CHAPTER 5

Conclusion and Future Scope

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5.1 Introduction

The thesis is mainly focused on investigating and improving the photovoltaic performance parameters of the PCDTBT:PC_{61}MB-based bulk heterojunction organic solar cell (BHJ OSC) fabricated by low-cost solution process. This chapter includes the chapter-wise objectives and major findings of the thesis as described in the following section.

5.2 Chapter-Wise Major Observations

Chapter-1 introduces the inorganic/organic semiconductors and the charge transport phenomena involved with them. Different types of organic solar cell structures have been discussed. The bulk heterojunction (BHJ)-based organic solar cells (OSCs) have been discussed in detail. The working principle and photovoltaic parameters of the OSCs have also been introduced. A detailed literature survey on PCDTBT:PC_{61}BM and other related active layers based BHJ OSCs have been discussed. OSCs with an electron transport layers (ETL) of ZnO and a hole transport layer (HTL) of PEDOT:PSS, PQT-12, and MoO_3 have also been reviewed. Based on the research gaps observed from the literature survey, the scope of the thesis is outlined at the end of this chapter.

Chapter-2 reports the fabrication and characterization of PCDTBT:PC_{61}BM based BHJ OSCs. Two distinct BHJ OSCs with device structures of ITO/ZnO QDs (ETL)/PCDTBT:PC_{61}BM (Active layer)/PEDOT:PSS (HTL)/Ag and ITO/ZnO QDs (ETL)/PCDTBT:PC_{61}BM (Active layer)/PQT-12 (Interface layer)/PEDOT:PSS

(HTL)/Ag have been studied. The floating film transfer method (FTM) derived PQT-12 film is used as an interface layer in between the PCDTBT:$PC_{61}BM$ active layer and PEDOT:PSS HTL layer. The major observations and findings from the chapter are summarized below:

- ❖ The effect of the FTM-derived PQT-12 as an interface layer between PCDTBT:$PC_{61}BM$ and PEDOT:PSS has been investigated by analyzing the electrical as well as optical behaviour of the fabricated BHJ OSC.
- ❖ The electrical characterization has been performed by current-voltage and Nyquist plots, whereas the optical characterization has been performed by absorption, photoluminescence (PL), and external quantum efficiency plots.
- ❖ Insertion of FTM-derived PQT-12 as an interface layer results in improved photovoltaic parameters compare to the device without interface layer of PQT-12.
- ❖ Improvement in the photovoltaic parameters such as short circuit density (Jsc) from 5.12 to 5.62 mA/cm^2, open-circuit voltage (Voc) from 419 to 562 mV, and fill factor from 0.24 to 0.33 are observed and attributed to the enhancement in charge transportation as well as absorption due to insertion of PQT-12 as an interface layer.
- ❖ Although the photovoltaic parameters (power conversion efficiency from 0.53 to 1.05 %) have been improved, the OSC's performance is still low, and hence further enhancement is needed.

Chapter-3 investigates the effects of the thicknesses of the ZnO QDs ETL and PQT-12 HTL on the performance of the ITO/ZnO QDs/PCDTBT:$PC_{61}BM$/ PQT-12/Ag based BHJ OSC. The PQT-12 film is grown by the floating-film transfer method (FTM) while the colloidal ZnO QDs have been used for the ETL as discussed in Chapter-2. The major findings of this chapter are summarized as follows:

- PQT-12 used as HTL layer in the ITO/ZnO QDs/PCDTBT:PC_{61}BM/PQT-12/Ag shows better performance over the ITO/ZnO QDs/PCDTBT:PC_{61}BM/ PEDOT:PSS /Ag device considered in Chapter-2. This shows that FTM based PQT-12 can act as a better HTL material than the PEDOT:PSS in the BHJ OSCs.
- The performance parameters for different thicknesses of solution-processed spin-coated ZnO ETL and FTM-derived PQT-12 HTL have been investigated. Based on the results, the best suitable values of the ZnO QDs ETL and PQT-12 thicknesses have been obtained for the ITO/ZnO QDs/PCDTBT:PC_{61}BM/PQT-12/Ag BHJ OSC under study.
- The ZnO QDs ETL of 35 nm and PQT-12 HTL of 20 nm thicknesses show the best photovoltaic parameters. It offers a short circuit current density (Jsc) of 10.42 mA/cm^2, open-circuit voltage (Voc) of 672 mV, fill factor of 0.38, and power conversion efficiency of 2.66 %. The above results are much higher than those obtained for other values of the thicknesses the ETL and HTL of the OSC under study.
- The maximum obtained power conversion efficiency with the 35 nm of ZnO QDs ETL and 20 nm of PQT-12 HTL is 2.66 %. It is relatively low which opens up the opportunities for further improvement.

Chapter-4 investigates the performance of the CdSe QDs:PCDTBT:PC_{61}BM based inorganic-organic hybrid Nano composites based BHJ OSC. The performance parameters of ITO/ZnO QDs/PCDTBT:PC_{61}BM/MoO_3/Ag and ITO/ZnO

QDs/PCDTBT:PC_{61}BM:CdSe QDs/MoO_3/Ag based BHJ OSCs have been compared. The ZnO QDs and MoO_3 are used as the ETL and HTL, respectively in these structures. The major observations and findings from the chapter are summarized below:

- ❖ The proposed PCDTBT:PC_{61}BM:CdSe QDs active layer based BHJ OSC of ITO/ZnO QDs/PCDTBT:PC_{61}BM: CdSe QDs/MoO_3/Ag structure shows better photovoltaic parameters over the ITO/ZnO QDs/PCDTBT:PC_{61}BM/ PQT-12/Ag structure studied in Chapter-3.
- ❖ The electrical and optical characterizations have been carried out to investigate the synergistic effect of CdSe QDs and PCDTBT:PC_{61}BM in the photoactive layer to improve the performance of the BHJ OSCs.
- ❖ Significant improvement in the photovoltaic parameters such as short circuit density (Jsc) from 13.30 mA/cm^2 to 14 mA/cm^2, open-circuit voltage (Voc) from 699 mV to 854 mV, and fill factor from 0.38 to 0.42 have been observed when PCDTBT:PC_{61}BM is replaced by PCDTBT:PC_{61}BM:CdSe QDs as the active layer in the BHJ OSC structure under study.
- ❖ The proposed ITO/ZnO QDs/PCDTBT:PC_{61}BM:CdSe QDs/MoO_3/Ag BHJ OSC shows the maximum power conversion efficiency of 5.02 % which is much higher than that of the PCDTBT:PC_{61}BM based BHJ OSCs considered in Chapter-2 and Chapter-3.

5.3 Future Scope of Work

Based on the research expertise gained through the works carried out in the present thesis, some scopes of future research in the related area can be outlined as follows:

- ❖ PCDTBT:PC_{61}BM bulk heterojunction organic solar cell may be fabricated on a flexible substrate such as polyamide, PET, PEN, etc.

- Various metal nanoparticles such as Au, Ag and Al, etc., may be used upon/under the PCDTBT:$PC_{61}BM$ film to produce a plasmonic effect to further enhance OSC performance.
- Different nanostructures, such as nanowires, nanorods, and nanotubes of metal oxides such as ZnO, TiO_2, MoO3, etc., may be used for transport layers, which may improve the optical property of the PCDTBT:$PC_{61}BM$ based BHJ OSC.
- Another donor polymer may be mixed with the PCDTBT:$PC_{61}BM$ active layer for better collect solar spectrum range using ternary structure.
- Doped ZnO and MoO_3 may be used as ETL and HTL, respectively, in the PCDTBT:$PC_{61}BM$ based BHJ OSC to improve the charge transportation and hence performance of the OSC.