PREFACE

The key motivation of this thesis is to realize a solvothermal processed, low cost, non-toxic, environment friendly simplest broadband photoconductor structure based on Cu_2SnS_3 (CTS) QDs. The CTS QDs has been used in the present study as an active material for visible-NIR regions due to its strong absorption coefficient which results from its higher surface to volume ratio. Apart from of having a higher surface to volume ratio CTS nanostructures have proved their potentiality in the field of visible-NIR photodetection in comparison to traditional highly toxic, rare, and unstable QDs structure like PbS, PbSe, CdTe, HgTe etc. A low-cost photoconduction structure of CTS QDs has been realized on small spaced Ag electrodes to improve the performance of the structure in comparison to previously reported CTS structures not involving QDs nanostructure for broadband photodetection. The fabricated QDs photoconductor suffers from the poor mobility of QDs film resulting from the long insulating legend over the QDs structure used at the time of synthesis. The poor mobility in the proposed CTS QDs consequences of low responsivity and detectivity, which were improved by integrating this material with ultra-high mobility material graphene. The well control and most precise CVD technique has been used to synthesize a good quality of graphene. The CTS QDs/Graphene structure has been realized to improve the optoelectronic properties of CTS QDs for visible-NIR regions. In the proposed hybrid structure graphene work as an electron transport layer and improve the optical response of 2D/0D-Graphene/CTS QDs based photodetector. The limited band i.e., visible-NIR performance of the 2D/0D-Graphene/CTS QDs hybrid structure has been further improved by introducing a new class of 2D-material. The 2D-SnS_2, a low dimensional material, has been investigated further due to their higher absorption coefficient, high

stability with good mobility to enhance the performance of 2D/0D-Graphene/CTS QDs and also the detection range extension. The limitation of graphene i.e., the poor absorption for broad spectrum region is improved in the 2D/0D-SnS_2/CTS QDs and also a bandwidth extension from Vis-NIR to UV-visible-NIR spectrum has been realized. The photoconduction structure of the SnS_2 nanoflakes has also been studied before realizing its broadband photodetection structure with CTS QDs. The present thesis consists of SIX chapters which are briefly outlined as the following.

Chapter-1 present the brief introduction of photodetectors and photodetection process along with traditional materials used for broadband photodetection. This chapter discusses the limitation and challenges of traditional materials based broadband photodetection structures in advance optoelectronic applications. The challenges and limitation of broadband photodetection structures which leads to the exploration of a new class of low dimensional materials has also been discussed in this chapter. This chapter also includes a focused study on the structural and optical properties of Cu_2SnS_3, 2D-graphene and 2D-SnS_2 nano-materials used in this thesis. In later half section of this chapter dedicated to an extensive literature review on low dimensional materials based photodetector structures with more focus on 0D-QDs, 2D and TMDs. A detailed survey on CTS and its nanostructures including QDs based broadband photodetector structures over other QDs like PbS, PbSe, HgTe, CdTe, etc., has been done. In the continuation, the hybrid structure of QDs with various 2D materials like graphene, TMDs i.e., 2D-SnS_2 has been studied to know the potentiality of Graphene/CTS QDs as well as SnS_2/CTS QDs photodetection structure over other broadband 2D/0D structures. Based on the study of various 1D/0D/2D photodetection structures, the scope of the present thesis has been outlined at the end of this chapter.

Chapter-2 include the synthesis and characterization of CTS QDs synthesized by a one-pot solvothermal technique. The simplest photoconductor structure of CTS QDs has been fabricated over a small spaced Ag electrode to improve the overall optical response along with the speed of structure in comparison to other CTS-based structures that possess poor optical characteristics like responsivity, detectivity, EQE, sensitivity, and transient response. The fabricated device structure also shows the improved optical

characteristics in Vis-NIR regions in comparison to traditionally used QDs structures like PbS, PbSe, HgTe, etc.

Chapter-3 reports the integration of CTS QDs with a high mobility material i.e., 2D-graphene and has been realized a 2D/0D-Graphene/CTS QDs based Vis-NIR broadband photodetector with improved optical characteristics over stand alone CTS QDs based structure discussed in **Chapter-2**. The Chemical vapor deposition (CVD) has been used to synthesize mono/few layer graphene. The chemical vapor deposition (CVD) technique has been incorporated to synthesize a mono/few layer graphene over other synthesized techniques due to its good control, large area growth, low defect, and good uniformity. The optical characteristics of the proposed 2D/0D hybrid photodetector have been measured by measuring the responsivity, detectivity, EQE, and sensitivity for Vis-NIR illumination. The hybrid structure of CTS QDs with graphene in this chapter improves the performance of the CTS QDs based structure due to the high mobility of graphene which works as a carrier transporter for photogenerated carriers in QDs.

Chapter-4 reports the limitation of 2D-graphene i.e., the low absorption of light about 2.3% for broad light spectrum and introduces a new class of 2D-materials called transition metal dichalcogenide (TMDs). Out of various TMDs a less explored, large bandgap tunable, low dimensional 2D-SnS_2, with high stability and non-toxicity along with higher absorption coefficient over other TMDs materials has been explored. Further, the low-cost solvothermal technique has been used to synthesize high-quality hexagonal-shaped SnS_2 nanoflakes/nanosheets. The fabrication and characterizations of the simplest photoconduction structure of 2D-SnS_2 nanoflakes have been studied in this chapter. The optical performance of the fabricated device has been measured for broadband illumination with the efficient optical performance of the structure for UV regions. In addition, the temperature stability of the SnS_2 photoconductor structure has been investigated under the large variation of temperature from 60^{o}C to 120^{o}C to prove the thermal stability of this structure by observing the I-V response of the structure.

Chapter-5 investigate the fabrication and characterizations of hybrid 2D-SnS_2

nanoflakes/ 0D CTS QDs broadband photodetectors. This chapter is about the bandwidth extension of SnS_2 nanoflakes device structure discussed in **Chapter-4** and also the improvement in their optical characteristics for a broad range of spectrum i.e., UV-Vis-NIR. The structure has been proposed to utilize the role of both active materials for carrier generation under light illumination. The SnS_2 works as an active light absorber for the UV region while CTS QDs work as active light absorber under Vis-NIR regions. In addition, the SnS_2 nanoflakes sheet work as a carriers transporter for both photocarriers generated in CTS QDs and SnS_2 under the broad light illumination. The better performance of the structure in terms of broadband realization has been achieved in comparison to the Graphene/CTS QDs hybrid structure discussed in **Chapter-3**. Both the active materials in this chapter have been synthesized by a simple one-pot solvothermal synthesis over the CVD technique used to synthesized 2D-graphene.

Chapter-6 has been devoted to summarizing the major finding of the works presented in various chapters of the thesis. Finally, some future scopes of research in the related area of the thesis are outlined at the end of this chapter.