ISSN 1726-5479

SENSORS & TRANSDUCERS

vol. 139
4/12

LSM320HAY30
MEMS module

MEMS and Modern Technologies

International Frequency Sensor Association Publishing

Sensors & Transducers

Volume 139, Issue 4, April 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
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 139
Issue 4
April 2012

www.sensorsportal.com

ISSN 1726-5479

Research Articles

MEMS Non-Silicon Fabrication Technologies
Poonam Goel 1

Improved Modeling of the Comb Drive Levitation Effect by Using Schwartz-Christoffel Mapping
Fengyuan Li and Jason Vaughn Clark 24

Review of MEMS Based Application in Medical Industries
Kochuthomman Joseph Mampilly, Arjun Ashok, Sudha Ramasamy and Prabhu Ramanathan........ 35

Investigation of the Effect of Residual and Axial Stress, on Pull-in Instability of a Fully Clamped Micro-beam under Electrostatic Actuation, Considering Fringing Field Effect
Saber Azizi, Mohammad Reza Ghazavi, Ghader Rezazadeh, Farrokh Mobadersani........ 45

A Feasibility Study of Analogue and Digital Silicon Photomultiplier as an Alternative to PMT for Low Light Level Applications
Johnson Mundupuzhakal, Yashwant Acharya, Pranav Adhyaru, Bishwajit Chakrabarty 52

Simulation and Design Optimization of Piezoelectricaly Actuated Valveless Blood Pump for Hemofiltration System
Shahzadi Tayyaba, Nitin Afzulpurkar, Muhammad Waseem Ashraf 63

Realization of Porous Silicon Distributed Bragg Reflector for Optical Sensing Applications
P. N. Patel, V. Mishra, A. K. Panchal, N. H. Maniya 79

Study of Creep Recovery for Force Transducers Compared with Creep Behavior
Ebtisam H. Hasan, Rolf Kumme and Günther Haucke 87

Surface Plasmon Resonance Based Fiber Optic Sensor Utilizing Metal Nanoparticles: Influence of Ambient Temperature
Sachin K. Srivastava, Vikas Arora, Sameer Sapra and Banshi D. Gupta........ 95

Nanostructured $Ni_{0.5}Zn_{0.5}Ce_3O_5$ Oxide Based Electronic Nose Sensitive to Ammonia at Operable Temperature
S. V. Bangale, R. D. Prakshale, S. R. Bamane........ 109

Development of Nanostructured Polypyrrole (PPy) Thin Film Sensor For NO_2 Detection
M. A. Chougule, Shashwati Sen, V. B. Patil........ 122

Initial Study on Optical Tomographic Instrumentation System Based on CMOS Area Image Sensors
Mariani Idroas, Suhaila Mohd Najib, M. Nasir Ibrahim, Ruzairi Abd. Rahim, Muhammad Saiful Badri Mansor 133

Modification of the Wheatstone-Bridge for Measurement of a Process Variable by a Resistive Transducer Using Lab VIEW
Narayana K. V. L and Bhujanga Rao A......... 141

The Biophysics of Nucleic Acids Sensing by Hybridization on a Lab-on-Chip Device
Giorgio Ventimiglia and Salvatore Petralia... 152

Development of MEMS Varactor on Microwave Laminate Board for RF Applications
Poonam Goel, C. Anthonisamy.. 162

Sensitivity Analysis of Piezo-electric Devices to Perturbed Boundary Conditions
Arthur Savchenko.. 175

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).

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, Vol. 139, Issue 4, April 2012, pp. 162-174

Sensors & Transducers

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

Development of MEMS Varactor on Microwave Laminate Board for RF Applications

[*] Poonam GOEL, C ANTHONISAMY
[*] Department of Electrical Communication Engineering,
Centre for Electronics Design and Technology
Indian Institute of Science, Bangalore, India
E-mail: poonam.goel13@gmail.com

Received: 3 March 2012 /Accepted: 23 April 2012 /Published: 30 April 2012

Abstract: This paper presents the development of an electrostatically actuated MEMS varactor on microwave laminate board for RF MEMS applications using a convenient and economical fabrication approach. MEMS varactor is implemented using multilayer technology in which bottom electrode is patterned on microwave laminate board whereas beam structure and spacer (to create air gap) are realized using thin copper foil. Metal micromachining process is modified to attain straight beams on thin metal foil. A copper foil of 40um thickness is used to realize beam structure. 15 μm thickness copper foil is micromachined to form spacer. MEMS varactor is characterized for deflection and resonant frequency using Laser Doppler Vibrometer. Measured, analytically modelled and finite element method 3D tool Coventorware simulation pull-in voltages are 171 V, 153 V, 177 V respectively. Measured and FEM simulation pull-in voltage showed good agreement within 3.5 %. Measured and modelled capacitance tuning ratio is within 9.3 % which is acceptable. It is observed that measured resonant frequency is 2.8 kHz whereas modelled is 3.23 kHz which shows close agreement within 13.3 %. The proposed device has found major application in microwave and millimeter systems because microwave laminate board is the most preferred substrate for RF systems.
Copyright © 2012 IFSA.

Keywords: RF MEMS, Varactor, Microwave laminate, Milling, Micromachining, Photochemical.

---

1. Introduction

RF MEMS technology has poised to revolutionize communication system due to its advantages of low insertion loss, negligible DC power consumption and creating the feasibility of monolithic integrated

system. But in spite of its advantages, this technology is not being much used in commercial systems, the reason being its high cost and integration issues Conventional RF MEMS fabrication needs high class clean room and sophisticated equipments which adds in the device cost. In addition to that, RF MEMS device fabricated on conventional substrates such as Si, Quartz, Glass etc. are packaged individually and are integrated in RF system using bonding techniques which may cause parasitics. Integration of individually fabricated and packaged RF MEMS device in system needs extra impedance matching circuitry which makes the system complex. These issues can be overcome by creating RF MEMS on microwave laminate board integrated with RF system i.e. monolithic RF system which is similar to system on chip.

