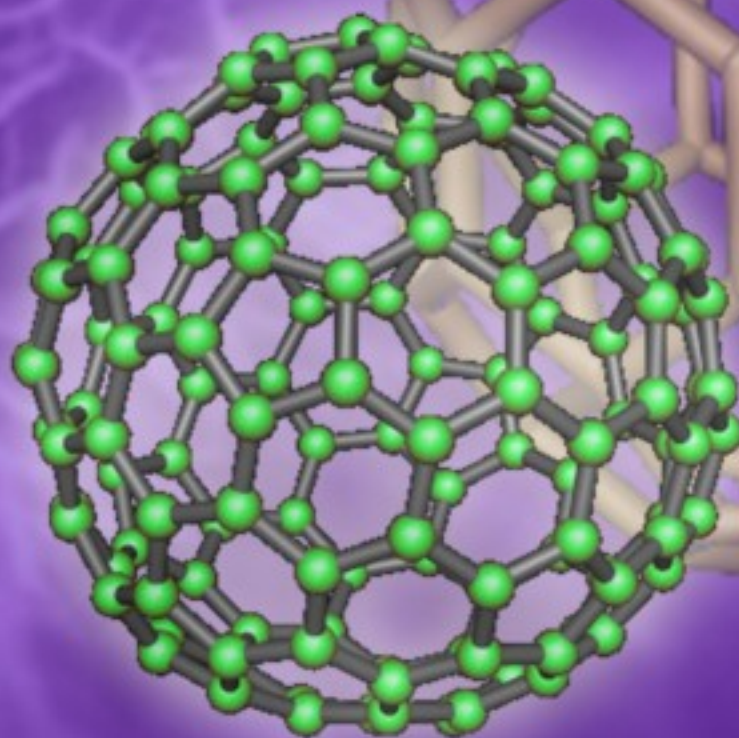
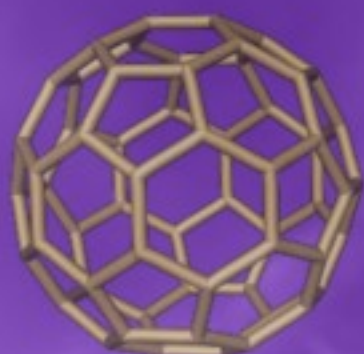


ISSN 1726-5479

SENSORS & TRANSDUCERS

11^{vol. 110}
/09



Nanosensors and Nanodevices

International Frequency Sensor Association Publishing





Editors-in-Chief: professor Sergey Y. Yurish,
Phone: +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, Vygantas, 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 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, 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, 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
Dimitropoulos, Panos, University of Thessaly, Greece
Ding, Jianning, Jiangsu Polytechnic University, China
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, 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
Granel, 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
Homentcovski, 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

Kim, Min Young, Kyungpook National University, Korea South
Ko, Sang Choon, Electronics and Telecommunications Research Institute, 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
Raouf, 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 Politècnica de Catalunya, Spain
Rodriguez, Angel, Universidad Politécnica 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
Saxena, Vibha, Bhabha Atomic Research Centre, Mumbai, India
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
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
Soleymannpour, 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
Sunriddetchka, 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
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 Shiyou University, China
Wang, Kedong, Beihang University, China
Wang, Liang, Advanced Micro Devices, 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
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
Zourob, Mohammed, University of Cambridge, UK

