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Preparation & Characterization of Thin film for Gas sensing Application

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Abstract— In view of the growing interest in nanocrystalline spinel ferrites and its use in novel applications, the aim of the present work is to design and develop a gas sensor of spinel ferrite (AB_2O_4) based materials in nanocrystalline thin film form synthesized via spray pyrolysis technique, operable at room temperature with low cost and for larger applicability. The structural, microstructural, magnetic, electrical, dielectric and gas sensing properties of the spinel ferrite material under study will be investigated in the light of sensitivity, selectivity, response time and long term stability. Modification in the properties of spinel ferrite for gas sensing application will be achieved through cation substitution, stoichiometric control, and synthesis condition and synthesis parameters. Spinel ferrites with a AB_2O_4 formula are very promising complex oxide for gas sensing application. The most interesting point for spinel ferrite in gas detection is the chemical composition and structure which is helpful to be a gas sensor material design to improve sensitivity and selectivity, response and long time stability.

Keywords – Spinel Ferrite(AB_2O_4), Gas Sensor.

I. INTRODUCTION

Modern economy is technology driven, promising revenues that are mind-boggling. Sensor is one such product of biotechnology that is becoming increasingly popular in many fields like environment, monitoring, food analysis, detection of gases, health care and diagnostics [1-4]. Research and development in this field is wide, at the forefront of multidisciplinary science that involve the collaboration of physics, chemistry, biology, electronics, nanotechnology and engineering.

Today, the use of large number of vehicles and machines affects the human life and all living organism. The vast going industries are responsible for producing pollution in the atmosphere. The air pollution is found to be hazardous to human life. Many reducing and toxic gases like LPG, H_2S, CO, hydrocarbon, CO_2 and Cl_2 are also responsible for the many diseases [5, 7]. Recently, gas sensing applications of soft ferrites have been identified for detection of some reducing gases which are used commonly at homes, car, laboratories, industries, service stations [6, 7].

Biosensors have also been developed to detect the wide range of biochemical parameters using number of approaches. Recently, the most fascinating includes immune sensors and nucleic acid sensors [8, 9]. In general, a biosensor is an analytical device which detects, transmits and records the information about physiological biochemical change for the specific analytes by producing a signal proportional to the concentration of the target analytes. A basic biosensor assembly includes the receptors, transducers and processors.

Apart from air pollution, chromium contamination of soil and ground water is one of the significant environmental problems now a days. Chromium is a most common pollutant at hazardous waste sites as well as common inorganic contaminant of the lead. Chromium compounds are commonly used in several industrial processes like leather tanning, textile coloring process, metal plating and alloying [10]. For detecting chromium waste there is need to develop cheap and portable sensors, which could be embedded inside water systems for real time monitoring of chromium ions. Piezoelectric ceramics (PZT) are promising materials for the fabrication and development of these sensors based on transduction to frequency aging [11]. These materials are less expensive and easier to handle and can be used for biological of sensor applications.

Various materials are used for the design, fabrication and development of sensors used for different applications. These materials include prominently the ferrites, piezoelectric ceramics. Ferrites are the promising material which shows both electrical and magnetic properties which are tunable as per the desired applications. On the basis of their excellent electrical and magnetic properties, they are used as a transformer cores, antenna rods, memory chips, permanent magnets [12, 13]. The magnetic nano particles of ferrites are recently used in medical field for targeted drug delivery, cancer treatment [14, 15]. The recent application of ferrites

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includes catalyst and sensors. The electrical properties of the ferrites are found to be more important and useful in sensor applications. The properties such as DC resistivity, thermoelectric power and dielectric loss show significant dependence of temperature and frequency of applied AC field. The electrical properties are also sensitive to the microstructure, grain boundary and porosity.

The electrical resistance of ferrite composition significantly varies with change in environmental gas changing [16]. It is also sensitive to the humidity, water vapour dissolved in air. Therefore, ferrite materials are very much useful for gas sensing and humidity sensing applications.

Ferrites are the ferrimagnetic transition metal oxides containing iron oxide as a major part and metal oxide. On the basis of their crystal structure, they are grouped in three classes namely spinel, garnet and hexagonal. Spinel ferrites are the important magnetic materials and are widely studied for numerous applications by number of researchers [17-19]. In the recent years, nano crystalline spinel ferrites have attracted scientist and technologist because of their superior properties compared to bulk counterparts. The nano crystalline ferrites exhibit high electrical resistivity and high porosity apart from high Curie temperature, high saturation magnetization and high coercivity. Thus, the nano crystalline spinel ferrites in thin film form can be effectively employed in sensor applications.

