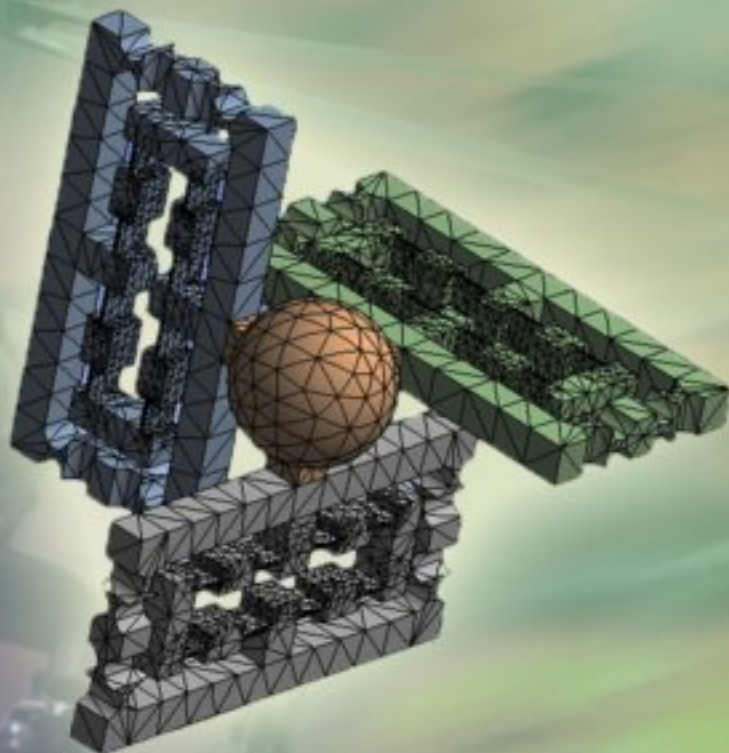
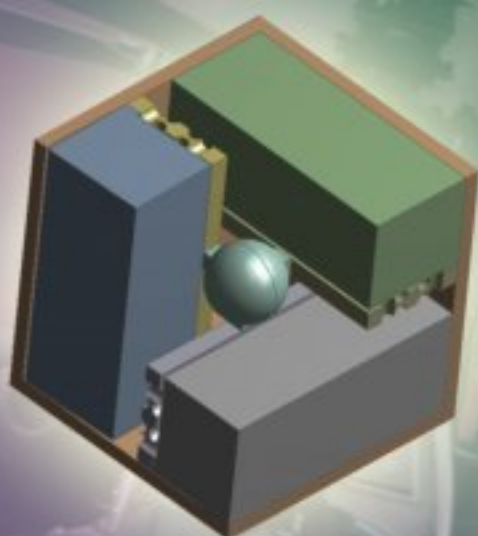


ISSN 1726-5479

# SENSORS & TRANSDUCERS

8<sup>vol. 119</sup>  
/10



## Sensors and Transducers Applications

International Frequency Sensor Association Publishing



**Editors-in-Chief:** professor Sergey Y. Yurish, tel.: +34 696067716, fax: +34 93 4011989, 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, Vyantas**, Kaunas University of Technology, Lithuania  
**Avachit, Patil Lalchand**, North Maharashtra University, India  
**Ayesh, Aladdin**, De Montfort University, UK  
**Bahreyni, Behraad**, University of Manitoba, Canada  
**Baliga, Shankar, B.**, General Motors 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**, VIT University, Tamil Nadu, 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**, Université 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  
**Dimitropoulos, Panos**, University of Thessaly, Greece  
**Ding, Jianning**, Jiangsu Polytechnic University, China  
**Kim, Min Young**, Kyungpook National University, Korea South  
**Djordjevic, Alexandar**, 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  
**Drljaca, Predrag**, Intersema 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 Alcala, 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  
**Khan, Asif**, Aligarh Muslim University, Aligarh, India  
**Sapozhnikova, Ksenia**, D.I. Mendeleyev Institute for Metrology, Russia  
**Saxena, Vibha**, Bhabha Atomic Research Centre, Mumbai, India

**Ko, Sang Choon**, Electronics. and Telecom. Research Inst., Korea South  
**Kockar, Hakan**, Balikesir University, Turkey  
**Kotulska, Malgorzata**, Wroclaw University of Technology, Poland  
**Kratz, Henrik**, Uppsala University, Sweden  
**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  
**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  
**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  
**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 Setebal, 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  
**Prateepasen, 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  
**Raof, Kosai**, Joseph Fourier University of Grenoble, France  
**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 Politecnica de Catalunya, Spain  
**Rodriguez, Angel**, Universidad Politecnica de Cataluna, 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  
**Schneider, John K.**, Ultra-Scan Corporation, USA  
**Seif, Selemeni**, Alabama A & M University, USA  
**Seifter, Achim**, Los Alamos National Laboratory, USA  
**Sengupta, Deepak**, Advance Bio-Photonics, India  
**Shah, Kriyang**, La Trobe University, Australia  
**Shearwood, Christopher**, Nanyang Technological University, Singapore  
**Shin, Kyuho**, Samsung Advanced Institute of Technology, Korea  
**Shmaliy, Yuriy**, Kharkiv National Univ. of Radio Electronics, Ukraine  
**Silva Girao, Pedro**, Technical University of Lisbon, Portugal  
**Singh, V. R.**, National Physical Laboratory, India  
**Slomovitz, Daniel**, UTE, Uruguay  
**Smith, Martin**, Open University, UK  
**Soleymampour, 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.**, Northwestern University, 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  
**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, Tao**, University of California, Irvine, USA  
**Yang, Dongfang**, National Research Council, Canada  
**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, Quintao**, 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  
**Zorob, Mohammed**, University of Cambridge, UK

# Contents

Volume 119  
Issue 8  
August 2010

[www.sensorsportal.com](http://www.sensorsportal.com)

ISSN 1726-5479

## Research Articles

### Fully Decoupled Compliant Parallel Mechanism: a New Solution for the Design of Multidimensional Accelerometer

Zhen Gao and Dan Zhang ..... 1

### Optical Temperature Probe Based on the Fluorescence Decay Time of Tris-(dibenzoylmethane) mono (5-amino-1,10-phenanthroline)-europium(III)

Hung T. Lam, Leah Tolosa, Govind Rao ..... 14

### Applications of InAs Hall Effect Sensors

H. Bourbaba, C. Benachaiba, S. Kadri, A. Saidane ..... 22

### A Simple Model for Complex Fabrication of MEMS based Pressure Sensor: A Challenging Approach

Himani Sharma, P. A. Alvi and J. Akhtar ..... 30

### Acoustic Temperature Transducer

Tariq M. Younes, Mohammad A. K. Alia, Shebel Al-Sabbah ..... 46

### Theoretical Performance of GaAs Solar Cell, with Band Gap Gradient Layer on the Back Region

Hassane Benslimane, Hemmani Abderahman, and Helmaoui Abderrachid ..... 58

### Design of Simple Instrumentation System for the Quality Analysis of Milk (Casein Analysis)

V. G. Sangam, M. Sandesh., S. Krishna., S. Mahadevanna ..... 65

### Development of a Portable Water Quality Analyzer

Germán Comina, Martin Nissfolk, José Luís Solís ..... 72

### A Modified Technique of Active Power Measurement for Industrial Frequency Applications

Satish Chandra Bera and Dhritinandan Kole ..... 82

### New Organic Solvent Free Three-Component Waterproof Epoxy-Polyamine Systems

C. M. Lacnjevac, S. Zlatković, S. Cakić, J. Stamenković, M. B. Rajkovic, G. Nikolić and S. Jelic.... 91

### Measurement Equation is to be Extensively Used: What One May Expect from Dynamic Measurements

Kristina Abramchuk, George Abramchuk ..... 104

### Preparation and study the Electrical, Structural and Gas Sensing Properties of ZnO Thick Film Resistor

M. K. Deore, V. B. Gaikwad, N. K. Pawar, S. D. Shinde, D. D. Kajale, G. H. Jain ..... 117

### Amperometric Glucose Biosensor based on Immobilization of Glucose Oxidase in Polyethylenimine and Poly (carbamoylsuphonate) Polymer Matrix

