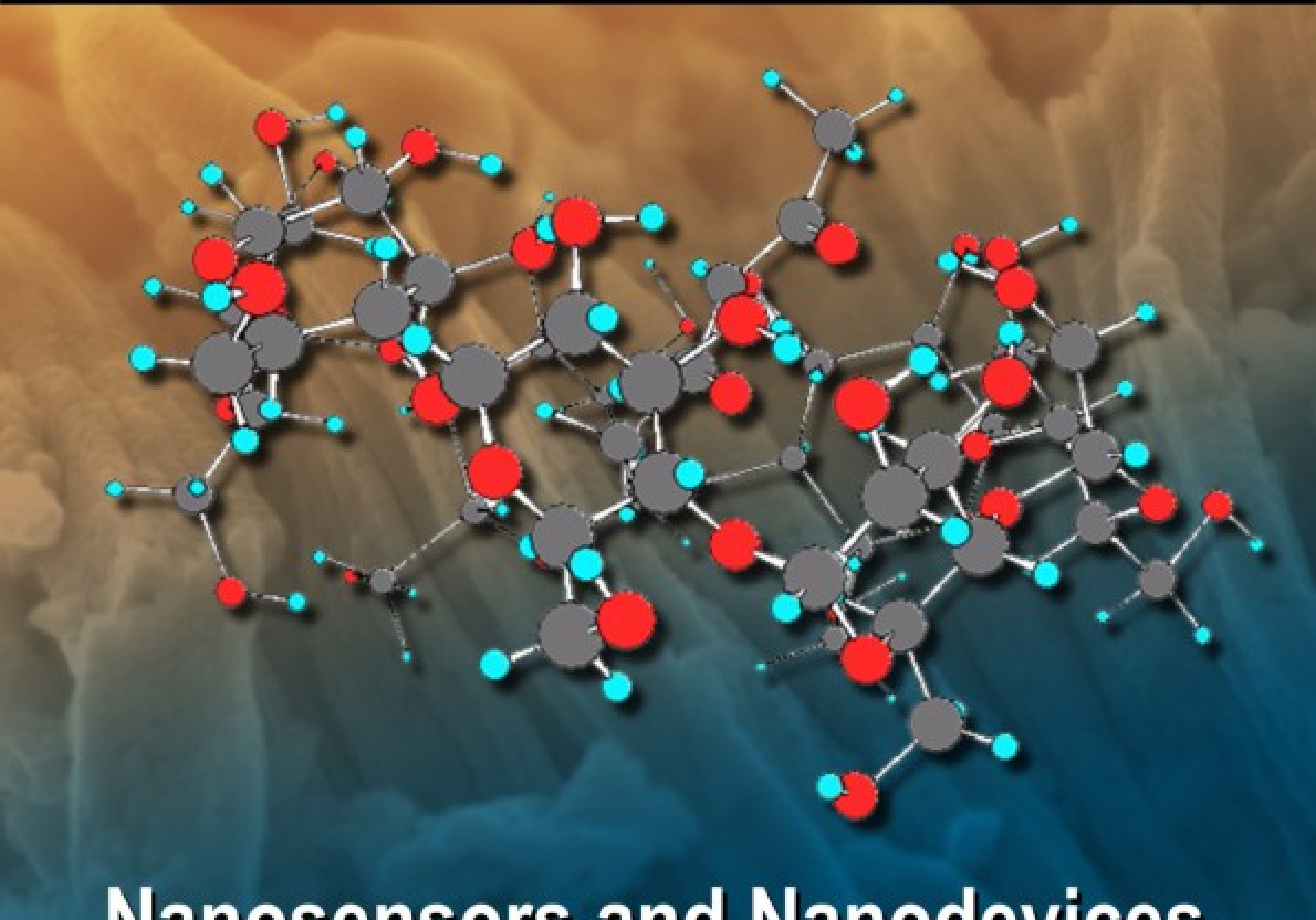
ISSN 1726-5479

SENSORS & TRANSDUCERS

11/12 vol. 146



Nanosensors and Nanodevices

International Frequency Sensor Association Publishing

IFSA

Sensors & Transducers

Volume 146, Issue 11
November 2012

www.sensorsportal.com

ISSN 1726-5479

Contents

Volume 146
Issue 11
November 2012

www.sensorsportal.com

ISSN 1726-5479

Research Articles

Authors are encouraged to submit article in MS Word (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com
Please visit journal's webpage with preparation instructions: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm

International Frequency Sensor Association (IFSA).


IARIA
The Fourth International Conference on Sensor Device Technologies and Applications
SENSORDEVICES 2013
25 - 31 August 2013 - Barcelona, Spain
Tracks: Sensor devices - Ultrasonic and Piezosensors - Photonics - Infrared - Gas Sensors - Geosensors - Sensor device technologies - Sensors signal conditioning and interfacing circuits - Medical devices and sensors applications - Sensors domain-oriented devices, technologies, and applications - Sensor-based localization and tracking technologies - Sensors and Transducers for Non-Destructive Testing
Deadline for papers: 30 March 2013
http://www.iaria.org/conferences2013/SENSORDEVICES13.html


IARIA
The Seventh International Conference on Sensor Technologies and Applications
Deadline for papers: 30 March 2013
SENSORCOMM 2013
25 - 31 August 2013 - Barcelona, Spain
Tracks: Architectures, protocols and algorithms of sensor networks - Energy, management and control of sensor networks - Resource allocation, services, QoS and fault tolerance in sensor networks - Performance, simulation and modelling of sensor networks - Security and monitoring of sensor networks - Sensor circuits and sensor devices - Radio issues in wireless sensor networks - Software, applications and programming of sensor networks - Data allocation and information in sensor networks - Deployments and implementations of sensor networks - Under water sensors and systems - Energy optimization in wireless sensor networks
http://www.iaria.org/conferences2013/SENSORCOMM13.html


IARIA
The Sixth International Conference on Advances in Circuits, Electronics and Micro-electronics
CENICS 2013
25 - 31 August 2013 - Barcelona, Spain
Deadline for papers: 30 March 2013
Tracks: Semiconductors and applications - Design, models and languages - Signal processing circuits - Arithmetic computational circuits - Microelectronics - Electronics technologies - Special circuits - Consumer electronics - Application-oriented electronics
http://www.iaria.org/conferences2013/CENICS13.html

