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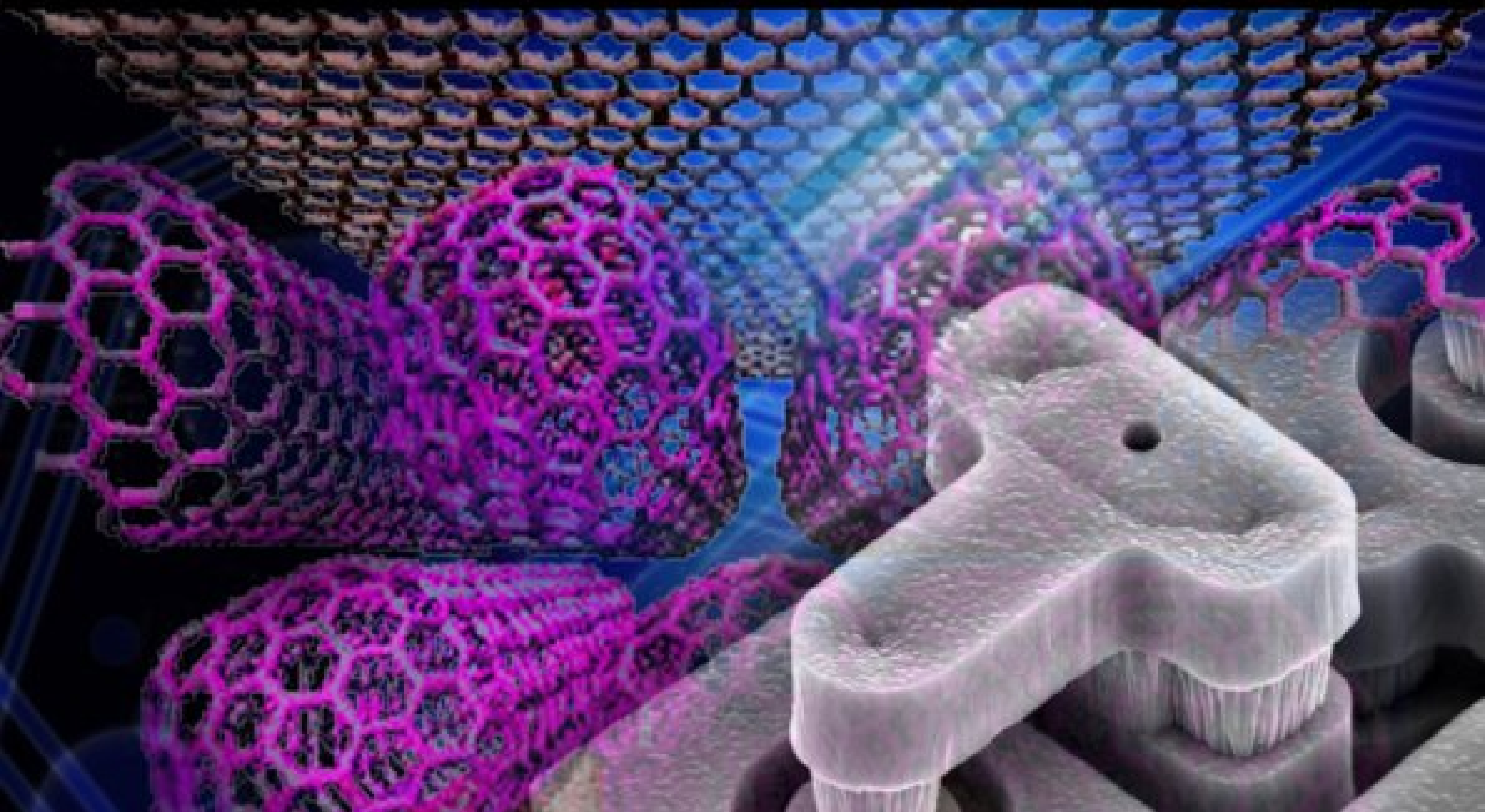

MEMS & NEMS: Devices and Systems

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Foreword

The 10th annual NSTI Nanotech Conference and Trade Show was held this year during 20-24 May at the Santa Clara Convention Center, in Santa Clara, California. The conference has grown this year to host 3000 attendees and 250 exhibitors, while the resulting proceedings boasts over 3000 pages of peer-reviewed micro and nanotechnology research.

A number of authors publishing in the Joint Electronics and Microsystems Symposia track were invited to submit a revised version of their papers to this special issue. Papers were selected from a number of symposia within the track, including: MEMS & NEMS, Sensors & Systems, Micro & Nano Fluidics, and MSM – Modeling Microsystems. These symposia brought together researchers from a number of disciplines to discuss topics ranging from theoretical developments, to design and fabrication, through to industrial applications of MEMS and NEMS sensors, devices and systems.