U. B. Trivedi, D. Lakshminarayana, I. L. Kothari, N. G. Patel, H. N. Kapse, P. B. Patel, C. J. Panchal ..... 129

### Development of Bio-analyzer for the Determination of Urinary Chloride

R. Vasumathi, P. Neelamegam ..... 142




<b>Identification and Speed Control of PMDC Motor using Time Moments</b> <i>Prasanta Sarkar, Sagarika Pal, Swadhin Sambit Das</i> .....	151
<b>Parameter Estimation and Speed Control of PMDC Servo Motor Using Method of Time Moments</b> <i>Prasanta Sarkar, Sagarika Pal, Swadhin Sambit Das</i> .....	162
<b>Determination of the Region of Stabilizing Controller Parameters of Polytopic Polynomials</b> <i>I. Thirunavukkarasu, V. I. George, Mukund Kumar Menon, S. Shanmuga Priya</i> .....	174
<b>Identification of Natural Ventilation Parameters in a Greenhouse with Continuous Roof Vents, using a PSO and GAS</b> <i>Abdelhafid Hasni, Belkacem Draoui, Mahieddine Latfaoui and Thierry Boulard</i> .....	182
<b>Dynamic Modeling of Step Climbing Wheeled Robot</b> <i>Srijan Bhattacharya, Neeta Sahay, Sagarika Pal, Subrata Chattopadhyay</i> .....	193
<b>ECG Signal Denoising and QRS Complex Detection by Wavelet Transform Based Thresholding</b> <i>Swati Banerjee, Dr. Madhuchhanda Mitra</i> .....	207
<b>Admittance, Conductance, Reactance and Susceptance of New Natural Fabric Grewia Tilifolia</b> <i>V. V. Ramana C. H., Jayaramudu J., Jeevan Prasad Reddy D., Madhusudhana Rao K. and Varadarajulu A.</i> .....	215
<b>Role of Catecholamine in Tumor Angiogenesis Linked to Capacitance Relaxation Phenomenon</b> <i>Guangyue Shi, Guanjie Sui, Jianxia Jiang, T. K. Basak</i> .....	223

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


International Frequency Sensor Association (IFSA).

[www.sensorapps.org](http://www.sensorapps.org)



**SENSORS APPLICATIONS SYMPOSIUM**

**Hyatt Regency San Antonio  
February 22-24, 2011  
San Antonio, TX**



**Conference Co-Chairs:**  
Shreekanth Mandayam,  
Rowan University, USA  
  
Deniz Gurkan,  
University of Houston, USA  
  
**Technical Program Chair:**  
Steven Griffin,  
University of Memphis, USA

**The 2011 IEEE sensors Applications Symposium (SAS-2011)** provides an established forum for sensor users and developers to meet and exchange information about novel and emergent applications in smart sensors, homeland security, biology, system health management, and related areas. Collaborate and network with scientists, engineers, developers and customers, in a balance of formal technical presentations, workshops, and informal interface meetings. Suggested topics for SAS-2011 include:



**Sensors**

- Biosensors/Arrays
- Smart sensors and standards
- Sensor networking
- MEMS and nanosensors
- Virtual sensors

**Sensor Applications**

- Homeland security
- Multisensor data fusion
- Nondestructive evaluation and remote sensing
- Integrated systems health management (ISHM)
- Commercial development

Additional topics for workshops and new session tracks are especially welcome—please contact the organizers. Papers presented at SAS-2011 will be eligible for consideration for publication in a **Special Issue** of the *IEEE Transactions on Instrumentation & Measurement*.

For additional information, please visit the Sensors Applications Symposium website at [www.sensorapps.org](http://www.sensorapps.org)

**Important Dates:**

- 15 October 2010: Abstract submission deadline
- 15 November 2010: Notification of acceptance
- 10 January 2011: Final manuscript submission deadline



The Second International Conference  
on Sensor Device Technologies and Applications

## SENSORDEVICES 2011

August 21-27, 2011 - French Riviera, France



### Important deadlines:

Submission deadline	March 23, 2011
Notification	April 30, 2011
Registration	May 15, 2011
Camera ready	May 22, 2011

### Tracks:

- Sensor devices
- Photonics
- Infrared
- Ultrasonic and Piezosensors
- 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

<http://www.iaria.org/conferences2011/SENSORDEVICES11.html>



The Fifth International Conference on Sensor  
Technologies and Applications

## SENSORCOMM 2011

August 21-27, 2011 - French Riviera, France



### Important deadlines:

Submission deadline	March 23, 2011
Notification	April 30, 2011
Registration	May 15, 2011
Camera ready	May 22, 2011

### Tracks:

- APASN: Architectures, protocols and algorithms of sensor networks
- MECSN: Energy, management and control of sensor networks
- RASQOFT: Resource allocation, services, QoS and fault tolerance in sensor networks
- PESMOSN: Performance, simulation and modelling of sensor networks
- SEMOSN: Security and monitoring of sensor networks
- SECSN: Sensor circuits and sensor devices
- RIWISN: Radio issues in wireless sensor networks
- SAPSN: Software, applications and programming of sensor networks
- DAIPSN: Data allocation and information in sensor networks
- DISN: Deployments and implementations of sensor networks
- UNWAT: Under water sensors and systems
- ENOPT: Energy optimization in wireless sensor networks

<http://www.iaria.org/conferences2011/SENSORCOMM11.html>



The Fourth International Conference on Advances  
in Circuits, Electronics and Micro-electronics

## CENICS 2011

August 21-27, 2011 - French Riviera, France



### Important deadlines:

Submission deadline	March 23, 2011
Notification	April 30, 2011
Registration	May 15, 2011
Camera ready	May 22, 2011

### 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/conferences2011/CENICS11.html>

## Preparation and Study the Electrical, Structural and Gas Sensing Properties of ZnO Thick Film Resistor

<sup>1\*</sup>M. K. DEORE, <sup>2</sup>V. B. GAIKWAD, <sup>3</sup>N. K. PAWAR, <sup>2</sup>S. D. SHINDE,  
<sup>5</sup>D. D. KAJALE, <sup>5</sup>G. H. JAIN

<sup>1\*</sup>Dept. of Physics, Arts, Commerce and Science College, Ozar (Mig) – 422 206, India

<sup>2</sup>Dept. of Chemistry, K.T.H.M. College, Nashik -422 005, India

<sup>3</sup>Dept. of Physics, K.A.A.N.M.Sonawane College Satana, India

<sup>5</sup>Dept. of Physics, Arts, Commerce and Science College, Nandgaon- 423 106, India,

E-mail: <sup>1\*</sup>deoremadhav@rediffmail.com, <sup>5</sup>gotanjain@rediffmail.com