Sensors & Transducers Journal, Vol. 146, Issue 11, November 2012, pp. 133-144

Sensors & Transducers

ISSN 1726-5479

http://www.sensorsportal.com

Nanostructured $CdFe_2O_4$ Thick Film Resistors as Ethanol Gas Sensors

*** S. V. BANGALE, R. D. PRAKSHALE, S. R. BAMANE**
Metal Oxide Research, Laboratory, Department of Chemistry,
Dr. Patangrao Kadam Mahavidyalaya, Sangli, 416416 (M.S.) India
Tel.: 0233-2535993, fax: 0233-2535993
* E-Mail: bangale_sv@rediffmail.com

Received: 6 April 2012 /Accepted: 23 November 2012 /Published: 30 November 2012

Abstract: Semiconductive nanoparticles of $CdFe_2O_4$ were synthesized by a solution combustion technique. This process is a convenient, environment friendly, inexpensive and efficient for the preparation of $CdFe_2O_4$ nanomaterial. The synthesized material is characterized by Thermo gravimetric Differential analysis (TG/DTA), X-ray Diffraction studied (XRD), Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) techniques. Conductance response of the nanocrystalline $CdFe_2O_4$ thick film is measured by exposing the film to reducing gases like ethanol, acetone, ammonia, H_2S and hydrogen. The sensor exhibited a fast response and a good recovery. The results demonstrated that $CdFe_2O_4$ can be used as a gas-sensing material which has a high sensitivity and good selectivity to ethanol gas at 200 ppm. *Copyright © 2012 IFSA.*

Keywords: $CdFe_2O_4$, TEM, Ethanol gas sensor, Thick film, Gas response.

1. Introduction

Semiconductor metal oxides as gas sensing materials have been extensively studied for a long time due to their advantageous features, such as good sensitivity to the ambient conditions and simplicity in fabrication [1-10]. Nevertheless, there are still some critical limitations to be overcome for the commercial sensors based on particulate or thin-film semiconductor metal oxides, such as limited maximum sensitivity, high working temperatures and lack of long-term stability. Recently, several groups reported the sensors based on semiconductor nanowires and nanoribbons. Ethanol-sensing material has been widely and deeply studied. Conventional ethanol sensors, mostly based on SnO_2

[11], ZnO [12], TiO_2 [13], and Fe_2O_3 [14], and usually suffering from cross-response to other gases, need a high working temperature, or have low long-term stability, although they have rather high response to ethanol. So the research for new ethanol-sensing materials and developing the properties of conventional ethanol sensing materials has become an active research field. New ethanol sensors are based on In_2O_3 [15], V_2O_5 [16], and complex oxide [17-21]. Their properties still need further investigation. Ethanol is explosively utilized for beverages, industrial and scientific sectors. Ethanol is a hypnotic [22] gas having toxic nature. Heavy exposure and/or consumption of alcoholic beverages, particularly by smokers, increase the risk of cancer [23-24] of the upper respiratory and digestive tracks. Alcoholic cirrhosis leads to liver cancer. Amongst the women, the chance of breast cancer increase with alcoholic consumption or exposure. Those working on ethanol synthesis have great chances of being victims of respiratory and digestive track cancer. So there is a great demand and emerging challenges for monitoring ethanol gas at trace level.

In this paper, we have synthesized $CdFe_2O_4$ nanoparticles by novel combustion reaction. One of our aims is to develop a general synthesis method and explore the gas sensing properties of the $CdFe_2O_4$ nanopowder. We found that the process is a convenient, environment friendly, inexpensive and efficient. Furthermore, the $CdFe_2O_4$obtained possesses excellent gas-sensing responses to reducing gas and grain size is about 50-100 nm. This discovery could aid in the synthesis of low cost and $CdFe_2O_4$ is outstanding in promoting the sensing properties of C_2H_5OH in air.

2. Materials and Methods

2.1. Materials

All the reagents are of analytical grade and are used as received without further purification. Cadmium nitrate [$Cd(NO_3)_26H_2O$], iron nitrate [$Fe(NO_3)_26H_2O$], citric acid are purchased from Sigma-Aldrich chemical reagents Co. (USA).

2.2. Methods

For the present study, polycrystalline $CdFe_2O_4$ powder was prepared by combustion route using Citric acid as fuel. The materials used as precursors were Cadmium nitrate hexahydrate Cd $(NO_3)_2$ $6H_2O$, Fe $(NO_3)_26H_2O$ Iron nitrate hexahydrate (all these were procured from A.R. Grade of Qualligen) and Citric acid (Nuclear band). Citric acid possesses a high heat of combustion. It is an organic fuel and provides a platform for redox reactions during the course of combustion. Initially the Cadmium nitrates, Iron nitrates and Citric acid are taken in the 1:1:4 stoichiometric amount and dissolved in a 250 ml beaker then slowly string by using glass rod then clear solution was obtained. Solution formed was evaporated on hot plate in temperature range 70 ^{0}C to 80 ^{0}C gives thick gel. The gel was kept on a hot plate for auto combustion and heated in the temperature range 170 ^{0}C to 180 ^{0}C. The nanocrystalline $CdFe_2O_4$ powder was formed within 40-50 minutes. And then sintered at about 800 ^{0}C for about 4 hours then we got brown colour shining powder of nanocrystalline $CdFe_2O_4$.

2.3. Thick Film Formation

Cadmium ferrites powder was ground in an agate pastel-moter to ensure sufficiently fine particle size. The fine powder was calcined at 800 ^{0}C for 24 h in air and re-ground. The thixotropic paste was formulated by mixing the resulting $CdFe_2O_4$ fine powder with a solution of ethyl cellulose (a temporary binder) in a mixture of organic solvents such as butyl carbitol acetate, and turpineol. The ratio of inorganic and organic path was kept as 75:25 in formulating the paste. The paste was then used to prepare thick films. The thixotropic paste was screen printed on a glass substrate in desired patterns. The films prepared were fired at 500 ^{0}C for 24 h.

