A Review: Study The Effect of Solvent Properties on Morphology At The Interface of Active Layer of Solar cell

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Abstract- *Organic solvents such as DCB, CB, toluene, xylene, etc produced toxic gases when they react with other organic solvents. So, more environmentally friendly solvents are such as water, Isopropanol or ethanol, polar and capable of hydrogen bonding with these organic solvents. Surfactant link between two immiscible solvents by Intermolecular forces such as hydrogen dipole-dipole bonding, hydrogen-hydrogen bonding, etc. these forces strong or weak depends on the boiling point. Higher the boiling point gives higher intermolecular forces which strongly attracted and then interfacial tension will act to minimize the area if contact increasing the curvature of the surface called as interfacial effects in solids and liquids. These effect leads to affect the solvent bulk properties like surface tension, boiling point, viscosity, solubility, evaporation rate, pressure vapour, etc.*

Obtained blend solution due to good phase separation between polymer and fullerene when deposited on film. This result's applicable for making a hetero-junctions having larger interfacial area which helps for improvement of efficiency in OSC's.

Keywords- microemulsion, intermolecular forces, Surfactant.

I. INTRODUCTION

Fossil fuels resources are fast depleting and that the fossil fuel is gradually coming to an end. Thus, the immediate need would be to alleviate the problems caused by the depletion of oil, natural gas and nuclear energy. Fossil fuel alternatives, such as solar energy can contribute to environmentally friendly, renewable energy production and reduction of problems from fossil fuels and nuclear energy.
Solar energy is a very large, inexhaustible source of energy. It is greater than present consumption rate on the earth of all commercial energy sources. In principle solar energy could supply all the present and future energy needs of the world. Polymer-based organic photovoltaic systems absorb light and transport charge to produce electricity from sunlight by the photovoltaic effect. These photovoltaic technologies made by solution blend processing of the active layer which gives cost-effective, lightweight with the flexibility for solar energy conversion platform. These solar cells based on photoinduced electron transfer from a donor to an acceptor. Due to the high electron affinity and ability to transport charge effectively, fullerenes are used as acceptors. It is observed that Bulk heterojunctions improve the efficiency. The best organic solar cells currently achieve an efficiency of about 5%. If we have to improve the efficiency of organic solar cells, the active layers morphology and electronic properties are required to optimise. Recently, in organic photovoltaic, newly developed organic materials are used for fabrication process due to their great potential applications. They give excellent generations, separation and high chargetransporting properties relating to solar energy applications.

II. BASIC WORKING PRINCIPLE OF OSCS

As the incident light hits the cell, the donor material absorbs sunlight, producing excitons, which are then transported to the donor/acceptor interface. Electrons that exist in a higher energy state are transferred to the acceptor material and extracted at the cathode (metal electrode). Holes travel through the donor layer to the anode (transparent electrode).
The Ideal structure for (n-type: acceptor, p-type: donor) cell in order to maximize surface contact [1].
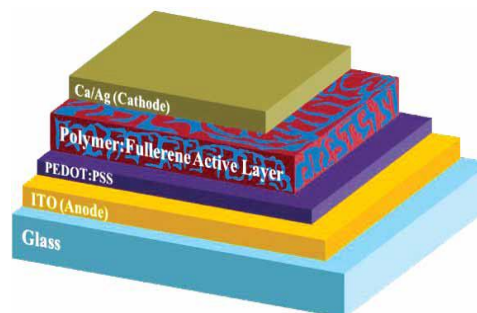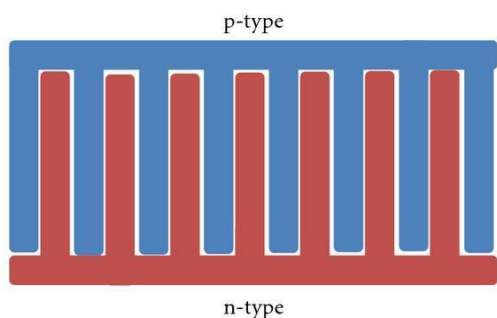
The bulk hetero junction is presently the most widely used photoactive layer, because the interface (hetero junction) between both components is all over the bulk (above Figure). As a result of the intimate mixing, the interface where charge transfer can occur has increased enormously. Control of morphology is not only required for a large charge-generating interface and suppression of exciton loss, but also to ensure percolation pathways for both electron and hole. They transport to the collecting electrodes. OSCs are in which the composite active layer is inserted between two electrodes. A breakthrough to truly appealing power conversion efficiencies exceeding 2.5% to 5.1% under simulated AM1.5 illumination realized for bulk-hetero junction solar cells based on polymers as a donor (Donors: MDMO-PPV = poly[2-methoxy-5-(3´,7´-dimethyloctyloxy)-p-phenylene vinylene]; P3HT= poly(3-hexylthiophene); PFDTBT:poly[2,7-[9-(2´-ethylhexyl)-9-hexylfluorene]-alt-5,5-(4´,7´-di-2-thienyl2´,11´,3´benzothiadiazole), water-soluble poly[3-(potassium-6-hexanoate)thiophene-2,5-diyl] (P3KHT) and fullerene and its derivative [PCBM] as an acceptor.