*Received: 8 May 2010 /Accepted: 17 August 2010 /Published: 31 August 2010*

---

**Abstract:** Thick films of AR grade ZnO were prepared on glass substrate by screen-printing technique. These films were dried and fired at different temperatures between 550 °C, 600 °C and 650 °C for one hour in air atmosphere. The gas sensing performance of thick films was tested for various gases. ZnO films showed larger response (sensitivity) to H<sub>2</sub>S gas (100 ppm) at 250 °C for firing temperature 650 °C. The Morphological, Compositional and Structural properties of the ZnO thick films were performed by Scanning electron microscopy (SEM), Energy dispersive spectroscopy (EDX) and XRD technique respectively. Chemical composition of ZnO film samples changes with firing temperature showing non-stoichiometric behaviours. XRD study indicated the formation of polycrystalline ZnO films with hexagonal wurtzite structure. The gas response (sensitivity), selectivity, response and recovery time of the sensor were measured and presented. *Copyright © 2010 IFSA.*

**Keywords:** ZnO gas sensor, Thick films, Sensitivity, Selectivity, Response and recovery time.

---

### 1. Introduction

Growing industrialization and ever increasing pollutants from vehicular exhaust have resulted into increased air pollution. The problems related to air quality monitoring are important issues of the current research activity. In fact, a key component in many process controls, product development, environmental monitoring etc. is the measurement of concentration of one or the other gaseous component of the ambient. In such situations suitable sensors can provide the necessary interface

between the ambient and the back up electronic instrumentation to detect the target gas. Solid-state sensors have dominated this field for over the past three decades [1, 2].

A wide range of gas sensors are developed using metal oxide semiconductors (MOS) because of its advantageous features like sensitivity to the ambient conditions, low material cost, easy processing and simplicity in fabrication.[3, 4]. The most commonly used n-type MOS in gas sensors are based on ZnO [5–8], SnO<sub>2</sub> [9], TiO<sub>2</sub> [10], In<sub>2</sub>O<sub>3</sub> [11], known for their changes in electrical conductivity when exposed to test gases. At elevated temperatures (100 °C –600 °C), The choice of n-type semiconductors is mainly related to their increased resistance during first oxygen adsorption and the subsequent decrease of resistance after oxygen removal by ambient reducing agents; this is usually the preferred direction for sensing reducing agents, since it requires very simple circuitry.

Among the n-type semi conducting oxides, ZnO is one of the metal oxide semiconducting material of wurtzite structure, with a direct large-band gap of about 3.37 eV at low temperature and 3.30 eV at room temperature [12-16]. It is sensitive to many sorts of gases at moderate temperature, ZnO is one of the most widely applied oxide-gas sensor. ZnO gas sensing materials owe to their high chemical stability, low cost, and good flexibility in fabrication. ZnO sensor elements have been fabricated in various forms including single crystal [17, 20, 21, 34], sinter pellet [22, 23, 24], thin film [19, 25, 26-30, 32], and thick film [18, 31, 33, 35].

The aim of this work is to describe the behavior of thick-film gas sensors obtained by screen-printing a ZnO-based paste on glass substrate the thick film semiconductor sensors typically porous and sintered metal oxides. The advantages are well known: versatility in the conception, miniaturization, mass production at low cost, etc.

In this work the ZnO film show the good response to the Hydrogen sulphide (H<sub>2</sub>S) gas. H<sub>2</sub>S 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. It is also used in large quantities to extract heavy water. Monitoring and control of H<sub>2</sub>S in ambient is therefore important in laboratories and industrial areas where it is used as a process gas, generated as a byproduct or produced naturally in wastewater swamps.

## 2. Operating Principle of Gas Sensor

The most general working principle of the semiconductor gas sensors proposed is a simple receptivity change due to adsorption – desorption of gases. The electrical conductance of a highly porous semi conducting thick-film sensor changes in the presence of toxic gases due to two main reactions occurring on the surface [36]. In the first reaction atmospheric oxygen molecules are physisorbed on the surface sites, which while moving from site to site, get ionized by taking an electron from the conduction band and is thus ionosorbed on the surface as O<sup>2-</sup>ads [37] (see Fig. 1). This leads to a decrease in conductance of the sensor material.

The resulting equation is



In the case of ZnO films, electrons are also extracted from the interstitial zinc atoms Zn<sub>i</sub><sup>2+</sup> (which act as an electron donor) [38]. The interstitial zinc atoms in such cases are ionized via the following reversible reaction





In the second step the reducing gas ( $R$ ) like  $H_2S$  present in the air ambient, reacts with the chemisorbed oxygen, thereby releasing an electron back to the conduction band and increasing the conductance of the semiconductor.



At higher temperature  $RO$  desorbs.

If the operating temperature is low, the product  $RO$  will not desorb, thus passivating the surface for further adsorption of oxygen. On the other hand if the operating temperature is too high, oxygen will not physically adsorb [39]. Therefore, the sensor performs only within a specific temperature window.

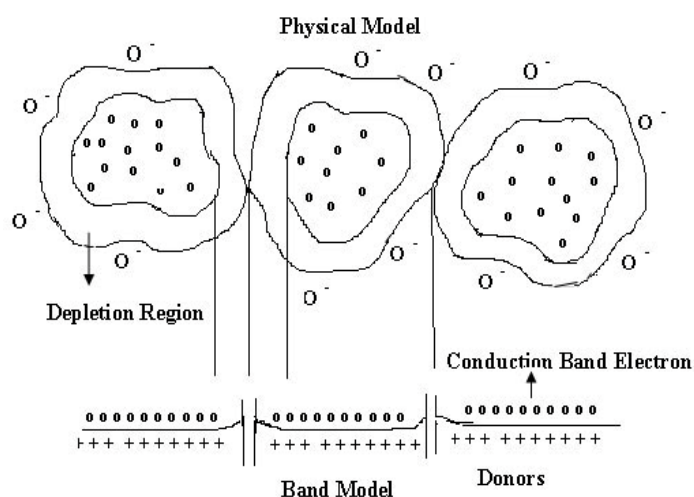


Fig. 1. Physical and band model of semiconductors.

### 3. Experimental

#### 3.1. Preparation of ZnO Films

The AR grade ZnO powder (99.9 % pure) was milled for 2 hr to obtain fine-grained powder. The thixotropic paste was formulated by mixing the fine powder of ZnO with a solution of ethyl cellulose (a temporary binder) in a mixture of organic solvents such as butyl cellulose, butyl carbitol acetate and terpineol, etc. The ratio of the inorganic to organic part was kept at 75:25 in formulating the paste. This paste was screen printed [40, 41] on a glass substrate in a desired pattern. The films were fired at 550 °C for 30 min. Silver contacts are made for electrical measurements.

#### 3.2. Details of Gas Sensing Unit

The sensing performance of the sensors was examined using a 'static gas sensing system' [42], shown in Fig. 2. 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 sensor. 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 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.

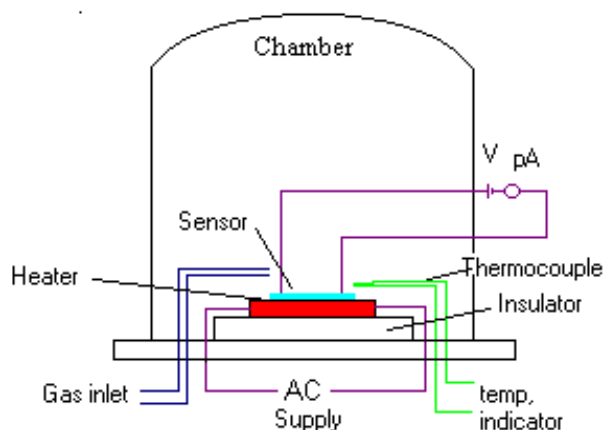


Fig. 2. Block diagram of gas sensing unit.