2.4. Characterization Techniques

The as –prepared samples were characterized by TG/DTA thermal analyzer (SDT Q600 V 20.9 Build 20), XRD Philips Analytic X-ray B.V. (PW-3710 Based Model diffraction analysis using Cu-K_α radiation), scanning electron microscope (SEM, JEOL JED 2300) A JEOL JEM–200 CX transmission electron microscope operating at 200 kV analysis.

2.5. Fabrication and Analysis of Gas Sensors

The sensing performance of the sensors was examined using a "static gas-sensing system. There were electrical feeds through the base plate. The heating was constant on the base plate to heat the sample under test up to required operating temperatures. The current passing through the heating element was monitored using a relay with adjustable ON/OFF time intervals. A Cr-Al thermocouple was used to sense the operating temperature of the sensors. The output of the thermocouple was connected to digital temperature indicators. A gas inlet valve was fitted at one port of the base plate. The required gas concentration inside the static system was achieved by injecting a known volume of test gas using a gas-injecting syringe. A constant voltage was applied to the sensors, and current was measured by a digital Pico-ammeter. Air was allowed to pass into the glass dome after every Gases exposure cycle as shown in Fig. 1.

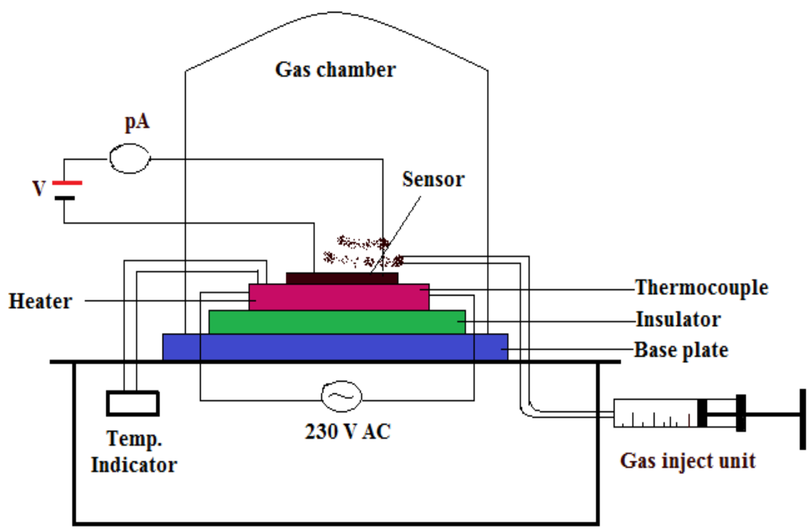


Fig. 1. Block diagram of static gas sensing setup.

3. Result and Discussion

3.1. TG-DTA Analysis

The TG curve recorded for thermal decomposition of $CdFe_2O_4$ is shown in Fig. 2. The curve indicates that the slight weight loss in $CdFe_2O_4$ powder due to little loss of moisture, carbon dioxide and nitrogen gas. The DTA curve of $CdFe_2O_4$ recorded in static air, curve shows that $CdFe_2O_4$ did not decompose, but weight loss was due to dehydrogenation decarboxylation and denitration and yield final product at 775 ^{0}C. This weight loss and weight gained was very negligible. This weight change was in the range of 0.02 % only. These indicate that the synthesized powder was almost stable from the beginning.

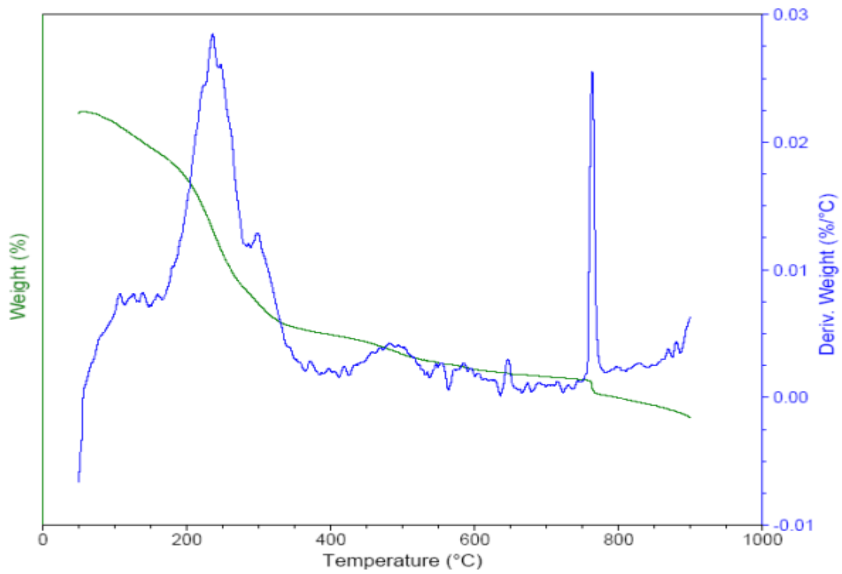


Fig. 2. TG - TDA curve of $CdFe_2O_4$ as synthesized powder.

3.2. X-Ray Diffraction Studies

The XRD pattern shown in the Fig. 3. The XRD pattern shows that the product is pure spinel oxide $CdFe_2O_4$ with a cubic structure. The diffraction data are good agreement with JCPD card of $CdFe_2O_4$ (JCPDS No.24-1016) The average crystalline size of $CdFe_2O_4$ spinel powder was estimated with the help of Scherrer's equation $t = 0.9\lambda / \beta \cos\theta$ [25-28] where t is the thickness of the crystals (in angstroms), λ is the X-ray wavelength and θ is the Bragg angle β is the integral breath that depends on the width of the most predominant peak at 100% intensity =1.54056 A^{o}. The average particle size of nanocrystalline $CdFe_2O_4$ was ~ 48 nm. $CdFe_2O_4$ nanocrystals are more attractive in the field of gas sensing application.

