DTIP 2024

Design, Test, Integration & Packaging of MEMS/MOEMS

Dresden, Germany – June 2nd-5th, 2024

Technical program

Monday, June 3rd

9:00 – 9:30 Registration and welcome coffee/tea.

9:30 – 10:25 Starting session: materials
Chairperson: Emile Martincic, Univ. Paris-Saclay

Emile Martincic / Peter Schneider / Uwe Marschner	*Welcome address*
C. Tsai, Z. Xiong, C. Lee	*Investigation of Micro Pyroelectric Infrared Sensor Performance under Different Electrode Materials*
Abstract—The purpose of this paper is to use a microelectromechanical system (MEMS) technology to fabricate a human infrared sensor. The research explores the effects of changing the electrode materials on the human infrared sensor's performance. In terms of materials, double-sided polished glass is used as the chip substrate. The bottom electrodes are deposited using electron beam evaporation with materials such as chromium, copper, gold, platinum, and silver. Etching technique is used to define the lower electrode pattern. The sensing layer is created using an RF magnetron sputtering to deposit a ZnO thin film as the sensing material. The sensing layer's shapes are defined using etching technique. The top electrode is deposited using electron beam evaporation with the same materials as the bottom electrode, followed by the metal lift-off method to define the top electrode pattern. Experimental results show that using a silver top electrode achieves the highest response voltage.	
W. Hortschitz, F. Keplinger, G. Kovacs	*Materials for encapsulating micro-system-based electric-field sensors*
There is a fundamental challenge in the development of all sensors in that they need access to the quantity to be measured, but they also must be protected from harmful influences from the environment. In the case of DC electric field sensors this task is especially difficult. In principle, there are two large groups of solid materials that can be used for housing and encapsulation, namely, conductors and insulators. Both entail special restrictions and benefits. Conductors can guide the field and allow the design of a field concentrator but can also reduce or even shield the electric field if the geometry is unfavorable. Insulators are needed to separate different functional parts, e.g., electrodes, but exhibit polarization and charging effects that influence the electric field. These effects can be mitigated often by calibration. However, insulators are also prone to charging effects and the charges involved are source of strong electric fields, which can interfere with the measurement to a great extent. Compared to their macroscopic sensor versions, microsystem based electric field sensors offer great advantages but they are extremely vulnerable to mechanical damage. Even the smallest dust particle scan hamper the movement of the fragile mechanical structures. Furthermore, charged particles can reach the sensor's surface along the electric field. This is especially problematic in everyday applications where these charges can accumulate on surfaces. In this work, the influence of different insulators on the static electric field is presented. The insulators are tested on their own and as part of a rudimentary encapsulation together with conductive elements. In a custom-made set-up, the stability of the electric field inside the encapsulation, made of stainless steel, was studied with a commercial electric field mill. Above this encapsulation were fields ranging from □200 V/m up to ~4200 V/m applied by a parallel plate capacitor.	

10:25 – 11:00 : Pause

11:00 – 12:00 : RF devices
Chairperson: Yves-Alain Peter, Polytechnique Montréal, Canada

T. Furcatte, J. Barcelo Aguilo, W. Trzpil, M. Gely, M. Kazar Mendes, G. Jourdan, S. Hentz, M. Sansa	Optimizing optomechanical resonators for ultra-high-frequency timing applications
Optomechanical resonators emerge as a compelling high-performance alternative for GHz timing references, thanks to the intrinsic assets of this transduction over electrical methods. However, timing applications present system-level design challenges necessitating a particular approach to the design of the resonators. Here we present the first study of such constraints, and provide general design guidelines. Starting from the identification of key performance parameters, we explore the relevance of two optomechanical resonator geometries. First, we experimentally study silicon microdisks, which garner significant attention for sensing purposes, unveiling their suboptimal suitability for timing applications. Then we introduce an alternative geometry, based on a ring-like mechanical structure. We elucidate its advantages in terms of quality factor and dynamic range, and clarify its design principles. It is anticipated that the ring-like resonators will exceed existing performance standards for oscillators, thereby facilitating operation across frequency ranges spanning from 1 GHz to 5 GHz.	

