

ISSN 1726-5479

# SENSORS & TRANSDUCERS

9<sup>vol. 120</sup>  
/10



## TEDS Sensors, IEEE 1451 Standards

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, 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**, N.I. Center for Higher Education, (N.I. University), India  
**Chen, Jiming**, Zhejiang University, China  
**Chen, Rongshun**, National Tsing Hua University, Taiwan  
**Cheng, Kuo-Sheng**, National Cheng Kung University, Taiwan  
**Chiang, Jeffrey (Cheng-Ta)**, Industrial Technol. Research Institute, Taiwan  
**Chiriac, Horia**, National Institute of Research and Development, Romania  
**Chowdhuri, Arijit**, University of Delhi, India  
**Chung, Wen-Yaw**, Chung Yuan Christian University, Taiwan  
**Corres, Jesus**, Universidad Publica de Navarra, Spain  
**Cortes, Camilo A.**, Universidad Nacional de Colombia, Colombia  
**Courtois, Christian**, Universite de Valenciennes, France  
**Cusano, Andrea**, University of Sannio, Italy  
**D'Amico, Arnaldo**, Università di Tor Vergata, Italy  
**De Stefano, Luca**, Institute for Microelectronics and Microsystem, Italy  
**Deshmukh, Kiran**, Shri Shivaji Mahavidyalaya, Barshi, India  
**Dickert, Franz L.**, Vienna University, Austria  
**Diegues, 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  
**Djordjevich, 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  
**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, Selemani**, 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 Shiyou 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  
**Zourob, Mohammed**, University of Cambridge, UK

# Contents

Volume 120  
Issue 9  
September 2010

www.sensorsportal.com

ISSN 1726-5479

## Research Articles

<b>Design of a Modular Signal Conditioning Circuit for Biopotential Sensors</b> <i>Winncy Y. Du, Winston Jose, Jake Askeland</i> .....	1
<b>MEMS Accelerometers Sensors: an Application in Virtual Reality</b> <i>Daniel Corrêa, Douglas Santos, Leonardo Contini, Alexandre Balbinot</i> .....	13
<b>Contactless Quality Monitoring Sensor Based on Electrical Conductivity Measurements</b> <i>Armin Satz, W. Granig, D. Tumpold and F. Reininger</i> .....	27
<b>Gas Sensing Properties of Pure and Cr Activated WO<sub>3</sub> Thick Film Resistors</b> <i>V. B. Gaikwad, R. L. Patil, M. K. Deore, R. M. Chaudhari, P. D. Hire, S. D. Shinde, G. H. Jain</i> .....	38
<b>Ellipsometric Immunosensor for Detection of Amyloid Precursor Protein with a View of Alzheimer's Disease Diagnostics</b> <i>Alexei Nabok, Mohd Kamarulzaki Mustafa, David Parkinson, Anna Tsargorodskaya</i> .....	53
<b>Optical Tomography System: Charge-coupled Device Linear Image Sensors</b> <i>M. Idroas, R. Abdul Rahim, M. H. Fazalul Rahiman, R. G. Green, M. N. Ibrahim</i> .....	62
<b>Spray Pyrolyzed Polycrystalline Tin Oxide Thin Film as Hydrogen Sensor</b> <i>Ganesh E. Patil, D. D. Kajale, D. N. Chavan, N.K. Pawar, V. B. Gaikwad, G. H. Jain</i> .....	70
<b>Research of a Novel Three-dimensional Force Flexible Tactile Sensor Based on Conductive Rubber</b> <i>Fei Xu, Yunjian Ge</i> .....	80
<b>Induction Magnetometers – Design Peculiarities</b> <i>Valeriy Korepanov, Vira Pronenko</i> .....	92
<b>Noise Feature Analysis in Pulse Temperature Modulated MOS Gas Sensors</b> <i>Nimisha Dutta and Manabendra Bhuyan</i> .....	107
<b>Drowsy Driver Detection via Steering Wheel</b> <i>Herlina Abdul Rahim, Zulkifli Yusop and Ruzairi Abdul Rahim</i> .....	119
<b>Microwave Detection of Soil Moisture Using C-Band Rectangular Waveguide</b> <i>Jayesh Pabari, Shrutisingh Yadav and Rajani Singh</i> .....	134
<b>Performance Characterization of a Long-Stroke Direct-Drive Electromagnetic Linear Actuator</b> <i>Mohammad I. Kilani</i> .....	142
<b>Sensitivity Enhancement of Biochemical Sensors Based on Er<sup>+3</sup> Doped Microsphere Coupled to an External Mirror</b> <i>Alireza Bahrampour, Azam Gholampour Azhir, Razie Taghiabadi, Kazem Rahimi Yazdi</i> .....	152

**Design and Development of Embedded Based System for the Measurement of Dielectric Constant Spectroscopy for Liquids**

V. V. Ramana C. H., Narsinga Rao S., Ashok Kumar M., Jayaramudu J., Kathalingam A., Sudhakar S., Mi-Ra Kim, Yeon- Sik Chae and Jin-Koo Rhee..... 162

**Implementation of Distributed Measurement Process on Clinical Blood Analyzer**

P. Neelamegam, S. Kumaravel, K. Muruganathan ..... 171

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).

