Versatile Applications of Metal/Mixed Metal Oxides as Sensors

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ABSTRACT:

The metal oxides / mixed metal oxides have various applications as catalyst, photocatalyst, sensors, superconductors, adsorbent, ceramics, fuels, antifungal agents and have large number of applications in medicines. These metal / mixed metal oxides play a very important role in day to day human life. Today metal oxides are attracting special attention of scientists due to their easy mode of formation and multifunctional behavior. In this article an attempt has been made to focus on their applications as Sensors in various chemical reactions.

Keywords: Metal oxides, Mixed metal oxides, chemical reactions, Sensors

INTRODUCTION:

Metal oxides are formed as a consequence of co-ordination tendency of metal ions so that oxide ions form co-ordination sphere around metal ions and give rise to close packed structure. The different physical, magnetic, optical and chemical properties of metal oxides are of great interest to chemists because these are extremely sensitive to change in composition and structure. The current knowledge on oxide materials allows to affirm that most of their physio-chemical properties display an acute size dependence. Physio-chemical properties of special relevance in chemistry are mostly related to the industrial use of oxides as sensors, ceramics, absorbents and/or catalysts. A bunch of novel application within these fields rely on the size-dependence of the optical transport, mechanical, and surface/ chemical properties of oxide nanomaterials. Size effects in oxide chemistry have frequently two interrelated faces, structural/electronic quantum-size and size-defect or non-stoichiometry effects. Hence, here we will describe the influence of these two phenomena in the main physio-chemical properties of oxides.

Optical properties:

The optical conductivity is one of the fundamental properties of metal oxides and can be experimentally obtained from reflectivity and absorption measurements. While reflectivity is clearly size-dependent as scattering can display drastic changes when the oxide characteristic size (primary/secondary particle size) is in/out the range of photon wavelength [1], absorption features typically command main absorption behavior of solids. Due to quantum-size confinement, absorption of light becomes both discrete – like and size-dependent. For Nano-crystalline semiconductors, both linear (one exciton per particle) and non-linear optical (multiple excitons) properties arise as a result of transitions between electron and hole discrete or quantized electronic levels.

Transport Properties:

Oxide materials can present ionic or mixed ionic/ electronic conductivity and it is experimentally well established than both can be influenced by the nanostructure of the solid. The number of electronic charge carriers in a metal oxide is a function of the band gap energy according to the Boltzmann statistics. The electronic conduction is referred to as n- or p-hopping – type depending on whether the principal charge carrier is, respectively electrons or holes. The number of "free" electron/ holes of an oxide can be enhanced by introducing non-stoichiometry and, in such case, are balanced by the much less mobile oxygen/ cation vacancies. In an analogous manner of hoping –type conduction takes place when ions can hop from site to site within a crystal lattice as a result of thermal activation [2].

Mechanical properties:

Main mechanical properties concern low (yield stress and hardness) and high (superplastic) temperature observables. Information on oxide nanomaterials is scarce and mainly devoted to analyzing sinter ability, ductility, and superplastic [3].

Sensors:

Metal / Mixed metal oxides have wide application as sensors some of them have been described here. Komilla Suri *et al*. [4] Gas and humidity sensors based on iron oxide polypyrole nanocomposites Iron – oxide sensor Nanocomposites of iron oxide and polypyrrole were prepared by simultaneous gelation and polymerization process. The composites in the pellet from were used for humidity and gas sensing investigations. Gas sensing was performed for CO_2 N_2 and CH_4 gases at varying pressures. The sensors showed a linear relationship between sensitivity and pressures for all the gases studied. The sensors showed highest sensitivity to CO_2 gas. R. Tongpool *et al*. [5] Sol gel processed iron oxide silica nanocomposite films as room temperature humidity sensors. Iron oxide- silica nanocomposite films have been fabricated using sol-gel process and spin coating technique. Iron oxide and silica were segregated. As Si content in the films increase, the films were more compact. The iron oxide films calcined at 400^0C were hematite but in the presence of silica, iron oxide is composed of hematite and magnetite.Neri *et al*. [6] Role of the Au oxidation state in the Co sensing mechanism of Au/iron oxide-based gas sensors. A study on the CO sensing mechanism of sensors based on Au-doped/ iron oxide thick films is reported. Thick films were prepared from coprecipitated powders of Au/Fe_2O_3 calcined at temperatures between 100 and 400^0C.A detailed micro structural characterization by XRD, TEM and XPS has shown that nanometer sized gold particles with gold in a positive oxidation state are predominant after calcination of the powders at 100^0C. The anomalous response observed over the film annealed at the lowest temperature has been related to the participation of Au (III) ions in the CO sensing mechanism. Jorge F. Fernandez –S anchez *et al*. [7] Novel optical NO_2- Selective sensor based on Phthalocyanines – iron (H) incorporated into a nanostructured matrix. A novel highly optical NO_2-selective complexing agent. In order to solubilize the iron phthalocyanine and to obtain the monomer species, a N-donor ligand was used as a solvent. The effect of the type and concentration of the N-donor ligand, and the influence of the iron phthalocyanine concentration were investigated as well as the effect of the composition and the morphological characteristics of the nanostructured material.P.Althainz *et al*. [8] The influence of the response of iron oxide gas sensors. Microgranular layers of iron oxide have been prepared by the deposition of dried aerosol droplets of iron oxalate and subsequent decomposition to investigate the gas sensing properties of this special morphology. For comparison, compact iron-oxide films have been prepared by sputtering of iron and successive oxidation. Several different granular gas detectors have been produced consisting of spherical particles with sizes between 0.2 and 1.2 μm in narrow size distributions. The compact films exhibit a pronounced sensitivity increase with molecular weight of the vapor. In contrast, the granular layers detect all gases with similar sensitivities and react faster than the compact layers. G. Neri *et al*. [9] .A study of wake influence in co response on gold – doped iron oxide sensors. A temperature programmed desorption (TPD) study of the water and CO- interaction with the surface of gold doped iron oxide sensors is presented. TPD data has shown that CO does not adsorb in the absence of water. The adsorption of CO occurs when water is present as adsorbate, through the formation of a surface formate intermediate. TP reaction of CO with oxygen in both dry and wet air has shown that water also promotes CO oxidation, likely via the same formate intermediate. The effect of water on the CO sensing of Au/Fe_2O_3 sensors was also investments. Chakraborty *et al*. [10] Selective detection of methane and butane by temperature modulation in iron doped tin oxide sensors. In the present study we find that it is possible to develop sensors based on iron doped tin dioxide, which can detect both methane and butane (present in CNG and LPG, respectively) at a temperature at 350^0C. However, the same sensors can selectively detect butane at a temperature of 425^0C. The incorporation of palladium as a catalyst in Fe-doped SnO_2 sensors removes the typical selectivity, and the temperature of the maximum response coincide for methane and butane.G. Neri *et al*. [11] Humidity sensing properties of Li-iron oxide based thin films. Li-doped iron oxide thin films deposited on a porous ceramic substrate by a liquid-phase method (LPD) were investigated as humidity sensors. Large variations in the resistance, up to about 4-5 order of magnitude, were observed by changing the relative humidity (RH) between 10 and 90%. The role of Li on the response to water vapor of iron oxide thin films is discussed. Frank Retting *et al*. [12] .