## 4. Material Characterization

### 4.1. X-ray Diffraction

In Order to understand the structural properties of ZnO film samples fired at different temperatures in air atmosphere, the X-ray diffraction study was undertaken. X-ray diffraction analysis of ZnO film samples were carried out in the  $20-80^\circ$  range using  $\text{CuK}\alpha$  radiation. Fig. 3 shows an XRD pattern of ZnO film samples plotted in the range  $20-80^\circ(2\theta)$  versus intensity having several peaks of zinc oxide indicating random orientation for the polycrystalline nature and measured interplaner distances agreed with the values reported for ZnO in the literature. The observed peaks match well with the reported ASTM data of Zinc oxide, confirming the polycrystalline nature. The higher peak intensities of an XRD pattern is due to the better crystallinity and bigger grain size can be attributed to the agglomeration of particles [43].

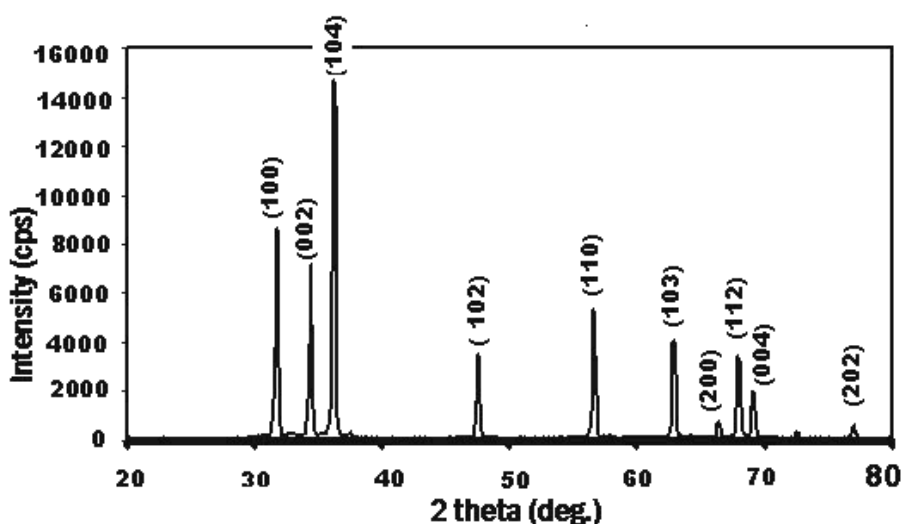
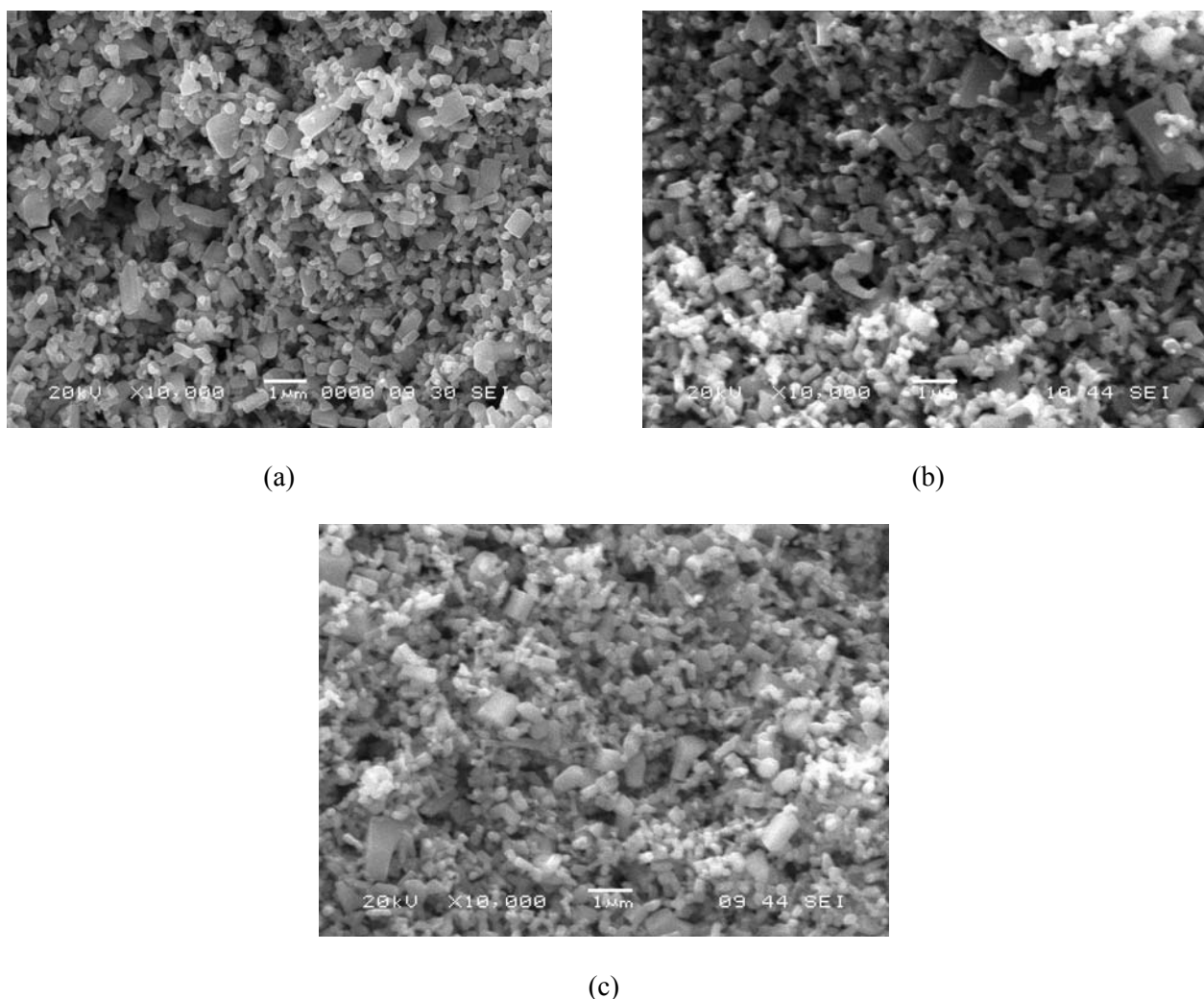


Fig. 3. XRD Pattern of ZnO.

## 4.2. Micro Structural Analysis

Micro structural characterization was carried out by using scanning electron microscopy. Fig. 4 (a, b, c) shows SEM images of ZnO thick film fired at 550 °C, 600 °C and 650 °C respectively. The micrographs consists of large number of grain sizes ranging from 0.1  $\mu\text{m}$  to 1  $\mu\text{m}$ , leading to high porosity and large effective surface area available for the adsorption of oxygen species.

The comparison of these micrographs shows the interesting changes in morphology. It is found that the grain size and the crystalline quality increased with increase in firing temperature. The firing temperature increases the atomic mobility; the atoms can be moved to more energetically favoured sites such as voids, grain boundaries and interstitial positions. An increase in temperature improves the crystallinity and thus increases the mobility of atoms at the surface of films.



**Fig. 4.** SEM image of ZnO film fired at (a) 550 °C; (b) 600 °C; and (c) 650 °C.

## 4.3. Elemental Analysis

The Composition of ZnO thick films fired at different temperatures was analyzed by energy dispersive spectrometer (6360LA) (EDX). Table 1 shows the composition of the films fired at different temperatures. The EDAX spectrum showed the presence of only Zn and oxygen. The mass percentage

of oxygen was found to increase with increasing firing temperature and it shows the adsorption of oxygen increases with temperature on the surface of film. From the analysis it was found that ZnO films are non-stoichiometric.