Contents

Volume 110
Issue 11
November 2009

www.sensorsportal.com

ISSN 1726-5479

Research Articles

| | |
|--|-----|
| Sensors Based on Nanostructured Materials: Book Review <i>Sergey Y. YURISH</i> | 1 |
| Glucose Binding Protein as a Novel Optical Glucose Nanobiosensor <i>Majed DWEIK</i> | 1 |
| Hydrogen Sensor Based on Carbon Nano-tube Fortified by Palladium <i>A. Kazemzadeh, A. F. Hessari, M. Kashani, H. Azizi and N. Jafari</i> | 9 |
| Nanostructured ZrO₂ Thick Film Resistors as H₂-Gas Sensors Operable at Room Temperature <i>K. M. Garadkar, B. S. Shirke, Y. B. Patil and D. R. Patil</i> | 17 |
| Pull-in Phenomena and Dynamic Response of a Capacitive Nano-beam Switch <i>Farid Vakili-Tahami, Hamed Mobki, Ali-asghar keyvani-janbahan, Ghader Rezazadeh</i> | 26 |
| Palladium Surface Modification of Nanocrystalline Sol-Gel derived Zinc Oxide Thin Films and its Effect on Methane Sensing <i>P. Bhattacharyya, S. Maji, S. Biswas, A. Sengupta, T. Maji, H. Saha</i> | 38 |
| Gas Sensing Properties of Indium Tin Oxide Nanofibers <i>Shiyong Xu, Yong Shi</i> | 47 |
| Design, Modeling and Optimization of a Piezoelectric Pressure Sensor based on a Thin-Film PZT Membrane Containing Nanocrystalline Powders <i>Vahid Mohammadi, Mohammad Hossein Sheikhi</i> | 56 |
| Synthesis and Properties of Thin Film Nanocomposites Sn-Y-O for Gas Sensors <i>Stanislav Rembeza, Ekaterina Rembeza, Elena Russkih, Natalia Kosheleva</i> | 71 |
| Electroanalytical Nanoparticles Electrode based on NanoTiO₂/MWCNTs Mixture <i>Ganchimeg Perenlei, Wee Tee Tan</i> | 78 |
| Structural Properties of Nanosized NiFe₂O₄ for LPG Sensor <i>N. N. Gedam, A. V. Kadu, P. R. Padole, A. B. Bodade and G. N. Chaudhari</i> | 86 |
| Low-Cost Wireless Nanotube Composite Sensor for Damage Detection of Civil Infrastructure <i>Mohamed Saafi, Lanouar Kaabi</i> | 96 |
| Cross Linking Polymers (PVA & PEG) with TiO₂ Nanoparticles for Humidity Sensing <i>Monika Joshi and R. P. Singh</i> | 105 |
| Resolution Enhancement of Thermal and Optical Nanolithography Using an Organic Dry Developing Resist and an Optimized Tip <i>Salman Noach, Michael Manevich, Naftali P. Eisenberg and Eli Flaxer</i> | 112 |

| | |
|---|-----|
| Wireless Sensor Network: Modeling and Analysis of MEMS based Nano-Nodes <i>Rohit Pathak, Satyadhar Joshi.....</i> | 120 |
| Respiration and Heartbeat Measurement for Sleep Monitoring using a Flexible AIN Piezoelectric Film Sensor <i>Nan Bu, Naohiro Ueno and Osamu Fukuda.....</i> | 131 |
| Design Optimization of Cantilever based MEMS Micro-accelerometer for High-g Applications <i>B. D. Pant, Shelley Goel, P. J. George and S. Ahmad</i> | 143 |

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).

SENSORDEVICES 2010:

**The First International Conference
on Sensor Device Technologies and Applications**

July 18 - 25, 2010 - Venice, Italy



The inaugural event SENSORDEVICES 2010, The First International Conference on Sensor Device Technologies and Applications, initiates a series of events focusing on sensor devices themselves, the technology-capturing style of sensors, special technologies, signal control and interfaces, and particularly sensors-oriented applications. The evolution of the nano- and microtechnologies, nanomaterials, and the new business services make the sensor device industry and research on sensor-themselves very challenging.

Conference tracks

Sensor devices
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

Important dates

Submission (full paper): February 20, 2010
Notification: March 25, 2010
Registration: April 15, 2010
Camera ready: April 20, 2010



<http://www.iaria.org/conferences2010/SENSORDEVICES10.html>

Electroanalytical Nanoparticles Modified Electrode Based on TiO₂/MWCNT Composites

*GANCHIMEG.P^a, W.T.TAN^a, NOR AZAH Yusof^a, J. K. GOH^b

^aDepartment of Chemistry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor D.E., Malaysia

^bSchool of Science, Monash University Sunway Campus, 46150 Bandar Sunway, Selangor D.E., Malaysia

