TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

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1. INNOVATIVE MONOLITHIC AND WAFER-LEVEL PACKAGED 3D ACCELEROMETER

Micromachined accelerometers that are fabricated using complementary metal-oxide-semiconductor (CMOS)-compatible fabrication processes are beneficial as they are conducive to integrating high-performance on-chip signal conditioning circuits with sensing elements and can achieve short design cycle times. Such monolithic accelerometers with the sensing element and signal conditioning electronics integrated on a single chip can provide key benefits such as reduced cost (in volume applications), reduced size, and enhanced performance. Moreover, monolithic accelerometers are conducive to integration in inertial measurement units (IMUs) for applications such as navigation in portable devices.

Miniaturized 3-axis accelerometers, which can sense acceleration in each of the three orthogonal directions (axes), are finding expanding applications in areas such as automotive (for example, navigation for dead reckoning assistance of the global positioning system), inclination measurement, aircraft, pedometers, gaming controls, robotics, as well some medical applications.

Chip scale packaging, in which the final footprint of the device is basically determined by the die itself, can provide key advantages, such as smaller size, less weight, an easier assembly process, reduced cost, and enhanced electrical performance owing to reduced parasitics. Wafer level chip-scale packaging is a form of chip scale packaging in which the package is substantially or completely constructed before the wafers are sawed into dies Such packaging techniques can have key economic benefits as well as allow a low form factor and comprehensive control over integrated circuit production.

Wafer level packaging technologies have been developed for MEMS (micro-electromechanical system) devices. However, such techniques have tended to not achieve packaging of MEMS devices along with integration of the CMOS electronics simultaneously.

US-based Memsic, Inc. now offers a unique MXC400xXC monolithic 3D accelerometer that utilizes wafer level packaging (WLP) technology. The significant technology achievement combines a 3D IC sensor with full WLP, translating to a 60% reduction in cost and a 50% decrease in size. The technology can facilitate next-generation mobile consumer devices, such as mobile phones, tablet computers, toys, or wearable devices.

The technology innovation is enabled by Memsic's patented, proprietary thermal accelerometer technology, where the MEMS sensor structure is etched directly into standard CMOS wafers, enabling a unique CMOS monolithic solution. The MEMS inertial sensor and signal processing circuitry are integrated on a standard monolithic CMOS wafer.

Memsic's thermal accelerometer technology utilizes thermal convection of heated gas molecules inside a sealed cavity to sense acceleration or inclination. The heated gas molecules are used to detect acceleration utilizing thermocouples. Unlike capacitive MEMS accelerometers, which use a solid mass structure, Memsic's approach uses a heating element to heat the gas molecules and temperature sensors such as thermocouples to measure the difference in temperature between the period when there is no acceleration and when there is applied acceleration. When experiencing acceleration, the less dense air molecules in the heated gas move in the direction of acceleration, while the cool and denser molecules move in the opposite direction, generating a temperature differential. The temperature from one side of the MEMS structure to the other side is proportional to acceleration.

Such thermal accelerometers are intrinsically amenable to monolithic fabrication and purportedly are more compatible with the integration of the signal conditioning circuitry, interface, and embedded algorithm circuitry on a single chip using wafer level packaging.

Applications for Memsic's thermal accelerometer technology include products for automotive stability control and rollover detection, digital cameras, projectors and so on. The technology has been taken to an enhanced level through combining 3D sensing with full WLP while retaining the same small size and economical cost.

The MXC400xXC 3D monolithic WLP accelerometer has benefits for space- and cost-sensitive consumer devices. In addition to economical cost, the device provides 12-bit resolution on all three axes, programmable FSR (full-scale range) of±2g/±4g/±8g, an 8-bit temperature output, plus orientation/shake detection. With a package size of 1.2 x 1.7 mm, board space is reduced by 50% compared to industry-standard 2x2 mm solutions. Moreover, the MXC400xXC has no moving parts, rendering the sensor structure robust with respect to shock and vibration (it can endure shock in excess of 200,000g with no change in sensor performance).

