PREFACE

In the present era of science and technology, in order to save human efforts, increase accuracy and efficiency of the task, automation is very important and essential for facilitating the life in every walk. Today intelligent devices are playing very important role in automation because of their high sensitivity, accuracy, efficiency, fast speed, and intelligent control system with advanced computing capabilities.

Today, due to automation, almost each and every field of life is now influenced by the presence of the automatic processing and controlling systems. Automation in industries, agriculture fields, medical science, transport services, space research centers, environmental study centers etc. is extensively making use of sophisticated intelligent devices and instruments. For adequate controlling of the parameters in such types of businesses we have to rely on the functioning and decisions making ability of such sophisticated intelligent instruments.

It is very important that the controlling action taken (output) by the instrument must be the most appropriate response to the present state of the input. The most appropriate output response is possible only when the input is properly monitored, sensed and selected by the input section of the instrument. So the most important part of the input section, sensor and transducer unit, must be highly accurate, precise, sensitive, fast and dynamic in nature.

Sensor is the first block of instrument that senses the input and interacts with the smallest variation in input signal. During the transduction action the corresponding change in input signal is converted into the most appropriate form that instrument needs to produce adequate output response.

Air pollution is one of the most severe problems that create catastrophic effect in the life of living beings. Presently several sources of air pollution such as industries, vehicles, mines etc. are continuously emitting very harmful gases and pollute air. For controlling the air pollution, automatic control systems use gas sensors. Today there is great need of highly sensitive and selective gas sensors that possess good dynamic response characteristics with longer life. The sensor having smaller size and moderate cost is also one of the most important requirements.
Metal oxide semiconductor gas sensors are seemed to be able to fulfill almost all the criterion required for their use in practical applications. Fe₂O₃, being a metal oxide semiconducting material, is studied for its characteristics for its status, reliability and suitability in practical and commercial applications as gas sensing material.

A brief summary of the comprehensive report of the thesis and its distribution in different chapters is presented as follows:

The thesis comprises of seven chapters.

**Chapter 1** is associated with ‘General introduction and literature survey’. The chapter is about understanding of automatic control system. The most important characteristics and parameters required for highly efficient, accurate and effective sensor are discussed in details. The present status of use of Fe₂O₃ material for gas sensing application is discussed. The various issues and practices, available in the literature, regarding improving the efficiency of Fe₂O₃ material as a gas sensing material are also illustrated. The adsorption- desorption phenomena, surface to volume ratio, oxidation-reduction mechanism are thoroughly studied and explained in the chapter.

**Chapter 2** is devoted to the ‘Experimental techniques used for characterization’ of the material for confirmation of the status of materials those have been used and tested for gas sensing performance. The chapter contains details about physical characterization techniques used for characterization of the material such as Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), and Energy Dispersive Analysis by X-ray (EDAX), UV-visible spectroscopy, Atomic Force Microscopy (AFM) analysis, X-ray diffraction (XRD) and Thermo gravimetric analysis (TGA). The various techniques used for preparation of films are also properly explained. The physical system used for testing the gas responses of the films on exposure to various gases is also discussed thoroughly in this chapter.

**Chapter 3** is about the details of ‘chemistry of Fe and its corresponding oxide forms’. Being the d block element and transition metal, the issues regarding use of Fe₂O₃ for gas sensing purpose are discussed in this chapter. Issues related to modification of Fe₂O₃ material and their effects on the gas sensing behavior of the material are the major issues in the chapter. The various issues observed in the literature about use of Fe₂O₃ as gas sensing materials are also thoroughly illustrated.
Chapter 4 deals with the ‘Gas sensing properties of Pure and modified Fe$_2$O$_3$ thick film resistor’ gas sensor. The gas sensing properties of pure and surface modified (dipping technique) Fe$_2$O$_3$ thick films are discussed. The chapter discusses practical technique used for thick film preparation and technique used for surface modification of pure Fe$_2$O$_3$ thick films. The gas sensing performances of pure and surface modified thick films tested for various gases are presented in the chapter. The chapter comprises two sections. The 1st Section is associated with gas sensing performance of Pure Fe$_2$O$_3$ thick films and the ZnO modified Fe$_2$O$_3$ thick films. The ZnO modified Fe$_2$O$_3$ thick film with dipping time 30 minutes was found to be more selective and sensitive to H$_2$S gas as compared to Pure Fe$_2$O$_3$ thick film at comparatively lower temperature. The electrical profile, thermal analysis through TGA, microstructural analysis through SEM and elemental analysis of the films are thoroughly discussed in this chapter. Section II contains the gas sensing performance of Cr$_2$O$_3$ modified thick films the details of the gas sensing are presented in the chapter.

Chapter 5 is about ‘nano Fe$_2$O$_3$ material as a gas sensing material’. The chapter is associated with comparative study of gas sensing performance of bulk Fe$_2$O$_3$ material thick film resistor and nano Fe$_2$O$_3$ thick film resistor gas sensors. It clearly interprets the reasons for using the nano material for gas sensing applications. The chapter is divided into two sections. Section I is associated with detailed study of gas sensing performance of AR grade nano Fe$_2$O$_3$ thick films. Whereas in section second, the study of synthesis of nano Fe$_2$O$_3$ in laboratory and gas sensing performance of thick films of as prepared material is presented. The synthesis techniques used for nano Fe$_2$O$_3$ material is also discussed. For studying the gas sensing properties of the material, the thick films of nano Fe$_2$O$_3$ material were prepared by screen printing technique. The gas sensing performance, sensitivity and selectivity of the film were tested for various gases. The nano Fe$_2$O$_3$ film showed maximum sensitivity to ethanol gas at temperature 350 °C. The gas response profile is discussed thoroughly in this chapter. Structural characterization of the material is done using XRD. The diffraction patterns of nano Fe$_2$O$_3$ material are obtained from TEM. The results of characterization are studied and discussed. Issue of response and recovery time related to gas sensing performance is studied for its suitability for practical application.
The effect on sensing ability of the films offered by difference in surface morphology, surface to volume ratio and other issues related to these films are also discussed.

**Chapter 6** Gas sensing performance is associated with surface structure. To study the issue Fe2O3 material in thin film form was studied. This chapter contains two sections. Section 1st contains the study associated with the technique used for preparing thin films and effect of structure of the film on its gas sensing performance. The thin films were prepared by spray pyrolysis techniques. The films were studied for their gas sensing performance for various gases. The details of issues related to gas sensing and characterization are discussed.

The basic formation of the crystal structure depends on the temperature. So section 2nd covers the study associated with effect of temperature on formation of crystal structure of the films annealed at different temperatures. The effect of the annealing temperature of the film on the gas sensing properties of the film is the main topic of importance in this section. The spray pyrolysis technique used for film preparation is also thoroughly discussed. The films were characterized by SEM, AFM and XRD for study of their structural formation. The electrical properties of the films are studied and discussed. The gas sensing properties of the films, sensitivity and selectivity, are studied using static gas sensing system. The results corresponding to change in annealing temperature are discussed in details.

**Chapter 7** is about the “scope for future research and development in the field of metal oxide semiconductor gas sensor”. The scope of modification of metal oxide semiconductor material for its more useful role in electronic nose is also discussed. It also emphasizes various issues regarding the MOS gas sensors and the modifications and improvements required there in.

**Annexure** gives information about publications in international journals during the research work. It also includes the list of International/ National conferences attended and paper presented. The work appreciated by the international bodies ICST 2010 is also enclosed.