The spinel ferrites in thin film form prepared by chemical methods are found to be most useful for gas sensing applications. The chemical methods include spray pyrolysis; spin coating, chemical bath deposition techniques [20-22]. The spray pyrolysis technique is effective for the preparation of uniform thin film of spinel ferrites. Many parameters in spray pyrolysis technique like nozzle diameter, nozzle pressure, substrate, substrate temperature should be designed carefully and optimized before the deposition of homogenous thin film of high quality.

In summary, there are large numbers of reports available in the literature on the synthesis of spinel ferrite oxide semiconductor for the use of gas sensing applications. These studies revealed that spinel ferrite effectively can be used as a gas sensor at room temperature. However, despite the large variety of available oxide based gas sensors researchers continue to search for more effective gas sensor materials with high sensitivity, fast response time and selectivity to detect gases at lower concentration.

Problem Statement :

Gas detection is attracting an increasing important role for range of various needs viz. environmental, safety, food industry, diagnostic and patient monitoring. Gas sensor detection is based on variability of electrical, acoustic, optical, mass or calorimetric properties of the material. Detection based on variability of electrical properties is simple, fast and low cost. Gas detection environment changes of electrical properties are predominantly based on changes electrical resistance.

Spinel ferrites with a AB_2O_4 formula are very promising complex oxide for gas sensing application. The most interesting point for spinel ferrite in gas detection is the chemical composition and structure which is helpful to be a gas sensor material design to improve gas sensor parameters.

II. EXPERIMENTAL ANALYSIS

2.1 Film deposition :

For fabrication of spray pyrolysis set up, various parameters have been taken in to consideration. The parameters like nozzle diameter, nozzle pressure, substrate, substrate temperature should be designed carefully and optimized before the deposition of homogenous thin film.

Ferrite compounds are very important because of their optical, electrical & magnetic properties. Nickel Ferrite ($N_iF_{e2}O_4$), Nickel ZinkFerrite ($Ni_{0.7}Zn_{0.3}Fe_2O_4$), Manganese Ferrite ($MnFe_2O_4$), & Manganese Zink Ferrite ($Mn_{0.8}Zn_{0.2}Fe_2O_4$) spinel ferrite thin films were prepared by spray pyrolysis technique. The films were deposited on glass slides for all studies. The samples were heated under vacuum at temperatures for a defined time (Furnace - Annealing Temp - 500 ^{0}C for 4 hours).

2.2 Charactrization:

The crystal structure and morphology of the prepared thin films will be studied using X-ray diffraction (XRD), Scanning electron Microscope (SEM). The electrical properties will be studied as a function of temperature using two probe / four probe technique. Using electrical data, resistivity, and activation energy and parameters will be studied. The dielectric parameters like dielectric constants, dielectric loss and dielectric loss tangent will also be studied as a function of frequency. The Magnetic properties will be studied at room temperature using pulse field hysteresis loop technique / Vibrating Sample Magnetometer (VSM). Attempts will be made to study magnetic properties at low temperature.The gas sensing properties will be studied into consideration the cation substitution, stoichiometric control, and synthesis condition and synthesis parameters. Analysis of the sensor parameters will be carried out using engineering approach.

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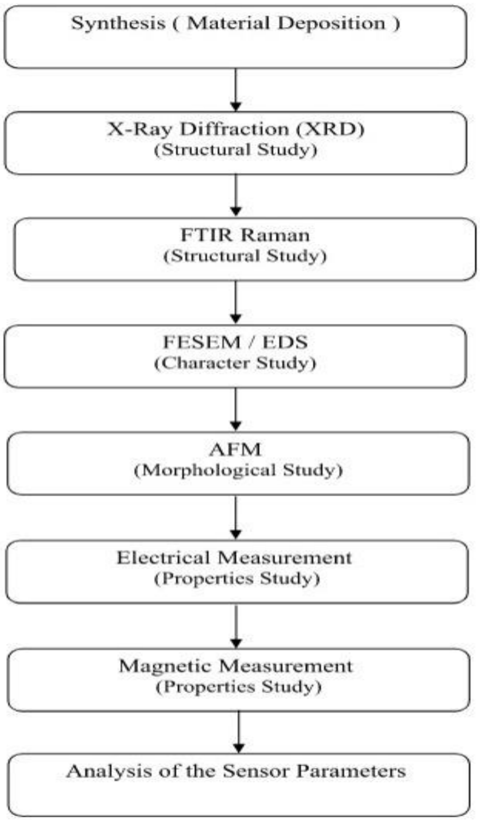

Fig No. 2.2 Charactrization

Objectives:

The main objectives of the present work are as under:

- To optimize synthesis parameter and synthesis condition.
- To prepare nanocrystalline spinel ferrite (Manganese / Nickel) thin film.
- To confirm the nanocrystalline nature and phase purity by XRD technique.
- To measure the thickness of the prepared thin film.
- To study the surface morphology using SEM technique.