The joint symposia are motivated by the dream of smarter, smaller, and more complex systems that integrate micro and nano system technologies with intelligence, power and communication ability at the same micro or nano scale. The resulting increase in complexity poses an enormous challenge to engineers when designing, modeling, and fabricating such integrated micro and nano systems. The joint symposia aimed at bringing together researchers from different disciplines to exchange ideas about how to best develop such systems.

As with the joint symposia, this special issue includes papers ranging from those with a higher level focus to those covering low-level physical aspects of MEMS and NEMS devices and their modeling and fabrication. Four of the papers presented in this special issue correspond to invited talks: Sanna et al., examine miniaturization trends in preventative medicine and include some results from the EU project ANGEL; Adams et al., describe the results of the NASA funded GEMSTONE project, which involved creating and field-testing a small system of atmospheric probes; French and Yang explore the opportunities and pitfalls of scaling, whilst Nieva presents a number of new trends for using MEMS sensors in harsh environments.

We are very thankful both to the NSTI directors and Nanotech chairs (Dr. Matthew Laudon and Dr. Bart Romanovicz) and to the *Sensors & Transducers Journal* for offering the opportunity to publish this special issue.

Guest Editors:

Dr. Elena Gaura

Reader in Pervasive Computing
Director of Cogent Computing Applied Research Centre
Faculty of Engineering and Computing
Coventry University, UK
e.gaura@coventry.ac.uk
www.cogentcomputing.org

Dr. James P. Brusey

Senior Lecturer in Systems Engineering
Senior Research Fellow of Cogent Computing Applied Research Centre
Faculty of Engineering and Computing
Coventry University, UK
j.brusey@coventry.ac.uk
www.cogentcomputing.org

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New Trends on MEMS Sensor Technology for Harsh Environment Applications

Patricia M. NIEVA
Department of Mechanical and Mechatronics Engineering,
University of Waterloo, 200 University Ave. West, Waterloo, N2L 3G1
E-mail: pnieva@uwaterloo.ca
http://simslab.uwaterloo.ca

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Abstract: MEMS and NEMS sensor systems that can operate in the presence of high temperatures, corrosive media, and/or high radiation hold great promise for harsh environment applications. They would reduce weight, improve machine reliability and reduce cost in strategic market sectors such as automotive, avionics, oil well logging, and nuclear power. This paper presents a review of the recent advances in harsh-environment MEMS and NEMS sensors focusing on materials and devices. Special emphasis is put on high-temperature operation. Wide-bandgap semiconductor materials for high temperature applications are discussed from the device point of view. Micro-opto mechanical systems (MOEMS) are presented as a new trend for high temperature applications. As an example of a harsh environment MOEMS sensor, a vibration sensor is presented. *Copyright © 2007 IFSA.*

Keywords: MEMS, NEMS, MOEMS, Sensors, Harsh Environments, Fabry-Perot Interferometry

1. Introduction

Micro and nano electro mechanical systems (MEMS and NEMS) have emerged as a technology that integrates micro/nano mechanical structures with microelectronics, mainly for sensing and actuation applications. Silicon-based MEMS technology has enabled the fabrication of a broad range of sensor and actuator systems. These systems are having a great impact in areas that benefit from miniaturization and increased functionality. They have been commercialized for applications such as ink jet printing, crash sensing, and optical projection to name a few. The main advantage of silicon-based technology is the possibility of integration with microelectronics. A great deal of attention is being drawn to the development of integrated MEMS and NEMS to produce smart devices and systems. In automotive or aerospace for example, a misfiring cylinder has a negative impact on the health of the engine and the emissions control. When a cylinder misfires, the remaining cylinders operate at abnormally higher loads resulting in excessive cylinder pressure levels, overheating, knock, pre-ignition, and severe engine damage. Misfire is also accompanied with high emissions of unburned hydrocarbons and CO. Smart MEMS sensors capable of operating "in cylinder", where the temperatures are around 400 °C for automotive engines or up to and above 900 °C for gas turbine engines, could continuously monitor the combustion quality of the cylinders of automotive engines reducing emissions and improving fuel economy. However, the mechanical and electrical properties of silicon (Si) limit their application in harsh environmental conditions. When the environment temperature is too high (>180 °C), conventional microelectronics suffer from severe performance degradation [1]. Hence, they must reside in cooler areas or be actively cooled. The additional components such as longer wires, extra packaging and/or bulky expensive cooling systems, add undesired size and weight to the system, which at the same time impact the overall reliability of the system. They also require extra supply voltage, which is undesirable for HT applications where power source is very limited. It is then clear that further development, in terms of new MEMS/NEMS materials (including new functional layers such as piezoelectric films) and/or new technologies, is needed to minimize these difficulties. This is especially important where high temperature capability is crucial to realizing improved electronic control and reducing weight.

