

ISSN 1726-5479

SENSORS & TRANSDUCERS

6^{vol. 129}
/11



Electronic Circuits, Signal Conditioning and ASIC

International Frequency Sensor Association Publishing



Editors-in-Chief: professor Sergey Y. Yurish, tel.: +34 696067716, e-mail: editor@sensorsportal.com

Editors for Western Europe

Meijer, Gerard C.M., Delft University of Technology, The Netherlands
Ferrari, Vittorio, Università di Brescia, Italy

Editor South America

Costa-Felix, Rodrigo, Inmetro, Brazil

Editor for Eastern Europe

Sachenko, Anatoly, Ternopil State Economic University, Ukraine

Editors for North America

Datskos, Panos G., Oak Ridge National Laboratory, USA
Fabien, J. Josse, Marquette University, USA
Katz, Evgeny, Clarkson University, USA

Editor for Asia

Ohyama, Shinji, Tokyo Institute of Technology, Japan

Editor for Asia-Pacific

Mukhopadhyay, Subhas, Massey University, New Zealand

Editorial Advisory Board

- Abdul Rahim, Ruzairi**, Universiti Teknologi, Malaysia
Ahmad, Mohd Noor, Northern University of Engineering, Malaysia
Annamalai, Karthigeyan, National Institute of Advanced Industrial Science and Technology, Japan
Arcega, Francisco, University of Zaragoza, Spain
Arguel, Philippe, CNRS, France
Ahn, Jae-Pyoung, Korea Institute of Science and Technology, Korea
Arndt, Michael, Robert Bosch GmbH, Germany
Ascoli, Giorgio, George Mason University, USA
Atalay, Selcuk, Inonu University, Turkey
Atghiaee, Ahmad, University of Tehran, Iran
Augutis, Vygtantas, Kaunas University of Technology, Lithuania
Avachit, Patil Lalchand, North Maharashtra University, India
Ayesh, Aladdin, De Montfort University, UK
Azamimi, Azian binti Abdullah, Universiti Malaysia Perlis, Malaysia
Bahreyni, Behraad, University of Manitoba, Canada
Baliga, Shankar, B., General Monitors Transnational, USA
Baoxian, Ye, Zhengzhou University, China
Barford, Lee, Agilent Laboratories, USA
Barlingay, Ravindra, RF Arrays Systems, India
Basu, Sukumar, Jadavpur University, India
Beck, Stephen, University of Sheffield, UK
Ben Bouzid, Sihem, Institut National de Recherche Scientifique, Tunisia
Benachaiba, Chellali, Universitaire de Bechar, Algeria
Binnie, T. David, Napier University, UK
Bischoff, Gerlinde, Inst. Analytical Chemistry, Germany
Bodas, Dhananjay, IMTEK, Germany
Borges Carval, Nuno, Universidade de Aveiro, Portugal
Bousbia-Salah, Mounir, University of Annaba, Algeria
Bouvet, Marcel, CNRS – UPMC, France
Brudzewski, Kazimierz, Warsaw University of Technology, Poland
Cai, Chenxin, Nanjing Normal University, China
Cai, Qingyun, Hunan University, China
Campanella, Luigi, University La Sapienza, Italy
Carvalho, Vitor, Minho University, Portugal
Cecelja, Franjo, Brunel University, London, UK
Cerda Belmonte, Judith, Imperial College London, UK
Chakrabarty, Chandan Kumar, Universiti Tenaga Nasional, Malaysia
Chakravorty, Dipankar, Association for the Cultivation of Science, India
Changhai, Ru, Harbin Engineering University, China
Chaudhari, Gajanan, Shri Shivaji Science College, India
Chavali, Murthy, N.I. Center for Higher Education, (N.I. University), India
Chen, Jiming, Zhejiang University, China
Chen, Rongshun, National Tsing Hua University, Taiwan
Cheng, Kuo-Sheng, National Cheng Kung University, Taiwan
Chiang, Jeffrey (Cheng-Ta), Industrial Technol. Research Institute, Taiwan
Chiriac, Horia, National Institute of Research and Development, Romania
Chowdhuri, Arijit, University of Delhi, India
Chung, Wen-Yaw, Chung Yuan Christian University, Taiwan
Corres, Jesus, Universidad Publica de Navarra, Spain
Cortes, Camilo A., Universidad Nacional de Colombia, Colombia
Courtois, Christian, Universite de Valenciennes, France
Cusano, Andrea, University of Sannio, Italy
D'Amico, Arnaldo, Università di Tor Vergata, Italy
De Stefano, Luca, Institute for Microelectronics and Microsystem, Italy
Deshmukh, Kiran, Shri Shivaji Mahavidyalaya, Barshi, India
Dickert, Franz L., Vienna University, Austria
Dieguez, Angel, University of Barcelona, Spain
Dighavkar, C. G., M.G. Vidyamandir's L. V.H. College, India
Dimitropoulos, Panos, University of Thessaly, Greece
Ding, Jianning, Jiangsu Polytechnic University, China
Djordjevic, Alexander, City University of Hong Kong, Hong Kong
Donato, Nicola, University of Messina, Italy
Donato, Patricio, Universidad de Mar del Plata, Argentina
Dong, Feng, Tianjin University, China
Driljaca, Predrag, Instersema Sensoric SA, Switzerland
Dubey, Venketesh, Bournemouth University, UK
Enderle, Stefan, Univ. of Ulm and KTB Mechatronics GmbH, Germany
Erdem, Gursan K. Arzum, Ege University, Turkey
Erkmen, Aydan M., Middle East Technical University, Turkey
Estelle, Patrice, Insa Rennes, France
Estrada, Horacio, University of North Carolina, USA
Faiz, Adil, INSA Lyon, France
Fericean, Sorin, Balluff GmbH, Germany
Fernandes, Joana M., University of Porto, Portugal
Francioso, Luca, CNR-IMM Institute for Microelectronics and Microsystems, Italy
Francis, Laurent, University Catholique de Louvain, Belgium
Fu, Weiling, South-Western Hospital, Chongqing, China
Gaura, Elena, Coventry University, UK
Geng, Yanfeng, China University of Petroleum, China
Gole, James, Georgia Institute of Technology, USA
Gong, Hao, National University of Singapore, Singapore
Gonzalez de la Rosa, Juan Jose, University of Cadiz, Spain
Grael, Annette, Goteborg University, Sweden
Graff, Mason, The University of Texas at Arlington, USA
Guan, Shan, Eastman Kodak, USA
Guillet, Bruno, University of Caen, France
Guo, Zhen, New Jersey Institute of Technology, USA
Gupta, Narendra Kumar, Napier University, UK
Hadjiloucas, Sillas, The University of Reading, UK
Haider, Mohammad R., Sonoma State University, USA
Hashsham, Syed, Michigan State University, USA
Hasni, Abdelhafid, Bechar University, Algeria
Hernandez, Alvaro, University of Alcalá, Spain
Hernandez, Wilmar, Universidad Politecnica de Madrid, Spain
Homentcovschi, Dorel, SUNY Binghamton, USA
Horstman, Tom, U.S. Automation Group, LLC, USA
Hsiai, Tzung (John), University of Southern California, USA
Huang, Jeng-Sheng, Chung Yuan Christian University, Taiwan
Huang, Star, National Tsing Hua University, Taiwan
Huang, Wei, PSG Design Center, USA
Hui, David, University of New Orleans, USA
Jaffrezic-Renault, Nicole, Ecole Centrale de Lyon, France
Jaime Calvo-Galleg, Jaime, Universidad de Salamanca, Spain
James, Daniel, Griffith University, Australia
Janting, Jakob, DELTA Danish Electronics, Denmark
Jiang, Liudi, University of Southampton, UK
Jiang, Wei, University of Virginia, USA
Jiao, Zheng, Shanghai University, China
John, Joachim, IMEC, Belgium
Kalach, Andrew, Voronezh Institute of Ministry of Interior, Russia
Kang, Moonho, Sunmoon University, Korea South
Kaniusas, Eugenijus, Vienna University of Technology, Austria
Katake, Anup, Texas A&M University, USA
Kausel, Wilfried, University of Music, Vienna, Austria
Kavasoglu, Nese, Mugla University, Turkey
Ke, Cathy, Tyndall National Institute, Ireland
Khelifaoui, Rachid, Université de Bechar, Algeria
Khan, Asif, Aligarh Muslim University, Aligarh, India
Kim, Min Young, Kyungpook National University, Korea South
Ko, Sang Choon, Electronics. and Telecom. Research Inst., Korea South
Kotulska, Malgorzata, Wroclaw University of Technology, Poland
Kratz, Henrik, Uppsala University, Sweden
Kockar, Hakan, Balikesir University, Turkey