**IMU Market 2007-2012**  
Yole's IMU market report  
IFSA offers a SPECIAL PRICE

**Competitive market analysis of the RLG – FOG – DTG - Quartz and MEMS based Inertial Measurement Units**

*This report not only describes the market at the player and application level, but it provides a global view of the IMU market allowing the report user to build diversification strategies taking into account technical requirements.*

[http://www.sensorsportal.com/HTML/IMU\\_Markets.htm](http://www.sensorsportal.com/HTML/IMU_Markets.htm)



**Emerging MEMS 2010**  
Technologies & Markets 2010 Report

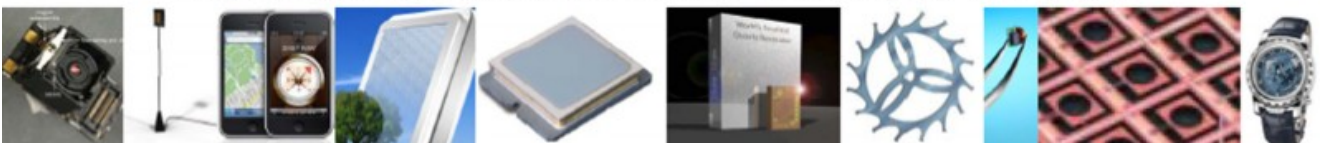
**Innovative developments in MEMS devices will add more than \$2B to the total MEMS market by 2015 !**

*This report presents a market and technical overview for MEMS-based Auto Focus, Electronic Compass, Energy Harvesting, Micro-bolometers, Micro displays, Micro fuel cells, Micro speakers, Micro structures, Microtips, Oscillators and RFID.*

*Estimated to be \$550M in 2009 a few % of the total MEMS business, Emerging MEMS markets have the potential to add \$2.2B to the overall MEMS market by 2015.*

IFSA offers a SPECIAL PRICE

[http://www.sensorsportal.com/HTML/Emerging\\_MEMS.htm](http://www.sensorsportal.com/HTML/Emerging_MEMS.htm)



## The Sixth International Conference on Systems



# ICONS 2011

January 23-28, 2011 - St. Maarten,  
The Netherlands Antilles



### Important deadlines:

Submission (full paper)	September 25, 2010
Notification	October 20, 2010
Registration	November 5, 2010
Camera ready	November 5, 2010

<http://www.iaria.org/conferences2011/ICONS11.html>

### Tracks:

- Systems' theory and practice
- System engineering
- System instrumentation
- Embedded systems and systems-on-the-chip
- Target-oriented systems [emulation, simulation, prediction, etc.]
- Specialized systems [sensor-based, mobile, multimedia, biometrics, etc.]
- Validation systems
- Security and protection systems
- Advanced systems [expert, tutoring, self-adapting, interactive, etc.]
- Application-oriented systems [content, eHealth, radar, financial, vehicular, etc.]
- Safety in industrial systems
- Complex Systems

## The Seventh International Conference on Networking and Services



# ICNS 2011

May 22-27, 2011 - Venice, Italy



### Important deadlines:

Submission (full paper)	January 10, 2011
Notification	February 20, 2011
Registration	March 5, 2011
Camera ready	March 20, 2011

<http://www.iaria.org/conferences2011/ICNS11.html>

### Tracks:

- ENCOT: Emerging Network Communications and Technologies
- COMAN: Network Control and Management
- SERVI: Multi-technology service deployment and assurance
- NGNUS: Next Generation Networks and Ubiquitous Services
- MPQSI: Multi Provider QoS/SLA Internetworking
- GRIDNS: Grid Networks and Services
- EDNA: Emergency Services and Disaster Recovery of Networks and Applications
- IPv6DFI: Deploying the Future Infrastructure
- IPDy: Internet Packet Dynamics
- GOBS: GRID over Optical Burst Switching Networks

## The Third International Conference on Bioinformatics, Biocomputational Systems and Biotechnologies



# BIOTECHNO 2011

May 22-27, 2011 - Venice, Italy



### Tracks:

#### A. Bioinformatics, chemoinformatics, neuroinformatics and applications

- Bioinformatics
- Advanced biocomputation technologies
- Chemoinformatics
- Bioimaging
- Neuroinformatics

#### B. Computational systems

- Bio-ontologies and semantics
- Biocomputing
- Genetics
- Molecular and Cellular Biology
- Microbiology

#### C. Biotechnologies and biomanufacturing

- Fundamentals in biotechnologies
- Biodevices
- Biomedical technologies
- Biological technologies
- Biomanufacturing

### Important deadlines:

Submission (full paper)	January 10, 2011
Notification	February 20, 2011
Registration	March 5, 2011
Camera ready	March 20, 2011

<http://www.iaria.org/conferences2011/BIOTECHNO11.html>

## Optical Tomography System: Charge-coupled Device Linear Image Sensors

<sup>1</sup>M. Idroas, <sup>2</sup>R. Abdul Rahim, <sup>3</sup>M. H. Fazalul Rahiman,  
<sup>4</sup>R. G. Green, <sup>2</sup>M. N. Ibrahim

<sup>1</sup>Faculty of Chemical and Natural Resources Engineering, Universiti Teknologi Malaysia,  
81310 Skudai, Johor, Malaysia

<sup>2</sup>Faculty of Electrical Engineering, Universiti Teknologi Malaysia,  
81310 Skudai, Johor, Malaysia