Silicon carbide (SiC) [2, 3] and group III nitride device technologies [5, 6] are promising for smart MEMS/NEMS sensors operating in harsh environments. In the past decade, tremendous progress has been made in the growth of single crystal SiC wafers and epitaxial growth of crystalline SiC layers on Si and/or SiC wafers [2, 10-15]. However, SiC wafers are not (yet) suitable for MEMS and NEMS, as micromachining of these wafers is still a challenge [2-4]. Issues such as high mechanical stress, deposition uniformity and low etch rates need to be tackled before high-quality SiC structural films can be produced [3]. In addition, the affinity of SiC to form carbides and/or silicides by reacting with metals at temperatures above 600 °C affect metal contacts degrading the performance of SiC MEMS and NEMS sensors [4]. Furthermore, very little is known about the elastic behavior and long-term stability of SiC micro- and nano-structures at elevated temperatures. Hence, despite the obvious benefits of using SiC for the development of MEMS and NEMS for harsh environments, there are still many hurdles that have to be overcome before it becomes appropriate for manufacturing and can be used reliably in commercial applications [2, 3]. Group III nitrides are beneficial as piezoelectric functional components for high temperature operation. For example, Aluminum nitride (AlN) preserves its piezoelectric properties up to 1150 °C [5] and gives the opportunity of building up on-chip smart systems with a high degree of processing control. However, only a few reports exist about such applications [6] and despite of all the progress made in the last few years, they still cannot be used for integrated MEMS or NEMS devices.

Remote sensing through optical signal detection has major advantages for safe signal transmission in harsh environments. It is highly resistant to electromagnetic interference (EMI) and radio frequency interference (RFI) and at the same time, it eliminates the necessity of on-board electronics, which has been one of the main obstacles in the development of smart MEMS sensors for high temperature applications. An economical way to deal with higher temperatures and other aggressive environmental conditions is to build MEMS sensors out of robust materials (e.g. Si, Silicon nitride, SiC) and integrate them with optical signal detection techniques to form MOEMS [7-9]. For instance, Fabry-Perot (FP) microstructures have been used to meet the demand of MEMS sensor systems for harsh environments [7, 8]. In this combination, the small and precise size of the sensing elements offers considerable flexibility in choosing the response range and sensitivity of the final sensors. Optical technology has also been used to power a wireless telemetry module for high temperature MEMS sensing and communication [9]. In this paper, we review the current status and the main obstacles in wide bandgap semiconductor devices and microsystem components for MEMS and NEMS. We also highlight recent advances and trends in MOEMS sensors in the context of using them for high temperature applications. The use of Fabry-Perot microstructures for the development of a new MOEMS displacement sensor for high temperature applications is discussed. Analysis, modeling and experimental results are presented to show their sensitivity and accuracy.

2. Silicon Carbide Semiconductor Devices

SiC is the most mature and the only wide bandgap semiconductor that has silicon dioxide as its native oxide [10]. This allows for the creation of metal oxide semiconductor (MOS) devices. The outstanding material and electronic properties and chemical inertness of SiC make it a leading candidate for MEMS and NEMS in a variety of harsh conditions [2, 10-17]. Regarding its material properties, SiC has a knoop hardness of 2480 kg/mm^2 compared to that of silicon (850 kg/mm^2) [12]. In addition, SiC has a Young's Modulus has a Young's Modulus of 700 GPa, as compared to Si (190 GPa) [11a] or other wide bandgap semiconductors such as Gallium Nitride (295 GPa) [13] and AlN (310 GPa) [5]. When compared to silicon, SiC has a larger bandgap (2.3-3.4 eV), a higher breakdown field ($30x10^5$ V/cm), a higher thermal conductivity (3.2-4.9 W/cm K), and high saturation velocity (cm/s) [12]. Piezoresistive- and capacitive-based sensors are among the most widely used SiC MEMS and NEMS sensing mechanisms.

2.1. Piezoresistive-Based Sensors

The piezoresistive effect in SiC has been used for pressure, force, and acceleration sensors. In general, the piezoresistivity for wide band-gap semiconductors is comparable to that of Si but they can operate at much higher temperatures. However, the contact resistance variation at elevated temperatures can be indistinguishable from the piezoresistance change [16]. In addition, SiC has a relatively low gage factor (30 compared to 90 of Si [11]) which decreases the sensitivity of the sensors as the temperature increases. Okojie et al. [13] developed a piezoresistive pressure transducer which was made of 6H-SiC piezoresistors on a 6H-SiC substrate. The sensor was tested up to 600 °C and 200 psi but due to the significant decrease of the gage factor at high temperatures, the output of the transducer required a temperature compensation scheme above 400 °C. More recently, Wu et al. [14] developed bulk micromachined pressure sensors for HT applications using polycrystalline and crystalline 3C-SiC piezoresistors grown on a Si substrate. The piezoresistors fabricated from poly-SiC films showed -2.1 as the best gauge factor and exhibited sensitivities up to 20.9-mV/V psi at room temperature. Single-crystalline 3C-SiC piezoresistors exhibited a sensitivity of 177.6-mV/V psi at room temperature and 63.1-mV/V psi at 400 °C. Their estimated longitudinal gauge factor along the [100] direction was estimated at about -18 at room temperature but dropped to -7 at 400 °C. Atwell et al. [15] developed a bulk-micromachined 6H-SiC piezoresistive accelerometer for impact applications. The accelerometer was tested up to 40,000 g. Sensitivities ranging from 50 to 343 nV/g were measured for differing sensing elements but non-linear behavior was observed over the shock range relative to a commercial accelerometer (with sensitivity of 1.5 μV/g).