Microwave laminate board is the most commonly used substrate for RF systems due to availability of wide range dielectric constant microwave laminate boards with low tangent loss. Since a decade, researchers are working on implementation of RF MEMS devices on microwave laminate board. RF MEMS switches [1, 2, 3, 4], phase shifter[5], monolithic phased antenna array with embedded RF MEMS phase shifter [6, 7] are already reported on microwave laminate board. In addition, fluidic microsystems [8, 9], MEMS capacitive pressure sensor[10] are also reported using PCB technology. There are fabrication processes reported to realize RF MEMS on microwave laminate board such as high density inductively coupled plasma chemical vapour deposition (HDICP CVD) which is a low temperature (90 ºC -170 ºC) process for microwave laminate board [11] and metal micromachining process using laser milling and computer numerical controlled (CNC) milling to realize RF MEMS membrane [4]. Still there is need to refine existing processes, in addition to the development of new fabrication approaches and processes to implement RF MEMS on microwave laminate board to cut down the cost and make fabrication processes commercially feasible.

In this paper we are demonstrating a low cost and convenient fabrication approach to realize MEMS varactor on microwave laminate board using modern PCB technology. Print and etch is used to pattern copper clad of microwave laminate board whereas micromachined thin metal foil is used to realize beam structure and spacer. This approach does not use any metal deposition/lithography/etching process. With the proposed approach, RF MEMS device can be implemented on microwave laminate board integrated in RF system. The major application of MEMS varactor is in distributed MEMS transmission lines which are already demonstrated to implement phase shifter and tunable filters. We reported meso-scale electrostatically actuated phase shifter on microwave laminate board (MEPL) [5] which operates similar to distributed MEMS transmission line phase shifter and also monolithic phased antenna array with embedded MEPL phase shifter [6].

MEMS varactor design aspects are discussed in section 2. Device fabrication and assembly are explained under section 3. In device fabrication approach, PCM (photo-chemical milling) process and conventional metal foil micromachining processes are described. Experimental set-up and measurement results are presented under section 4. Section 5 summarizes the major contribution of this research work.

2. Design of MEMS Varactor

This MEMS (Fig. 1) varactor is operated using electrostatic actuation mechanism. Electrostatic actuation takes place by applying DC bias voltage between beam and bottom electrode. Electrostatic force actuates the air bridge out of plane (along Z-axis), which causes change in capacitance. The electromechanical modelling is done to find out the actuation voltage for MEMS air bridge.

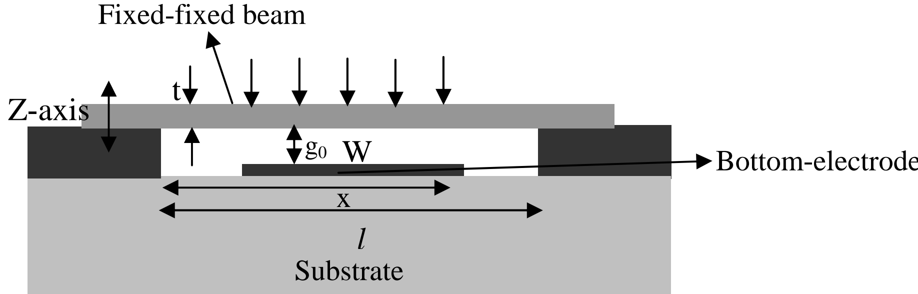


Fig. 1. Fixed –fixed beam with uniform load in the centre.

Electrostatic actuation is based on the Coulomb's law by which the electrostatic force (F_e) between oppositely charged plates separated by a gap *g* and a potential of *V,* is given by

$$F_e = \frac{1}{2} V^2 \frac{dC(g)}{dg} = -\frac{1}{2} \frac{\varepsilon_0 wWV^2}{g^2}, \tag{1}$$

where the parallel plate capacitance *C* depends on the position of the movable bridge electrode whose width is *w*. The width of the bottom electrode is *W*. The beam is stable as long as the electrostatic force is balanced by the beam restoring force.

$$\frac{1}{2} \frac{\varepsilon_0 wWV^2}{g^2} = k(g_0 - g) \tag{2}$$

Beam restoring force is the mechanical force due to beam stiffness *k*. In Eq. (2), g_0 is the original height of the beam electrode above the bottom conductor. Since the Coulomb force increases quadratically as *g* is reduced, electrostatic force dominates the elastic restoring force. Once the bias voltage exceeds a certain level, and the beam becomes unstable. This phenomenon is known as pull-in which occurs at around g=1/3g_0. For reliable operation of this phase shifter the deflection should be below this value. The corresponding bias voltage is given by

$$V_P = \sqrt{\frac{8kg_0^3}{27\varepsilon_0 A}}, \tag{3}$$

where $A = w \times W$ is the actuation area (*w* is beam width and *W* is bottom electrode width). In this design, fixed-fixed beam is deflected with a uniformly distributed force directly above the center bottom electrode conductor trace [12]. Spring constant can be obtained from:

$$k = 32Ew\left(\frac{t}{L}\right)^3 \frac{1}{8\left(\frac{x}{L}\right)^3 - 20\left(\frac{x}{L}\right)^2 + 14\left(\frac{x}{L}\right) - 1}, \tag{4}$$

where *E* is Young's modulus of elasticity, *t* is the beam thickness, *L* is the beam length, *k* is spring constant of beam structure and x (from Fig. 1):

$$x = {(L+W)}/{2}$$

Resonant frequency of the beam structure is given by the following expression:

$$f_r = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \tag{5}$$

where *m* is mass of beam which can be evaluated using beam material density and volume. Young's modulus of copper is taken 128GPa. Air gap is selected depending on the availability of copper foil thicknesses whereas beam thickness is decided under consideration of manual handling during fabrication. Other design parameters are selected with the help of analytical model. The finalized design parameters of the MEMS varactor are listed in Table 1.

