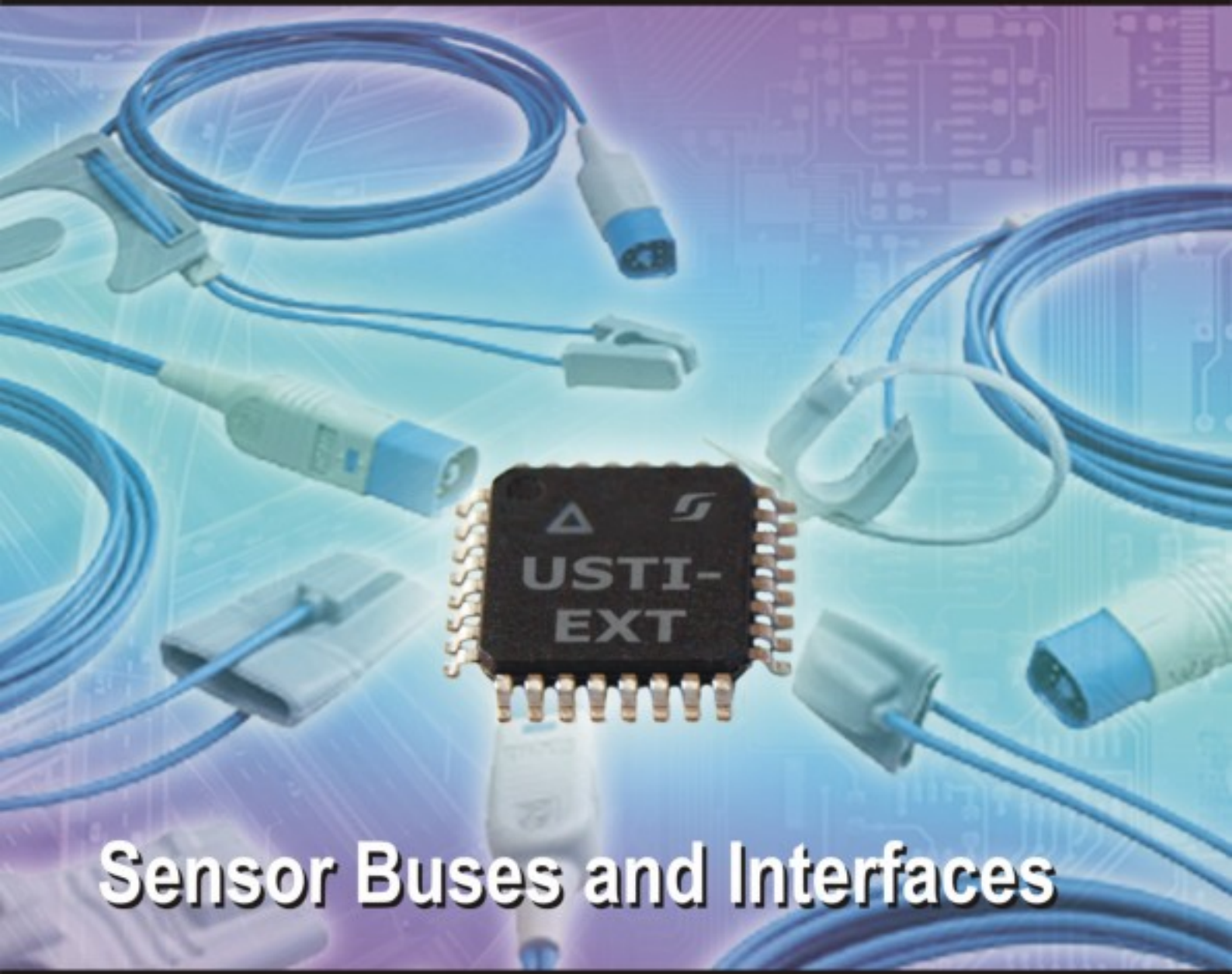
ISSN 1726-5479

SENSORS & TRANSDUCERS

vol. 140
5/12



Sensor Buses and Interfaces

International Frequency Sensor Association Publishing

IFSA

Sensors & Transducers

Volume 140, Issue 5, May 2012 | **www.sensorsportal.com** | **ISSN 1726-5479**

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

Editors for Western Europe
Meijer, Gerard C.M., Delft University of Technology, The Netherlands
Ferrari, Vittorio, Universitá di Brescia, Italy

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

Editor South America
Costa-Felix, Rodrigo, Inmetro, Brazil

Editor for Eastern Europe
Sachenko, Anatoly, Ternopil State Economic University, Ukraine