α-Iron oxide. An intrinsically semiconducting oxide material for direct thermoelectric oxygen sensors. Intrinsically semiconducting oxide materials offer the possibility for highly sensitive direct thermoelectric gas sensors. Intrinsic α-Fe_2O_3 has been chosen as a well suited candidate for direct thermoelectric gas sensors. The used temperature modulation technique combined with a regression analysis allowed a determination of the measured thermopower within 6.4 s and the possibility for self-diagnostics. These presented results shows a possible realization of fast, accurate, highly sensitive direct thermoelectric gas sensors'. Comini *et al*. [13] Influence of Iron addition on ethanol and Co sensing properties of tin oxide prepared with the RGTO technique. Effects of iron introduction in RGTO prepared tin oxide gas sensors are presented. The films were deposited by sputtering from a tin target with the introduction of an adjustable number or iron inset. Iron content was varied in the range 0-7%. The thin films are investigated by the volt-amperometry technique for electrical and gas-sensing properties. The response of the sensors is stable and reproducible at all operating temperatures tested (200-500^0C) during 3 months of operation. Cantalini *et al*. [14]. Niobium – doped αFe_2O_3 semiconductor ceramics sensors for the measurement of nitric oxide gases. The NO, NO_2 and NOx gas-sensitivity properties of Nb-doped α-Fe_2O_3 sintered compacts have been studied in the 0–100 ppm gas concentration and 150–300 °C temperature ranges, by d.c. and a.c. techniques. Sensors have been prepared by suspending a 130 m^2 g^{-1} α-Fe_2O_3 powder in a standard Nb solution in order to yield Nb/Fe atomic percentages between 0.5 and 20 at.%. Sintering has been performed at 800 °C for 2 h. The 20% doped material shows a gas sensitivity (S), defined as R_G/R_A, where R_A and R_G are the electrical resistances in air and in the sample gas, respectively, as high as 36 at 100 ppm NO_2 and 200 °C working temperature. An electrical equivalent circuit including a constant phase element (CPE), which can simulate the electrical response of the sensor in the 0–100 ppm NO_2 gas concentration range, is also presented. Camilla Baratto *et al*. [15]. Iron doped indium oxide by modified RGTO deposition for ozone sensing nanostructured thin films based on indium oxide have been prepared by a modified rheotaxial growth and thermal oxidation (RGTO) deposition technique. The layers were additivities with 8–30% iron in order to stabilize the microstructure and to enhance the sensing properties toward ozone. The electrical test of the sensing layers indicated high sensitivity to ozone together with a relatively low cross-sensitivity to interfering gases. Clemens J. Belle *et al*. [16] .Size dependent gas sensing properties of Spinel iron oxide nanoparticles. Spinel iron oxide nanoparticles of sizes from 12 to 60nm have been prepared via a hydrothermal synthesizes. The electrical and gas sensing properties were characterized by impedance spectroscopy using multielectrode substrates. The materials exhibit good sensor responses towards NH_3 with low cross sensitivities towards H_2 and NO at 250^0C. A linearly increasing sensor response towards NH_3 and H_2 with decreasing particle size was found. Tuquabo Tesfamichael *et al*. [17]. Thin film deposition and characterization of pure and iron doped electron beam evaporated tungsten oxide fa gas sensors. Pure tungsten oxide (WO_3) and iron-doped (10 at.