Table 1. Design parameters of the fabricated device.

Design parameter	Value
Beam thickness (μm)	40
Beam length (μm)	6000
Beam width (μm)	300
Bottom electrode width (μm)	4000
Air gap (μm)	15
Young's Modulus (GPa)	128

The analytically modelled pull-in voltage obtained using equation (3) is 153 V. But, this expression for pull-in voltage assumes 1-dimensional beam movement and deformed beam without considering torsion. It considers only parallel plate capacitance without fringing effects. Fringing effect is due to the fields at the edges. Therefore 3D simulation are carried out in Coventorware which is a finite element method based electromechanical simulation software, for an accurate modelling incorporating the effects which were not included in the analytical approach. Coventor simulation pull-in voltage is 171 V. Analytically modelled and FEM 3D Coventorware simulation pull-in voltage is within 10.5 % which is acceptable. The device with design parameters listed in Table 1 is fabricated and characterized. Device fabrication details are discussed in next section.

3. Fabrication of MEMS Varactor

A thin copper foil is used to form top beam structure membrane as well as spacer layer to create the air gap between beam and bottom electrode. Air gap equal to metal foil thickness is created by inserting metal foil spacer between beams and bottom electrode. Beams and spacer are patterned on copper foil using photochemical milling. Bottom electrode conductor traces are patterned on microwave laminate copper clad using '*print and etch*'. Beam structures membrane is attached to microwave laminate metal clad with spacer metal in between. In order to minimize the fabrication cost, no metal deposition/lithography/etching is used. Fabrication processes are modified to meet these challenges during fabrication of MEMS varactor on microwave laminate board.

3.1. Patterning Copper Clad of Microwave Laminate Board

Microwave laminate board Arlon AD250 of height 60mils with dielectric constant 2.5 is used as substrate. Microwave laminate board cleaning is done by soft rubbing with scrub and giving 1min dip in 10 % Sulphuric acid (H_2SO_4) solution. After this, the sample is thoroughly washed with the DI water to remove the acid contents and kept in the oven for 5min at 80 ℃ temperature to dehydrate water

contents from microwave laminate board. The cleaning process removes organic particles, dust and other external particles from the substrate surface. Microwave laminate board with both side metallization layers as shown in schematic Fig. 2 (a), is cleaned to pattern the bottom electrode and ground conductor traces of MEMS varactor. Here dry film photo-resist is laminated and exposed for lithography on the microwave laminate board. Print and etch technique is used to realize conductor traces on one side and conductor clad is completely etched away from the other side of microwave laminate board, as shown in schematic Fig. 2 (b). Width of the bottom electrode conductor trace is 4000um, whereas the slot spacing between centre conductor and side conductor is 1000 µm.

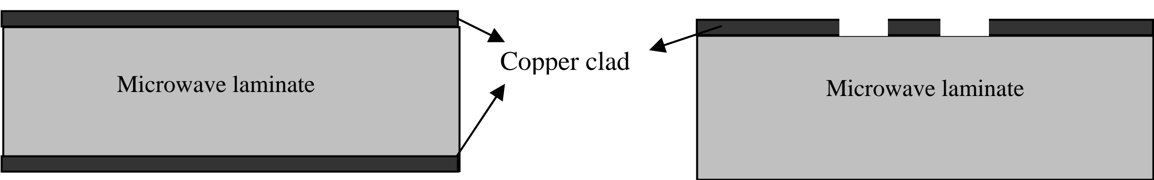


Fig. 2. (a) Microwave laminate board with both side metallization; (b) CPW patterned on the microwave laminate board

3.2. Copper Foil Micromachining to Create Beam Structures

Copper foil of 40um thickness foil is used as membrane to realize beam structures. In conventional MEMS microfabrication, metal patterning is carried out using wet chemical etching or dry etching whereas Ramadoss et al [4] reported CNC/laser milling to pattern films to implement MEMS on PCB. Initially, attempts were made to patterns copper foil using wet chemical etching. In wet chemical etching, sample is dipped in wet etchant and kept still. Beam structures realized using wet chemical etching resulted in wrinkled beam structures (Fig. 3). Fig. 4 is 3D image of beam structures taken with Wyco profilometer which depicts that surface profile variation of patterned beam structure is 64 µm to 212 µm along Z-axis. Wrinkles in beam structures are due to internal residual stresses of the foil. Measured residual stress of 40um thick copper foil is ~74MPa. Therefore internal residual stress of the copper foil should be managed to achieve straight beam structures which is possible using photochemical milling (PCM).

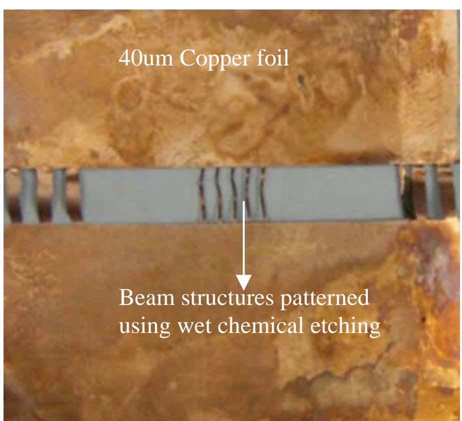


Fig. 3. Multiple beam structures patterned on copper foil using wet chemical etching.