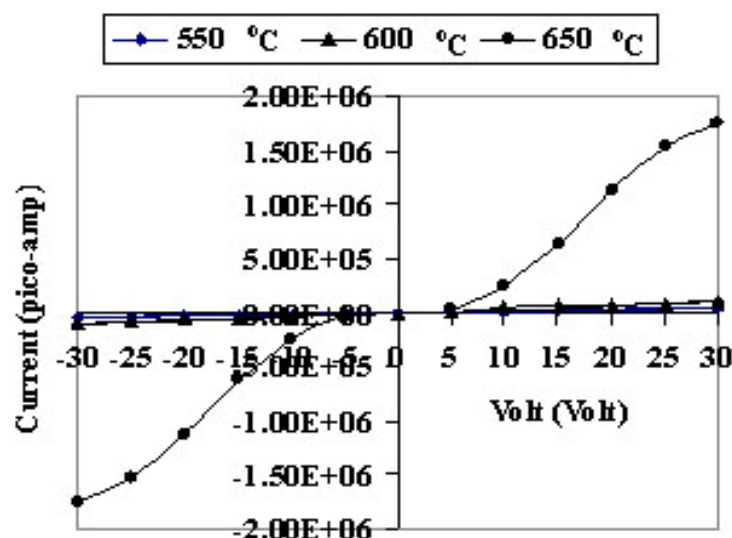
**Table 1.** Composition of the films at different firing temperature.

Firing Temperatures	Element	At.Wt. %	Mass %
550 °C	O	46.90	17.77
	Zn	53.10	82.33
600 °C	O	47.87	18.35
	Zn	52.13	81.65
650 °C	O	48.52	18.74
	Zn	51.48	81.26

## 5. Electrical Properties

### 5.1. I-V Characteristics

Fig. 5 shows the I-V characteristics of pure ZnO film at room temperature in the air atmosphere. The linearity in the graph indicates the ohmic nature of contact.



**Fig. 5.** I-V Characteristics of pure ZnO.

### 5.2. Electrical Conductivity

Fig. 6 represents the variation of conductivity with temperature for ZnO films in air ambience for different temperatures. The conductivity of these films goes on increasing with increase in temperature, indicating negative temperature coefficient (NTC) of resistance. This shows the semi-conducting nature of the films. The film fired at 550 °C shows the large conductivity than other firing temperatures because as the temperature increases the adsorption of oxygen species on the surface of the film is more and hence the conductivity decreases.



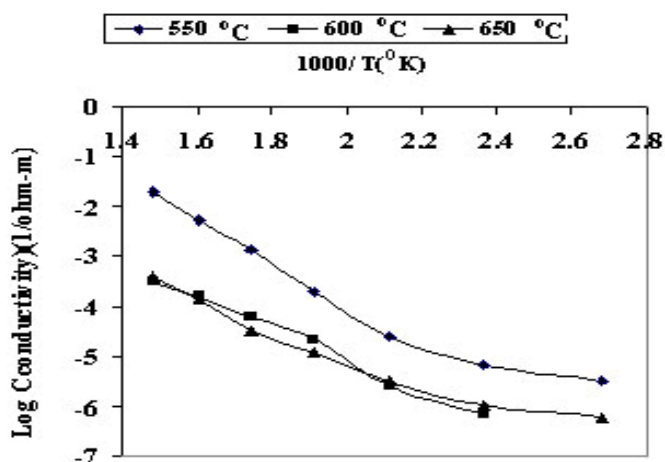


Fig. 6. Variation of conductivity with temperature.

## 6. Gas Sensing Performance of ZnO Film

The conductance of the sensor in dry air was measured by means of conventional circuitry by applying constant voltage and measuring the current by Pico ammeter. The conductance was measured both in the presence and absence of test gas. The gas response(s) (sensitivity with temperature) is defined as the ratio of change in conductance in gas to air to the original conductance in air

$$S = \frac{G_g - G_a}{G_a} \quad (4)$$

where  $G_a$  = conductance of sensor in air;  
 $G_g$  = Conductance of sensor in gas.

### 6.1. Gas Response with Temperature

The gas sensing performances of thick films were tested for various gases. Fig. 7 represents the variation in the gas response at different firing temperature for various gases at 100 ppm with operating temperatures ranging from 50 °C to 450 °C. It is noted from the graph that response increases with further increase in temperature from 150 °C to 300 °C and then decreases with further increase in operating temperature.

The film fired at 650 °C show the maximum response  $H_2S$  gas at 250 °C as compared to the other firing temperatures.

### 6.2 Selectivity of Pure ZnO Film

The selectivity or specificity is defined as the ability of a sensor to respond to certain gas in the presence of other gases.

Fig. 8 represents the bar diagram indicating selectivity of pure ZnO film fired at 650 °C and operated at different temperatures for different gases. It is clear from the bar diagram that the ZnO film is the more selective to  $H_2S$  gas against the other gases.

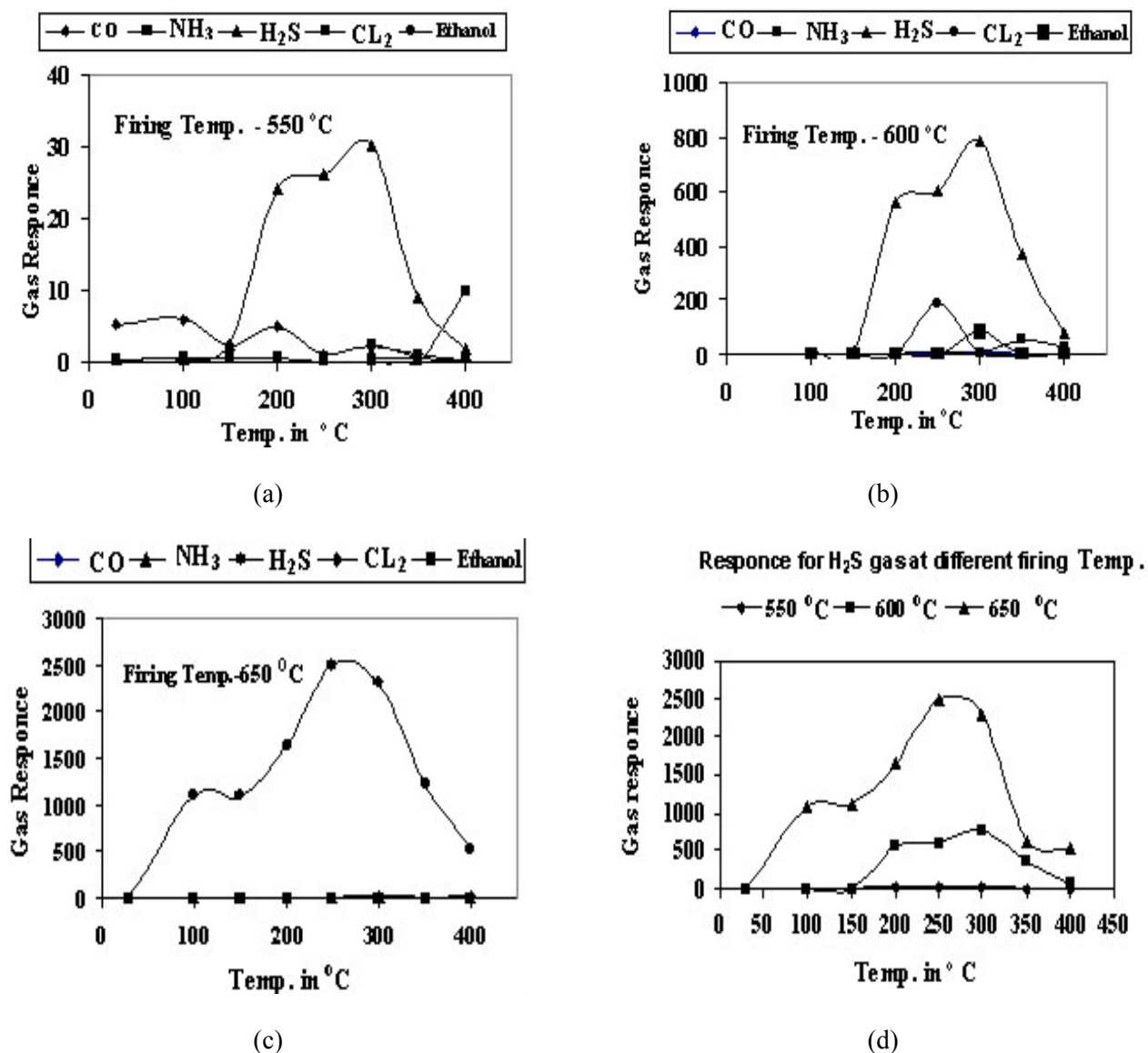


Fig. 7. Variation of Gas Response with different firing temperatures.