<sup>3</sup>School of Mechatronic Engineering, Universiti Malaysia Perlis,  
02600 Arau, Perlis, Malaysia

<sup>4</sup>School of Engineering, Sheffield Hallam University, Sheffield, United Kingdom  
E-mail: [mariani@fkkksa.utm.my](mailto:mariani@fkkksa.utm.my)

*Received: 12 August 2010 / Accepted: 14 September 2010 / Published: 27 September 2010*

---

**Abstract:** This paper discussed an optical tomography system based on charge-coupled device (CCD) linear image sensors. The developed system consists of a lighting system, a measurement section and a data acquisition system. Four CCD linear image sensors are configured around a flow pipe with an octagonal-shaped measurement section, for a four projections system. The four CCD linear image sensors consisting of 2048 pixels with a pixel size of 14 micron by 14 micron are used to produce a high-resolution system. A simple optical model is mapped into the system's sensitivity matrix to relate the optical attenuation due to variations of optical density within the measurement section. A reconstructed tomographic image is produced based on the model using MATLAB software. The designed instrumentation system is calibrated and tested through different particle size measurements from different projections. *Copyright © 2010 IFSA.*

**Keywords:** Bubbles velocity, Optical tomography, Inverse algorithm.

---

### 1. Introduction

Industrial processes are often controlled using process measurements at one or more points. The amount of information contained in such measurements is often minimal, and in some cases

(multiphase flow) there are no adequate sensors [1]. To understand better certain chemical processes, a more sophisticated approach is needed. Process tomography is a means of visualizing the internal behaviour of industrial processes, where tomographic images provide valuable information about the process for assessment of equipment designs and on-line monitoring [2].

Current activity in the development of new investigative techniques has focused on the use of tomography to provide cross-sectional and three-dimensional images of internal multi-phase flow behaviour in actual process flow [3]. The tomographic system usually consists of an array of sensors, a signal conditioning and data acquisition system, and a reconstruction and display system [4], where the collected data are processed using a reconstruction algorithm to provide an image [5].

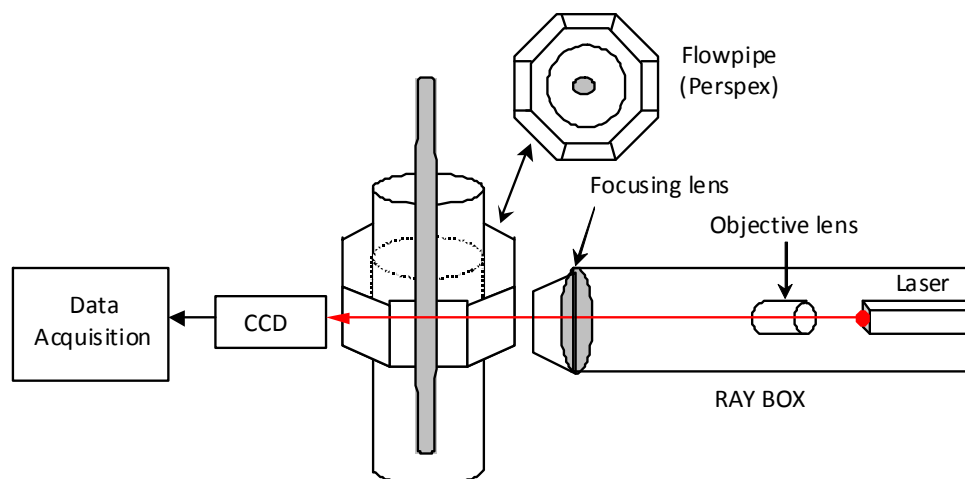
There are several modalities used in process tomography such as electrical (impedance, capacitance, inductance), radiation (optical, x-ray, positron electromagnetic (PET), magnetic resonance) and acoustic (ultrasonic) [6]. Optical techniques are non-intrusive in nature and safe as the transducer does not require direct physical contact with the measurand. The technique has high efficiency [7] and could improve manufacturing in the chemical industries [8]. For processes handling transparent fluids and where optical access is possible, optical techniques can provide high-resolution images [9]. The optical tomography technique with its direct optical is capable of performing on-line measurements [10].

An optical tomography system based on optical fibres was developed by Horbury et al [11] aimed at providing information on particle size distribution, where three projections are used with each consisting of 16 or 32 pixels. Three ranges of bead size - 100 - 150  $\mu\text{m}$ , 150 - 300  $\mu\text{m}$  and 425 - 600  $\mu\text{m}$  are used.

This paper presents a four projection, optical tomography system using charge coupled devices (CCD) as detectors. The CCD based optical tomography system has high definition sensors. Each of the four devices has 2048 sensors (or pixels), with sensor size of 0.014 mm by 0.014 mm. Moreover, the system is capable of sizing the whole volume of process flow and the technique is non-intrusive.

## 2. Design of the Optical Tomography System

The optical tomography system consists of four projections; each channel or projection has a lighting system, detection system, triggering system and data acquisition system. Fig. 1 shows the single projection set-up of the system.