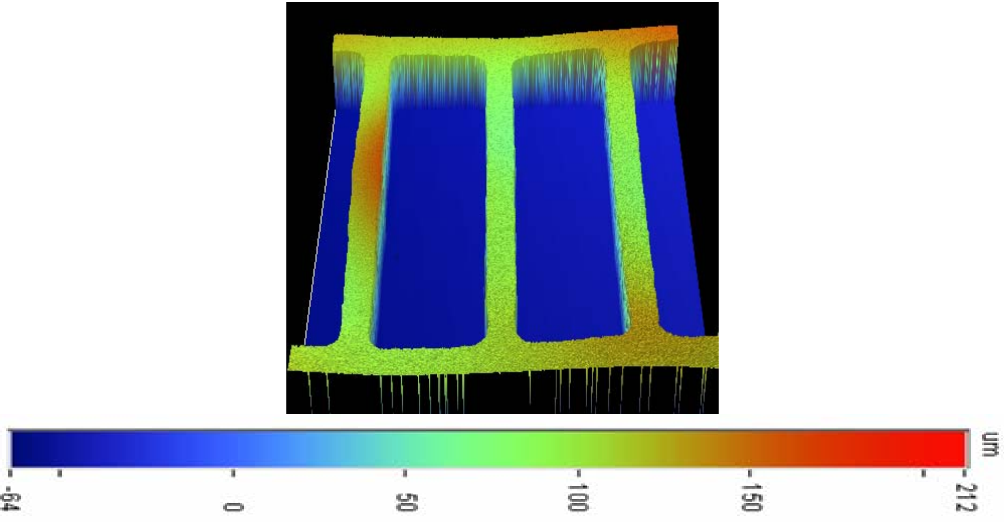


Fig. 4. Wyco optical profilometer 3D images of beams patterned on copper foil using wet chemical etching.

3.2.1. Photochemical Milling (PCM)

To remove the effect of induced residual stress on beam structures during copper foil micromachining, a modified technique photochemical milling is proposed. In PCM, etching is done with chemical etchants under controlled temperature and pressure of etchants. In this, etching line consist of multi-chambered machine that has driven-wheel conveyors to move the plates and arrays of spray nozzles above and below the plates. The etchant is an aqueous solution of acid that is heated and directed under the pressure on both sides of the plate. The etchant reacts with the unprotected metal essentially corroding it away quickly. After neutralizing and rinsing, the remaining part of resist is removed and metal foil is cleaned and dried. It can be used for materials of thicknesses ranging up to 200 µm. Metals that can be patterned include aluminium, brass, copper, manganese, nickel, silver, steel, stainless steel, zinc and titanium. Etching is controlled by varying pressure, temperature, spray system, etchant concentration, or distance between object and nozzle [13].

Copper foil of 40 µm thickness is used to create beam structures membrane. Copper foil is cleaned by soft rubbing with scotch and 1min dip in 10 % Sulphuric acid. Copper foil is laminated on both sides and structures are patterned on dry photoresist using lithography. Ferric chloride or cupric chloride solutions can be used for copper foil micromachining with PCM. The constituents for cupric chloride etchant are 10 % hydrochloric acid and 3 % hydrogen peroxide in 100 gm/lt cupric chloride. Whereas additives for ferric chloride solution are 10 % hydrochloric acid and 300 gm/lt ferric chloride. Here we used cupric chloride solution as etchant because it is more suitable to get better side walls of copper foil and recycling of the solution is possible. Ferric chloride solution will cause more sludge formation and hence can not be recycled. Ferric chloride may be better etchant for stainless steel like metals. There are varieties of spray bank system such as fish tail, flower type, cone type etc. Here we used wide range of fish tail type spray system which covers wide length of 6 inches wafer. There are two possible ways of etching 1) etching on both side top and bottom and 2) single side only from top or bottom. Single side etching can be used for foils of thickness up to 10um and its better to use double sided etching for thick copper foils of >10um because single side etching may cause under-etching for thick foils >10 µm. Here we used double sided etching as copper foil is >10 µm. Etching is done at temperature of 40 degree under 10 Psi pressure. PCM process flow is presented in Fig. 5. The spacing between consecutive beams can be obtained 1.25 times the foil thickness. PCM created the feasibility of achieving straight beams by controlling the residual stress induction in the etched areas as shown in Fig. 6. PCM patterned beams investigations are made to visualize the beam straightness with Wyco profilemeter. 3D images of Wyco profilometer (Fig. 7) shows that beams are at the same level along

Z-axis without any crumbling with variation of ±300 nm. Experienced pull-in voltage of demonstrated MEMS varactor is 177V which is comparable to MEMS based electronically steerable antenna reported in [7]. It is closely observed that PCM patterned beams are with very fine etched side walls, as shown in microscopic image (Fig. 8).

