Chapter 4

Duel feed approach for preparation of P3HT:PCBM

Bulk-heterojunction

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This Chapter introduces the novel Duel Liquid Feed Ultrasonic Spray Method for preparation of P3HT: PCBM Bulk-heterojunction active layer in Organic Solar Cells. The merits of this approach over the usual single feed way are discussed. Effect of various process parameters on the structural, electrical and optical properties of the bulk-heterojunction of P3HT: PCBM has been presented. The suitability of the active layer for its application in OSC has been studied using steady-state photoluminescence spectroscopy.

Previous chapter of the thesis described in details the deposition methods those are currently in use for the deposition of active layer in the organic solar cells fabrication. To achieve the maximum possible efficiency in organic photovoltaic devices the phase separation of donor-acceptor materials must ensure formation of relatively pure phases with continuous path to the generated electrons and holes to reach their respective electrode. The conventional single liquid feed deposition method is not suitable to provide the pure phases of donor and acceptor materials. This method normally provides the P3HT rich domains and PCBM rich domains. So, although the photoluminescence response may show good quenching, every separated charge at the interface may not reach to their respective electrodes due to unavailability of the continuous path of pure hole conducting/electron conducting phase in the device or due to low charge carrier mobilities of the impure phases. Thus the active layer formed may not provide the ideal structure for the active layer.

1. Review

Spray technique is one of the promising techniques with the ability of large area roll to roll device fabrication for commercial level production of organic solar photovoltaic cells; it’s an alternative technique to deposit the active layers of the polymer solar cells. Spray coating is a high-throughput, large-area deposition technique that offers the ability to deposit a broad spectrum of fluids with different properties and various solute concentrations. Many research groups are trying to develop these promising techniques to improve the device performance and fabrication ability. Vak at el. deposited the active layer of organic solar cell using the airbrush [1]. Chen et al. demonstrated the multi-spray approach for formation of active layer in which both the donor and acceptor materials are sprayed separately using the airbrush [2]. With the spray techniques like airbrush the droplet size of the
The spray is about few hundred micrometers in size which is not able to provide the donor acceptor material phase separation at nanoscale. To overcome this problem Steirer et al. and Girotto et al. [3] deposited the conducting organic electrode [4] and active layer [5] with the novel ultrasonic spray technique. Tait et al. fabricated the active layer by concurrently pumped ultrasonic spray coating and optimized thickness of organic solar cells, with a peak efficiency of 4.1%, 72% fill factor, 9.3 mA/cm² short circuit current density and a 620 mV open circuit voltage [6]. Rispens et al. reported that the single crystals of PCBM (electron acceptor) grown from chlorobenzene show crystal packing in which the electrons can hop easily in three dimensions [7]. Green et al. reported active layers produced from chlorobenzene solvent were significantly smoother and more homogeneous [8].

2. **Merits of dual liquid feed:**

   In the single liquid feed spray method both the materials (donor and acceptor) are intimately mixed and dissolved in the single solvent. The mixed solution is sprayed on the substrate and during solidification process leading to thin film, the donor and acceptor may get phase separated. But as stated earlier, this phase separation is not complete and we get donor rich and acceptor rich domains. To get better control over phase separation researchers have tried addition of some additive solvents in the base solution. In the proposed dual liquid feed option we can dissolve the donor and acceptor materials in two different solvents or separately in the same solvent. The two solutions are then fed to two separate solution inlets available in the duel liquid feed ultrasonic nozzle. Thus, both the materials are only allowed to be in contact of each other at the tip of the ultrasonic nozzle, which prevent the intimate mixing of the two components. The micrometer sized drops generated are carried towards the substrate with the help of carrier gas and get deposited on the substrate. This forms the better and well connected pure phases of donor and acceptor material, which provides the continuous path to the dissociated electrons and holes to reach corresponding electrodes.

In this study, we decided to fabricate the active layer using the Duel Liquid Feed Ultrasonic Nozzle in following three ways.