2.2. Capacitive-Based Sensors

Capacitive-based sensors have also been used to sense pressure, force, acceleration, and flow rate. They are attractive for HT applications because the device performance is not susceptible to contact resistance variations but they exhibit performance degradation due to the wiring parasitic capacitances and test setup. SiC capacitive sensors are mainly used for pressure sensing and they are mainly fabricated using bulk-micromachining techniques. Young et al. [16] developed a single crystal 3C-SiC capacitive pressure sensor fabricated on a silicon substrate. The sensor demonstrated sensing capabilities up to 400 °C and was tolerant of contact resistance variations. However, it exhibited different responses at different temperatures of operation, which was attributed to trapped air inside the cavity and thermal mismatch. A promising approach to pressure sensing in corrosive environments was developed by Pakula et al. [17] using post-processing surface micromachining. The sensing membrane was fabricated in low-stress PECVD SiC. To avoid problems related with wiring parasitic capacitances, the sensor was integrated monolithically to a CMOS readout circuit. The sensor showed stable behavior from 10 mbar up to 5 bar.

3. Optical MEMS Sensors

Optical MEMS sensors are highly adaptable to harsh environments, can measure displacement, pressure, temperature and stress, can be easily incorporated into sensor arrays by using multiplexing methods, and are suitable for liquid and gas measurements. In addition, they are highly resistant to electromagnetic interference (EMI) and radio frequency interference (RFI) and at the same time, they eliminate the necessity of onboard electronics. However, simpler processing techniques and therefore lower manufacturing costs are desirable. Moreover, simplification of the sensing elements and the fabrication processes will be helpful for their mass production and commercialization. Fiber-Optic MEMS and MOEMS sensors are lately being developed for harsh environmental conditions [7, 18-20].

3.1. Fiber-Optic MEMS Sensors

Fiber-optic MEMS are robust, highly resistant to EMI and RFI, and can potentially detect displacements on a sub-nanometer scale. However, their performance depends on mechanical–thermal noise, photodetector noise, fabrication imperfections, and assembly. From all these, the main disadvantage is the need to adjust the optical interrogation system relative to the moving MEMS component. Eklund and Shkel [18] demonstrated that the finesse of a Fiber Optic Fabry-Perot MEMS can decrease up to one order of magnitude due to surface roughness, curvature or a slight deviation from parallelism, thus greatly reducing the resolution of the sensor. Xiao-qi et al. [19] developed a fiber-optic MEMS pressure sensor for harsh environments based on Fabry–Perot interferometry. A dual-wavelength demodulation method was used to interrogate the sensor and results show that the sensor has reasonable linearity and sensitivity within 0.1 MPa to 3 MPa. However, the fabrication is complicated and expensive. In addition, misalignments between the sensor and the fiber cause an increase of the signal-to-noise ratio due to instability of the reflected signal. To overcome these limitations, integration techniques have to be developed which can be either hybrid (e.g. detachable connection of optical fibers with sensor heads). Another solution could also be the integration into MOEMS employing substrate integrated waveguides. However, one of the disadvantages of these waveguides is that leakage losses can be substantial, especially at high temperatures.

3.2. MOEMS Fabry-Perot Sensors

Fabry-Perot Interferometric techniques can be easily applied to membranes or cantilevers that, if fabricated with robust materials (e.g. Si, silicon nitride, SiC, etc.), can be utilized to develop contact-free sensor components with high sturdiness in harsh conditions. Compared to sensors that utilize optical fibers or multi-chip structures [18, 19], single-chip Fabry-Perot MOEMS sensors do not require alignment or sophisticated optical stabilization techniques [7, 8, 20]. In contrast to cumbersome and ambiguous fringe-counting optical detection schemes associated with large cavity FP sensors used in the literature, the small cavity length of these sensors (2-3 μm) allows small intensity shifts to be uniquely related to the relative displacement of the moving mirror. This high resolution results in an improvement of functionality, reliability and sensitivity compared to classical fiber-optic sensors, and make them ideal for the manufacturing of on-chip smart systems at a minimum cost.

