Chapter 6

Final Conclusion & Future Working Proposa

6.1 Final Conclusion:

This research work has been a delightful learning experience for me. This project has opened a new avenue for me to acquire self-development through collaborative activities. I had explored in the various phases of research development through this work which allowed me to get a real insight into the world of nanoscience and nanotechnology. While I was going through various problems and challenges during this research work, every bit of those moments had brought intense desire and enthusiasm in me to create or innovate. Through this research, I gradually acquainted with the fact that how nanoscience and nanotechnology can help to generate a pollutant-free environment and the world can be benefited even in the field of electronics and optoelectronic devices. Every segment of this thesis work is concerned predominantly with the application of pollutant elimination from the environment and the current generation under solar light illumination and under darkness which is a boon to the electronic and optoelectronic device's application. This particular research work is divided into three specific parts. Those areas are given below:

1) Synthesis of GO, RGO, semiconductor nanomaterial, RGO-based nanocomposite materials, MoS_2 and MoS_2-based nanocomposite material.

2) Structural, morphological and optical characterizations of the as-synthesized nanomaterials and nanocomposite materials have been done.

3) The potential application of the as-synthesized and well-characterized materials in the field of optoelectronic devising and photocatalysis has been studied extensively.

Remarkably, we have accomplished to synthesize GO by modified Hummer's method from pre-oxidized graphite. The GO has transformed into RGO by using different reducing agents like hydrazine hydrate, ethylene glycol and ethylenediamine. The RGO-based nanocomposite materials and controlled nanomaterials are produced using low cost, easy processable solvothermal technique. MoS_2 nanosheets and MoS_2-based nanocomposite were synthesized by a simple hydrothermal method. After successful synthesis of the nano samples, it has been characterized by XRD, $UV-vis$, PL, XPS, TEM, $HRTEM$, SEM, Raman spectroscopy, $TCSPC$, AFM etc.

The successful synthesis and formation of nanomaterials as per our expectations have invigorated us to probe into the photocatalytic activity and optoelectronic device application. Our mother earth is getting polluted day by day due to the rapid growth of industrialization. Hence all leaving creatures including human beings are in immense trouble. Specifically, the aquatic ecology is gradually moving deep into threats. Smart nanomaterials and RGO or MoS_2-based nanomaterials are capable enough to fight against these ecological menaces to revive from this situation. As-synthesized materials show very good light to electric conversion efficiency. We have applied our samples for optoelectronics applications. Thus the major aim of this work is to investigate novel nanomaterials which certainly bring positive consequences for these diverse ecological and energy issues.

Chapter 2 concerns with reduced graphene oxide – zinc sulfide ($RGO-ZnS$) composite for solar light-responsive photocurrent generation and photocatalytic 4-nitrophenol degradation. Controlled-ZnS nanorod and $RGO-ZnS$ nanocomposite were synthesized through the solvothermal process. The

TEM image depicts that the ZnS nanorods are uniformly anchored on RGO sheets. The photocurrent generation of in large-area solution-processable $RGO-ZnS$ thin-film device showed 37 % photosensitivity under 180 $mWcm^{-2}$ of simulated solar light illumination. The $RGO - ZnS$ thin-film device showed time constant for growth and decay of photocurrent are $24\,s$ and $20\,s$ respectively. The $RGO - ZnS$ nanocomposite shows its superiority over controlled-ZnS towards $4 - NP$ reduction under simulated solar light illumination. High photosensitivity and enhanced photocatalytic activity occur mainly due to its superior adsorption capability, the better absorption capacity of solar light, efficient charge separation, and transportation between RGO and ZnS nanostructure.

Chapter 3 deals with solar light-responsive photocatalytic degradation of tetracycline by $RGO - CdS$ nanocomposite and its optoelectronic device application. The CdS nanorods and $RGO - CdS$ nanocomposite were synthesized by a single step, one-pot solvothermal technique. The structural and morphological of the as-synthesized catalysts were characterized by XRD and TEM analysis. The photo-induced charge transfer through the interface of CdS nanorod and RGO sheet is established by the PL measurement. The reduction of GO and formation of RGO was confirmed by Raman spectroscopy. A higher degradation rate constant for $RGO - CdS$ composite was observed compared to controlled-CdS under simulated solar light illumination. In $RGO - CdS$ nanocomposite, RGO plays a crucial role by efficiently separating the photo induced charges, which subsequently increases the photocatalytic performance of the $RGO - CdS$ composite.

Chapter 4 presents the photocurrent generation in reduced graphene oxide-cadmium zinc sulfide nanocomposite and its photocatalytic performance towards $4 - NP$ degradation. The composite was synthesized by solvothermal process. The synthesized materials were characterized by structurally and optically by XRD, TEM, $HRTEM$, Raman-spectroscopy, $UV-vis$, and PL measurements. The photocatalytic activity of the $RGO - CdZnS$ nanocomposite has increased by 2.2 times in comparison to controlled-$CdZnS$ samples towards the reduction of $4 - NP$. Large area thin film $RGO - CdZnS$ photodetector shows an enhanced photoresponse with P-value is 47 %, under 160 $mWcm^{-2}$ light intensity. Dynamic photoresponse of $RGO - CdZnS$ thin-film device under simulated solar light shows the time constants for growth and decay of photocurrent are $22s$ and $25s$ respectively.

Chapter 5 states the sonochemical functionalization of MoS_2 by zinc phthalocyanine and its visible-light-induced photocatalytic activity. Mono-layer and multi-layer MoS_2 were synthesized by a simple hydrothermal method. The $MoS_2 - ZnTTBPc$ nanocomposites in all ratios (1 : 1, 2 : 1, 3 : 1, 4 : 1, 5 : 1) have been synthesized by the Sonochemical process and all synthesized materials have been analyzed through different techniques such as XRD, $UV - Vis$, PL, $TCSPC$, Raman and $FTIR$ analysis. $MoS_2 - ZnTTBPc$ (3 : 1) composite showed the highest energy transfer efficiency (90 %). The existence of a monolayer of MoS_2 is confirmed by Raman analysis. The positive synergetic effect in $ZnTTBPc$ and single-layered- MoS_2 sheets act as co-catalyst on the photocatalytic activity. It could thus be a prospect as a new photocatalyst for eliminating different aquatic pollutants and other optoelectronic devices.

6.2 Future Working Proposal:

In this thesis, we have studied photocurrent generation in $RGO - ZnS$, $RGO - CdS$ and $RGO - CdZnS$ nano composite materials and the photocatalytic activities of these composite and $MoS_2 - ZnTTBPc$ nano composite material has also been explored. Although we have studied a lot on the optoelectronic and photocatalytic effect of these nanocomposites still there is a scope of further study on the following problems of possibilities for us to carry on with this work as future endeavors. Some of these are as follows:

1) Controlled-RGO based optoelectronic device will be fabricated, where bandgap of RGO will be tuned by controlling the degree of reduction of GO. This will allow us for selective use in different wavelengths.

2) Excellent photocurrent generation in $RGO - ZnS$, $RGO - CdS$ and $RGO - CdZnS$ composite has been observed. Different optoelectronic devices like photo FET, photo-transistor, solar cell, etc. will be fabricated using these composites as active materials.

3) Our work established $RGO - ZnS$, $RGO - CdS$, $RGO - CdZnS$, and $MoS_2 - ZnTTBPc$ composite as an excellent photocatalyst. These photocatalysts will be utilized to degrade other aquatic pollutants of the environment.

We expect these studies will explore the versatility in their applications.