Editor for Asia
Ohyama, Shinji, Tokyo Institute of Technology, Japan

Editor for Africa
Maki K.Habib, American University in Cairo, Egypt

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
Azamimi, Azian binti Abdullah, Universiti Malaysia Perlis, Malaysia
Bahreyni, Behraad, University of Manitoba, Canada
Baliga, Shankar, B., General Monitors Transnational, USA
Baoxian, Ye, Zhengzhou University, China
Barford, Lee, Agilent Laboratories, USA
Barlingay, Ravindra, RF Arrays Systems, India
Basu, Sukumar, Jadavpur University, India
Beck, Stephen, University of Sheffield, UK
Ben Bouzid, Sihem, Institut National de Recherche Scientifique, Tunisia
Benachaiba, Chellali, Universitaire de Bechar, Algeria
Binnie, T. David, Napier University, UK
Bischoff, Gerlinde, Inst. Analytical Chemistry, Germany
Bodas, Dhananjay, IMTEK, Germany
Borges Carval, Nuno, Universidade de Aveiro, Portugal
Bouchikhi, Benachir, University Moulay Ismail, Morocco
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
Calvo-Gallego, Jaime, Universidad de Salamanca, Spain
Campanella, Luigi, University La Sapienza, Italy
Carvalho, Vitor, Minho University, Portugal
Cecelja, Franjo, Brunel University, London, UK
Cerda Belmonte, Judith, Imperial College London, UK
Chakrabarty, Chandan Kumar, Universiti Tenaga Nasional, Malaysia
Chakravorty, Dipankar, Association for the Cultivation of Science, India
Changhai, Ru, Harbin Engineering University, China
Chaudhari, Gajanan, Shri Shivaji Science College, India
Chavali, Murthy, N.I. Center for Higher Education, (N.I. University), India
Chen, Jiming, Zhejiang University, China
Chen, Rongshun, National Tsing Hua University, Taiwan
Cheng, Kuo-Sheng, National Cheng Kung University, Taiwan
Chiang, Jeffrey (Cheng-Ta), Industrial Technol. Research Institute, Taiwan
Chiriac, Horia, National Institute of Research and Development, Romania
Chowdhuri, Arijit, University of Delhi, India
Chung, Wen-Yaw, Chung Yuan Christian University, Taiwan
Corres, Jesus, Universidad Publica de Navarra, Spain
Cortes, Camilo A., Universidad Nacional de Colombia, Colombia
Courtois, Christian, Universite de Valenciennes, France
Cusano, Andrea, University of Sannio, Italy
D'Amico, Arnaldo, Università di Tor Vergata, Italy
De Stefano, Luca, Institute for Microelectronics and Microsystem, Italy
Deshmukh, Kiran, Shri Shivaji Mahavidyalaya, Barshi, India
Dickert, Franz L., Vienna University, Austria
Dieguez, Angel, University of Barcelona, Spain
Dighavkar, C. G., M.G. Vidyamandir's L. V.H. College, India
Dimitropoulos, Panos, University of Thessaly, Greece
Ding, Jianning, Jiangsu Polytechnic University, China
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
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
Khelfaoui, Rachid, Université de Bechar, Algeria
Khan, Asif, Aligarh Muslim University, Aligarh, India
Kim, Min Young, Kyungpook National University, Korea South
Ko, Sang Choon, Electronics. and Telecom. Research Inst., Korea South
Kotulska, Malgorzata, Wroclaw University of Technology, Poland
Kockar, Hakan, Balikesir University, Turkey
Kong, Ing, RMIT University, Australia
Kratz, Henrik, Uppsala University, Sweden

Krishnamoorthy, Ganesh, University of Texas at Austin, USA
Kumar, Arun, University of Delaware, Newark, 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, Fengyuan (Thomas), Purdue University, USA
Li, Genxi, Nanjing University, China
Li, Hui, Shanghai Jiaotong University, China
Li, Sihua, Agiltron, Inc., USA
Li, Xian-Fang, Central South University, China
Li, Yuefa, Wayne State University, USA
Liang, Yuanchang, University of Washington, USA
Liawruangrath, Saisunee, Chiang Mai University, Thailand
Liew, Kim Meow, City University of Hong Kong, Hong Kong
Lin, Hermann, National Kaohsiung University, Taiwan
Lin, Paul, Cleveland State University, USA
Linderholm, Pontus, EPFL - Microsystems Laboratory, Switzerland
Liu, Aihua, University of Oklahoma, USA
Liu Changgeng, Louisiana State University, USA
Liu, Cheng-Hsien, National Tsing Hua University, Taiwan
Liu, Songqin, Southeast University, China
Lodeiro, Carlos, University of Vigo, Spain
Lorenzo, Maria Encarnacio, Universidad Autonoma de Madrid, Spain
Lukaszewicz, Jerzy Pawel, Nicholas Copernicus University, Poland
Ma, Zhanfang, Northeast Normal University, China
Majstorovic, Vidosav, University of Belgrade, Serbia
Malyshev, V.V., National Research Centre 'Kurchatov Institute', Russia
Marquez, Alfredo, Centro de Investigacion en Materiales Avanzados, Mexico
Matay, Ladislav, Slovak Academy of Sciences, Slovakia
Mathur, Prafull, National Physical Laboratory, India
Maurya, D.K., Institute of Materials Research and Engineering, Singapore
Mekid, Samir, University of Manchester, UK
Melnyk, Ivan, Photon Control Inc., Canada
Mendes, Paulo, University of Minho, Portugal
Mennell, Julie, Northumbria University, UK
Mi, Bin, Boston Scientific Corporation, USA
Minas, Graca, University of Minho, Portugal
Mishra, Vivekanand, National Institute of Technology, India
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
Mrad, Nezih, Defence R&D, Canada
Mulla, Imtiaz Sirajuddin, National Chemical Laboratory, Pune, India
Nabok, Aleksey, Sheffield Hallam University, UK
Neelamegam, Periasamy, Sastra Deemed University, India
Neshkova, Milka, Bulgarian Academy of Sciences, Bulgaria
Oberhammer, Joachim, Royal Institute of Technology, Sweden
Ould Lahoucine, Cherif, University of Guelma, Algeria
Pamidighanta, Sayanu, Bharat Electronics Limited (BEL), India
Pan, Jisheng, Institute of Materials Research & Engineering, Singapore
Park, Joon-Shik, Korea Electronics Technology Institute, Korea South
Passaro, Vittorio M. N., Politecnico di Bari, Italy
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
Pugno, Nicola M., Politecnico di Torino, Italy
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
Rastogi Shiva, K. University of Idaho, USA
Reig, Candid, University of Valencia, Spain
Restivo, Maria Teresa, University of Porto, Portugal
Robert, Michel, University Henri Poincare, France
Rezazadeh, Ghader, Urmia University, Iran
Royo, Santiago, Universitat 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
Sapozhnikova, Ksenia, D.I.Mendeleyev Institute for Metrology, Russia
Sandacci, Serghei, Sensor Technology Ltd., UK
Saxena, Vibha, Bhbha Atomic Research Centre, Mumbai, India
Schneider, John K., Ultra-Scan Corporation, USA
Sengupta, Deepak, Advance Bio-Photonics, India
Seif, Selemani, Alabama A & M University, USA
Seifter, Achim, Los Alamos National Laboratory, USA
Shah, Kriyang, La Trobe University, Australia
Sankarraj, Anand, Detector Electronics Corp., USA
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, University of Toledo, USA
Somani, Prakash R., Centre for Materials for Electronics Technol., India
Sridharan, M., Sastra University, India
Srinivas, Talabattula, Indian Institute of Science, Bangalore, India
Srivastava, Arvind K., NanoSonix Inc., USA
Stefan-van Staden, Raluca-Ioana, University of Pretoria, South Africa
Stefanescu, Dan Mihai, Romanian Measurement Society, Romania
Sumriddetchka, Sarun, National Electronics and Comp. Technol. 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, Industr. Research Inst. for Automation and Measurement, Poland
Tan, Ooi Kiang, Nanyang Technological University, Singapore,
Tang, Dianping, Southwest University, China
Tang, Jaw-Luen, National Chung Cheng University, Taiwan
Teker, Kasif, Frostburg State University, USA
Thirunavukkarasu, I., Manipal University Karnataka, India
Thumbavanam Pad, Kartik, Carnegie Mellon University, USA
Tian, Gui Yun, University of Newcastle, UK
Tsiantos, Vassilios, Technological Educational Institute of Kaval, Greece
Tsigara, Anna, National Hellenic Research Foundation, Greece
Twomey, Karen, University College Cork, Ireland
Valente, Antonio, University, Vila Real, - U.T.A.D., Portugal
Vanga, Raghav Rao, Summit Technology Services, Inc., USA
Vaseashta, Ashok, Marshall University, USA
Vazquez, Carmen, Carlos III University in Madrid, Spain
Vieira, Manuela, Instituto Superior de Engenharia de Lisboa, Portugal
Vigna, Benedetto, STMicroelectronics, Italy
Vrba, Radimir, Brno University of Technology, Czech Republic
Wandelt, Barbara, Technical University of Lodz, Poland
Wang, Jiangping, Xi'an 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, Sen, Drexel University, USA
Xu, Tao, University of California, Irvine, USA
Yang, Dongfang, National Research Council, Canada
Yang, Shuang-Hua, Loughborough University, UK
Yang, Wuqiang, The University of Manchester, UK
Yang, Xiaoling, University of Georgia, Athens, GA, USA
Yaping Dan, Harvard University, USA
Ymeti, Aurel, University of Twente, Netherland
Yong Zhao, Northeastern University, China
Yu, Haihu, Wuhan University of Technology, China
Yuan, Yong, Massey University, New Zealand
Yufera Garcia, Alberto, Seville University, Spain
Zakaria, Zulkarnay, University Malaysia Perlis, Malaysia
Zagnoni, Michele, University of Southampton, UK
Zamani, Cyrus, Universitat de Barcelona, Spain
Zeni, Luigi, Second University of Naples, Italy
Zhang, Minglong, Shanghai University, China
Zhang, Qintao, University of California at Berkeley, USA
Zhang, Weiping, Shanghai Jiao Tong University, China
Zhang, Wenming, Shanghai Jiao Tong University, China
Zhang, Xueji, World Precision Instruments, Inc., USA
Zhong, Haoxiang, Henan Normal University, China
Zhu, Qing, Fujifilm Dimatix, Inc., USA
Zorzano, Luis, Universidad de La Rioja, Spain
Zourob, Mohammed, University of Cambridge, UK

