Synopsis

In the past few decades the field of organic electronics particularly organics photovoltaic (OPVs) find wide interest among researchers. It finds many advantages such as light weight, low temperature fabrication requirements, mechanical flexibility, can be fabricated by roll-to-roll process methods. Since, the OPVs are thin film devices the optical absorption and device interfaces are very important factor in deciding the device performance. The optical absorption is dictated by the semiconducting active layer which generates the charge carrier for the effective current generations. The absorption of the active layer can be enhanced by various methods to improve the electron-to-photon conversion ratio. The interface properties play crucial role because the semiconductor generated exciton needs to be splitted and collected effectively at the electrode. This can be effectively achieved by aligning energy level of the active layer, interface layer and electrode. Further, the device efficiency is also correlated with the morphology at the various interfaces which controls the charge carrier flow across the different layers.

In the chapter-1, the details about the motivation of the work, generation of the solar cell and the invention of the photovoltaic and then discussed about working principle of OPVs and finally summary of the work is given. In the chapter-2, the materials, methods and characterization technique details are given.

In the chapter-3, plasmonic device was designed to enhance the photocurrent density in an inverted bulk heterojunction organic solar cell. Aluminum nanoparticles dispersed in the hole transport layer at the rear end of the device structure are observed to enhance the device performance through multiple effects including enhanced absorption and better charge collection. Modeling and simulations are used to understand the mechanisms of optical transport that underline the enhancements which are experimentally observed.

In the chapter-4, the ternary blend system, binary acceptor (PC71BM and MoS2) and a donor (PTB7) system was studied. Usually, the ternary system enhances the device performance through optical properties and electrical properties. The optimized ternary blend system showed increment of 17% power conversion efficiency. The origin of improved in PCE is discussed based on the increment in JSC and fill factor. Further, the improvement in JSC and FF is discussed based on light harvesting and improved charge carrier mobility in the active matrix. The optical absorption and energy transfer mechanism of the ternary blend film is explained by absorption and photoluminescence measurement respectively.

In the chapter-5, the interface defect states (electrode/active layer) were studied in OPVs. the formation of Schottky barrier contact (SBC) leads reconstruction of charges at the metal/semiconductor (MS) interface because of the wave function overlap between semiconductor and metal contact. The Schottky barrier contact formation is not only a signature of material's work function but it also sensitive to the interface trap states, the crystal orientation of the interacting materials and other interface properties. In this work, the effect of aluminum cathode morphology on the polymer Schottky diode and bulk heterojunction (BHJ) photovoltaic device performance suggests. The electron collecting contacts in Schottky barrier diode and bulk-hetero junction photovoltaic device have been deposited using aluminum in pellet and nanoparticle form. Devices fabricated by using Al nanoparticle showed improvement in dark as well as photocurrent density. The enhancement in JSC leads to overall improved power conversion efficiency.

Enhanced performance in Schottky structured diode and OPV device have been correlated with electrode microstructure and its interface properties like improved electrically active contact, enhanced charge transport and optical properties. Electrical conductivity is discussed based on enhanced electrical coherence across organic semiconductor and electrode interface whereas optical property is discussed based on light confinement and hence longer optical path length inside active layer of the device. Therefore, the contributions of electrical enhancement lead to improvement in short-circuit current density (JSC) in BHJ solar cell. Further, PCE was correlated with the density of interface trap states studied by drive level capacitance profiling technique (DLCP).

In the chapter-6, the composite of PEDOT:PSS/NaYF4:Yb3+/Er3+ was investigated as a hole transport layer (HTL) in an inverted bulk hetero junction solar cell architecture. Up-conversion nano-composite (PEDOT:PSS/NaYF4:Yb3+/Er3+) was prepared and embedded in a P3HT:PC60BM based polymer solar cell to harvest light from the IR region. The up-conversion nano-composite absorbs light from the wavelength region between 940nm to 1060nm and the associated emission occurs in the visible wavelength region between 540nm to 560nm. Emission region of nanocomposite covers the absorption region of P3HT:PC60BM which will facilitate improvement in optical absorption. Various loadings of PEDOT:PSS/NaYF4:Yb3+/Er3+ were prepared and then the optimized ratio was investigated to study the up-conversion process in the OPV device. OPV with UCNP modified HTL device showed considerably higher photocurrent than without UCNP. The enhancement in power conversion efficiency (⍰) has been investigated through structural, optical and electrical characterization. Optical and electrical properties of the device, suggests that improvement in conversion efficiency could be combination of up-conversion process and back scattered light by up-conversion nanoparticle (UCNP) in the HTL. The current due to up conversion mechanism and light scattering are quantified.