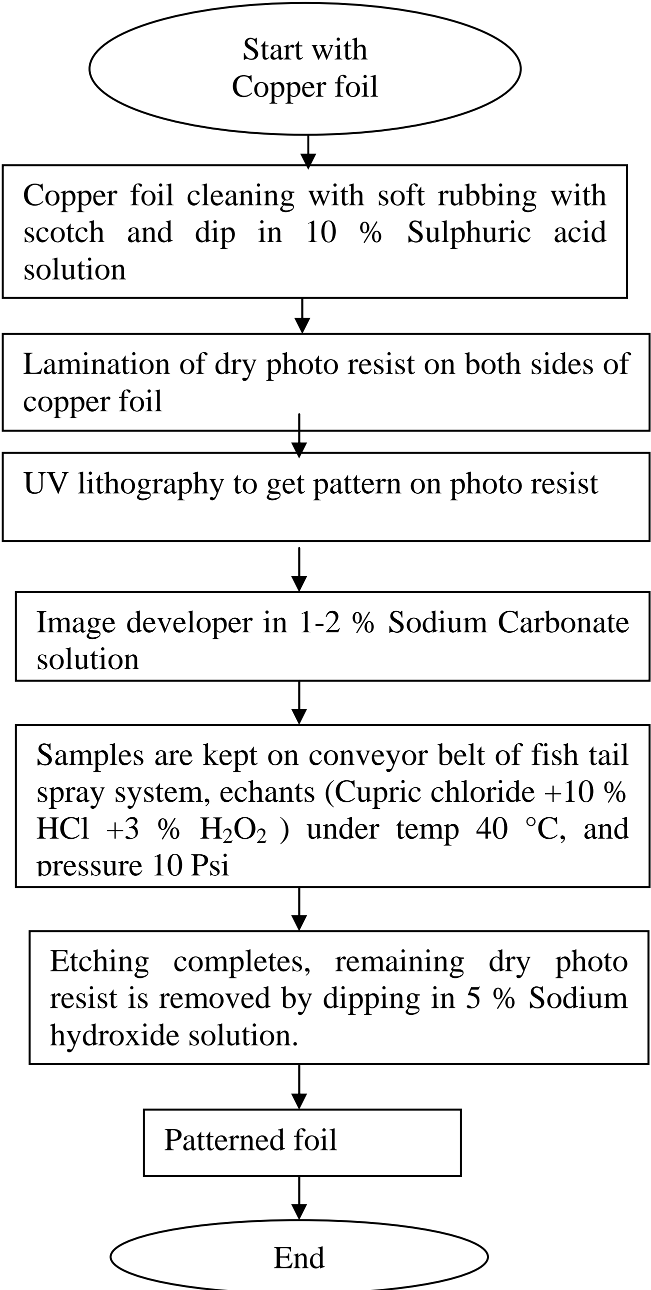


Fig. 5. Photo-chemical milling process steps followed to pattern copper foil.

3.3. Spacer Formation

Copper foil of 15 µm thickness is used to define the air gap between beam structures membrane and bottom electrode. Spacer is formed by photochemical milling (PCM) of the copper foil. Top view of spacer realized by patterning 15 um copper foil using PCM is shown in Fig. 9. Length by width of spacer is 20 mm × 10 mm.

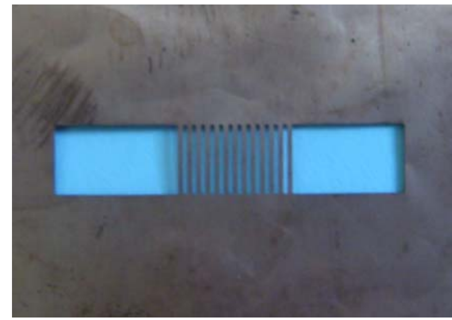


Fig. 6. Multiple bridge structures patterned on copper foil using photochemical milling.

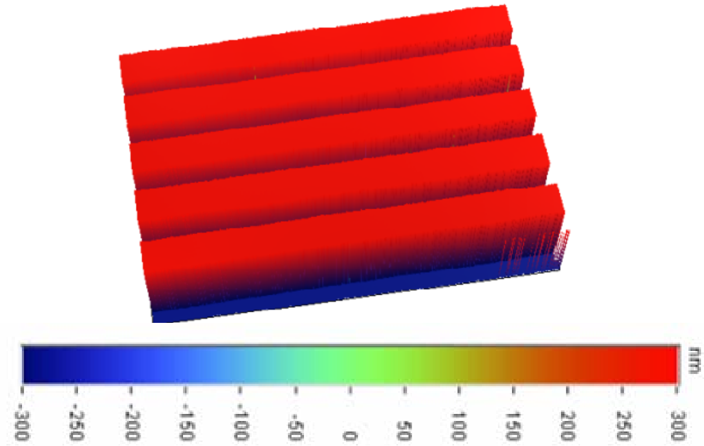


Fig. 7. Wyco optical profilometer 3D images of beam patterned on copper foil using PCM.

Fig. 8. Microscope images of the beam patterned on copper foil using.

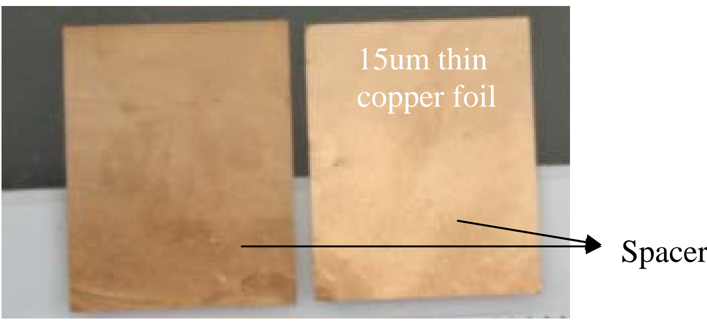


Fig. 9. Spacer realized in 15um thin copper foil.

3.4. Assembly of MEMS Varactor

Microwave laminate board with patterned conductor traces, spacer, and beam structures are assembled alongwith a glass/plexi-glass on top and bottom to realize the MEMS varactor as shown in Fig. 10. Glass/plexiglass is used at the top of the configuration for the protection as well as to maintain the straightness of the beam structures realized on the copper foil. In this multilayer assembled MEMS varactor, base material of the microwave laminate board and topmost plexiglass/glass (thickness 2mm) acts as the top and the bottom package layers respectively. Fig. 11 is photograph of MEMS varactor fabricated on microwave laminate. Although the final assembled device is completely covered with the plexi-glass to protect the bridges, samples prepared specifically for the electromechanical characterizations are assembled with the top plexi-glass having cavity to make direct contact of the laser beam of the LDV and the beam structure. LDV measurements of the device with glass along bridge may cause inaccuracy in the measurements due to multiple reflecting surfaces.