*E-mail: ganaa_p2002@yahoo.com

Received: 10 June 2009 /Accepted: 24 November 2009 /Published: 30 November 2009

Abstract: MWCNT modified, TiO₂ modified and TiO₂/MWCNT composites modified glassy carbon electrodes were fabricated by SCM. The oxidation peak currents were obtained for the oxidation of ascorbic acid using various modified and unmodified electrodes. The electrocatalytic activity of MWCNT was further improved when it was coupled with TiO₂ nanoparticles at the GCE. Electrochemical performance of the TiO₂/MWCNT/GCE was investigated for detection of 0.5 mM ascorbic acid in 0.1 M NaCl. Under the optimized parameters, a linear calibration curve was obtained in concentration of 0.05-2 mM ascorbic acid with a sensitivity of 45 μ A/mM ($R^2=0.997$). A detection limit of TiO₂/MWCNT/GC modified electrode was found to be 7.8 μ M. SEM was used to characterize the morphology of the TiO₂/MWCNT composites at BPPGE. *Copyright © 2009 IFSA.*

Keywords: MWCNT; TiO₂; TiO₂/MWCNT; Modified GCE; Ascorbic Acid; Cyclic Voltammetry

1. Introduction

Ascorbic acid (AA) well known vitamin C, is a water soluble vitamin. Ascorbic acid is an extremely important substance, widely used in human metabolic redox mechanism. Human body does not store it automatically, so the supply must be taken daily either from food containing high vitamin C or supplements. There are many available sources from various kinds of food stuffs, which are rich in natural ascorbic acid, such as fruits and vegetables. Therefore, the significance of detecting ascorbic acid is important to numerous industries especially food and pharmaceuticals. Some reports have

proposed different methods for ascorbic acid detection, such as simple titrimetry [1], chromatography [2, 3], spectrometry [4, 5] and electrochemistry [6, 7].

Voltammetric method is one of the most commonly used methods of analyte detection because of its simplicity, high sensitivity and is less time consuming [8]. Application of some modified electrodes in electrochemical analysis is found to catalyze the oxidation process of ascorbic acid. Amongst these modified electrodes that are known to have catalytic effect on oxidation process of ascorbic acid are: polymer [9-12], amino acid [13], carbon nanotubes [14, 15] and some inorganic compounds [16, 17].

Multi walled carbon nanotubes (MWCNT) modified electrodes attract great attention in voltammetric study, due to its high electrical conductivity, chemical stability and mechanical strength. In recent time, the usage of MWCNT as modified electrodes is increasing significantly because of its high sensitivity [18-20]. Furthermore, MWCNT modified electrodes are widely applied in detection of ascorbic acid when it is not in presence of other substances [21]. Also these modified electrodes are used in simultaneous detection of ascorbic acid in presence of some interfering substance like dopamine [22, 23, 24], uric acid [25, 26, 27] and even the presence of both interfering substances [28, 29, 30]. This paper will discuss the electrochemical behavior of composites modified electrode based on $\text{TiO}_2/\text{MWCNT}$ in presence of ascorbic acid using voltammetric techniques. The usage of this electrode is applicable in the electrochemical study as an analytical sensor material.

2. Experimental

2.1. Instrumentations

The voltammetric analyzer BAS (Bioanalytical Systems, West Lafayette, IN, USA): CV-50W was used in electrochemical measurements of linear sweep voltammetry (LSV), cyclic voltammetry (CV). A conventional three-electrode cell was employed, a platinum wire - a counter electrode (CE), an Ag/AgCl in 2 M NaCl - a reference electrode (RE) and a 3 mm diameter bare glassy carbon electrode (GCE) - working electrode (WE). A GCE was used after careful polishing by 0.3 μL alumina slurry, ultrasonic grinding for 1 minute and rinsing with distilled water before each modification process. Scanning electron microscopy (SEM) was used to characterize the surface of the $\text{TiO}_2/\text{MWCNT}$ composites at 5 mm diameter basal plane pyrolytic graphite electrode (BPPGE) (Model JOEL, JSM-6400 machine).

2.2. Reagents

Ascorbic acid (purity of 99.7 %) and titanium dioxide (TiO_2) nanoparticles solution (dispersion in water by 5 % weight, <100 nm particle size) were obtained from Aldrich (USA). MWCNT with purity of 95 %, 20–40 nm diameter and 5-15 μm length in powder form was used without further purification. All other chemicals were of analytical grade pure and prepared with deionized distilled water. Deaerated with oxygen-free nitrogen gas was purged before the measurement. Analyte and electrolyte solutions were freshly prepared before each experiment.