%) tungsten oxide (WO_3:Fe) nanostructured thin films were prepared using a dual crucible Electron Beam Evaporation (EBE) technique. The films were deposited at room temperature under high vacuum onto glass as well as alumina substrates and post-heat treated at 300 °C for 1 h. The heat-treated films were investigated for gas sensing applications using noise spectroscopy. It was found that doping of Fe to WO_3 produced gas selectivity but a reduced gas sensitivity as compared to the WO_3 sensor.Chien Tsung Wang *et al*. [18].Synthesis of iron-doped vanadium tin oxide Nano crystallites for Co gas sensing Iron-doped vanadium–tin oxide nanoparticles have been synthesized by a hydrolysis and co-precipitation method from iron(II) acetate, vanadium(III) acetylacetonate and tin tetrachloride. Based on sensitivity measurements in a semiconductor CO gas sensor, the iron doping resulted in a shift of the maximum sensitivity toward the lower temperature side. A correlation between the surface state and sensor performance is proposed. Dragos – Viorel Brezoi *et al*. [19] Phase evolution included by polypyrrole in iron oxide- polypyrene nanocomposite. Nanocomposite of polypyrrole and iron oxide were prepared using simultaneous gelation and polymerization processes. Varied amounts of pyrrole were added to a solution containing in Fe (III) salt as precursor and 2-metoxy ethanol as solvent. The properties of Nano composites formed by combining conducting polymers and oxides nano particles are strongly dependent on concentration of polymer and have brought out more fields of applications such as smart windows, toners in photocopying, conductive paints, drug delivery, recharge able batteries. These nanocomposites were used for humidity and gas sensors. Ramesh Chandra Biswal *et al*. [20] .Pure and Pt-loaded gamma iron oxide as sensor for detection of sub ppm level of acetone. In this study, pure and Pt-loaded nanocrystalline γ-Fe_2O_3 have been prepared by precipitation using ultrasonic irradiation. The synthesized powders were characterized by X-ray diffraction (XRD), thermo-gravimetric analysis (TGA), differential thermal analysis (DTA), transmission electron micrograph (TEM), selected area electron diffraction (SAED), scanning electron microscope (SEM) and energy dispersive X-ray (EDX). J.L. Gunjakar *et al*. [21] Chemical deposition of Nano crystalline nickel oxide from urea containing bath and its use in liquefied petroleum gas sensor. Nanocrystalline nickel oxide (NiO) was deposited onto glass substrates using a chemical deposition method from a bath containing nickel (Ni^{2+}) ions and urea at 363 K. The chemically deposited nickel oxide films were effectively used as a liquefied petroleum gas (LPG) sensor and the maximum response of 36.5% was recorded on exposure to 0.3 vol% of LPG at 698 K.S. Banno *et al*. [22] Selective nitrogen dioxide sensor based on nickel copper oxide mixed with rare earths Scandium – doped nickel copper oxide bulk, which consists of $Ni_{0.8}Cu_{0.2}O$, CuO, Sc_2O_3, and $Sc_2Cu_2O_5$, responds only to NO_2 (50 – 500 ppm) among NOx gases. Thin films of the oxide are prepared by an r.f. magnetron sputtering method, and their NOx- sensing characteristics are studied. The disappearance of crystalline $SC_2CU_2O_5$ in the film might affect the sensing performance for NOx.I. Hotovy *et al*. [23]. Preparation of Nickel oxide thin films for gas sensors applications. Nickel oxide (NiO) thin films were prepared by dc reactive magnetron sputtering from a nickel metal target in an Ar+O_2 mixed atmosphere in two sputtering modes. The oxygen content in the gas mixture varied from 15% to 45%. The films prepared in the oxide-sputtering mode were amorphous while the films in metal-sputtering mode exhibited polycrystalline (fcc) NiO phase, found that good Nio stoichiometric films are obtainable with a polycrystalline (fee) structure at 40% oxygen content in the metal-sputtering mode. Jan Hrfac *et al*. [24] Nitric oxide sensor based on carbon fiber covered with nickel porphyrin layer deposited using optimized electro polymerization procedure.Electropolymerization regime of meso-tetrakis (3-methoxy-4-hydroxyphenyl) porphyrin is optimized to yield films possessing both electrocatalytically and perm selective properties towards nitric oxide oxidation. The sensor composed of electrochemically oxidized carbon fiber, covered solely with nickel porphyrin derivative layer electropolymerized. Nafion coating can further enhance selectivity properties as well as aids to the stability of the sensors responses', Cao, *et al*. [25] Highly sensitive non-enzymatic glucose sensor, based on electro sum copper oxide doped nickel oxide composite micro fibers. An improved non enzymatic glucose sensor based on copper oxide-doped nickel oxide composite microfibers (CuO-NiO-MFs) modified fluorine