into crystalline and amorphous domains in a nano-scale, ultra-thin film, typically less than 100 nm in thickness.

Source 2: '*Theoretical Description of Structural and Electronic Properties of Organic Photovoltaic Materials': [31]*

2. ORGANIC SOLAR CELLS AS DEVICES

The architecture of nearly all high-efficiency solution-processable (i.e., potentially inexpensive) organic solar cells is the bulk heterojunction (**Figure 1*a***). Here, electron donor [e.g., P3HT (poly-3-hexylthiophene)] and acceptor [e.g., PCBM (phenyl-C_{61}-butyric acid methyl ester)] materials are blended from a solution to form the device's active layer. Sunlight is absorbed mainly by one component (typically a molecular donor) with the generation of strongly bound electron-hole pairs (excitons). The excitons diffuse to the heterojunction, in which they dissociate into electrons and holes, collected at the corresponding electrodes.

In the book it is clearly stated that the function of the active layer is "*to absorb sunlight and separate charges*".

Source 3: Patent WO/2015/011060A1 **'***Organic photovoltaic cells with enhanced photocurrent': [32]*

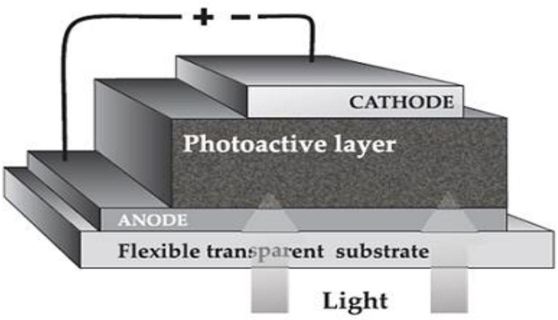
"*The **active layer** of conventional organic photovoltaic (OPV) devices comprises two organic semiconductor layers: an electron donor layer containing organic molecules with a low electron affinity (low LUMO level, Lowest Unoccupied Molecular Orbital level) and low ionization potential (low HOMO level, Highest Occupied Molecular Orbital level), and an electron acceptor layer containing organic molecules with a higher LUMO-level and a higher HOMO-level than the donor layer. The active layer, which is typically 50 nm to 100 nm thick, is sandwiched between two electrodes. "*

2.2.3.4 Synonym Contexts

Proceeding with the research, I came across an eBook called '*Organic Solar Cell*' that uses both the term '*active layer'* and a variation of the concept, i.e. the synonym '**photoactive layer**'. [33]
The paragraph shows how the two terms are interchangeable:

*"[…] the **photoactive layer** consists of a bicontinuous blend of an electron donor and an electron acceptor […]"* and "*An Organic photovoltaic cell (OPV) is composed of a film of organic photovoltaic **active layer**, sandwiched between a transparent electrode and a metal electrode. […] Typically, the active layer device is composed of a blend film of conjugated polymer (as electron donor) and a small molecular acceptor."*
Another source, an article published in the *Journal of Materials Chemistry [34],* proves the interchangeability of the terms:

*"Photovoltaic devices based on a blend of two conjugated polymers as the **photoactive layer** was first reported back in the 1990s."*



The image taken from '*Science and Education Publishing'* [35] depicts the same type of stratification illustrated by the image in Section 1.1. This is a graphical confirmation that active layer and photoactive layer are interchangeable concepts.

2.2.3.5 Translated term

The equivalent term of **active layer** into Spanish is **capa activa.** To support the translation, two fragments have been provided. The first source is a patent (ES2323372T3): [36]

*[…] **Las capas activas** presentan habitualmente una zona con donadores de electrones y una zona con aceptores de electrones, ambas están mezcladas entre sí y/o están unidas entre sí por ejemplo a través de una capa de agotamiento. Los portadores de carga generados en la capa activa mediante la incidencia de la luz (pares de electrón-hueco) se evacuan mediante aspiración en las capas adyacentes en cada caso por separado."*

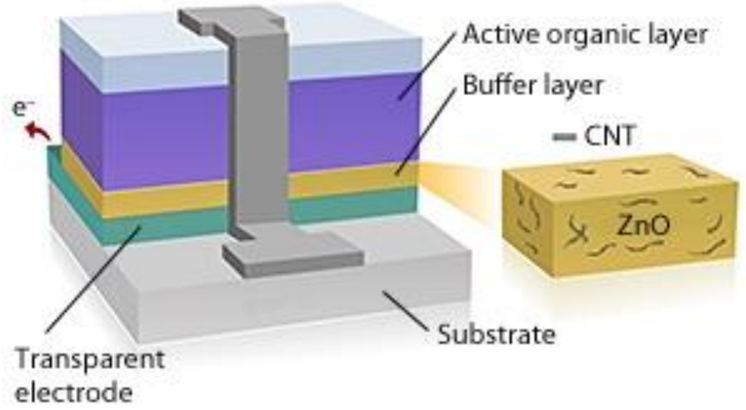
The second defining context is taken from a scientific review called '*Revista Elementos*': [37]

*"Celda solar orgánica […] este tipo de celdas tiene como **capa activa** una película delgada (100 nm aprox.) que está compuesta por una mezcla homogénea de un donor (polímero semiconductor altamente conjugado) y un aceptor de electrones (generalmente un derivado de fullereno), así en cualquier punto dentro de la película se tiene una mezcla donor/aceptor, resolviendo el inconveniente de las celdas con heterojuntura, puesto que las redes interpenetrantes aumentan las interfaces entre los dos materiales, disminuyendo la distancia entre ellos, favoreciendo el proceso de disociación del excitón y disminuyendo los procesos de recombinación, lo que incrementa la eficiencia de las celdas solares orgánicas."*

2.2.4 BUFFER LAYER

2.2.4.1 Image

The image shows the substrates of an organic solar cell, including the buffer layer.



2.2.4.2 Source of the term

The concept **buffer layer** is mentioned and depicted in the patent US20140084266A1 'Semi-transparent, transparent, stacked and top-illuminated organic photovoltaic devices'. [38]

2.2.4.3 Defining context

2.2.4.3.1 Preferred Context

An appropriate and thorough definition of **buffer layer** is given within the patent itself where the term has been selected:

*"The **buffer layer** provides a physical barrier between the active layer and the plurality of nanowires to prevent damage to the active layer during the forming of the electrode." [39]*

2.2.4.3.2 Other Contexts

The contextual fragments included in this paragraph all contribute to enrich the definition of the head term previously given. The patent WO/2015/011060A1 represents an example: [40]

"*Often a **buffer layer** is provided between the active layer and the electrodes, for avoiding direct contact between the active layer and the electrodes."*

In addition, the two following defining contexts are taken from the patent EP2348556A1 '*Organic thin-film solar cell*': [41]

*"In general, an organic thin film solar cell has a small film thickness, thus, the upper electrode and the lower electrode often short-circuit so that yield in fabrication of the cells may decrease. Such short-circuit can be avoided by stacking of a **buffer layer**."*

*"As materials for formation of the **buffer layer**, preferred are compounds having a sufficiently high carrier mobility such that the short-circuit current does not decrease even when the film thickness of the **buffer layer** increases*."

A further source, 'Organic Electronics' book, explains the function of the layer within the OPV cell: [42]

*"[…] **buffer layers** often behave as an exciton blocking layer to prevent excitons generated in the active layers from quenching at the organic/metal interface."*

2.2.4.3.3 Contexts for different typologies of the term and its synonyms

Variations of the head term were encountered. Such variations are here listed:

- **Anode buffer layer (ABL)**

*"An ideal **anode buffer layer (ABL)** in conventional structure should have good optical transmission and proper energy level to improve hole extraction and block electron to diminish electron–hole recombination. Moreover, the ABL should also have good solution processability and excellent film-forming property for low-cost device fabrication". [43]*

"The role of an anode buffer layer is the improvement of the anode electrode efficiency in collecting and extracting positive carriers". [44]

- **Cathode buffer layer (CBL)**

"The role of a cathode buffer layer is the improvement of the cathode electrode efficiency in collecting and extracting negative charge carriers". [45]

"[…] *π-conjugated polymers* have been used as materials for **cathode buffer layers**". [46]

The following image, taken from the e-journal '*Energy and Environment Science*' shows a schematic of the two typologies of buffer layers explained above and their position in the OPV relatively to the active layer.

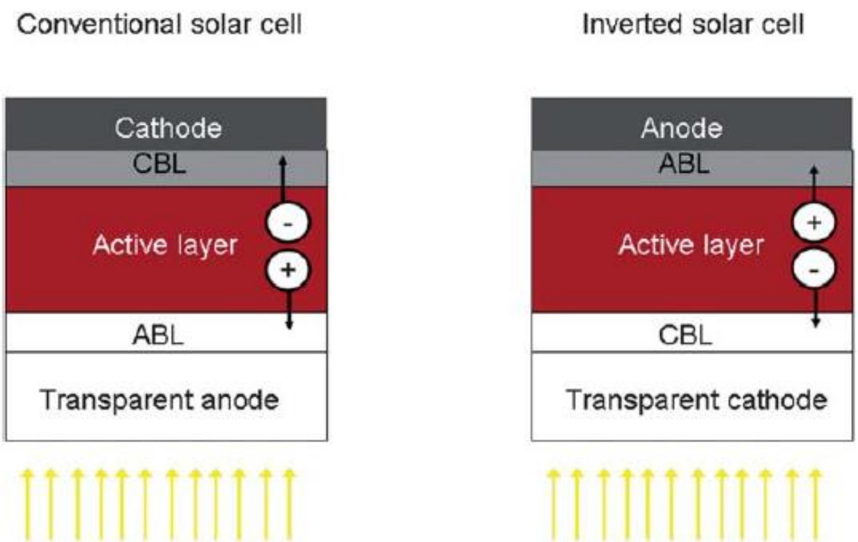


Fig. 1 Typical device structures of single-junction conventional and inverted polymer solar cells. ABL: anode buffer layer; CBL: cathode buffer layer.