A. Cismaru, Gm Sardi, G. Tagliapietra, J. Iannacci, F. Giacomozzi, R. Marcelli	Improved Design of Metamaterial Resonating Filters driven by RF MEMS Switches
In this paper, the design of three-port K-band resonating filters, including an SPDT with RF MEMS switches and triangular Sierpinski-shaped resonators, has been studied. This contribution is intended to improve the performance of switched metamaterial-inspired resonators using a three-port configuration instead of a two-port structure to enhance the isolation between the resonators and the electrical matching for K-Band operation, decreasing, at the same time, the insertion losses. Electromagnetic simulations have been performed to optimize the performance of the SPDT, the individual filters, and the whole structure. Preliminary experimental results are also presented.	
NR MD Ashif, U. Gengenbach, I. Sieber	Process Development for Digital Fabrication of Radio Frequency Transmission Lines with Off-the-Shelf Equipment
This paper explores the potential of digital fabrication of radio frequency (RF) transmission lines for driving electro-optical devices in photonic integrated circuits. The focus lies on utilization of readily available off-the-shelf equipment. This research focuses on the development and optimization of digital fabrication techniques tailored specifically for RF transmission lines. The presented methodologies pave the way for a more inclusive and accessible landscape in the field of RF components additive on demand fabrication, facilitating advancements in communication systems and technology. In this paper, we employ both inkjet printing and extrusion printing techniques to explore the potential for fabricating coplanar waveguide (CPW) transmission lines.	

12:00 – 13:30 : Lunch pause

13:30 – 14:30 : Biomedical applications
Chairperson: Yoshio Mita, UNiv. Tokyo, Japan

O. Francais, I. Kury Abi Nakhoul, P. Davidson, L. Rousseau, P. Poulichet, S. Robben, J. Roy, P. Thiebaud, AR Ribeiro	Impedance-based spectroscopy system for monitoring cell polarizations on MEA
This paper presents results obtained using Bioelectrical Impedance Spectroscopy (BIS) for cell culture monitoring on Micro-Electrode Arrays (MEA), in the case of mouse embryonic fibroblasts (MEFs). A 4-Terminal configuration is used and enables to highlight not only cellular membrane polarization but also ionic charge displacement at lower frequency. The MEA had been fabricated using a microelectronic process with gold electrodes and SU8 photoresist as an insulating layer. Compared to classical 2-Terminal configurations, the set-up used offers a more clear understanding of ionic and interfacial polarization which occur when biological samples are submitted to an electric field in the frequency range between 1 Hz up to several MHz. These results are a good starting point to consider afterwards experiments with myofibers and cardiomyocytes arrays for cellular state monitoring using impedance measurements.	
S. Riahi, G. Becan, M. Ammar, A. Bosseboeuf, F. Laourine, B. Boutaud, D. Bouville, A. Harouri, P. Coste, E. Lefeuvre	Evaluation of optical interferometry for thickness uniformity control of Parylene HT coating on titanium substrates
This paper addresses the challenge of accurately measuring the thickness of parylene HT coatings using White Light Scanning Interferometry (WLSI), a non-destructive technique. Our results indicate a significant correlation between WLSI and mechanical profilometry measurements affirming the reliability of WLSI for thickness control. Additionally, we propose a novel parylene HT etching process to compare to WLSI and mechanical profilometry measurments.	
O. Francais, J. Roy, THN Dinh, A. Rezgui, L. Rousseau, P. Poulichet	Reusable microfluidic chip combining auto-electrode alignment with lateral microfluidic accesses for biomedical applications
While microfluidic offers a wide array of possibilities for cellular analysis, several issues still plague its automation as a Lab-On-Chip (LoC) device when electrodes need to be integrated and packaged with microfluidic accesses. In this work, a fully reusable and open-source setup microfluidic chip is presented allowing the casting and use of lateral access for microfluidic setup, to mitigate the effects of sedimentation on input as well as a fabrication setup for precise alignment of an easily dismounted LoC setup. Electric connections are combined with the closure of the channel taking advantage of an innovative packaging based on 3D printed and dedicated PCB having electrical tips.	