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 © 2012 by International Frequency Sensor Association. All rights reserved.

Sensors & Transducers Journal

Contents

Volume 140
Issue 5
May 2012

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).

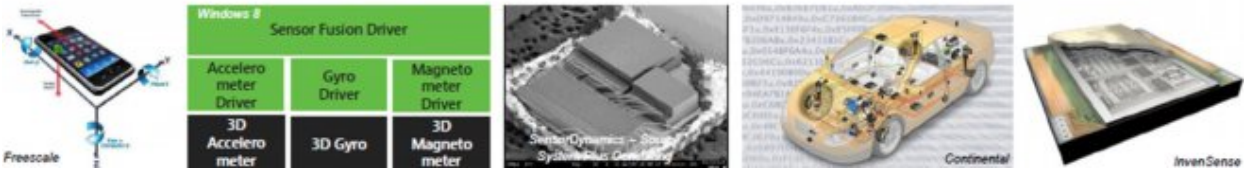
Inertial Combo Sensors for Consumer & Automotive

Technology, Applications, Industry & Market Report to 2016

Promoted by IFSA

This report is focused on the analysis of the opportunities and the challenges for inertial combo sensors in those high-volume market areas.

http://www.sensorsportal.com/HTML/Inertial_Combo_Sensors_Market.htm



Uncooled Infrared Imaging Market: Commercial & Military applications

Market & Technology Report to 2016

Promoted by IFSA

This new 2011 IR report , is an updated and in depth analysis of commercial markets covered in the 2010 report in addition we have included a new analysis of the military markets.

http://www.sensorsportal.com/HTML/Detectors_for_Thermography.htm

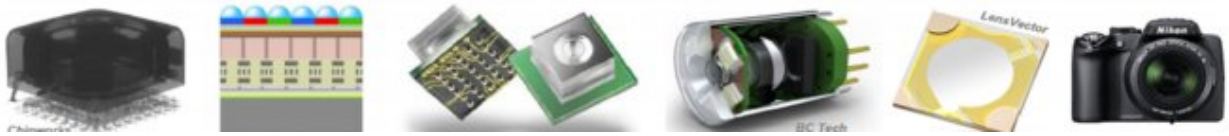
CMOS Image Sensors Technologies & Markets - 2010 Report

Disruptive technologies are paving the way to the future of digital imaging industry !