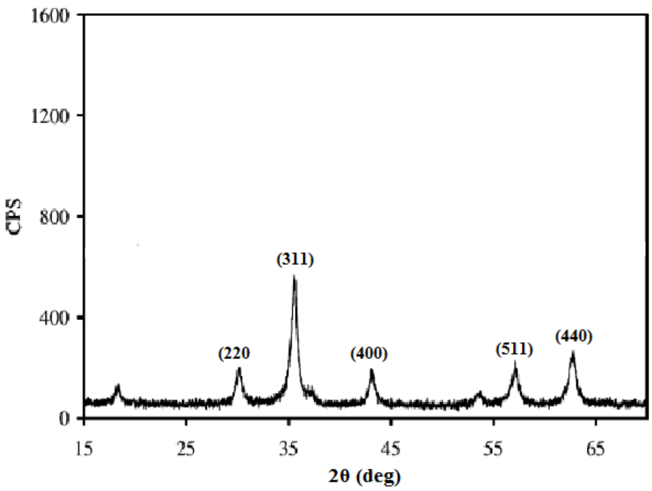


Fig. 3. X-ray diffraction patterns of $CdFe_2O_4$ as synthesized powder.

3.3. Particle Size Analysis

Particle size distribution studies have been carried out by using dynamic light scattering techniques (DLS) Via Laser input energy of 632 nm). It was observed that cadmium iron oxide nanoparticles have narrow size distribution within the range of about 30-50 nm (Fig. 4), which are similar to the values calculated from Scherrer equation.

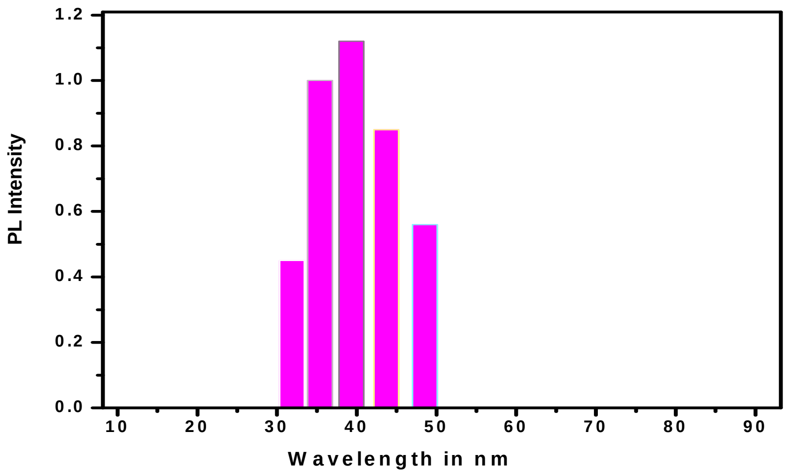
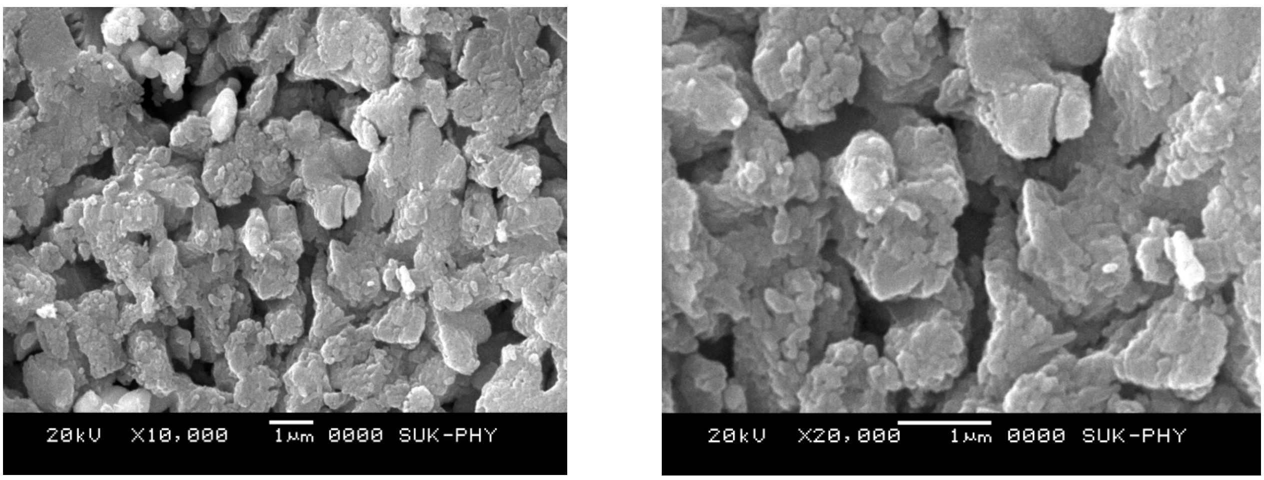


Fig. 4. Particle size Distribution of mixed precursor $CdFe_2O_4$ at 800 ^{0}C in air for 4 h.

3.4. SEM Analysis

The microstructure of the 800 ^{0}C sintered samples can be visualized from scanning electron microscope (SEM) tool. Fig. 5 depicts SEM images of $CdFe_2O_4$ powder it shown the particle morphology of high resolution the particle are most irregular in shape with a nanosized range of 80-150 nm some particles are found as agglomerations containing very fine particles. It can be observed that $CdFe_2O_4$have uniformed size. It seems that surfaces are smooth, spongy and pores are seen in the micrograph.

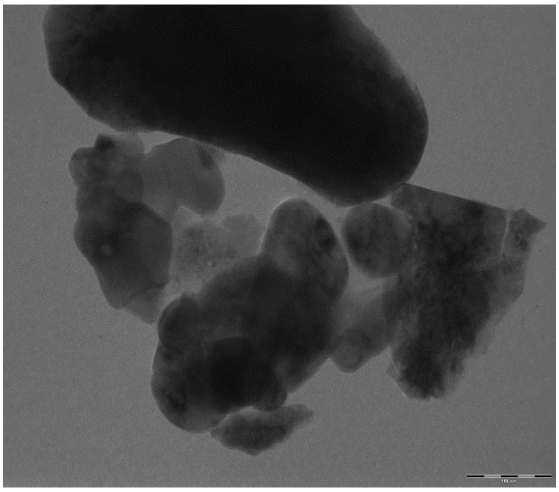


(a) (b)

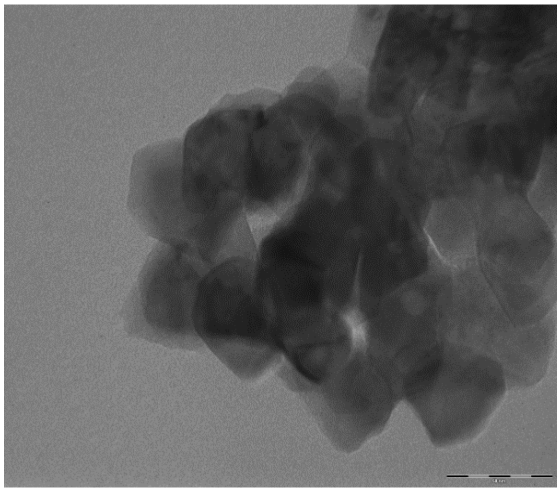
Fig. 5. SEM images of mixed precursor $CdFe_2O_4$ at 800 ^{0}C in air for 4 h
(a) low resolution, and (b) high resolution.

