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# HIGH PERFORMANCE INVERTED POLYMER SOLAR CELLS

## : Using Conjugated Donor-Acceptor Terpolymer

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**ABSTRACT**
*The demand for electricity is increasing day by day. Since electricity is the life force of modern civilization and we can get as much as we want from sun, solar cells has gained maximum attention over a short period of time. The development of conjugated alternating donor-acceptor terpolymer will give a simplistic and cost effective method to improve their light absorbing capability and tuning of energy levels. In this paper the typical current-voltage behavior, power conversion efficiency of a normal organic solar cells is compared with the recent progress of conjugated D-A terpolymers for efficient PSCs and also discussed how these photovoltaic performance get influenced by all these factors by providing useful guidelines to design new terpolymers towards high efficiency PSCs.*

**KEYWORDS –** *Polymer solar cells, D-A Terpolymer, current-voltage behavior, photovoltaic performance.*

## I. INRODUCTION

Electricity can be generated by two different resources–conventional and nonconventional. Due to rapid increase in the energy demand, exhaustion of conventional resources and climatic changes we go for renewable resources, out of which solar energy came into picture. Solar panels are active solar devices that convert sunlight into electricity. Plastic solar cell technology is based on conjugated polymers and molecules. Polymer solar cells usually consist of an electron or hole lightweight, low cost, efficiency. Low cost and efficient processing are key factors to be blocking layer on the top of an indium tin oxide conductive glass followed by an electron donor and an electron acceptor. In an inverted cell, the electric charges exit the device in the opposite direction as in a normal device because the positive and negative electrodes are reversed. PCSs have attracted various attentions in the past, because of eco-friendly, flexibility, lightweight, low cost, efficiency. Low cost and efficient processing are key factors to be considered for the future practical application of polymer solar cells. Over the past decade organic solar cells with inverted structures composed of electron donating and electron accepting fullerene bulk hetero junction have allured consciousness towards their boosted parameters. Recently as a result of these immense efforts, OSCs has improved its power conversion efficiency over 17.3%. It is familiar that the efficiency of a PSCs depends on short circuit current density (Jsc), open circuit voltage (Voc), and fill factor (FF).1)By attaining proper optical bandgap (Eg) to get strong and broad absorption in visible and infrared region, 2) high and balanced charge carrier movement to ensure efficient charge transport we can obtain efficient photovoltaic performance. Mostly organic films for photovoltaic applications are deposited by spin coating and vapor-phase deposition. Terpolymer is a polymer that results from copolymerization of three discrete monomers . Propitiously, D-A copolymers with electron rich and electron deficient properties have gained accomplishment atleast for small region, which improved photovoltaic performance in PSCs**.** Moreover, there exist some limitations in the performance of D-A copolymer solar cells. 1) It is difficult to obtain a full spectrum adsorption, 2)

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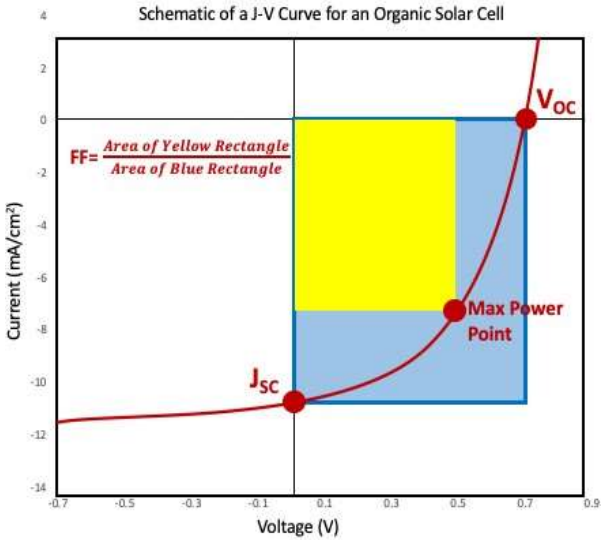
solubility can be tuned only by changing all solubilizing side chains in D or A units, 3) less cost effective in synthesizing D-A copolymer from other monomers and pairing them with single layers or front and rear sub cells. Compared with the alternating D-A copolymers, adding a third component of either D-units or A-units to the polymer provides a chance to improve their light absorbing capability, tuning of energy levels and morphological control which leads to an increased power conversion efficiency from enhanced short circuit current density, open circuit voltage and fill factor values in polymer solar cells. Hence because of these improved efficiency D-A terpolymers are used in PSCs .