IFSA offers a SPECIAL PRICE

Image sensors have come a long way since the first introduction of CCD sensor technology in the 1990's. They made a big jump in the 2000's with the introduction of CMOS sensor technology which gave birth to the low-cost, high volume camera phone market. Image sensors are now part of our everyday life: from cell-phone cameras, to notebook webcams, digital cameras, video camcorders to security & surveillance systems. In the future, new markets are also emerging such as sensors for medical applications, automotive security features, but also gaming and home TV webcams ... The reason why we are now releasing our first report on the CMOS image sensor industry is that we feel that we are at an historic turning point for this young, but still maturing industry.

http://www.sensorsportal.com/HTML/CMOS_Image_Sensors.htm



Sensors & Transducers Journal, Vol. 140, Issue 5, May 2012, pp. 106-114

www.sensorsportal.com

Sensors & Transducers

ISSN 1726-5479
© 2012 by IFSA
http://www.sensorsportal.com

Applications of Electronic Nose Based on MOX and QMB Sensors

[1*] Valeria Messina and [1] Noemì Walsőe de Reca

[1] CINSO-CITEDEF (Centro de Investigaciones en Sólidos),
Unidad ejecutora UNIDEF (MINDEF-CONICET)
Juan Bautista de la Salle 4397, Villa Martelli, Buenos Aires, Argentina
E-mail: vmessina@citedef.gob.ar

Received: 27 March 2012 /Accepted: 23Mayl 2012 /Published: 31 May 2012

Abstract: The electronic nose emerged in the mid 80's due that the food industry needed quicker instruments to be applied in food control for the characterization of smell, in order to complement the work done by human panels. But scientific researchers noticed that electronic nose could also be used in other fields, such as environmental contamination, health, defence, automotive industry, control of hazardous substances, etc. The aim of this research article is to explain how electronic nose work and to report the latest researches obtained with electronic nose in the Centre of Investigation of Solids (CINSO). *Copyright © 2012 IFSA.*

Keywords: Electronic nose, MOX sensors, QMB sensors, extra-virgin olive oil, garlic, tomato, volatile compounds.

1. Introduction

Of the five senses, smell has always been the most difficult to define. Understanding how it works has been the goal of researchers for many years. The smell depends on many chemicals that give a character and unique qualities [1].

The ability to measure and identify the optimal development of odour and taste characteristics is a constant crucial point in the development of many products [2]. The electronic nose can be defined as an instrument with sensors or chemicals columns which has a program containing a chemometric recognition model, which can distinguish and compare individual or complex odour in a sample.

The data obtained from electronic nose is qualitative, due that the aim of the instrument is to analyze and recognize the traces of complex odour by evaluating together the volatile components of the sample analyzed imitating the human olfactory system.

1.1. System Electronic Nose

The human olfactory system consists of a set of olfactory cells that interact with aromatic molecules. The signals are sent to the olfactory bulb and from there to the brain, which processes all the information [2, 3]

On the other hand, with electronic nose the system is similar as the human olfactory, the volatile molecule interacts with a sensor system or a column system, where each sensor or column equivalent to a human olfactory cell and the data provided are processed by a computer system in order to obtain a response equivalent to the odour fingerprint of the sample analyzed.

The use of electronic nose based on different sensor technologies has been suggested for the rapid detection of quality-related volatile compounds for various food products. Gas sensors that are commonly used in electronic noses are non-selective toward individual compounds but show sensitivity toward certain classes of compounds. This property induces their potential for monitoring quality, associating it with varying levels of different classes of produced volatile compounds.

The electronic nose consists of three basic components: the sampling system, the detection system (sensors or columns) and the system of data processing.

1.2. The Sampling System

The techniques used to obtain volatile compounds from the sample and to transport it to the sensor system or columns are by headspace techniques. These techniques are based on generating a vapor phase (headspace) in equilibrium with the sample, solid or liquid, at a given temperature.

The headspace is the amount of gases that are introduced into the sensor or column. The gases are volatile compounds obtained from the sample during its thermal equilibrium.

1.3. The Detection System

In the market there are three types of noses that differ mainly in the detection system: gas sensors, mass spectrometry and gas chromatography.

• Sensors gases: gas sensors exhibit the property of modifying any of its electrical properties of the odour when the compounds interact with its surface. A battery of sensor response is obtained which is the sum of the interactions made by all the volatile molecules and the resulting diagram can be interpreted as a fingerprint of the odour of the sample analyzed.

There are different types of sensors that can be classified according to material used: semiconductors doped tin oxide, conducting polymers and piezoelectric crystals (quartz microbalance).

- Mass spectrometry: sensors coupled to a mass spectrometer as detection system. The spectrum obtained is equivalent to the response of a multisensor with many sensors as ions formed.
- Gas Chromatography: The spectrum obtained is equivalent to the response of a multisensor.

1.4. Data Analysis

The amount of information obtained from the detection system is very large. To handle this large data set it is necessary to use statistical tools to visualize natural groupings of samples.

The first step is to process the sensor signals in order to transform the data into a suitable form for subsequent treatments. Next, the processed data can be analyzed using various statistical techniques: principal component analysis (PCA), cluster analysis (CA), SIMCA (Soft Independent Modelling Class Analogy), KNN (K-Nearest Neighbours) and principal component regression (PCR) [4].

2. Materials and Methods

Since 1998, the CINSO (Center for Research in Solid-CITEDEF CINSO /UNIDEF-MINCEF-CONICET), has worked with a prototype called electronic nose MOSES II. It was designed by the University Tübingen (Germany) GmbH and Lennartz Elektronische.

2.1. Electronic Nose

An electronic nose MOSES II (Modular Sensor System) was used to discriminate odours. MOSES II contains two modules of gas sensors, one of them composed of eight quartz microbalance sensors (QMB). This type of sensors consists of vibrating quartz crystals covered with polymeric selective coatings, on which gases are adsorbed. The initial vibration frequency (υ_0) of crystals decreases according to the mass increase because of the gases adsorption and the difference between υ_0 and the final frequency (υ_f) results proportional to the adsorbed gas concentration.

The other module of MOX sensors (SnO_2) is composed by eight pure and doped semiconductive SnO_2 sensors. Doping with different elements increases SnO_2 selectivity for different gases. The SnO_2 surface conductivity changes as the semiconductor adsorbs oxidising or reductive gases [16]. The adopted configuration results very flexible for general purposes and convenient for a wide range of applications.

These types of sensors allow us to make the fingerprint of the odour through the signals obtained from the set of sensors. Briefly, and as examples, some of the themes developed in the CINSO with the electronic nose will be mentioned.