3.5. TEM Analysis

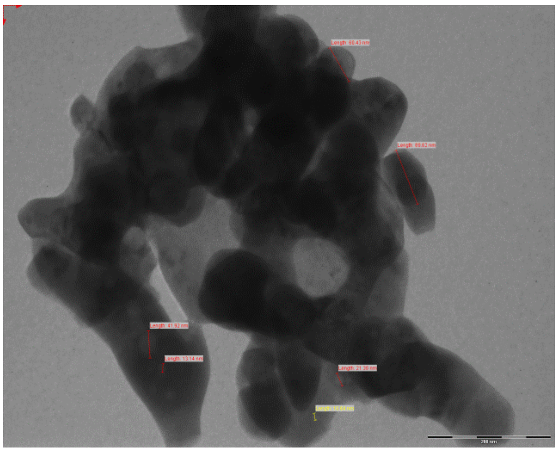
Fig. 6 (a, b) show TEM micrographs of the specimens calcined at 800 ^{0}C, respectively. It can be seen that calcining temperature has an obvious influence on morphology for samples. The 800 ^{0}C sample consists of spheroidic grains with narrow size distribution (60 ± 100 nm), where as 800 ^{0}C sample is composed of small grains with various shapes due to the coexistence of multi-phases. According to the result from XRD, however, we consider that the spheroidic particles (~ 50 nm in size) mainly distributed in the left and right sides of Fig. 6(c) belong to the phase of CdO; whereas the aggregates with smaller grain size located in the centre of Fig. 3 (a) is a mixture of $CdFe_2O_4$. The selected area electron diffraction (SAED) pattern Fig. 6 (d) shows the spot type pattern which is indicative of the presence of single crystallite particles. No evidence was found for more than one pattern, suggesting the single phase native of the material.



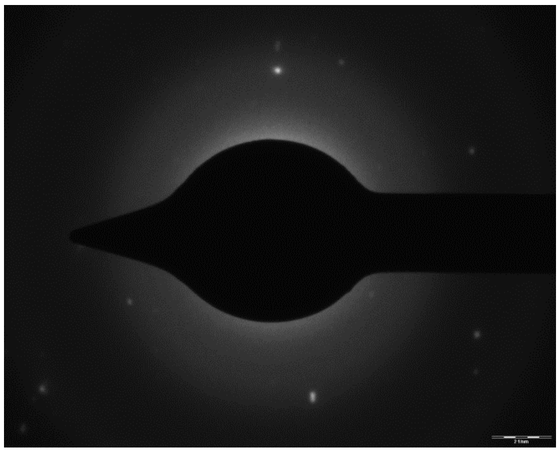
(a)



(b)



(c)



(d)

Fig. 6. TEM (a, b, c) images of mixed precursor $CdFe_2O_4$ (b) SAED pattern.

3.6. Thickness Measurement

The thicknesses of the films were observed to be in the range from 25-35µm. The reproducibility of the film thickness was achieved by maintaining the proper rheology and thixotropy of the paste.

4. Electrical Properties of Sensor

4.1. I-V Characteristics

Fig. 7 depicts I-V characteristics of $CdFe_2O_4$ films. It is clear from the symmetrical I-V characteristics that the silver contacts on the films were ohmic in nature. The voltage applied was in the range 1-30 V.

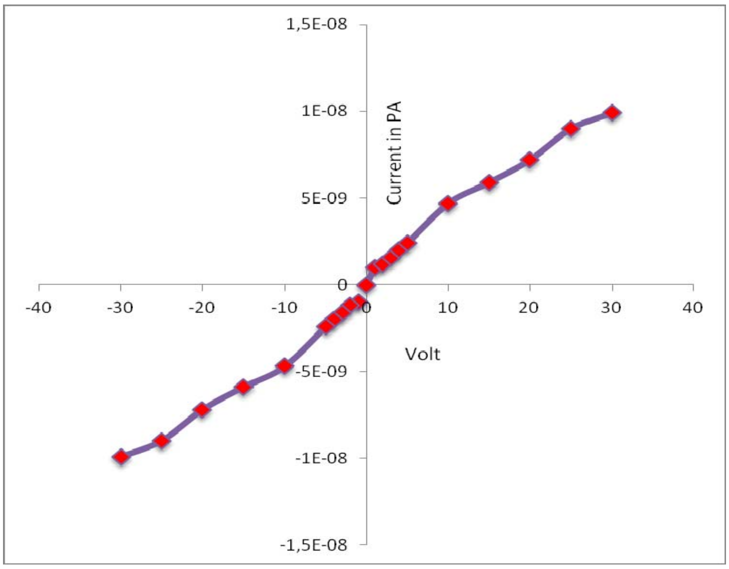


Fig. 7. I-V characteristics of the sensor.

4.2. Electrical Conductivity

The variation of resistivity $CdFe_2O_4$ with temperature is shown in Fig. 8 and it was found that the resistivity of $CdFe_2O_4$ sample decreases with operating temperature. The decreases in resistivity with increasing temperature could be attributed to negative temperature coefficient of resistance and semiconducting nature of $CdFe_2O_4$. It is observed from Fig. 8 that the electrical resistivity of the $CdFe_2O_4$ films is nearly linear in the temperature range from 50-400 ^{0}C in ambient air.