2.3. Preparation of the $\text{TiO}_2/\text{MWCNT}/\text{GC}$ Modified Electrode

In this work, solvent casting method (SCM) was used for modifying the bare GCE. A stock solution of TiO_2 nanoparticles was obtained in dispersion in water form. 1 mg MWCNT powder was dispersed into 1 mL dimethylformamide (DMF) with ultrasonication for 30 minutes. 1 μL suspension of MWCNT/DMF and 1 μL TiO_2 (dispersed in water) were deposited onto the clean electrode surface,

and then mixed composites were dried in oven for 2 minutes (40 °C) to remove the solvents. A TiO₂/MWCNT film modified GCE immersed in 0.1 M NaCl aqueous solution was characterized by voltammetric techniques.

3. Results and Discussion

3.1. Current Enhancement

Fig.1 shows the linear sweep voltammograms for the oxidation of 0.5 mM ascorbic acid on the surface of MWCNT modified, TiO₂ modified, TiO₂/MWCNT composites modified and unmodified (bare) glassy carbon electrodes in 0.1 M NaCl electrolyte solution (pH 6). The oxidation process of ascorbic acid appeared irreversible. A well-defined oxidative peak current was obtained at +221 mV versus Ag/AgCl when using TiO₂/MWCNT composites modified electrode with a scan rate of 100 mV/s. Current enhancements of 3.1 and 5 folds were observed when ascorbic acid was oxidized on the surface of MWCNT/GCE (Fig.1b) and TiO₂/MWCNT/GCE (Fig.1a) as compared with when it was on the surface of unmodified GCE (Fig.1d). Slight peak shifts to positive direction were observed at those modified electrodes when compared to that observed at an unmodified electrode. However, TiO₂/GC modified electrode (Fig.1c) itself did not show a noticeable electrocatalytic effect. When TiO₂ was coupled with MWCNT as composites, TiO₂ produced an enhancement in electrocatalytic activity of MWCNT. Consequently, TiO₂/MWCNT/GC composites modified electrode, which is a more sensitive electrode, was used in rest of the experiments.

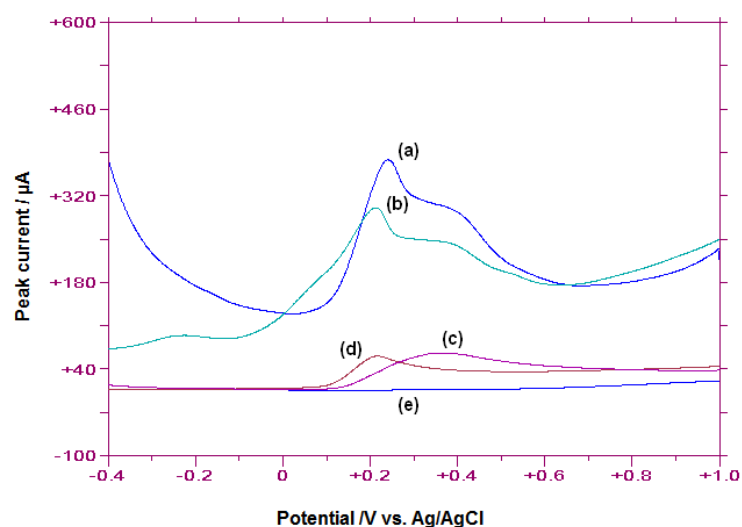


Fig.1. Voltammograms obtained for the oxidation of 0.5 mM ascorbic acid in 0.1 M NaCl with a scan rate of 100 mV/s using (a) TiO₂/MWCNT/GCE; (b) MWCNT/GCE; (c) TiO₂/GCE; bare glassy carbon electrodes (d) in presence and (e) absence of ascorbic acid.

3.2. Effect of Potential Cycling

Cyclic voltammogram recorded for the oxidation of 0.5 mM ascorbic acid at the TiO₂/MWCNT composites modified GCE immersed in 0.1 M NaCl for 20 potential cycling (voltammogram is not

shown). From the second cycle of the voltammogram, the peak current of ascorbic acid slightly decreased, from fourth cycling onward the peak current stabilized. Even after 20th potential cycle, the oxidation peak of ascorbic acid remained high; consequently, it can be concluded that TiO₂/MWCNT/GCE is stable electrode.