1. a) P3HT dissolved in Chlorobenzene feed through channel 1 and
b) PCBM dissolved in Chlorobenzene feed through channel 2 simultaneously through the Duel Liquid Feed Ultrasonic Nozzle.
c) The system will be referred as CC hereafter.
2. a) P3HT dissolved in Dichlorobenzene feed through channel 1 and 
   b) PCBM dissolved in Dichlorobenzene feed through channel 2 
   simultaneously through the Duel Liquid Feed Ultrasonic Nozzle.
   c) The system will be referred as DD hereafter.
3. a) P3HT dissolved in Dichlorobenzene feed through channel 1 and 
   b) PCBM dissolved in Chlorobenzene feed through channel 2 simultaneously through the Duel Liquid Feed Ultrasonic Nozzle.
   c) The system will be referred as CD hereafter.

The active layer deposited was studied with and without annealing for 10 min at 120 °C. The films/devices not annealed are denoted with letter A e.g. CCA and films/devices that are annealed are denoted with number 10 e.g. CC10.

Our aim was to study in detail the effect of different solvent combinations on the important properties of the blend such as the carrier mobilities and phase separation. Dark I-V measurement of single carrier devices, PL spectroscopy, UV-Visible spectroscopy, optical microscopy and Atomic Force Microscopy have been used to probe these properties

3. Experimental Setup:-

Experimental arrangement of dual liquid feed ultrasonic spray system is as shown in the schematic representation in Fig. 4 of Chapter 2. Tip of the ultrasonic nozzle is operated at ultrasonic frequency i.e. 120 kHz for used nozzle, ultrasonic frequency signal is generated using the ultrasonic frequency generator and carried out through the ultrasonic broadband cable to the ultrasonic nozzle. For precise solution delivery to the ultrasonic nozzle two fluid pumps are used for the solutions of donor and acceptor materials separately. Both the fluid pumps are controlled by separate pump controllers. The pumps are synchronized with each other so that solution can be sprayed with all possible combinations of On-Off cycles of individual pumps. To deposit the film at desired temperature substrate were put on the hot plate. PID temperature controller was used for precise control on the substrate temperature.
4. Experimental Process flow:

Following Figure 1 gives the process-flow towards fabrication of the P3HT:PCBM bulk-heterojunction through the duel liquid feed ultrasonic nozzle and its study.

**Figure 1 Process-flow towards fabrication of the P3HT:PCBM bulk-heterojunction through the duel liquid feed ultrasonic nozzle and its study.**

**Steps involved:**

1. Patterning of the ITO substrate is done using the technique described in the 2nd chapter.
2. Cleaning of glassware and substrates using the method described the 2nd chapter.

3. Preparation of P3HT and PCBM solutions:
   i) 2.22 mg of P3HT is dissolved in 1 ml of the solvent and the solution is kept for stirring for 24 hour.
   ii) Similarly 2.24 mg of PCBM is dissolved in 1 ml of the solvent and the solution is kept for stirring for 24 hour.

4. After overnight stirring, P3HT solution is filtered with PTFE filter, having pore size 0.25 µm to ensure the removal of solute crystals from the solution.

5. Keep the prepared PCBM solution for ultrasonication in ultrasonic bath for about 1 hour and filter the solution with PTFE 0.25 µm filter prior to deposition.

6. Both the filtered solutions are feed in the fluid pumps for further deposition.

7. Solution flow rates of both the fluid pumps are adjusted for 10 ml/hr, with 1 sec ON time and 3 seconds OFF time.

8. When substrate heater is made ON, at same time start the Nitrogen Air flow on heater so that temperature of hot plate gets stabilized under the carrier gas flow. During deposition maintain the nitrogen flow rate to 8 lpm.

9. Anneal the PEDOT:PSS coated ITO slides for 10 min prior to deposition.

10. Keep the clean glass/ITO slides on hot plate for deposition and wait few minutes for temperature stabilization.

11. Sequence for dual feed solution deposition;
   i. Set the programmer of fluid pump as per requirement.
   ii. Start the ultrasonic generator and check the atomization power is 1.7 watt.
   iii. Start the fluid pump controller and run the program by pressing green push button.
   iv. Turn off the ultrasonic generator after completing the predefined number of cycles.
   v. Remove the deposited film.

12. Anneal the deposited films on glass for required time and keep them for further process/Characterization in vacuum desiccators.
13. Anneal the deposited films on ITO/PEDOT:PSS for required time and move them in vacuum chamber for back electrode deposition.

14. After metallization device is tested for IV characteristics with Keithley source-measure meter for the mobility measurement.