Haueis et al. [8] developed a Si-based resonant force sensor packaged with fiber-optic signal detection for high temperature operation. An off-chip capacitive detection system was also used to verify the operation of the sensor up to 175 °C. The optical detection showed a resolution of the resonator deflection to be more than ten times better than the capacitive detection. Wang et al. [20] developed a new Fabry-Perot pressure microsensor which has been successfully tested up to 30 psi and 120 °C. Over the pressure ranging from 0 to 21 psi, very small cross sensitivity to temperature was observed in mid or higher end of the pressure range. However, because of the bridge configuration of the sensor, a corrugated diaphragm needs to be used to alleviate both, the signal averaging effect and the cross-sensitivity to temperature.

4. Fabry-Perot MOEMS Sensor for High Temperature Applications

We have developed the MOEMS Fabry-Perot displacement sensor (MFPD) shown in Fig. 1 that is suitable for high temperature applications and can be easily integrated with standard Si micromachining. Details on the development and fabrication were presented in Ref. [7]. The MFPD consists of a cantilever beam fabricated in low-stress LPCVD silicon nitride. The cantilever beam forms the top mirror of the Fabry-Perot interferometer while the silicon substrate below provides the bottom mirror. As shown schematically in Fig. 4, the two mirrors form an optical microcavity for a monochromatic laser beam incident at the top. For this cavity arrangement, the total interferometric light back-reflected depends on the height of the optical microcavity at the location where the laser beam is directed (spot). When the substrate vibrates, there is a relative deflection of the beam with respect to the substrate and hence a change in the microcavity height. If the mechanical characteristics of the device are known, the amplitude of the substrate motion can be calculated by measuring the back-reflected light.

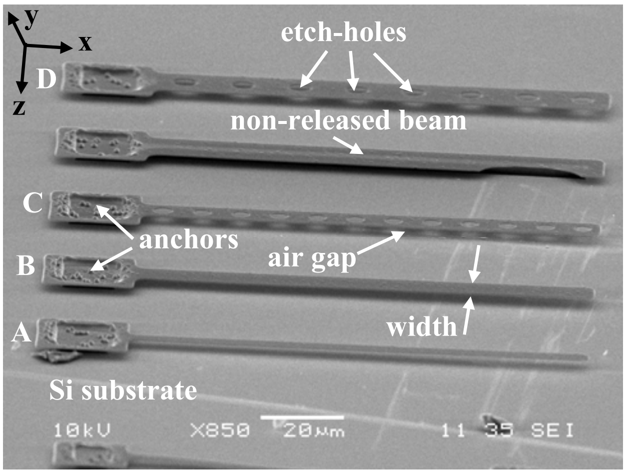

Fig. 1. Fabry-Perot MOEMS displacement sensors with a fundamental resonant frequency of ~ 45 kHz [7].

To the best of our knowledge this MFPD sensor is the first surface micromachined Fabry-Perot in the literature that employs a single layered cantilevered structure together with a new extrinsic intensity-modulated optical interrogation method based on the reflectance of the device (and not the transmittance) to measure displacement in high temperature environments. Cantilever beams have advantages over bridge structures because the lowest natural frequency is 16 % of a bridge with the same dimensions, allowing measurement of lower frequencies. Also residual stresses do not significantly affect the resonant frequency of cantilevers [21], but do change the resonant frequency of a bridge operating at high temperatures [22]. In addition, they eliminate problems due to stress-stiffening effects and variation of the optical path length due to coupled photo-elastic and thermal-optical effects, all of which are critical to the successful realization of sensors for high temperature applications.

4.1. Optical Signal

The optical microcavity of the MFPD corresponds to a Fabry-Perot in reflectance and its optical response is given by the *power reflectance*, *R*, of the top of its surface [7]. Assuming no variation in the top mirror thickness (*t*) or the relaxed cavity height (*h*), *R* is only a function of the top layer thickness and the time-dependant air cavity height at the location of the laser beam spot. Fig. 3 shows the power reflectance of the MFPD as a function of the relaxed air gap height (dotted curve). This function was obtained from the optical signal shown in Fig. 2, measured for the MFPD type A shown in Fig. 1, vibrating at a frequency of 62 kHz, and fitted to the AC component of the theoretical power reflectance model described in detail in Ref. [7] with h, δ_r, and t_1 as the fitting parameters. As it can be easily observed, the function is periodic (period $\lambda/2$) and represents the optical transfer function of the microcavity of the sensor.

