Co-located with
SPIE Optics + Optoelectronics

SPIE Microtechnologies

Technical Summaries

www.spie.org/emt

Conference Dates: 18-20 April 2011

Prague Congress Centre
Prague, Czech Republic

Connecting minds for global solutions

Contents

SPIE

Conference 8066: Smart Sensors, Actuators and MEMS

Monday-Wednesday 18-20 April 2011

Part of Proceedings of SPIE Vol. 8066 Smart Sensors, Actuators, and MEMS V

8066-01, Session 1

Wireless SAW sensor for high temperature applications: material point of view

O. Elmazria, Univ. Henri Poincaré Nancy (France)

Scientific and industrial communities have expressed a real need for chemical and physical sensors with capability operate at elevated temperatures.

In addition to being small, simple and robust, surface acoustic wave (SAW) devices have the advantage of being passive (batteryless), remotely requestable (wireless) and inexpensive if fabricated on a large scale. The use of SAW devices as passive and wireless sensors allows them to operate in extreme conditions such as those with high levels of radiation, high temperatures up to 1000°C, or electromagnetic interference, in which no other wireless sensor can operate. This is obviously conditioned by the fact that the materials constituting the device can withstand these harsh conditions.

Knowing that the available conventional piezoelectric substrates such as quartz, lithium niobate (LiNbO3) or lithium tantalate (LiTaO3) cannot be used at high temperature, R&D is focused on new generation of piezoelectric materials stable in these conditions. Now, there is a large consensus on the use of Langasite (La3Ga5SiO14 or LGS) for such aim. Indeed, this material has been extensively studied at high temperature showing a very high stability up to its melting temperature at 1473°C and a great resistance to thermal shock treatment. However, it is also characterized by relatively high acoustic propagation losses, which dramatically increase with frequency and temperature, thus limiting the operating frequency below 1 GHz at high temperature. AlN/Sapphire layered structure exhibits, however, a good stability until 900°C and a low propagation loss showing then a good alternative to LGS for high frequency application. Stoichiometric LiNbO3 could also be a promising way for such applications

In this lecture, general principle of the SAW sensor in wired and wireless configurations will be developed and a review of recent works concerning the field of high temperature applications will be presented with specific attention given to the characterisation of materials constituting the SAW device, piezoelectric substrate and metallic electrodes.

8066-02, Session 1

Design and fabrication of piezoresistive p-SOI wheatstone bridges for high-temperature applications

J. Kähler, Technische Univ. Braunschweig (Germany); L. Döring, Physikalisch-Technische Bundesanstalt (Germany); S. Merzsch, A. Stranz, A. Waag, E. Peiner, Technische Univ. Braunschweig (Germany)

For measurements while depth drilling, commercial sensors are available for a temperature range up to 175 °C. They are used for early identification of potential sources of error and timely response to critical situations. Today, there is a trend towards higher temperatures, e.g. for geothermal projects, where drilling depths of 7000 m and temperatures up to 250 °C are expected. Conventional piezoresistive silicon sensors cannot be used at these temperatures due to an exponential increase of leakage currents which results in a drop of the bridge voltage. Therefore, for a trouble-free operation above 175 °C high-temperature resistant measuring bridges are required.

A well-known procedure to expand the temperature range of silicon sensors and to reduce leakage currents is to employ Silicon-On-Insulator (SOI) instead of standard wafer material. Diffused resistors can be operated up to 200 °C, however, but show the same problems beyond due to leakage of the p-n-junction. Our approach is to use p-SOI where the resistors as well as the interconnects are defined by etching down to the oxide layer. Leakage is suppressed and the temperature dependence of the measuring bridge is drastically reduced to 2.622 µV/K (at a supply current of 1 mA).

The novel design and process flow will be presented in detail. The characteristics of Wheatstone bridges made of silicon, n-SOI, and p-SOI will be shown for temperatures up to 300 °C. Besides, thermal FEM-simulations will be described revealing the effect of stress between silicon and the silicon-oxide layer during temperature cycling.

Modern depth drilling systems are equipped with various electronic modules and sensors to enhance the drilling process. For measurements while drilling, commercial sensors are available for a temperature range up to 175 °C. These sensors can be used for an early identification of potential sources of error and timely response to critical situations. The main reasons for failure are vibrations caused by interactions between chisel and formation (e.g. the bore hole). This leads to above-average tool wear, reduced feed and with it increased cost. Today, there is a need of operating electronic and sensor systems at even higher temperatures. For geothermal projects, e.g, drilling depths of about 7000 m and temperatures up to 250 °C are expected. Conventional silicon-based sensors cannot be used at these temperatures due to an exponential increase of leakage currents which results in a drop of the bridge voltage. Therefore, high-temperature resistant sensing elements are required for a trouble-free operation above 175 °C.