tin oxide (FTO) electrode was prepared by electrospinning and calcination technologies without using any immobilization. Its application for detecting glucose concentration of human serum sample showed good agreement with the results obtained from automatic biochemical analyzer. Fei Cao *et al*. [26]. Nickel oxide micro fibers immobilized onto electrode by electrospinning and calcination for non-enzymatic glucose sensor and effect of calcinations temperature on the performance. Nickel oxide microfibers (NiO-MFs) were directly immobilized into the surface of fluorine tin oxide (FTO) electrode by electrospinning and calcinations without using any immobilization matrix for nonenzymic glucose sensor which are among the best values reported in literature. Additionally, excellent selectivity and stability have also been obtained. Maxime Pontie *et al*. [27] Improvement in the performance of a nickel complex – based electro chemically sensor for the detection of nitric oxide in solution. The electroformation of the tetrasulfonated nickel phthaolocyanine (NiTSPc) film in alkaline solution onto carbon fiber microelectrode is investigated in order to improve the electrochemical detection of nitric oxide (NO) in solution. The phthalocyanine film formed by cyclic voltammetry gives a modified microelectrode with a good sensitivity to NO, higher than the obtained one with nickel phthalocyanine and/or porphyrin deposited by controlled potential electrolysis. Fethi Bedioui *et al*. [28] Elaboration and use of nickel planar macrocyclic complex-based sensors for the direct electrochemical measurement of nitric oxide in biological media. We described here the electrochemical detection of nitric oxide, NO, in biological systems by using chemically modified ultramicro carbon electrodes. In the first part of the paper, the different steps involved in the electrochemical preparation and characterization of the nickel – based sensor are described. Fei Cao *et al*. [29] Highly sensitive nonenzymic glucose sensor based on electro spun copper oxide doped nickel oxide composite microfibers. An improved nonenzymic glucose sensor based on copper oxide- doped nickel oxide composite microfibers (CuO-NiO-MFs) modified fluorine tin oxide (FTO) electrode was prepared by electrospinning and calcination technologies without using any immobilization. The nonenzymic glucose sensors that have been reported in the literature. Additionally, its application for detecting glucose concentration of human serum sample showed good agreement with the results obtained from automatic biochemical analyzer.Kuo-Chuan Ho *et al*. [30] Chemiresistor type No gas sensor based on nickel phthalocyanine thin films .The sensing characteristics of nickel phthalocyanine (NiPc) thin films for use in a chemoreceptor type nitric oxide gas sensor are discussed. The gas-sensing properties, including current transient, sensitivity, response time, and aging, are studied. A kinetic model proposed in the literature for sensing NO_2 with lead phthalocyanine (PbPc) thin films, in which adsorption involves displacement of surface adsorbed O_2 from a range of heterogeneous sites, can be used to explain our experimental results. For a lower concentration range, between 5 and 50 ppm NO, the sensitivity lies between 0.41 and 0.42, while for a higher concentration range, between 50 and 500 ppm, the sensitivity decreases to about 0.17 to 0.19.C.V. Gopal Reddy *et al*. [31] Semiconducting gas sensor for chlorine based on inverse spinel nickel ferrite. Nickle ferrite, a p-type semi conducting oxide with an inverse spinel structure has been used as a gas sensor to selectively detect chlorine in air. This compound was prepared by two different routes namely, the citrate and co-precipitation method and sensor properties of the resulting compounds from both the methods were compared. X-ray diffraction was used to confirm the structure. The sensitivity to chlorine has been compared with that of other inferring gases. A probable explanation has been proposed to explain the selective sensitivity to oxidizing gases like chlorine. Sangsoo Noh *et al*. [32] Electrical properties of nickel oxide thin films for flow sensor application In this work, Ni oxide thin films, with thermal sensitivity superior to Pt and Ni thin films, were formed thorough annealing of Ni films deposited by a r.f. magnetron sputtering. The annealing was carried out in the