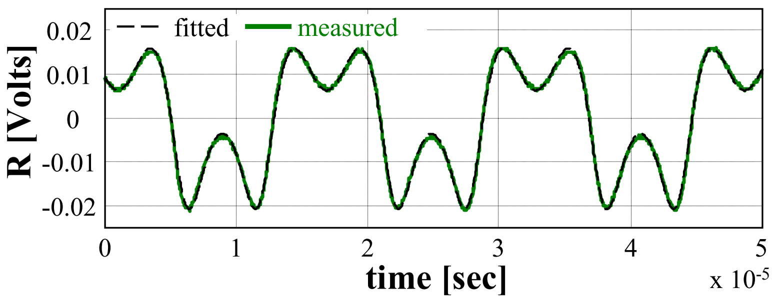

Fig. 2. Measured interferometric optical signal from the MFPD cantilever beam A (Fig. 1) vibrating at an amplitude of the relative displacement of ~143.8 nm and fitted to the theoretical power reflectance.

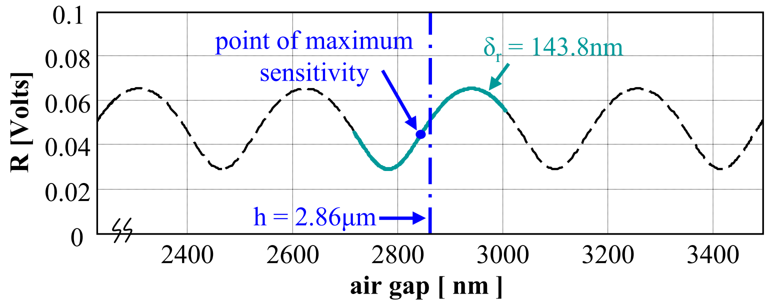

Fig. 3. Reflectance of the MFPD type A shown in Fig. 1 as a function of air gap height.

The total displacement of the beam with respect to the substrate is indicated by the solid line. The fitted values of h and t_1 are within ~3.3 % and ~1.5 %, respectively, of the measured values listed in Table 1. The static air gap height at the location of the laser beam spot defines the operation point of the sensor which in this case is very close to the point of maximum slope or maximum sensitivity of the transfer function [7]. Motions as small as tenths of nanometers can be resolved using this new extrinsic intensity-modulated optical interrogation method.

Table 1. Summary of measured parameters for the Fabry-Perot MOEMS displacement sensors shown in Fig.1.

Beam Type	Length (µm)	Width (µm)	Etch-Hole diameter (µm)	Air Gap @ spot (µm)	Spot Location (µm)
A	122.5	4.25	-	2.84	5
B	119.6	8.17	-	2.66	17.5
C	123.5	9.31	3.92	2.60	17.5
D	118.5	13.39	5.56	2.62	22.5

4.2. Frequency Response

The experimental setup used for the determination of the frequency response of the MFPD sensors was described in Ref. [7] and it is presented schematically in Fig. 4. The optical measurement system detects the interferometric optical signal coming from the vibrating Fabry-Perot structure and transforms it into an electrical signal. This electrical signal is then processed to determine the relative deflection of the top mirror with respect to the bottom mirror of the MFPD at the frequency of excitation. The MFPD frequency response is determined by repeating this sequence for the different frequencies in the range of interest.

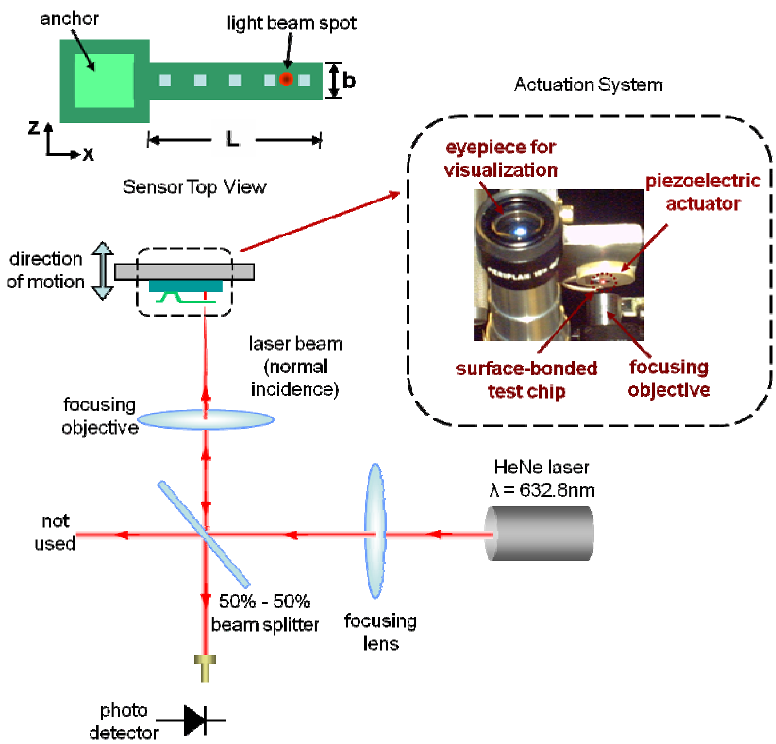

Fig. 4. Schematic of the optical setup for the measurement of the interferometric back-reflected light (MFPD sensor shown as mounted).

