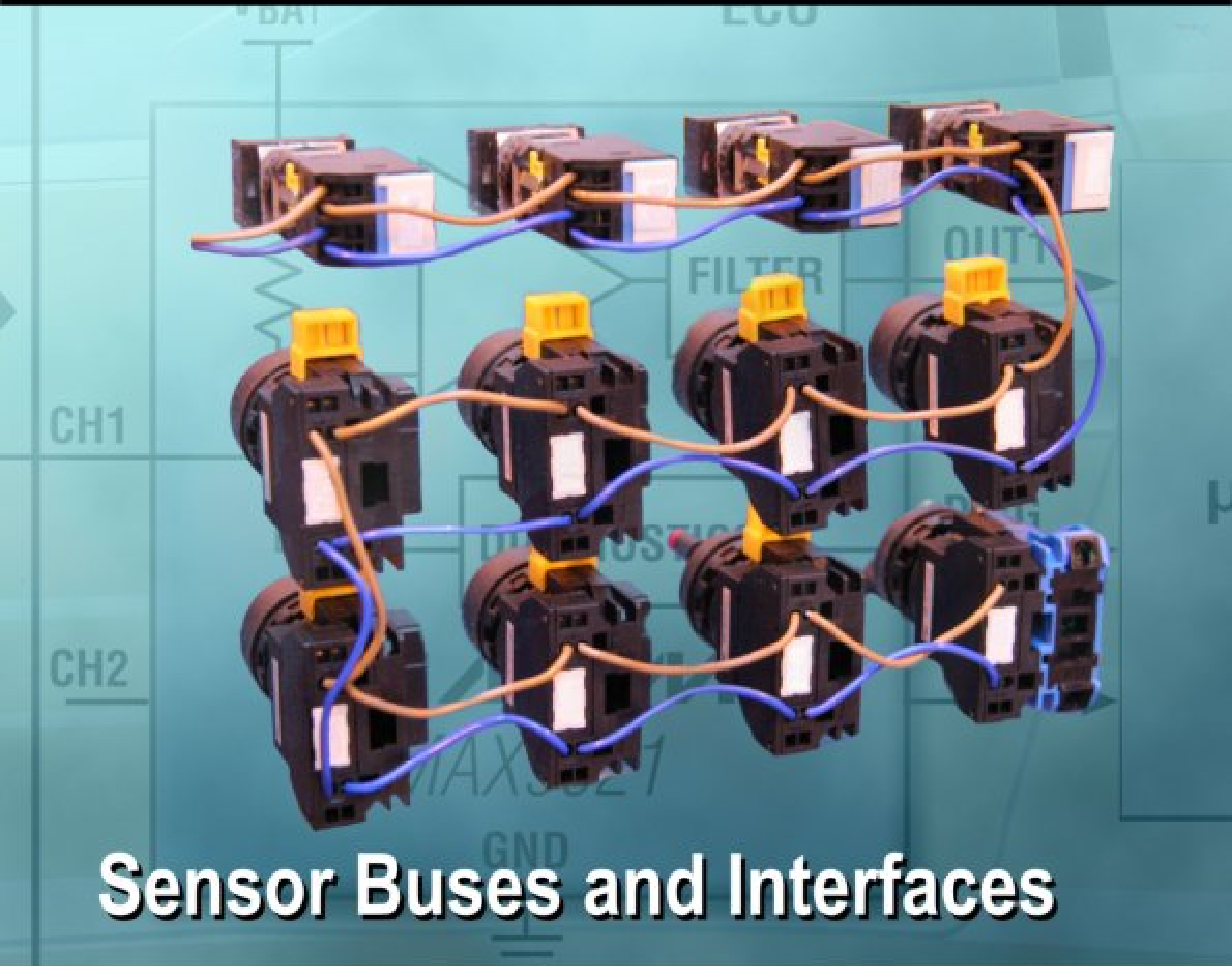
ISSN 1726-5479

SENSORS & TRANSDUCERS

5/10
vol. 116



Sensor Buses and Interfaces

International Frequency Sensor Association Publishing
IFSA

Sensors & Transducers

Volume 116, Issue 5, May 2010

www.sensorsportal.com

ISSN 1726-5479

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, Universitá 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, Nothern 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
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 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, Bhbha 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
Raoof, 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
Soleymanpour, Ahmad, Damghan Basic Science University, Iran
Somani, Prakash R., Centre for Materials for Electronics Technol., India
Srinivas, Talabattula, Indian Institute of Science, Bangalore, India
Srivastava, Arvind K., 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, Qintao, University of California at Berkeley, USA
Zhang, Weiping, Shanghai Jiao Tong University, China
Zhang, Wenming, Shanghai Jiao Tong University, China
Zhang, Xueji, World Precision Instruments, Inc., USA
Zhong, Haoxiang, Henan Normal University, China
Zhu, Qing, Fujifilm Dimatix, Inc., USA
Zorzano, Luis, Universidad de La Rioja, Spain
Zourob, Mohammed, University of Cambridge, UK