temperature range of 300-500^{0}C under atmospheric condition because of their high resistively and very linear TCR, Ni oxide thin films are superior to pure NI and Pt thin films for flow and temperature sensor applications.Abdollah Salini *et al*. [33] Highly sensitive sensor for picomolar detection of insulin at physiological PH, using GC electrode modified with guanine and electro deposited nickel oxide Nano particles. The electro chemical behavior of insulin at glassy carbon (GC) electrode. The modified electrode was applied for insulin detection using cyclic voltammetry of hydrodynamic amperometry techniques. It is promising for for the monitoring of insulin in chromatographic effluents' Mu *et al*. [34] Nano nickel Oxide modified non – enzymatic glucose sensors with enhanced sensitivity through an electro chemical process strategy at high potential. Development of fast and sensitive sensors for glucose determination is important in food industry, clinic diagnostics, biotechnology and many other areas. in these years, considerable attention has been paid to develop non-enzymatic electrodes to solve the disadvantages of the enzyme modified electrodes, such as instability, high cost, complicated immobilization procedure and critical operating situation et.al. The non-enzymatic sensors response quickly to glucose and the response time is less than 5's, demonstrating excellent electrolytical activity and assay performance the proposed non-enzymatic sensors can be used for the assay of glucose in real sample. Scandium – doped nickel copper oxide bulk, which consists of $Ni_{0.8}Cu_{0.2}O$, CuO, Sc_2O_3, and $Sc_2C_u2O_5$, responds only to NO_2 (50-500ppm) among NOx gases. Thin films of the oxide are prepared by an r.f. magnetron sputtering method, and their NOx- sensing characteristics are studied. The disappearance of crystalline $Sc_2Cu_2O_5$ in the film might affect the sensing performance for NOx. D. Barreca *et al*. [35] Supported copper oxide Nano systems were synthesized by chemical vapor deposition (CVD) on Al_2O_3 substrates and characterized by means of glancing incidence X-ray diffraction (GIXRD), secondary ion mass spectrometry (SIMS) and field emission scanning electron microscopy (FESEM). The obtained results revealed good responses even at moderate operating temperatures, with characteristics directly dependent on the system composition and Nano – organization. Mingqing Yang *et al*. [36] Copper oxide Nano particles sensors for hydrogen cyanide detection.Uprecedented selectivity and sensitivity In the current work, CuO Nano particles were synthesized in a facile way, and characterized by scanning electron microscopy, transmission electron microscopy, X-ray diffraction, X-ray photo electron spectroscopy, and thermo gravimetry. Using these CuO Nano particles, CuO functionalized QCM resonators were fabricated and explored for HCN sensing. The current results would provide an exciting alternative to fast, sensitive and selective detection of trace HCN, which would be of particular benefit in the area of public security and environmental application. Hong bing wei *et al*. [37] A novel hydrogen sulfide room temperature sensor based on copper nanocluster functionalized tin oxide thin films. A novel room temperature solid state senor for the detection of hydrogen sulfide is described. The sensor was fabricated by first depositing a thin film of tin oxide on to a glass substrate followed by surface functionalizing with monolayer protected copper Nano clusters (MPCs). Capped with different capping agents prepared as per the Brust synthesis. The response time for all the samples is smaller than 2 min. Wei. Wang *et al*. [38] Low temperature H_2O sensor based on copper oxide/ tin dioxide thick film. Nano structured tin dioxide (SnO_2) powders were prepared by a sol-gel dialytic process and the doping of CuO on it was completed by a deposition precipitation method. The thick film sensors were fabricated from the CuO/ SnO_2 polycrystalline powders. Sensing behavior of the sensor was investigated with various gases including CO, H_2, NH_3 hexane, acetone, ethanol, methanol and H_2S in air. It might have promising applications in the future.Saumya *et al*. [39] Electropunk Pallodium (IV) doped copper oxide composite Nanofibers for non emetic glucose sensor. Pd (IV) doped CO oxide composite nanofibers (PCNFs) have been successfully fabricated via