A well-known procedure to expand the temperature range of piezoresistive sensors is to employ Silicon-On-Insulator (SOI) material as a well comprising the resistors. The aim is to isolate the thin silicon well (2 µm to 50 µm) from the bulk material (approximate 300 µm) through an oxide layer (0.5 µm to 2 µm) and with it to reduce the leakage currents. However, at higher temperatures (> 200 °C) this concept faces the same problems due to the p-n-junction. Therefore, in this approach we use p-SOI where, the resistors as well as the interconnects are realized by etching down to the oxide layer. In this case the leakage currents can be completely neglected. With the help of the novel process the temperature dependence of the Wheatstone bridge is very small (2.622 µV/K at a supply current of 1 mA).

The novel strain gauge design and its fabrication will be presented in detail. Moreover, Wheatstone bridges made of silicon, n-SOI, and p-SOI will be tested for high-temperature applications. Bridge voltages will be measured in dependence on temperature (up to 300 °C) and material. Besides, thermal FEM-simulations will be performed in order to analyze the stress between silicon and the silicon-oxide layer during temperature cycling caused by different thermal coefficients of expansion. It will be demonstrated that the novel measuring bridges are suitable for high-temperature applications, e.g. piezoresistive sensors.

8066-03, Session 1

Microthruster with integrated heater and platinum thin film resistance temperature detector (RTD) investigated up to 1000°C

N. Miyakawa, W. Legner, T. Ziemann, EADS Deutschland GmbH (Germany); D. Telitschkin, EADS Astrium GmbH (Germany); H. Fecht, Univ. Ulm (Germany); A. Friedberger, EADS Deutschland GmbH (Germany)

We have fabricated microthruster chip pairs - one chip with microthruster structures such as injection capillaries, combustion chamber and nozzle, the other chip with platinum thin film devices such as resistance temperature detectors (RTDs) and a heater. To our knowledge, this is the first MEMS-based microthruster with integrated temperature sensors. The microthruster structures were machined through DRIE process. The platinum thin film was sputtered on thermally oxidized silicon wafers WITHOUT adhesion layer. In order to passivate the thin film devices and to enable the direct bonding of a chip pair, the wafer surface with thin film devices was coated with PECVD-SiO¬¬2 and subsequently planarized through a chemical mechanical polishing (CMP) process.

The effects of anneal up to 1050°C on the surface morphology of platinum thin films with varied geometry as well as with / without PECVD-SiO2 coating were investigated in air and N2 and results will also be presented. It was observed that by reducing the lateral scale compatible with unmodified lab disposables, contrarily to contact imaging systems [2].

For the observation and understanding of tumor progression, cell proliferation and motility studies are of great importance [3]. For these studies, a sensor system that monitors cell motility in four wells simultaneously (of a 24-well plate), has been developed. The validation of the system has been carried out by optical visualization of micro-beads with known dimensions (12 µm diameter); this yields an object resolution of approximately 5 µm, which makes the sensor setup suitable for individual cell observation.

In the present work we focus on motility tests on adherently grown mammalian epithelial cells. By using our system, the simultaneous observation of two stimulated (with 50 ng/ml HGF) and control samples of MDCK (Madin-Darby Canine Kidney) cells is carried out in real-time.

The presented imaging platform is an attractive and versatile alternative to conventional time-lapse microscopy to monitor in vitro assays. Furthermore, the high-throughput feature makes its use advantageous for the simultaneous tracking of biological samples exposed to different analytes.

REFERENCES

[1] M. Poujade et al., “Collective Migration of an Epithelial Monolayer in Response to a Model Wound”, PNAS, 104 (41), 15988-15993, 2007.

[2] M. Gabriel et al., “Inexpensive integrated cell imaging device”, Proc. of MicroTAS, 1600-1602, 2008.

[3] S. Suresh, “Biomechanics and Biophysics of Cancer Cells”, Acta Biomaterialia, 3, 413-438, 2007.

8066-59, Poster Session

Analytical investigation of the pull-in voltage in capacitive mechanical sensors

J. Lardies, M. Berthillier, Univ. de Franche-Comté (France)

A MEMS capacitive sensor is basically an electrostatic transducer and an analytical approach is used to model a MEMS-based capacitive-type sensor. A new relatively simple closed-form model to evaluate the pull-in voltage associated with a rigidly clamped square diaphragm or a circular diaphragm subject to electrostatic forces due to a bias voltage is developed. The method incorporates the nonlinear and non uniform nature of the electrostatic force associated with a clamped diaphragm deformation. Our approach is based on a linearized uniform approximation of the nonlinear electrostatic force due to the bias voltage and the use of a 2D load deflection model for MEMS based capacitive acoustical sensor. The spring hardening effect associated with nonlinear stretching of the central region of a clamped diagram is also considered. The resulting electrostatic pressure on the diaphragm, the pull-in voltage, and the deflection of the midpoint of the diaphragm for different bias voltage are studied.The method can be extended to determine the pull-in voltage for other microstructures such as cantilever beams under electrostatic excitation. A comparison of the results obtained using the developed analytical model of the communication with the results obtained by Senturia, Hsu and Bergqvist is presented.