5. Mobility measurement:

The donor and acceptor phases in the active layer of organic photovoltaic solar cell devices show considerable change in hole and electron mobility. The hole mobility $10^{-9} \text{m}^2\text{V}^{-1}\text{s}^{-1}$ of P3HT and electron mobility $10^{-8} \text{m}^2\text{V}^{-1}\text{s}^{-1}$ of PCBM has been reported, which shows ten a order of difference in electron and hole mobility of the materials [9].

Frequently used tool for investigating charge carrier mobilities of low mobility media is to examine the space-charge-limited current through a semiconductor in the dark [10,11]. Since the SCLC is directly proportional to the charge-carrier mobility [12]:

$$j_{\text{SCLC}} = \frac{9}{8} \varepsilon \mu \frac{V^2}{L^3} \quad \cdots \cdots \cdots (1)$$

Where, $\varepsilon$ is the dielectric constant of material, $V$ is the internal voltage of the device, $\mu$ is the charge carrier mobility and $d$ is the thickness of the active layer.

If only the dependence of the charge carrier mobility on the electric field is taken into account, the SCLC is given by:

$$j_{\text{Dark}} = \frac{9}{8} \varepsilon \mu_0 \exp \left( 0.89y \sqrt{\frac{V}{L}} \right) \frac{V^2}{L^3} \quad \cdots \cdots \cdots (2)$$

Here $V$ related to the applied voltage ($V_{\text{bias}}$) as:

$$V = V_{\text{bias}} - V_{\text{bi}} - V_{\text{Rs}} \quad \cdots \cdots \cdots (3)$$

Where the built-in voltage ($V_{\text{bi}}$) is the voltage at which the J-V characteristics become quadratic. The $V_{\text{Rs}}$ is the voltage drop across the series resistance of the substrate.

Here, $V_{\text{bi}} = 0$ and we also assumed that $V_{\text{Rs}} = 0$. 
All the mobility measurements were done by fitting the experimental data with Eqs. (2) For the measurement of hole mobility in P3HT ITO/PEDOT:PSS/P3HT:PCBM/Au structure has been used as the hole only device [13,14]. Same structure has been adapted in our studies. Following Figure 2 gives the schematic of device structure used for hole mobility measurement studies and Figure 3 shows the energy band diagram for the device structure.

![Figure 2: Schematic representation of device structure for mobility measurement](image1)

![Figure 3: Schematic representation of energy band diagram of mobility device](image2)

The experimental data were fitted with equation (2) and the best fitted values of e (field activation factor) and m (mobility) were obtained. The data fitting was done using software ORIGIN. Following Figure 4 shows the experimental data and the best fits to the experimental data obtained. The values of e (field activation factor) and m (mobility) are also shown in the inset.
5.1 For chlorobenzene

![Graph](image)

Equation: \[ y = \frac{9}{8} \times 8.85419 \times 10^{-12} \times 3.4 \times m \times (x^2/(1E-7)^3) \times \exp\left(0.89\times e\times \sqrt{x/1E-7}\right) \]

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Standard Error</th>
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<tr>
<td>CCAa</td>
<td>e</td>
<td>-2.47718E-4</td>
</tr>
<tr>
<td>CCAa</td>
<td>m</td>
<td>3.85025E-8</td>
</tr>
</tbody>
</table>

Adj. R-Square: 0.9986

![Graph](image)

Equation: \[ y = \frac{9}{8} \times 8.85419 \times 10^{-12} \times 3.4 \times m \times (x^2/(1E-7)^3) \times \exp\left(0.89\times e\times \sqrt{x/1E-7}\right) \]

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Standard Error</th>
</tr>
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<tbody>
<tr>
<td>CC10b</td>
<td>e</td>
<td>-3.52497E-4</td>
</tr>
<tr>
<td>CC10b</td>
<td>m</td>
<td>1.84429E-7</td>
</tr>
</tbody>
</table>

Adj. R-Square: 0.99714

Figure 4: Hole mobility measurements for the P3HT:PCBM blend films prepared with both components in the chlorobenzene solvent (System CC)(a) device without annealing (b) device with 10 min annealing
5.2 For Dichlorobenzene

Figure 5: Hole mobility measurements for the P3HT:PCBM blend films prepared with both components in the dichlorobenzene solvent (System DD)( (a) device without annealing (b) device with 10 min annealing)
5.3 For Chlorobenzene : Dichlorobenzene