Finally, a precise description of the term is given within the article '*The role of buffer layers in polymer solar cells'[47] .* The fragment includes the superordinate **buffer layer** and its subordinate concepts (hierarchical relation generic/specific) **anode/cathode buffer layer**. In addition two synonyms of the head term are showed: "**interfacial layers**" and "**interlayers**". Here is the text:

"*Usual device structures include **buffer layers**, both at the anode and at the cathode interface, mainly to favour charge collection and extraction, but also to improve the device's overall performance. **Buffer layers** are actually essential for achieving highly efficient polymer solar cells and can no more be considered as ''optional" […] [T]he structure of polymer solar cells usually includes functional layers at the active layer/electrode interfaces to favour charge collection and extraction. These additional layers, called **buffer layers** or **interfacial layers** or **interlayers**, can no more be considered as ''optional'', but are essential for achieving maximum performance in polymer solar cells. So, the usual structures for single junction polymer solar cells include both an anode buffer layer(ABL) and a cathode buffer layer (CBL)[…]".*

2.2.4.4 Translated term

The literal translation of the term into Spanish is **capa tamponadora.** However, although the term has been encountered in Spanish patents, it was not included in a good defining context. Therefore, I opted for other kinds of sources. During the investigation, I noticed that a Spanish concept, **capa intermedia**, presents a considerable number of occurrences**.** This concept represents the equivalent term "interlayer", which is one of the synonyms of buffer layer. The following fragment is contained in the Master's thesis *'Optimización de los procesos de fabricación de células solares orgánicas mediante técnicas de impression*': [48]

"Sobre el electrodo de ITO se sitúa, una capa intermedia para disminuir la rugosidad del ITO, evitando así cortocircuitos, y además favorece la extracción de huecos. Esta capa habitualmente estácompuesta de PEDOT:PSS (poli-3,4-etilendioxitiofeno con sulfonato de poliestireno). A continuación se depositar a la capa activa y aquí es donde se produce el efecto fotovoltaico y la absorción de luz."

Another important aspect to note is the preference towards the term **capa buffer** in Latin American Spanish sources. *Capa buffer* represents a 'hybrid' term consisting of a mixture of the Spanish translation ("capa") and the original English form ('buffer').

2.2.5. BILAYER HETEROJUNCTION

2.2.5.1 Image

The picture shows the structure of a bilayer heterojunction and its relation with the active layer of an OPV cell. [49]

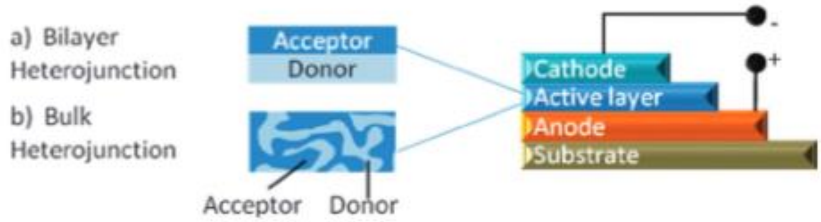


Fig. 1 The architecture structure of bilayer heterojunction (a) and BHJ (b) OPV devices.

2.2.5.2 Source of the term

The term **bilayer heterojunction** has been encountered in the article '*Reason why bulk heterojunction is preferred to bilayer*' included in *'Chemistry Society Review'. [50]*

2.2.5.3 Defining context

2.2.5.3.1 Preferred Context

The article mentioned above also provides a very neat defining context for the term under investigation: [51]

*"The active layer is made up of two light-absorbing organic semiconductors, one with an electron-donating character (donor) and the other with an electron accepting character (acceptor). These semiconductors could either be deposited as two distinct layers where the donor–acceptor interface resides only between the two layers (**bilayer heterojunction**), or be blended as an almost homogeneous mix where interfacial interaction between donor and acceptor exists throughout the blended bulk layer."*

2.2.5.3.2 Other Contexts

The majority of sources on *bilayer heterojunction* describes the concept in relation to another term, namely *bulk heterojunction*. Both the heterojunctions represents a specific typology of active layer and own different characteristics. Thus, it is vital to highlight the features of both terms in order to distinguish them and avoid confusion. The following excerpt further proves the co-occurrence of the two terms:

*"While in the **bilayer heterojunction** the donor and acceptor phases are completely separated from each other and can selectively contact the anode and cathode, in the bulk heterojunction both phases are intimately intermixed*". [52]

Furthermore, an image is provided to graphically clarify the distinction regarding the structure of the two type of heterojunctions: [53]

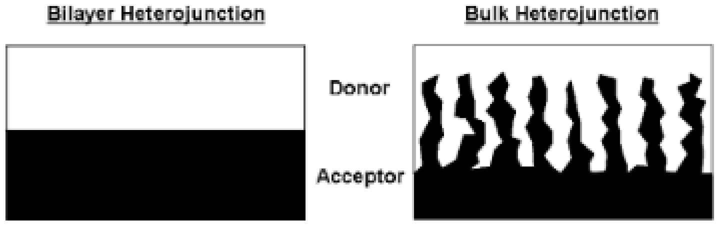


Figure 4. Illustration of bilayer and bulk heterojunction active layers.

Other extracts highlight the limits of the bilayer heterojunction and the reason why the bull heterojunction is preferred:

"Since the ***bilayer heterojunction*** *concept was proposed in 1986 by Tang et al., many advances in bilayer solar cells has been achieved through the use of various material combinations. Although bilayer devices can exhibit good charge transport, their power conversion efficiencies (PCEs) are limited by the small interface between the electron donor and acceptor.*
Moreover, the short exciton diffusion lengths of the organic materials […] restrict the thickness of the active layer, leading to inefficient absorbance. To overcome these problems, Heeger et al.proposed the use of bulk heterojunction (BHJ) solar cells." [54]

*"****Bilayer heterojunction*** *architecture has been intensively investigated and still is an invaluable tool for the evaluation of new active materials, nevertheless, performance of OPVs based on this structure is limited by the short exciton diffusion length in organic materials ".* [55]

2.2.5.3.3 Synonym Context

Planar heterojunction represents a synonym of *bilayer heterojunction*. Many occurrences of the term were found in a variety of patents and scientific articles.

2.2.5.4 Translated term

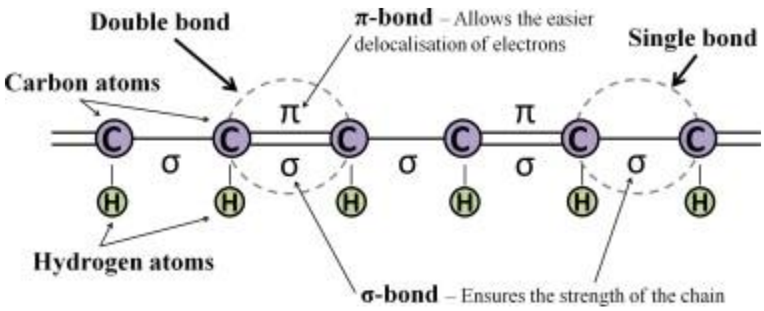
The Spanish equivalent of the term, namely **heterounión de bicapas**, has been encountered in the review 'Acta Universitaria' of the University of Guanajuato. The following fragment has been extracted from the publication number 5 of the volume 22:

"Los polímeros funcionan como materiales del tipo p-conductores de huecos- y, de forma general, el fullereno tiene el carácter del tipo n-aceptor y conductor de electrones. Las combinaciones de estos materiales dan origen principalmente a dos tipos de arquitecturas las cuales son conocidas como "**heterounión de bicapas**" y "heterounión de volumen" (BHJ). En la primera, los materiales son depositados en forma de capas secuenciales, una encima de la otra entre los dos electrodos." [56]

2.2.6 CONJUGATED POLYMER

2.2.6.1 Image

The illustration depicts "a simplified schematic of a conjugated backbone: a chain containing alternating single and double bonds".



2.2.6.2 Source of the term

The term "**conjugated polymer"** was found in the patent US20130276886A1 'Polymer solar cells and functionalized conjugated polymers'. [57]

2.2.6.3 Defining contextual fragments

2.2.6.3.1 Preferred Context

The most complete and accurate definition of **conjugated polymer** is given by the review called '*Polymer International*': [58]

"Conduction with the help of delocalized π-electrons is, however, possible in ***conjugated polymers****. These polymers are characterized by a succession of conjugated (alternating single and double) bonds. There is one π-orbital perpendicular to the plane of the macromolecule in addition to the in-plane σ-orbitals. The π-electrons are delocalized over several carbon atoms in the chain to form π-bands. The presence of an energy gap between the filled and empty bands imparts a semiconducting nature to the polymer instead of a metallic one. The delocalized π-electrons are primarily responsible for the electrical and optical properties in these systems.*

2.2.6.3.2 Other Contexts

Another clear definition was encountered in the e-book '*The Physics of Polymers':* [59]

"The large majority of polymers […] have similar electrical and optical properties: They are insulators and they are colorless, i.e., they possess no mobile charges and the lowest electronic excitations are in the UV region. There exists a peculiar class of polymers with quite different properties; these are ***polymers with conjugated*** *double* ***bonds*** *in the main chain. They are semiconductors or conductors and interact with light."*

Other defining contexts related to the concept were found in patents.