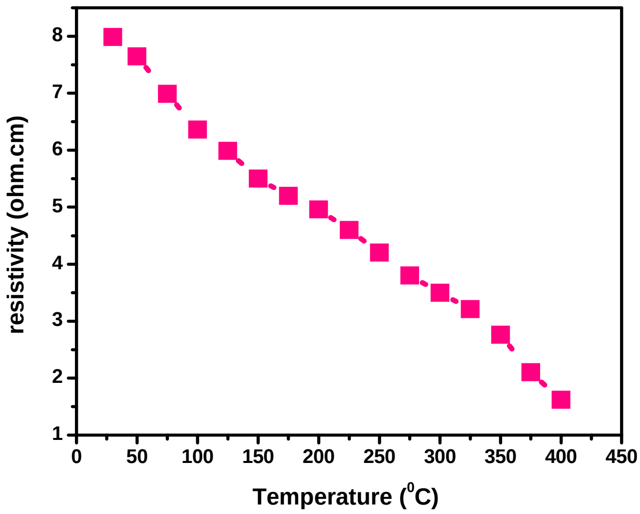


Fig. 8. Resistivity-temperature profiles of $CdFe_2O_4$.

5. Sensing Performance of Sensor

5.1. Gas Response, Selectivity, Response and Recovery Time

The relative response (S) to a target gas is defined as the ratio of the change in conductance of a sample upon exposure of the gas to the original conductance in air, which can be calculated by fallowing equation.

$$S = \frac{G_g - G_a}{G_a},$$

where G_a is the conductance in air, and G_g is the conductance in a sample gas. Specificity or selectivity is defined as the ability of a sensor to respond to a certain gas in the presence of different gases. Response time (RST) is defined as the time requires for a sensor to attain 90 % of the maximum increases in conductance on exposure to the target gas. Recovery time (RCT) is the time taken to get back 90 % of the original conductance in air.

5.2. Sensing Performance of $CdFe_2O_4$ Thick Films

5.2.1. Response of Sensors to Various Gases

The response of $CdFe_2O_4$ sample variation for different gases with operating temperature is represented in Fig. 9. It is clear from the figure that the gas responses goes on increasing and attain to their respective maxima and decreased further with increase in operating temperatures. It is clear from the figure that the $CdFe_2O_4$ shows the largest response to ethanol vapours at 350 ^{0}C.

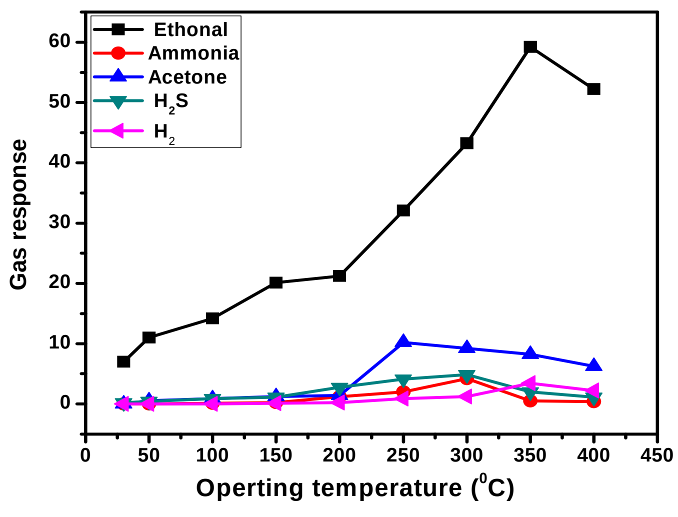


Fig. 9. Variation for different gas responses with operating temperatures.

5.2.2. Active Region of Sensor

Fig. 10. depicts the variation of gas response of $CdFe_2O_4$ sample with ethanol vapour concentrations. It is clear from the figure that the gas response goes on increasing linearly with gas concentration up to 200 ppm and saturated beyond it. The rate of increase in gas response was relatively larger up to 200 ppm. The monolayer of the gas molecules formed on the surface could cover the whole surface of

the film. The gas molecules from that layer would reach the surface active sites of the film. The excess gas molecules would remain idle and would not reach surface active site of the sensor. So, the gas response at higher concentrations of the gas is not expected to increase further in large extent. Thus, the active region of the sensor would be up to 200 ppm.

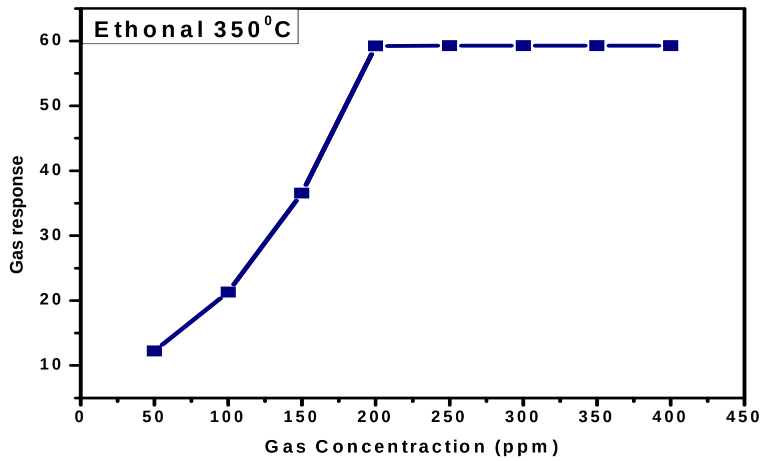


Fig. 10. Variation of gas response with gas concentration.

5.2.3. Selectivity Factors of $CdFe_2O_4$ for Various Gases

It is observed from Fig. 11. That the $CdFe_2O_4$ sensors give maximum response to ethanol vapours (200 ppm) at 350 ^{0}C. The sensors showed highest selectivity for ethanol against all other tested gases Acetone, H_2S, H_2 and NH_3.