14:30 – 15:00 : Pause

(Monday june 3rd – continued)

15:00 – 17:00 : Sponsors slot + 5 min Poster presentations
Chairperson: O. Français, ESYCOM, Univ. G. Eiffel, France

H. Pfannenstiel, M. Ungerer, I. Sieber	Digital Twin Architecture to Use for Optimizing an AoD-Printing Process
YC Liu, BJ Lwo, TC Chung	Transmission Line Designs on Glass-Embedded Fan Out Antenna in Packaging for 5G Applications
Y. Fang, H. Han, D. Gai, K. Ouyang, S. Qu, DF. Wang, T. Ono, T. Itoh	Thermoelastic Damping for Structural Optimization Applicable to Resonant Galvanometers
S. Chen, DF. Wang, T. Ono, T. Itoh	A Passive Non-uniform Magnetic Field Sensing Mechanism with A Composite Cantilever
J. Kishore, AK Pandey	Design and Modeling of Differential Capacitive Hexagonal Beam based MEMS Accelerometer
VD Dwivedi, AK Mishra, N. Jani, PK Menon, AK Pandey	Closed Loop Sense Feedback Control for A Dual Proof Mass MEMS Vibratory Gyroscope
A. Godinez Perez Medina, A. Brenes, J. Juillard	Design of a novel electrostatic MEMS resonator with hybrid nonlinear behavior

Tuesday, June 4th

8:30 – 9:00 Welcome and coffee

9:00 – 9 :45
Invited talk

Jan Grahmann	MEMS scanners: Mastering front & backend from customer-specific development to pilot production
The use of micro scanning mirrors in mobile applications like automotive LiDAR sensors, head-mounted displays or portable micro beamer is today an industrial reality. In this talk, the workflow insights from a research starting point to an industrial tailored applications will be presented.	

9 :45 – 10:00 : Pause

10:00 – 11 :00 : Design, simulation and validation
Chairperson: Romolo Marcelli, CNR, Italy

D. Mayer, P. Schneider	Challenges in design and validation of MEMS based IoT solutions
The emergence of MEMS and decreasing costs for microelectronics and wireless communication enable new fields of use for sensors. For instance, instead of temporal instrumentation with high performance accelerometers for condition monitoring of a machine, a permanent installation of low-cost sensors, or even a widespread sensor network, becomes feasible. Consequently, the development and validation process for such sensors has to integrate more requirements derived from the target application. This means, rather than qualifying a sensor as a high-precision measurement device for many potential use cases, the design goal is a sensor system that fits a limited number of use cases and provides sufficient precision. Also, in the case of smart sensors, which incorporate signal analysis or even artificial intelligence, validation of hardware and software must be integrated. This is particularly challenging, when adaptative or learning algorithms are implemented into the sensor system. The paper gives an overview of trends in industrial MEMS applications, the respective testing and validation strategies. Proposals for improved procedures are discussed, using current work on sensor developments.	

I. Sieber, A. Deleut, L. Petani, C. Pylatiuk	Design and simulation of a body-worn optical xylene measuring device for use in pathology
In pathology, xylene is used in various process steps to prepare tissue samples for further examination and is essential despite potential health risks. To protect employees, it is desirable to monitor exposures to individuals using a wearable detector. This article presents the design and simulation of a xylene measuring device based on a multi pass cell, which is the size of a smartphone and thus allows the measuring unit to be worn comfortably on the body. The geometrical and metrological requirements result in a beam path of approximately 2000 mm, folded to such an extent that it undercuts 28 reflections on its path.	
P. Tacyniak, S. Basrour, M. Defoort	A Pspice model to numerically design piezoelectric-based acoustic power transfer
Acoustic power transfer (APT) has become a strategic stake with the increase of wireless smart devices located in electromagnetic proof environments. This is especially the case for medical implants where the transferred power has to go through human tissues, itself made of different layers (epidermis, dermis, muscle, bones), and through the metallic case of the medical implant. Each of these layers are mechanically coupled, making the optimization of the emitter and receiver of such system a complex task. To overcome this issue, we developed a procedure based on Pspice to accurately simulate APT between an emitter and a receiver, as it propagates through an intermediate layer. The procedure is based on Leach model which is the Pspice equivalent model of Mason electro-mechanical analogy. In this article, we propose a model which fits two 3-layer APT experiments, consisting in piezoelectric emitters and receivers with an intermediate layer of alternatively titanium and tungsten. The results provided by the simulations give a qualitative fitting of the APT and would enable to design, study and optimize n-layer APT systems for applications such as wireless medical implant recharging.	