**Fig. 1.** The ultrasonic attenuation model [12].

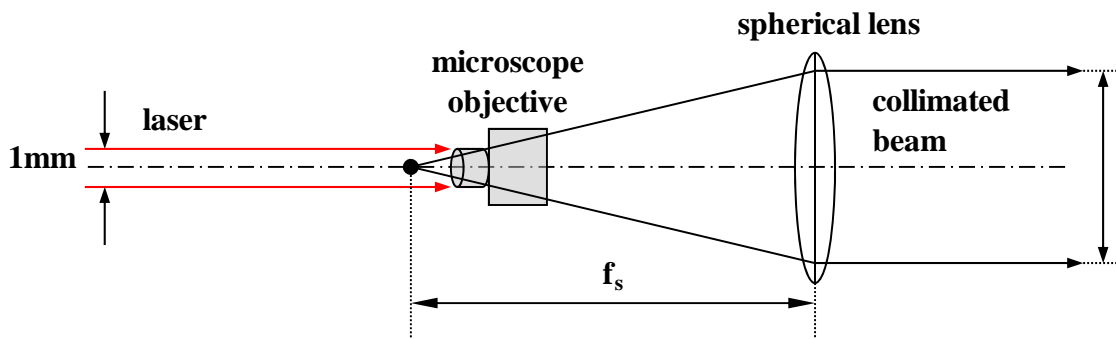


## 2.1. The Lighting System

The lighting system consists of a laser diode, an objective lens and a spherical lens. All of these components are assembled in a metal-box termed the 'ray-box'.

The laser module used in the system produces red light at a wavelength of 680 nanometer. The laser module operates at low power since the CCD linear image sensor (ILX551A) is very sensitive to light. The CCD can be easily saturated if the light illuminating it is too bright. The other reason is due to safety as the laser module used is a Class II type.

The laser has a beam diameter of 1 mm. The minimum required output in order to illuminate the CCD linear image sensor is 28 mm. To provide reasonably uniform illumination the laser is to be expanded to 40 mm i.e. a beam expander of 40 times. The beam expander lens is used with a spherical lens as a telescope with a magnification of 40 times (Fig. 2).



**Fig. 2.** Collimated beam produced by laser [12].

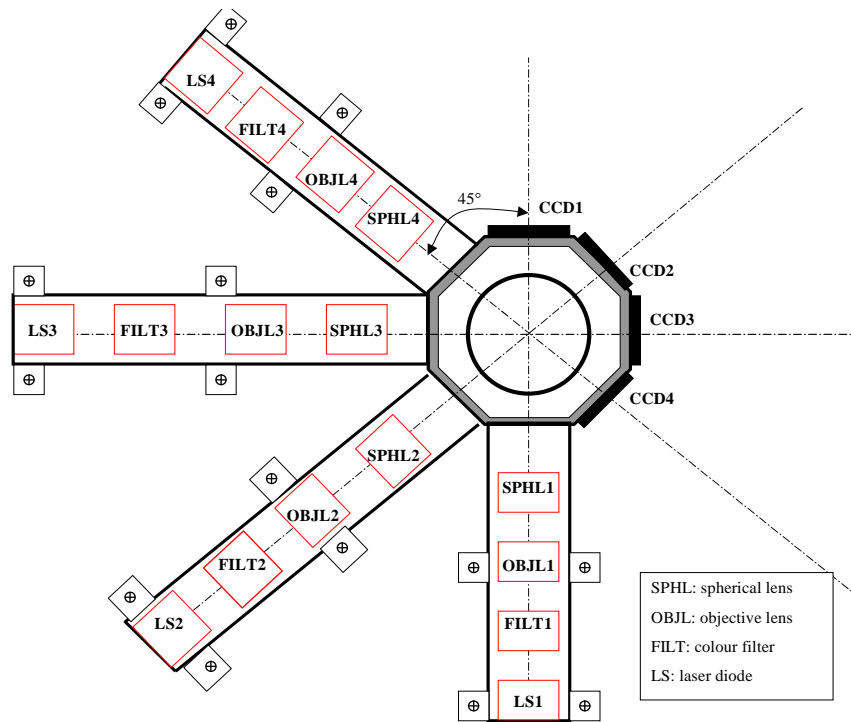
The diameter of the spherical lens is 50 mm to ensure the magnified beam is transmitted out properly onto the CCD linear image sensor. The output light from the ray-box is collimated and monochromatic, and is passed through a 1 mm width slit at the 'nose' of the ray-box.

## 2.2. The Detection System

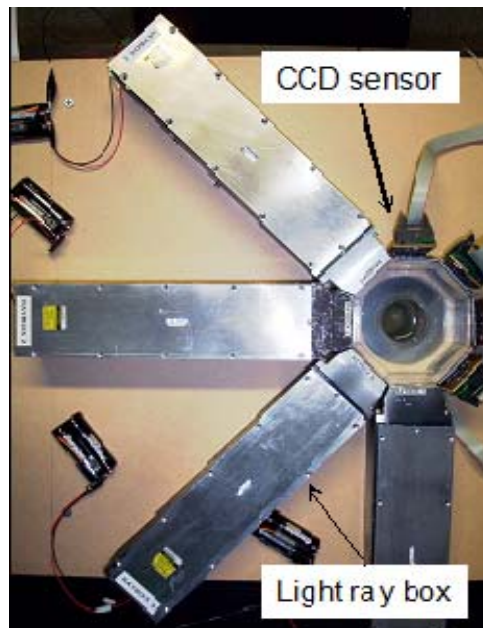
The detection system is the sensing components in the optical tomography system where objects in the test cell are sensed using a charge coupled device (CCD) linear image sensor. The linear image sensor used is the Sony ILX551A with 2048 pixels where each pixel size is 14-micron by 14-micron. The output of the CCD linear image sensor is then acquired by the data acquisition system. The linear image sensor is capable of scanning only a line of an object compared to an area image sensor, which can capture or scan a specific area depending on the size of the image sensor. However, the linear image sensor is relatively low cost and produces a high definition line scan which is readily transferred to a computer for further analysis.