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2. OPPORTUNITIES FOR INERTIAL SENSORS IN ACTIVITY MONITORING

Athletic performance has traditionally been measured in the laboratory to test such parameters as biomechanics and physiology. Lab testing is removed from the actual performance or training environment and, therefore, may not provide valid information about a person's athletic performance in real-world conditions. Individuals can particularly improve their athletic performance by gaining a better understanding of their performance during competitions and in the actual training environment. The ability to more conveniently monitor athletic performance in the training or competitive environment has been enabled by advances in low-power, ultra-compact micro inertial sensors (accelerometers and gyro sensors) and micro electronics.

Inertial sensors, which are capable of measuring human motion thousands of times per second, allow for unobtrusively measuring athletic performance. Such sensors are finding increased opportunities to measure activity level in applications such as sports or gait analysis. Accelerometers are able to measure the time derivative of velocity; while velocity is the time derivative of position. Therefore, accelerometers are able to measure the dynamics of motion and position. Accelerometers can, moreover, determine an individual's physical activity and effort. In sports monitoring, gyros often measure angular velocity.

However, it can be challenging to interpret data from inertial sensors into valuable metrics for use by sports or health enthusiasts, athletes, coaches, or researchers.

Indicative of expanding opportunities for inertial sensing technology in sports, health, and activity monitoring, in July 2014, it was reported that Wilson Sporting Goods has licensed patents owned by US-based University of Michigan pertaining to wireless sensor technology, developed by the lab of Noel Perkins, professor of mechanical engineering at the University of Michigan. Wilson Sporting Goods, which has exclusive rights to the technology for tennis and American football and non-exclusive rights to use the system in inflatable balls, is the sixth (and largest) company to license the technology since 2005.

Such technology dovetails with the sporting goods industry's increased, keen interest in digitally-oriented, sensor-enabled solutions that provide enhanced, real-time data for athletic performance analysis and training. Such technology, which can measure motion to the nearest millisecond, has opportunities to profoundly revitalize and even transform the sporting goods arena. For instance, a tennis racket could transmit data that helped analyze where one's stroke needs improvement.

Irrespective of the sport, the raw data is derived from inertial sensors. How the data is used and is distilled into coaching tips depends on a particular sport. The software created by Perkins' lab for data analysis is customized for each sport and other new applications.

The technology was originally developed for fly fishing. Using sensors to measure and chart the motion of his fly fishing rod during casting, Perkins could determine the portion of his casting stroke that was causing a problem. By embedding wireless inertial sensors in sports equipment, he could record a tremendous amount of information, often 6,000 pieces of data per second. Perkins' lab also developed algorithms that interpret the data of most interest to athletes and coaches and convey it in a compelling format.

Perkins' company, Cast Analysis, has a license for fly fishing. Within the field of sports, products using the technology have been or are being developed for basketball, golf, bowling, softball, baseball, soccer, and so on. The sensor technology can measure human performance through tracking, for example, gross or fine motor movements, health, or development of a new skill. Outside of sports, Perkins noted, there are uses and developments in support of medicine, human health, and rehabilitation, worker safety, soldier performance, and obvious uses in gaming devices.

Perkins indicated to Technical Insights that they and their licensees employ three-axis sensing of acceleration and three-axis sensing of angular velocity, for a total of 6 degrees of freedom sensing. This inertial sensor solution can take the form of separate MEMS accelerometers and angular rate gyros or designs that combine both capabilities within one chip.

In tennis, metrics that their technology can provide include the linear and angular acceleration, velocity, and position of the racket as a function of time, and metrics derivable from these, including racket speed, orientation of impact, and ball spin,

He indicated that, in essence, patents for the University of Michigan wireless motion sensor technology claim the use of the technology attached to or embedded in sports equipment. They also have several extending applications pending.

US Patent 7234351 B2, Electronic measurement of the motion of a moving body of sports equipment (published June 26, 2007), for which the inventor is Noel C. Perkins and the original assignee is The Regents Of The University Of Michigan, pertains to an application of rate gyros and accelerometers allowing electronic measurement of the motion of a rigid or semi-rigid body, such as that associated with sporting equipment, including a fly rod during casting, a baseball bat, tennis racquet, or a golf club during swinging. For example, data can be collected by one gyro is extremely useful in analyzing the motion of a fly rod during fly casting instruction, and can also be used during the research, development and design phases of fly casting equipment (such as fly rods and fly lines). The data collected by three gyros and three accelerometers is described as extremely useful in analyzing the three dimensional motion of other sporting equipment, such as baseball bats, tennis racquets, and golf clubs. The data can be used to support instruction as well as design of the sporting equipment.