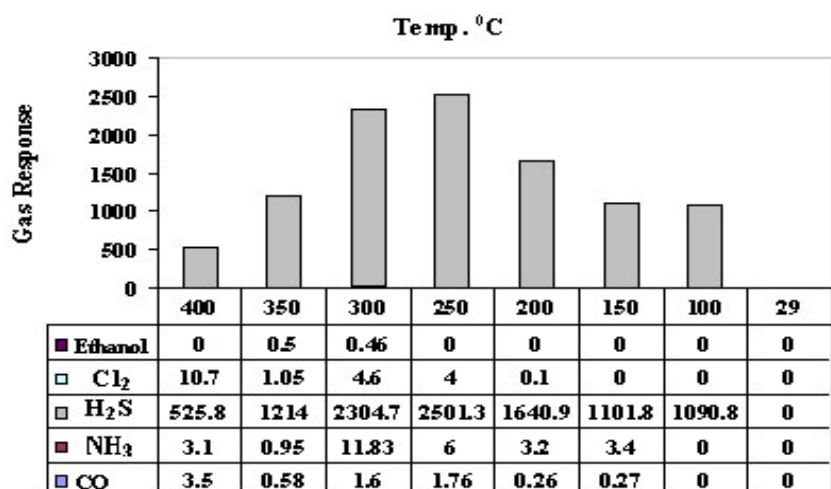


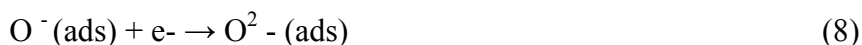
Fig. 8. Selectivity of ZnO film.

## 7. Response and Recovery Time of Pure Film

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 response and recovery time of pure ZnO film was 4 s and 60 s respectively. The large recovery time would be due to lower operating temperature. At lower temperature  $O_2^-$  species is more prominent adsorbed on the surface, it is less reactive compared to other species of oxygen,  $O^-$  and  $O^{2-}$ .

## 8. Result and Discussion

The gas sensing mechanism of the semiconductor based sensors belongs 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 semiconductor based sensors. The amount of oxygen adsorbed on the sensor surface depends on operating temperature, partial size and specific surface area of the sensor [45]. The atmospheric oxygen molecules adsorbed on the surface of n-type ZnO in the form of  $O$ ,  $O_2^-$  and  $O^{2-}$ , there by decreasing the conductance. The state of oxygen on the surface of ZnO sensor undergoing the following reactions [46].

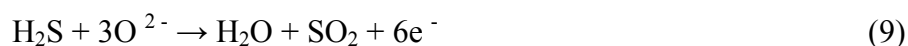


The oxygen species captures electron from the material, which results in the concentration changes of holes or electrons in ZnO semiconductor.

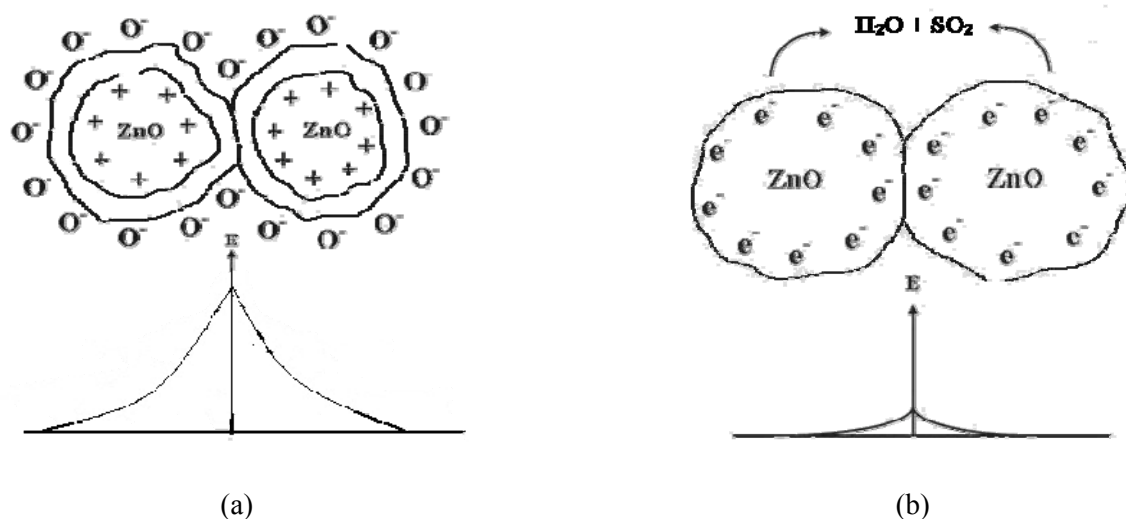
Fig. 9 (a) shows the adsorption of oxygen species on the surface of ZnO, abstracting electrons and thus causing an increase in potential barrier of the grain boundaries.

When ZnO films are exposed to the reducing gases, the reductive gas reacts with the oxygen adsorbed on the surface. Then the electrons are released back to the semiconductor, resulting in the change in the electrical conductance of ZnO sensor. On the surface of the ZnO film there are two kinds of oxygen, one is the adsorption oxygen, and the other is the lattice oxygen.

Fig. 9 (b) shows when ZnO comes in contact with  $H_2S$  gas the potential barrier would decrease as result oxidative conversion of  $H_2S$  gas and desorption of oxygen. Then the electrons are released back in to the semiconductor, resulting in the change in the electrical conductance of ZnO film. It can be expressed in the following reaction [47, 48]



The oxidation of  $H_2S$  is a process of thermal activation, but the desorption of oxygen is enhanced with the increase of temperature. So a comprised reaction rate of  $H_2S$  oxidation must take place at a proper temperature. In the present study, the optimized temperature was found to be 250 °C.



**Fig. 9.** Oxygen (a) adsorption, (b) desorption on surface of pure ZnO when react with  $\text{H}_2\text{S}$  gas.

The Films are fired at different temperatures. Then it shows that the mass percent of oxygen increase on the surface of the film with increased firing temperature. Hence the film surface becomes more reactive to the reductive gas and there is desorption of oxygen. Then the electrons are released back in to the semiconductor, resulting in the change in the electrical conductance of ZnO film. For low operating temperature the product RO( R-Reducing Gas) will not desorbs , thus passivating the surface for further adsorption of oxygen ,on the other hand for high operating temperature oxygen will not physically adsorbed . Hence the ZnO film shows the performance only within a specific temperature window. Here the ZnO film showed highest response to  $\text{H}_2\text{S}$  gas (100ppm) at 250 °C. It can be completely recovered by heating to a temperature of over 450 °C.

