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Review (Derleme)

Investigation of Solar Cell Efficiencies and Stabilization Using Polymer-Based Photovoltaic Cells

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Exciton-hole separation,
Exciton transfer,
Efficiency improvement.

Abstract The use of polymer electronics has the power to revolutionize the field of solar cells by reducing the production costs of large-scale nano-electronic applications. At the same time, the performance and stability of polymer-based devices are still low compared to their inorganic counterparts. New and comprehensive experimental and theoretical research is needed to reduce energy losses and increase efficiency in these devices. For this purpose, we present the knowledge, development, efficiency levels of polymer based solar cells, the performance of polymer membranes in solar cell. We will examine the relationship between the parameters of the eccentricity and hol carrier parameters, load bearing losses and solar cell variables in the polymer based solar cell with technological importance. Finally, the latest study demonstrates that, in accordance with experimental observations, the reduction of load-carrier losses is more important than reducing excitation and photon losses to optimize the performance of solar-cell devices.

Polimer Tabanlı Fotovoltaik Hücrelerin Kullanımı ile Solar Hücre Verimlerinin Artışı ve Stabilizasyonun İncelenmesi

Anahtar Kelimeler:
Polimer solar hücre verimi,
Eksiton- hol ayırımı,
Eksiton taşıma,
Verimlilik artırma.

Özet: Polimer elektroniğinin kullanımı, geniş ölçekli nano elektronik uygulamaların üretim maliyetlerini düşürerek solar hücre alanında devrim yaratma gücüne sahiptir. Aynı zamanda inorganik muadilleriyle karşılaştırıldığında polimer tabanlı cihazların performansı ve kararlılığı, halen düşüktür. Bu cihazlardaki enerji kayıplarının azaltması ve verimliliğinin artırılması konusunda yeni ve kapsamlı deneysel ve teorik araştırmaların yapılması gereklidir. Bu amaçla, bu makalede, polimer esaslı güneş hücrelerinin tanımı, gelişimi, verimlilik düzeyleri, polimer membranların solar hücrede kullanım performansları hakkında bilgi sunuyoruz. Teknolojik önemi olan polimer esaslı güneş-hücresinde fotondaki eksiton ve hol taşıyıcı parametrelerinin, yük taşıma kayıplarının ve solar hücre değişkenlerinin verimlik parametreleriyle ilişkisinin inceleyeceğiz. Son olarak, son çalışmada, deneysel gözlemlerle uyumlu olarak, yük-taşıyıcı kayıplarının azaltılmasının, güneş-hücre aygıtlarının performansını optimize etmek için eksiton ve foton kayıplarını azaltmaktan daha önemli olduğunu ortaya koymaktadır.

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1. INTRODUCTION

In recent years, the demand for sustainable and clean energy sources has led to intense growth in the development of solar cells that convert sunlight directly into electricity. Solar cell is one of the most promising technologies for collecting solar energy as the largest non-carbon based natural resource. Photovoltaic technology must meet three efficiency, stability and low cost factors to achieve industrial demonstration (Antohe, Iftimie et al. 2017). Silicon photovoltaics, the first generation of solar cells, have a long life span of around 25 years and their power conversion efficiency (PCE) is as high as 20%, but the production processes are very complex and expensive. Photovoltaic uptake is growing to provide adequate alternatives to conventional solar cells. The lowest cost and the simplest production method for solar cells is a useful method of providing roll-to-roll printing for large-scale production. Some of the most promising technologies used to reduce the production costs of solar cells are based on the process of solving small molecule organic or polymer solar cells, including dye-sensitive solar cells (Chen, Cheng et al. 2014).