"The present invention," the patent noted, "was originally motivated by the sport of fly fishing. However, devices according to the present invention can be used for training in many other sports including golf, tennis and baseball. In each of these sports, the equipment (club, racquet, bat) could be instrumented with a small and lightweight (for example, micro-electromechanical systems

[MEMS]) three-axis accelerometer and three-axis rate gyro. This pair of devices, accelerometer and rate gyro, would provide the necessary information to define the motion of the rigid body (club, racquet, bat) in space. Thus, the electronic signals could be used to produce a three-dimensional image of the rigid body as it moves in space as well as specific features of this motion that may serve as metrics of performance (for example, specific acceleration, velocity, and position measures). As in fly casting instruction, instruction in these other sports may profit from the ready analysis made possible through this instrumentation."

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3. WEARABLE GRAPHENE NANOELECTRONIC HETERODYNE VAPOR SENSOR

Diabetes monitoring has typically been done using electrochemical or optical detection methods to measure blood glucose levels. Electronic glucose monitoring has traditionally involved piercing a finger to obtain a blood sample. The finger has a particularly high density of capillaries and, therefore, is an ideal site for a blood sample. However, the finger also has a high density of nerve-endings, rendering it a painful site for puncture. The finger prick method of glucose monitoring tends to be uncomfortable, cumbersome, and time consuming.

Conventional optical systems can be susceptible to interference from ambient light conditions, while electrochemical glucose sensors can have accuracy issues and can be subject to interference caused by compounds that can be oxidized or reduced at the working potential.

Graphene nanosensors have the potential to provide exceptional sensitivity; and such sensors can offer high carrier mobility to achieve ultra-fast molecule detection, high surface-to-volume ratio, low-power consumption, and compatibility for integration with contemporary electronics.. However, there have been some challenges in achieving a low-cost, reliable method for mass production of graphene sensor arrays.

Researchers at the University of Michigan are developing a rapid-response, highly sensitive and reliable, wearable graphene nanoelectronic vapor sensor that could be embedded in a micro gas chromatography system to provide enhanced monitoring of chronic diseases, such as diabetes or hypertension, as well as address other applications such as environmental protection or workplace safety (for example, detecting hazardous chemical leaks or indicating air quality) or military applications.

The device would sense the airborne biomarkers, exhaled or released through the skin, which are associated with a particular disease. For instance, acetone is a biomarker for diabetes. It could also detect other biomarkers, such as nitric oxide or oxygen, which at unusual or undesirable levels could indicate conditions such as high blood pressure, anemia, or lung disease. The platform technology could allow for measuring a variety of chemicals simultaneously or modification of the device to target specific chemicals.

Nanoelectronic sensors for detection of molecules tend to depend on the detection of the charge transfer between the sensor and a molecule in the air or in a solution. Such sensors are based on charge detection, in which molecular binding changes the sensor's charge density, leading to the sensing signal. Such detection techniques have resulted in strong bonds between the molecules to be detected and the sensor. The binding can result in a low detection rate.

In contrast to detecting molecular charge, the researchers employ a heterodyne mixing technique, which looks at the interaction between the dipoles associated with the molecules and the nanosensor at high frequencies. Molecular dipole detection is enabled by the graphene nanoelectronic sensor. This technique can lead to an ultra-fast response time of tenths of a second rather than tens or hundreds of seconds characteristic of existing technology. The method also can significantly boost the sensor's sensitivity, enabling it to detect molecules in sample sizes at a ratio of several parts per billion.

The nanoelectronic graphene vapor sensors would be embedded in a micro gas chromatography system. Moreover, the latter can be integrated on a single chip with low-power operation, and embedded in a badge-sized device that can be worn on the body to provide non-invasive and continuous monitoring of specific health conditions.