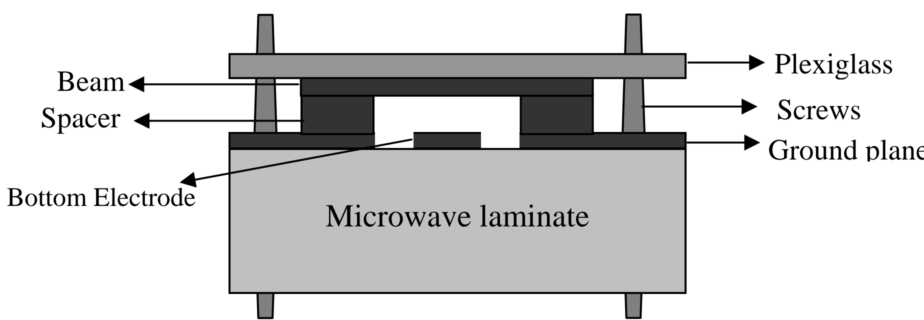


Fig. 10. Cross-sectional view of assembled MEMS varactor.

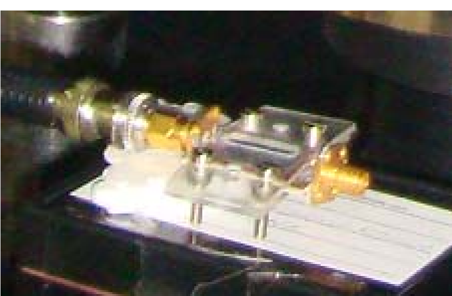


Fig. 11. Assembled MEMS varactor.

4. Measured Results

Laser Doppler Vibrometer (LDV), which is based on the principle of Doppler effect, is used for beam deflection and resonant frequency measurements. Fig. 12 shows the experimental set-up to perform the electro-mechanical characterization of the MEMS varactor. The laser beam of the LDV is focused on the beam structures of the device through the cavity made in plexi-glass for measurements. AC (peak to peak 10 V) plus variable DC bias is applied across bottom centre electrode and air bridge. Measured deflection and resonant frequency characteristics are discussed next.

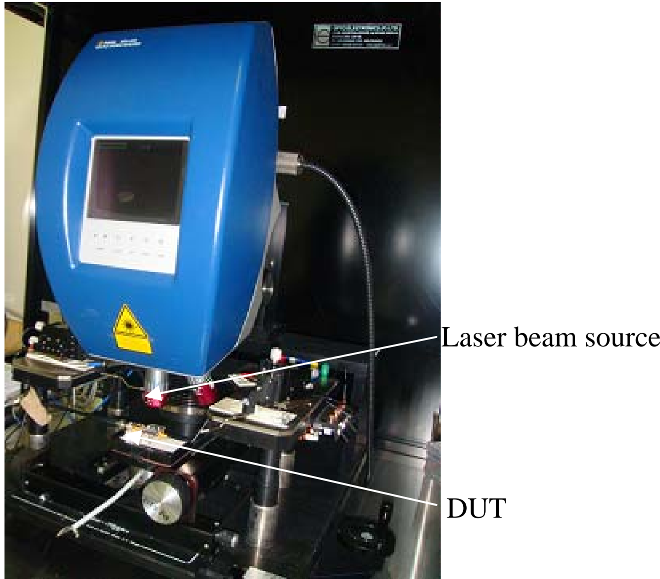


Fig. 12. Lased Doppler Vibrometer set up for the electromechanical testing.

4.1. DC Bias Voltage vs. Displacement Measurements

Electromechanical characterization of MEMS varactor is performed to measure deflection variation on applying DC bias voltage. Beam displacement is noted on increasing the DC bias voltage in steps which is shown in Fig. 13. Variation of capacitance with voltage is also shown in the same plot where capacitance is evaluated from the displacement. Measured pull-in voltage is 177 V, analytically calculated, and FEM 3D simulation performed in Coventorware 153 V and 171 V respectively (shown in Table 2). Measured and simulation pull-in voltage showed better agreement within 3.5 % compared to analytically modelled which is due to 1-D analytical beam model limitations discussed in section II. Experienced pull-in voltage of demonstrated MEMS varactor is comparable to the pull-in voltage reported by Ramadoss et al for MEMS based electronically steerable antenna [7]. The pull-in voltage can be reduced using thinner copper foil for beam structures. Here we used 40 um to ease the manual handling of the membrane. Measured tuning ratio of the MEMS varactor is 1.36, whereas modelled tuning ratio is 1.5. Therefore measurements showed close agreement with modelled tuning ratio within 9.3 %. The difference in measured and predicted displacement is due to rough surface of microwave laminate board copper clad. Measured peak to peak surface roughness of copper clad is ~6 um.

Table 2. Comparison in pull-in voltages.

	Pull-in voltage (V)
Measured (V)	177
Coventorware simulation (V)	171
Analytically modelled pull in (V)	153

4.2. Resonant Frequency of the Beams

Resonant frequency measurements are carried out using LDV. From LDV measurements of deflection magnitude with respect to frequency shown in Fig. 14, in which beam deflection is measured for frequency range of 0-10 kHz. It is observed that measured resonant frequency is 2.8 kHz. Beam resonant frequency is analytically evaluated using expression 5, which is 3.23 kHz. Therefore measured and modelled resonant frequencies are in agreement within 13.5 %.

