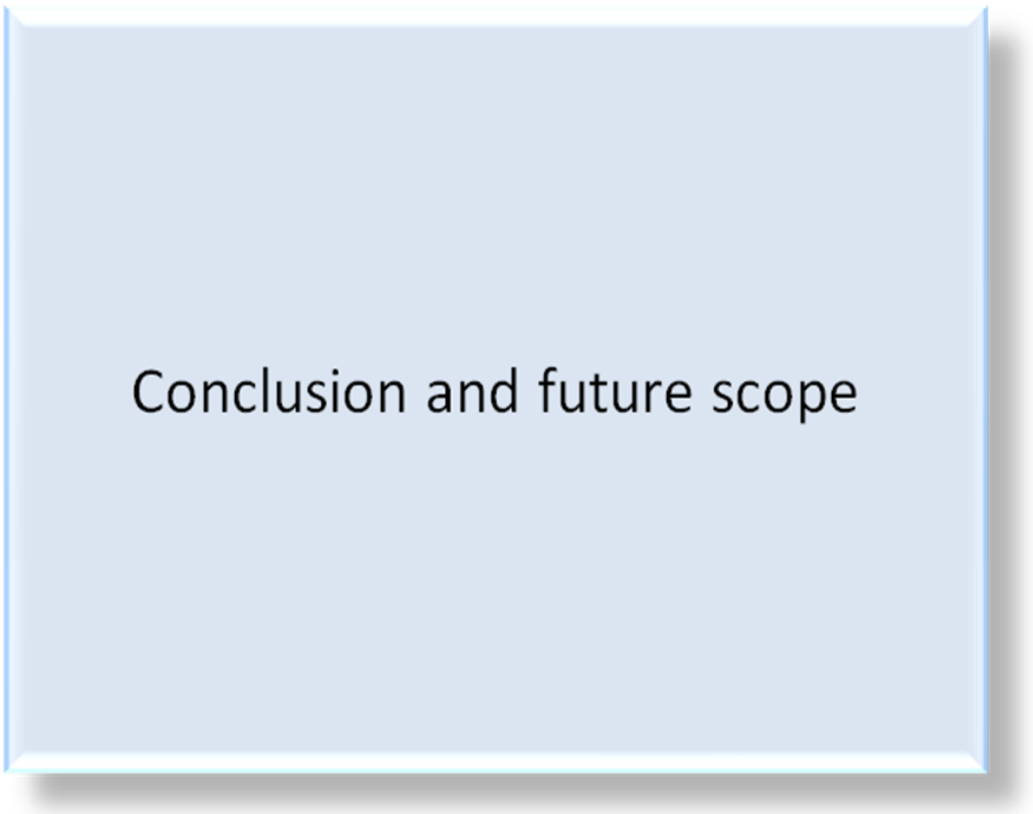
Chapter 6



The chapter summarizes the concluding remarks and highlights the major findings along with the future prospect of the present investigation

6.1 Conclusion

Polymer based organic solar cells are recently attracting a great deal of attention in the research due to their less production cost, ease of maintenance and transport. Among different types of structures, conjugated polymer based bulk heterojunction (BHJ) device is very important due to its ease of fabrication, light weight, flexibility, disposability and comparatively low cost. In a conjugated polymer nanocomposite based BHJ device the polymer plays the role of the donor and the nanofiller acts as the acceptor. Low band gap polymer such as poly(3-alkylthiophene), poly(9-vinylcarbazole) (PVK) are the most common donor material. To tailor the device characteristics of a BHJ device, various anisotropic nanoparticles such as zinc oxide (ZnO) nanorods and gold (Au) nanorods are incorporated into the polymer matrix. Such nanostructures provide a continuous path for charge transport that can reduce the charge recombination inside the active layer. Semiconductor ZnO nanorods have numerous advantages as an electron acceptor including high electron mobility, high electron affinity, significant chemical and physical stability etc. Conversely, Au metallic nanorods offer excellent light harvesting inside the active layer due to the surface plasmon resonance (SPR) in the visible and near infra-red region.

Another important class of polymer based hybrid photovoltaic device is the quasi solid state dye sensitized solar cells (DSSCs) employing polymer nanocomposite based gel electrolytes. Due to the problems regarding solvent leakage and durability of the device, the conventional liquid electrolyte based DSSCs are replaced by polymer electrolyte based devices. Gelatin is found to be the most suitable gel electrolyte due to its non-toxicity, low-cost, excellent film-forming ability etc. Anisotropic nanofillers such as Au nanorods and multi-walled carbon nanotubes (MWCNTs) offer significant electron transport through the continuous channel of the nanostructure. This reduces the charge recombination inside the electrolyte. Additionally, ZnO nanoparticle photoanode can be used as a relevant alternative to TiO_2 in DSSCs due to its ease of fabrication, low production cost, higher electron mobility and less toxicity than TiO_2. One-dimensional ZnO photoanodes offer a direct path for electron transport, thus resulting in larger diffusion length than in the spherical nanoparticle films.

In this thesis, we provide an insight into the fabrication of different series of BHJ and quasi solid state DSSCs by using various nanocomposite materials. The effect of

nanofillers on the device performance has been studied. The thesis also provides an account of the effect of aspect ratio of the anisotropic nanoparticles on the efficiency of the devices.