## 9. Summary and Occlusions

- The ZnO material is oxygen deficient, the increase in firing temperature increases the oxygen. Species and this temperature tend to become a material stoichiometric.
- The larger oxygen deficiency would enable ZnO to adsorb more oxygen ions helping the sensor to recover fastly.
- The pure ZnO film shows the highest response to the  $\text{H}_2\text{S}$  gas over the operating temperature 250 °C at 100 ppm level for firing temperature 650 °C.
- The film shows the very rapid response (4 sec.) and recovery (60 sec.) time to  $\text{H}_2\text{S}$  gas.
- The ZnO thick film was observed to be highly selective to  $\text{H}_2\text{S}$  gas.
- The quick response of the sensor could be attributed to larger oxygen deficiency in ZnO material.
- A quick response and fast recovery were the special characteristics of the ZnO material.

## Acknowledgements

The author (MKD) is grateful to B.C.U.D., University of Pune, and U.G.C., New Delhi, for financial assistance to this project and very much thankful to The Serchitnis, M.V.Prasrak Samaj, Nashik, Principal, K.T.H.M. College, Nashik and Principal, Arts, Commerce and Science College, Ozar (Mig) and for his keen interest in this project. The author (VBG) and (GHJ) are grateful to U.G.C., New Delhi, for financial assistance to this project.



## References

- [1]. P. T. Moseley and B. C. Tofield, Solid State Gas Sensors, *IOP Publishing Ltd, Adam Hilger*, Bristol UK, 1987.
- [2]. K. Ihokura and J. Watson, The Stannic Oxide Gas Sensors: Principles and Applications, *CRC Press*, London, 1994.
- [3]. M. J. Madou and S. R. Morrison, Chemical Sensing with Solid State Devices, *Academic Press*, New York, 1989, p. 491.
- [4]. P. T. Moseley, A. M. Stoneham and D. E. Williams, Oxide semiconductors: patterns of gas response behaviour according to material type, in P. T. Moseley, J. Norris and D. E. Williams (eds.), *Techniques and Mechanism in Gas Sensing*, *Adam Hilger*, New York, 1991, p. 108.
- [5]. X. Jiaqiang, C. Yuping, C. Daoyong, S. Jianian, *Sens. Actuators B: Chem.*, 113, 2006, pp. 526.
- [6]. W. J. Moon, J. H. Yu, G. M. Choi, *Sens. Actuators B: Chem.*, 87, 2002, pp. 464.
- [7]. J. D. Choi, G. M. Choi, *Sens. Actuators B: Chem.*, 69, 2000, pp. 120.
- [8]. H. Y. Bae, G. M. Choi, *Sens. Actuators B: Chem.*, 55, 1999, pp. 47.
- [9]. P. S. More, Y. B. Kholam, S. B. Deshpande, S. R. Sainkar, S. K. Date, R. N. Karekar, R. C. Aiyer, *Mater. Lett.*, 57, 2003, pp. 2177.
- [10]. A. M. Ruiz, G. Sakai, A. Cornet, K. Shimanoe, J. R. Morante, N. Yamazoe, *Sens. Actuators B: Chem.*, 93, 2003, pp. 509.
- [11]. T. V. Belysheva, L. P. Bogovtseva, E. A. Kazachkov, N. V. Serebryakova, *J. Anal. Chem.*, 58, 2003, pp. 583.
- [12]. D. M. Bagnall, Y. F. Chen, Z. Zhu, T. Yao, S. Koyama, M. Y. Shen, T. Goto, *Appl. Phys. Lett.*, 70, 1997, pp. 2230.
- [13]. P. Yu, Z. K. Tang, G. K. L. Wong, M. Kawasaki, A. Ohtomo, H. Koinuma, Y. Segawa, *Solid State Commun.*, 103, 1997, pp. 459.
- [14]. D. C. Look, D. C. Reynolds, J. R. Sizelove, R. L. Jones, C. W. Litton, G. Cantwell, W. C. Harsch, *Solid State Commun.*, 150, 1998, pp. 399.
- [15]. D. C. Look, *Mater. Sci. Eng., B*, 80, 2001, pp. 383.
- [16]. S. J. Pearton, D. P. Norton, K. Ip, Y. W. Heo, T. Steiner, *Prog. Mater. Sci.*, 50, 2005, pp. 293.
- [17]. Y. Liu, J. Dong, P. J. Hesketh, M. Liu, Synthesis and gas sensing properties of ZnO single crystal flakes, *J. Mater. Chem.*, 15, 2005, pp. 2316-2320.
- [18]. C. Xiangfeng, J. Dongli, A. B. Djurišić, Y. H. Leung, Gas-sensing properties of thick film based on ZnO nano-tetrapods, *Chem. Phys. Lett.*, 401, 2005, pp. 426-429.
- [19]. P. P. Sahay, S. Tewari, S. Jha, M. Shamsuddin, Sprayed ZnO thin films for ethanol sensor, *J. Mater. Sci.*, 40, 2005, pp. 4791-4793.
- [20]. J. Xu, Y. Chen, Y. Li, J. Shen, Gas sensing properties of ZnO nanorods prepared by hydrothermal method, *J. Mater. Sci.*, 40, 2005, pp. 2919-2921.
- [21]. Q. Wan, V. Li, Y. J. Chen, VHe, J. P. Li, V. Lin, T. H. Wang, Fabrication and ethanol sensing characteristics of ZnO nanowire gas sensors, *Appl. Phys. Lett.*, 84, 2004, pp. 3654-3656.
- [22]. X. Xu, X. Liu, D. Cui, M. Li, M. Jiang, A novel method for improving the performance of ZnO gas sensors, *Sens. Actuators B*, 114, 2006, pp. 301-307.
- [23]. B. B. Rao, Zinc oxide ceramic semi-conductor gas sensor for ethanol vapour, *Mater. Chem. Phys.*, 64, 2000, pp. 62-65.
- [24]. B. Baruwati, D. K. Kumar, S. V. Manorama, Hydrothermal synthesis of highly crystalline ZnO nanoparticles: A competitive sensor for LPG and EtOH, *Sens. Actuators B*, 119, 2006, pp. 676-682.
- [25]. F. D. Paraguay, M. M. Yoshida, J. Morales, J. Solis, W. L. Estrada, Influence of Al, In, Cu, Fe and Sn dopants on the response of thin films ZnO gas sensor to ethanol vapour, *Thin Solid Films*, 373, 2000, pp. 137-140.
- [26]. S. M. Chou, L. G. Teoh, W. H. Lai, Y. H. Su, M. H. Hon, ZnO:Al thin film gas sensor for detection of ethanol vapor, *Sensor*, 6, 2006, pp. 1420-1427.
- [27]. X. L. Cheng, H. Zhao, L. H. Huo, S. Gao, J. G. Zhao, ZnO nanoparticulate thin film: preparation, characterization and gas-sensing property, *Sens. Actuators B*, 102, 2004, pp. 248-252.
- [28]. C. Ge, C. Xie, S. Cai, Preparation and gas-sensing properties of Ce-doped ZnO thin film sensors by dip-coating, *Mater. Sci. Eng. B*, 137, 2007, pp. 53-58.
- [29]. X. Zhou, T. Jiang, J. Zhang, X. Wang, Z. Zhu, Humidity sensor based on quartz tuning fork coated with sol-gel-derived nanocrystalline zinc oxide thin film, *Sens. Actuators B*, 2006.