Kong, Ing, RMIT University, Australia
Kumar, Arun, University of South Florida, USA
Kumar, Subodh, National Physical Laboratory, India
Kung, Chih-Hsien, Chang-Jung Christian University, Taiwan
Lacnjevac, Caslav, University of Belgrade, Serbia
Lay-Ekuakille, Aime, University of Lecce, Italy
Lee, Jang Myung, Pusan National University, Korea South
Lee, Jun Su, Amkor Technology, Inc. South Korea
Lei, Hua, National Starch and Chemical Company, USA
Li, Genxi, Nanjing University, China
Li, Hui, Shanghai Jiaotong University, China
Li, Xian-Fang, Central South University, China
Li, Yuefa, Wayne State University, USA
Liang, Yuanchang, University of Washington, USA
Liawruangrath, Saisunee, Chiang Mai University, Thailand
Liew, Kim Meow, City University of Hong Kong, Hong Kong
Lin, Hermann, National Kaohsiung University, Taiwan
Lin, Paul, Cleveland State University, USA
Linderholm, Pontus, EPFL - Microsystems Laboratory, Switzerland
Liu, Aihua, University of Oklahoma, USA
Liu Changgeng, Louisiana State University, USA
Liu, Cheng-Hsien, National Tsing Hua University, Taiwan
Liu, Songqin, Southeast University, China
Lodeiro, Carlos, University of Vigo, Spain
Lorenzo, Maria Encarnacio, Universidad Autonoma de Madrid, Spain
Lukaszewicz, Jerzy Pawel, Nicholas Copernicus University, Poland
Ma, Zhanfang, Northeast Normal University, China
Majstorovic, Vidosav, University of Belgrade, Serbia
Malyshev, V.V., National Research Centre 'Kurchatov Institute', Russia
Marquez, Alfredo, Centro de Investigacion en Materiales Avanzados, Mexico
Matay, Ladislav, Slovak Academy of Sciences, Slovakia
Mathur, Prafull, National Physical Laboratory, India
Maurya, D.K., Institute of Materials Research and Engineering, Singapore
Mekid, Samir, University of Manchester, UK
Melnyk, Ivan, Photon Control Inc., Canada
Mendes, Paulo, University of Minho, Portugal
Mennell, Julie, Northumbria University, UK
Mi, Bin, Boston Scientific Corporation, USA
Minas, Graca, University of Minho, Portugal
Moghavvemi, Mahmoud, University of Malaya, Malaysia
Mohammadi, Mohammad-Reza, University of Cambridge, UK
Molina Flores, Esteban, Benemérita Universidad Autónoma de Puebla, Mexico
Moradi, Majid, University of Kerman, Iran
Morello, Rosario, University "Mediterranea" of Reggio Calabria, Italy
Mounir, Ben Ali, University of Sousse, Tunisia
Mulla, Imtiaz Sirajuddin, National Chemical Laboratory, Pune, India
Nabok, Aleksey, Sheffield Hallam University, UK
Neelamegam, Periasamy, Sastra Deemed University, India
Neshkova, Milka, Bulgarian Academy of Sciences, Bulgaria
Oberhammer, Joachim, Royal Institute of Technology, Sweden
Ould Lahoucine, Cherif, University of Guelma, Algeria
Pamidighanta, Sayanu, Bharat Electronics Limited (BEL), India
Pan, Jisheng, Institute of Materials Research & Engineering, Singapore
Park, Joon-Shik, Korea Electronics Technology Institute, Korea South
Penza, Michele, ENEA C.R., Italy
Pereira, Jose Miguel, Instituto Politecnico de Seteal, Portugal
Petsev, Dimiter, University of New Mexico, USA
Pogacnik, Lea, University of Ljubljana, Slovenia
Post, Michael, National Research Council, Canada
Prance, Robert, University of Sussex, UK
Prasad, Ambika, Gulbarga University, India
Prateepsen, Asa, Kingmoungut's University of Technology, Thailand
Pullini, Daniele, Centro Ricerche FIAT, Italy
Pumera, Martin, National Institute for Materials Science, Japan
Radhakrishnan, S., National Chemical Laboratory, Pune, India
Rajanna, K., Indian Institute of Science, India
Ramadan, Qasem, Institute of Microelectronics, Singapore
Rao, Basuthkar, Tata Inst. of Fundamental Research, India
Raouf, Kosai, Joseph Fourier University of Grenoble, France
Rastogi Shiva, K., University of Idaho, USA
Reig, Candid, University of Valencia, Spain
Restivo, Maria Teresa, University of Porto, Portugal
Robert, Michel, University Henri Poincare, France
Rezazadeh, Ghader, Urmia University, Iran
Royo, Santiago, Universitat Politècnica de Catalunya, Spain
Rodriguez, Angel, Universidad Politècnica de Catalunya, Spain
Rothberg, Steve, Loughborough University, UK
Sadana, Ajit, University of Mississippi, USA
Sadeghian Marnani, Hamed, TU Delft, The Netherlands
Sandacci, Serghei, Sensor Technology Ltd., UK
Sapozhnikova, Ksenia, D.I.Mendeleev Institute for Metrology, Russia
Saxena, Vibha, Bhabha Atomic Research Centre, Mumbai, India
Schneider, John K., Ultra-Scan Corporation, USA
Sengupta, Deepak, Advance Bio-Photonics, India
Seif, Selemeni, Alabama A & M University, USA
Seifter, Achim, Los Alamos National Laboratory, USA
Shah, Kriyang, La Trobe University, Australia
Silva Giraó, Pedro, Technical University of Lisbon, Portugal
Singh, V. R., National Physical Laboratory, India
Slomovitz, Daniel, UTE, Uruguay
Smith, Martin, Open University, UK
Soleymanpour, Ahmad, Damghan Basic Science University, Iran
Somani, Prakash R., Centre for Materials for Electronics Technol., India
Srinivas, Talabattula, Indian Institute of Science, Bangalore, India
Srivastava, Arvind K., NanoSonix Inc., USA
Stefan-van Staden, Raluca-Ioana, University of Pretoria, South Africa
Sumriddetchka, Sarun, National Electronics and Computer Technology Center, Thailand
Sun, Chengliang, Polytechnic University, Hong-Kong
Sun, Dongming, Jilin University, China
Sun, Junhua, Beijing University of Aeronautics and Astronautics, China
Sun, Zhiqiang, Central South University, China
Suri, C. Raman, Institute of Microbial Technology, India
Sysoev, Victor, Saratov State Technical University, Russia
Szewczyk, Roman, Industrial Research Inst. for Automation and Measurement, Poland
Tan, Ooi Kiang, Nanyang Technological University, Singapore
Tang, Dianping, Southwest University, China
Tang, Jaw-Luen, National Chung Cheng University, Taiwan
Teker, Kasif, Frostburg State University, USA
Thirunavukkarasu, I., Manipal University Karnataka, India
Thumbavanam Pad, Kartik, Carnegie Mellon University, USA
Tian, Gui Yun, University of Newcastle, UK
Tsiantos, Vassilios, Technological Educational Institute of Kaval, Greece
Tsigara, Anna, National Hellenic Research Foundation, Greece
Twomey, Karen, University College Cork, Ireland
Valente, Antonio, University, Vila Real, - U.T.A.D., Portugal
Vanga, Raghav Rao, Summit Technology Services, Inc., USA
Vaseashta, Ashok, Marshall University, USA
Vazquez, Carmen, Carlos III University in Madrid, Spain
Vieira, Manuela, Instituto Superior de Engenharia de Lisboa, Portugal
Vigna, Benedetto, STMicroelectronics, Italy
Vrba, Radimir, Brno University of Technology, Czech Republic
Wandelt, Barbara, Technical University of Lodz, Poland
Wang, Jiangping, Xi'an Shiyong University, China
Wang, Kedong, Beihang University, China
Wang, Liang, Pacific Northwest National Laboratory, USA
Wang, Mi, University of Leeds, UK
Wang, Shinn-Fwu, Ching Yun University, Taiwan
Wang, Wei-Chih, University of Washington, USA
Wang, Wensheng, University of Pennsylvania, USA
Watson, Steven, Center for NanoSpace Technologies Inc., USA
Weiping, Yan, Dalian University of Technology, China
Wells, Stephen, Southern Company Services, USA
Wolkenberg, Andrzej, Institute of Electron Technology, Poland
Woods, R. Clive, Louisiana State University, USA
Wu, DerHo, National Pingtung Univ. of Science and Technology, Taiwan
Wu, Zhaoyang, Hunan University, China
Xiu Tao, Ge, Chuzhou University, China
Xu, Lisheng, The Chinese University of Hong Kong, Hong Kong
Xu, Sen, Drexel University, USA
Xu, Tao, University of California, Irvine, USA
Yang, Dongfang, National Research Council, Canada
Yang, Shuang-Hua, Loughborough University, UK
Yang, Wuqiang, The University of Manchester, UK
Yang, Xiaoling, University of Georgia, Athens, GA, USA
Yaping Dan, Harvard University, USA
Ymeti, Aurel, University of Twente, Netherland
Yong Zhao, Northeastern University, China
Yu, Haihu, Wuhan University of Technology, China
Yuan, Yong, Massey University, New Zealand
Yufera Garcia, Alberto, Seville University, Spain
Zakaria, Zulkarnay, University Malaysia Perlis, Malaysia
Zagnoni, Michele, University of Southampton, UK
Zamani, Cyrus, Universitat de Barcelona, Spain
Zeni, Luigi, Second University of Naples, Italy
Zhang, Minglong, Shanghai University, China
Zhang, Qintao, University of California at Berkeley, USA
Zhang, Weiping, Shanghai Jiao Tong University, China
Zhang, Wenming, Shanghai Jiao Tong University, China
Zhang, Xueji, World Precision Instruments, Inc., USA
Zhong, Haoxiang, Henan Normal University, China
Zhu, Qing, Fujifilm Dimatix, Inc., USA
Zorzano, Luis, Universidad de La Rioja, Spain
Zourob, Mohammed, University of Cambridge, UK