Xudong (Sherman) Fan, professor, biomedical engineering department, University of Michigan, noted that the overall sensing principle of the solution involves using micro-gas chromatography (uGC) to separate vapor molecules and then using the high speed nanoelectronic vapor sensor (graphene) embedded in the GC channel for vapor detection. The technique does not involve magnetic field detection. The researchers apply molecule dipole detection in the graphene vapor sensors. They add an external electric field through the graphene sensor. The field flips the vapor molecules near the graphene surface, which modulates the molecular dipole. The change in the dipole induces a change in the graphene, which generates a sensing signal.

Using GC technology, different vapors can be separated, enabling the device to have specificity, based on how long it takes a particular type of vapor molecule to travel through the GC channel. The dipole is used for detecting the presence of vapor molecules.

Fan indicated that the researchers are supported by two grants from the National Science Foundation (NSF). One grant involves conducting research on understanding the graphene-molecule interaction and developing more sensitive and faster nanoelectronic vapor sensors. The other grant involves conducting a market survey and customer discovery to commercialize the technology. He indicated it may take 3 to 4 years for product roll-out.

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4. RECENT PATENTS IN THE FIELD OF OPTICAL SENSORS

One of the fastest growing industries in the energy sector is wind energy. It helps to meet the increasing global demands for energy. To improve the wind turbine performance and maximize the output, it is crucial to monitor and maintain the condition of turbines.

A recent patent in optical sensing (WO/2014/124646) relates to a wind turbine component having an optical fiber wind sensor to monitor the operations of the wind turbine.

Since 1967, approximately 74,358 patents have been registered under optical sensing. Out of these, approximately 38 patents have been classified under the wind turbine category. Since 2004, optical sensing has been gaining popularity in the wind turbine industry. From 2004 to August 2014, approximately 38 optical sensing patents were filed under the wind turbine category. Over the past few years, interest in optical sensing has been growing in the wind turbine industry due to the huge strides made in the optical sensing industry. Optical sensors are highly suited to the wind turbine industry because of their resistance to lightning and electric noise as well as electromagnetic interference. Moreover, optical sensors are cost effective, reliable, and practical monitoring tools.