2.2. Samples Analyzed with an Electronic Nose

2.2.1. Effect of Light on Odour Profile, Volatile Compounds and Vitamins of Extra-virgin Olive Oil

Extra-virgin olive oil varieties samples were properly obtained from fresh, mature fruits of good quality provided by an Oil mill from Chacras de Coria (Mendoza, Argentina)

Varieties of Argentine extra virgin olive oil were exposed to light and darkness during 24 weeks. Odour changes were monitored using an electronic nose. Samples from both varieties were placed in clear glass bottles of 500 mL, containing a headspace of 3% and hermetically closed.

Samples were located in illuminating equipment at a distance of 80 cm from the lights tube (D65 Osram-temperature: 4227 8C and luminance of 1580 lux). Samples were exposed to light and

darkness during 8 h, 5 day's a week during 120 days. Analysis was carried at intervals of 2 weeks until 24 weeks. Procedure was repeated thrice and triplicate samples were taken each time.

2.2.2. Effect of Frying on the Odor Profile of Olive Oil Extra Virgin, Volatile Compounds and Vitamins

Changes in the odour profile of extra virgin olive oil varieties (Arbequina (ARB) and Arauco (ARA)) were monitored during frying process with an electronic nose.

For thermal oxidation, frying pans were filled with 600 mL of extra virgin olive oil (EVOO) and heated at 180 °C. Oil samples were obtained at the beginning of the experiment and then, four times at intervals of 15 min (t_{15}) during 60 min (t_{60}). Frying procedure was repeated thrice and triplicate samples were taken each time.

2.2.3. Electronic Nose Study of Powdered Garlic

Garlic cloves of eight different cultivars (Fuego, Sureño, Perla, Castaño, Gostoso, Nieve, Norteño and Unión (being the original Spanish names given at INTA preserved) cultivated at INTA-La Consulta, Mendoza (Argentina) were peeled, weighted, cut into slices and dehydrated by two different methods: I) Oven-drying and II) lyophilization.

In the first case, samples were dried in oven at 50 °C for 24 h. The second process consisted in lyophilization in a Virtis-Freeze mobile (12 L). Freezing in liquid nitrogen was performed in order to produce an immediate cooling and to avoid the enzymatic hydrolysis of precursor compounds to preserve the flavour. Study of the odour profile of garlic was applied to discriminate garlic specimen dried by lyophilization and oven-dried and humidified specimen (before dried by both techniques) for each cultivar.

Samples remained in the lyophilizing equipment for 24 h and then, they were placed in sealed vials to preserve them from humidity until electronic nose measurements were performed.

2.2.4. Tomato Quality during Short-Term Storage Assessed by Colour and Electronic Nose

Wild-type tomato plants cv. Money Maker and tomato plants overexpressing and silencing Asr1 gene under the control of promoters 35S and B33 were grown under controlled conditions in a greenhouse (200 μmol PARs-1 m-2, 60% RH, 23 °C).

Fruits were harvested manually from plants grown in the National Institute of Agropecuary Technology, during the summer at the ripening stage 5 (light red) (USDA colour chart, 1975). Fruits of uniform shape and size and free from fungal infection were selected. After harvest, fruits were washed with a solution of hypochlorite (150 ppm de Cl_2 as hypochlorite of sodium), air-dried at atmospheric temperature, and individually labelled and weighed. Samples were kept at 19 ± 0.5 ^{0}C and 85% RH and analyzed weekly (7 days) for three weeks (21 days).

An assay based on an electronic olfactory system was set to evaluate tomato fruits by sensing the aromatic volatiles during post harvest storage of 21 days at 19 ± 0.5 ^{0}C in darkness. Olfactory system measurements were coupled with colour values. Odour profile and senescence parameters were carried out at 7-day intervals.

3. Results and Discussion

3.1. Effect of Light on Odour Profile, Volatile Compounds and Vitamins of Extra-virgin Olive Oil

Principal Component Analysis applied to analyze data obtained from the responses of the eight sensors of SnO_2 doped (MOX) samples for Arauco extra virgin olive oil exposed to light and darkness showed a principal component (PC1) which explained 84.4 % of the total variance. The CP_1 was correlated positively with SnO_2 sensors (data not shown). On the other hand, Arbequina extra virgin olive oil samples subjected to light and darkness, explained 95.6 % of the total variance and was also correlated positively SnO_2 with sensors (data not shown).

Fig. 1 shows the average of the eight SnO_2 doped sensors (MOX) as a function of Principal Components (PC_1) in relation to exposure (light and darkness) as a function of time (weeks) for Arauco and Arbequina extra virgin olive oil.

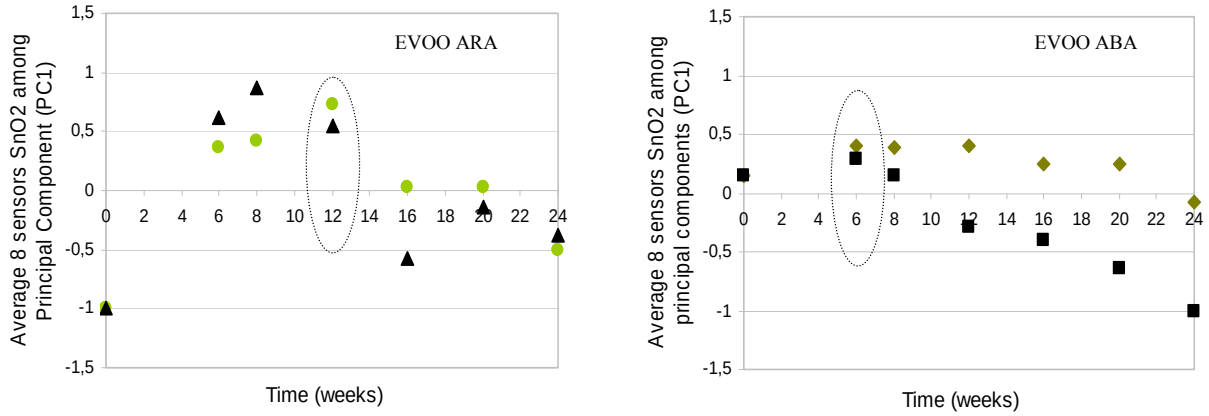


Fig. 1. Average of eight sensors of SnO_2 on CP_1 in olive oil extra virgin (EVOO) of: (a) varietal Arauco (ARA) exposed to light (□ ●) and darkness (▲) as a function of time (weeks) and (b) varietal Arbequina (ARB) exposed to light (♦) and darkness (t ■) as a function of time (weeks).