![Image of a graph showing hole mobility measurements for the P3HT:PCBM blend films prepared with P3HT in chlorobenzene solvent and PCBM in dichlorobenzene solvent (System CD). (a) device without annealing (b) device with 10 min annealing]

Figure 6: Hole mobility measurements for the P3HT:PCBM blend films prepared with P3HT in chlorobenzene solvent and PCBM in dichlorobenzene solvent (System CD). (a) device without annealing (b) device with 10 min annealing
5.4 Comparative chart for all solvent combinations:

<table>
<thead>
<tr>
<th>Device Name</th>
<th>Solvent</th>
<th>Annealing time (min)</th>
<th>Mobility (m^2 V^{-1} s^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P3HT</td>
<td>PCBM</td>
<td></td>
</tr>
<tr>
<td>CCA</td>
<td>Chlorobenzene</td>
<td>Chlorobenzene</td>
<td>0</td>
</tr>
<tr>
<td>CC10</td>
<td>Dichlorobenzene</td>
<td>Dichlorobenzene</td>
<td>10</td>
</tr>
<tr>
<td>DDA</td>
<td>Dichlorobenzene</td>
<td>Dichlorobenzene</td>
<td>0</td>
</tr>
<tr>
<td>DD10</td>
<td>Dichlorobenzene</td>
<td>Chlorobenzene</td>
<td>10</td>
</tr>
<tr>
<td>CDA</td>
<td>Dichlorobenzene</td>
<td>Chlorobenzene</td>
<td>0</td>
</tr>
<tr>
<td>CD10</td>
<td>Dichlorobenzene</td>
<td>Chlorobenzene</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 1: Calculated hole mobilities with space–charge-limited current for different solvent combinations.

Devices were fabricated with device structure shown in Fig. 2 and calculated values for hole mobility as represented in the Table 1. Devices prepared using chlorobenzene solvent shows increase in the hole mobility due to increased crystallinity of P3HT in the films. But in other two cases P3HT has been dissolved in dichlorobenzene solvent. It is reported earlier that the dichlorobenzene solvent improves the crystallinity of P3HT in the film. Thus for the devices with P3HT dissolved in dichlorobenzene, the hole mobility is high without annealing the films. It can be seen from the table that the mobility value is even better than that for annealed films with P3HT dissolved in chlorobenzene. Moreover, the hole mobility value is higher in the case where (P3HT in dichlorobenzene + PCBM in chlorobenzene) combination is used than the case where both P3HT and PCBM are dissolved in common dichlorobenzene solvent. This may be due to possibility of more pure phase formation in former case (due to restricted miscibility of two solvents) than the later. Decrease in mobility in DD and CD structure after annealing, however needs further probing.
6. UV-Visible spectroscopy:

Optical absorption of P3HT is very sensitive to changes in local environment and molecular arrangement of P3HT molecules and can be interpreted using the Spano model of weakly interacting H-aggregates [15,16]. According to this model, the ratio of the 0–0/0–1 vibronic transitions (at ~595 and ~550 nm, respectively, see (Fig. 7)) can be related to the magnitude of aggregation and, therefore, intermolecular coupling within the system. In addition, the disordered polymer chains give rise to a higher energy, lower wavelength, λ, absorption (at λ < 540 nm). Following figures shows the absorption spectra for the blend films deposited with CC, DD and CD systems.

6.1 For Chlorobenzene

![Figure 7: UV-Visible absorption for P3HT and PCBM blend both in the chlorobenzene solvent UV-Visible absorption where normalized to the 0-1 vibronic transition (~550nm), CCA-As deposited, CC10- annealed for 10 min at 120°C and P3HT-As deposited in chlorobenzene.](image-url)
6.2 For Dichlorobenzene

Figure 8: UV-Visible absorption for P3HT and PCBM blend both in the dichlorobenzene solvent UV-Visible absorption where normalized to the 0-1 vibronic transition (~550nm), DDA-As deposited, DD10- annealed for 10 min at 120°C and P3HT-As deposited in dichlorobenzene.