**Fig: Terpolymer Based Solar Cells**


## II. TYPICAL CURRENT-VOLTAGE BEHAVIOR AND POWER CONVERSION EFFICIENCY

Organic photovoltaics similar to inorganic photovoltaics are generally characterized through current-voltage analysis. This analysis provides multiple device metrics values that are used to understand device performance. One of the most crucial metrics is the Power Conversion Efficiency (PCE). PCE is proportional to the product of the short circuit current , the open circuit voltage and the fill factor , all of which can be determined from a current voltage curve.

$$PCE = \frac{V_{OC} \times J_{SC} \times FF}{P_{in}}$$




The short circuit current is the maximum photocurrent generation value.It corresponds to the y-intercept value of standard current- voltage curve in which current is plotted along y-axis and voltage is plotted against x-axis. Within organic solar cells, the short circuit current can be impacted by a variety of material factors. These

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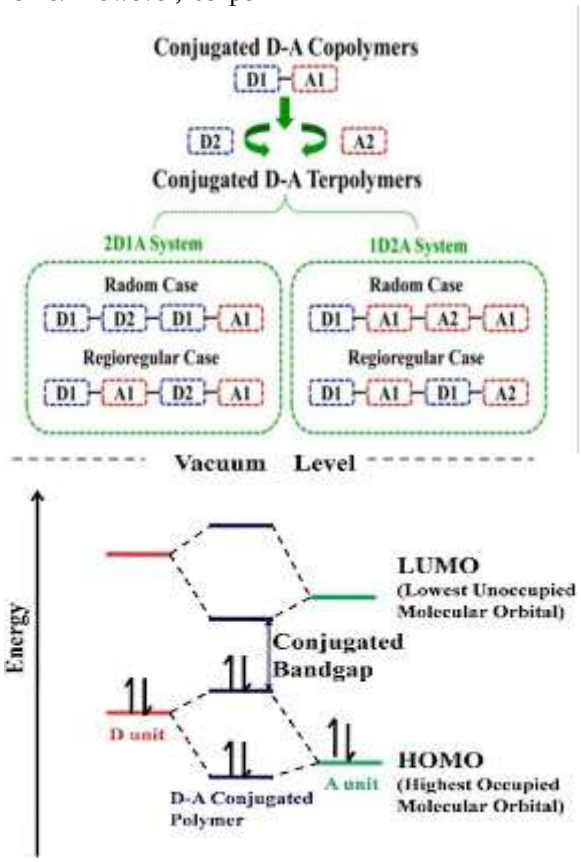
includes the optical absorption profile and general energetic driving forces that lead to a more efficient extraction of charge carriers. The open circuit voltage is the voltage when there is no current running through the device. This corresponds to the x-intercept on a currentvoltage curve. Within bulk heterojunction organic photovoltaic devices, this value is highly depended on HOMO and LUMO energy levels and work functions for the active layer materials. Since power is the product of voltage and current, the maximum power point occurs when the product between voltage and current is maximized. The fill factor can be thought of as the squareness of a current-voltage curve. It is the quotient of the maximum power value and the product of the open-circuit voltage and shortcircuit current. This is shown in above figure. For organic photovoltaics , this fill factor is essentially a measure of how efficiently generated charges are extracted from the device. This can be thought of as a competition between charges transporting through the device, and charges that recombine. However, as per researchers have been able to fabricate PSCs with fill factors of over 75% via an inverted BHJ and by using alternating D-A terpolymer. Functional monomers are classified into two- electron acceptor and electron donor depending upon the type of conjugation of double bond and functional groups.

## III. CONJUGATED D-A POLYMERS

Conjugated polymers are active .components in many electronic devices because of their interaction with light and transport carriers. Through the appropriate alternative of repeating units, these polymers can be made electron-rich and electron-deficient. D-A polymers with an alternating array of donor acceptor components have attracted particular interest. Such polymers due to their in-chain DA interactions lower the band gap (Eg) , and are the important light harvesting systems in the solar cells .




**Energy levels in D-A terpolymer**

One of the major drawback in the existing method ie, in case of alternating D-A copolymer is, they have either wide band gap, with absorption in near infrared region resulting in imperfect spectrum match with solar irradiation.

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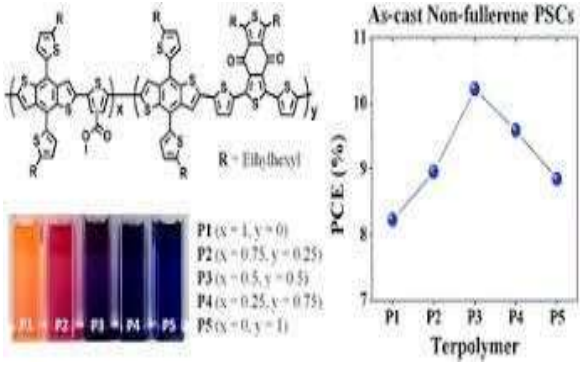
This drawback can be solved in D-A terpolymers: the newly generated absorption band caused by π-π* transition in the terpolymer of the 2D1A system or intramolecular charge transfer interactions in the terpolymer of the 1D2A system can be easily achieved by adding proper additional component in the polymer backbone. Furthermore, the HOMO/LUMO energy levels can also be well tuned in D-A terpolymers.