Arauco extra virgin olive oil at initial time (t_0) with light and darkness exposure showed a negative value on the PC_1, indicating a low response of the sensors. On the other hand, olive oil exposed to light after 12 weeks showed an increase in response of the sensors. Showing a defined separation between light and darkness exposure.

On the other hand, the data obtained from the responses of SnO_2 doped sensors for Arbequina Olive oil, showed a slightly positive value on the PC_1 at initial time (t_0) for samples exposed to light and darkness. Arbequina varieties showed a notable change in the odour from week 6, compared to Arauco (after l2 weeks of exposure) [5].

Analysis of Variance (ANOVA) results of volatile compounds (3-methyl butanal; *n*-pentanal; *n*-hexanal; *n*-heptanal and *n*-nonanal) in both varieties did not show significant differences between light and darkness exposure. Tocopherols (alpha and gamma) showed an important degradation for both varieties after light and darkness exposure, the most important decrease for both varieties was that corresponding to light exposure.

3.2. Effect of Frying on the Odour Profile of Olive Oil Extra Virgin, Volatile Compounds and Vitamins

Analysis applied to data obtained by electronic nose shows the grouping of extra virgin olive oil (EVOO) of Arauco (ARA) and Arbequina (ARB) as a function of different frying times.

One PC_1 was found, accounting 96.6 % of the total variation. PC_1 showed a positive correlation between MOX (doped SnO_2) sensors (S1: □, S2: □, S3: □, S4: □, S5: □, S6: □, S7: □, S8: □) and EVOO (ARA) for all frying times: 15 min (▲), 30 min (▲), 45 min (▲), 60 min (▲). Conversely, EVOO (ARB) showed a negative correlation with doped SnO_2 sensors for all frying times (15 min (●), 30 min (●), 45 min (●) and 60 min (●)).

Fresh samples for EVOO ARA at initial time (▲) and ARB at initial time (●), were located on negative PC_1. EVOO (ARA) corresponding to frying time 60 min (▲) showed the highest positive scores representing the highest sensors response (S1: □, S2: □, S3: □, S4: □, S5: □, S6: □, S7: □, S8: □).

The analysis of variance showed an increase in the production of volatile compounds, in particular: 3 - methyl butanal, *n*-pentanal, *n*-hexanal, *n*-heptanal and *n*-nonanal for both varieties [6, 7].

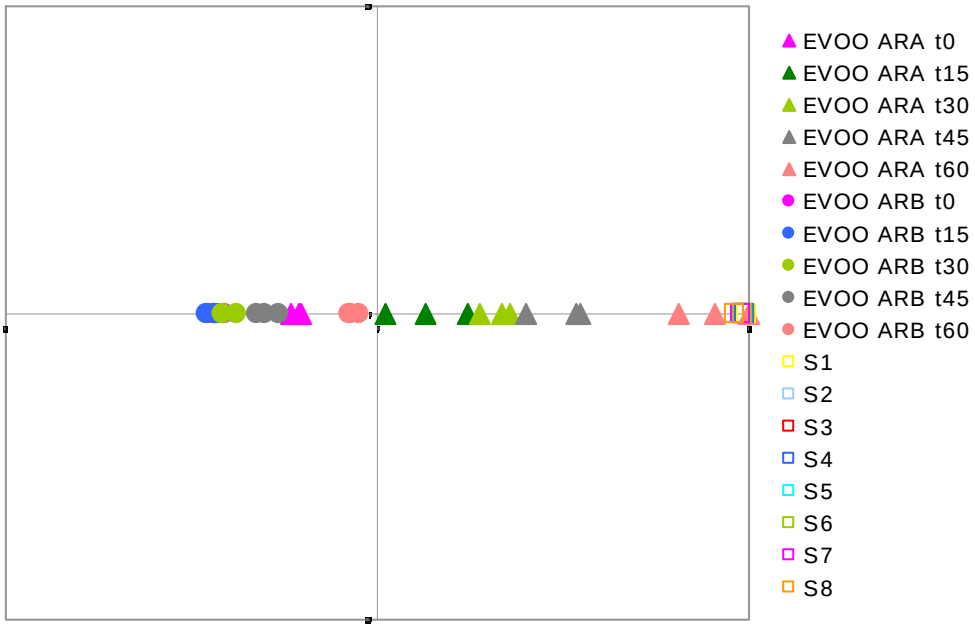


Fig. 2. Principal components analysis of electronic nose data corresponding to different frying time of extra-virgin olive oil (EVOO) for ARA (Arauco), at initial time (▲),15 min (▲),30 min (▲),45 min (▲),60 min (▲),and ARB (Arbequina), at initial time (●), 15 min (●), 30 min (●), 45 min (●) and 60 min (●) with different doping of SnO_2 (S1: □, S2: □, S3: □, S4: □, S5: □, S6: □, S7: □, S8: □).

3.3. Electronic Nose Study of Powdered Garlic.

3.3.1. Oven-dried and Lyophilized Samples

Applying the stepwise linear discriminant analysis to the principal components of the 16 signals (eight corresponding to MOX and eight to QMB sensors) properties, a 95 % successful classification was reached with cross validation. Values of the two first discriminant functions of each specimen,

accounting 95.7 % of the system variability (77.3 % for the first and 18.4 % for the second one). Two groups were defined according to samples oven-dried and lyophilized (data none shown).

3.3.2. Oven-dried and Lyophilized Samples with and Without Humidification

Including all the samples (dried and lyophilized, with and without humidification) a model could be built reaching a correct 87.3 % classification, by cross validation (69 success and 10 errors) applying the stepwise LDA on the principal components of the sensor curves properties (data of electronic nose). The three discriminant principal functions explained 95.6 %, 3.3 % and 0.5 % of the variance, respectively. Fig. 3 represents the bidimensional plot of the two first functions (summarizing 98.9 %). It enabled to observe that every non humidified specimen exhibited a similar behaviour, clustering in the inferior left zone of the plot. It is also observed that by humidification, the behaviour of oven-dried powders resulted different from that of lyophilized powders exhibiting a clearer separation among cultivars.