Polymeric materials are indispensable elements of technological applications due to their physical and chemical properties (Cho, Kim et al. 2017). These materials are lightweight, easy to work, flexible and durable, and are used extensively for their chemical stability. (Dang, Zhou et al. 2014). Renewable energy is used in solar energy, fuel cell membranes as polymer solar cells (PSC) instruments, polymer light emitting diodes (PLEDs), polymer field effect transistors, polymer data storage and energy storage devices (Dang, Zhou et al. 2014). High efficiency, functionality and performance occur in areas where inorganic materials are insufficient in the development of technological devices (de la Mora, Amelines-Sarria et al. 2017). Among all types of photovoltaics, bulk heterocycle polymer solar cells (BHPSCs) and PSCs have attracted a great deal of attention due to their cheap, easy and fast fabrication and the potential to achieve light solar cells (Fan, Zhu et al. 2018). BHPSCs have been considered for nearly two decades and PSCs have been introduced for only 10 years. Comparison of these two types of photovoltaics shows a higher performance for PSCs (Gao, Li et al. 2019). In this review, the history of both devices was first reported and their configurations and mechanisms were introduced (Han, Zhang et al. 2017). Commonly applicable materials are presented and compared for their layers. In addition, the opto-electronic properties of the absorbent layers are reviewed and compared (Holliday, Li et al. 2017).

Photovoltaic Cell

In the first step, photons are absorbed by an electron photoactive material stimulated from the HOMO energy level of the conjugated polymers to the LUMO energy level (Lan, Cai et al. 2018). Then, the energy-lower dielectric constant provided by the photons, localized electrons, and the holy wave function create coulomb attraction between electrons and holes. This bond causes the electron-hol pair to be named as exciton. Excitation energy is much more (0.1-1.4 eV) than room temperature energy(Lee, Jeong et al. 2014).

The exiton travels at a certain distance prior to the recombination process and the appropriate distance is called the excitation length of the exciton. This distance is generally between 5-70 nm. When the exiton is diffused, uniformly accelerated band levels are generated by two different organic materials, heterogeneities are generated by light-induced charge transfers from the LUMO energy level of the acceptor at the donor-acceptor interface to the LUMO energy level of the donor (Li, Chen et al. 2018). This process can occur between the LUMO energy level of the acceptor molecule and the HOMO energy level of the donor molecule when the binding energy of the excitons is equalized (Li, Budiawan et al. 2018). This charge transfer is competitive with the luminance process (time unit 1ns). However, it is obvious that this process is more favorable, and the charge transfer time unit has been found to be faster than 45 fs in polymer-fluorene

systems. As a result of light-induced induction, the charge transfer pairs are formed by the incorporation of the electrons of the acceptor molecule and the donors of the donor molecule. Considering these reasons, there is an electron-hole transport network for charge separation (Li, Hu et al. 2017).

Drifting and evolving current are the main driving force for the load carrying system. Drift current occurs as a result of a potential barrier in the solar cell. This potential barrier is necessary for the decomposition of the recombined monomolecules and for the combined pairs to overcome the collumbic force to completely separate the charges. It has emerged as a result of different business functions between potential electrodes. The anode, which has a high job function, and the cathode having a low job function, form this area. The charge transfer mechanism can be depicted as diffusion current as a result of the difference in charge concentration inside the solar cell. Hol and the density of electrons is due to the high affinity of the hetero junctions (Li, Yu et al. 2017). Then electrons and halls heterojunction when the latter diffuses out of the formation of the diffusion current is observed. The active layer in the load-bearing systems in the active layer has a tendency to carry lower hol and electron than the inorganic semiconductors (Li, Ying et al. 2018). During the movement of the electrons and hols, a large imbalance is observed as a result of the gap load limiter current (SCLS). Then, for the efficiency of the solar cell, extremely high degrees of hol and electron transport balance is required. Then, free loads occur and lead to the appropriate electrode. Hols is directed to the polymer in the anode function, while electrons tend to the catheter. The work function of the cathode and anode is very important for load bearing efficiency (Liang and Wang 2017). The HOMO energy level of the conjugate polymer is matched to the work function of the anode while the LUMO energy level must match by creating the ohmic contact with the work function of the cathode (Liu, Zeng et al. 2019).