Sensors & Transducers Journal (ISSN 1726-5479) is a peer review international journal published monthly online by International Frequency Sensor Association (IFSA).
Available in electronic and on CD. Copyright © 2009 by International Frequency Sensor Association. All rights reserved.

Sensors & Transducers Journal

Contents

Volume 116
Issue 5
May 2010

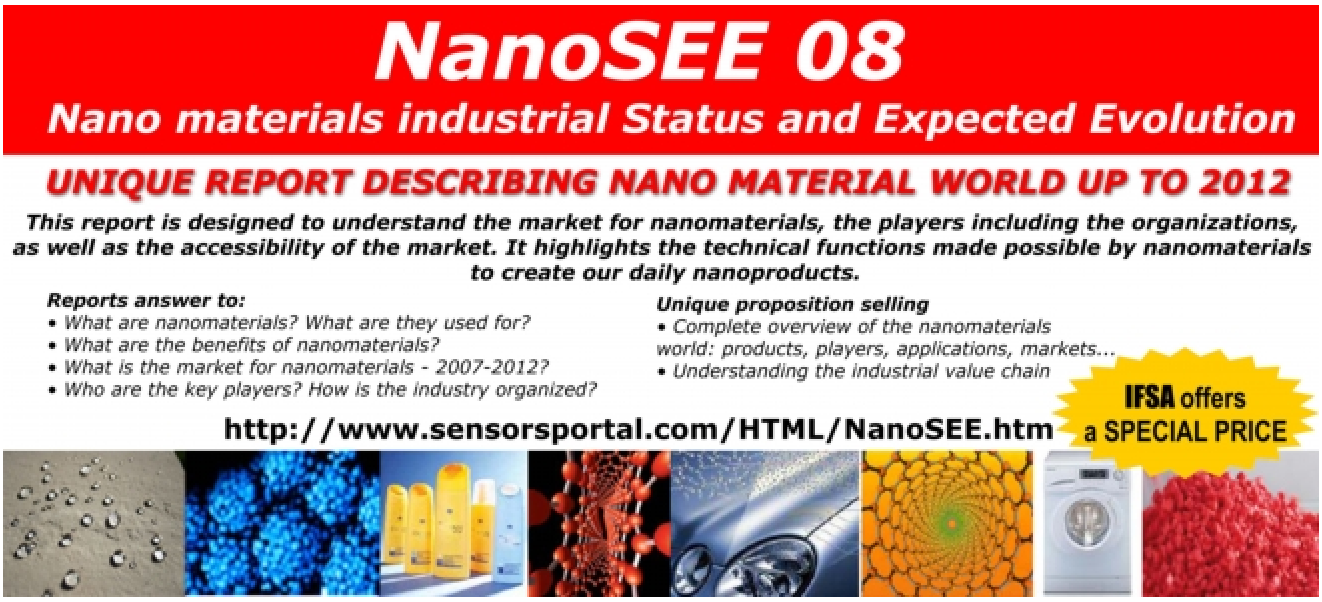
www.sensorsportal.com

ISSN 1726-5479

Research Articles

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

International Frequency Sensor Association (IFSA).