## V. CONJUGATED D-A TERPOLYMERS AS ELECTRON-DONORS IN PSCS :

Compared with alternating D-A copolymer, conjugated D-A terpolymer have fine tuned optical properties, energy levels, charge transfer properties and fine molar ratio. polymer solar cells. Consequently, highly stable conjugated D-A alternating copolymer as electron-acceptors had

## IV. COJUGATED D-A TERPOLYMERS AS ELECTRON-ACCEPTORS IN PSCS

The past efforts have resulted in Backbone composition for conjugated D-A alternating a 11% PCE values for the fullerene based BHJ overcome the inherent disadvantage of fullerene derivatives like weak light absorption and difficult structure tunability. Addition to this fine-tuned optical and energetic properties have attained by these polymer acceptors, leading to high performance. To overcome highly crystalline features in D-A alternating copolymer acceptors, certain conjugated D-A terpolymers with highly efficient nonfullerene acceptors are reported recently.




A series of conjugated D-A terpolymers P2-P4 based on 4,8-bis(5-(2-ethylhexyl)thiophen-2-yl) benzo(1,2-b:4,5-b')dithiophene (BDT) as the electron donating unit, and 1,3-bis(2ethylhexyl)benzo(1,2-c:4,5-c')dithiophene-4,8dione (BDD) as the strong electron-accepting unit are synthesized to investigate the effect contents of BDD on their optical and electromechanical properties. By varying the contents of BDD in the terpolymer structure, solubility, absorption range and energy leve could be efficiently tuned. Non-fullerene BHJ PSCs were fabricated using the synthesized terpolymers P2-P4.

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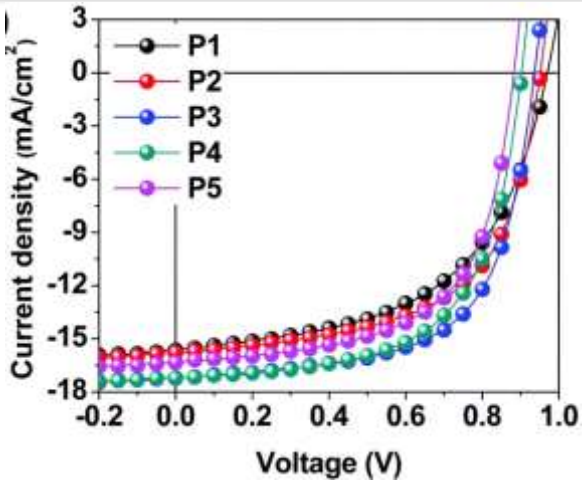


Current density (Jsc)-Voltage(V) curve

From recent researches, a promising advantage about certain polymer donors were found out - the medium-bandgap PBDB-T copolymer consisting of BDT and BDD units, have demonstrated a high Power Conversion Efficiency (PCE) of 9.15% in a non-fullerene PSCs.

## VI. REGIOREGUALAR D-A TERPOLYMERS IN PSCS

The above mentioned conjugated D-A terpolymers are random terpolymers, where three components are connected to each other in a free manner having high efficiency PSCs. For instance, in contrast to their conjugated D-A alternating copolymers, the batch-to-batch variation in one-pot synthesized random terpolymers is largely pronounced for their random linkage. Beside this, the disordered molecular structures could also prevent their closely package to some extent, which leads to a decrease in the photovoltaic performance in solar cells. These limitations overcome by using regioregular D-A terpolymers, where three subunits are regularly arranged in the backbone. In this regioregular D-A terpolymers, the factors that depends for high performance PSCs like light absorption properties, energy levels and fill factor can be well controlled by adjusting these three subunits in backbone.

## VII. CONCLUSION

As we all know electricity accessibility using non-renewable resources are diminishing, the idea of producing electricity using renewable resources like solar are widely used recently. Polymer solar cells are used, which are considered to be 30% more efficient when compared to conventional solar cells and more practical in application. Traditional solar panels are bulky type, wherein polymer soar cells are of compact. The major advantage is that, they can even work on cloudy days since they are compact and less bulky. In order to improve its light absorption capability, fine tuned energy levels and power conversion efficiency, Donor-Acceptor concept is used. By using conjugated D-A Terpolymer we can improve all above factors. In the past two decades, terpolymers efforts were devoted to developing binary D-A alternating copolymer as donor materials for high efficiency polymer solar cells, leading to a significant progress in Power Conversion Efficiency (PCE) over 14% in single junction BHJ PSCs. In contrast to these, random and regioregular terpolymers incorporated with either -D or -A as third component controlled stoichiometry because of effective and cost effective approach to improve their light absorption, tune energy levels and optimize inter chain packing resulting in highefficient Polymer Solar Cells (PSCs).

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