In summary, the principle of solar cell operation consists of 3 critical steps.

• Photon absorption and exiton formation by the active layer

• To produce mobile carriers in the donor-acceptor interface and charge separation (separation of excitons) with photoinduction.

• Separation of electrons and load collection in the load bearing system

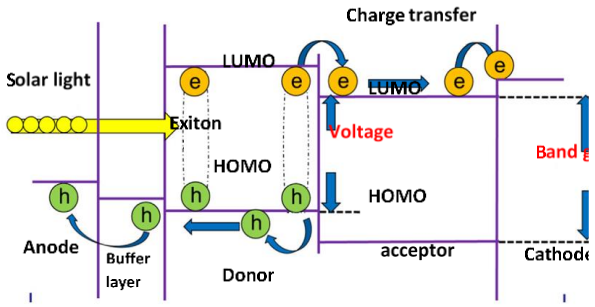

Figure1. Working Principle of Organic Solar Cells

Inorganic and organic solar cells are divided into two general classes. Most of the inorganic based cells are used in gallium. Solar cells consisting of silicon and gallium crystals have a high cost and have a short life span. These structures with high productivity have many disadvantages. Although it has relatively higher power conversion efficiency than organic solar cells, it is the limitation of non-panel application areas. However, the organic solar cells have a unique position in the process of cleanability and the ability to process, ease of application. Due to the mobility of the organic compound in the solvent, it can be used in all surface coating materials. This is done with dye sensitive solar cells (Rasool, Van Doan et al. 2019).

Polymer-based solar cell devices for the power efficiency of poly (3-hexylthiophene) (P3HT) semiconductor polymer and a carbon-60 derivative of [6,6] -phenyl-C61-butyryl acid methyl ester (PCBM) using as a homogeneous mixture It was prepared. The solar cell type containing the donor acceptor is called "bulk

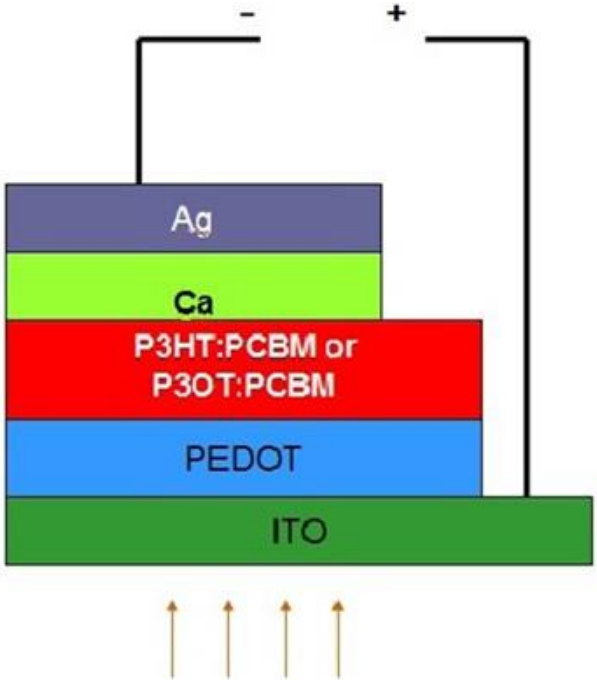

Figure 2. Layer structure of organic solar cell.

heterojunction" (Fan, Zheng et al. 2017). These solar cells, where flexible materials are used, are useful for forming extensive parallel parts. When we examine this type of organic solar cell, we can see that the flexible and transparent ITO coated PET surface is coated with PEDOT: PSS, active mixture P3HT: PCBM and finally aluminum, which are known as gap-carrier layer, respectively. The photons from the sun pass through the layers of PET, ITO and PEDOT: PSS, respectively, to reach the P3HT: PCBM film, and use the energy they have to form the exitons, which are electron-gap pairs. Electron-hole pairs of ITO and aluminum electrodes from each other is separated from the work function level between the effect caused by the electric field difference. The electrons are transferred to the aluminum and the holes to the ITO electrode. In this way, the formation of current in the circuit is provided and photon energy conversion to electrical energy is completed (Fan, Zheng et al. 2017, Putri, Jin et al. 2019).