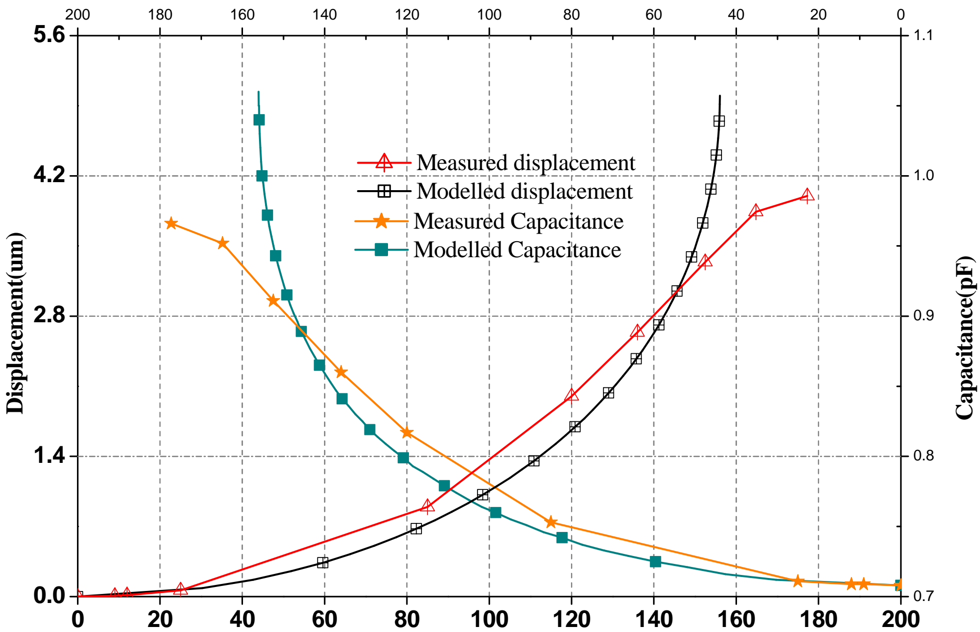


Fig. 13. Comparison in analytically modelled and measured voltage vs. displacement.

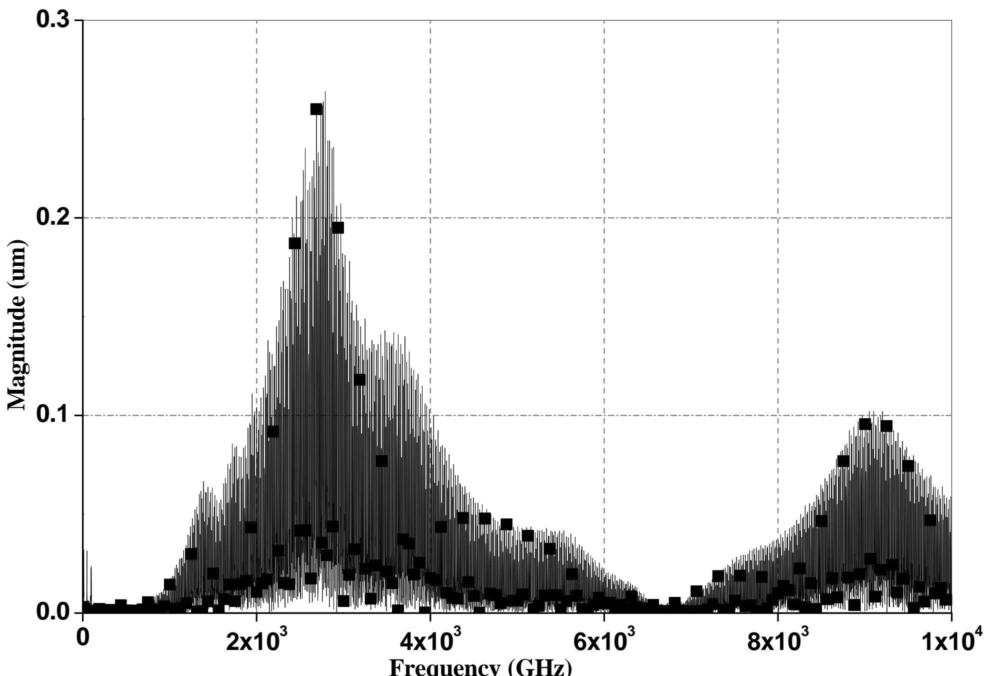


Fig. 14. LDV resonant frequency characteristics.

5. Summary

This paper demonstrates the development of an electrostatically actuated MEMS varactor on microwave laminate board for monolithic RF systems using modern PCB fabrication technology without using clean room and sophisticated fabrication equipments. The main purpose is to demonstrate the fabrication approach developed to realize RF MEMS. MEMS varacor is implemented to validate the concept. Measured and predicted characteristics of beam showed good agreement. Although the pull-in voltage of demonstrated MEMS varactor is high but it can be easily reduced using

thinner metal foil, or using multilayer membrane consist of thin metal with low Young's modulus polymer. There are beam structures such as crab leg, meandered arms to attain low pull-in voltage. Secondly, buck converter can be used to step-up voltage. This MEMS varactor can be used in distributed MEMS transmission lines for RF applications to implement phase shifter, filter, and tunable antenna on microwave laminate. This approach can be used to realize MEMS devices on unconventional substrates such as printed circuit board, low temperature cofired ceramics, liquid crystal polymers (LCP).

Acknowledgement

Authors would like to acknowledge Prof. K. J. Vinoy, Microwave lab, Indian Institute of Science, Bangalore, India. Authors would like to thank Prof. Rudra Pratap, Department of Mechanical Engineering, Indian Institute of Science, Bangalore, India, for allowing us to use Laser Doppler Vibrometer.

References

[1]. B. Ghodsian, C. Jung, B. A. Cetiner, F. D. Flaviis, Development of RF-MEMS switch on PCB substrates with polyimide planarization, *IEEE Sensors Journa*l, Vol. 5, No. 5, October 2005, pp. 950-955.