The Sony ILX551A is a 22-pin DIP linear image sensor with a built-in timing generator and clock-drivers ensuring direct drive at 5 volts logic for easy use.

The four ray-boxes are arranged surrounding the hexagon part of the measurement section with the corresponding CCD linear image sensors on the opposite side (Fig. 3 and 4). Individual CCD drivers are connected to each of the CCD linear image sensors used.



**Fig. 3.** The measurement section of the optical tomography system [13].



**Fig. 4.** A photograph of the CCD tomographic system [13].

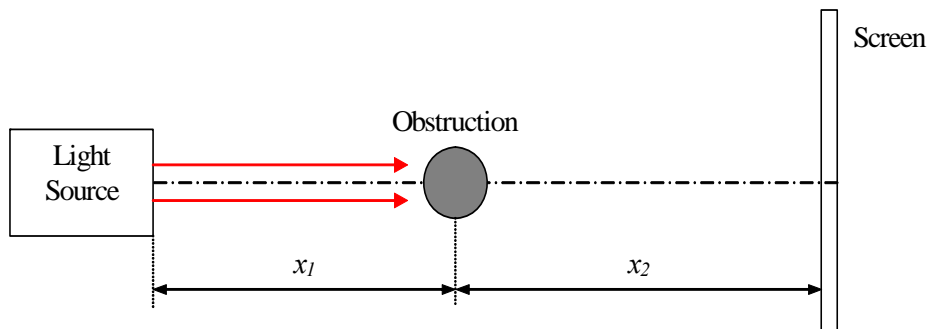
### 2.3. Triggering and DAS System

A triggering system which is based on a PIC microcontroller, i.e. PIC16F84, is used to coordinate the timing and synchronization between the units in the system. The Keithley DAS was chosen as the data acquisition system, and it is capable of acquiring data at a maximum rate of 333 kHz. An external trigger and clocking input are connected to the data acquisition system for acquiring output voltage of every pixel on the CCD linear image sensor.

### 3. The Effect of Diffractions

An opaque body placed midway between a screen and a point source casts an intricate shadow made up of bright and dark regions due to bending of the light [14]. This phenomenon is called diffraction.

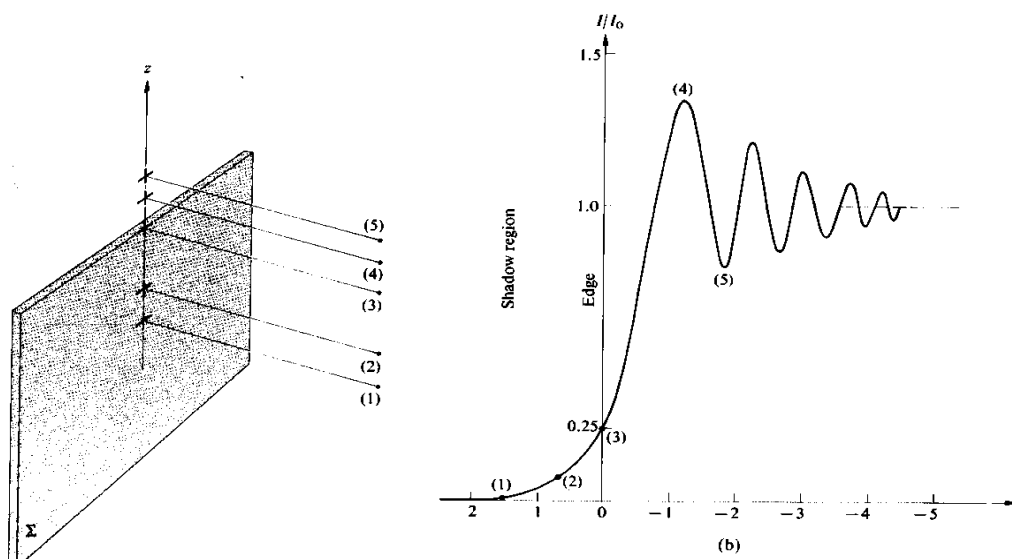
When the light source or the screen is close to the obstruction (Fig. 5), and the light comes from a point source, the diffraction effect is called Fresnel or Near-field diffraction. Whereas when the light source is extended and both it and the screen are far from the obstruction, this type of diffraction effect is called Fraunhofer or Far-field diffraction. It is assumed that the diffraction effect in the optical tomography system is mainly Fresnel diffraction, since the particle is close to the CCD linear sensor (the farthest distance between the particle and the sensor is 71 mm).