- Patent US20130214213A1 [60]

"***Conjugated polymers*** *have shown some promise in providing a photovoltaic effect. Conjugated polymers are made of alternating single and double carbon-carbon (C—C) or carbon-nitrogen (C—N) bonds. The conjugated polymers have a δ-bond backbone of interesting* sp^2 *hybrid orbitals. The* p_z *orbitals on the carbon atoms overlap with neighboring* p_z *orbitals to provide π-bonds. The electrons that comprise the π-bonds are delocalized over the whole molecule. These polymers exhibit electronic properties similar to those seen in inorganic semiconductors. The semiconducting properties of the photovoltaic polymers are derived from their delocalized π-bonds."*

- Patent US20130276886A1 [61]

"*A functionalized* ***conjugated polymer*** *comprising alternating copolymer donor and acceptor units in which at least one of the donor and acceptor units comprises a linking group and a functional group attached to the linking group."*

An additional feature of the term is given by the following fragment taken from a PhD thesis:

"*In general, the* ***conjugated polymer*** *such as P3HT is the dominant absorber of incident sunlight having a band-gap ~1.9 – 2.1 eV."* [62]

Moreover, the review '*Photosynthesis Research'* demonstrates the relationship existing between conjugated polymer and active layer. Here is an extract of the source: [63]

Interest in organic solar cells stems primarily from the promise of ease of processing. This is because, to date, many organic solar cell devices have used polymers as integral parts of their construction. For example, conjugated polymers often participate as electron donors and hole conductors in the active layer of organic solar cells.

Similarly, the link between the terms is also shown in the book "*Organic Solar Cells, Green Energy and Technology*": [64]

"Typically, the active layer PSC device is composed of a blend film of conjugated polymer (as electron donor) and a small molecular acceptor."

2.2.6.3.3 Synonym Contexts

Further interesting sources supplied synonyms of the term "**conjugated polymer"**. Therefore, it was essential to deepen the research and examine more aspects related to the concept.
The e-book '*Organic Optoelectronic Materials*' explained the scientific reason for calling conjugated polymers as **conducting polymers** under particular circumstances:

*"The unique characteristic of conducting polymers is the conjugated molecular structure of the polymer main chain where the π-electrons delocalize over the whole polymer chain. **Conjugated polymers** become **conducting polymers** after doping."* [65]

In other instances, the concept **π-conjugated polymer** is proved to be used as a synonym of the head term. Here is an example taken from the e-book '*Polymer Photovoltaics: Materials, Physics and Device Engineering*': [66]

Organic semiconducting materials have become the cornerstone of organic electronics, including photovoltaic cells, light-emitting diodes, field effect transistors, and electrochromic devices. The synthesis of new organic semiconducting materials and the development of new synthetic methods for preparing semiconducting organic materials are two important issues that have attracted great attention. In this chapter, we mainly focus on the new chemistry for the synthesis of conjugated polymers used for organic photovoltaics.

Palladium-mediated cross-coupling reactions such as Suzuki–Miyaura, Sonogashira, Heck, and Stille reactions have been widely used in the synthesis of π-conjugated semiconducting materials. Recently, some new π-conjugated donor–acceptor type copolymers have shown great prospects for photovoltaic cell applications.

However, not being utterly familiar with the subject area of investigation and neither with the jargon used, I decided to look up the terms above mentioned in the '*Encyclopedia of Polymeric Nanomaterials* (Springer)' to verify whether the research conducted up to that point and my understanding was correct. The head term, i.e. **conjugated polymer,** and its synonyms, namely **conducting polymer** and **π-conjugated polymer**, contained in the contextual fragments illustrated above, were encountered. Regarding the synonym **π-conjugated polymer**, there is evidence that it can be substituted with the equivalent **pi-conjugated polymer** as the following extract from a patent (US8097348B2) illustrates:

"Thus, certain pi-conjugated polymers are well known to possess semiconducting properties which are due to the formation of interconnected molecular orbitals along the pi-bonding and pi-antibonding structure of the conjugated backbone." [67]

However, **pi-conjugated polymer** presents few occurrences within the sources compared to its equivalent term that uses the symbol "π" instead of the corresponding letters "pi". Perhaps, the symbol is considered more appropriate for scientific purposes.

2.2.6.4 Translated term

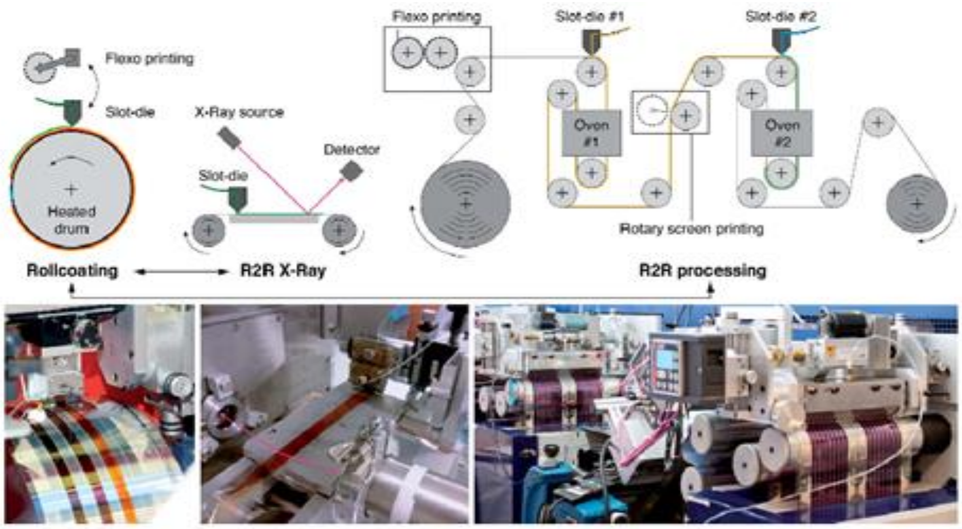
An occurrence of the equivalent Spanish term, which is ***polímero*** **conjugado**, is showed in the following excerpt, taken from the Master's thesis '*Células solares transparentes: desarrollo actual y aplicaciones*':

*"Se utilizan **polímeros conjugados** capaces de conducir los electrones. La especial configuración de sus enlaces, alternando dobles y simples, permite la conducción electronica como semiconductor, obteniendo comportamientos análogos a semiconductores inorgánico dopados. Los materiales moleculares presentan propiedas semiconductoras cuando sus átomos de carbono presentes en la molécula o en la cadena polimérica están unidos como orbitales hidridos $sp^2 + p_z$. Los orbitales p_z forman orbitales moleculares π y π^* deslocalizados, los cuales son reconocidos como la alternancia de unions "simples" y "dobles" carbon-carbón."* [68]

2.2.7. ROLL-TO-ROLL PROCESS

2.2.7.1 Image

The image taken from '*Energy and environment science*' e-journal shows systematic *roll-to-roll* processing methods (above) and the corresponding photographs (below). [69]



2.2.7.2 Source of the term

The term **roll-to-roll process** is used in the patent US20150056735A1 ‘*Method for manufacturing membrane layers of organic solar cells by roll to roll coating*’. [70]

2.2.7.3 Defining contextual fragments

2.2.7.3.1 Preferred context

The most meticulous defining context found is contained in an article of the ‘*Journal of Materials Chemistry*’: [71]

> In summary, the R2R process (scheme in Fig. 1a) is characterized by the deposition of a polymer solution (ink) by using a roll (gravure roll) with an engraved texture that allows us to print the ink on the desired flexible substrate. The gravure roll is partially immersed in the ink container and during the rotation it draws ink out of the ink container with it. A blade pushes and scrapes the roll before to come in contact with the substrate in order to remove the excess polymer. Then the substrate moves between the impression roll and the gravure roll; the impression roll applies a force and pushes the substrate on the gravure roll allowing the transfer of the ink. Then, a hot air flow drier included along the R2R line provides a thermal treatment on the ink for drying it, thus obtaining a dry, homogeneous polymer film. The flexible substrate coated with film is finally collected using an output roll, by recovering it on a reel.