Contents

Volume 129
Issue 6
June 2011

www.sensorsportal.com

ISSN 1726-5479

Research Articles

A Review of Concept of Force Measurements between the Past and Today <i>Ebtisam H. Hasan</i>	1
Design, Development and Testing of a Semicircular Type Capacitive Angular Position Sensor <i>Nikhil Gaurav, Sagarika Pal</i>	16
Design, Development and Calibration of a Portable Capacitive Moisture Meter <i>Mahmoud Soltani, Reza Alimardani</i>	24
Laser Power Measurement Using Commercial MEMS Pressure Sensor along with PSoC Embedded Read-out <i>J. Jayapandian and K. Prabakar</i>	33
Design and Development of Embedded System for the Measurement of Thermal Conductivity of Liquids by Transient Hot Wire Method <i>Nagamani Gosala, Raghavendra Rao Kanchi</i>	42
Performance Assessment of PCA, MF and SVD Methods for Denoising in Chemical Sensor Array Based Electronic Nose System <i>S. K. Jha and R. D. S. Yadava</i>	57
Simple Design of a PID Controller and Tuning of Its Parameters Using LabVIEW Software <i>Subrata Chattopadhyay, Ganesh Roy and Mrutyunjaya Panda</i>	69
The DC Motor Speed Controller Using AT89S52 Microcontroller to rotate Stepper Motor attached into Potentiometer in Variable Regulated Power Supply <i>Marhaposan Situmorang</i>	86
Use of Polythiophene as a Temperature Sensor <i>D. S. Kelkar, A. B. Chourasia, V. Balasubramanian</i>	97
Modeling of a Non-invasive Electromagnetic Sensor for the Measurement Glycaemia <i>A. Rouane, D. Kourtiche, S. M. Alavi</i>	105
CdO Doped Indium Oxide Thick Film as a Low Temperature H₂S Gas Sensor <i>D. N. Chavan, V. B. Gaikwad, Ganesh E. Patil, D. D. Kajale, G. H. Jain</i>	122
Design and Simulation of Double-spiral Shape Micro-heater for Gas Sensing Applications <i>Mahanth Prasad, R. P. Yadav, V. Sahula and V. K. Khanna</i>	115
Glucose Concentration Sensor Based on Long Period Grating Fabricated from Hydrogen Loaded Photosensitive Fiber <i>T. M. Libish, J. Linesh, M. C. Bobby, B. Nithyaja, 1S. Mathew, C. Pradeep and P. Radhakrishnan</i>	142

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/Submission.htm

International Frequency Sensor Association (IFSA).

Call for Books Proposals

Sensors, MEMS, Measuring instrumentation, etc.

International Frequency Sensor Association Publishing



Benefits and rewards of being an IFSA author:

1) Royalties.

Today IFSA offers most high royalty in the world: you will receive 50 % of each book sold in comparison with 8-11 % from other publishers, and get payment on monthly basis compared with other publishers' yearly basis.

2) Quick Publication.

IFSA recognizes the value to our customers of timely information, so we produce your book quickly: 2 months publishing schedule compared with other publishers' 5-18-month schedule.

3) The Best Targeted Marketing and Promotion.

As a leading online publisher in sensors related fields, IFSA and its Sensors Web Portal has a great expertise and experience to market and promote your book worldwide. An extensive marketing plan will be developed for each new book, including intensive promotions in IFSA's media: journal, magazine, newsletter and online bookstore at Sensors Web Portal.

4) Published Format: pdf (Acrobat).

When you publish with IFSA your book will never go out of print and can be delivered to customers in a few minutes.



You are invited kindly to share in the benefits of being an IFSA author and to submit your book proposal or/and a sample chapter for review by e-mail to editor@sensorsportal.com These proposals may include technical references, application engineering handbooks, monographs, guides and textbooks. Also edited survey books, state-of-the art or state-of-the-technology, are of interest to us.

Mobile Advertising Solutions for Sensor Industry: How to reach 80,000+ addressable mobile audiences?

An industry first Smartphone mobile advertising solution for sensors manufacturers and distributors



50% OFF

for limited time interval



Create your account today and use a **discount coupon code ls10001** to start advertising your sensors now:

https://www.lesensor.com/sensor/Profiles/CreateNewAccount.aspx?sensor_portal=ls10001

CdO Doped Indium Oxide Thick Film as a Low Temperature H₂S Gas Sensor

¹D. N. CHAVAN, ²V. B. GAIKWAD, ³GANESH E. PATIL, ³D. D. KAJALE,
^{3*}G. H. JAIN

¹Department of Chemistry, Arts Commerce and Science College, Lasalgaon 422 306, India

²Materials Research Lab., K.T.H.M. College, Nashik 422 005, India

³Materials Research Lab., Arts, Commerce and Science College, Nandgaon 423 106, India

*E-mail: gotanjain@rediffmail.com

Received: 22 May 2011 /Accepted: 20 June 2011 /Published: 30 June 2011

Abstract: The thick films of AR grade In₂O₃ were prepared by standard screen-printing technique. The gas sensing performance of thick film was tested for various gases. It showed maximum gas response to ethanol vapor at 350 °C for 80 ppm. To improve the gas response and selectivity of the film towards a particular gas, In₂O₃ thick films were modified by dipping them in an aqueous solution of 0.1 M CdCl₂ for different intervals of time. The surface modified (10 min) In₂O₃ thick film showed maximum response to H₂S gas (10 ppm) than pure In₂O₃ thick film at 150 °C. Cadmium oxide on the surface of the film shifts the gas response from ethanol vapor to H₂S gas. A systematic study of sensing performance of the thick films indicates the key role played by cadmium oxide on the surface of thick films. The selectivity, gas response and recovery time of the thick films were measured and presented. *Copyright © 2011 IFSA.*

Keywords: Thick film, Ethanol vapor, CdO, H₂S gas sensor, Gas response, Selectivity.

1. Introduction

Now-a- days the vast growing industries, various machines and an increasing large number of vehicles are responsible for spoiling the healthy life of human beings and all living organisms. Air pollution is found to be very dangerous as it is related to the respiratory systems. Some gases like CO, CO₂, H₂S and Cl₂ evolved are found to be very toxic and create allergic and respiratory diseases like asthma, allergic bronchial asthma and rhinitis [1-4].

The need for a novel gas sensor capable of providing reliable operation in harsh environments is now greater than ever. Such sensors find a range of applications, including the monitoring of traffic pollutants or food quality with specially designed electronic noses [5, 6]. Gas sensors based on metal oxides are commonly used in the monitoring of toxic pollutants and can provide the necessary sensitivity, selectivity and stability required by such systems [7]. Gas sensing at room temperature is of great interest; most of the currently available sensors, except a few types of polymer-based gas sensor operate at elevated temperature [8, 9]. Thick film technology is often used to fabricate such sensors and possesses many advantages; for example, low cost, simple construction, small size and good sensing properties [10]. In addition, this approach provides reproducible films consisting of a well-defined microstructure with grains and grain boundaries that can be studied easily [11].

Hydrogen sulphide (H_2S) is a toxic gas with a peculiar foul smell. It is corrosive and is naturally occurring due to decomposition of some organic matter in wastewater, volcanic gases, hot springs with smells like rotten eggs, coking ovens, craft paper mills, food processing, coal mines, oil and natural gas industries. It is used in large amounts in various chemical industries, research laboratories and as a process gas in the production of heavy water.

Gas sensors have been used for industrial process controls, for the detection of toxic environmental pollutants, in human health and for the prevention of hazardous gas leaks, which comes from the manufacturing processes [12-14]. Though these are different types of gas sensors that have been used to detect several inflammable, toxic and odorless gases, the gas sensors based on metal-oxide are playing an important role in the detection of toxic pollutants and the control of industrial processes. Hydrogen sulphide (H_2S) detection is nowadays a very important target for different processes, such as coal or natural gas manufacturing. This gas can be very dangerous for human bodies when its concentration is greater than 250 ppm. Monitoring and controlling of H_2S is crucial in laboratories and industrial areas. Semiconductor gas sensor in the form of thin or thick films, based on metal-oxide like SnO_2 , WO_3 and p-n heterojunctions, have been reported in the literature for H_2S detection [15-21].

Gas sensitivity, selectivity and durability are the most important sensor properties. In order to attain high response and excellent selectivity, different approaches such as microstructure control, additives, physical or chemical filters, operating temperature etc. have been adopted to modify the sensing properties of semiconductor metal oxide gas sensors. It is well known that sensing mechanism is based on the surface reaction of the particles with the exposed gas (adsorption and desorption of the test gas). Semiconductor metal oxide has attracted great attention in the past few years [22, 23]. It is well known that the semiconductor metal oxide such as ZnO , SnO_2 , Fe_2O_3 , Ga_2O_3 , Sb_2O_3 , In_2O_3 etc. are sensitive to toxic and inflammable gases [24].

Indium oxide (In_2O_3) belongs to the class of wide – band gap metal oxide, which has a wide application in preparing transparent conducting windows [25]. Moreover, this oxide has been shown to be a promising material for semiconductor gas sensor [26, 27]. As a gas sensing material In_2O_3 has been extensively applied to detect O_3 , NO_2 and CO etc. [28, 29]. But, up till now, there are very few reports on the H_2S sensing properties of In_2O_3 .