III. RESULT & DISCUSSION

In the present work, the efforts are made to use the engineering approaches for the improvement of gas sensor parameters (sensor sensitivity and selectivity, stability and reliability). We have to study in this work that the Nickel Ferrite ($N_iF_{e2}O_4$), Nickel Zink Ferrite ($Ni_{0.7}Zn_{0.3}Fe_2O_4$), Manganese Ferrite ($MnFe_2O_4$), & Manganese Zink Ferrite ($Mn_{0.8}Zn_{0.2}Fe_2O_4$) thin films appear to be quite suitable for an application as gas sensors. The necessary properties are a low density and a high surface area, which implies a small crystallite size. This method allows to obtain nanostructured and porous layers, by optimizing the deposition parameters. These results have to be confirmed by structural and microstructural characterizations (G-XRD–X-Ray Diffraction and SEM- Scaning Electron Microscopy, IR/FTIR, Raman, UV-Visible, PL – Photo Luminea, AFM – Automic Force Microscopy, EDX – Energy Dispersive X-Ray Spectroscopy, VSM – Vibrating Sample Magnetometer, applied to the thin films, enabled us to make the link between the microstructure of thin layers and their surface area.

In the present work, the spinel ferrites with a AB_2O_4 formula are very promising complex oxide for gas sensing application. The most interesting point for spinel ferrite in gas detection is the chemical composition and structure which is helpful to be a gas sensor material design to improve gas sensor parameters.

Chemical Composition data:

$$\text{Weigh (gm)} = \frac{\text{Molarity x Molecular Weight x Volume}}{1000}$$

1) Nickel Ferrite :- $N_iF_{e2}O_4$

Sr. No.	Name of Material	Weight of Material	Distilled Water
1	Nickel Nitrate	1.45	50
2	Ferrite Nitrate	4.04	50

2) Nickel ZinkFerrite :- $Ni_{0.7}Zn_{0.3}Fe_2O_4$

Sr. No.	Name of Material	Weight of Material	Distilled Water
1	Nickel Nitrate	0.712	50
2	Zink Nitrate	0.133	50
3	Ferrite Nitrate	4.04	50

3) Manganese Ferrite : $MnFe_2O_4$

Sr. No.	Name of Material	Weight of Material	Distilled Water
1	Manganese Nitrate	0.89475	50
2	Ferrite Nitrate	4.04	50

4) Manganese Zink Ferrite : $Mn_{0.8}Zn_{0.2}Fe_2O_4$

Sr. No.	Name of Material	Weight of Material	Distilled Water
1	Manganese Nitrate	0.57264	50
2	Zink Nitrate	0.059496	50
3	Ferrite Nitrate	4.04	50

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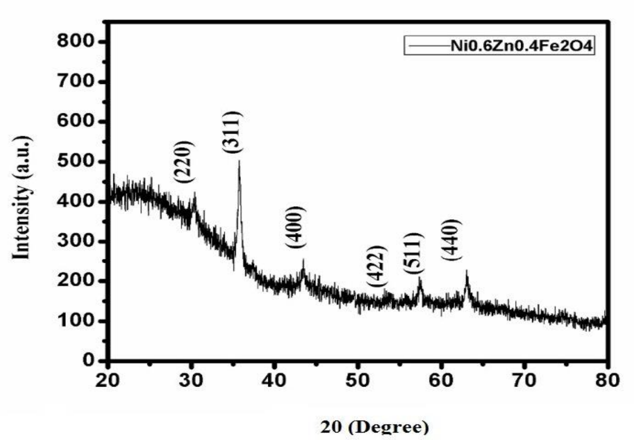

Fig. 1. X-Ray diffraction characteristics

IV. Conclusion

In the present work, the efforts are made to use the engineering approaches for the improvement of gas sensor parameters. After X-Ray diffraction characteristics we observed

that the Lattice Constant (A^0) & Crystal size (nm) by Scherrer Formula of the the Nickel Ferrite ($N_iF_{e2}O_4$), Nickel Zink Ferrite ($Ni_{0.7}Zn_{0.3}Fe_2O_4$), Manganese Ferrite ($MnFe_2O_4$), & Manganese Zink Ferrite ($Mn_{0.8}Zn_{0.2}Fe_2O_4$) matches to the standard format.

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