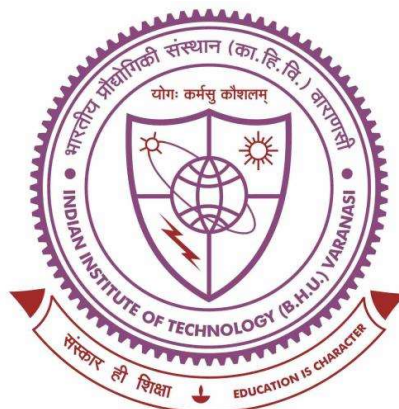


***Study of Some Low Dimensional Metal Oxides for  
Optoelectronic Device Applications***



**Thesis submitted in partial fulfilment for the  
Award of Degree**

***Doctor of Philosophy***

***in***

***Physics***

**by**

***Prashant Kumar Pandey***

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**INDIAN INSTITUTE OF TECHNOLOGY  
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**Sincerely**

**(Prashant Kumar Pandey)**



*Dedicated*  
*To*  
*My Beloved*  
*Family*



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# Preface

Metal oxide based nanomaterials and nanocomposites have drawn significant interest of the research community worldwide and played crucial role in developing excellent optoelectronic devices for several technological applications. The key motivation of this thesis work is to synthesize and study the luminescence properties of the rare-earth doped  $\text{Bi}_2\text{O}_3$  phosphors and structural, optical, and electrical properties of Ag-ZnO nanocomposites for diverse applications such as light emitting diode, color-tunable devices, and UV- detectors. The  $\text{Bi}_2\text{O}_3$  has been used as a host matrix for the preparation of red emitting phosphors whereas, ZnO has been used as a host for UV- detection owing to their multitudinous properties such as excellent thermal and chemical stability, low cost, environment-friendly synthesis, near-UV absorption, and good solubility for rare-earth elements.

The research work presented in this thesis has been divided into **seven** chapters.

**Chapter 1** presents a brief introduction about the low-dimensional materials, metal oxides, optoelectronic devices, luminescence phenomena and their classification, phosphor materials, properties of the rare-earth elements, and UV- detectors. This chapter discusses the limitations and challenges of the phosphors and low-dimensional materials used for the application in the commercial wLEDs, tunable light sources, and UV- detection. The challenges and limitations of these applications which lead to the exploration of new doped phosphors and nanomaterials have also been discussed in this chapter. This chapter also includes a focussed study on the structural and luminescence properties of the  $\text{Bi}_2\text{O}_3$  phosphors and ZnO based UV-detector used in the thesis work. Based on the study of various low- dimensional materials used in different optoelectronic

applications, the motivation behind the thesis work has been outlined at the end of this chapter.

**Chapter 2** deals with the methodology of sample preparation and different experimental tools and analysis techniques that have been used for sample synthesis and studying the various structural, luminescence and electrical properties of the prepared compositions. The synthesis techniques include urea assisted auto-combustion and co-precipitation methods. The specifications and working of the instruments used to characterize the samples are also discussed. The structural analysis is done using the XRD and FTIR data. To check the morphology and particle size of the prepared phosphors we have performed HR-SEM and TEM analyses. The elemental confirmation and oxidation states of the phosphors were validated using XPS analysis. The absorption characteristics and band gap energies were analyzed using the UV-Vis absorption spectroscopy. To shed light on the luminescence properties of the phosphors we have performed PL analysis. We have used temperature-dependent PL analysis to study the thermal stability of the phosphors prepared for solid state lighting applications and display devices. Moreover, the structural and optical properties of various compositions of Ag-ZnO nanocomposites were carried out and their correlations with electrical properties have been investigated thoroughly. The electrical analysis of the samples was probed to study the photoresponse and I-V characteristics of the fabricated Ag-ZnO based nanocomposites for UV detector applications.

**Chapter 3** presents the study of pure  $\text{Bi}_2\text{O}_3$ ,  $\text{Sm}^{3+}$  (1% – 5%) doped  $\text{Bi}_2\text{O}_3$  and  $\text{Li}^+$  (0.5% – 3%) co-doped in 5%  $\text{Sm}^{3+}$  doped  $\text{Bi}_2\text{O}_3$  ( $\text{Bi}_2\text{O}_3:5\text{Sm}^{3+}$ ) phosphor synthesized via co-precipitation method. The structural analysis has been carried out for phase identification, authentication of phase purity, and calculation of crystallite size and microstrain. Some

results from the absorption spectra such as red-shift in the doped and co-doped samples have been discussed. The effects of  $\text{Li}^+$  co-doping on the reddish-orange emission of  $\text{Sm}^{3+}$  doped  $\text{Bi}_2\text{O}_3$  has been discussed in this chapter. The reduced microstrain and increased crystallinity of the phosphors as a result of  $\text{Li}^+$  co-doping and their correlation with the luminescence of  $\text{Sm}^{3+}$  ions are discussed.

**Chapter 4** describes the result of  $\text{Na}^+$  co-doping on the photoluminescence and structural properties of  $\text{Sm}^{3+}$  doped  $\text{Bi}_2\text{O}_3$  phosphors. The structural and elemental properties were investigated by XRD, FTIR, and XPS analysis. The chapter also presents the morphological study of the phosphors and an augmentation in the grain size after  $\text{Na}^+$  co-doping has been discussed. Photoluminescence excitation and emission analysis evince the improvement in the intensity after 1%  $\text{Na}^+$  co-doping in the 5%  $\text{Sm}^{3+}$  doped  $\text{Bi}_2\text{O}_3$  phosphor. Moreover, the temperature-dependent PL study is discussed which reveals good thermal stability of the phosphor. The reddish-orange emission of the prepared  $\text{Na}^+$  co-doped  $\text{Bi}_2\text{O}_3:5\%\text{Sm}^{3+}$  phosphor shows that it can be a potential red phosphor for lighting and display devices.

**Chapter 5** deals with the study of energy transfer dynamics, and emission color tuning in  $\text{Sm}^{3+}/\text{Eu}^{3+}$  co-doped  $\text{Bi}_2\text{O}_3$  phosphors. The chapter demonstrates a viable scheme for tailoring the PL emission of phosphors through precisely controlling dopant concentrations. We have reported that the emission is tuned from reddish-orange towards the red region as depicted in chromaticity diagram. A detailed energy transfer process between the rare earth ions is discussed. Furthermore, the temperature-dependent PL study has been carried out to elucidate the thermal stability of the phosphors. Therefore, this chapter shows that our research opens up new possibilities for the development of color-tunable luminous materials for various optoelectronic and display device applications.

**Chapter 6** presents the structural, optical, and electrical properties of Ag-ZnO nanocomposites, synthesized by precipitation method. The structural and elemental properties were investigated by XRD and FTIR analysis. Moreover, the correlation of structural and optical properties with enhanced photocurrent has been investigated thoroughly. The absorption and electrical properties infer that the samples have a broad absorption and an enhanced photoresponse in the UV region of the electromagnetic spectrum.

Conclusion of the overall studies has been summarized in the last **chapter 7**. This chapter also comprises further future research plans on this topic.