This fact enabled to infer that lyophilized powders (either dry or humidified) better retained their odour profile than oven-dried powders, maintaining the properties of each cultivar [8]

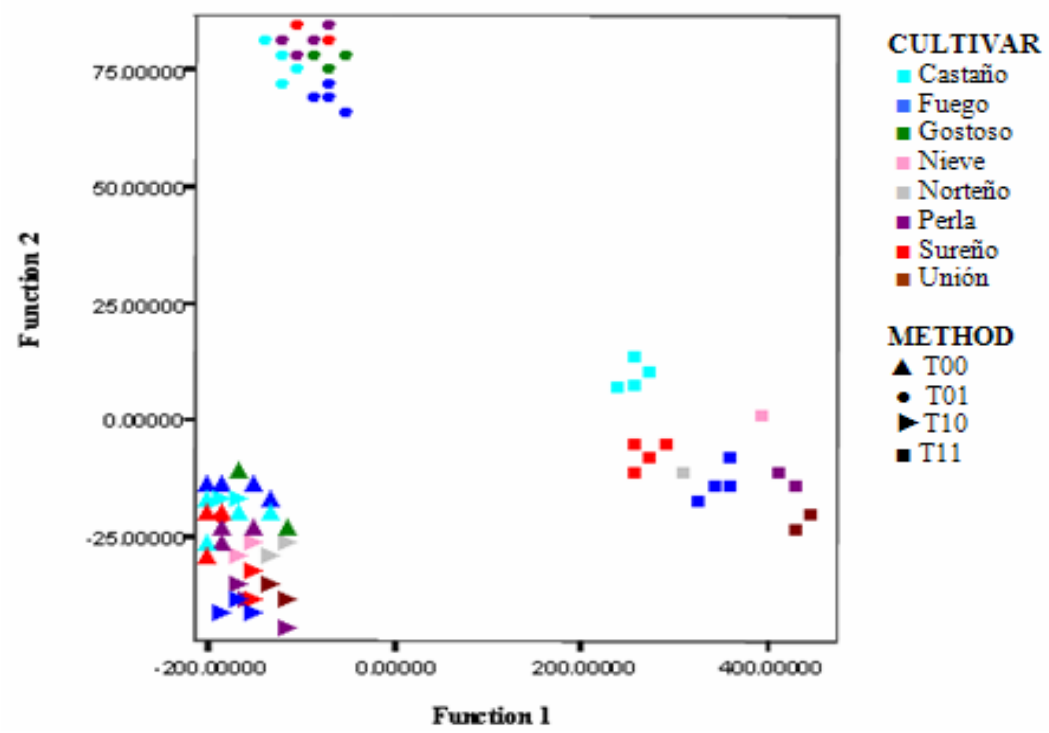


Fig. 3. Stepwise linear discriminant analysis applied on the principal components of the properties of the sensors curves of the electronic nose (using all the cases) for oven-dried-non humidified with distilled water (T00: ▲); oven-dried- humidified with distilled water (T01: ●); lyophilized-non humidified with distilled water (T10: ►) and lyophilized- humidified with distilled water (T11: ■) cultivars (Castaño: ■, Fuego: ■, Gostoso: ■, Nieve: ■, Norteño: ■, Perla: ■, Sureño: ■ , Unión: ■).

3.4. Tomato Quality during Short-Term Storage Assessed by Colour and Electronic Nose

Discriminant function analysis applied to electronic nose data for MOX sensors showed three components, accounting for 99.2 % of the total variance. In the present assay, separation among groups according to storage time (0, 7, and 14 days) was observed for wildtype. Over expressed

(Money Maker) lines/plants of tomato showed difference between odour profile for day 0 and day 21, even tough a no clear discrimination between 7 and 14 days was observed (Fig. 4).

Fruit lost weight almost linearly with shelf life ($P < 0.001$) presenting an averaged loss of 21% ($r2 = 0.98$) for over expressed (Money Maker) lines/plants, 13 % ($r2 = 0.97$) for silenced (Money Maker), and 14 % ($r2 = 0.98$) for wild type during 21 days of storage.

Colour values L^*, a^*, and b^* data showed that colour properties changed during storage for all the lines considered. Correlations between odour profiles and colour parameter were obtained showing that the electronic nose is a useful technique for monitoring short-term storage of tomato [9].

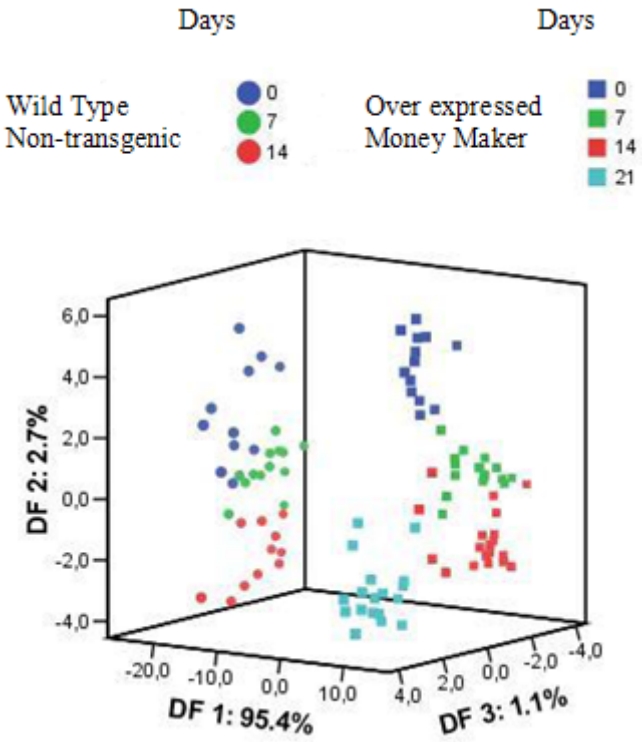


Fig. 4. Discriminant analysis of electronic nose for transgenic tomatoes (Money Maker over-expressed) and non-transgenic (WildType) as a function of storage (Money Maker over-expressed: ● day 0; ● day 7; ● day 14 and ■ day 21) and non-transgenic (WildType: ■ day 0; ■ day 7; ■ day 14).