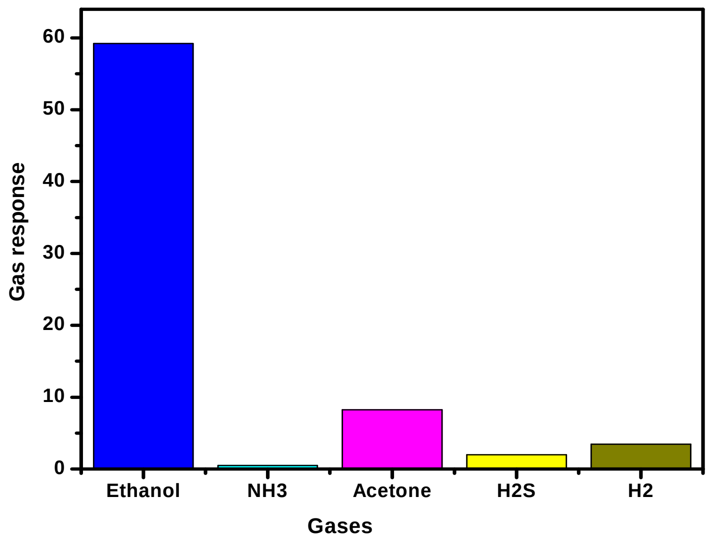


Fig. 11. Selectivity factor of sensor for various gases.

5.2.4. Response and Recovery Time

Fig. 12 depicts the response and recovery of $CdFe_2O_4$ sensor are the response was quick (~ 40 s) to 200 ppm of ethanol, while the recovery was fast (~ 50 s) .The quick response may be due to faster oxidation of gas. The negligible quantity of the surface reaction product and its high volatility explains its quick response and fast recovery to its initial chemical status.

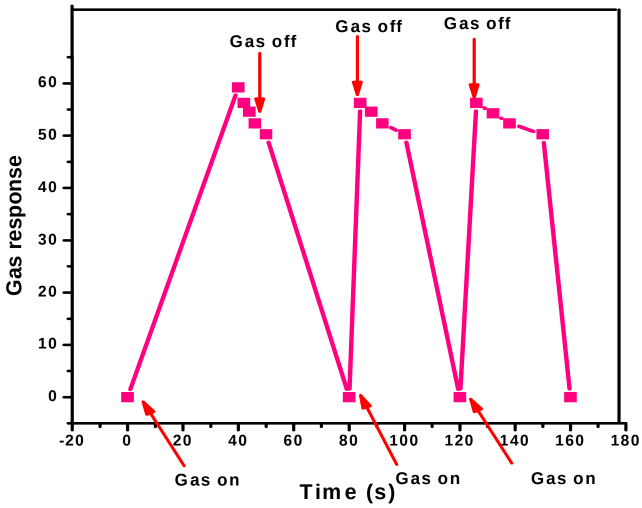


Fig. 12. Response and recovery of the sensors.

6. Discussion

The working principle of the thick film semiconducting gas sensors is based on the change of the electronic conductivity of the semiconducting material upon exposure to ethanol vapours. The interaction of ethanol gas molecules with surface of thick film causes the transfer of electrons between semiconducting surface and adsorbents. The atmospheric oxygen molecule O_2 is adsorbed on the surface of the thick film. They capture the electrons from conduction band of the thick film material as

$$O_{2(air)} + 4e^{-} \rightarrow 2O^{2-}_{(film\ surface)}.$$

It results in decreasing electronic conductivity of the film. The $CdFe_2O_4$ sample was not as per the stoichiometric proportion and all samples were observed to be oxygen-deficient. This deficiency gets reduced duo to adsorption of atmospheric molecular oxygen. This helps to decrease electronic conductivity of the film. Upon exposure, ethanol molecules get oxidized with the adsorbed oxygen ions, by following a series of intermediate stages, producing CO_2 and H_2O. This results in evolving oxygen as electrically neutral atoms trapping behind the negative charges on the film surface. Upon exposure of ethanol gas, the energy released in decomposition of ethanol molecule would be sufficient for trapped electron to jump increase in the conductivity of the thick film of $CdFe_2O_4$. These generated electrons and donor level in the energy band gap of $CdFe_2O_4$will contribute to increase in conductivity. When ethanol reacts with oxygen a complex series of reactions take place, ultimately converting the ethanol to carbon dioxide and water as fallows

$$C_2H_5OH_{\ (gas)} + 6O^{2-}_{(film\ surface)} \rightarrow 2CO_{2(gas)} + 3H_2O_{(gas)} + 12e^{-}_{(cond.band)}. \quad (1)$$

This shows n-type conduction mechanism. Thus on oxidation, single molecule of ethanol liberates twelve electrons (1) in conduction band and results in increase in conductivity of the sensors. Increase in operating temperature causes oxidation of large number of ethanol molecules, thus producing very large number of electron resulting conductivity increases to a large extent. This may be the reason why the gas response increases with operating temperature. The thermal energy (temperature) at which the gas response is maximum, is the actual thermal energy needed to activate the material for progress in reaction. However, the response decreases at higher operating temperature, as the oxygen adsorbates are desorbed from the surface of the sensor. Also, at higher temperature, the carrier concentration increases due to intrinsic thermal excitation and the Debye length decreases. This may be one of the reasons for decreased gas response at higher temperature.

7. Conclusions

From the study, following conclusions can be made for the sensing performance of the sensors.

(I) Nanocrystalline $CdFe_2O_4$ has synthesized by self combustion route. This synthesis route may be used for the synthesis of other metal oxide.

(II) The phage formation of the $CdFe_2O_4$is investigated by TG-DTA, XRD, TEM techniques. The synthesized product shows single phage of inverse spinel structure with an average diameter 50-100 nm.

(IV) Among all other additives tested, $CdFe_2O_4$ is outstanding in promoting the ethanol gas sensing mechanism.

(V) $CdFe_2O_4$ to be optimum and showed highest response to ethanol vapours at 350 ^{0}C.

(VI) The sensor showed very rapid response (~ 40s) and gives recovery (~ 50s) to ethanol vapours.

(VII) Sensing mechanism of $CdFe_2O_4$was the substitution of lattice oxygen by ethanol gas. Material gains electrons in this substitution.

(VIII) The sensor has good selectivity to ethanol against, Acetone, H_2S, NH_3 and H_2,

Acknowledgement

The author S. V. Bangale is thankful to director IIT Bombay for providing the TEM facility.

References

[1]. K. Byrappa, M. Yoshimura, Handbook of Hydrothermal Technology, *Noyes Publications*, New Jersey, USA, 2001.

[2]. Z. V. Marinkovic, L. Mancic, P. Vulic, O. Milosevic, The influence of mechanical activation on the stiochometry and defect structure of a sintered ZnO-Cr_2O_3 system, *Mater, Sci*., 453, 2004, pp. 456-461.