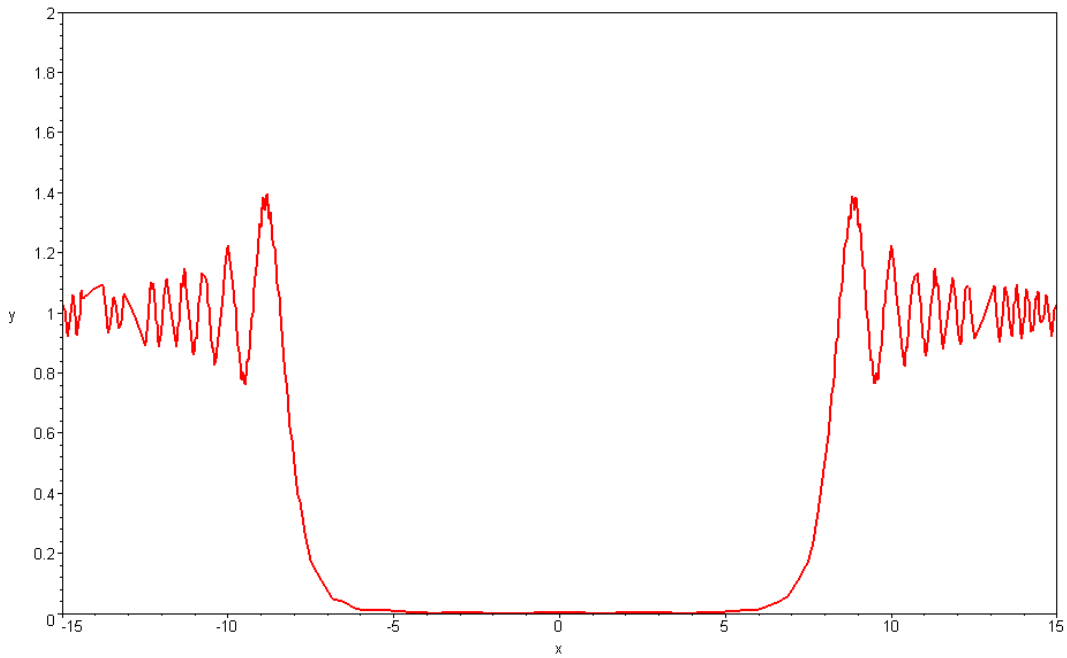
**Fig. 5.** A light strikes an obstruction [12].

The effect of diffraction is closely related to the size of the obstruction. If the size of the particle or the obstruction is very large compared to the wavelength of the light source, the diffraction effects will be small. Diffraction effects become more pronounced, as the size of the obstruction becomes smaller.

The diffraction patterns of the measured particles were compared with the calculated Fresnel diffraction patterns. Fig. 6 and Fig. 7 show the diffraction pattern for opaque screen and opaque sphere, respectively.



