Chapter 7

Summary and Conclusions

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It is necessary to create novel photovoltaic device designs in addition to the well-established, conventional silicon and thin-film panels if solar electricity is to reach its full potential as a clean, renewable energy source. This thesis entitled "***Investigations on Dye Sensitized Solar Cells to Optimize its Performance***" submitted for the degree of Doctor of Philosophy (Science) in Physics of the University of North Bengal, principally focuses on dye sensitized solar cells, a still-evolving type of photovoltaic converter whose advantages include, for the most part, inexpensive, safe, and readily available materials as well as easy manufacturing processes. The whole work presented in this thesis is mainly devoted to the comprehensive study and understanding of the role of different components of DSSC. It investigates their optimization conditions to enhance the device performance in terms of efficiency, stability and cost-effectiveness. This study explored several key parameters towards the performance optimization of DSSC.

The first chapter discusses the world's current energy situation as well as the importance of renewable energy sources. This chapter provides a brief discussion of the various types of photovoltaic devices that are available. This chapter also includes a basic introduction to DSSC, its construction, working principle and the roles of its various components. To fully comprehend the DSSC's working principles, components, and potential areas of research that could lead to commercialization, a thorough review of the relevant literature was conducted in this chapter.

Chapter 2 provides a basic theory and in-depth explanation of experimental techniques used in the study, viz. X-ray diffraction analysis (XRD), scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS) research, UV-VIS spectroscopy and Raman spectroscopy. In addition, in this chapter, the fundamentals of measuring current-voltage (I-V) characteristics and electrochemical impedance spectroscopy, as well as a detailed explanation of the critical factors affecting device performance, are also covered.

The photovoltaic performance of a DSSC is primarily determined by the Photoanode material chosen, including surface morphology and the sensitizing dye used. Although many different DSSCs have been investigated, most of them are not commercially popular due to issues such as low conversion efficiency, higher production costs, and lower stability and durability. Among all dye sensitizers, the ruthenium complexes are the most popular. The main disadvantages of Ruthenium dyes are their rareness, high cost, and complicated synthesis process. Furthermore, ruthenium polypyridyl complexes contain heavy metals that are hazardous to the environment. In order to find out low-cost and environment-friendly alternatives to these expensive ruthenium compounds, we have used anthocyanin extracted from pomegranate (*Punica granatum*) and curcumin extracted from fresh turmeric (*Curcuma longa*) as sensitizers. Additionally, ZnO has been used as a potential alternative to TiO_2 due to its fascinating electrical and optical properties. Both ZnO nanoparticles and ZnO nanorods are used as photoanode material. ZnO nanorod based DSSC showed better performance as 1-D single-crystalline rod-like structure of ZnO nanorods provides a higher surface-to-volume ratio enabling better dye loading as well as it provides a direct path for faster charge transfer through them. Efforts are made to improve device performance using low-cost sensitizers and semiconductor materials. These research findings are put together in Chapter 3.

The Chapter 4 investigates the effect of WO_3 as a working electrode material for DSSC as an alternative to TiO_2. Despite having several advantageous properties, the performance of pure WO_3-based DSSC was found to be extremely poor. Surface modification of the WO_3 photoanode was done by spin coating ZnO nanoparticles synthesized via the sol-gel method. Device performances were recorded for different concentrations of ZnO precursor solution. The concentration of the ZnO precursor solution was found to have a strong influence on the DSSC's photovoltaic performance. It was observed that, although the incorporation of a thin layer of ZnO onto WO_3 enhances the power conversion efficiency by creating an energy barrier and limiting the electron back-recombination, the thicker layer of ZnO degrades the cell performance by forming an aggregation of Zn^{+2} ions and N_3 dye and reducing the dye adsorption quantity of WO_3 film.

Dye aggregation on the metal-oxide surface of a DSSC affects the photoelectron injection by increasing charge recombination and hence limits the overall device performance. The use of additives such as Chenodeoxycholic acid (CDCA) is a very useful and widely used strategy in lowering the self-aggregation of dye molecules by suppressing unfavourable dye-dye interactions and thereby enhancing the photoconversion efficiency. However, the strong binding of CDCA molecules to the ZnO surface partially displaces dye molecules and consequently reduces photon harvesting. Therefore, to maximize the positive effect of the co-adsorbent, it is very crucial to carefully optimize the amount of CDCA. The impact of the proper concentration of CDCA as an anti-dye-aggregation material in boosting the DSSC performance based on Rose Bengal dye is discussed in Chapter 5. Additionally, in order to minimize charge recombination, the impact of a very thin and compact ZnO blocking layer was also examined. At optimized co-adsorbent concentration, the reduced dye loading due to the presence of CDCA and consequently decreased light-harvesting was compensated by the increased electron injection efficiency leading to maximum device efficiency of 1 %. oreover, when a compact ZnO blocking layer was applied to the FTO prior to depositing the mesoporous ZnO active layer, the performance was further improved from 1.00 percent to 1.22 percent. This resulted from the inhibition of electron back transfer from the FTO to the liquid electrolyte.

Chapter 6 focuses on the use of gel electrolytes in DSSC rather than liquid electrolytes. The leakage of liquid electrolyte, electrode corrosion, photodegradation of attached dyes, and solvent volatility all limit the long-term performance of liquid electrolyte-based DSSCs. Gel electrolytes were used to overcome these limitations because they reduce the volatility of organic solvents and prevent leakage. To improve the cell stability, gel electrolyte-based DSSCs were created using ethyl cellulose (EC) as the gelation material in a conventional liquid electrolyte containing LiI and I_2 as the redox couple in acetonitrile solvent. TiO_2 and ZnO were used as photoanode materials in various types of DSSCs. The effect of EC concentration on the performance of DSSCs, including stability over time, was also studied.

Although the efficiency of the gel-based DSSC is less than that of the liquid electrolyte DSSC, the cell characteristics were equivalent to those for gel electrolyte-based DSSCs by other researchers. A Comparison of these two kinds of DSSCs reveals that, despite having slightly lower photovoltaic performance than liquid electrolyte DSSC, gel-based DSSC performance is noticeably more stable than liquid electrolyte performance over time. The stability of both TiO2 and ZnO photoanode based DSSCs can be improved by using an EC based gel electrolyte with the correct EC wt%.