[3]. S. Levy, D. Diella, V. Pavese, A. Dapiaggi, M. Sani, A P-V equation of state, thermal expansion, and P-T stability of synthetic ($ZnCr_2O_4$ spinel), *Am. Mineral*. 90, 2005, pp. 1157-1167.

[4]. X. Niu, W. Du, W. Du, Preparation and gas sensing properties of ZnM_2O_4 (M = Fe, Co, Cr) *Sens. Actuators B,* 99, 2004, pp. 405-415.

[5]. R. G. Chandran, K, C, Patil, A rapid method to prepare crystalline fine particle chromite powder, *Mater. Lett*., 12, 1992, pp. 437-450.

[6]. Z. V. Marinkovic, L. Mancic, R. Maric, O. Milosevic, Preparation of nanostructure Zn-Cr-O spinel powder by Ultrasonic spray pyrolysis, *J. Eur. Ceram. Soc*., 21, 2001, pp. 2051-2067.

[7]. S. V. Bangale, D. R. Patil and S. R. Bamane, Nanostructured Spinel $ZnFe_2O_4$ for the Detection of Chlorine Gas, *Sensors & Transducers*, Vol. 134, Issue 11, November 2011, pp. 107-119.

[8]. S. V. Bangale, S. M. Khetre, D. R. Patil and S. R. Bamane, Simple Synthesis of $ZnCo_2O_4$ Nanoparticles as Gas-sensing Materials, *Sensors & Transducers*, Vol. 134, Issue 11, November 2011, pp. 95-106.

[9]. S. V. Bangale, S. R. Bamane, Nanostructured $MgFe_2O_4$ Thick Film Resistors as Ethanol Gas Sensors Operable at Room Temperature, *Sensors & Transducers,* Vol. 137, Issue 2, February 2012, pp. 176-188.

[10].D. R. Patil, L. A. Patil, Ammonia Sensing Resistors Based on Fe_2O_3-Modified ZnO of ZnO Based Thick Film Sensor to NH_3 at Room Temperature, *Sens. Actuators B,* 120, 2006, pp. 316.

[11].T. Siyama, A. Kato, A new detector for gaseous components using semiconductor thin film, *Anal. Chem*., 34, 1962, pp. 1502–1503.

[12].T. Jinkawa, G. Sakai, J. Tamaki, N. Miura, N. Yamazoe, *J. Mol. Catal. A: Chem*., 155, 2000, pp. 193.

[13].F. Paraguay, J. Morales, W. Estrada, E. Andrade, M. Miki-Yoshida, *Thin Solid films,* 373, 2000, pp. 137.

[14].C. Garzella, E. Bontempi, L. E. Depero, A. Vomiero, G. Della Mea, G. Sberveglieri, *Sens. Actuators B,* 93, 2003, pp. 495.

[15].C. V. G. Reddy, W. Cao, O. K. Tan, W. Zhu, *Sens. Actuators B,* 81, 2002, p. 170.

[16].V. S. Vaishnav, P. D. Patel, N. G. Patel, Measurement of the dc resistance of semiconductor thin film–gas systems: Comparison to several transport models, *Thin Solid Films,* 490, 2005, p. 94.

[17].J. F. Liu, X. Wang, Q. Peng, Y. D. Li, Vanadium Pentoxide Nanobelts: Highly Selective and Stable Ethanol Sensor Materials, *Adv. Mater*., 17, 2005, pp. 764.

[18].J. Liu, X. Wang, Q. Peng, Y. Li, Vanadium Pentoxide Nanobelts: Highly Selective and Stable Ethanol Sensor Materials, *Advanced Materials,* 17, 2005, pp. 764-767.

[19].Zhang Tianshu, P. Hing, Zhang Jiancheng, Kong Lingbing, Ethanol-sensing characteristics of cadmium ferrite prepared by chemical coprecipitation, *Materials Chemistry and Physics,* 61, 1999, pp. 192-198.

[20].Xiangdong Lou, Shuping Liu , Dongyang Shi , Wenfei Chu, Ethanol-sensing characteristics of $CdFe_2O_4$ sensor prepared by sol–gel method, *Materials Chemistry and Physics*, 105, 2007, pp. 67–70.

[21].Fengxiu Miao, Zanhong Deng, Xianshun L, Guixin Gu, Songming Wan, Xiaodong Fang, Qingli Zhang, Shaotang Yin, Fundamental properties of $CdFe_2O_4$ semiconductor thin film, *Solid State Communications,* 150, 2010, pp. 2036–2039.

[22].Y. L. Liu, Z. M. Liu, Y. Yang, H. F. Yang, G. L. Shen, R. Q. Yu, *Sens. Actuators B,* 107, 2005, pp. 600.

[23].G, H. Sodhi, Fundamental Concepts of environmental Chemistry, *Narosa Publishing House*, New Delhi, 2002, p. 135.

[24].C. Xiangfeng, L. Xinggin and M. Guangyao, *Sens. Actuators B*, Vol. 65, 2000, pp. 64

[25].S. V. Bangale, S. R. Bamane, Preparation and Study of H_2S Gas Sensing Behavior of $ZnFe_2O_4$ Thick Film Resistors, *Sensors & Transducers*, Vol. 137, Issue 2, February 2012, pp. 123-136.

[26].S. V. Bangale, S. M. Khetre and S. R. Bamane, Synthesis, characterization and hydrophilic properties of nanocrystalline $ZnFe_2O_4$ oxide, *Archives of Applied Science Research*, 3, 2011, pp. 471-479.

[27].Sachin V. Bangale and S. R. Bamane, Synthesis characterization and electrical properties of nanocrystalline ZnMgO by combustion route, *Der Chemica Sinica*, 2, 2011, pp. 22-29.

[28].Sachin V. Bangale, D. R. Patil and S. R. Bamane, Preparation and electrical properties of nanocrystalline $MgFe_2O_4$ oxide by combustion route, *Archives of Applied Science Research*, 3, 2011, pp. 506-513.

Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

Submission of papers

Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 8-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm Authors must follow the instructions strictly when submitting their manuscripts.

Advertising Information

Advertising orders and enquires may be sent to sales@sensorsportal.com Please download also our media kit: http://www.sensorsportal.com/DOWNLOADS/Media_Kit_2012.pdf