In this work, In_2O_3 thick films were prepared by screen printing on to glass substrates. The films surface were modified by dipping them into the aqueous solution of 0.1 M $CdCl_2$. The sensing performance of the films were tested by static gas sensing system for different gases such as H_2S , CO , CO_2 , H_2 , LPG, NH_3 , Cl_2 , O_2 and ethanol vapor etc.

2. Operating Principle of Gas Sensor

Since long it has been known that adsorption of reducing gas molecules results in decrease in electrical resistance of oxide material [30]. The In_2O_3 materials are characteristically n-type semiconductor due to non-stoichiometry associated with oxygen vacancy and/or metal excess which acts as donor states thus providing conduction electrons. However, the overall surface resistance of such films is generally influenced by chemisorptions (chemical adsorption) of oxygen from air on the surface and at the grain boundaries. The chemisorbed oxygen traps conduction electrons and remains as negatively charged species (O_2^- , O^- or O^{2-} depending on temperature.) on the surface [31]. The process results in an increase of surface resistance. In presence of reducing gases the trapped electrons are released due to the reaction between the gas molecules and negatively charged chemisorbed oxygen species resulting in decreasing in resistance of the materials. When the gas is removed from the sensor environment, the resistance again increases and the material recovered to original resistance.

3. Experimental

3.1. Preparation of Pure In_2O_3 Thick Films

The AR grade powder of In_2O_3 was calcined at 1000 °C for 6 h. Then In_2O_3 powder was milled for 2 hrs using planetary ball mill to obtain fine-grained powder. The thixotropic paste was formulated by mixing the fine powder of In_2O_3 with a solution of ethyl cellulose (a temporary binder) in a mixture of organic solvents such as butyl cellulose, butyl carbital acetate and terpineol etc. The weight ratio of the inorganic to organic part was kept at 75:25 in formulating the paste. This paste was screen printed on a glass substrate in a desired pattern [32, 33]. The sensitivity increases with the porosity as well as with thickness of the thick film [34]. The thick films were fired at 550°C for 30 min. Silver contacts are made for electrical measurements.

3.2. Preparation of Surface Modified In_2O_3 Thick Films

The pure In_2O_3 thick films were surface modified by dipping them into 0.1 M aqueous CdCl_2 solution for different intervals of time: 5, 10, and 20 min. [35]. These thick films were dried under IR lamp at 80 °C for 1h and followed by firing at 550 °C for 30 minutes. During firing process, at higher temperature CdCl_2 would be converted into CdO .

3.3. Thickness Measurements

The thickness of the thick films was measured by using the Taylor-Hobson (Talystep, UK) system and was observed in the range from 60 to 65 μm . The reproducibility of the thickness was achieved by maintaining the proper rheology and thixotropy of the paste

3.4. Details of Gas Sensing Unit

The sensing performance of the thick films was examined using a 'static gas sensing system'. There were electrical feeds through the base plate. The heater was fixed 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 operated with an electronic circuit with adjustable ON-OFF time intervals. A Cr-Al thermocouple was used to sense the operating temperature of the thick film. The output of the thermocouple was connected to a digital temperature indicator. A gas inlet valve was fitted at one of

the ports of the base plate. The required gas concentration inside the static system was achieved by injecting a known volume of a test gas using a gas-injecting syringe. A constant voltage was applied to the thick film sensor, and the current was measured by a digital Pico ammeter. The air was allowed to pass into the glass chamber after every gas exposure cycle.

4. Characterizations

4.1. Structural Analysis

The purity and crystallinity of the calcined powder structure was examined using X-ray diffractogram (XRD) with $\text{CuK}\alpha$ radiation (wavelength 1.5418 Å). The average grain size was calculated according to Debye-Scherrer's equation, it was observed to be 51 nm, provided in Eq. (1).

$$D = \frac{0.9\lambda}{K\beta\cos\theta} \quad (1)$$

where β is the full width at half-maximum intensity (in radians) of a peak at an angle θ ; K is a constant, depending on the line shape profile; λ is the wavelength of the X-ray source.

Fig. 1 depicts that the XRD patterns are indexed with pure In_2O_3 with cubic structure. The observed peaks in figure are matched well with (JCPDS Card No. 01-071-2194) reported data of In_2O_3 [36].

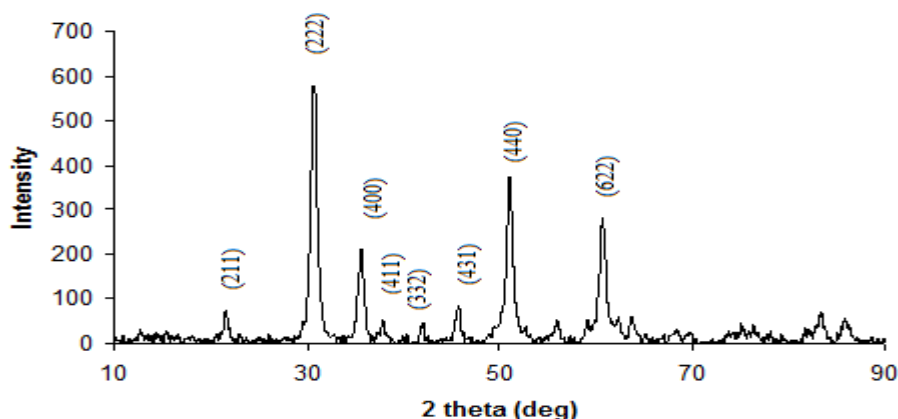


Fig. 1. X-ray diffractogram of pure In_2O_3 .

4.2. Microstructural Analysis

Fig. 2 shows the micrographs of pure In_2O_3 and surface modified In_2O_3 thick films. The comparison of these micrographs shows the interesting changes in morphology. Scanning electron microscopic (SEM) studies were carried out by using JEOL JSM 6360 (LA) Japan. Fig. 2(a) depicts the SEM image of pure In_2O_3 thick film fired at 550 °C. The thick film consists of voids and a wide range of grains with size distribution ranging from 0.25 μm to 0.5 μm , distributed non-uniformly. Fig. 2 (b) represents the SEM image of surface modified In_2O_3 (10 min.) thick film fired at 550 °C. It shows a number of small particles distributed uniformly between the larger grains around the In_2O_3 , which may be attributed to the presence of CdO. The grain size range was observed to be from 0.22 μm to 0.5 μm . The presence of CdO particles on the surface of the thick films alters the adsorption-desorption ability of the thick films. The altered surface morphology of the thick films shifts the affinity and reactivity of

thick films towards the H₂S gas. EDAX analysis of CdO surface modified thick films shows the presence of CdO and the appearance from the thick films indicates that the CdO particles are present at the surface of the In₂O₃ thick films.

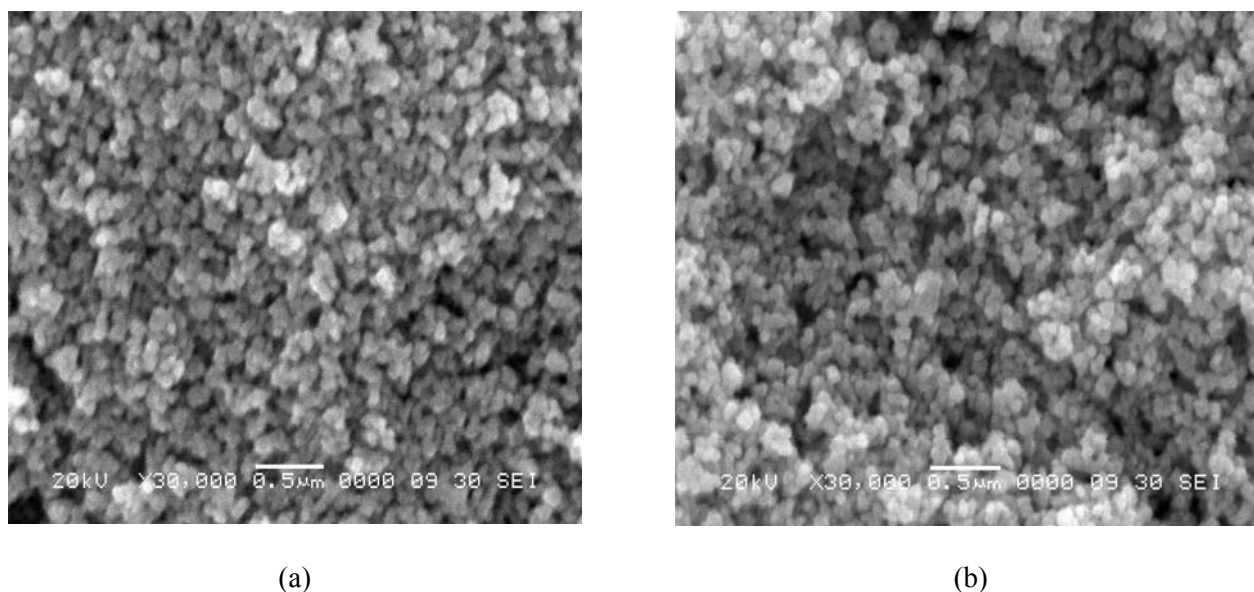


Fig. 2. SEM images of (a) pure In₂O₃ and (b) CdO surface modified In₂O₃ (10 min.) thick films.