3.3. Effect of Scan Rate

Experiment to investigate the effect of scan rate was carried out for the oxidative of 0.5 mM ascorbic acid in 0.1 M NaCl at the TiO₂/MWCNT/GCE using various scan rates ranging from 10 mV/s to 300 mV/s. The result showed that when the scan rate (ν) increased, the oxidation current (I_p) also increased, and peak potential slightly shifted to positive direction due to the heterogeneous kinetics and IR drop effect. It was observed that in high scan rate, the peak current was obtained not very significant, so a linear dependence was obtained in the range of 10-70 mV/s scan rates (Fig.2). A correlation coefficient of $R^2=0.99$ and a slope of 0.45 were obtained from the graph of logarithm peak current ($\log I_p$) versus square root of scan rate ($\log \nu$). This suggested oxidation process of ascorbic acid is diffusion controlled.

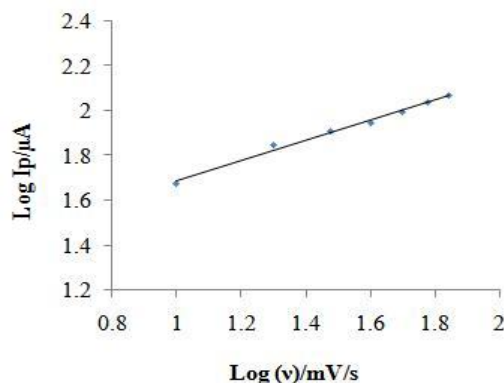


Fig.2. A plot of $\log(\nu)$ vs. $\log(I_p)$ for the oxidation of 0.5 mM ascorbic acid on the surface of TiO₂/MWCNT/GCE with different scan rates of 10-70 mV/s.

3.4. Effect of pH

In this experiment, pH buffer solutions (pH 2–12) were prepared and used to optimize the condition of electrolyte solution. The result of electrocatalytic process of ascorbic acid at the TiO₂/MWCNT/GC modified electrode in different pH solutions is shown in Fig.3. It was observed that when pH variation increased, the peak potential for oxidation of ascorbic acid shift toward negative direction. As can be seen from a graph, the peak currents recorded with a significant increase in low pH value (pH 2 - 6). While a decrease in peak currents was noticed after from pH 7 onward. Hence, the optimum condition of electrolyte solution chosen was pH 6.

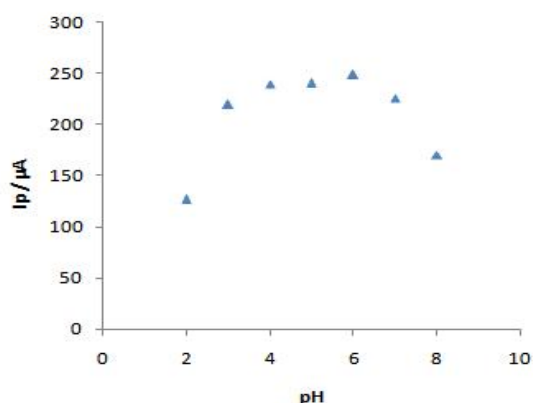


Fig.3. A plot of pH vs. I_p for the oxidation of ascorbic acid at the $\text{TiO}_2/\text{MWCNT}/\text{GCE}$ with different pH conditions and a scan rate of 100 mV/s.

3.5. Calibration Graph

The dependence of peak current on concentration of ascorbic acid (range of 0.05 mM - 5 mM) was carried out at the $\text{TiO}_2/\text{MWCNT}/\text{GC}$ composites modified electrode using CV with a scan rate of 100 mV/s. A linear response was found with a correlation coefficient $R^2=0.997$ in the concentration of ascorbic acid up to 2 mM. The sensitivity of the modified electrode obtained from the equation was 45 $\mu\text{A}/\text{mM}$, and detection limit was 7.8 μM (based on $3\delta/m$).

3.6. Effect of Supporting Electrolyte Concentration

The voltammograms recorded for the oxidation of ascorbic acid at $\text{TiO}_2/\text{MWCNT}/\text{GC}$ modified electrode in NaCl supporting electrolyte of various concentrations of 0.1 M – 4 M. Anodic peak resolutions of ascorbic acid increased from when the concentration of the electrolyte was 0.1 M until when it was 2 M. But in higher concentration range of 3 M and 4 M, the peak current decreased because of large amount cations around the vicinity of the electrode surface in the aqueous solution. It can be concluded from the forgoing, the most optimum range of concentrations are 0.1 M - 2 M for supporting electrolyte in voltammetric experiment.