Sensors & Transducers Journal, Vol. 116, Issue 5, May 2010, pp. 131-138

Sensors & Transducers

ISSN 1726-5479
© 2010 by IFSA
http://www.sensorsportal.com

Angle-tip Fiber Probe as Humidity Sensor

Pabitra NATH
Department of Electronic and Communication Technology, Gauhati University,
Guwahati 781014, Assam, India
E-mail: pnath07@gmail.com

Received: 16 January 2010 /Accepted: 24 May 2010 /Published: 31 May 2010

Abstract: In this paper, I present a simple fiber optic relative humidity sensor (FORHS) using an angled-tip multimode optical fiber. The sensing region is fabricated by coating moisture sensitive Cobalt Chloride ($CoCl_2$) doped polyvinyl alcohol (PVA) film on the surface of fiber optic tip. Light signal introducing from flat-end of the fiber is back-reflected at the fiber tip-air interface by the effect of total internal refection. The change of relative humidity (RH) in the outstanding medium affects of evanescent field absorption at the fiber tip-sensing film interface thus, modulates the back-reflected signal. With the present sensing investigation, RH ranging from 5 % to 95 % can be measured with high degree of repeatability and has a fast response time of about 2 seconds. *Copyright © 2010 IFSA.*

Keywords: Fiber optic sensor, Relative humidity, Angled-tip fiber probe

1. Introduction

Humidity monitoring is critical for different industrial and laboratory applications. Presence of high level of humidity affects the quality of products and performance of devices installed in various environments. For instance, in microelectronic industries, the performance of many electronic devices is seriously affected by high level of humidity present in the environment. Again, in tea industries, proper level of RH in drier chamber determines the quality of tea yields from the industry. Practical realization of RH sensor is rather a difficult task as this has to be in direct contact with the process environment. There are number of FORHSs that have been reported and demonstrated by different researchers [1-6] in the recent past. In most of these sensors, a moisture sensitive chemical is coated on an unclad region of the optical fiber and variation of evanescent wave absorption due to the presence of moisture in the outstanding medium is monitored for RH sensing investigation. Anhydrous $CoCl_2$ is one of the most commonly used chemical for this purpose. Anhydrous $CoCl_2$ is blue and has a strong absorption in the wavelength range of 550-750 nm when it is dry. However, as it interacts with the moisture present in air it turns in to pink (~680nm) showing excellent transmission in that particular wavelength range. Absorption spectrum of $CoCl_2$ in gelatin at different humidity level is described in [6]. FORHSs based on unclad U-bent sensing region [2] or straight unclad fiber sensing region [4] work well in the RH range of 20 % to 75 %. However, such sensing region is fragile and has to be very handled very carefully because little stress experiencing on it may permanently damage the optical fiber. Hence, an unclad fiber may not always safe and suitable for RH sensing applications. In recent years, optical fibers with one end either an angle-polished or curve shaped fiber tips have been extensively studied for measurement of various parameters [7-10]. Compared to U-bent or a straight unclad FORHS, an angled tip [8] fiber probes offer advantages in terms of:

i). better geometrical flexibility;
ii). can be used as a probe for RH sensing investigation;
iii). sensing scheme is more robust for handling;
iv). RH variation in a small volume of environment can be measured.

In the present work, a simple high dynamic range RH sensor with high sensitivity using an angled-tip multimode optical fiber is demonstrated. The fiber tip is coated with moisture sensitive $CoCl_2$ doped PVA film. Light signal propagating from flat-end of the fiber is back-reflected at the fiber tip-air interface by the effect of total internal refection. The change of humidity surrounding the sensing region of the fiber modulates the back-reflected light signal. With the present sensing scheme humidity variation in the range of 5 % to 95 % can be measured with high degree of repeatability and has a fast response time of about 2 seconds.

2. Sensing Principle

Fig. 1 shows the fiber sensing tip for the present investigation. The FORHS presented here is an intrinsic type sensor. The sensing principle of the present FORHS is based on intensity modulation of back-propagated light signal from an angled-shape fiber tip which has been coated with moisture sensitive PVA/ $CoCl_2$ film. Light signal propagating from the flat-end of the fiber undergoes total internal-reflection at the fiber tip-air interface and would reflect back to the entry port of the fiber. The critical angle condition for the total internal reflection to occur is given by

$$\theta_c(\lambda) = \text{arc sin}\,[n_a(\lambda)/n_1(\lambda)] \tag{1}$$

Here, $n_1(\lambda)$ is the refractive index of the fiber core which is a wavelength dependant quantity and $n_a(\lambda)$ is the index of refraction of the external medium surrounding the fiber sensing tip. For, the present case we have used sensor grade step-index multimode optical fiber of core/cladding diameter 980/1000 μm with $n_1(\lambda) = 1.4673$ and $n_a(\lambda) = 1$ thus, giving $\theta_c(\lambda) \sim 43^0$.