2.2.7.3.2 Other contexts

Another source, the ‘*Journal of Materials Chemistry*’, explains the feature of innovation and of this peculiar kind of printing technique:

“*These latest developments bring roll-to-roll inkjet printing production of OPVs a step closer, by proving the feasibility of creating these devices reliably using a high-volume* ***roll-to-roll process****.” [72]*

In addition, the fragment included in the patent WO2013100284A1 presents the *roll-to-roll process* as an advantageous and cheap production system of OPVs: [73]

“*Organic solar cells […] can be produced in large quantities due to their easy processability and low cost, and can be manufactured into thin films by a* ***roll-to-roll process****. Therefore, the organic solar cells have an advantage that flexible, large-sized electronic elements can be produced.”*

2.2.7.3.3 Synonym contexts

First of all, it is important to highlight two facts: the concept **roll-to-roll process** is frequently written without dashes and *‘roll-to-roll’* can be replaced with the acronym *R2R*. These types of variations are interchangeable. Secondly, it is possible to notice that the head term is often substituted with a considerable number of synonyms.
For instance, many sources show the usage of **roll-to roll processing:**

“*R2R processing is generally considered to offer a viable route to mass production of polymer.”*
(Royal Society Chemistry Advances) [74]

Moreover in “*Nanomaterials, Polymers and Devices: Materials Functionalization and Device fabrication*” e-book: [75]

“*Production of the modules can be performed by* ***roll-to-roll (R2R) processing****, where a roll of substrate is rolled through different deposition steps and rerolled, which introduces tremendous advantages in production capacity and module price.”*

Other sources prefer a different terminology: ***roll-to-roll methods*** (in ‘*Royal Society Chemistry Advances’*) :

“Polymer and organic solar cells (OPV) have reached a technological level where they can be manufactured using fast roll-to-roll based methods.” [76]

In both cases, the terms emphasise the idea that the process involves a complex of techniques and phases. The basic idea is also shared by the synonyms of the head term, namely ***roll-to-roll***

manufacturing, roll-to-roll production, roll-to roll technology, ***roll-to-roll techniques*** and ***roll-to-roll fabrication process.***

Instances are given respectively by the e-book '*Organic Thin Film Transistor Integration: A Hybrid Approach'* and the e-journal '*Science and Education Publishing':*

*"The development of high-volume **roll-to-roll manufacturing** platforms for fabrication of organic circuits on continuous, flexible, low-cost substrates, has been reported. These platforms are based on the integration of lithography, vacuum deposition, and printing technologies. It has been forecast that an organic semiconductor fabrication facility can be built for far less than the cost of a silicon semiconductor fabrication facility."[77]*

*"Since organic materials are highly compatible with a wide range of substrates, they present versatility in their production methods. These methods include solution processes (inks or paints), high throughput printing techniques, **roll-to-roll technology** and many more, that enable organic solar cells to cover large thin film surfaces easily and cost-effectively."[78]*

2.2.7.4 Translated term

The literal equivalent term of roll-to-roll process in Spanish is **proceso rollo a rollo.** However, the following definition provides an example of a synonym, which is **flexicografía**. It has been extracted from the Master's thesis 'Optimización de los procesos de fabricación de células solares orgánicas mediante técnicas de impression':

*"R2R **Flexicografía:***
Funciona mediante un cilindro, parcialmente inmerso en un tanque donde la tinta le es transferida continuamente, y queda retenida en figuras previamente grabadas en el exterior de dicho cilindro. Esto permite que se deposite la tinta y así poder imprimirla o depositarla hacia una imagen 3D espejo en otro cilindro, lo que permite realizar la transferencia final." [78]

The following fragment – taken from the Master's thesis 'Evaluación de tecnologías fotovoltaicas orgánicas' - shows another variant. Many source leave the English term untranslated:

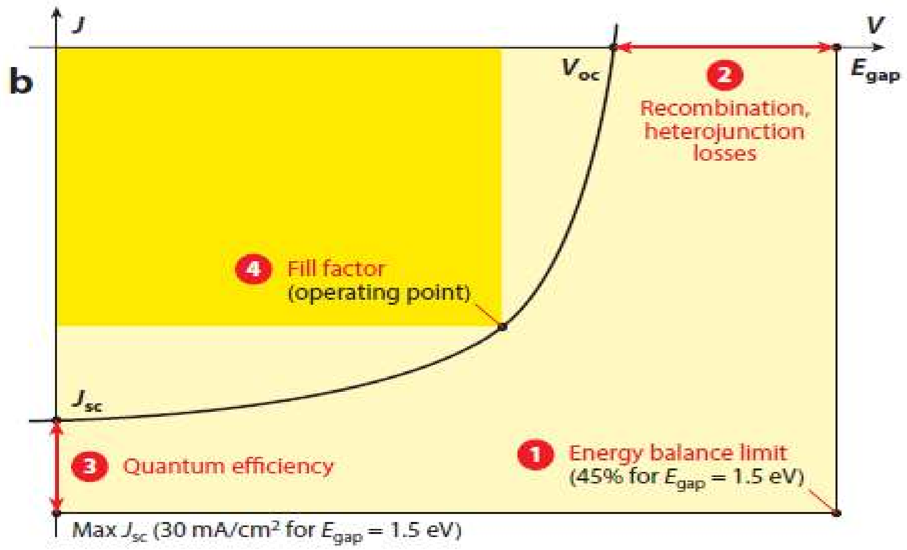
*"La mayor productividad con el menor coste de fabricación se puede conseguir mediante la técnica de **roll-to-roll**. Se trata de un sistema sencillo. Un sustrato largo (flexible o rígido) se desliza por un*

sistema de rodillos mientras las distintas capas que forman la célula solar se van depositando encima. Se consiguen productividades del orden de 10.000 m2/h a costes menores de 30 €/m." [79]

2.2.8. POWER CONVERSION EFFICIENCY

2.2.8.1 Image

The image below illustrates how some factors, such as energy balance limit, recombination and heterojunction losses, quantum efficiency, and fill factor contribute to the definition of the power conversion efficiency of an OPV device. [80]



2.2.8.2 Source of the term

The term '**power conversion efficiency**' appears in the patent WO2015171689 '*Functional interlayers of fullerene derivatives and applications in organic solar cells*'. [81]

2.2.8.3 Defining Contexts

2.2.8.3.1 Preferred Context

A direct definition of **power conversion efficiency** is outlined in the PhD Thesis *'New Architectures and Designs for Organic Photovoltaics'*: [82]

The power conversion efficiency of an OPV is defined as the ratio between power incident on the device active area from the sun to the maximum power extracted at the electrodes

$$\eta_{PCE} = \frac{P_{MAX}}{P_{IN}} = \frac{J_{MPP}V_{MPP}}{P_{IN}} = \left(\frac{J_{SC}V_{OC}}{P_{IN}}\right) \times FF \qquad (4.11)$$

However, the meaning of the formula is accessible only to those with scientific and mathematical backgrounds, which is why the complete explanation of the formula has not been provided. In addition, other sources had not been showed or cited in this report due to the complexity of the equations used to describe the concept of *power conversion efficiency* for lay people.

2.2.8.3.2 Other Contexts

The following fragments, containing the term under investigation, i.e. *power conversion efficiency*, are here gathered since they provide similar and related information about the concept.

Power conversion efficiency is a parameter used to evaluate the performance of the organic solar cell. That is expressed in the following extract of '*Journal Materials Chemistry*': [83]

*"The sun is a reliable source of luminous energy with an essentially constant power output. From this point of view, it is an excellent light source when testing the **power conversion efficiency** of a device and it is of course also the real source of light energy against which one has to measure the efficiency of a given device when it comes to energy production using a photovoltaic in a real application."*

Another fragment has been selected from the e-book *'Characterization of Organic Solar Cells':[84]*

"*To reach high **power conversion efficiency** organic solar cells, electrons and holes have to be generated with high quantum and energy efficiency, and subsequently be transported and collected selectively at opposite electrodes."*

Overall, considering the examples above, it is noticeable that the term is defined more accurately through equations although they require a specific knowledge of the subject area by the reader.

2.2.8.3.3 Synonym Context

Energy conversion efficiency is a synonym of power conversion efficiency. However, it is rarely used in texts. The following are two fragments taken from the e-journal '*Science of Education publishing*': [85]

"Consequently, the energy conversion efficiency doesn't have to be as high as the conventional cell's efficiency. An extensive use of organic solar cells could contribute to the increased use of solar power globally and make renewable energy sources friendlier to the average consumer."

"Therefore, the commercialization seems only possible by maximizing the energy conversion efficiency through a development of new conjugation system organic materials with reduced band gap."

However, in many instances the term is replaced with its acronym **PCE** due to the fact that scientific jargon tend to prefer the usage of notations.

2.2.8.4 Translated term

An occurrence of the equivalent term, which is ***eficiencia de conversion energética***, has been extracted from the PhD thesis 'Espectroscopia de absorción transitoria como instrumento de investigación en fotovoltaica orgánica: estudios de generación de carga en la mezcla activa de celdas solares, caso de estudio: fluorinacion de polímero': [86]

"*La **eficiencia de conversion energética**" (η o PCE, Power conversion efficiency) es la figura de merito principal en todas las celdas solares. PCE se define como la relación entre la máxima densidad de potencia que se puede extraer de la celda,* I_{out}^{max} *, y la irradiancian incidente que entra a la celda* I_{in}*. Hay una manera sencilla de calcular este cociente usando variables medibles en el laboratorio, como se muestra en la Ecuacion 1.*