In PCBM, the fullerene cage carries a substituent that prevents extensive crystallization upon mixing with the conjugated polymer and enhances the miscibility. A special solvent used for the active layer that improves the nanoscale morphology for charge generation and transport. AFM, SEM, FTIR, Raman Spectroscopy, Photo luminance, UV-vis, XRD and TEM, etc studies have resolved the details of the phase separation in these blends. The prospect that lightweight and flexible polymer solar cells can be produced by different deposition technique and now aim is increasing the efficiency to 8–10% [2].

Since the introduction of the bulk heterojunction approach for preparation of polymer solar cells in 1995, one research focus is directed to better understand the influence of morphology on the physical properties of the active layer and the performance of devices, particularly the nano scale organization of the phase segregated compounds [3].

To enhance charge transport and minimize charge recombination to improve the morphology of polymers: fullerene blend by using optimise parameters such as adding additives in blend or organic solvent, thermal annealing, solvent annealing. This nano scale morphology in turn controls the exciton diffusion and charge transport properties. Nanoscale morphology must be a balance between a large interfacial area and continuous pathways for carrier transportation.

Ankit Kumar*et al reported that* the reference device for all the experiments had the structure ITO/PEDOT:PSS/P3HT: PCBM/Ca/Al. For device fabrication, RR-P3HT and PCBM separately dissolved in 1,2-dichlorobenzene, then blended together with 1:1 wt∕wt ratio to form a 2 wt% solution. This RR-P3HT/PCBM solution spin coated at 700 rpm for 40 s, the wet film dried then annealed at 110 ∘C for 10 min. It shows a maximum in efficiency value (approximately 4.5%) at 7 nm PCBM thickness. So annealing shows that the nanocrystallization, diffusion of the components in the blend and improve the nanoscale morphology which can strongly affect the transport pathways for free charge carriers. On annealing, this resulted in smoother films but with a higher effective area of contact between the cathode and the electron transporting PCBM layer and sharp interface, which lead to better electron transport characteristics [4].

Steffan COOK *et al* demonstrate the use of chloroform and ethanol mixed solvents in fabricating P3HT: PCBM blend films with varying degrees of P3HT crystallinity inherent after the spin-coating step. Films of P3HT: PCBM (1: 1 w/w) spin-coated at 3000 rpm for 60 sec from chloroform or chloroform/ethanol mixed solutions with compositions of 7, 8, and 8.5% ethanol composition solutions. Control over the morphology of polythiophene (P3HT) and methanofullerene (PCBM) blend films achieved by using mixtures of chloroform and ethanol as the solvent. Increasing aggregation of polythiophene in mixtures of ethanol in chloroform observed by the red shifting of the polythiophene absorption spectra. An increasing amount of ethanol resulted in more crystalline P3HT appearing in the subsequent spin-coated film with larger phase segregation between P3HT and PCBM components [5].

Li-Min Chen, *et al* also suggested that the different parameters control the morphology of Polymer: Fullerene Bulk Hetero junctions such as:

III. EFFECT OF SOLVENTS

Solution processing allows the freedom to control phase separation and molecular self-organization during solvent evaporation and film treatment. Spin-coating from single-solvent solutions results in thin films, which possess optoelectronic properties determined by the solution parameters and the spin-coating process, for example concentration, blending ratio, spin speed and time, etc. Meanwhile, solvent properties, such as boiling point, vapour pressure, solubility, and polarity, also have considerable impact on the final film morphology. The wettability of the organic solvents are also affect the film morphology [4].
In 2001, Shaheen *et al* demonstrated the effect of solvent and morphology on device performance for the poly- [2-(3,7-dimethyloctyloxy)-5-methyloxy]-para-phenylene-vinylene (MDMO-PPV):[6,6]-phenyl-C61-butyric acid methyl ester (PCBM) blend system. By replacing toluene with chlorobenzene (CB), the PCE of the device dramatically improved to 2.5%. A more intimate mixing and stronger inter chain interaction accounted for this improvement. The solubility of the polymer blend is much better in chlorobenzene than in toluene; thus, a much more uniform mixing of the donor and acceptor which improve roughness of the polymer blend film, where the chlorobenzene-based sample has a much smoother film surface. Liu *et al.* investigated the poly(2-methoxy-5-(20-ethoyl-hexyloxy)-1,4-phenylene vinylene (MEH-PPV):C60 blend devices and observed the effect of solution-induced morphology on device performance. Using non aromatic solvents, such as tetrahydrofuran (THF) and chloroform, resulted in larger VOC and smaller JSC, Ma et al. also observed that P3HT:PCBM polymer films smoother and more uniform when chloroform replaced with CB.

The high efficiency is the result of improved morphology, crystallinity, and cathode contact due to better choice of solvent as well as post-annealing treatment. Better solubility of fullerenes in CB resulted in a finer phase separation and higher JSC. However, for most chlorobenzene-cast films, the polymer nanospheres homogeneously distributed; therefore, only at very-high PCBM loadings can this phenomenon of PCBM clusters surrounded by a ''skin'' layer be perceived. The JSC of CB-cast films decreased with heavier PCBM loadings, indicating that an optimal phase-separated domain size is imperative for good device performance. The solubility of the fullerene phase can strongly affect the solvent selection. Larger fullerene balls tend to be less soluble [4].

IV. EFFECT OF ANNEALING

Annealing processes in polymer solar cells can be divided into two categories: thermal annealing and solvent annealing. Both techniques concentrate on improving the nanoscale lateral phase separation. Padinger's work in 2003 attracted tremendous attention in the field, achieving 3.5% PCE by annealing the RR-P3HT:PCBM blend, which showed that post-annealing and annealing with an external bias are both important. The solvent-annealing approach controls the polymer nanomorphology through the solvent-removal speed. Zhao et al. described a solvent-vapor-annealing approach with similar principles. The advantage of solvent annealing over thermal annealing is produced by sustaining the P3HT ordered structure upon higher PCBM loadings. The effects of solvent boiling point and film drying time on the polymer crystallinity and absorption studied by Chu et al. Fast solvent removal leads to not only the reduction of P3HT crystallinity, but also increases the interlayer distance of the polymer in the blend film [4].

V. EFFECT OF ADDITIVES

Additives effect on the film morphology and device performance, namely on JSC, VOC, and FF in the polyfluorene copolymer/fullerene system. In the poly(2,7-(9,9-dioctyl-fluorene)-alt-5,5-(40,70-di-2-thienyl-20,10,3-benzothiadiazole)):C61-PCBM blend system, mixing a small volume of CB into chloroform developed a finer and more uniform distribution of domains, which enhanced the JSC. Earlier efforts on the solvent-mixture approach concentrated on two miscible solvents, in which both the polymers and fullerenes have considerable solubility. Recently, advances in cooperative effect of solvent mixtures using solvents with distinct solubility have been obtained [4].

VI. THE SOLVENT AND KINETIC PARAMETERS

solvent evaporation rate, crystallization behaviour, and post treatments showcomparable significance in determining the morphology of thephotoactive layer. Local morphology information causes that high-resolution microscopy techniques have become the main investigation tools for morphology characterization have proven their versatility for detailed characterization of the morphology of the active layer [4].

VII. MORPHOLOGY OF ACTIVE LAYERS

Rispens *et al* have compared the surface topography of MDMO-PPV/PCBM active layers by varying the solvent from xylene (XY) through chlorobenzene (CB) to 1,2-

dichlorobenzene (DCB) and found a decrease in phase separation from XY through CB to DCB. The TEM images demonstrate a morphology in which PCBM-rich domains are dispersed in the MDMO-PPV-rich matrix. The size of the PCBM-rich domains in the blend films changes tremendously with the choice of solvent.The solubility of both MDMO-PPV and PCBM in toluene is somewhat less than in chlorobenzene.