For present sensing investigation the fiber tip is polished to an angle greater than the critical angle (43^0) thus, most of the forward going modes will be back-reflected to the entry port of the fiber. The sensing region was dip-coated with 3% $CoCl_2$doped in1% PVA solution and was allowed to dry for 24 hours followed by annealing at 60^0 Centigrade for 2 hours. For light signal propagating from flat-end of the fiber, there would be evanescent wave absorption at the fiber sensing tip- sensing film interface. The change of RH in the outstanding medium affects the evanescent wave absorption of the back-reflected light signal and thus, modulates the irradiance of the light signal. Since all the back-reflected light modes interact with the sensing region of the fiber, the present technique is found to be sensitive than that of an uncladed FORHS [4] where some of the selected modes were involved for interaction with RH in the medium. For the present case, I use 2-dip and 3-dip coating film on the sensing region of the fiber.

(a) (b)

Fig. 1. (a) Photograph of an angled-tip optical fiber; (b) Magnified view of photo (a). For dimensional comparison a 5 rupees coin is also shown in the photograph. The angle of the fiber tip was measured to be 50^0.

3. Experimental Arrangement

Experimental arrangement for the present sensing investigation is shown in Fig. 2. Light signal from an intensity stabilized laser source (λ = 670nm, 5mW) is coupled to the flat-end of the optical fiber through an objective O. The sensing tip of the fiber is placed inside a plexiglass climate chamber. Using a beam splitter the useful back-reflected light signal from the sensing region is directed to the detector (photodiode). For rapid humidity variation, a small volume of climate chamber is taken with moisture inlet (MI) and outlet (MO) provision. For calibration, a standard resistive based digital electronic hygrometer is kept inside the climate chamber.

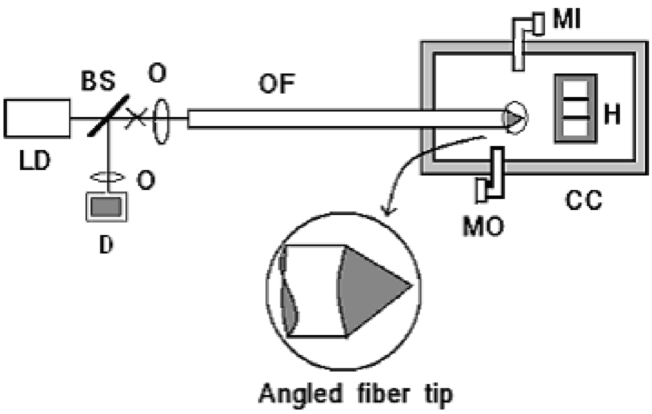


Fig. 2. Schematic of the experimental set-up for RH sensor: LD laser diode; BS beam splitter; O objective; OF optical fiber; H hygrometer; MI moisture inlet; MO moisture outlet; CC climate chamber; D detector.

4. Results and Discussion

To study the characteristics of the present sensor, initially low humidity level was maintained inside the chamber. To obtain low level of humidity, initially calcium sulphate is introduced inside the climate chamber and humidity level down to 5 % has been achieved. Moisture contained air is then gradually introduced through the MI of the climate chamber. The change of humidity level and the corresponding sensor response for 2-dip coated fiber tip with time is shown in Fig. 3.

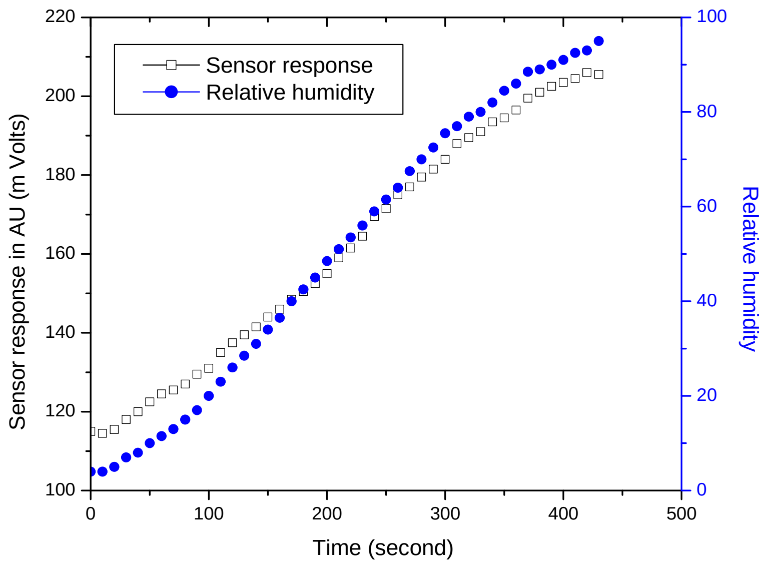


Fig. 3. Sensor response curve for 2-dip coated film with humidity variation inside the climate chamber.