4.3. Quantitative Elemental Analysis by EDAX

The quantitative elemental analysis of the pure and CdO surface modified In₂O₃ thick films was carried out by using an energy dispersive spectrophotometer (EDS) JEOL – JED– 2300 LA Japan. The constituent elements such as In, O and Cd associated with various thick films are presented in Table 1.

It is clear from the Table 1 that the weight percentage of cadmium is increased with dipping time and reached to a maximum. The thick film with the dipping time of 10 min. as observed to be more oxygen deficient (55.03wt.%). This oxygen deficiency may make the sample possible to adsorb a large amount of oxygen species.

Table 1. Quantitative elemental analysis of pure and CdO surface modified In₂O₃ thick films.

Film	In (wt%)	O (wt%)	Cd (wt%)
Pure In ₂ O ₃	41.33	58.67	-
CdO Surface Modified, Dipping time: 5 min.	37.90	61.17	0.94
Dipping time: 10 min.	41.73	57.05	1.22
Dipping time: 20 min.	41.30	58.10	1.98

5. Electrical Properties

5.1. I-V Characteristics

Fig. 3 shows the I-V characteristics of pure In₂O₃ and surface modified CdO thick films at room temperature. I-V Characteristics are observed to be symmetrical in nature, indicating the ohmic nature of silver contact.

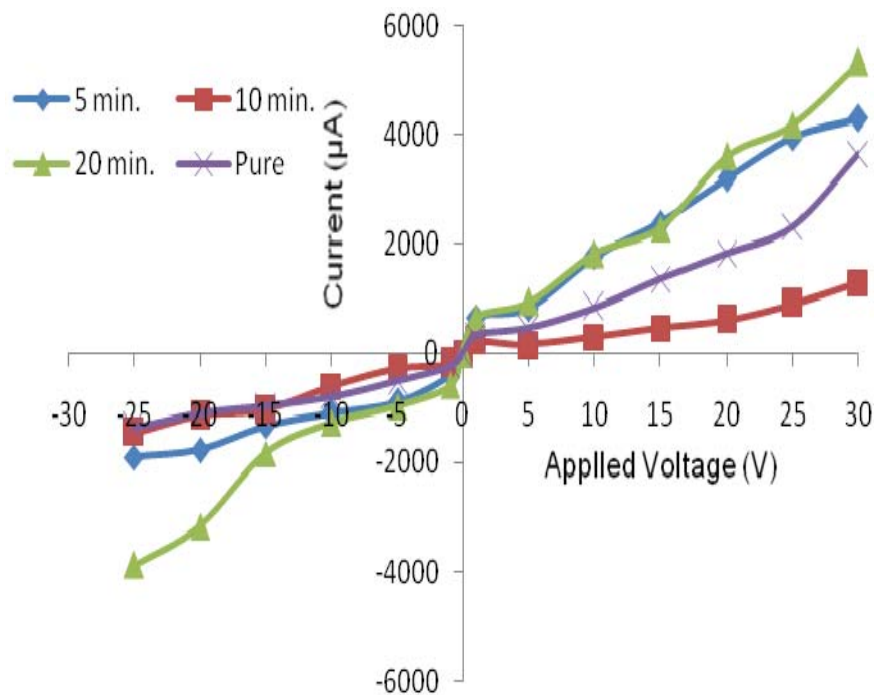


Fig. 3. I-V Characteristics of pure In_2O_3 and surface modified CdO thick films.

5.2. Dependence of Electrical Conductivity with Temperature

Fig. 4 shows the dependence of electrical conductivity of pure In_2O_3 and surface modified by CdO In_2O_3 thick films in air ambience. The electrical conductivity of these thick films goes on increasing with increase in temperature, indicating negative temperature coefficient (NTC) of resistance. This shows the semi conducting nature of the thick films.

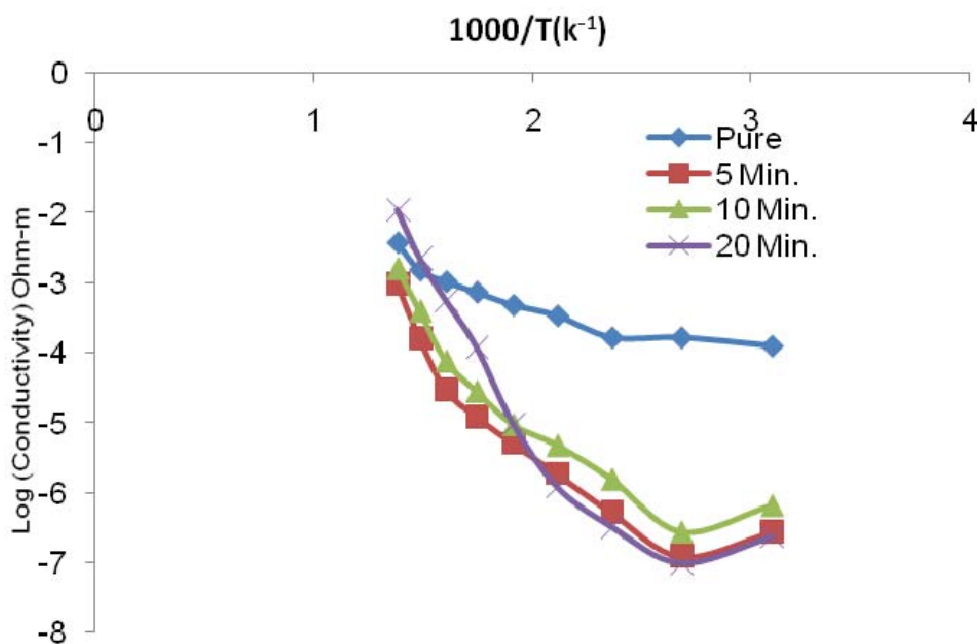


Fig. 4. Variation of electrical conductivity with temperature.

6. Gas Sensing Performance

6.1. Gas Response of Pure In₂O₃ Thick Film

Gas response of thick films was defined as the ratio of the change in conductance of a sample on exposure to the test gas to the conductance in air [37].

$$\text{Gas response} = \left| \frac{G_g - G_a}{G_a} \right| = \left| \frac{\Delta G}{G_a} \right| \quad (2)$$

where G_a = conductance of sensor in air, G_g = Conductance of sensor in gas. & ΔG is the change in conductance.

Fig. 5 shows the variation in the gas response of ethanol vapour (100 ppm) with operating temperatures ranging from 50 °C. to 450 °C. It is noted from the graph that response increases with increasing temperature, and attains a maximum at 350°C, and decreases with further increase in operating temperature.

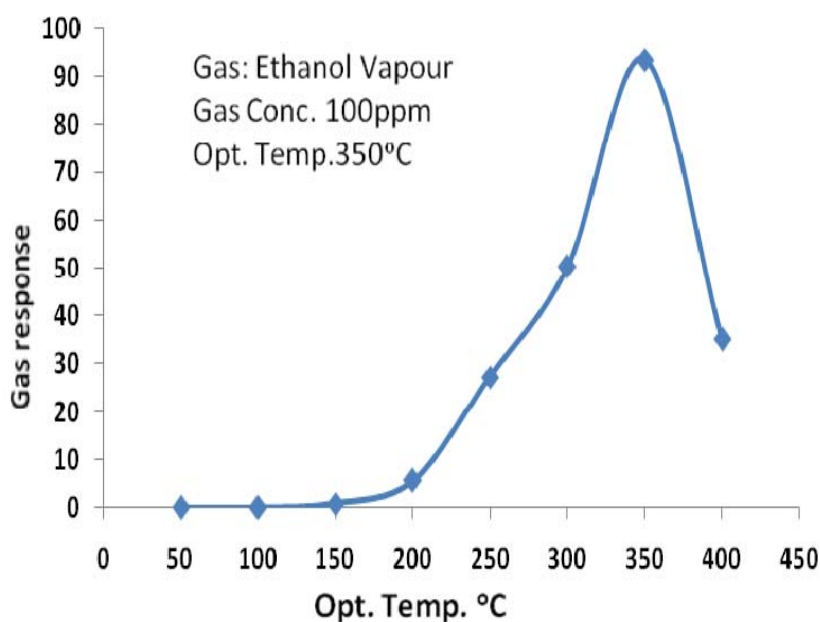


Fig. 5. Variations of ethanol vapor response of pure In₂O₃ thick film with operating temperature.

6.2. Selectivity of Pure In₂O₃ Thick Film

Selectivity is defined as the ability of sensor to respond to a certain gas in the presence of other gases. Selectivity is another important parameter of a gas sensor. The sensor must have rather high selectivity for its application. Pure In₂O₃ thick film is examined for different gases at different operating temperatures and the results are shown in Fig. 6. The bar diagram indicating selectivity of pure In₂O₃ thick film at 350°C to ethanol vapour against the other gases. The thick film is the most selective to ethanol vapor against the other gases.