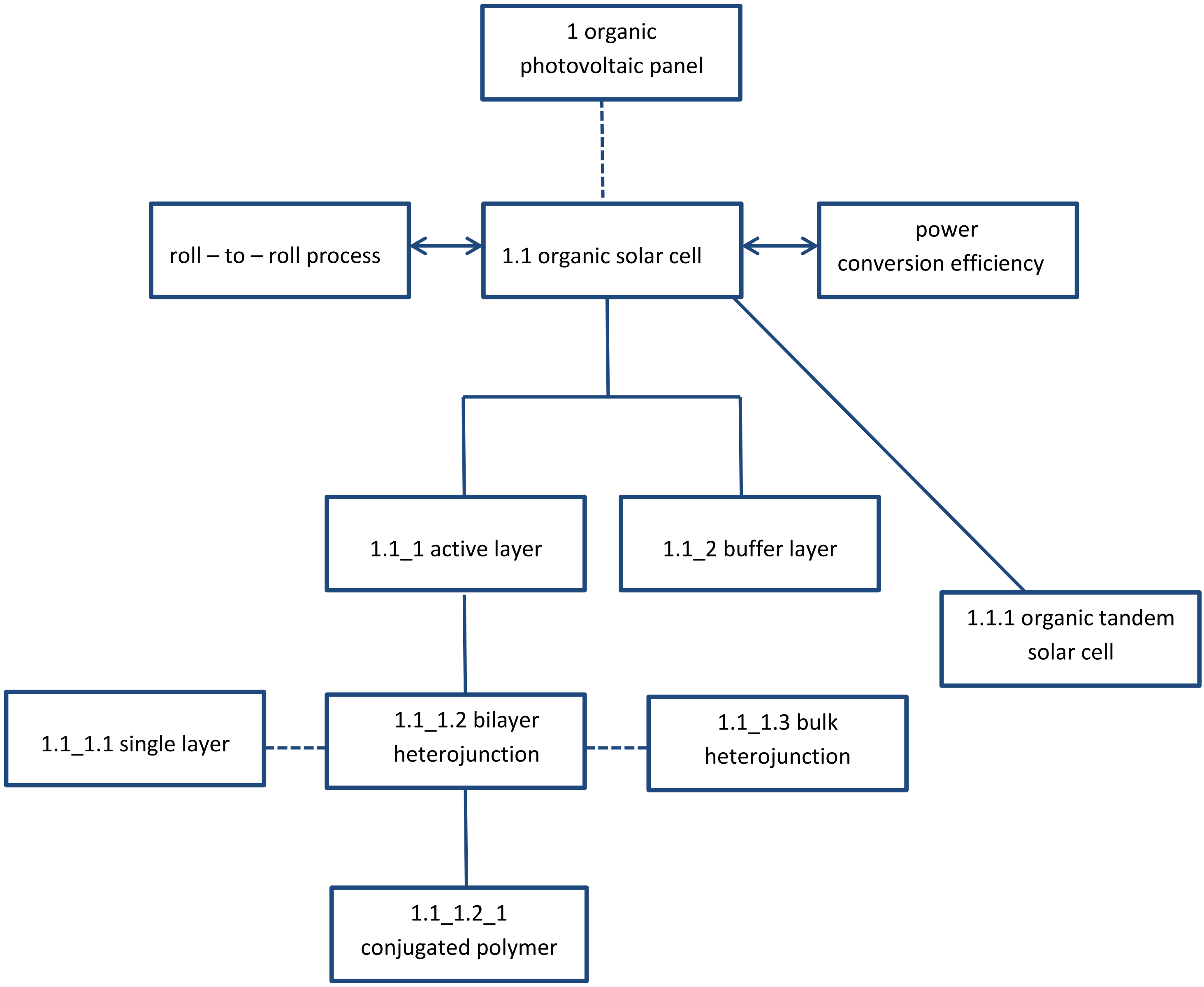
Ecuación 1

$$\eta = \frac{I_{max,out}}{I_{in}} = \frac{FF \cdot J_{SC} V_{OC}}{I_{in}}$$

SECTION 3. THE GRAPHIC REPRESENTATION OF CONCEPTS

This section contains a diagram representing the structure of an Organic Photovoltaic device.

The solid line represents the concept relation between each of the 8 terms included in the concept system of this report, whereas the dash line defines the relation between the extra terms, not part of the concept map but useful to render it more complete, namely *Organic Solar Panel, Single layer* and *Bulk heterojunction.*



SECTION 4. TERM RECORDS

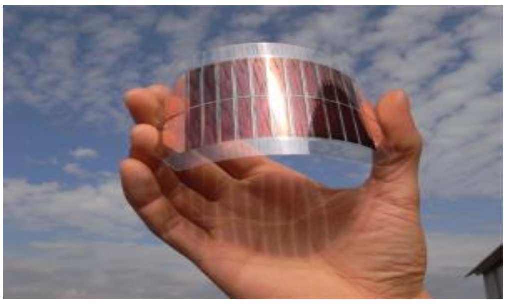
4.1 Premise

This section is dedicate to the compilation of the term records. Each of the eight English terms are associated with their respective translations into Spanish. The terms are presented through a "hierarchical" classification rather than an alphabetical one *('Recommendation for work terminology').* The essential data is integrated with extra information, namely short form of the preferred term and synonyms. An illustration is also provided in order to visualize the concept.

4.2 Term records

1. ORGANIC SOLAR CELL

IMAGE



ENTRY LEVEL

Subject field: ENGY (Energy & Fuels)

Subfield: Solar energy

Concept relation: generic

Original entry language: EN - English

TERM LEVEL

Term: organic solar cell

Term type: head term

Context: *"**Organic solar cells** (OSC) or organic photovoltaics (OPV) based on 77-conjugated polymers (e.g. poly-3-hexylthiophene (P3HT)) and fullerene derivatives (e.g. [6,6]-phenyl C61 butyric acid methyl ester (PCBM)) have attracted attention over the past decades because they may provide a cost-effective route to wide use of solar energy for electric power generation. These organic semiconductors have the advantage of being chemically flexible for material modifications, as well as mechanically flexible for the prospective of low-cost,* *large scale processing such as screen-printing or spraying on flexible substrates. […] The photovoltaic process in organic solar cell devices consists of four successive possesses: light absorption, exciton dissociation, charge transport, and charge collection. Absorption of a photon creates an exciton (bounded electron-hole pair). The exciton diffuses to the interface of two different components, where exciton dissociation, or charge separation, occurs, followed by positive charges (*holes) moving to the anodes and negative charges (electrons) to the cathode."

Source: WO/2011/068968A2

OTHER INFORMATION:

Short form: OSC, OPV

Synonym: organic photovoltaic cell, polymer solar cell, polymer-based solar cell, plastic solar cell

Target language: **ES - Spanish**

TERM LEVEL

Term: célula solar orgánica

Term type: head term

Context: "La sucesión de pasos en la generación de electricidad en una **célula solar orgánica** sería, entonces: se absorbe un fotón en el polímero; el excitón emigra (se difunde) dentro del dominio del polímero hasta que alcanza una interfaz con el fulereno; entonces debido a la distinta afinidad electrónica y a la diferencia energética, el electrón salta al fulereno dejando el hueco en el polímero, es decir, se produce una transferencia de carga. Una vez se separa el excitón en cargas libres, éstas se transportan por dominios de cada uno de los materiales que percolan hasta ser recogidas en los contactos. Esta forma de funcionar establece un punto clave que desde entonces se ha mantenido se necesitan dos semiconductores para que la célula solar funcione, uno tipo p (o donante de electrones) y otro tipo n (o aceptor de electrones)."

Source: Revista Española de Fisica, Enero-Marzo 2014

Term: celda solar orgánica

Term type: head term

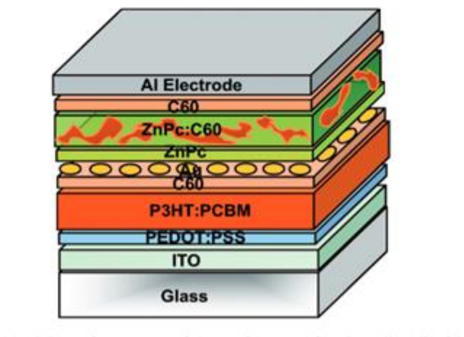
Context: *"Las **celdas solares orgánicas** usan semiconductores de carbono para los procesos de absorción, generación y transporte de cargas, las cuales se colectan finalmente en los electrodos metálicos. El reto principal de usar materiales orgánicosse centra en la generación*

eficiente de cargasa pesar de sus constantes dieléctricas bajas, comparadas con las de los materiales inorgánicos, en los que la generación de cargas libres sucede es inmediata. Una constante dieléctrica pequeña produce la formación de "excitones" es decir, especies excitadas de pseudo-cargas que aun interaccionan fuertemente, en los que la carga positiva remanente en el HOMO (orbital molecular ocupado de mayor energía) interacciona con el electrón que ha sido promovido por la acción de un fotón al LUMO (orbital molecular desocupado de menor energía) todo esto provocando la deformación de los alrededores."
Source: Doctoral Thesis "Espectroscopia de absorción transitoria como instrumento de investigación en fotovoltaica orgánica: estudios de generación de carga en la mezcla activa de celdas solares, caso de estudio: fluorinacion de polímero."

Note: The term **célula solar orgánica** is taken from Spanish sources, while **celda solar orgánica** is extracted from Latin American Spanish ones.

2. ORGANIC TANDEM SOLAR CELL

IMAGE



ENTRY LEVEL

Subject field: ENGY (Energy & Fuels)

Subfield: Solar Energy

Concept relation: Specific

Original entry language: **EN – English**

TERM LEVEL

Term: organic tandem solar cell

Term type: head term

Context 1: *"An organic tandem photovoltaic device includes a first electrode, a second electrode spaced apart from said first electrode, first and second photoactive organic bulk heterojunction layers, and an interconnecting layer. The interconnecting layer is between and electrically connects the first and second photoactive organic bulk heterojunction layers. […] [It] is required in connecting two adjacent photovoltaic devices. The desired functions of the interconnecting layer are to facilitate rapid charge carrier injection and provide recombination centers for injected charge carriers to recombine so the currents from two adjacent photovoltaic cells can match up equally. Most importantly, only a well-designed interconnecting layer can effectively increase the performance of* ***organic tandem solar cells*** *far beyond the performance of each individual solar cell."*

Source: WO/2014/144028A1

Context 2: **"*Organic tandem solar cells*** with two or more subcells electrically coupled in series have the unique advantage that the open circuit voltage (V_Oc) is increased to the sum of the V_Oc of the individual subcells."