With the increase of RH inside the chamber, the absorbance of the $CoCl_2$/PVA film decreases and thus higher back-reflected signal would be received by the photodiode. The investigation is also carried out for 3-dip coated fiber tip and the normalized sensor response for these two films are shown in Fig. 4. This variation clearly indicates that with increasing film thickness the sensitivity (the fractional change in power per unit change in relative humidity) of the sensor response increases with film thickness as now more $CoCl_2$molecule would be available per unit area in the sensing region. However, optimum signal modulation and hence sensitivity would be achieved when penetration depth of the evanescent field at the fiber tip matches with the sensing film thickness.

We then investigate the sensor response for another angle-tip fiber maintained at 80^0 with same fiber core diameter. A comparative study of the sensor response for two cases. 50^0 and 80^0 angled sensor tips are shown in Fig. 5. For 80^0 angled-tip optical fiber, less area of the sensing region is exposed to moisture environment thus, yields lower sensitivity and dynamic range than to a 50^0 angled fiber tip. In the present case, highest sensitivity and dynamic range would be possible for fiber angle-tip which has maximum back-reflectance light signal and large sensing area for exposure to the moisture environment. Thus, a fiber tip of 45^0 angle would have maximum back-reflectance light signal and the largest sensing area for exposure to the environment. Hence, optimum level of sensitivity and dynamic range can be expected for this tip.

To study to repeatability behavior of the sensor moisture contained compressed air is introduced slowly into the climate chamber and sensor characteristic is observed for both increasing and decreasing cycle of relative humidity inside the chamber. The sensor response was observed for 2-dip coated film with 50^0 angle fiber sensing tip. Three such cycles were taken and the graphical format of the obtained data is shown in the Fig. 6. This investigation was carried out several times and similar response was observed every time. Thus, good degree of repeatability is seen in the sensor.

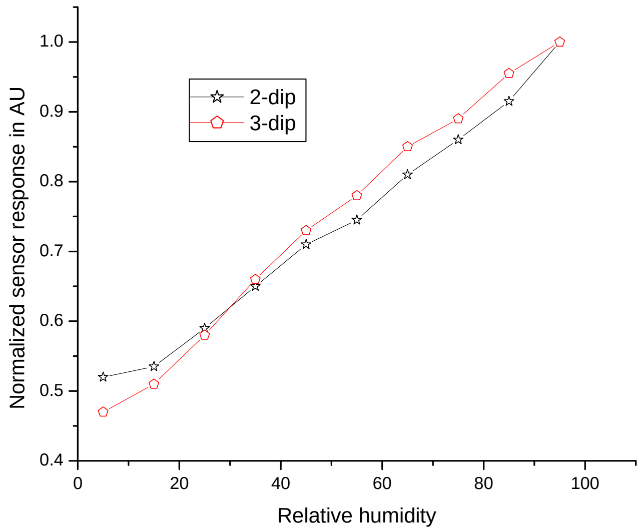


Fig. 4. Normalized sensor response for 2-dip and 3-dip coated film on fiber sensing tip.

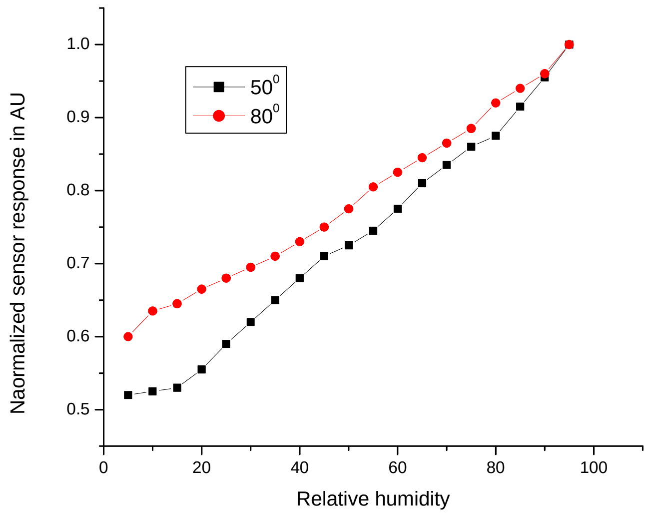


Fig. 5. Normalized Sensor response for two fiber angled tips maintained at 50^0 and 80^0.