Numerical results are presented showing the effectiveness of the method in nonlinear identification problems. Using our model, we can derive simple design equations, calculate the small signal model for frequency response computation and simulate the MEMS large-signal transient behaviour.

8066-60, Poster Session

Biomimetic MEMS to assist, enhance and expand human sensory perceptions: survey on state-of-the-art developments

T. Makarczuk, U. Schmid, Technische Univ. Wien (Austria); T. R. Matin, Univ. Kebangsaan Malaysia (Malaysia); M. O. Macqueen, Aramis Technologies (Malaysia); I. C. Gebeshuber, Univ. Kebangsaan Malaysia (Malaysia)

The human body is equipped with six general senses: smell, hear, taste, touch, see and temperature sensing. These senses are of extraordinary value but we cannot change them even if this proves to be a disadvantage in our modern times. However, we can assist, enhance and expand these senses via MEMS. Current MEMS cover the range of the human sensory system, and additionally provide data about signals that are too weak for the human sensory system (in terms of signal strength) and signal types that are not covered by the human sensory system.

Biomimetics deals with knowledge transfer from biology to technology. Biomimetics that is applied by researchers coming from biology, science and engineering is a promising method especially in the development of MEMS that assist, enhance and expand human sensory perception.

In our interdisciplinary approach existing MEMS sensor designs are modified and adapted (to keep costs at bay), via biomimetic knowledge transfer of outstanding sensory perception in ‘best practice’ organisms (e.g. thermoreception, UV sensing, electromagnetic sense). The MEMS are then linked to the human body (mainly ex corpore to avoid ethics conflicts), to assist, enhance and expand human sensory perception (artificial eyes, magnetic sense for facilitated orientation, etc.).

Examples of created products comprise sensors that vibrate when a blind person approaches a kerb stone edge, devices that allow divers better orientation under water (echolocation, ultrasound), special glasses that allow vision in the ultraviolet range, vibrating devices on the steering wheel that inform car drivers of low fuel level, enhanced hearing capabilities (ultrasound, infrasound) and electromagnetic senses.

The combination of Malaysia’s high biomimetic inspiration potential and prototyping facilities in Europe can create a significant added value for commercial customers.

8066-61, Poster Session

System modeling of a piezoelectric energy harvesting module for environments with high dynamic forces

A. Frey, M. Schreiter, J. Seidel, I. Kuehne, Siemens AG (Germany)

This paper reports the design of a piezoelectric energy harvesting module for a tire based wireless sensor node. System considerations comprise the generator design, material impact and the generator interface circuitry. A design procedure is presented, which allows identifying a geometry design space for the piezo microgenerator consistent with required boundary conditions.

The addressed tire pressure monitoring application (TPMS) for the microsystem requires a mounting inside of the car tire. In this environment a large dynamic force range occurs for a given mass. The acceleration is in the range of some ten up to some thousand units of gravitational acceleration. Therefore, a conventional spring-loaded generator cantilever design with a mass in the gram-range is critical. For our design we use a piezoelectric MEMS generator approach without additional mass. The intrinsic mass of the cantilever is in the microgram region and the resulting acceleration forces are very small.

For the energy transfer from the environment to the generator we suggest a non-resonant excitation scheme. Tire related forces during the period of tread shuffle passage are to be used for a pulsed excitation of the generator. After the excitation the cantilever starts oscillating. During each oscillation cycle electrical energy is extracted by the interface circuit to provide it to the load. The cantilever amplitude decays exponentially until it is reset to the initial value during the next tread shuffle passage.

The cantilever consists of a silicon carrier layer and a self-polarized piezoelectric PZT thin film realized with a MEMS compatible sputtering technology. The carrier layer serves three purposes: it provides mechanical stability of the structure, it contains the neutral axis and it is used as a storage element for the harvested mechanical energy. The generator has a triangular shape to realize a uniform stress distribution and therefore a maximum amount of harvested energy per active piezoelectric area. The geometry of the generator is completely defined by three parameters: area (some ten mm2), carrier thickness (some ten µm) and the piezoelectric layer thickness (some µm).

All relevant system parameters are analytically calculated. Based on the stress distribution in the cantilever layers the mechanical energies

Smart Sensors, Actuators, and MEMS V (Proceedings Volume)

Proceedings of SPIE Volume: **8066**

Editor(s): **Ulrich Schmid**; **José Luis Sánchez-Rojas**; **Monika Leester-Schaedel**

Date: **1 June 2011***

ISBN: **9780819486554**

Softcover

Member: **$120.00**
Non-member: **$160.00**

ADVANCE ORDER

* Estimated Publication Date