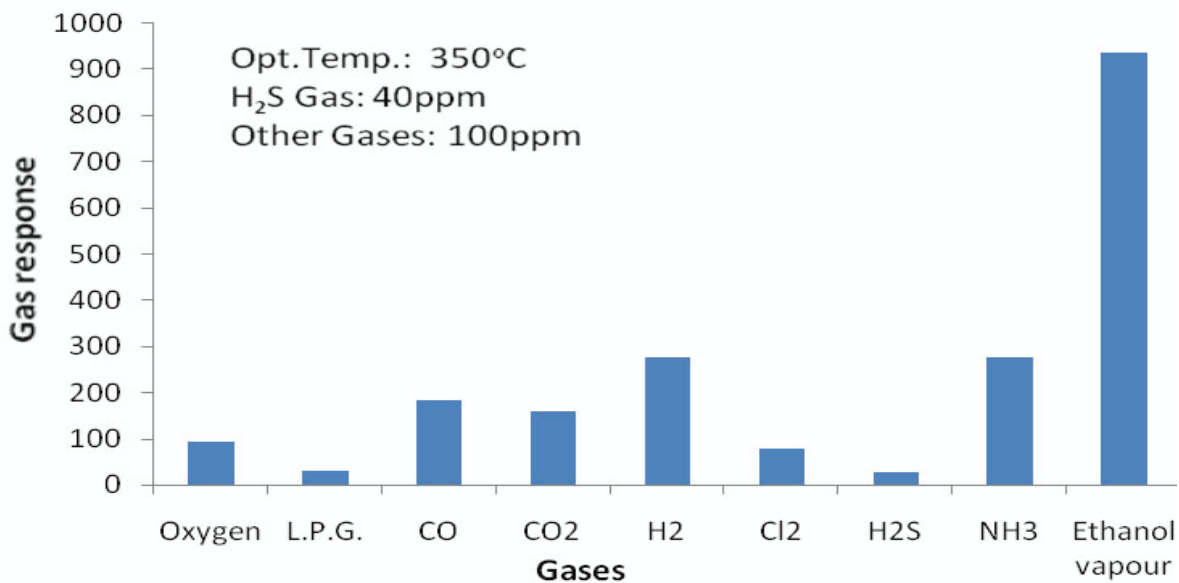


Fig. 6. Selectivity of pure In₂O₃ thick film.

6.3. Gas Response with Operating Temperature

Fig. 7 shows the variation in the gas response of pure and CdO surface modified In₂O₃ thick films to H₂S gas with operating temperature ranging from 50 °C to 450 °C. The H₂S gas response of pure In₂O₃ thick film fired at 550 °C was 5.3 at 150 °C while that of CdO surface modified (10 min.) In₂O₃ thick film was 8971 at the same operating temperature. The CdO surface modified of In₂O₃ thick films was observed to be good response for H₂S gas sensing than the pure In₂O₃ thick film. The CdO surface modified (10 min.) In₂O₃ thick film showed maximum gas response to H₂S gas. The amount of CdO incorporated onto the In₂O₃ thick film surface would be optimum to cover the surface uniformly, leading to the enhanced adsorption mechanism.

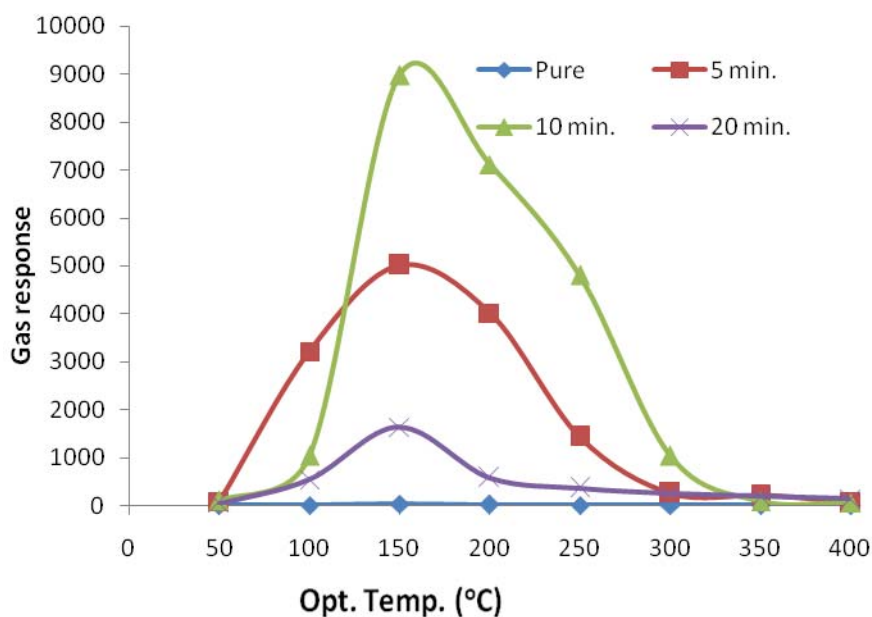


Fig. 7. Variation of H₂S gas response with operating temperature.

The gas response to H₂S gas goes on increasing with increasing the amount of CdO up to a certain limit attains maximum gas response and decreases with increasing the amount of CdO. The largest gas response in case of the sample (10 min.) may be because of more available sites (misfits). The surface of CdO misfit regions enhances the oxygen adsorption on the surface. Thus the number of oxygen species adsorbed on the activated surface would be larger. The larger the number of oxygen species adsorbed, the faster would be oxidation of H₂S gas. The pure In₂O₃ thick film showed highest response to ethanol vapor, while CdO surface modified thick film shows highest response to H₂S gas. The alteration in nature of gas sensing response from ethanol vapor to H₂S gas for the CdO surface modified In₂O₃ thick film could be largely due to possibility of formation of cadmium sulphide more easily. This would increase the conductance of the thick film crucially, enhancing gas response. The abrupt decrease of response for the thick film doped with more amount of Cd is probably due to the reduction of active sites correlated with the agglomeration of Cd grains. At higher concentrations, the Cd would mask the entire base material and would resist the gas to reach to the surface active sites, so gas response would decrease further [38].

6.4. Selectivity of CdO Surface Modified In₂O₃ Thick Films

It is well known that the gas sensitivity is greatly influenced by the operating temperature and the amounts of additives. In order to determine the optimum operating temperature and additive amount, the gas response of CdO thick films with different CdO content to 10 ppm H₂S gas were measured at different operating temperatures. The gas response of pure In₂O₃ thick film to H₂S gas was also measured for comparison. The results are shown in fig. 8 It can be seen obviously from Fig. 8 that the pure In₂O₃ thick film has a poor response to H₂S gas, while the CdO surface modified thick films with different amounts of Cd, all exhibit much higher gas responses than the pure one. Among all the CdO surface modified In₂O₃ thick films, the one with dipping time 10 min. (0.38 wt.%) shows the largest gas response to H₂S gas. Whilst, the gas sensing property change trend is similar to the specific surface area change trend of the samples. The lower operating temperature could lead to lower energy consumption, while is one of current pursuits in solid-state gas sensors. Based on the above results, we can see that the CdO/In₂O₃ thick films exhibit much better gas response and lower operating temperature. Fig. 8 represents the bar diagram indicating selectivity of CdO surface modified In₂O₃ thick film dipped for 10 min. and the operating temperature was 150 °C to H₂S gas against the other gases. The CdO surface modified In₂O₃ thick film dipped for 10 min. was the best selective to H₂S gas.

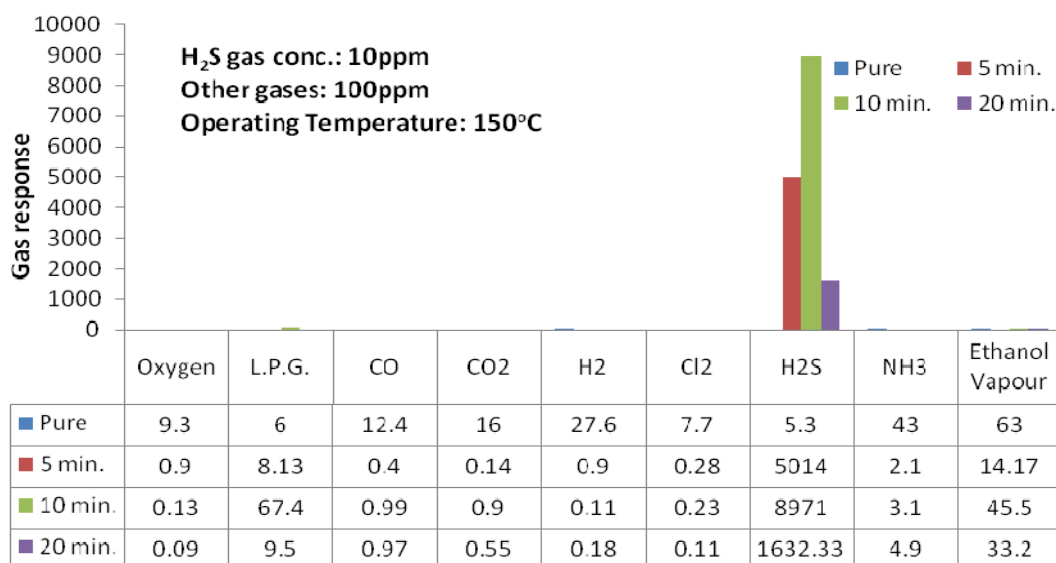
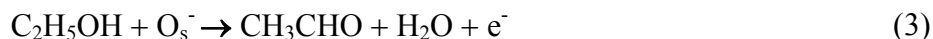


Fig. 8. Selectivity of pure and CdO surface modified In₂O₃ thick films at operating temp. 150 °C.