To measure the response time of the designed sensor, moisture contained pressurized air is rapidly introduced into the climate chamber and the corresponding sensor reading has found to be approximately of 2 seconds for responding each degree of change in humidity level inside the chamber in the RH range 35 % to 75 % while for humidity below 35 % and above 75 % it took approximately 5-6 seconds. The performance of the present sensor is to be investigated for different composition of $CoCl_2$ doped PVA solutions. The present technique can also be exploited for sensing of other parameters such as pH value, temperature etc. by coating suitable sensing chemicals on the fiber tip.

5. Conclusions

I present a novel technique for measurement of RH using angle-shaped fiber tip as sensing region and highlighted its advantages over the U-shaped probe fiber optic RH sensor. No comparative study of the present sensor has been performed with U-shaped fiber sensor or a side polished fiber sensor. The advantage of the technique is its flexibility and relative humidity in a small volume of environment can be measured. Further compared to U shaped fiber probe, the sensing region of the present sensor is more robust for handling.

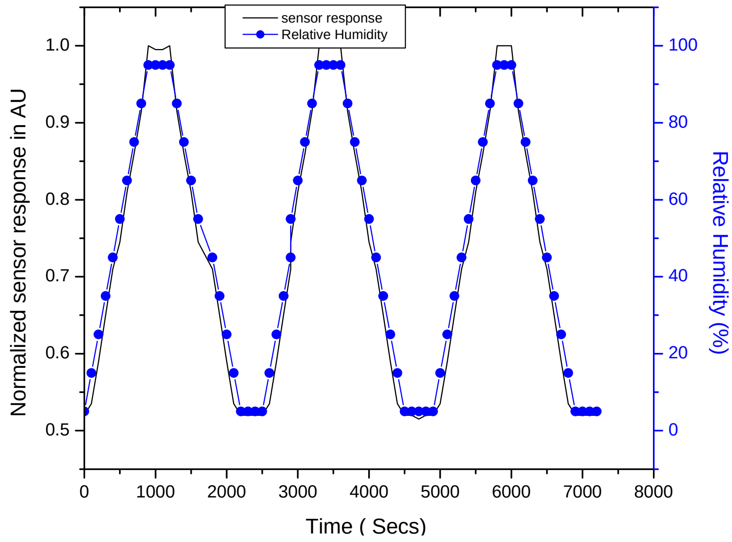


Fig. 6. Repeatability behavior of the fiber optic humidity sensor with 2-dip coated $CoCl_2$/PVA film angled-tip maintained at 50^0.

