TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

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1. ADVANCEMENTS IN 3D IMAGE SENSING

Lidar (light detection and ranging) measures parameters such as distance from an object or size of the object by analyzing changes in the wavelengths of laser light reflected from a target. Lidar can provide three-dimensional (3D) imaging. However, 3D imaging laser technology can be expensive and rather bulky. Such technology had also had limitations in accuracy, cost, and convenience for 3D scanning.

Researchers at California Institute of Technology (Caltech), under the direction of Dr. Ali Hajimiri, have developed an integrated silicon nanophotonic coherent imager (NCI), with a 4 × 4 array of coherent pixels, which has opportunities to enable low-cost 3D scanning, and is less cumbersome than conventional 3D scanning. The tiny NCI chip uses Lidar technology to capture height, width, and depth information from each pixel. On-chip optical processing can determine the intensity and depth of each point on the imaged object based on the phase and amplitude of the optical wave incident on each pixel. The NCI operates using a modified time-domain frequency modulated continuous wave (FMCW) ranging scheme, which can allow it to surmount the traditional resolution limitations of frequency domain detection. The researchers demonstrated 3D imaging with a 15 micrometer depth resolution and 50 micrometer lateral resolution (limited by pixel spacing) at up to 0.5 meter range.

The NCI has been claimed to provide the greatest depth measurement accuracy of any such nanophotonic 3D imaging device. Each pixel in the image generated by the NCI can provide distance and intensity information. Each pixel on the NCI serves an independent interferometer, using the interference of light waves to detect the signal's phase, frequency, as well as intensity. This information is used to determine distance to the target point. The array of

Lidars on the NCI allows for simultaneously imaging different parts of an object or scene without requiring any mechanical movement within the imager. Data from all of the pixels combined can generate a full 3D scan.

In the NCI, an object is illuminated by coherent light (the light waves have the same frequency, and their peaks and troughs are aligned with each other). The reflected light is detected by on-chip grating couplers that function as pixels. The use of coherent light allows very accurate 3D depth measurement and also allows the device to fit in a very confined space.

The researchers were able to create Lidar elements down to only a couple of hundred microns in size, sufficiently small to form an array of 16 coherent detectors on an active area of 300 microns × 300 microns. The first proof of concept of NCI has only 16 coherent pixels, which can require moving larger objects to create a 3D image.

However, the researchers noted that the array of 16 pixels could be readily scaled up to hundreds of thousands of pixels. Imagers with large arrays of tiny Lidars could have opportunities in applications such as driverless vehicles, smart phones, ultra-sensitive human-machine interfaces.

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2. HIGH-RESOLUTION MEMS BAROMETRIC PRESSURE SENSOR

A barometric pressure sensor is an absolute pressure sensor that measures local ambient pressure, or fluctuations in atmospheric pressure. Absolute pressure entails pressure that is measured relative to a vacuum. As pressure changes with altitude, barometric pressure sensors can be used as altimeters.

Microelectromechanical systems (MEMS) technology can provide key benefits for barometric pressure sensing, such as, smaller size, reduced power consumption, and ease of integration with electronic signal conditioning circuitry.

Capacitive MEMS barometric sensor technology can provide such advantages as relatively low cost and power consumption, good stability and resolution, immunity to temperature effects (piezoresistive sensors are inherently sensitive to temperature changes), and so on. To minimize effects of stray capacitance, the electronics should be located close to the sensing element. Capacitive sensors are well-suited for absolute sensing applications.

MEMS barometric pressure sensors have traditionally been used in high volumes in automotive engine management to compute the air-fuel ratio for optimized energy efficiency.

Another application with high-volume opportunities is in indoor navigation. More precision and unerring navigation in buildings can benefit location-based services for mobile phones; for example, a cell phone that provided navigation to a sale at a particular store or to a certain restaurant. Precise indoor navigation, in environments where a GPS signal is compromised, could also benefit (for example, first responders) or enable passengers in large, unfamiliar airports to find the correct check-in counter and departure gate.

The navigational capabilities of GPS units inside buildings can be impaired by inaccurate floor accuracy. Precise navigation within buildings requires vertical or floor navigation accuracy. The barometric pressure sensor can provide such floor-accurate navigation. By measuring air pressure, the precise altitude of a measurement point can be determined. Such sensors are able to recognize the different altitudes that one experiences as he/she moves up a flight of stairs.

Indicative of the opportunities for MEMS barometric pressure sensors, Infineon Technologies AG (based in Germany) has released an ultra-high (±5cm) resolution, miniature, low-power MEMS digital barometric pressure sensor for mobile and wearable devices and Internet of Things devices. The sensor can enable development of enhanced navigation, location, well-being, gesture recognition and weather monitoring applications.