7. Discussion

7.1. Pure In₂O₃ Thick Film as an Ethanol Vapor Sensor

Indium Oxide is a basic oxide. Interaction of ethanol vapor with the oxide surfaces is quite complicated and sensor signal depends both on the density and nature of surface centers. There are two general ways of ethanol vapor conversion [39]: dehydration and oxidative dehydrogenation. The first one takes place mainly over the surface with Bronsted acidity and gives a low sensor response. On the contrary, dehydrogenation process needs Lewis acid-base pairs [40] and leads to high response due to reaction with chemisorbed oxygen O_s⁻ :

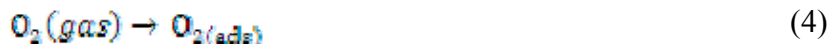


In metal oxide surface oxygen species with a negative charge and metal cations play a role of Lewis basic and acidic centers, respectively. Therefore, in the case of similar adsorptive ability of samples the selectivity of ethanol vapor conversion into acetaldehyde and the sensor signal value depend on the ratio between strong (Lewis) and weak (Bronsted) acid centers. It means that over the surfaces showing mainly Bronsted acidity, ethanol vapor undergoes conversion via C₂H₄ (dehydration) and such materials have poor sensitivity towards ethanol vapor. On the contrary, samples with a dominant Lewis acidity show high response towards C₂H₅OH vapor because of dehydrogenation conversion

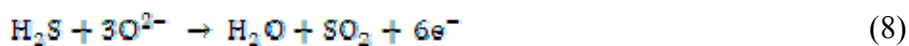
7.2. CdO Surface Modified In₂O₃ Thick Film as a H₂S Gas Sensor

The In₂O₃ sensors were surface modified by dipping it into a 0.1 M CdCl₂ solution. The CdO species would be distributed uniformly throughout the surface of In₂O₃ thick film. Due to this not only the initial resistance of the sensor is high but this amount is sufficient to promote the catalytic reaction effectively, and the overall change in the resistance on exposure of reducing gas (H₂S) leading to high sensitivity.

As generally mentioned earlier, the gas-sensing mechanism of In₂O₃-based thick films belong to the surface controlled type, which is based on the change in conductance of the semiconductor. The oxygen adsorbed on the surface directly influences the conductance of the In₂O₃-based sensors. The amount of oxygen adsorbed on thick film surface depends on the operating temperature, particle size and specific surface area of sensor. The state of oxygen on the surface of CdO/In₂O₃ thick film undergoes the following reaction,



The oxygen species capture electrons from the material, which results in the concentration changes of holes or electrons in the CdO/In₂O₃ semiconductor. When the CdO/In₂O₃ thick film is exposed to H₂S gas, the reductive gas reacts with the oxygen adsorbed on the thick film surface. Then the electrons are released back in to the semiconductor, resulting in the change in the electrical conductance of CdO surface modified In₂O₃ thick films. It can be expressed in the following reaction:



CdO surface modified In₂O₃ thick film when exposed to H₂S gas, cadmium oxide is converted into cadmium sulphide and cadmium sulphide shows metallic in nature, so conductivity would be very low in air and very high on exposure of H₂S gas and therefore, the gas response would be highest for modified thick film. For the CdO/In₂O₃ thick film, the low gas response at low operating temperature can be attributed to the low thermal energy of the gas molecules, which is not enough to react with the surface adsorbed oxygen species. As a result, the reaction rate between them is essentially low [41, 42] and low gas response is observed. On the other hand, the reduction in response after the optimum operating temperature may be due to the difficulty in exothermic gas adsorption at higher temperature [43]. Therefore the maximum gas response can just be observed at the right operating temperature. Figure 10 illustrates the effect of dispersion of surface additive on the film conductivity. When amount of CdO on the surface of the sensor is less than the optimum, the surface dispersion, may be poor and the sensitivity of the sensor is observed to be decreased. Since the amount may not be sufficient to promote the reaction more effectively. On the other hand, as the amount of CdO on the surface is more than optimum, the CdO atoms would be distributed more densely on the surface of sensor. As a result, the initial resistance of the thick film would be decreases and the overall change in resistance on the exposure to gas would be smaller leading to lower response to the target gas. Uniform and optimum dispersion of an additive dominates the depletion of electrons from semiconductor. Oxygen adsorbing on additive (misfits) removes electrons from the additive and additive in turn removes the electron from the nearby surface region of the semiconductor and could control the conductivity.

7.3. Response and Recovery Time

Response and recovery time are the basic parameters of the gas sensors. Which are defined as the time taken for the sensor to attain 90 % of maximum change in resistance on exposure to gas is the response time. The time taken by the sensor to get back 90 % of the original resistance is the recovery time [44]. The 90 % response and recovery time were attained within 6s and 128 s respectively. The very short response time is the important features of the CdO surface modified (10 min.) In₂O₃ thick film. The large recovery time would be due to lower operating temperature. At lower temperature O₂⁻ species is more prominently adsorbed on the surface and thus it is less reactive as compared to other species of oxygen, O⁻ and O²⁻.

8. Summary

Following conclusions can be drawn from the experimental results:

1. The In₂O₃ thick film was found to be non stoichiometric and oxygen deficient material. It showed negative temperature coefficient in nature.
2. The pure In₂O₃ thick film showed highest response to ethanol vapor (100 ppm) at 350 °C.
3. The pure In₂O₃ thick films were modified by CdCl₂ aqueous solution by dipping technique. The surface modified (10 min.) thick film showed best response to H₂S gas (10 ppm) at 150 °C.
4. The surface modification shifts the gas response of the thick film from ethanol vapor to H₂S gas.
5. Due to introduction of CdO on the surface of In₂O₃ thick film, would alter the adsorption-desorption relationship of the sensor. The optimum dipping time was found to be 10 min.
6. The surface modification alters only the surface morphology of the thick film not the bulk properties.
7. The surface modification facilitated adsorption of larger number of oxygen ions on the surface, could immediately oxidize the exposed H₂S gas leading to faster response time of the sensor.

Acknowledgements

The authors are grateful to U.G.C., New Delhi and B.C.U.D., University of Pune for granting financial assistance to this project. The author (DNC) is very much thankful to the Principals, Arts, Commerce and Science College, Nandgaon, NVPM's A. C. S. College Lasalgaon and K.T.H.M. College, Nasik for providing laboratory facilities. Pune, Department of Physics, Chemistry, University of Pune and M.V. P. Samaj, Nasik for providing characterization facilities.

References

- [1]. N. L. Satyanarayana, K. Madhusudan Reddy, S. V. Manorama, Nanosized Spinel NiFe₂O₄; a novel material for the detection of liquefied petroleum gas in air, *Mater. Chem. Phys.*, 82, 2003, pp. 21-26.
- [2]. C. V. Gopal Reddy, S. V. Manorama, V. J. Rao, Semiconducting gas sensor for chlorine based on inverse spinel nickel ferrite, *Sens. Actuators, B*, 55, 1999, pp. 90-95.
- [3]. N. Imanaka, K. Okamoto, G. Adachi, A new type of chlorine gas sensor with the combination of Cl⁻ anion and Al³⁺ cation conducting solid electrolytes, *Mater. Lett.*, 57, 2003, pp. 1966-1969.
- [4]. T. Miyata, T. Hikosaka, T. Minami, High sensitivity chlorine gas sensor using multicomponent transparent conducting oxide thin films, *Sens. Actuators, B*, 69, 2000, pp. 16-21.
- [5]. M. Sugimoto, The past, present and future of ferrites, *J. Am. Ceram. Soc.*, 82, 1999, pp. 269-280.
- [6]. K. Raj, B. Moskowitz, R. Casclari, advances in ferrofluid technology, *J. Magn. Magn. Mater.*, 149, 1995, pp. 174-180.
- [7]. R. D. McMichael, R. D. Shull, L. J. Swartzendruber, L. H. Bennett, R. E. Watson, Magnetocaloric effect in superparamagnets, *J. Magn. Magn. Mater.*, 111, 1992, pp. 29-33.
- [8]. M. J. Madou, S. R. Morrison, Chemical Sensing with Solid State Devices, *Academic Press*, New York, 1989.
- [9]. T. Seiyama (Ed.), Chemical sensor- current state and future outlook, chemical sensor technology, Vol. ½, *Kodansha and Elsevier*, Amsterdam, 1988.
- [10]. S. Ryeol, H. K. Hong, C. H. Kwon, D. H. Yun, K. Lee, Y. K. Sung, Ozone sensing properties of In₂O₃ based semiconductor thick films, *Sens. Actuators, B*, 66, 2000, pp. 59-62.
- [11]. I. J. Golonka, B. W. Lieznerski, K. Nitesh, H. Teteryez, Thick film humidity sensors, *Meas. Sci. Technol.*, 8, 1997, pp. 92-98.
- [12]. N. Guillet, R. Lalauze, J. P. Viricelle, C. Pijolat, L. Montanaro, Development of a gas sensor by thick film technology for automotive applications: choice of materials—realization of a prototype, *Mater. Sci. Eng., C*, 21, 2002, pp. 97.
- [13]. P. S. More, Y. B. Kholam, S. B. Deshpande, S. K. Date, N. D. Sali, S. V. Bhoraskar, S. R. Sainkar, R. N. Karekar, R. C. Aiyer Introduction of δ-Al₂O₃/Cu₂O material for H₂ gas-sensing applications, *Mater. Lett.*, 58, 2004, pp. 1020.
- [14]. L. Wang, R. V. Kumar, Thick Film Miniaturized HCl Gas Sensor By Thick Film, *Sens. Actuators, B*, 98, 2004, pp. 196.
- [15]. T. Maekawa, J. Tamaki, N. Miura, N. Yamazoe, Gold-loaded tungsten oxide sensor for detection of ammonia in air, *Chem. Lett.*, 1992, pp. 639.
- [16]. J. Tamaki, T. Maekawa, N. Miura, N. Yamazoe, CuO-SnO₂ element for highly sensitive and selective detection of H₂S, *Sens. Actuators, B*, 9, 1992, pp. 197.
- [17]. D. J. Yoo, J. Tamaki, S. J. Park, N. Miura, N. Yamazoe, Copper Oxide-Loaded Tin Dioxide Thin Film for Detection of Dilute Hydrogen Sulfide, *Jpn. J. Appl. Phys.*, Part 2, 34, 1995, pp. 455.
- [18]. J. L. Solis, S. Saukko, L. B. Kish, C. G. Granqvist, V. Lantto, Nanocrystalline tungsten oxide thick films with high sensitivity to H₂S at room temperature, *Sensors and Actuators, B*, 77, 2001, pp. 316.
- [19]. J. L. Solis, S. Saukko, L. B. Kish, C. G. Granqvist, V. Lantto, Semiconductor gas sensors based on nanostructured tungsten oxide, *Thin Solid Films*, 391, 2001, pp. 255.
- [20]. J. L. Solis, A. Hoel, L. B. Kish, et al., Gas-sensing properties of nanocrystalline WO₃ films made by advanced reactive gas deposition, *J. Am. Ceram. Soc.*, 84, 2001, pp. 1504-1508.
- [21]. L. A. Patil, D. R. Patil, Heterocontact type CuO-modified SnO₂ sensor for the detection of a ppm level H₂S gas at room temperature, *Sens. Actuators, B*, 120, 2006, pp. 316.