Acknowledgement

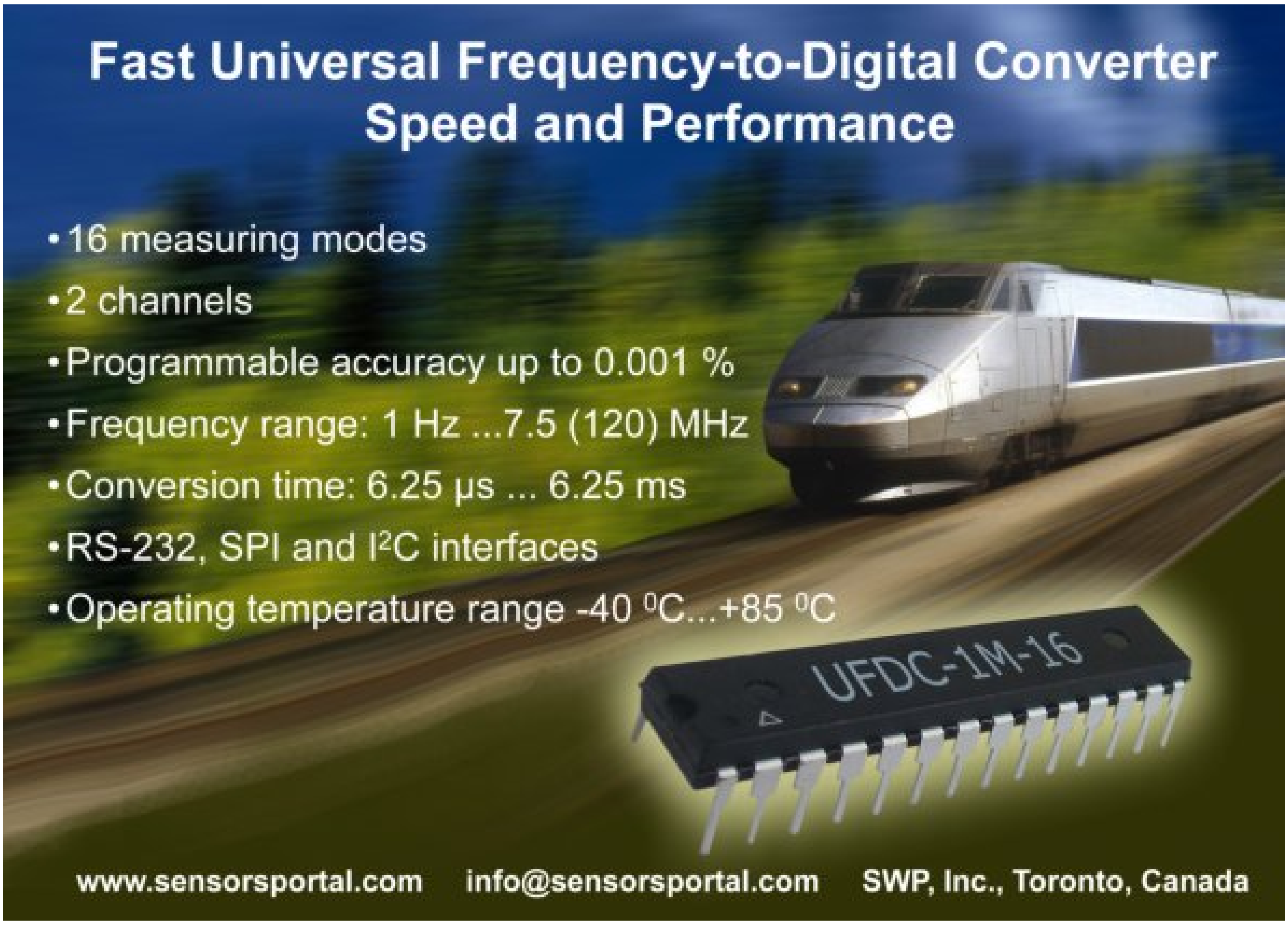
The author acknowledges the financial support received from the University Grant Commission (UGC), New Delhi, India.

References:

[1]. B. D. Gupta, Ratnanjali, *A* novel probe for a fiber optic humidity sensor, *Sens. Actuators B*, 80, 2001, pp. 132-135.
[2]. S. K. Khijwania, K. L Srinivasan, J. P. Singh, An evanescent–wave optical fiber relative humidity sensor with enhanced sensitivity, *Sens. Actuators B*, 104, 2005, pp. 217-222.
[3]. T. L. Yeo, D. Eckstein, B. McKinley, L. F. Boswell, T. Sun and K. T. V. Grattan, Demonstration of a fiber-optic sensing technique for the measurement of moisture absorption in concrete, *Smart Mater. Struct.*, 15, 2006, pp. 40-45.
[4]. R. Jindal, S. Tao, J. P. Singh, and P. S. Gaikwad, High dynamic range fiber optic relative humidity sensor, *Opt. Eng.*, 41, 5, 2002, pp. 1093-1096.
[5]. P. Nath, H. K. Singh, P. Datta, K. Ch. Sarma, Cobalt Chloride doped polymer film for relative humidity measurement, *Sensors & Transducers*, Vol. 91, Issue 4, April, 2008, pp. 127-133.
[6]. A. P. Russell, K. S. Fletcher, Optical sensors for the determination of moisture, *Anal. Chim. Acta*, 170, 1985, pp. 209-210.
[7]. I. K. Ilev and Ronald W. Waynant, All-fiber-optic sensor for liquid level measurement, *Rev. Sci. Instrum.* 70, 1999, pp. 2551-2554.
[8]. M. Bottacini, N. Burani, M. Foroni, F. Poli, S. Sellleri, All- plastic optical-fiber level sensor, *Micro. Opt. Tech. Lett.* 46, 6, 2005, pp. 520-522.
[9]. P Nath, P. Datta, K. Ch. Sarma, All Fiber optic sensor for liquid level measurement, *Micro Opt Technol Lett.,* Vol. 50, No. 7, July, 2008, pp. 1982-1984.