This DPS310 pressure sensor is well-suited for indoor navigation and assisted location applications, such as, floor detection in shopping malls and parking garages, as well as outdoor navigation where the sensor can improve navigation accuracy or support dead reckoning in the event the GPS signal is not available or is impaired. Moreover, the ability to provide accurate data for calculating elevation gain and vertical speed can benefit activity tracking in mobile and wearable health and sports devices, and very precise pressure measurement can also drive opportunities in gesture recognition and detection of rapid weather changes.

The Infineon pressure sensor, which is based on the capacitive sensing principle, can provide high precision across a broad range of temperatures even when the temperature changes rapidly, as can be the case in mobile devices. In high-precision mode, the sensor is able to measure heights within ±5cm enabling precise detection of transient states, a key challenge in indoor navigation. Such high-accuracy height measurement can also benefit sports and fitness applications that need to discriminate between the different types of steps a wearer might be taking and the corresponding calorie consumption rate.

The new pressure sensor leverages Infineon's semiconductor process technologies that were originally developed for the company's automotive sensors. The sensors are highly reliable and can be integrated in safety applications such as airbags. The new device is compact: 2.0mm x 2.5mm x 1.0mm. In low-power mode, its power consumption is 3 microamperes at one measurement per second; decreasing to less than 1 microampere in standby mode.

The pressure sensor has a pressure range of 300hPa to 1200hPa, and a temperature range from -40 degrees C to 85 degrees C. Engineering samples of the pressure sensor have been slated for availability in May 2015, with volume production slated for Q3 2015.

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3. SELF-POWERED WIRELESS SENSOR SYSTEM

Smart homes or buildings employ many different sensors to monitor the indoor environment of the home. The sensors available in the market to collect information about different aspects of the indoor environment such as lighting, heating, ventilation, cooling, security, and so on, can use batteries or a power cable for power or activation. Battery-enabled sensors need regular maintenance and are not cost efficient, whereas, power cables have certain restrictions in terms of length, which further limits the placement of the sensors in the appropriate area. There is a need for a sensor system that is self-powered and monitor different parameters. In addition, the device should be cost efficient and easy to use.

To address the above-mentioned needs, researchers from Case Western Reserve University (based in Ohio in the US) are developing an energy harvesting wireless sensor system with the help of a piezoelectric resonant device that can harvest power from the vibrations that occur normally in buildings.

The wireless sensor and piezoelectric resonant device are integrated into existing materials such as a printed circuit board. The piezoelectric resonant device is employed to harvest energy from small vibrations and motions. According to the researchers, the wireless sensor would be of the size of a nickel, which would be easier to mount on the energy source. The sensor is mounted on the energy source with the help of peel and stick tape. The wireless sensor system will be able to collect information about the ventilation, heating, cooling, lighting, humidity, temperature, and many more aspects. The wireless sensor system will convert the vibration into electrical energy, monitor the above-mentioned parameters and communicate the information to the central hub. If a user forgets to turn off appliances such as lighting or television, he/she will be able to monitor the energy usage and control the appliances with the help of his smartphone even when away from home.

Once the project is successfully commercialized, it will have opportunities to be used in existing as well as newly built buildings. At present, the researchers are powering the sensors with the help of vibrations from ventilation fans, swinging doors, television speakers, and other sources. The researchers are planning to use in the future vibrations from electric motors, food processors, floor polishing machines, air conditioners, vent outlets, refrigerators and many more household appliances that vibrate. These wireless sensors will further facilitate the Internet of Things, which includes collecting and sending information to connect devices without human intervention. They can help enable next generation smart buildings that include self-powered sensors. This model will certainly reduce the cost of energy usage.

The project is funded by the US Department of Energy, which has granted $750,000 to develop a technology-enabled smart building. The project is being supported by Intwine Connect LLC, a Chagrin Falls, OH-based company. The researchers are currently working on identifying different sources of vibration in buildings. Once the wireless sensors are successfully commercialized, they have opportunities to get a good response from the construction industry, especially for application in buildings under construction.

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4. RECENT PATENTS IN THE FIELD OF NANOSENSORS

Nanosensors are tiny devices able to detect and respond to stimuli with dimensions on the order of one billionth of a meter. Nanosensors use materials that are capable of detecting biological or chemical substances, as well as physical stimuli such as pressure, force, motion, and so at the nano-scale. Bottom-up assembly and top-down lithography are some of the methods for fabricating nanosensors.