3.7. SEM

Fig.4. shows scanning electron micrographs of surface of the $\text{TiO}_2/\text{MWCNT}$ composites after electrolysis. Morphology was performed at the 5 mm diameter basal plane pyrolytic graphite electrode (BPPGE) in the presence of ascorbic acid. Thin film of $\text{TiO}_2/\text{MWCNT}$ composites (with different sizes) formed homogeneously on the BPPGE surface (Fig.4a). It can be seen clearly from Fig.4b, MWCNT was presented by thin fibers, which were shaped as bundles with some them joined together. The stability of the film was evident as the SEM remains were not scattered even after many potential cycling.

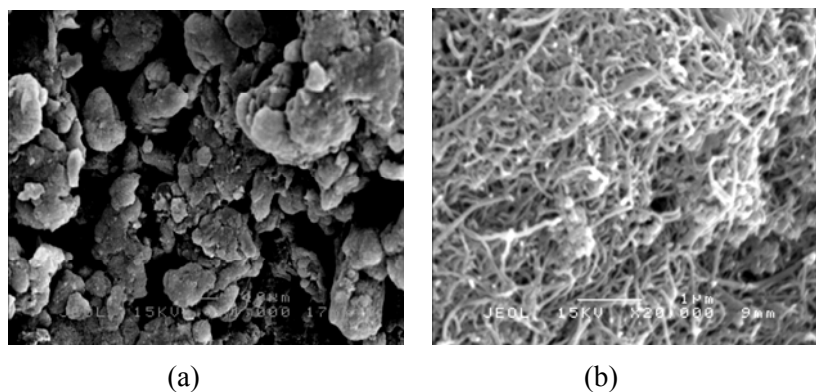


Fig.4. Scanning Electron Micrographs of the TiO₂/MWCNT composites at BPPGE were characterized after electrolysis with enlargements of (a) 1.000 and (b) 20.000 times.

4. Conclusions

MWCNT modified GCE has been successfully fabricated coupled with TiO₂ nanoparticles as composites using SCM. The TiO₂/MWCNT/GC modified electrode showed an enhancement of peak current when compared with MWCNT/GC modified electrode in the oxidation of ascorbic acid. The peak current was found to be significantly dependent on pH, scan rate and concentration of ascorbic acid and supporting electrolyte. The TiO₂/MWCNT/GC modified electrode possessed some advantages such as a good detection limit, high stability and simplicity in electrochemical studies as such can be used in sensor electrode.

References

- [1] M. M. Aly, *Analytica Chimica Acta*, 106, 1979, 379-383
- [2] Airton Vicente Pereira, Orlando Fatibello-Filho, *Analytica Chimica Acta*, 366, 1998, 55-62
- [3] Fabiano O. Silva, *Food Control*, 16, 2005, 55-58
- [4] M.C. Yebra, R.M. Cespón, A. Moreno-Cid, *Analytica Chimica Acta*, 448, 2001, 157-164
- [5] Kate Grudpan, Kiattisak Kamfoo, Jaroon Jakmune, *Talanta*, 49, 1999, 1023-1026
- [6] B. Nalini and S. Sriman Narayanan, *Analytica Chimica Acta*, 405, 2000, 93-97
- [7] Li Tian, Li Chen, Li Liu, Nan Lu, Wenbo Song, Hongding Xu, *Sensors and Actuators B* 113, 2006, 150-155
- [8] M. J. Esteve, R. Farre, A. Frigola, J. C. Lopez, *Food Chemistry*, 52, 1995, 99-102
- [9] Suely S.L. Castro, Valdir R. Balbo, Paulo J.S. Barbeira, Nelson R. Stradiotto, *Talanta*, 55, 2001, 249-254
- [10] Ageliki B. Florou, Mamas I. Prodromidis, Miltiades I. Karayannis, Stella M. Tzouwara-Karayanni, *Analytica Chimica Acta*, 409, 2000, 113-121
- [11] T. Selvaraju and R. Ramaraj, *Electrochem. Commun.*, 5, 2003, 667-672
- [12] A. Malinauskas, R. Garjonyte, R. Mažeikiene, I. Jureviciute, *Talanta*, 64, 2004, 121-129
- [13] Ai-Min Yu, Hong-Yuan Chen, *Analytica Chimica Acta*, 344, 1997, 181-185
- [14] Zonghua Wang, Jun Liu, Qionglian Liang, Yiming Wang and Guoan Luo, *Analyst*, 127, 2002, 653 - 658
- [15] Ping Zhang, Fang-Hui Wu, Guang-Chao Zhao, Xian-Wen, *Bioelectrochem*, 67, 2005, 109-114
- [16] Chen-Xin Cai, Kuan-Hong Xue, Shi-Min Xu, *Journal of Electroanalytical Chemistry* 486, 2000, 111-118
- [17] M.H. Pournaghi-Azar, H. Razmi-Nerbin, *J. of Electroanal. Chem*, 488, 2000, 17-24
- [18] Arben Merkoci, *Microchim Acta*, 152, 2006, 157-174
- [19] Xuan Dai, Gregory G. Wildgoose and Richard G. Compton, *Analyst*, 131, 2006, 901-906