11:00 – 11:20 : Pause

11:20 – 12:20 : Short Course on System level Modeling (Part I)
Chairperson: Peter Schneider

T. Bechtold	Towards System-Level Modeling and High-Fidelity Simulations of MEMS: Challenges, State-of-the-Art, Perspectives
Virtual fabrication, virtual experimentation and test using computer simulations are already an integral part of the design methodology for microelectromechanical devices and systems in order to realize cost-efficient and time-economizing development cycles. It enables the detailed analysis of the device and system operation of competing design variants in a very early stage of the development process. A successful design strategy requires modelling methodologies on different levels of abstraction and computational expense. Since, by their nature as sensors or actuators, the constituent components of a microsystem link different energy and signal domains such as mechanical, fluidic, thermal, electrical, and other physical or chemical quantities, an important aspect will be the physically consistent treatment of coupled fields and coupled energy and signal domains on the device and on the system level in an accurate, but yet efficient manner. Modelling and simulation on the continuous-field level (such as finite element analysis) prove to be useful, when a single physical energy domain or a specific subcomponent is subject to optimization, but become computationally expensive, when multiple coupled energy domains with all their mutual interactions have to be considered. Optimal prototyping of microsystems, however, requires the concurrent co-optimization of transducer elements and their control circuitry. However, full system analysis on the continuous-field level becomes prohibitive due to non-linear coupling mechanisms between different energy domains and the huge number of degrees of freedom to be considered for complex 3D device geometries. Therefore, reduced-order and system-level modelling techniques have to be employed as they constitute the key to the predictive simulation of entire microsystems.	

12:20 – 13:50 : Lunch pause

13:50 – 14:30 : Short Course on System level Modeling (Part II)
Chairperson: Peter Schneider

T. Bechtold	Towards System-Level Modeling and High-Fidelity Simulations of MEMS: Challenges, State-of-the-Art, Perspectives

14:30 – 15:00 : Pause

(Tuesday june 4th – continued)

15:00 – 16:30 : Special Session on Modelling Methodology + Panel Discussion
Chairperson: Peter Schneider

G. Schrag, G. Bosetti	Physically Based System-level Modeling of Acoustic MEMS Transducers by Generalized Kirchhoffian Networks: a Perspective View
Two exemplary applications from the field of acoustic and ultrasonic transducers are used to demonstrate how system models can be derived within a generic thermodynamic framework in a way that they are optimally adapted to the problem in terms of their level of abstraction. The models are formulated as generalized Kirchhoff networks and are physically based, so that relevant design parameters are accessible at system level. The flexibility of the method w.r.t. to true to detail modeling on the one hand is shown for the case of a silicon microphone. The efficiency of the models is demonstrated for the optimization of a system consisting of an ultrasonic transducer and an acoustic horn. A perspective view of this methodology shows that it could represent the basis for a uniform and comprehensive platform for systematic microsystem design that can be modularly and flexibly adapted to new problems and requirements.	
A. Ehrenhofer, P. Bakardjiev, W. Yawen, A. Voigt, U. Marschner, A. Richter, T. Wallmersperger	System design and models for active materials
B. Schwartz, G. Brokmann, T. Ortlepp	Workflow for Modelling Electrical Properties of Piezoresistive Silicon MEMS Devices
A workflow has been developed to model the electrical properties of piezoresistive silicon micro- electromechanical system (MEMS) devices, such as silicon pressure sensors and strain gauges. The workflow involves physically-based simulation of the semiconductor processing and the mechanical properties of the structure using finite element methods (FEM). Additionally, it involves calculating the mobility of the majority charge carriers using physical models. This workflow enables the computation of the electrical characteristics of MEMS devices across a wide temperature range (230-410 K) in relation to dopant concentration, stress, and temperature, prior to fabrication.	
Panelists: Gabi Schrag, Tamara Bechtold, Adrian Ehrenhofer, Geert Brokmann Moderator: Peter Schneider	Panel Discussion