Source: WO/2010/036963A1

OTHER INFORMATION:

Short form: n/a

Synonym: polymer tandem solar cells, double junction polymer solar cell, multi-layer polymer solar cell and organic photovoltaic multi-cell

Target language: **ES – Spanish**

TERM LEVEL

Term: célula solar orgánica tipo tándem

Term type: head term

Context: *"Desde que se fabricó la primera célula solar orgánica, muchos han sido los avances que se han realizado con el objetivo de mejorar la eficiencia de la conversión de ellos pueden citarse la generación múltiple de excitones, el empleo de nanomateriales como las perovskitas o nuevas arquitecturas como la tándem.*

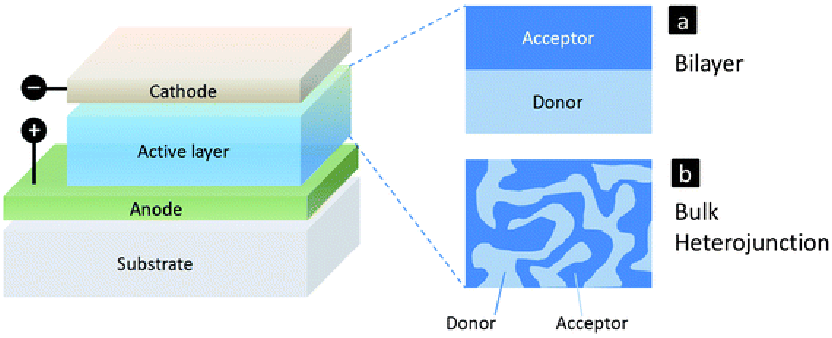
El concepto de ***célula tándem****, en la que dos o más células solares con ventanas de absorción complementarias se encuentran superpuestas y conectadas (en serie o en paralelo), es uno de los avances más prometedores para solucionar uno de los problemas más relevantes de las OSCs: la pérdida de fotocorriente o corriente de cortocircuito, I*

SC, debido a una baja absorción de fotones."

Source: Master thesis **"**Utilización de polímeros de bajo band-gap en células fotovoltaicas"

3. ACTIVE LAYER

IMAGE



ENTRY LEVEL

Subject field: CHEM (Chemical & Materials Technology)

Subfield: Chemical elements & compounds

Concept relation: partitive

Original entry language: **EN - English**

TERM LEVEL

Term: active layer

Term type: head term

Context: *"The **active layer** of conventional organic photovoltaic (OPV) devices comprises two organic semiconductor layers: an electron donor layer containing organic molecules with a low electron affinity (low LUMO level, Lowest Unoccupied Molecular Orbital level) and low ionization potential (low HOMO level, Highest Occupied Molecular Orbital level), and an electron acceptor layer containing organic molecules with a higher LUMO-level and a higher HOMO-level than the donor layer. The active layer, which is typically 50 nm to 100 nm thick, is sandwiched between two electrodes."*

Source: WO/2015/011060A1 (patent)

OTHER INFORMATION:

Short form: n/a

Synonym: photoactive layer

Target Language: ES - Spanish

TERM LEVEL

Term: capa activa

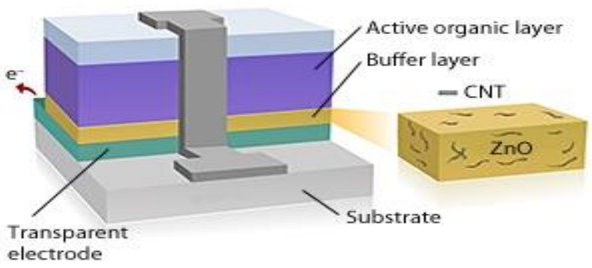
Term type: head term

Context: *[…] **Las capas activas** presentan habitualmente una zona con donadores de electrones y una zona con aceptores de electrones, ambas están mezcladas entre sí y/o están unidas entre sí por ejemplo a través de una capa de agotamiento. Los portadores de carga generados en la capa activa mediante la incidencia de la luz (pares de electrón-hueco) se evacuan mediante aspiración en las capas adyacentes en cada caso por separado."*

Source: ES2323372T3

4. BUFFER LAYER

IMAGE



ENTRY LEVEL

Subject field: CHEM (Chemical & Materials Technology)

Subfield: Chemical elements & compounds

Concept relation: partitive

Original entry language: EN - English

TERM LEVEL

Term: buffer layer

Term type: head term

Context: **"***Often a **buffer layer** is provided between the active layer and the electrodes, for avoiding direct contact between the active layer and the electrodes."*

Source: WO/2015/011060A1

OTHER INFORMATION:

Short form: BL

Synonym: interfacial layer, interlayer

Target language: **ES - SPANISH**

TERM LEVEL

Term: capa tamponadora

Term type: head term

Term: capa intermedia

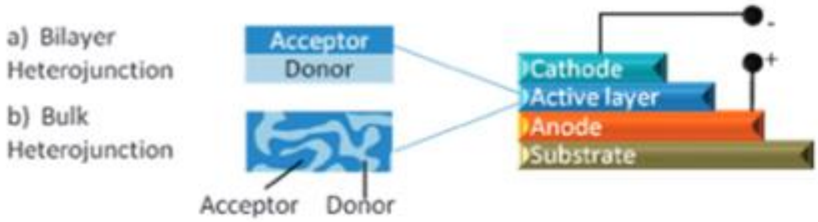
Term type: synonym

Context: “Sobre el electrodo de ITO se sitúa, una **capa intermedia** para disminuir la rugosidad del ITO, evitando así cortocircuitos, y además favorece la extracción de huecos. Esta capa habitualmente está compuesta de PEDOT:PSS (poli-3,4-etilendioxitiofeno con sulfonato de poliestireno). A continuación se depositar a la capa activay aquí es donde se produce el efecto fotovoltaico y la absorción de luz.”

Source: Master thesis “Optimización de los procesos de fabricación de células solares orgánicas mediante técnicas de impression”

5. BILAYER HETEROJUNCTION

IMAGE



ENTRY LEVEL

Subject field: ELEC (Electrical Engineering & Electronics)

Subfield: Electronic components & equipment

Concept relation: specific

Original entry language: **EN - English**

TERM LEVEL

Term: bilayer heterojunction

Term type: head term

Context: "One type of heterojunction device, the **bilayer heterojunction**, can be formed by subliming or spin coating one layer on top of another to form a planar junction. This arrangement is advantageous because electrons and holes travel to their respective electrodes through a thin layer (acceptor or donor) and thus recombination losses are relatively low."

Source: WO/2010/060145A1

OTHER INFORMATION:

Short form: n/a

Synonym: planar heterojunction

Target language: **ES - Spanish**

TERM LEVEL

Term: heterounión de bicapas

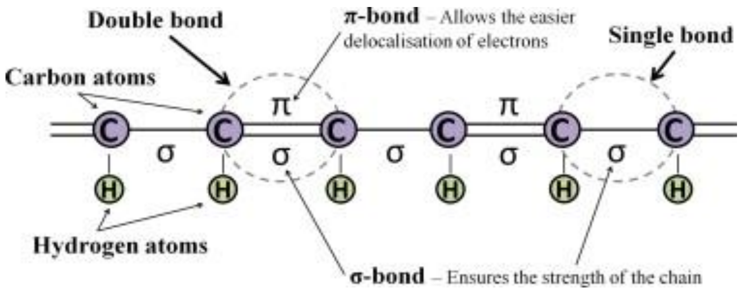
Term type: head term

Context: "Los polímeros funcionan como materiales del tipo p -conductores de huecos- y, de forma general, el fullereno tiene el carácter del tipo n -aceptor y conductor de electrons. Las combinaciones de estos materiales dan origen principalmente a dos tipos de arquitecturas las cuales son conocidas como "**heterounión de bicapas**" y "heterounión de volumen" (BHJ). En la primera, los materiales son depositados en forma de capas secuenciales, una encima de la otra entre los dos electrodos."