[2]. H.-P. Chang, J. Qian, B. A. Cetiner, F. D. Flaviis, M. Bachman, G. P. Li, Design and process considerations for fabricating RF MEMS switches on printed circuit boards, *Journal of Microelectromechanical Systems*, Vol. 14, No. 6, December 2005, pp. 1311-1322.

[3]. H.-P. Chang, J. Qian, B. A. Cetiner, F. De Flaviis, M. Bachman, G. P. Li, RF MEMS switches fabricated on microwave-laminate printed circuit boards, *IEEE Electron Device Letters, Vol.* 24, No. 4, April 2003, pp. 227-229.

[4]. R. Ramadoss, S. Lee, Y. C. Lee, V. M. Bright, K. C. Gupta, RF-MEMS capacitive switches fabricated using printed circuit processing techniques, *Journal of Microelectromechanical Systems, Vol.* 15, No. 6, December 2006, pp. 1595-1606.

[5]. P. Goel, K. J. Vinoy, A low cost approach for the fabrication of microwave phase shifter on laminates, *Microsyst Technol.,* 17, 2011, pp. 1653-1660.

[6]. P. Goel, K. J. Vinoy, A low-cost phased array antenna integrated with phase shifters cofabricated on the laminate, *Progress in Electromagnetics Research B,* Vol. 30, 2011, pp. 255-277.

[7]. A. Sundaram, M. Maddela, R. Ramadoss, L. M. Feldner, MEMS-based electronically steerable antenna array fabricated using PCB technology, *Journal of Microelectromechanical Systems*, Vol. 17, No. 2, April 2008, pp. 356-362.

[8]. A. Wego, S. Richter, L. Pagel, Fluidic microsystems based on printed circuit board technology, *Journal of Micromechanics and Microengineering*, 11, 2001, pp. 528-531.

[9]. T. Merkel, M. Graeber, L. Pagel, A new technology for fluidic microsystems based on PCB technology, *Sensors and Actuators*, 77, 1999, pp. 98-105.

[10].J. N. Palasagaram, R. Ramadoss, MEMS-capacitive pressure sensor fabricated using printed-circuit-processing techniques, *IEEE Sensors Journal*, Vol. 6, No. 6, December 2006.

[11].H.-P. Chang, J Qian, B A Cetiner, F D Flaviis, M Bachman, Design and process considerations for fabricating RF MEMS switches on printed circuit boards, *Journal of Microelectromechanical Systems*, Vol. 14, No. 6, December 2005, pp. 1311-1322.

[12].Rebeiz GM, RF MEMS theory, design, and technology, *IEEE Press,* New York, 2003.

[13].http://en.wikipedia.org/wiki/Photochemical_machining

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

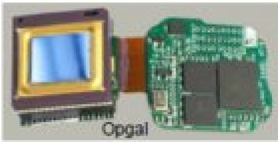
Uncooled Infrared Imaging Market: Commercial & Military applications

Promoted by IFSA

Market & Technology Report to 2016

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



Opgal

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

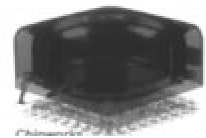
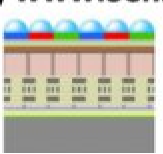
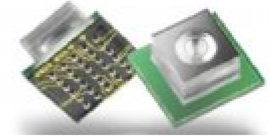
http://www.sensorsportal.com/HTML/MEMS_Energy_Harvesting_Devices.htm

CMOS Image Sensors Technologies & Markets - 2010 Report

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

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

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:

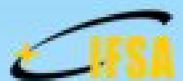
- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors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

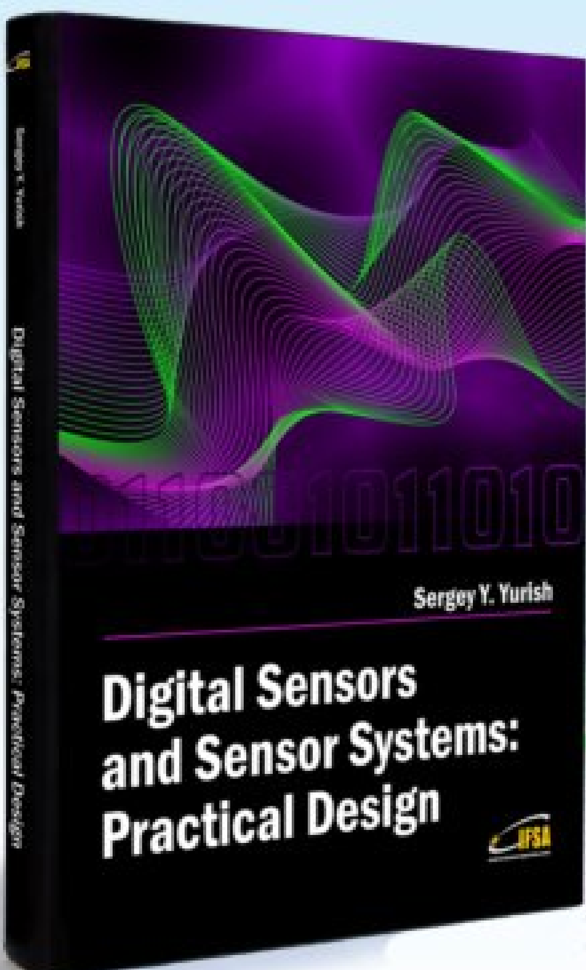
Advertising Information

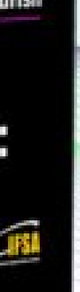
Advertising orders and enquires may be sent to sales@sensorsportal.com Please download also our media kit: http://www.sensorsportal.com/DOWNLOADS/Media_Kit_2012.pdf



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