16:30 – 17:45 : Logistics – from institute to Gläserne Manufaktur

17:45 – 18:30 : Guided tour @ Gläserne Manufaktur

17:00 – 23:00 : Social event

Wednesday, June 5th

8:30 – 9:00 Welcome and coffee

9:00 – 10:00 : MEMS devices (1)
Chairperson: Alina Cismaru, IMT Bucharest, Romania

S. Bargiel, F. Zamkotsian, L. Gauthier-Manuel, D. Belharet, R. Salut	MOEMS for space applications: the challenge of multi-wafer bonding
MOEMS devices are key devices for next generation optical instruments, including space missions for Earth and Universe Observation. They will be used for object/wavelength selection and wavefront control. MIRA is a European development of micro-mirror arrays, with 100 x 200µm2 silicon mirrors with remarkable surface quality and actual ability to work at cryogenic temperatures (162K). The challenge of multi-wafer bonding, especially on silicon micro-pillars is developed in this paper. Three bonding methods are proposed as well as various non-destructive and destructive methods of bonding characterisation. Low-temperature plasma-assisted Si-SiO2 direct bonding is described in details as very promising method to obtain strong bond on micropillars.	
A. Ustun, J. Zou	Micromachined Silicon Acoustic Delay Lines for High-Frequency Ultrasound Sensing and Imaging
This paper reports a new micromachined silicon acoustic delay line (SADL) design for transmitting high-frequency ultrasound signals while adding a certain amount of true time delay. Compared to traditional structures, with the use of a novel thin-film backside linker, the new SADL design can significantly increase the mechanical stiffness of the SADL structure for easy handling and assembly without degrading its acoustic performance. It can be easily scaled up or down to provide different ultrasound frequency response and time delays. For demonstration, high-frequency ultrasound transmission through a multi-channel SADL array has been successfully achieved. The new SADL design could provide a new practical approach for the development of high-frequency ultrasound arrays for high-resolution and high-speed ultrasound sensing & imaging applications.	
W. Al-Mogahed, S. Voigt, P. Mehner, G. Paschew, A. Richter, J. Mehner	Multi Fourier Horn Ultrasonic Nebulizer Based on Laser Structuring of Silicon
This paper reports a Silicon (Si)-based, multiple Fourier-horn ultrasonic nebulizer (MFHUN) which was fabricated through femtosecond laser cutting of Si to reduce the preparation time of samples and to study the effectiveness of this manufacturing process for Si-resonating structures. The geometrical characterization of the structures showed tolerances in the dimensions. These tolerances affected the efficient positioning of the liquid at the tip of the horn. Reducing the flow rate and adjusting the frequency of the structure when in contact with the liquid resulted in nebulization.	

10:00 – 10:20 : Pause

10:20 – 11:20 MEMS devices (2)
Chairperson: Franz Keplinger, TU Wien, Austria

L. Ackermann, M. Lewis, G. Aleksanyan, D. Palm, F. Pelke	Experimental Study on Repetitive Shock Measurements for MEMS Accelerometers
Shock robustness is gaining increasingly attention in the latest generations of MEMS accelerometers. During the entire product life cycle, the devices are exposed to situations with external overload. During these events, the functional mass can be pushed into its surrounding structures with thousands of g of force. In these situations, spring forces are the only recovering forces to pull the sensor out of the stopper and maintain functionality. Increasing miniaturization of the structures makes shock testing in development indispensable. During Wafer-Level Testing, the Repetitive Shock Routine test method is capable of applying thousands of shocks within seconds while surveilling sensor characteristic parameters over time. In this study, more than 400 test structures, that are comparable to consumer MEMS designs, were tested. Evaluation shows different long term behaviour of adhesion forces and failure events for in-plane and out-of-plane MEMS structures.	
T. Zhu, E. Lefeuvre, E. Herth, D. Bouville, A. Brenes	Novel design of SOI-based MEMS bell plates for resonant applications
This paper aims at proposing a design of MEMS bell plates manufactured in silicon technology on silicon on insulator (SOI) wafers. The etching process and the release of the structure are among the most sensitive steps of fabrication. The design we propose mitigates the adverse effects of under etching while remaining compatible with standard fabrication processes. Through qualitative analysis and Finite Element Method (FEM) simulations, we assess the impact of under etching on the anchor losses and illustrate a few geometrical designs that could decrease the effect of under-etching, as well as their effect on the frequency.	