Source: Review Acta Universitaria, Vol. 22 N. 5 July - August 2012

6. CONJUGATED POLYMER

IMAGE



ENTRY LEVEL

Subject field: CHEM (Chemical & Materials Technology)

Subfield: Polymers & rubbers

Concept relation: partitive

Original entry language: **EN - English**

TERM LEVEL

Term: conjugated polymer

Term type: head term

Context: *"**Conjugated polymers** are made of alternating single and double carbon-carbon (C-C) or carbon-nitrogen (C-N) bonds. The conjugated polymers have a δ-bond backbone of interesting sp^2 hybrid orbitals. The p_z orbitals on the carbon atoms overlap with neighboring p_z orbitals to provide π-bonds. The electrons that comprise the π-bonds are delocalized over the whole molecule. These polymers exhibit electronic properties similar to those seen in inorganic semiconductors. The semiconducting properties of the photovoltaic polymers are derived from their delocalized π-bonds."*

Source: WO/2015/067336A3

OTHER INFORMATION:

Short form: n/a

Synonym: π-conjugated polymer, pi-conjugated polymer

Target language: **ES - Spanish**

TERM LEVEL

Term: polímero conjugado

Term type: head term

Context: *"Se utilizan **polímeros conjugados** capaces de conducir los electrones. La especial configuración de sus enlaces, alternando dobles y simples, permite la conducción electronica como semiconductor, obteniendo comportamientos análogos a semiconductores inorgánico* *dopados. Los materiales moleculares presentan propiedas semiconductoras cuando sus átomos de carbono presentes en la molécula o en la cadena polimérica están unidos como orbitales hidridos $sp^2 + p_z$. Los orbitales p_z forman orbitales moleculares π y π^* deslocalizados, los cuales son reconocidos como la alternancia de unions "simples" y "dobles" carbon-carbón."*

Source: Master thesis: "Células solares transparentes: desarrollo actual y aplicaciones", September 2011.

7. ROLL-TO-ROLL PROCESS

IMAGE

ENTRY LEVEL

Subject field: ELEC: Electrical Engineering & Electronics

Subfield: Electronic components & equipment

Concept relation: associative

Original entry language: **EN - English**

TERM LEVEL:

Term: roll-to-roll process

Term type: head term

Context: "*Organic solar cells […] can be produced in large quantities due to their easy processability and low cost, and can be manufactured into thin films by a **roll-to-roll process**. Therefore, the organic solar cells have an advantage that flexible, large-sized electronic elements can be produced."*

Source: WO/2013/100284

OTHER INFORMATION:

Short form: R2R

Synonym: roll-to-roll method, roll-to-roll manufacturing, roll-to-roll production, roll-to roll technology, roll-to-roll technique and roll-to-roll fabrication process.

Target language: **ES - Spanish**

Term: procesamiento rollo a rollo

Term type: head term

Term: flexicografía

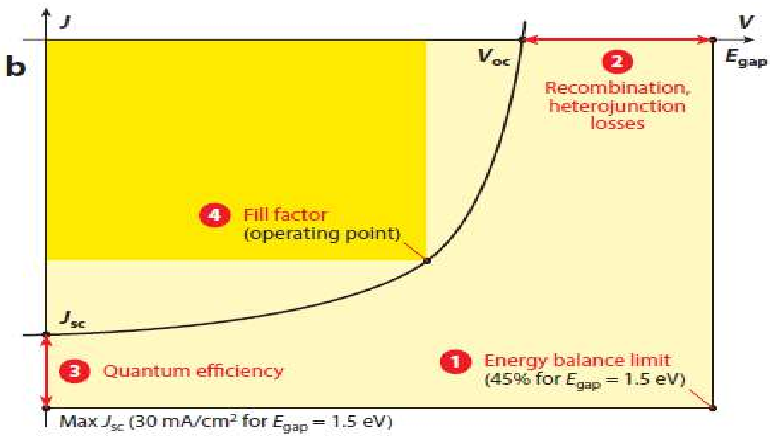
Term type: synonym

Context: *"R2R* ***Flexicografía:***

Funciona mediante un cilindro, parcialmente inmerso en un tanque donde la tinta le es transferida continuamente, y queda retenida en figuras previamente grabadas en el exterior de dicho cilindro. Esto permite que se deposite la tinta y así poder imprimirla o depositarla hacia una imagen 3D espejo en otro cilindro, lo que permite realizar la transferencia final."

Source: Master thesis "Optimización de los procesos de fabricación de células solares orgánicas mediante técnicas de impression"

8. POWER CONVERSION EFFICIENCY



<u>**ENTRY LEVEL**</u>

Subject field: ENGY: Energy & Fuels

Subfield: Solar energy

Concept relation: associative

Original entry language: **EN - English**

TERM LEVEL

Term: power conversion efficiency

Term type: head term

Context: "Several parameters determine the performance of a solar cell, namely, the open-circuit voltage (V_{oc}), short-circuit current ($/_{sc}$), and the so-called fill factor (FF). The overall **power conversion efficiency** η is defined as η = (FF)*($/_{sc}$ V_{oc})/P_m."

Source: WO2011068968A2

OTHER INFORMATION:

Short form: PCE

Synonym: energy conversion efficiency

Target language: **ES- Spanish**

TERM LEVEL

Term: eficiencia de conversión energética

Term type: head term

Context: *"La **eficiencia de conversion energética**" (η o PCE, Power conversion efficiency) es la figura de merito principal en todas las celdas solares. PCE se define como la relación entre la máxima densidad de potencia que se puede extraer de la celda, I_{out}^{max}, y la irradiancian incidente que entra a la celda $I_{in.}$ Hay una manera sencilla de calcular este cociente usando variables medibles en el laboratorio, como se muestra en la Ecuación 1.*

Ecuación 1

$$\eta = \frac{I_{max,out}}{I_{in}} = \frac{FF \cdot J_{SC}V_{OC}}{I_{in}}$$

Source: Doctoral thesis "Espectroscopia de absorción transitoria como instrumento de investigación en fotovoltaica orgánica: estudios de generación de carga en la mezcla activa de celdas solares, caso de estudio: fluorinacion de polímero."

BIBLIOGRAPHY

[1] Flora M. Li, Arokia Nathan, Yiliang Wu, and Beng S. Ong, Wiley: 2011 Organic Thin Film Transistor Integration: A Hybrid Approach, pp.270.

[2] Organic Photovoltaics: Materials, Device Physics, and Manufacturing Technologies, Christoph Brabec, Ullrich Scherf, Vladimir Dyakonov (editors), Wiley, 2014, 642

[3] New Architectures and Designs for Organic Photovoltaics, Nigel John Alley, Doctoral thesis, Dublin City University, April, 2012, pp.208

[4] Comparison of Organic Solar Cells and Inorganic Solar Cells, Askari Mohammad Bagher, Vol.3, No.3, 2014, pp.53-58, doi: 10.11648/j.ijrse.20140303.12.

[5] Energy for life – Organic Photovoltaics opens up new architectural opportunities, Sophie Verstraelen, 2015, pp.1-3, id:176192

[6] Sustainable energy, Askari. Mohammad Bagher, Science of Education publishing, Vol.2, No.3, 2014, 85-90, doi: 10.12691/rse-2-3-2

[7] US9184392B2

[8] DE102010028945A1

[9] Conjugated polymer nanostructures for organic solar cell applications, Jiun-Tai Chen et al., Polymer Chemistry, Vol.2, 2011, 2707, doi: 10.1039/c1py90032c

[10] Conjugated polymer nanostructures for organic solar cell applications, Jiun-Tai Chen et al., Polymer Chemistry, Vol.2, 2011, 2707, doi: 10.1039/c1py90032c

[11] Sustainable energy, Askari. Mohammad Bagher, Science of Education publishing, Vol.2, No.3, 2014, 85-90, doi: 10.12691/rse-2-3-2

[12] New Architectures and Designs for Organic Photovoltaics, Nigel John Alley, Doctoral thesis, Dublin City University, May, 2012, 101-102

[13] Sustainable energy, Askari. Mohammad Bagher, Science of Education publishing, Vol.2, No.3, 2014, 85-90, doi: 10.12691/rse-2-3-2

[14] Conjugated polymer nanostructures for organic solar cell applications, Jiun-Tai Chen et al., Polymer Chemistry, Vol.2, 2011, 2707, doi: 10.1039/c1py90032c

[15] Sustainable energy, Askari. Mohammad Bagher, Science of Education publishing, Vol.2, No.3, 2014, 85-90, doi: 10.12691/rse-2-3-2

[16] Sustainable energy, Askari. Mohammad Bagher, Science of Education publishing, Vol.2, No.3, 85-90, doi: 10.12691/rse-2-3-2

[17] Inorganics-in-Organics': recent developments and outlook for 4G polymer solar cells, Imalka Jayawardena et al., Nanoscale, Vol.5, 2013, pp. 8411–8427, doi: 10.1039/c3nr02733c

[18] Células solares basadas en plásticos semiconductores, Mariano Campoy Quiles, Revista Española de Física, Vol.28, No.1, 2014, 8

[19] Espectroscopia de absorción transitoria como instrumento de investigación en fotovoltaica orgánica: estudios de generación de carga en la mezcla activa de celdas solares, caso de estudio: fluorinacion de polímero, Elisa Collado Fregoso, Doctoral thesis, Imperial College London, May, 2013, p.8

[20] Small molecule semiconductors for high-efficiency organic photovoltaics, Yuze Lin et.al, Chemistry Society Review, Vol. 41, No.11, 2012, pp. 4245-4272, doi:10.1039/c2cs15313k

[21] Extremely stable all solution processed organic tandem solar cells with TiO_2/GO recombination layer under continuous light illumination, Abd. Rashid bin Mohd Yusoff et. al, Nanoscale,5,3013, pp. 11051-11057 doi: 10.1039/c3nr03068g

[22] Tandem polymer photovoltaic cells—current status, challenges and future Outlook, Srinivas Sista et. al, Energy & Environmental Science, Vol.4, 2011, pages 1606–1620, doi: 10.1039/c0ee00754d

[23] Organic Tandem Solar Cells: A Review, T. Ameri, et.al, Energy & Environmental Science, Vol. 2, 2009, Pages, 347-363, doi: 10.1039/b817952b