- [22].K. Y. Ho, M. Miyayama, Y. Hirooki, NO_x gas responding properties of Nd₂CuO_{4-y} thick film, *Mater. Chem. Phys.*, 49, 1997, pp. 7-11.
- [23].S. W. Lee, P. P. Tsai, H. Chen, Comparison study of SnO₂ thin and thick film gas sensors, *Sens. Actuators, B*, 67, 2000, pp. 122-127.
- [24].G. Korotcenkov, A. Cerneavschi, V. Brinzari, A. Vasiliey, M. Ivanoy, A. Cornet, J. Morante, A. Cabot, J. Arbiol, In₂O₃ films deposited by spray pyrolysis as a material for ozone gas sensor, *Sens. Actuators, B*, 99, 2004, pp. 297-303.
- [25].I. Hamberg, C. G Granqvist, Evaporated Sn-Doped In₂O₃. Films; Basic Optical Properties and Applications to Energy. Efficient Windows, *J. Appl. Phys.*, 60, 11, 1986, pp. R123-R160.
- [26].A. Gurlo, N Barsan, M. Ivanovskaya, U. Weimar, W. Gopel, In₂O₃ and In₂O₃-MoO₃ thin film semiconductor sensors: interaction with NO₂ and O₃, *Sens. Actuators, B*, 47, 1998, pp. 92.
- [27].G. Faglia, B. Allieri, E. Comini, L. E. Depero, L Sangaletti, and G. Sberveglieri. Electrical and structural properties of RGTO In₂O₃ sensors for ozone detection, *Sensors and Actuators, B*, 57, 1999, pp. 188-191.
- [28].H. Steffes, C. Imawan, F. Solzbacher, E. Obermeier, Fabrication parameters and NO sensitivity of reactively RF-sputtered In₂O₃ thin films, *Sens Actuators, B*, 68, 2000, pp. 249.
- [29].T. V. Belysheya, E. A. Kazachkov, E. E. Gutman. Gas sensing properties of in₂O₃ and Au-doped in₂O₃ films for detecting carbon monoxide in air, *J. Anal. Chem.*, 56, 2001, pp. 676.
- [30].Roy Morrison, S., Mechanism of semiconductor gas sensor operation, *Sens. Actuators*, 1987, B, 11, pp. 283-287.
- [31].P. K. Khanna, N. D. Singh, R. Kulkarni, S. Marimuthu, Charan, K. R. Patil and, G. H. Jain, One-step preparation of nanosized Ag-Pd co-powder and its allformation at low temperature, *Synthesis and Reactivity in Inorganic. Metal-Organic and Nano-Metal Chemistry*, 37, 2007, pp. 1-9 x.
- [32].K. D. Schierbaum, U. K. Kirner, J. F. Geiger, and W. Gopel, Schottky- barrier and conductive gas sensors based upon Pd/SnO₂ and Pt/TiO₂, *Sens. Actuators, B*, 4, 1991, pp. 87-94.
- [33].G. H. Jain, V. B. Gaikwad, D. D. Kajale, R. M. Chaudhari, R. L. Patil, N. K., Pawar, M. K. Deore, S. D. Shinde, L. A., Patil, Gas sensing performance of pure and modified BST thick film resistor, *Sensors and Transducers*, 90, 2008, pp. 160-173.
- [34].S. M. A. Durrani, E. E. Khawaja, M. F. Al-Kuhaili, CO-sensing properties of undoped and doped tin oxide thin films prepared by electron beam evaporation, *Talanta*, 65, 2005, pp. 1162-1167.
- [35].G. H. Jain, V. B. Gaikwad, L. A. Patil, Studies on gas sensing performance of (Ba_{0.8}Sr_{0.2})(Sn_{0.8}Ti_{0.2})O₃ thick film resistors, *Sens. Actuators, B*, 122, 2007, pp. 605-612.
- [36].V. D. Kapse, S. A. Ghosh, G. N. Chaudhari, F. C. Raghuvanshi, D. D. Gulwade, H₂S sensing properties of La-doped nanocrystalline In₂O₃, *Vacuum*, 83, 2009, pp. 346-352.
- [37].G. H. Jain, L. A. Patil, M. S. Wagh, D. R. Patil, S. A. Patil, D. P. Amalnerkar, Surface modified BaTiO₃ thick film resistors as H₂S gas sensors, *Sens. Actuators*, 117, 2006, pp. 159-165.
- [38].D. R. Patil, L. A. Patil, Cr₂O₃-modified ZnO thick film resistors as LPG sensors, *Talanta*, 77, 2009, pp. 1409-1414.
- [39].T. Jinkawa, G. Sakai, J. Tamaki, N. Miura, N. Yamazoe, Relationship sensors modified with acidic or basic oxides, *J. Mol. Catal.*, A, 155, 2000, pp. 193-200.
- [40].H. Idriss, E. G. Seebauer, Reactions of ethanol over metal oxides, *J. Mol. Catal. A*, 152, 2000, pp. 201-212.
- [41].T. Maosong, G. R. Dai, D. S. Gao, Surface modification of oxide thin film and its gas-sensing properties, *App. Surf. Sci.*, 171, 2001, pp. 226-230.
- [42].T. M. Kabayashi, Haruta, H. Sano, M. Nakane, A selective CO sensing Ti-doped α -Fe₂O₃ with co-precipitated ultrafine particles of gold, *Sens. Actuators*, 13, 1988, pp. 339-348.
- [43].Y. Hu, T. O. K., W. Cao, W. Zhu, Fabrication and characterization of nano-sized SrTiO₃-based oxygen sensor for near room-temperature operation, *Sensors*, 5, 2005, pp. 825-832.
- [44].N. Iftimie, E. Rezlescu, P. D. Popa, N. Rezlescu, Gas sensitivity of nanocrystalline nickel ferrite, *J. of Optoelectronics and Advanced Materials*, 8, 3, 2006, pp. 1016-1018.

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 addition, 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/Submission.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_2011.pdf

The Handbook of Laboratory Measurements and Instrumentation presents experimental and laboratory activities with an approach as close as possible to reality, even offering remote access to experiments, providing to the reader an excellent tool for learning laboratory techniques and methodologies. Book includes dozens videos, animations and simulations following each of chapters. It makes the title very valued and different from existing books on measurements and instrumentation.



This unique methodological book comprises 13 chapters. Each one presents a clearly defined learning objective, the essential concepts and a step-by-step guide for performing the experimental activity, various complementary multimedia contents and a final synthesis. The set of open questions that closes each module is intended to provide formative assessment.

The Handbook of Laboratory Measurements and Instrumentation significantly contributes to the dissemination of experimental activity in engineering education and to facilitate the conception, tuning and exploration of experimental systems for laboratory training. The full technical description of the equipment is provided to make the setups easily reproducible. Engineers, technicians and students who are working in measuring laboratories will find plenty of practical information here for solving daily problems.

Order online:

http://www.sensorsportal.com/HTML/BOOKSTORE/Handbook_of_Measurements.htm



www.sensorsportal.com