Z. Nazyrova, P. Menge M'Owono, S. Hage-Ali, E. Martincic	Piezoelectric ZnO chemical etching for zero-power MEMS applications
This paper presents wet chemical etching processes of piezoelectric ZnO (wurtzite atomic structure) films. ZnO films can be etched by most of acid and basic solutions. However, in MEMS processes, many etchants also attack sublayers (electrodes or insulating layers) and are therefore not compatible with MEMS processes. HCl, HF and H3PO4 were selected among the possibilities and carried out etching on Ti/Pt/ZnO sputtered silicon wafers. Vertical etching rates are found to be in the 0.2 to 5 µm/min and lateral etching rates are in between 0.5 to 17 µm/min. The ratio between lateral to vertical etching speed was found to reach a minimum value for low etchant concentrations of approximately 2%. The morphology of the semi-etched borders of the samples were observed by SEM and practical conclusions are extracted on the adequation of the wet etching process on the top electrode subsequent fabrication step.	

11:20 – 11:40 : Pause

11:40 – 12:40 Design and Characterization
Chairperson: Gabriele Schrag, TU Munchen, Germany

R. Takahashi, K. Misumi, K. Tsuji, Ac Eiler, S. Yasunaga, A. Higo, R. Nakane, T. Iizuka, M. Ezawa, Y. Mita	Su-Schrieffer-Heeger Topological Electrical Circuit Using In-Plane Mutual Inductance
Recently, topological state found in electrical circuits is getting more attention. In this paper, we proposed a new type of Su-Schrieffer-Heeger (SSH) topological electrical circuits achieved by using different mutual inductances. This new electrical circuit is expected to be applied to metamaterials by reducing the size of the circuit. We have fabricated a two-layer wiring device composed of Al as wiring and SiO_2 as insulator. Then, we have measured the impedance characteristics and observed topological state at 10.6 GHz. Our results have potential applications for future 5G technology	
L. Koker, Km Reichert, U. Gengenbach, M. Reischl, M. Ungerer	Modular Platform for Automated Characterisation of Printed Structures, Devices and Circuits
We present a real-time-controlled platform applied for automated characterisation of structures, devices and circuits printed on planar substrates. Its modular setup allows for implementation of different probe heads and a large number of instruments for electrical testing. Microscope optics are used to capture high-resolution images of entire printed substrates. Based on these images printed structures on the substrates are optically inspected for printing errors by means of image processing and electrically tested. Applications include fast identification of optimal printing parameters for various ink-substrate combinations, characterisation of complex printed devices and circuits and identification of known-good structures for multi-stage printing.	
F. Sakuma, S. Yasunaga, K. Misumi, A. Higo, Y. Mita	Constructing Temperature Constant Controlled Silicon-on-Insulator Bolometer
We propose a temperature constant closed-loop control of thermally leaky elements, in view of the first arrayed crystalline silicon-on-insulator-based bolometer. Despite its many benefits in physical properties and matureness in fabrication technology, crystalline silicon has not been suitable for constructing bolometer array mainly because of its high thermal conductance, leading to thermal coupling with neighboring elements. Here we propose to control each element at a temperature constant condition to avoid its temperature fluctuation that affects others. In this paper, we show our first proof-of-concept demonstration, that should become another configuration of a bolometer array with proper optimization.	

12:40 – 12:55 Closing session

12:55 – 14:00 Lunch

14:00 – 15:00 Commitees meeting