Chapter 9

Conclusions and Future Scope of Work
Conclusions

Systematic investigations were carried out to fabricate and evaluate different types of solar cells, since the nanocrystalline cell is feasible under laboratory conditions various nanocrystalline solar PV cells were developed and tested for their performance under ambient conditions. The working of nanocrystalline DSSC is based on the conduction by electron injection from the dye to the semiconductor and redox reaction to reduce the dye. The main technological challenges are the volatility of the iodide electrolyte, the inflexibility of glass substrates and the cell degradation, with the consequent reduction in useful life compared to silicon cells. The parameters of DSSC can be varied by changing its anode material, cathode material, type of dye, type of electrolyte, and the procedure adopted to fabricate the cell.

In this thesis different types of cells were developed and tested under standard conditions, for each type of cell at least ten samples were prepared and tested on the basis of various characterization carried out under the present study, following conclusions can be drawn:

1. Graphene nanoparticles and Gr-TiO₂ nanocomposites were synthesized and characterized to study their feasibility in DSSC. It was observed that the band gap and crystallite size of prepared nanocomposites was reduced. Further DSSCs with varying percentage of graphene in photo anode were fabricated and the characteristics of these DSSCs, including the J_sc, V_oc and photoelectrical conversion efficiency ‘η’ were investigated. The results clearly show that the introduction of graphene film improved the performance of the DSSC which was associated with increase in the absorption of light, a wide range of absorption wavelengths, shorter charge transportation distances, and the suppression of charge recombination after addition of graphene. It was also observed that at the optimum percentage of 3.0 wt.% of graphene, the photo conversion efficiency increases to 7.68 %.

2. Dye sensitized solar cell with a photo anode of TiO₂AgNWs nanocomposite was fabricated and characterized. The efficiency of the TiO₂AgNWs nanocomposite based DSSC was improved by using natural dye as well as synthetic dye. The addition of AgNWs was found to be determining factors for the performance enhancement of the dye-sensitized solar cell, also the variation
in DSSC parameters with change in dye is studied. Silver nanoparticles were synthesized successfully by polyol method. SEM images confirmed that the particles were in spherical shapes with average size of 22.1 nm. The short circuit current density $J_{sc}$ was found to increase from 6.95 to 12.58 mA/cm$^2$ by TiCl$_4$ treatment with no change in $V_{oc}$ and fill factor. Due to an increased photocurrent density and efficiency, the DSSCs fabricated with both TiCl$_4$ pre and post treatment showed enhancement in efficiency from 3.29% to 5.61%. P-V curves show the increase in output power density from 3.36 to 5.6 mW/cm$^2$. The fabricated DSSC using AgNPs with both pre and post TiCl$_4$ treated anode appears to have the maximum efficiency as compared to the cell without treatment. Due to effective electron transport and enhanced absorption of dye on TiO$_2$AgNPs anode surface, the fill factor increases to 0.74 and the maximum conversion efficiency of 7.3% was achieved.

3 CuO is incorporated into the structure of the TiO$_2$, and the presence of CuO leads to decreases in the band gap energy of the semiconductor. This decrease in the band gap energy lead to an increase in the open-circuit voltage and short circuit current as a result the DSSC efficiency increases from 4.67% to 6.52%.

4 ZnONPs were used in place of TiO$_2$, the DSSC was fabricated using ZnO nanoparticle and ZnO-CuO nanocomposites with N719 dye and platisol (platinum) coated cathode. It was observed that the efficiency of DSSC using only ZnONPs was 3.4%, whereas for nanocomposite the efficiency increases to 6.2%. However, there is no change in fill factor.

5 Nanocrystalline perovskite solar cells were also fabricated. Initially, methyl ammonium lead iodide was synthesized and characterized. The crystallite size calculated from the XRD data was 19.6 nm. The optical energy band gap was 2.94 eV. The SEM analysis show the crystalline nature of the perovskite. FTIR spectrum was recorded and the bends and stretch in the bonds are reported which describe the bonding in perovskites. The open circuit voltage $V_{oc}$ is around 0.54 V and efficiency 2.0% which is reasonable considering the working conditions. The efficiency may be improved with control over thickness and morphology of the deposited films. All the above results are obtained under ambient conditions and are in good agreement with the previous reported experimental and theoretical results.
Future scope of work

Monocrystalline and polycrystalline solar cells have achieved presentable conversion efficiencies and are available in market. The nanocrystalline solar cells such as DSSC, and perovskite solar cells are emerging technology. Further future work need to be done for the efficiency enhancement of DSSC using different cathode materials and electrolytes. The costly ruthenium dye may be replaced by natural sensitizers. More work is required on the stability study of these nanocrystalline solar cells. DSSCs are estimated to significantly provide renewable energy by the year 2020. Although progress is there in perovskite solar cells but work is required to be done to reduce the effect of moisture on perovskite solar cell parameters. Other nanocomposites such as TiO$_2$V$_2$O$_5$ may also be used for DSSC anode fabrication. Hence, future research may be focused on producing more stable, flexible, environmental resistant, lower cost and higher efficient DSSCs. The flexible substrates may be used in place of FTO. Their flexibility and variety of colors and shapes can be employed and can be used as decoration in colored windows that not only allow light through, but can use this light to generate electricity. Although less efficient than the silicon based solar cell, DSSC is more cost efficient due to the low cost of the materials and processing, than the silicon solar cells. I do hope that the work presented in this thesis will encourage further research in the direction of realization of more efficient and cost effective solar cells in future.