Optical sensors on wind turbine blades reduce stress on the blade, thus increasing the life of blade. Optical sensors can also be used in the wind turbine industry to detect ice on the blades of wind turbines. In the future, optical sensors are expected to be deployed in all wind turbines. Thus, recent trends in the optical sensing and wind turbine industry suggest that both investors and inventors are purely focusing on deploying these sensors to optimize the performance of wind turbines.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
A WIND TURBINE COMPONENT HAVING AN OPTICAL FIBRE WIND SENSOR	21.08.2014; WO/2014/124646	VESTAS WIND SYSTEMS A/S	LIM, Chee Kang	The application relates to a wind turbine component 18 having an optical fibre sensor 10 arranged to detect the wind speed over the surface of the component. In one embodiment, the optical fibre sensor 10 has a light loss portion 15 that allows some of the light transmitted in the core 11 of the optical fibre to escape. The amount that the optical fibre bends in the air flow across the surface causes the effective surface area of the light loss portion 15 to increase or decrease. With increased or decreased surface area of the light loss portion, more or less light is lost from the fibre. The intensity of the light transmitted in the fibre can therefore be used as a measure of the amount of bending, and therefore as a measure of the air flow's speed. In other embodiments, the optical fibre can comprise optical gratings, such as Fibre Bragg Gratings or Long Period Gratings. Further embodiments use interferometry to measure the extension of the optical fibre.
METHOD OF WIND TURBINE YAW ANGLE CONTROL AND WIND TURBINE	19.06.2014; US20140167415	MITA-TEKNIK A/S	Mykhaylyshyn Viktor	The present invention relates to the wind power engineering and to the method of controlling a yaw angle of the wind turbine, equipped with a horizontal rotor shaft as well as to the wind turbine for implementing the method. According to the method of the present invention, the time difference between the time moments when the rotor blades are in the lower vertical position, the said time moments derived from the reference signal of the sensor connected to the rotor shaft, and the time moments when the blades are on one line with the wind direction and the tower, the said time moments_derived from the periodic signal of the spurious amplitude modulation generated by the AC generator and caused by aerodynamic interaction between the blades and the tower, is used as the indication of actual position of the wind turbine rotor relative to the wind direction. The wind turbine of the present invention comprises a yaw controller including the functional units suitable for generating a control signal for rotating a nacelle of wind turbine based on the given time difference in order to compensate the existing yaw error.
WIND TURBINE OPTICAL WIND SENSOR	08.05.2014; US20140125058	Olesen Ib Svend	Olesen Ib Svend	The invention comprises a wind turbine optical wind sensor 10 mounted on the rotor 4 of a wind turbine, either on the blades 5 or on the hub 5. The sensor comprises a plurality of light sources, each generating respective sensor beams made up of at least two individual parallel component sensor beams. Transit times for particulate matter carried in the wind breaking the at least two component sensor beams are used to provide one or more of an indication of wind speed and/or a component of vertical wind speed. The data received from the sensor can be used in control processes for the operation of the wind turbine, particularly for temporarily pitching the rotor blades in adverse wind conditions, such as when vertical wind gusts are detected.
LONG FIBRE OPTIC SENSOR SYSTEM IN A WIND TURBINE COMPONENT	24.10.2013; US20130278918	VESTAS WIND SYSTEMS A/S	Glavind Lars	A sensor system for measuring an operating parameter of a wind turbine component is described. The fibre optic sensor system comprises a light source for outputting light in a predetermined range of wavelengths, and an optical fibre comprising a long Fibre Bragg Grating, extending continuously over a length of the optical fibre to provide a continuous measurement region in the optical fibre. The optical fibre is coupled to the wind turbine component such that the continuous measurement region is located at a region of the wind turbine component to be sensed, and such that the grating period at each location in the continuous measurement period is dependent upon the value of the operating parameter at that location. A light detector receives light from the optical fibre, and provides an output signal to the controller indicating the intensity of the received light; based on the detected light, a value for the operating parameter is determined.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
WIND TURBINE BLADE WITH CROSS-SECTIONAL SENSORS	24.10.2013; US20130280070	Lindby Torben	Lindby Torben	A wind turbine blade extending along a longitudinal axis from a root end to a tip end and in a transverse plane perpendicular to the longitudinal axis, the transverse plane having a main axis extending through an elastic center point, wherein the wind turbine blade comprises a sensor system including a first sensor set for measuring a first bending moment in a first sensor position at a first distance from the root end, the first sensor set comprising a first primary sensor for measuring a primary component and a first secondary sensor for measuring a secondary component, wherein a first primary sensor axis in the transverse plane is oriented in a direction defined by the first primary sensor and the elastic center point, and a first secondary sensor axis in the transverse plane is oriented in a direction defined by the first secondary sensor and the elastic center point, and wherein an angle between the first primary sensor axis and the first secondary sensor axis is in the range from 50° to 130°
WIND TURBINE BLADE WITH OPTICAL SENSOR SYSTEM	03.10.2013; US20130255398	Philipsen Morten	Philipsen Morten	Wind turbine blade comprising a sensor system with an optical path comprising a first optical sensor fiber, a second optical sensor fiber and a patch optical fiber, the first optical sensor fiber including a first core with a first core diameter wherein the first optical sensor fiber extends from a first end to a second end and comprising at least one sensor, the second optical sensor fiber including a second core with a second core diameter, wherein the second optical sensor fiber extends from a first end to a second end and comprising at least one sensor, the patch optical fiber including a patch core with a patch core diameter, wherein the patch optical fiber extends from a first end to a second end and connects the first optical sensor fiber and the second optical sensor fiber, wherein the first core diameter is the same as the patch core diameter.
Optical transmission strain sensor for wind turbines	10.05.2012; US20120116598	Vestas Wind Systems A/S	Olesen Ib Svend	Broad band optical strain sensing systems for a wind turbine. The strain sensing system includes an optical fiber with an input at one end and an output at the opposite end. The optical fiber is provided with Bragg sensors between the input and the output. By injecting light at the input of the fiber, measuring the spectral intensity distribution of at the output of the fiber and determining spectral locations of intensity notches in the spectral intensity distribution, it is possible to determine strain values at the locations of the Bragg sensors from the transmitted light.

Exhibit 1 lists some of the patents related to optical sensing.

Picture Credit: Frost & Sullivan

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