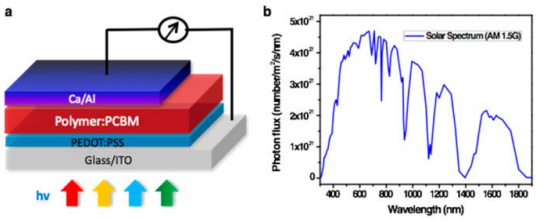

Figure 3. Layer structure of organic solar cell solar spectrum

Solar cell efficiency characteristics

Organic solar cells are generally characterized by the illumination of the AM 1.5 G solar simulator. The power conversion efficiency (PCE) in organic solar cells is determined by the parameters called open circuit voltage (Voc), short circuit current (Jsc) and Fi factor (FF). Figure 4 shows the power conversion efficiency of an organic solar cell by replacing the parameters we specified with the given graphic.

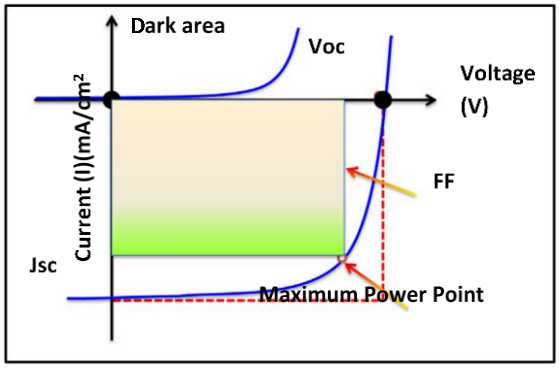

Figure 4. Solar Cell I-V Characteristics

Power Conversion Efficiency Calculation;

$$\eta = \frac{\text{Jsc.Voc.FF}}{\text{Pin}}$$

Short Circuit Current (I_{SC}), The voltage applied on the cell is Va = 0 V, while the measured current is the short circuit current (I_{sc}). It is equal to the luminous current, which is the current caused by the absorbed photons. The short-circuit current depends on the morphology of the device, the life span of the load carriers and their mobility. Reduction of the band gap increases the maximum theoretical short-circuit

current as it increases photon absorption (Goetzberger, Hebling et al. 2003).

Open Circuit Voltage (V_{OC}); is the highest possible voltage value in solar cells. If the electrodes are not interconnected, the current does not flow through the apparatus and the carriers (electrons and halls) formed by the photons that are absorbed create a voltage difference in the solar cell. This voltage difference generates the open circuit voltage. For example, in a simple p-n incorporation in the solar cell, the accumulation of light-induced carriers causes the electron to increase on the side of the p-n junction (p-n junction) and the hol on the p side. This charge separation creates an electric field in the junction zone and the net electric field decreases as the field is in the opposite direction to the electric field in the pre-formed discharge zone of the coupling. Since the electric field in the discharge zone prevents the passage of the forward bias diffusion stream, this decrease increases the diffusion current and a new equilibrium state occurs. In open circuit assemblies, the forward trend of the N-P coupling continues until the light-generated current is balanced with the forward bias diffusion current. The voltage required to achieve the equilibrium of these two currents creates the open circuit voltage of the solar cell (Goetzberger, Hebling et al. 2003).

The Filling Factor (FF), is defined as the ratio of the highest power output in the photovoltaic cell to the theoretical power output. The theoretical power output is calculated by multiplying the open circuit voltage by the short circuit current. It is an important parameter used in solar cell performance measurements.

$$FF = \frac{\text{Jmax.Vmax}}{\text{Jsc.Voc}}$$

Fi factor (FF), parallel resistor (Rsh) and series connected resistors (Rs) are determined. The effects of the series bonded resistors (Rs) are determined by applying the voltage. (Kumar Moluguri, Rama Murthy et al. 2016).