- [20] Shuhong Wei, Faqiong Zhao, and Baizhao Zeng, *Microchim Acta*, 150, 2005, 219–224
- [21] J.K. Goh, W.T. Tan, F.T. Lim, N.A.M. Maamor, *The Malaysian J. Anal. Sciences*, 12, 2 2008, 480 - 485
- [22] J. Tashkhourian, M.R. Hormozi Nezhad, J. Khodavesi, S. Javadi, *J. Electroanal. Chem*, 633, 2009, 85–91
- [23] Saeed Shahrokhian, Hamid Reza Zare-Mehrjardi, *Electrochimica Acta*, 52, 2007, 6310–6317
- [24] Ping Zhang, Fang-Hui Wu, Guang-Chao Zhao, Xian-Wen Wei, *Bioelectrochem.* 67, 2005, 109–114
- [25] Yifang Zhao, Yuqian Gao, Dongping Zhan, Hui Liu, Qiang Zhao, *Talanta*, 66, 2005, 51–57
- [26] Alaécio P. dos Reis, César R. T. Tarley, Lauro T. Kubota, *J. Braz. Chem. Soc*, 19, 8, 2008, 1567-1573
- [27] Shuhong Wei, Faqiong Zhao, and Baizhao Zeng, *Microchim Acta*, 150, 2005, 219–224
- [28] Umasankar Yogeswaran, Shen-Ming Chen, *Electrochimica Acta*, 52, 2007, 5985–5996
- [29] Suhee Jo, Haesang Jeong, Si Ra Bae, Seungwon Jeon, *Microchemical Journal*, 88, 2008, 1–6
- [30] Aihua Liu, Itaru Honma, Haoshen Zhou, *Biosensors and Bioelectronics*, 23, 2007, 74–80

2009 Copyright ©, International Frequency Sensor Association (IFSA). All rights reserved.
(<http://www.sensorsportal.com>)



International Armoured Vehicles 1-5 February 2010
Excel Centre,
London, UK

Apply for your Free Exhibition Pass now!

Please Quote:
SENSORPORTALS
www.armoured-vehicles.co.uk

This is the only international exhibition & conference dedicated exclusively to the armoured vehicle community. International Armoured Vehicles brings together senior military and industry experts, providing opportunities to gain expert insights on armoured vehicle trends, global procurement activity and lessons learnt from the battlefield, as well as to conduct business with the world's leading vehicle, system and component manufacturers and smaller specialist suppliers.

Exhibition Features:

- **Vehicle display:** including **TMV's** new 6x6M and **IVECO's** LMV
- **New technology display:** including **NIITEK's** mine detection system and **Rafael's** active protection system
- **Innovation briefings:** free presentations showcasing in-theatre applications of new technologies including **RUAG's** add-on armour and **DuPont's** spall liners
- **More stands** hosting more system, component and specialist suppliers new to the event including **Fabreeka** and **MDH Bioquell**