electrospinning and then employed to construct an amperometry non-enzymatic glucose sensor. These results indicate that PCNFs are promising candidates for aerometric non enzymatic glucose detection.Tudorache et al. [40] prepared humidity sensor applicative material based on copper-zinc-tungsten spinel ferrite the effect of partially substitution of iron with tungsten on the properties of copper-zinc spinel ferrite for humidity sensors application was presented. The electric properties of the Cu0.5Zn0.5W0.3Fe1.7O4 spinel ferrites heat-treated at different temperatures and humidity conditions were characterized and analyzed. As an application of the material the characteristics of a resistive and capacitive humidity sensors were analyzed using Cu0.5Zn0.5W0.3Fe1.7O4 ferrite as active material. Mukherjee *et al*. [41] Synthesis process induced improvement on the gas sensing characteristics of Nano-crystalline magnesium zinc ferrite particles. The gas sensing performances of the ferrite-based sensors can be improved by modifying their surfaces to volume ratio, grain size, morphology and meso-porous nature. Synthesis of phase pure ferrites with desired micro-structural features at lower calcinations temperature remains a challenging task. In order to improve their gas sensing performance, in the present work we have investigated the (synthesis) process induced modifications of the phase and micro-structural features of wet chemical synthesized ferrite sensing elements. These structural and micro-structural features are found to have significant influence on the gas sensing performances of Mg0.5Zn0.5Fe2O4 particles prepared using two different wet chemical routes. Mukherjee et al. [42] Promising methane-sensing characteristics of hydrothermal synthesized magnesium zinc ferrite hollow sphere. The promising methane-sensing characteristics (i.e. per cent response, response and recovery time) identified for Mg0.5Zn0.5Fe2O4 hollow sphere-based sensing elements are attractive for developing chemo resistive-type non-conventional complex oxide-based combustible gas sensors. Mukherjee et al. [43] studied Reducing gas sensing behavior of Nano-crystalline magnesium–zinc ferrite powders as an effective alternative of simple binary oxides, cubic spinel oxides are considered to be attractive to make sensitive and stable gas sensor, selective to a specific gas. We have focused the present work on the investigation of the gas sensing characteristics of cubic spinel based Nano-crystalline magnesium zinc ferrite powders. The conductance transients during response and recovery processes have been modeled using Langmuir adsorption isotherm and activation energies for gas adsorption and desorption processes have been estimated from the respective thermally activated kinetic processes.Sutka et al. [44] prepared gas sensing properties of Zn-doped p-type nickel ferrite. For characterization of gas sensor material, synthesized by sol–gel auto combustion method, X-ray diffraction (XRD), scanning electron microscopy (SEM), DC resistance and impedance spectroscopy (IS) measurements were employed. The response change of Zn doped nickel ferrite is related to the interruption of hole hopping between nickel ions. This was improved by change of conductivity type with temperature and gas exposure.Rezlescu et al. [45] studied semiconducting gas sensor for acetone based on the fine grained nickel ferrite .The sensitivity to some reducing gases (acetone, ethanol, methane and liquefied petroleum gas—LPG) of calcian doped nickel ferrite (NiFe2O4 + 1%CaO) and cobalt and manganese doped nickel ferrite, Ni0.99Co0.01MnxFe2−xO4−δ (x = 0.01 and 0.02), was investigated. Starting from nitrates, as raw materials, the samples were prepared by self-combustion method. The gas sensitivity largely depends on the composition, temperature and the test gas species. The ferrite compounds doped with Co and Mn are selective to detect reducing gases at low operating temperature. The mixed ferrite with Ni0.99Co0.01Mn0.02Fe1.98O4−δ composition is sensitive and selective to acetone gas.Reddy et al. [46] Semiconducting gas sensor for chlorine based on inverse spinel nickel ferrite is a p-type semiconducting oxide with an inverse spinel structure has been used as a gas sensor to selectively detect chlorine in air. The sensitivity to chlorine has been compared with that of other interfering gases. A probable explanation has been