**Fig. 6.** The opaque screen and the intensity distribution [14].



**Fig. 7.** Fresnel diffraction for spherical particle with a diameter of 2-mm.

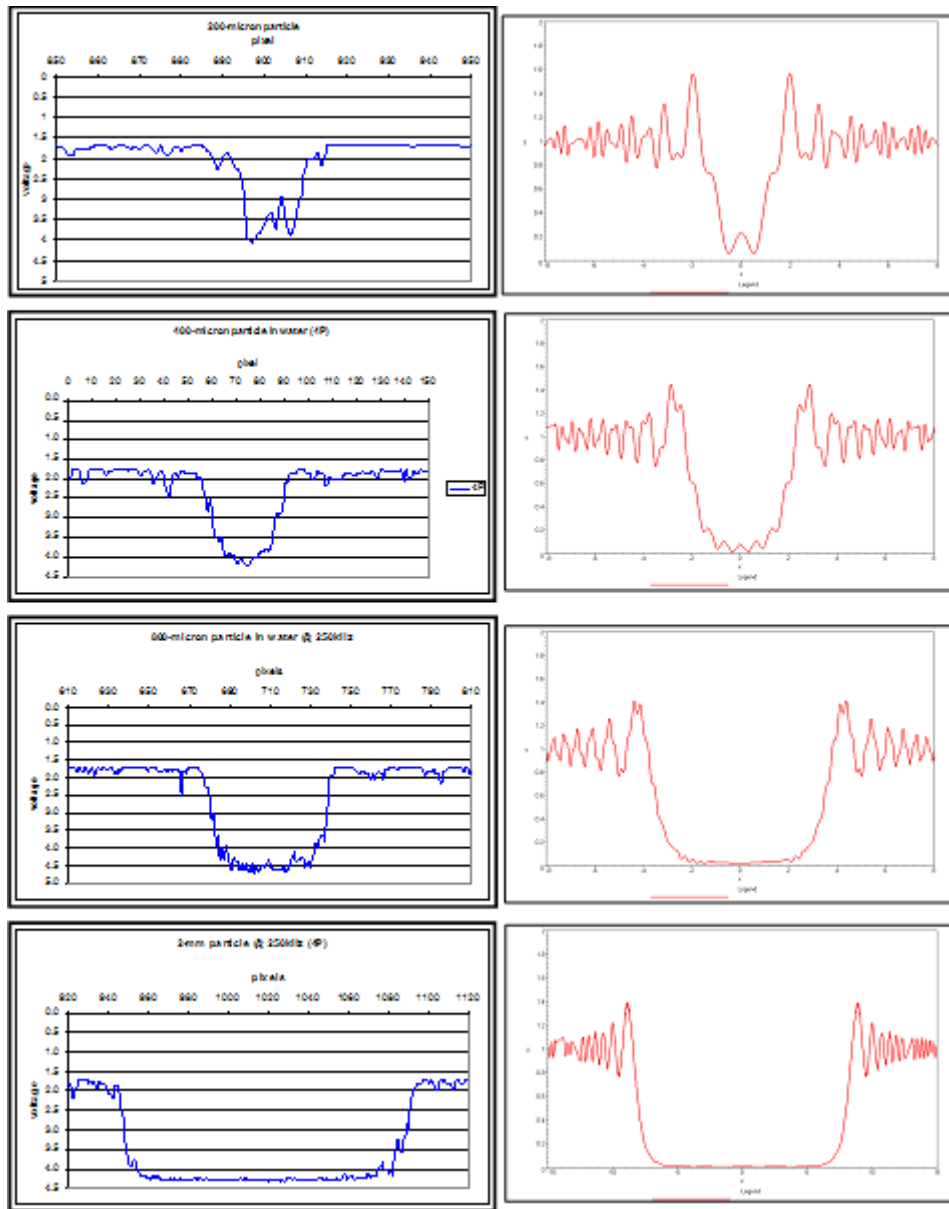
#### **4. Results and Discussions**

Test pieces (spherical shaped beads) with known diameters (ranging from 200 micron to 2 mm) were used in the experiment. The test pieces (200 micron, 400 micron, 800 micron and 2 mm diameters) were positioned at the centre of the measurement section. Ten diameter measurements for each projection were taken and averaged for the final measured diameter of the particle. The diameter measurement is based on the diffraction theory, where the measured value was taken at a threshold level of 25% of the signal's amplitude.

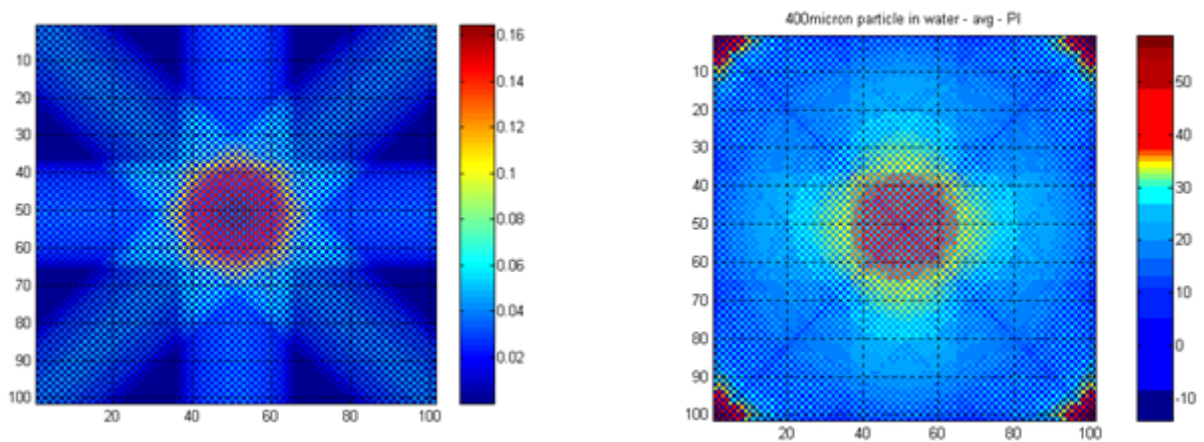
The measurements are obtained in the form of pixels which are in shadow. These measurements are converted to millimeters using one pixel as being equivalent to 0.014 mm. The measurements were repeated ten times for each of the four projections (projections 1, 2, 3 and 4) in order to obtain the mean and standard deviations of the measurement.

The tomographic reconstructed images of the measurements were performed using Matlab software on a computer. The images are reconstructed using the transpose and pseudo inverse sensitivity matrices. Fig. 8 shows the output voltage from the Keithley DAS for the test pieces and their corresponding simulation outputs. The designed system has accuracy better than 0.0085 mm (0.6 pixel), with the percentage error better than 1.456 %. The accuracy is acceptable because the error is less than 1 pixel i.e. 0.014 mm.

The tomographic image reconstruction of the test pieces was performed using the four projections measurements of each position of the particle. Fig. 9 shows an example of the particle's reconstructed image by means of transpose and pseudo inverse sensitivity matrices.



**Fig. 8.** Diffraction patterns for measured data (left) and model data (right) [12].



**Fig. 9.** Reconstructed tomographic images of a spherical particle using transpose (left) and pseudo inverse (right) matrices [13].

## 5. Conclusion

Particle size in many chemical processes is of great importance. Most of the techniques used in measuring particle size are based on sampling measurements, which may not represent the actual process flow. The optical tomographic instrumentation system based on the charge-coupled device linear image sensor is capable of performing particle size measurement over the full cross section of the pipe. Moreover, the processing and reconstructing the tomographic images based on transpose and pseudo inverse sensitivity matrices provide reasonable approximations to mathematical models of the inverse problem.