In the same study Yang *et al.* investigated the influence of the solvent evaporation rate on morphology formation. They found that a low evaporation rate of CB, simulated by drop casting, caused phase segregation. They used different techniques for good evaporation of solvent such as drop casting, ink-jet printing or ultimately roll-to-roll printing, results in lower solvent evaporation rates when compared with spin-coating. The maximum solubility of PCBM would be determined to roughly 1 wt % in toluene and 4.2 wt % in chlorobenzene so that for concentrations above these critical concentrations aggregation of PCBM is anticipated already in the solvent, causing large scale phase segregation in the spin-cast films. Compound concentration and the ratio between the two compounds in the solution are important parameters controlling morphology formation; high compound concentrations induce large-scale phase segregation upon film formation. Because phase separation occurs between the two components, a large internal interface is created so that most excitons would be formed near the interface and can be dissociated at the interface [6].

Hsueh-Chung Liao *et al* focuses on morphological control by processing with solvent additives. two central guidelines in selecting host solvent and additives : (1) host solvents usually possess high solubility to both electron donor and acceptor molecules whereas solvent additives have selective solubility to one of the components (typically the acceptor), and (2) solvent additives are typically less volatile with higher boiling points than host solvents. Ortho-dichlorobenzene (o-DCB) in most cases is an excellent host solvent with high solubility for conjugated semiconductors [7].

Rajiv Giridharagopal *et al* also suggested that basic electronic properties such as carrier mobility and recombination rates are also sensitive to the film morphology. Numerous factors can affect the morphology of an OPV film, including polymer, choice of solvent, thermal annealing, solvent-vapor annealing, and the inclusion of additives during processing. Annealing in P3HT/PCBM films is known to more than triple their power conversion efficiency from ~1.1 to 3.6% [8].

Lilian Chang *et al* reported that Various solvent additives, e.g., alkanedithiols, 1-chloronaphthalene (CN), 1,8-diiodooctane (DIO), and nitrobenzene (NB) affect the P3HT-PCBM phase separation mechanism in BHJ films. Alkanedithiols and DIO are selectively better solvents for the PCBM than for P3HT, which drives the P3HT to self-stack and arrange into ordered domains, while allowing PCBM to remain in solution longer to avoid excessive PCBM aggregation. The main objectives of this research are to examine the role of trace solvent in affecting the morphology and diffusion rate of PCBM in the active layer by monitoring the extent of phase separation. The size of PCBM agglomerations increases as the duration of heat treatment increases. The size and number density of PCBM agglomerations in ODCB cast samples are greater compared to CB-cast samples after heat treatment, which suggest that the PCBM diffusion rate is higher in layers cast from ODCB phase separation. CN is a good solvent for both P3HT and PCBM. CN allows both components to remain in solution for a longer period of time, increasing the mobility of both phases within the BHJ layer and accelerating phase separation due to their high solubility in the solvent and poor solubility in one another. NB is a poor solvent for both P3HT and PCBM. The NB/CB film appears to be more textured than the CB film as previously reported. The addition of a small volume fraction of NB into the BHJ casting solution appears to hinder PCBM diffusion and inhibit the growth of PCBM agglomerations. NB additive corroborates the LBIC result, which showed that the formation of large PCBM agglomerates lead to deterioration of device efficiency. The addition of NB was shown to suppress the formation of PCBM agglomerates. The use of NB as a chemical additive suppressed the formation of PCBM agglomerates while the other additives tested such as DIO and CN promotes PCBM agglomeration [9].

Jae Kwan Lee *et al* the alkanedithiols do not react with either the polymer or the fullerene. As indicated by spectroscopic techniques the alkanedithiol is removed while drying the film under high vacuum. They find that the alkanedithiol selectively dissolves the PCBM; C61-PCBM and C71-PCBM are readily dissolved in alkanedithiol, but P3HT and PCPDTBT are not soluble in alkanedithiol. Because of the alkanedithiol has a higher boiling point than the chlorobenzene host solvent, the PCBM tends to remain in solution (during drying) longer than the semiconducting polymer, thereby enabling control of the phase separation and the resulting morphology of the BHJ material. Two criteria for processing additives for use in the fabrication of BHJ solar cells have been identified: (i) selective (differential) solubility of the fullerene component and (ii) higher boiling point than the host solvent. The control of the BHJ morphology by selective solubility of the fullerene component in the BHJ

blend so they have investigated the class of 1,8-di(R)octanes with I or Br. Using 1,8-di-iodooctane as the processing additive, the efficiency of the BHJ solar cells was improved from 3.4% (for the reference device) to 5.1% [10].