proposed to explain the selective sensitivity to oxidizing gases like chlorine.Darshane et al. [47] studied nanostructured nickel ferrite is a liquid petroleum gas sensor. The present investigation deals with the synthesis of nanostructured nickel ferrite (NiFe2O4) and their liquid petroleum gas-sensing characteristics. The results suggest possibility of utilization of the nanostructured nickel ferrite, without addition of any precious metal ion, as the LPG detector.Galindo et al. [48] studied catalytic properties of nickel ferrites for oxidation of glucose, β-nicotinamide adenine dinucleotide (NADH) and nickel ferrite nanoparticles (NiFe2O4) were synthesized by electrochemical method and used as catalyst for direct oxidation of glucose, NADH and methanol. Characterization of these nanoparticles was carried out by X-ray diffraction, Mossbauer spectroscopy, and colloidal properties such as hydrodynamic radius and Zeta potential.Lokhande et al. [49] worked on magnetic studies on one-step chemically synthesized nickel ferrite thin films. Nickel ferrite thin films were synthesized at room temperature using one-step electrodeposition solution processing. Reaction kinetics was also proposed. An effect of air baking on the structural, surface morphological and magnetic properties was investigated.Petrila[50] Humidity sensor applicative material based on copper-zinc-tungsten spinel ferrite .The effect of partially substitution of iron with tungsten on the properties of copper-zinc spinel ferrite for humidity sensors application was presented. The electric properties of the Cu0.5Zn0.5W0.3Fe1.7O4 spinel ferrites heat-treated at different temperatures and humidity conditions were characterized and analyzed. As an application of the material the characteristics of a resistive and capacitive humidity sensors were analyzed using Cu0.5Zn0.5W0.3Fe1.7O4 ferrite as active material. Satyendra Singh et al. [51] worked on synthesis of nanorods and mixed shaped copper ferrite and their applications as liquefied petroleum gas sensor. The preparation and characterization of nanorods and mixed shaped (nanospheres/nanotubes) copper ferrite for liquefied petroleum gas (LPG) sensing at room temperature. The structural, surface morphological, optical, electrical as well as LPG sensing properties of the copper ferrite were investigated. Single phase spinel structure of the CuFe2O4 was confirmed by XRD data. The role of PEG in the synthesis for obtaining nanospheres/nanotubes has also been demonstrated.Khandekar et al. [52] worked on liquefied petroleum gas sensing performance of cerium doped copper ferrite. Moreover, the gas sensing properties of sintered samples were studied towards different reducing gases such as liquefied petroleum gas (LPG), acetone, ethanol and ammonia. The sample with 4% cerium doped CuFe2O4(Ce4) showed the maximum gas sensitivity (86%) towards LPG with fast response time of 5 s and good recovery time of 68 Satyendra Singh et al.[53] Investigated the effects of surface morphologies on response of LPG sensor based on nanostructured copper ferrite system. Gas sensing properties shows the spinel CuFe2O4 synthesized in 1:1 molar ratio exhibit best response to LPG adsorption/resistance measurement. Thus, resistance based LPG sensor is found robust, cheap and may be applied for kitchens and industrial applications.

CONCLUSION:

Above mentioned literature shows wide applications of metal /mixed metal oxides as Sensor in various reactions like nanostructured nickel ferrite is a liquid petroleum gas sensor. The investigation deals with the synthesis of nanostructured nickel ferrite (NiFe2O4) and their liquid petroleum gas-sensing characteristics. The results suggest possibility of utilization of the nanostructured nickel ferrite, without addition of any precious metal ion, as the LPG detector. Catalytic properties of nickel ferrites for oxidation of glucose, β-nicotinamide adenine dinucleotide (NADH) and nickel ferrite nanoparticles (NiFe2O4) were synthesized by electrochemical method and used as catalyst for direct oxidation of glucose, NADH and methanol. Characterization of these nanoparticles was carried out by X-ray diffraction, Mossbauer spectroscopy, and colloidal properties such as hydrodynamic radius and Zeta potential So, metal/mixed metal oxides have broad applications as sensor in various chemical reactions.

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