## References

- [1]. Scott, D. M., Introduction to process tomography, In Scotts D. M. and Williams R. A. (editors), *Frontier in Industrial Process Tomography*, New York, 1995.
- [2]. Abdul Rahim, R., Chiam, K. T., Fazalul Rahiman, M. H., Pusppanathan, J., Susiapan, Y. S-L. Optical tomography system: Digital sensors for masking purpose in parallel beam optical tomography system, *Sensors Letters*, 2008, 6, 5, pp. 752-758.
- [3]. Xu, C., Zhou, B., Yang, D., Tang, G., Wang, S. Velocity measurement of pneumatically conveyed solid particles using an electrostatic sensor, *Measurement Science Technology*, 2008, 19, p. 024005.
- [4]. Abdul Rahim R, Chiam K. T., Jayasuman P, Embedded System Based Optical Tomography: The Concentration Profile, *Sensor Review Journal*, Vol. 29, No. 1, 2009, pp. 54-62.
- [5]. Martínez Olmos, A., Carvajal, M. A., Morales, D. P., García, A., Palma, A. J. Development of an Electrical Capacitance Tomography system using four rotating electrodes, *Sensors and Actuators A: Physical*, 2008, 148, pp. 366–375.
- [6]. Beck, M. S., Williams, R. A. Process Tomography: A European innovation and its applications, *Measurement Science Technology*, 1996, 7, pp. 215-224.
- [7]. Kostov, Y., Rao, G. Low-cost optical instrumentation for biomedical measurements, *Review of Scientific Instruments*, 2000, 71, pp. 4361-4371.
- [8]. Leutwyler, K. Optical Tomography, *Scientific American*, 1994, pp. 147-149.
- [9]. Beck, M. S. and Williams, R. A. Sensor design and selection, In Scott, D. M. and Williams, R. A. (editors), *Frontiers in Industrial Process Tomography*, New York, 1995.
- [10]. Rahim, R. A., Rahiman, M. H., Chen, L. L., San, C. K., Fea, P. J. Hardware Implementation of Multiple Fan Beam Projection Technique in Optical Fibre Process Tomography, *Sensors*, 2008, 8, pp. 3406-3428.
- [11]. Horbury, N. M., Abdul Rahim, R., Dickin, F. J., Green, R. G., Naylor, B. D., Pridmore, T. P. Tomographic imaging of transparent slurries with particle sizing using optical fibres, In Scotts, D. M. and Williams, R. A. (editors), *Frontiers in Industrial Process Tomography*, New York, 1995.
- [12]. Idroas, M. A CCD-based optical tomographic instrumentation system for sizing particle, *PhD Thesis*, Sheffield Hallam University, United Kingdom, 2004.
- [13]. Idroas, M., Ling, S. Y., Ibrahim, M. N. Image reconstruction in charge coupled device based optical tomography, *Jurnal ElektriKa*, 2006, 1, pp. 1-8.
- [14]. Hecht, E. Optics, 2nd Edition, *Addison-Wesley*, 1987.



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>

## 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/Submission.htm> Authors must follow the instructions strictly when submitting their manuscripts.

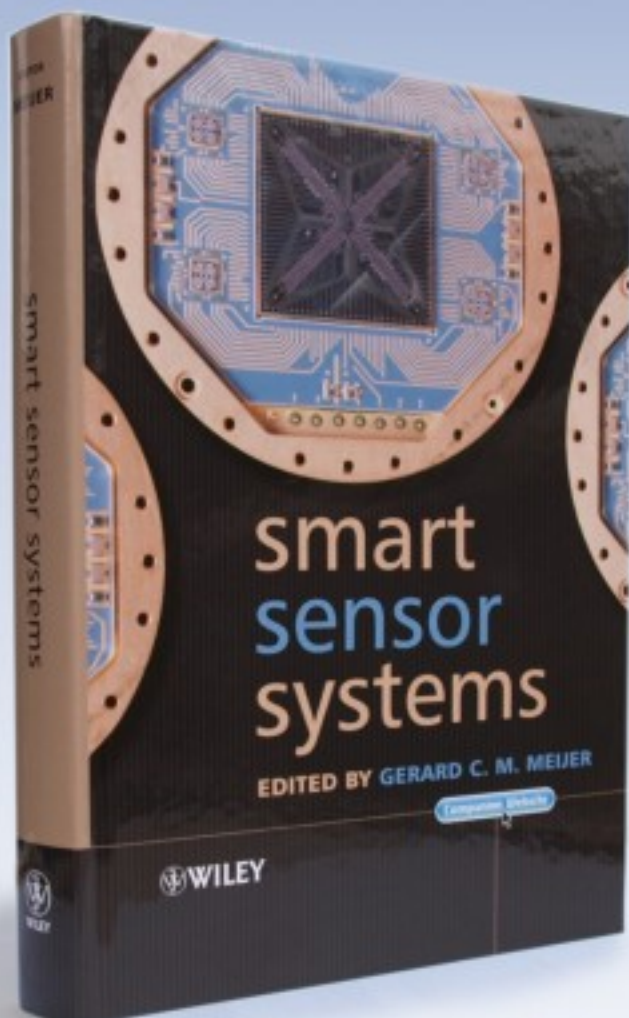
### Advertising Information

Advertising orders and enquires may be sent to [sales@sensorsportal.com](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)



 **WILEY**  
1807-2007

KNOWLEDGE FOR GENERATIONS



**'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)**