Power Conversion Efficiency (η), is a parameter that shows how much of the sunlight energy into photovoltaic cells is converted into electrical energy. Power output to power input ratio (Kumar Moluguri, Rama Murthy et al. 2016).

Quantum Yield (QE), refers to the ratio of the number of carriers deposited by the solar cell to the number of photons in the specific energy to the solar cell. Absorption of all photons at certain wavelengths in the solar cell and accumulation of all load carriers in the cell indicates that the quantum yield is 100% or 1. The quantum efficiency of the solar cell is expressed in two ways: external and internal quantum efficiency. External quantum efficiency includes losses due to reflections and transmission of incoming photons. The internal quantum efficiency only includes reflection and transmission losses of absorbed photons.

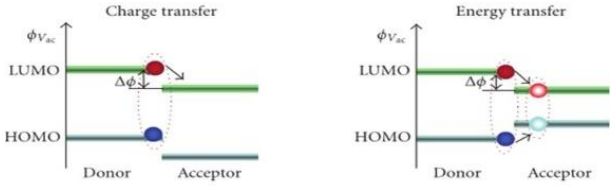

Figure 5. Load and energy transfer in organic solar cell

Efficient Analysis

Inorganic semiconductors absorb energy in the solar spectrum in the band cavities, but have less absorbency than organic materials in the cell, which require more efficient absorbent layers. For solar cells, efficient absorption layers are required, and this is achieved, however, by high purities (and higher costs). Another important difference between OPVs and conventional inorganic solar cells is in the minus binding energy. In both systems, excitons (induced states) occur upon photon absorption. In inorganic semiconductors, the energy required to decompose these excitons into charge carriers is relatively small (a few millyelectric volts easily obtained at room temperature) (Vogelbaum and Sauvé 2017). In organic semiconductors, the "minus binding energy"

may be 0.5 eV or higher, which requires the formation of a D / A heterojunction to provide the internal electrochemical driving force for the realization of the negative decomposition. Inorganic solar cells can be very efficient, because a single inorganic material can be used with an excitation binding energy at room temperature neglected. The physics of organic solar cells are very different because the excitons are connected with strong forces. You must have a receiver and a donor component so that the generated echo can access the interface quickly to separate. After the excitons are divided into two types: electrons and halls, they must move efficiently to the electrodes. Remember how much you can order your material and generally the better the mobility. The faster the electrons and holes move, the more efficient it is to separate.

• PBDB-T (electron donor for non-fulleren recipients)
• F - M (non-fulleren electron receiver)
• PTB7-Th (electron donor)
• PC 71 BM (fullerene electron receiver for PTB7)
• O6T-4F (electron receiver)

Unlike silicon solar cells where P and n semiconductors are separate layers, these organic connections are mixed types in which the donor and donor compounds are mixed together in the active layer (Fan, Zhu et al. 2018).

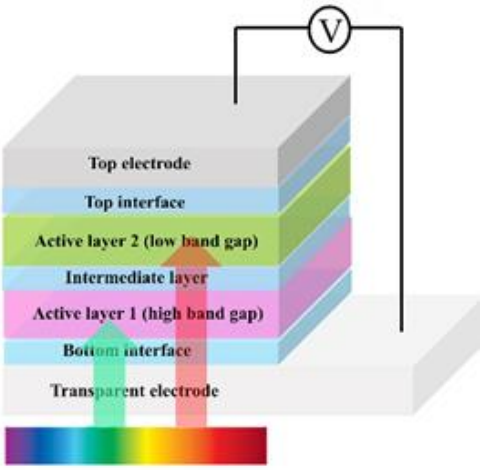

Figure 6. The dual layer structure of organic solar cell (Fan, Zhu et al. 2018)

Stacking when the light enters the bottom:

• Ag - silver electrode
• moox
• PBT7-Th: 06F-4F: PC 71 BM - low band junction
• ZnO
• M-PEDOT - polymer conductor
• PBDB-T: FM - high-band junction
• PFN-Br - conjugated polyelectrolyte electron interface
• ZnO
• ITO - indium tin oxide electrode

On the basis of our semi-experimental model estimation, the highest conversion efficiency of organic solar cells can theoretically reach more than 20% Chen [6].