6.3 For Chlorobenzene: Dichlorobenzene

Figure 9: UV-Visible absorption for P3HT in dichlorobenzene and PCBM in chlorobenzene solvent UV-Visible absorption where normalized to the 0-1 vibronic transition (~550nm), CDA-As deposited, CD10- annealed for 10 min at 120°C and P3HT-As deposited in dichlorobenzene.
Following Table-2 lists the ratios of the 0-0/0-1 vibronic transitions, the peak positions and the peak intensities.

<table>
<thead>
<tr>
<th>Sample Name</th>
<th>0-0/0-1 vibronic transitions ratio</th>
<th>Peak position</th>
<th>Peak intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCA</td>
<td>0.51379</td>
<td>457</td>
<td>1.67</td>
</tr>
<tr>
<td>CC10</td>
<td>0.71812</td>
<td>475</td>
<td>1.2</td>
</tr>
<tr>
<td>DDA</td>
<td>0.43875</td>
<td>466</td>
<td>1.72</td>
</tr>
<tr>
<td>DD10</td>
<td>0.59773</td>
<td>475</td>
<td>1.39</td>
</tr>
<tr>
<td>CDA</td>
<td>0.55408</td>
<td>462</td>
<td>1.56</td>
</tr>
<tr>
<td>CD10</td>
<td>0.67867</td>
<td>485</td>
<td>1.18</td>
</tr>
<tr>
<td>P3HT C</td>
<td>0.66667</td>
<td>520</td>
<td>1.03137</td>
</tr>
<tr>
<td>P3HT D</td>
<td>0.62087</td>
<td>515</td>
<td>1.06818</td>
</tr>
</tbody>
</table>

*Table 2: Parameters comparison from the absorption spectra.*

From the table it is observed that in all the blend films, a red shift in the absorption peak is observed. Such a red shift has been attributed to head-to-tail linkages in the polymer chain, increase in effective conjugation length of P3HT and increased aggregation of P3HT domains in the blend films [17]. Secondly, the ratio of 0-0/0-1 vibronic transitions gives idea about the shoulder located at ~600 nm. It has been seen as a spectral characteristic of crystalline P3HT [18]. The shoulder at 600 nm has been assigned to an inter-chain excitation [19]. Thus, it can be clearly seen that the as deposited films with different solvents shows better crystalline nature of P3HT. This has reflected in higher hole mobility value in bulk heterojunction made with different solvents for the donor and acceptors.

When same solvent is used for the deposition of P3HT and PCBM blend, (fig. 6 and 7) the probability of mixing the donor and acceptor phase during thin film formation is more. This is because miscibility of the same solvent as well as almost equal evaporation rates for the P3HT and PCBM solution drops. As both the materials are get mixed it shows suppressed 0-0/0-1 absorption ratio which indicates the poor aggregation of polymer chains. On annealing the blend films, polymer gets ordered and results in enhancement in 0-0/0-1 absorption feature. But, when we use the
different solvents for P3HT and PCBM materials, the probability of their intermixing is less due to two reasons: less miscibility between the two solvents and different evaporation times of the two solution droplets. This immiscibility of the two phases improves the crystallinity of the P3HT polymer chains in the blend which can be clearly seen in the UV-Visible spectroscopy results (fig. 8). Due to low miscibility of both the solvents in each other P3HT forms ordered structure in the film which enhances the 0-0/0-1 absorption. Upon annealing the overall crystallinity improves which shows reduced absorption in the short wavelength region. The fullerene absorption around ~340 nm is reduced on annealing. This has been ascribed to the increased domain size of PCBM [20].

7. Photoluminescence studies:

Here photoluminescence study of deposited samples is discussed in details, the excitation wavelength used was wavelength at which pure P3HT film shows highest absorption i.e. 514 nm.

![Figure 10: PL spectra for blend films prepared with three different systems D: Before annealing and E: annealed for 10 min at 120°C](image-url)
Following points can be noted from the results:

1. It has been reported for P3HT that the peak at ~650 nm is from P3HT, while that at 700-720 nm is contributed from both P3HT and PCBM molecules [21]. The band at ~825 nm is observed. Such emission has been reported for similar polymer/fullerene blends and attributed to emission from a CT state [22,23].

2. For common solvent as well as different solvent thin film formation, the PL spectrum has almost identical nature. Overall higher PL intensity for Dichlorobenzene-Dichlorobenzene case indicates formation of relatively larger phases of donor and acceptor, while overall lower PL intensity for chlorobenzene-chlorobenzene case indicates formation of relatively smaller phases of donor and acceptor. The case of Dichlorobenzene-chlorobenzene lies in between these two.