[10].P Nath, H. K. Singh P Datta, K Ch. Sarma, All-fiber optic sensor for measurement of liquid refractive index, *Sens Acts A,* Vol. 148, 2008, pp. 16-18.

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



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

Emerging MEMS 2010

Technologies & Markets 2010 Report

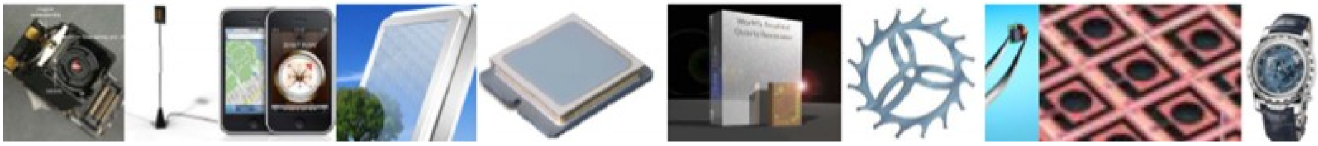
Innovative developments in MEMS devices will add more than $2B to the total MEMS market by 2015 !

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



MEMS Energy Harvesting Devices, Technologies and Markets, 2009

Market drivers analysis for challenges that go beyond energy density!

This report focuses on MEMS energy harvesting devices from both technology and market points of view.

Executive summary

1. *Introduction to micropower & energy harvesting technologies*
2. *Technology review – energy harvesting technologies*
3. *Technology review – energy storage technologies*
4. *ApplicationsEnergy harvesting devices*

IFSA offers a SPECIAL PRICE

http://www.sensorsportal.com/HTML/MEMS_Energy_Harvesting_Devices.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 additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

Topics Covered

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

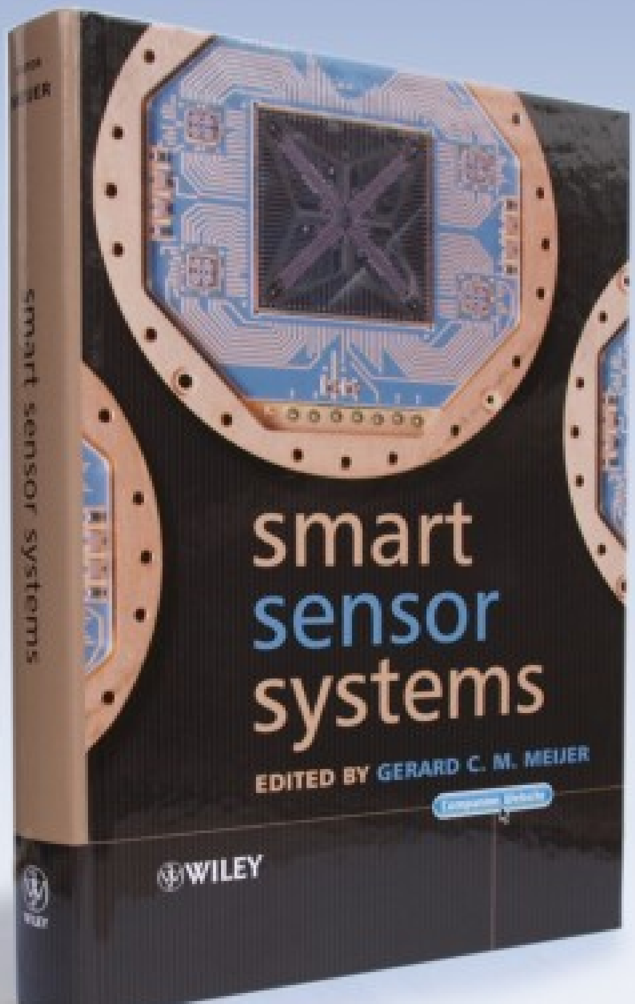
- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors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

Submission of papers

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

Advertising Information

Advertising orders and enquires may be sent to sales@sensorsportal.com Please download also our media kit: http://www.sensorsportal.com/DOWNLOADS/Media_Kit_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 semsor systems, their building blocks and methods of signal processing.'

Order online:
http://www.sensorsportal.com/HTML/BOOKSTORE/Smart_Sensor_Systems.htm

www.sensorsportal.com