The biggest problem with organic solar cells is their lifetime under sunlight and their exposure to air and moisture. Silicon solar panel assemblies tend to have a 25-year life [25].

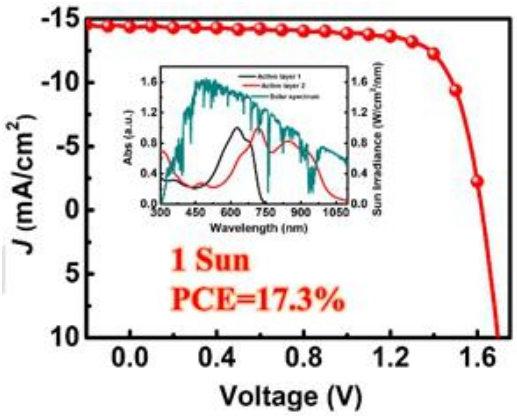

Figure 7. High yield characteristics of organic solar cell (Fan, Zhu et al. 2018)

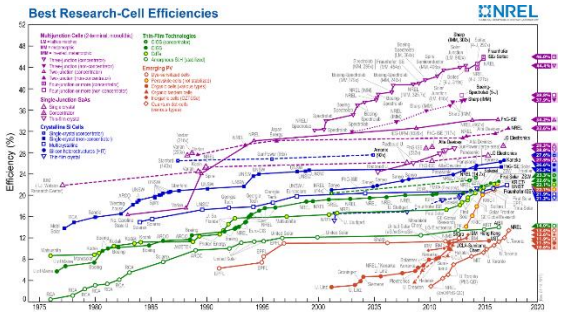

Figure 8. Graphic of increasing the yield of solar cell types

Although the efficiency of organic solar cells remains low compared to other technologies, it has been steady since 1990. In addition, the investigation of organic solar cells during the last decade has significantly improved the understanding of the axial and hectic load transport in irregular systems.

For Increasing Efficiency

• In order to form stimuli, the active layer should swallow the incoming photons as much as possible.

• The swelling spectrum of the active layer compatible with the solar spectrum and the solar radiation swallowing of 100 radyasyon200 nm thin films should be maximized.

Light Apsorsion of Polymer Active Layer

Although the sun has lost some energy after reflection and absorption into the atmosphere, it gives a tremendous amount of energy every second in the form of irradiation reaching the Earth at an energy density of about 1366 W / m 2 just outside the atmosphere. The solar spectrum includes energy density and photon flux over wavelength. It is integrated into an energy density of about 1000 W / m 2 with a 4.31 x 10 21 s -1 m -2 photon flow distributed across the wavelength range of 280 to 4000 nm. Most of the solar energy is concentrated in the visible and near infrared (near IR) region. Thus, in order to efficiently collect solar energy, the absorption spectrum of PSCs must have a great overlap with the solar spectrum in this region. For example, a semiconductor polymer with a band spacing of 1.1 eV (equivalent to wavelength photons below 1100 nm) can absorb no more than 77% of the solar energy generated. If the bandwidth exceeds 2 eV (less than 620 nm), only 30% of the solar energy can be absorbed. Thus, the first criteria when designing new polymers are high efficiency in the absorption of solar energy in the entire solar spectrum.