[24] Organic Tandem Solar Cells: A Review, T. Ameri, et.al, Energy & Environmental Science, Vol. 2, 2009, Pages, 347-363, doi: 10.1039/b817952b

[25] Utilización de polímeros de bajo band-gap en células fotovoltaicas, Rocío García Martínez, Master thesis, Universidad Politecnica de Cartagena, July,2015, p.12

[26] Organic non-fullerene acceptors for organic photovoltaics, Prashant Sonar et al., Energy & Enviromental. Science., Vol.4, 2011, 1558-1574, doi:10.1039/c0ee00668h

[27] WO/2015/171689

[28] Supramolecular Approaches to Nanoscale Morphological Control in Organic Solar Cells, Alexander M. Haruk et. al, International Journal of Molecular Sciences, 2015, pp. 13381-13406, doi: 10.3390/ijms160613381

[29] Supramolecular Approaches to Nanoscale Morphological Control in Organic Solar Cells, Alexander M. Haruk et. al, International Journal of Molecular Sciences, 2015, pp. 13381-13406, doi: 10.3390/ijms160613381

[30] New Architectures and Designs for Organic Photovoltaics, Nigel John Alley, Doctoral thesis, Dublin City University, May, 2012, p.9

[31] Theoretical Description of Structural and Electronic Properties of Organic Photovoltaic Materials, Andriy Zhugayevych and Sergei Tretiak, Annual Review of Physical Chemistry, Vol. 66, 2015, pp. 305-330, DOI: 10.1146/annurev-physchem-040214-121440

[32] WO/2015/011060A1

[33] Solar Cells, Materials, Manufacture and Operation, Clare Dyer-Smith, Jenny Nelson, London, Blackett Laboratory, 2013, pp. 443–466

[34] Advanced materials and processes for polymer solar cell devices, Martin Helgesen et al., Journal of materials chemistry, 2009, pp.36-60, doi: 10.1039/b913168j

[35] Introduction to Organic Solar Cells, Askari. Mohammad Bagher, Sustainable Energy, Vol. 2, No. 3, 2014, pp. 85-90, doi: 10.12691/rse-2-3-2

[36] ES2323372T3

[37] Celdas solares orgánicas, una perspectiva hacia el futuro, William Adolfo Chamorro et al., Revista Elementos, Vol.2, No 1, 2012,

[38] US20140084266A1

[39] US20140084266A1

[40] WO/2015/011060A1

[41] EP2348556A1

[42] An effective bilayer cathode buffer for highly efficient small molecule organic solar cells, Hao-Wu Lin et al., Organic Electronics, vol. 13, Issue 10, 2012, pp. 1925–1929,

[43] Simple synthesis of solution-processable oxygen-enriched graphene as anode buffer layer for efficient organic solar cells, Qianqian Zhu et al., Organic Electronics, Vol.27, 2015, pp.143–150, doi: 10.1021/nl2038979

[44] The role of buffer layers in polymer solar cells, Riccardo Po et al., Energy & Environmental Science, Vol.4, 2011, pp.285-310, doi: 10.1039/c0ee00273a

[45] The role of buffer layers in polymer solar cells, Riccardo Po et al., Energy & Environmental Science, Vol.4, 2011, pp.285-310, doi: 10.1039/c0ee00273a

[46] The role of buffer layers in polymer solar cells, Riccardo Po et al., Energy & Environmental Science, Vol.4, 2011, pp.285-310, doi: 10.1039/c0ee00273a

[47] The role of buffer layers in polymer solar cells, Riccardo Po et al., Energy & Environmental Science, Vol.4, 2011, pp.285-310, doi: 10.1039/c0ee00273a

[48] Optimización de los procesos de fabricación de células solares orgánicas mediante técnicas de impression, Rodolfo E. López Vicente, Master Thesis, Universidad politécnica de Cartagena, September, 2014, 45

[49] Reason why bulk heterojunction is preferred to bilayer, Chemistry Society Reviews, Vol 41, No. 11, 2012, pp. 4089–43

[50] Reason why bulk heterojunction is preferred to bilayer, Chemistry Society Reviews, Vol 41, No. 11, 2012, pp. 4089–43

[51] Reason why bulk heterojunction is preferred to bilayer, Chemistry Society Reviews, Vol 41, No. 11, 2012, pp. 4089–43

[52] Conjugated Polymer-Based Organic Solar Cells, Serap Gunes et al., Chemistry Review, 2007,vol.107, pp. 1324−1338, doi:10.1021/cr050149z

[53] Organic solar cells: An overview focusing on active layer morphology, Travis L. Benanti et al., Photosynthesis Research, 2006, 87, pp. 73–81

[54] Conducting polymer nanowires for chemiresistive and FET-based bio/chemical sensors, Carlos M.et al., Journal of Materials Chemistry, 2010,vol. 20, pp. 3295–3300, DOI: 10.1039/B915717D

[55] Reason why bulk heterojunction is preferred to bilayer, Chemistry Society Reviews, Vol 41, No. 11, 2012, pp. 4089–43

[56] Celdas solares orgánicas como fuente de energía sustentable, Oracio Barbosa-García et al., Reasearch paper, Acta Universitaria, Universidad de Guarajuanato, Vol. 22, N. 5, Julio-Agosto 2012, pp.36

[57] US20130276886A1

[58] Polymer electronic materials: a riview of charge transport, Manu Jaiswai et al., Polymer International, vol.55, 2006, pp. 1371-1384

[59] The Physics of Polymers, Concepts for understanding their structure and behavior, Strobl et al., G.R., 2007, vol. XIV,pag.295

[60] US20130214213A1

[61] US20130276886A1

[62] New Architectures and Designs for Organic Photovoltaics, Nigel John Alley, Doctoral Thesis, Dublin City University, May, 2012

[63] Organic solar cells: An overview focusing on active layer morphology, Travis L.Benanti et al., Photosynthesis Research, vol.87,2006, pp. 73-81

[64] Organic solar cells: An overview focusing on active layer morphology, Travis L.Benanti et al., Photosynthesis Research, vol.87,2006, pp. 73-81

[65] Organic Optoelectronic Materials, Y. Li, Springer Publishing Switzerland, 2015, Lecture Notes in Chemistry 91

[66] Polymer Photovoltaics: Materials, Physics and Device Engineering, Fei Huang et al., Royal Society of Chemistry, 2015, pp 422

[67] US8097348B2

[68] Células solares transparentes: desarrollo actual y aplicaciones, Luis Peña Asensio, Master thesis, Universidad Politecnica de Cartagena, September, 2011

[69] Advanced materials and processes for polymer solar cell devices, Martin Helgesen et al., Journal of Materials Chemistry, 2009

[70] US20150056735A1

[71] Roll to roll processing of ultraconformable conducting polymer nanosheets, A. Zucca et al., J.Mater.Chem.C, vol. 3, 2012, pp.6539—6548

[72] High efficiency, fully inkjet printed organic solar cells with freedom of design, T. M. Eggenhuisen, J.Mater.Chem.A, vol.3 ,2015,pp.7255

[73] WO/2013/100284A1

[74] Third-generation solar cells: a review and comparison of polymer:fullerene, hybrid polymer and perovskite solar cells, Junfeng Yan and Brian R. Saunders, Royal Society Chemistry Advances, vol.4, 2014, pp. 43286–43314

[75] Nanomaterials, Polymers and Devices: Materials Functionalization and Device fabrication, E.S.W.Kong, pp.320

[76] The OE-A OPV demonstrator anno domini 2011, Frederik C. et al., Krebs,Energy Environ. Sci., 2011,4, 4116

[77] Organic Thin Film Transistor Integration: A Hybrid Approach, Flora M. Li et al., 2011, Wiley-VCH Verlag GmbH & Co. KGaA

[78] Optimización de los procesos de fabricación de células solares orgánicas mediante técnicas de impression, Master thesis, Rodolfo E. López Vicent, Universidad politécnica de Cartagena, September 2014

[79] Evaluación de tecnologías fotovoltaicas orgánicas, Jonatan Mondéjar Martínez, Master thesis, Universidad politecnica de Cartagena, September, 2014, pp. 27

[80] Theoretical Description of Structural and Electronic Properties of Organic

[81] Photovoltaic Materials, A Zhugayevych, S Tretiak, 2015, pp. 304

[82] WO/2015/171689

[83] New Architectures and Designs for Organic Photovoltaics, Nigel John Alley, PhD thesis, Dublin City University, April , 2012, p.103

[84] Characterization of Organic Solar Cells, Eugene A. et al., reaserach paper, May, 2009

[85] Eugene A. et al. 2009. Characterization of Organic Solar Cells, Eugene A. et al., research paper, May.

[86] Themed issue: solar cells, J.Mater.Chem., vol.19, 2009, pp. 5276–5278, DOI: 10.1039/B911726C

[87] Sustainable Energy, Science of Education publishing, Vol. 2, No. 3, 2014, pp.85-90

[88] Elisa Collado Fregoso. Espectroscopia de absorción transitoria como instrumento de investigación en fotovoltaica orgánica: estudios de generación de carga en la mezcla activa de celdas solares, caso de estudio: fluori nacion de polímero, PhD thesis, Imperial College London.

[89] ISO 704:2000 Terminology work -Principles and methods, International standard, Switzerland, 2000, pp.38

[90] Berne, 2002, Recommendations for terminology work, COTSOES, pp.112