The important findings of the present investigation are summarized chapter wise below:

Chapter 2: Effect of aspect ratio of zinc oxide and gold nanorods on the photovoltaic performance of poly(9-vinylcarbazole) based bulk heterojunction solar cells

Section A

- The incorporation of ZnO nanorods into PVK matrix reduces the electrochemical and optical band gap of the polymer significantly by 0.88-1.0 eV.
- Effective exciton dissociation and electron transfer from PVK to ZnO occurs through PL quenching which offers the suitability of the nanocomposite in donor acceptor hybrid BHJ devices.
- The PCE of a hybrid BHJ solar cell can be increased to 0.44% with the incorporation of high aspect ratio ZnO nanorods into the active layer. With increasing the aspect ratio, J_{sc} of the devices increases due to the formation of large number of charges and more percolation pathways that allow the transport of electrons.

Section B

- The incorporation of high aspect ratio Au nanorods into the PVK matrix reduces its electrochemical as well as optical band gap significantly by 0.4-0.6 eV.
- The PCE of a BHJ photovoltaic device can be increased from 0.29 % to a remarkable value (1.45 %) with the incorporation of high aspect ratio Au nanorods into the active layer.
- The incorporation of high aspect ratio nanorods results in large degree of light harvesting in the BHJ photovoltaic device compared to low aspect ratio nanorods. A longer Au nanorod, gives rise to larger scattering intensity than the smaller one, resulting in prolonged light transport path, which further increases light absorption in the BHJ.

- Shunt formation between two electrodes is hindered with increase in aspect ratio of nanorods that causes increase in V_{oc}. Again, with increasing the aspect ratio, more percolation pathways may form that facilitates the transport of electrons and that is why, J_{sc} increases to a large extent.

Chapter 3: Enhanced photo conversion efficiency of a hybrid bulk heterojunction device based on poly(3-octylthiophene)/zinc oxide nanocomposite

- The incorporation of high aspect ratio ZnO nanorods results in increased charge formation in the nanocomposite that offer high value of J_{sc}.
- Additionally, more percolation pathways may form in the longer nanorods which improve the transport of electrons. Thus, it can provide better photocurrent in the device.
- Overall, the result of this study suggests that ZnO nanorod of aspect ratio 20 is the best candidate for obtaining a PCE of 1.33% in a set of BHJ device.

Chapter 4: Development of dye-sensitized solar cells based on gold (Au)/gelatin gel electrolyte: effect of different aspect ratio of Au nanorods

- The incorporation of high aspect ratio Au nanorods into gelatin results in the enhancement of device parameters, mainly in V_{oc}, J_{sc} and PCE due to the reduction of charge recombination and resistance in the electrolytes.
- The enhanced rate of collection and transport of electrons through different channel facilitates the enhancement of J_{sc} in the devices.
- At an optimum concentration of 0.04%, maximum PCE is obtained. Further increase in concentration causes a steep decrease in device parameters. This can be attributed to the formation of solid networks with the excess nanofiller that hinders the effective surface area for the electron transfer from the counter electrode to the electrolyte. This renders decrease in interfacial charge transfer value of the DSSCs.
- The result of this study suggests that Au nanorod of aspect ratio 3.5 is the best candidate for obtaining a PCE of 1.98% in a quasi-solid-state DSSC at 0.04% Au content.

Chapter 5: A quasi solid state dye sensitized solar cell based on gelatin/multiwalled carbon nanotube gel electrolyte and zinc oxide (ZnO) nanorod photoanode

- An optimum concentration of MWCNT (0.2%) in the gel electrolyte shows the best performance.
- As the aspect ratio of ZnO nanorods increases from 8 to 20, the PCE increases from 0.69% to 1.35% due to the rapid charge transport in the photoanode.
- ZnO nanorods offer an improved rate of collection and transport of electrons through the channels of the nanorods. It promotes the enhancement of device parameters.
- Moreover, a large amount of dye molecules are absorbed in the photoanode thus leading to a strong light harvesting in the device. This offers a significantly high J_{sc} value.
- The results of this study suggests that anisotropic ZnO nanorod photoanode of aspect ratio 20 shows a maximum PCE of 1.35% in a quasi solid state DSSC at an optimum MWCNT concentration of 0.2% in the gel electrolyte.

An overall summary of the present investigation may be made as Au nanorods provide better photovoltaic performance than ZnO in both types of solar cells. Due to surface plasmon resonance and larger scattering intensity provided by these nanorods, they offer large degree of light harvesting in the device. Moreover, Au nanorods in the gel electrolyte provide excellent electrocatalytic activity towards the redox reaction. This reduces the charge transfer resistance and charge recombination in the electrolyte. Consequently, better photovoltaic performance can be achieved.

6.2 Future Scope of the present investigation

Although a lot of works have been done on polymer based hybrid photovoltaic devices, only a few is included in this investigation. Still there are many scopes in this field to research. For instance:

- To study the effect of aspect ratio of many other anisotropic nanoparticles such as nanocubes, nanoprisms, nanoflowers etc. on device performance.
- Efficiency improvement of devices by multiparametric optimization.
- Study of these nanocomposites on flexible photovoltaic devices to find more applicability.