Louis A. Perez*et al,* a recent record solution processable small-molecule (SPSM) BHJ device containing a blend of 7,7′-(4,4-bis(2-ethylhexyl)-4H-silolo[3,2-b:4,5-b′]dithiophene- 2,6-diyl)bis(6-fluoro-4-(5′-hexyl-[2,2′-bithiophen]-5-yl)benzo[*c*] [1,2,5] thiadiazole) (*p* -DTS(FBTTh $_2$) $_2$) and (6,6)-phenyl C $_{71}$ - butyric acid methyl ester (PC $_{71}$ BM), demonstrated gains in PCE from 1.8 to 7% when 0.4 v/v% of the solvent additive 1,8-diiodooctane (DIO) added to the chlorobenzene (CB) casting solution. Spin casting and solution conditions for thin-film formation matched those used for device fabrication: that is, 3.5% wt/v solutions of *p* -DTS(FBTTh $_2$) $_2$ and PC $_{71}$ BM (60:40 weight ratio) in either CB or CB with 0.4 v/v% of DIO cast on glass/ITO/PEDOT:PSS substrates at 1750 rpm for 60 s.

Steffen Pfuetzner *et al* also studied the influence of different substrate temperatures during the deposition of the ZnPc:C60 blend layer in bulk heterojunction organic solar cells. Substrate heating during evaporation leads to an increase in photocurrent and fill factor [FF]. This is attributed to improved morphology resulting in better charge carrier percolation pathways within the ZnPc:C60 blend, leading to reduced transport losses and they show that controlled substrate heating during evaporation of ZnPc:C60 can increase OSC performance by over 60% [11].

By Jang Jo *et al* investigated for two annealing treatments with different morphology evolution time scales due to the diffusion and aggregation of PCBM molecules. Fast diffusion and aggregation of the PCBM molecules during P3HT crystallization resulted in poor BHJ morphology because of prevention of the formation of the more elongated P3HT crystals.

Annealing treatment is help in the formation of an ordered morphology via two evolution processes: i) crystallization or chain stacking of P3HT and ii) diffusion and aggregation of PCBM molecules into the blend. The optimized temperatures and annealing times work done by several research groups. All P3HT: PCBM films fabricated with blend solutions based on 1,2-dichlorobenzene (DCB), which has a relatively high boiling point (180^0C), because spin-coated films must have some remaining solvent for controlling the growth rate of the films. Disadvantages: The poor BHJ morphology after thermal annealing under these experimental conditions was attributed to the relatively fast diffusion and aggregation of the PCBM molecules during P3HT

crystallization, which interfered with the growth of the elongated fibrillar P3HT crystals and subsequent evolution of the well ordered BHJ morphology [12].

HUANG QiuLiu *et al* given an overview on the progress of the performance of BHJ solar cells is a combination of many factors, such as the molecular packing, the energy levels of donors and acceptors, the hole/electron mobility, and the quality of thin films and so on. The challenge in improving PCE is to optimize the interfacial area of the donor/acceptor materials and improve charge mobility within the active layer by increasing mesoscopic order and crystallinity [13].

Organic photovoltaic performance is sensitive to the nanoscale texture, or film morphology, in the photovoltaic active layer, particularly in bulk heterojunction devices. The ultimate goal is to establish an understanding of how device fabrication conditions effects [10].

Svetlana van Bavel *et al* reported that besides light absorption, other aspects such as efficient exciton dissociation, charge transportation, and charge collection are of crucial importance, and all of them are strongly influenced by the volume morphology of the photoactive layer [14].

VIII. CONCLUSION

We concluded and will focus on study about the effect of polymer/fullerene blend morphology evolution at the interface of the material by using the organic solvent. To obtain the ideal morphological structure and phase segregation by using emulsion of polymer/fullerene solution. For that we use water soluble polymer and fullerene which is dissolved in organic solvent. Getting ideal phase separation optimized different parameters for sprayed solution and obtained thin film as a active layer by using dual fed Ultrasonic spray system which will be apply for the bulk heterojunction in organic photovoltaic solar cell. Lot of efforts did for the develop new OSC's as well as efforts to effectively translate these laboratory to large-scale module production must confront the challenge of characterizing and optimizing organic film morphology. This is our future work.

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