New Developments in Polymer Designs

Major developments in the design of solar cell polymers are derived from the excretion of the donor-acceptor (D-A) copolymers (sometimes called & quot; push-and-pull & quot;), which leads to high-yielding BHJ PSCs. In these low-band spaced polymers, energy levels and molecular structures can be optimized by molecular engineering. Unlike homopolymer P3HT, the D-A copolymers comprise an electron-rich moiety (donor) and an electron-missing moiety (acceptor). Typical synthetic methods include Suzlene coupling reactions for thienyl repetitive units and Stille polycondensation or polymers containing phenyl repeating units. In the class of polymers, a phenomenon generally known as the quinodal effect is shown where D-A and the diminishing character of the single-bonds in the polymer backbone of the D-A - + D + - - increases. This leads to reduced bond length variation and effectively changes the energy levels and band cavities of the corresponding polymers (Kumar Moluguri, Rama Murthy et al. 2016). A unique feature of these polymers is that the HOMO and LUMO energy levels are largely determined by the HOMO energy level of the transmitter and the LUMO energy level of the acceptor. Thus, the energy levels of the polymers can be adjusted by individually engineering the donor and receiver units.

In the 1990s, the use of a fluorene-based D-A polymer PFDTBT in BHJ PSCs was not until 2003, although there were samples of D-A copolymers with as low a band gap as 1.1 eV. Now, D-A copolymers dominate the development of novel OPV materials in the community. For the further development of PSCs today, the rational design of donor polymers is still one of the most important issues. When designing donor polymers for PSCs, it is essential to carefully select the relative monomers for the preparation of donor polymers having the desired properties. However, the selection of suitable side chains, including location, size and shape, can significantly alter the properties of the polymers. Various strategies for designing high performance copolymers are given below (Lee, Lee et al. 2011, Deng, Yu et al. 2017, Liang and Wang 2017, Yi, Yi et al. 2017, Lin, Huang et al. 2019).

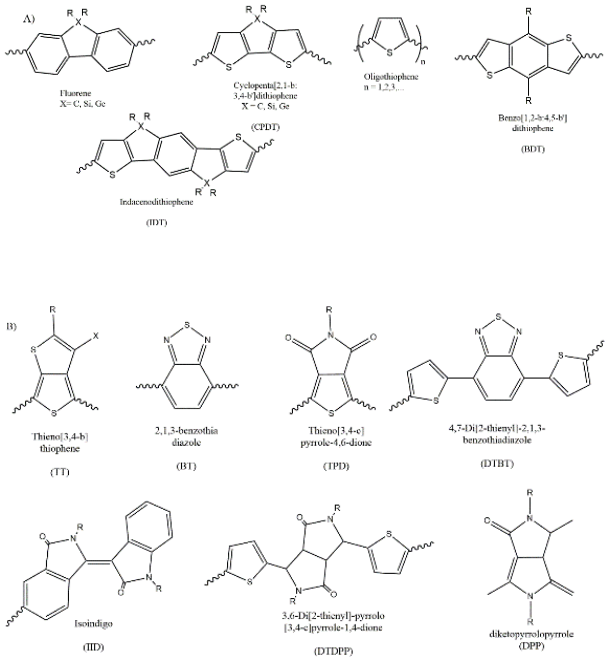

Figure 9. Structure of commonly used donor (A) and acceptor (B) particles.(Song, Ko et al. 2012, Stephen, Morse et al. 2016, Zhou, Sun et al. 2018)

2. RESULT

We evaluated the assessment of solar cells and provided some information on efficiency analysis. Anoragnic solar cells have high yields but many disadvantages. Elimination of these problems can be solved by developing organic-based cells and increasing their efficiency. We evaluated many parameters such as efficiency in polymer based organic solar cells and the effect of D and A components on excitone. Cell stability is important in large-scale polymer-based solar-cell yield calculations that have a major impact on photovoltaic performance. To this end, as a function of components D and A, the average exonite decomposition and charge transfer in all of the exemplified configurations is important. It has been shown that reducing load carrier losses for high efficiency is more important than reducing excitation and photon losses to improve device performance and that these findings are in good agreement with observations in experimental studies. As a result, we foresee that the polymers will lead to better understanding of the technology of solar cells and the development of more performance.

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