For more information please visit: www.armoured-vehicles.co.uk

BioMEMS 08

Yole's BioMEMS report up to 2012

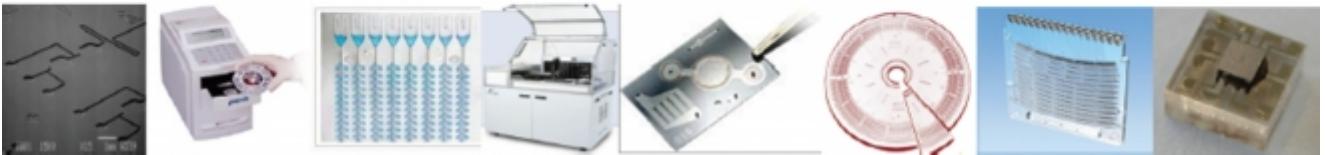
IFSA offers
a SPECIAL PRICE

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

The report will enable you to:

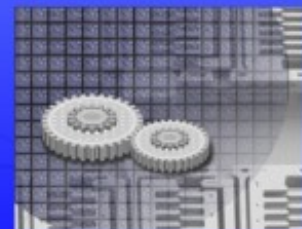
- Understand the Life Science market and define your strategy to address it
- Understand the main regulatory requirements (FDA, EMEA, JMHLW...)
- Get an overview of the main techniques in use or under development and the trends for the coming years
- Understand the real added value of Microsystems and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



International Frequency Sensor Association

is a professional association and Network of Excellence,
created with the aim to encourage the researches and developments
in the area of quasi-digital and digital smart sensors and transducers.



For more information about IFSA membership, visit
<http://www.sensorsportal.com>

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:

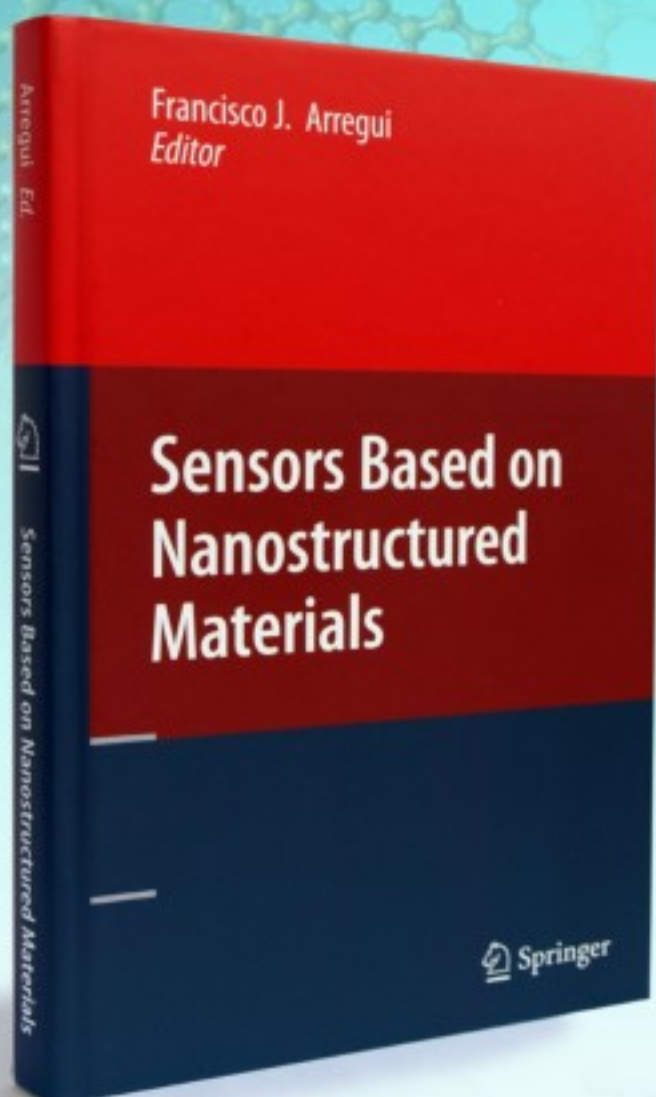
- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors 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 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_2009.pdf



'Sensors Based on Nanostructured Materials presents the many different techniques and methods of fabricating materials on the nanometer scale and specifically, the utilization of these resources with regard to sensors. The techniques which are described here are studied from an application-oriented perspective, providing the reader with a broader view of the types of nanostructured sensors available.'

Sensors Based on Nanostructures Materials is suitable for academic and industrial research scientists as well as engineers.'

"It is a valuable source for those who need to have a summary of nanosensors based on nanostructured materials fabricated with many different techniques."
(Sergey Y. Yurish, *Sensors & Transducers*, Vol.110, Issue 11, November 2009).

Order online:

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