3. After annealing the blend films the overall intensity picture for the chlorobenzene-chlorobenzene and Dichlorobenzene-Dichlorobenzene cases get reversed. Now chlorobenzene-chlorobenzene case shows higher intensity than the Dichlorobenzene-Dichlorobenzene case, indicating more phase separation in the former case than the later after annealing. The case of Dichlorobenzene-chlorobenzene, on the contrary shows altogether different behavior. The PL intensity corresponding to P3HT as well as PCBM (the 720
nm and 825 nm contribution) is observed to be reduced after annealing. It indicates that after annealing, the two phases are getting more intermixed rather than aggregating.

4. In all the three cases the blend films shows significant PL quenching before and after annealing as compared to their pristine polymer counterparts.

Figure 11: PL spectra of blend films prepared with three different methods and their comparison with pristine polymer films indicating PL quenching in the blend films: (a) blend films prepared by CC system and P3HT film using chlorobenzene as the solvent (b) blend films prepared by DD system and P3HT film using dichlorobenzene as the solvent and (c) blend films prepared by CD system and P3HT film using dichlorobenzene as the solvent
8. Optical Microscope Images

Figure 12: Optical microscope images in transmittance mode for chlorobenzene-chlorobenzene solvent system (a) without annealing (b) with annealing; for dichlorobenzene-dichlorobenzene solvent system (c) without annealing (d) with annealing and for chlorobenzene-dichlorobenzene solvent system (e) without annealing (f) with annealing, at centre of deposition area -20x zoomed.
Synthesis of organic thin films by dual feed Ultrasonic Spray Method and study of their nanomorphology for application in low cost organic solar cells

Figure 13: Optical microscope images in transmittance mode for chlorobenzene-chlorobenzene solvent system (a) without annealing (b) with annealing; for dichlorobenzene- dichlorobenzene solvent system (c) without annealing (d) with annealing and for chlorobenzene- dichlorobenzene solvent system (e) without annealing (f) with annealing, at centre of deposition area -50x zoomed.

Following are the conclusions that can be drawn from the observations of the optical microscope images:
1. The degree of intermixing of the donor and acceptor phases is more in dichlorobenzene-dichlorobenzene system than that in chlorobenzene-chlorobenzene system.

2. Donor and acceptor domains formed in different solvent system i.e. dichlorobenzene-chlorobenzene system are much larger as compared to the two identical solvent systems. This may be the result of different evaporation rates of the two solvents favoring merging of subsequent droplets leading to formation of larger domains.

3. In case of identical solvents system (i.e. CC and DD), increased contrast is observed after annealing of the films. This is due to well reported phenomena of PCBM diffusion out of P3HT matrix due to short term thermal annealing. This leads to more pure phase formation resulting in increased contrast in optical images, as well as increase in domain dimensions also. This shall increase the PL intensity after thermal annealing. In fact this is observed in the PL spectra presented in earlier section.

4. The different solvent system (i.e. CD), on the contrary, shows exactly opposite behavior upon thermal annealing. The un-annealed films show more contrast as compared to their annealed counterparts. Not only this, the dark area, representing P3HT phase appears to be well spread in the bulk after the annealing. This results in more interpenetrating phases. This is confirmed from the PL response of the annealed films. It has been shown in earlier section that, only in the CD system, the PL intensity decreases after thermal annealing.

The notion that the novel duel liquid feed method shall lead to pure phase formation has been tested by getting phase image through Atomic Force Microscopy. Figure 14 (a) shows the surface topography and (b) the phase image obtained through tapping mode AFM for the blend prepared by duel feed approach. The image clearly indicates highly pure phase separation between donor and acceptor phases.
9. Conclusions:

Based on the studies presented in this chapter following conclusions can be drawn:

I. The duel liquid feed ultrasonic method has been successfully demonstrated for fabrication of P3HT:PCBM active layer deposition.

II. Use of different solvents for the donor and acceptor phases leads to better quality of the active layer.

III. Advantage of using different solvents is clearly seen in terms of quality of phase separation of the two phases reflected in better PL quenching and optical images.

IV. The notion that the novel duel liquid feed method shall lead to pure phase formation has been confirmed through AFM phase image.
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