4. Conclusion

Studies carried out with the electronic nose system based on the headspace were satisfactory and showed that this technique may have wide application, not only for the food industry but in other areas of interest. It is important to mention that they act quickly and objectively, allowing it to be a complementary tool for sensory analysis.

References

[1]. Pearce, T., Gardner J. Predicting organoleptic scores of sub-ppm flavour notes. Part 1. Theoretical and experimental details. Part 2. Computational analysis and results, *Analyst*, 123, 6, 1998, pp. 2047-2066.

[2]. Piggott, J., Understanding flavour quality: Difficult or impossible ?, *Food Quality and Preference*, Vol. 33, Issue 4, 1994, pp. 191-197.

[3]. Bult, J., Wijk, R., Hummel, T. Investigations on multimodal sensory integration: Texture, taste, and ortho- and retronasal olfactory stimuli in concert, *Neuroscience Letters,* 411, 1, 2007, pp. 6-10.
[4]. Weber, D. C, Skillings, J. H., A first course in the design of experiments, *CRC,* New York, 2000.
[5]. Messina, V., Biolatto, A., Descalzo, A., Sancho, A., Walsöe de Reca, N. Effect of pan-frying in extra-virgin olive oil on odour profile, volatile compounds and vitamins, *International Journal of Food Science and Technology,* 2009, 44, pp. 552 – 559.
[6]. Messina, V., Biolatto, A., Descalzo, A., Sancho, A., Walsöe de Reca, N. Thermo-oxidation in Arauco and Arbequina Extra-virgin Olive Oil. Changes in Odour Using and Electronic Nose and SPME-GC-FID, *Sensors & Transducers*, 2010, 11, pp. 112-119.
[7]. Messina, V., Biolatto, A., Descalzo, A., Sancho, A., Baby, R., and Walsőe de Reca, N. Effect of light on odour profile, volatile compounds and vitamins of extra-virgin olive oil, *Journal of Food*, 2009, 7, pp. 59–66.
[8]. Baby, R., Sance, M., Bauzá, M., Messina, V., Rodríguez, E., Gómez, A., Walsöe de Reca, W., Burba, *Sensors & Transducers*, 2009, 107, pp. 26-34.
[9]. Messina, V., Dominguez, P., Sancho, A., Walsőe de Reca, N., Carrari, F., Grigioni, G. Tomato quality during short-term storage assesed by colour and electronic nose, *Journal of Electrochemistry*, 2012 (in press).

2012 Copyright ©, International Frequency Sensor Association (IFSA). All rights reserved.
(http://www.sensorsportal.com)

International Frequency Sensor Association

IFSA
www.sensorsportal.com

International Frequency Sensor Association (IFSA) is a professional association, created with the aim to encourage the researches and developments in the area of quasi-digital and digital smart sensors and transducers.

IFSA Membership is open to all organizations and individuals worldwide who have a vested interest in promoting or exploiting smart sensors and transducers and are able to contribute expertise in areas relevant to sensors technology.

More than 600 members from 63 countries world-wide including ABB, Analog Devices, Honeywell, Bell Technologies, John Deere, Endevco, IMEC, Keller, Mazda, Melexis, Memsis, Motorola, PCB Piezotronics, Philips Research, Robert-Bosch GmbH, Sandia Labs, Yokogava, NASA, US Navy, National Institute of Standard & Technology (NIST), National Research Counsil, etc.

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

The 3rd International Conference on Sensor Device Technologies and Applications

SENSORDEVICES 2012

19 - 24 August 2012 - Rome, Italy

Deadline for papers: 5 April 2012

Tracks: Sensor devices - Ultrasonic and Piezosensors - Photonics - Infrared - Geosensors - 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/conferences2012/SENSORDEVICES12.html

The 6th International Conference on Sensor Technologies and Applications

SENSORCOMM 2012

19 - 24 August 2012 - Rome, Italy

Deadline for papers: 5 April 2012

Tracks: Architectures, protocols and algorithms of sensor networks - Energy, management and control of sensor networks - Resource allocation, services, QoS and fault tolerance in sensor networks - Performance, simulation and modelling of sensor networks - Security and monitoring of sensor networks - Sensor circuits and sensor devices - Radio issues in wireless sensor networks - Software, applications and programming of sensor networks - Data allocation and information in sensor networks - Deployments and implementations of sensor networks - Under water sensors and systems - Energy optimization in wireless sensor networks

http://www.iaria.org/conferences2012/SENSORCOMM12.html

The 5th International Conference on Advances in Circuits, Electronics and Micro-electronics

CENICS 2012

19 - 24 August 2012 - Rome, Italy

Deadline for papers: 5 April 2012

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/conferences2012/CENICS12.html

Sensors & Transducers Journal

Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In 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. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

Topics Covered

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

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

Submission of papers

Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 8-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: http://www.sensorsportal.com/HTML/DIGEST/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_2012.pdf

International Frequency Sensor Association Publishing

Digital Sensors and Sensor Systems: Practical Design will greatly benefit undergraduate and at PhD students, engineers, scientists and researchers in both industry and academia. It is especially suited as a reference guide for practicians, working for Original Equipment Manufacturers (OEM) electronics market (electronics/hardware), sensor industry, and using commercial-off-the-shelf components, as well as anyone facing new challenges in technologies, and those involved in the design and creation of new digital sensors and sensor systems, including smart and/or intelligent sensors for physical or chemical, electrical or non-electrical quantities.

"It is an outstanding and most completed practical guide about how to deal with frequency, period, duty-cycle, time interval, pulse width modulated, phase-shift and pulse number output sensors and transducers and quickly create various low-cost digital sensors and sensor systems …" (from a review)

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

www.sensorsportal.com