The experimental frequency response of all the MFPD cantilever beams listed in Table 1 and measured using the technique described above are shown in Fig. 5. These measured frequency responses were measured using a 10 nm amplitude harmonic excitation. The tests were performed at atmospheric pressure (14.7 psi) and room temperature (23 °C). Their average fundamental frequency is 43.5 ± 3 kHz and their total viscous damping factor (mode 1) vary from 0.19 to 0.3. Also shown in this figure are these responses fitted to the analytical vibration mechanical model with the resonant frequency (*f*) and the total viscous damping factor (ζ) as fitting parameters. The excellent agreement between the experimental measurements and the analytical mechanical models suggests that air viscous damping is the dominant source of dissipation for these structures. For details in the analytical modeling the reader may refer to Ref. [7]. Furthermore, by decoupling the effects of squeeze-film and airflow damping, an array of MFPD microsensors will allow for the simultaneous detection of pressure and temperature in addition to displacement [22]. The primary means of viscous damping differentiation is the dependence of the viscosity and density of the air on temperature and pressure. By microfabricating an array of MFPD structures with different geometries, the air viscous damping effects can be modeled based on the height of the microcavities, resonant frequencies, and temperature and pressure of operation. Thus, successful decoupling of the damping coefficients will result in a sensitive sensor array capable of measuring both temperature and pressure in addition to displacement. Experimental verification of the use of the MFPD as a multifunctional sensor is underway.

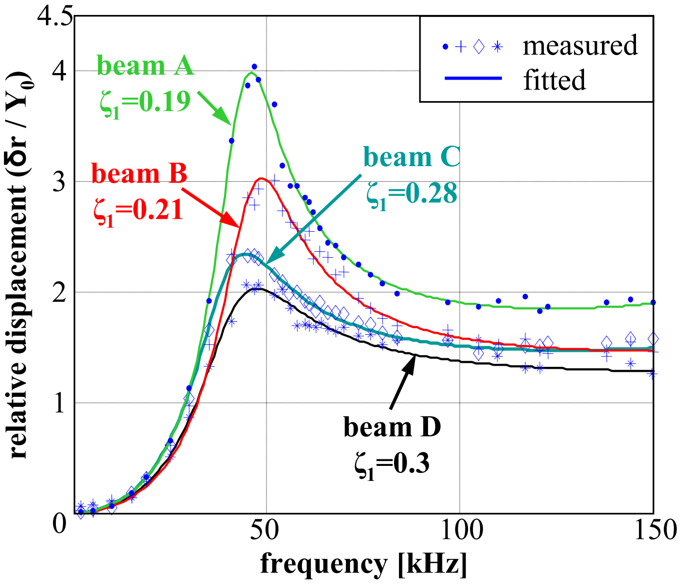

Fig. 5. Measured and fitted frequency response for all MFPD sensors listed in Table 1 [7].

4.2. Temperature Dependence

The mechanisms leading to temperature dependence of the MFPD frequency response are mainly due to (1) shift of the resonant frequency arising from the variation of the Young's modulus, density and coefficient of thermal expansion of the Si_xN_y film (2) variation of the take-off angle of the beam curling due to induced uniform stress (3) variation of the viscous damping coefficient due to variation of the density and the viscosity of the air, and (4) changes of the optical path lengths due to the coupled thermal-optical and photo-elastic effects [7].

For the MFPD type A depicted in Fig. 1, a variation of temperature from 23 °C to 600 °C causes a drift in the fundamental resonant frequency of about 6.1 %, which is much less than the 20 % drift reported for bridges in Ref. [23]. For the same MFPD, the take-off angle is ~5.7 mrad. Neglecting the effects of stress gradients, the same temperature change produces a variation in the take-off angle of ~0.38 mrad. This variant decreases the air gap height at the spot location by about 43 nm moving the point of operation of the sensor about 1.3 % and hence, decreasing the sensor's optical sensitivity [7]. However, if the temperature of operation of the sensor is known, both these effects can be corrected for.

Another mechanism that leads to sensor temperature dependence is the air viscous damping which depends on the viscosity and the density of the air, both of which are dependent on temperature. Fig. 6 shows the variation of the air viscous damping as a function of temperature for the FPMOD type A for the first two modes of vibration and at atmospheric pressure. It can be seen that the variation in viscous damping for a temperature varying from 23 °C to 600 °C is ~0.14. This corresponds to a decrease in relative displacement of ~2 and hence, a decrease of sensor sensitivity around the fundamental resonant frequency. However, the same variation of temperature only corresponds to a small variation of the optical path length (around 2.27 nm) due to the coupled thermal-optical and photo-elastic effects. Fig. 7 shows that the effect of the temperature is less significant if the point of operation is close to the point of maximum sensitivity [7].