- [30].K. W. Kim, P. S. Cho, S. J. Kim, J. H. Lee, C. Y. Kang, J. S Kim, S. J. Yoon, The selective detection of  $C_2H_5OH$  using  $SnO_2$ -ZnO thin film gas sensors prepared by combinatorial solution deposition, *Sens. Actuators B, Chemical*, Vol. 123, Issue 1, 10 April 2007, pp. 318-324 .
- [31].K. Arshak, I. Gaidan, Development of a novel gas sensor based on oxide thick films, *Mater. Sci. Eng. B*, 118, 2005, pp. 44-49.
- [32].H. J. Lim, D. Y. Lee, Y. J. Oh, Gas-sensing properties of ZnO thin films prepared by microcontact printing, *Sens. Actuators A*, 125, 2006, pp. 405-410.
- [33].Arshak, K. Gaidan, I. Gas sensing properties of  $ZnFe_2O_4/ZnO$  screen-printed thick films. *Sens. Actuators B*, 2005, 111-112, pp. 58-62.
- [34].P. Feng, Q. Wan, T. H. Wang, Contact-controlled sensing properties of flowerlike ZnO H. Mexiner, metal oxide sensor, *Sensors and Actuators B*, 33, 1996, pp. 198-202.
- [35].C. Liewhiran, S. Phanichphant, Influence of thickness on ethanol sensing characteristics of doctor- bladed thick film from flame-made ZnO nanoparticles, *Sensors*, 7, 2007, pp. 185-201.
- [36].H. Windischmann, P. Mark, *J. Electrochem. Soc.*, 126, 1979, pp. 627.
- [37].Marc, J. Madaou, S. Roy Morrison, Chemical Sensing with Solid State Devices, *Academic Press, New York*, 1989.
- [38].M. Takata, D. Tsubone, H. Yanagida, *J. Am. Ceram. Soc.*, V59, 1-2, 1976, pp. 4.
- [39].H. Windischmann, P. Mark, *J. Electrochem. Soc.*, 126, 1979, pp. 627.
- [40].G. H. Jain, V. B. Gaikwad, L. A. Patil, Studies on gas sensing performance of  $(Ba_{0.8}Sr_{0.2})(Sn_{0.8}Ti_{0.2})O_3$  thick film resistors, *Sens. Actuators B*, 122, 2007, pp. 605-612.
- [41].C. A. Harper, Hand book of thick film hybrid microelectronics, *McGraw Hill Book Co.*, New York, 1974.
- [42].G. H. Jain, L. A. Patil, M. S. Wagh, D. R. Patil, S. A. Patil, D. P. Amalnerkar, Surface modified  $BaTiO_3$  thick film resistors as  $H_2S$  gas sensors, *Sens. Actuators B*, 117, 2006, pp 159-165.
- [43].B. D. Cullity, Elements of X-ray diffraction, 2<sup>nd</sup> Edition, *Addison Wesley, Reading, M. A.*, 1978.
- [44].G. H. Jain, L. A. Patil, M. S. Wagh, D. R. Patil, S. A. Patil, D. P. Amalnerkar, Surface modified  $BaTiO_3$  thick film resistors as  $H_2S$  gas sensors, *Sens. Actuators B*, 117, 2006, pp. 159-165.
- [45].X. F. Chu., D. L. Jiang, Y. Guo, C. M. Zheng, Ethanol gas sensor based on  $CoFe_2O_4$  nano crystallines prepared by hydrothermal method, *Sens. Actuators*, 2006, 120, pp. 177-181.
- [46].Y. L. Liu, H. Wang, Z. M. Liu, H. F. Yang, G. L. Shen, R. Q. Yu, Hydrogen Sulfide sensing properties of  $NiFeO_4$  nanopowder doped with noble metal, *Sens. Actuators*, 2004, 102, pp. 148-154.
- [47].Y. Wang, J. Chen, X. Wu, *Mater. Lett.*, 2001, pp. 361-364.
- [48].C. Langfeng, L. Xingqin, M. Guangyao, *Sen. Actuators B*, 65, 2000, pp. 64-67.

2010 Copyright ©, International Frequency Sensor Association (IFSA). All rights reserved.  
(<http://www.sensorsportal.com>)

# BioMEMS 08

Yole's BioMEMS report up to 2012


**IFSA offers  
a SPECIAL PRICE**


**How Microsystems and Semiconductor Industries make money  
out of the Life Science market?**

**The report will enable you to:**

- Understand the Life Science market and define your strategy to address it
- Understand the main regulatory requirements (FDA, EMEA, JMH...)
- Get an overview of the main techniques in use or under development and the trends for the coming years
- Understand the real added value of Microsystems and Semiconductors to the Life Science industry
- Understand the main MEMS and Semiconductors success stories in the Life Science market

<http://www.sensorsportal.com/HTML/BioMEMS.htm>







## 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 it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency 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.

### 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:

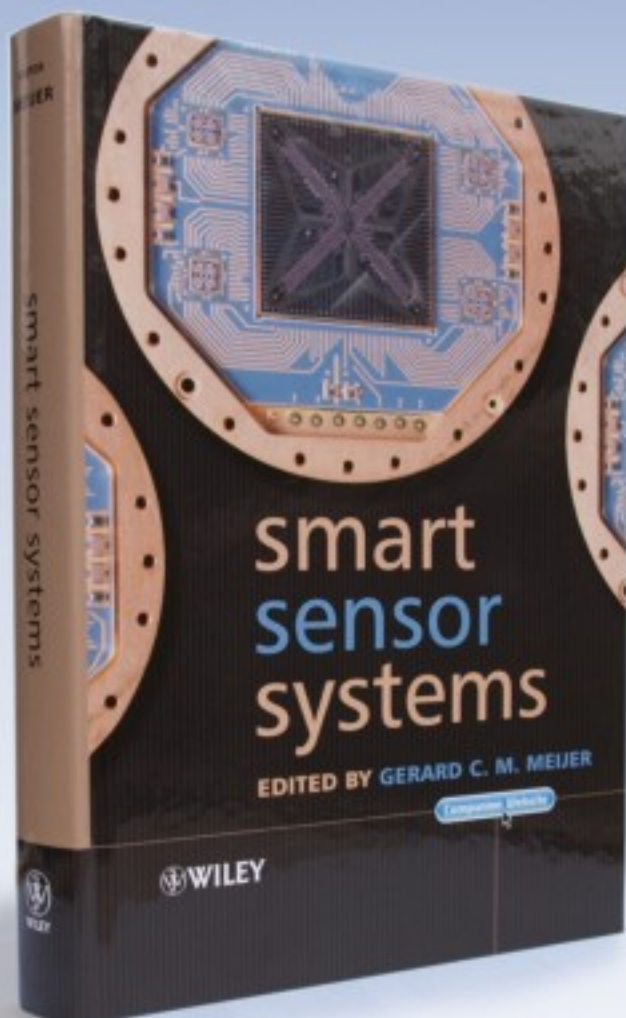
- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors 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](mailto: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](mailto:sales@sensorsportal.com) Please download also our media kit: [http://www.sensorsportal.com/DOWNLOADS/Media\\_Kit\\_2009.pdf](http://www.sensorsportal.com/DOWNLOADS/Media_Kit_2009.pdf)



**'Written by an internationally-recognized team of experts, this book reviews recent developments in the field of smart sensors systems, providing complete coverage of all important systems aspects. It takes a multidisciplinary approach to the understanding, design and use of smart sensor systems, their building blocks and methods of signal processing.'**



**Order online:**

[http://www.sensorsportal.com/HTML/BOOKSTORE/Smart\\_Sensor\\_Systems.htm](http://www.sensorsportal.com/HTML/BOOKSTORE/Smart_Sensor_Systems.htm)

**[www.sensorsportal.com](http://www.sensorsportal.com)**