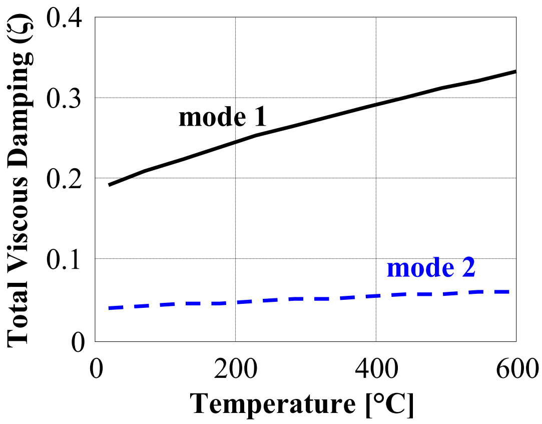

Fig. 6. Calculated temperature dependence of the total air viscous damping coefficient (n = 1, 2) for MFPD type A.

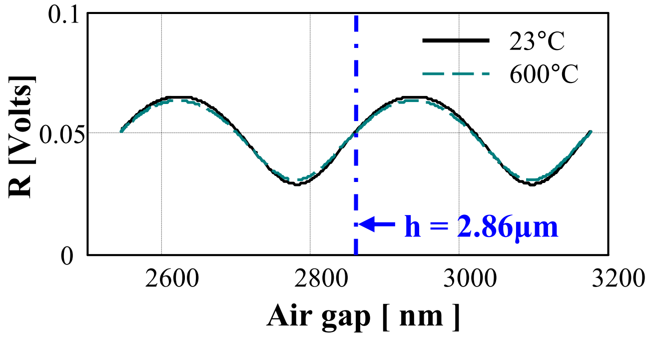

Fig. 7. Shift of the optical transfer function of the MFPD type A due to the temperature dependence of the optical path length.

The above results show that the sensitivity of the MFPD at high temperatures is mainly influenced by the effects of the thermally induced stress and the air viscous damping. Thermally induced stress can shift the operation point of the sensor, thus affecting the optical sensitivity, but it has a small effect on the variation of the optical path length. The significant effect that the temperature has on the air viscous damping reduces the overall sensitivity of the sensor, especially in regions around the fundamental resonant frequency. However, if the temperature is known, both of these effects can be compensated. A temperature-controlled sensor chamber is being designed to measure the effect of temperature in the frequency response of the MFPD cantilever beam at high temperatures.

Compared to standard interferometric techniques for the measurement of displacement (e.g.

stroboscopic and laser Doppler interferometers), the MFPD sensor needs neither a reference arm nor sophisticated stabilization techniques. Fig. 6 and Fig. 7 show that the power reflectance of the MFPD is a very sensitive measure of the air gap height. Using the solid MFPD cantilever beam type A, relative displacements as small as $0.139\,\mathrm{nm}/\sqrt{\mathrm{Hz}}$ were measured [7]. Furthermore, the small size of the sensor, the materials in which it can be built, and its simple construction make it suitable for on-chip integration and ideal for high-temperature applications. Though the optical detection of the frequency response of the MFPD cantilever beam has been implemented for a bare sensor, our experimental results demonstrate the accuracy of the optical interferometric readout on the determination of the frequency response of any free standing micromechanical device at the wafer level. The very simple configuration offered by this optical interferometric system is being considered in the future for integration in the sensor package.

5. Conclusions

We have reviewed recent advances in MEMS sensors for harsh-environments focusing on fabricated devices. SiC and group III semiconductor materials such as AlN, are an excellent candidate for the development of MEMS and NEMS for harsh environments. The excellent physical properties of particularly SiC enables its operation in harsh environments (e.g. high temperature, high pressure, high g, radiation and biological or chemical corrosive media). Piezoelectric properties of AlN, and good optical properties of robust materials such as SiC and silicon nitride may allow the improvement of functionality, reliability and sensitivity of classical sensors giving the opportunity of building up on-chip smart systems with a high degree of processing control. The review of different SiC sensor technologies shows unambiguously that although all necessary technology steps are well developed for the fabrication of SiC based MEMS devices, major problems such as reliability, packaging, wiring, and integration issues have to be overcome before they can be manufactured and used reliably in commercial high temperature applications.

The adaptability, resistance to EMI and RFI and high sensitivity make MOEMS sensors ideal for applications in harsh environments. In the past few years, much progress has been made in the development of simpler processing techniques and simplification of MEMS sensing elements. A new Fabry-Perot MOEMS displacement sensor for HT applications was presented. Results show that the small influence of high temperatures on the sensitivity of this sensor offers advantages in terms of size, cost, and operation in high temperature applications. In addition, by microfabricating an array of MFPD structures with different geometries, successful decoupling of the damping coefficients will result in a sensitive sensor array capable of measuring both temperature and pressure in addition to displacement. Finally, the simple configuration of the optical detection system makes it ideal for integration in the sensor package.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726- 5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually.

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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;
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