Nanoparticles, carbon nanotubes (CNTs), NEMS (nano-electromechanical systems), spintronics, biological systems, nanowires, nanocoatings and molecular electronics are some of the materials or techniques that are used to enable nanosensors.

Monitoring the environment and detection of chemical, biological, radiological, nuclear, and explosive (CBRNE) threat agents are some of the key applications that will be enabled by nanosensors. Universities and research institutes are mostly publishing the patents in this field and will help drive the commercialization of nanosensors. The APAC region has a strong emphasis on nanotechnology and nanosensors. The North American region has a strong emphasis on chemical and biological detection.

Nanosensors comprising nanoparticles hold great potential for diagnostics in advanced healthcare. Nanosensors can be used to diagnose issues at the molecular level in a more efficient way. Nanosensors also have potential in the automotive and transportation domain in, for example, sensing the condition of the engine oil and fuel economy; and detecting stress and strain due to air springs and suspension systems. Self-powered tire pressure sensors are another potential application of nanosensors.

Nanosensors have good convergence potential for developing innovative devices with advanced capabilities such as energy harvesting systems, and wireless sensor networks.

A recent patent regarding a nanosensor, US20150030544), assigned to Northeastern University, pertains to a nanosensor that emits a fluorescent signal upon detection of an analyte and a catalytic agent that catalyzes a reaction where the target substance is converted into a product.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Enzymatic Nanosensor Compositions and Methods	29.01.2015; US20150030544	Northeastern University	Clark Heather A.	Disclosed herein are compositions including a nanosensor that is sensitive to an analyte such that the nanosensor emits a fluorescent signal upon detecting the analyte, and a catalytic agent that catalyzes a reaction in which a target substrate is converted into one or more products, such that at least one of the one or more products is the analyte. In addition, methods of using the nanosensor-catalytic agent compositions to detect a target substrate are disclosed.
METHOD OF MAKING SILICON SENSITIVE ELEMENT FOR LUMINESCENT OXYGEN NANOSENSOR	10.01.2015; RU0002539120		Victor Y. Timoshenko (RU)	FIELD: chemistry. SUBSTANCE: method of making a silicon sensitive element for a luminescent oxygen sensor includes growing, on a substrate of monocrystalline silicon of p-type conductivity with surface crystallographic orientation (100) with resistivity of 1 to 10 mOm·cm, a layer of porous silicon nanofilaments by successively holding in the following solutions: first in an aqueous silver nitrate solution with concentration of 0.02-0.04 mol/l and hydrofluoric acid with concentration of 5 mol/l in ratio of 1:1 for 30-60 s to deposit silver nanoparticles on the surface of a silicon plate, then in a mixture of hydrofluoric acid with concentration of 5 mol/l and 30% hydrogen peroxide in ratio of 10:1 for 20-60 min to form silicon nanofilaments as a result of chemical etching of the silicon plate in places coated with silver nanoparticles, and finally in 65% nitric acid solution for 10-20 min to remove silver nanoparticles and stabilise the surface of the silicon nanofilaments, thereby obtaining porous silicon nanofilaments with length of 2-5 mcm, cross-sectional dimension of 30-300 nm, having luminescence in the range of 650-850 nm, the intensity of which depends on the presence of oxygen molecules. EFFECT: improved properties. 4 dwg
TRIBOELECTRICITY NANOSENSOR	02.10.2014; WO/2014/154017	BEIJING INSTITUTE OF NANOENERGY AND NANOSYSTEMS	LIN, Zonghong	A friction nanosensor based on an electron transfer mechanism, the sensor comprising: a first conductive element (11), a first friction layer (12) disposed in contact with the lower surface of the first conductive element (11), a second conductive element (21), a nanostructure, that is, a second friction layer (22), being chemically bonded to or directly growing on the upper surface of the second conductive element (21), and a space maintaining piece (30); the space maintaining piece (30) allows the lower surface of the first friction layer (12) and the upper surface of the second friction layer (22) to face each other and maintain a certain space therebetween; the first friction layer (12) and the second friction layer (22) at least partially contact each other under an external force, resume the original space therebetween under the action of the space maintaining piece (30) when the external force is removed, and at the same time output an electrical signal via the first conductive element (11) and the second conductive element (21); and the electric signal changes after the second friction layer (22) combines with a target substance to be probed. The sensor is self-driven, portable, and highly sensitive.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
SURFACE PLASMON-BASED NANOSENSORS AND SYSTEMS AND METHODS FOR SENSING PHOTONS AND CHEMICAL OR BIOLOGICAL AGENTS	25.09.2014; US20140285809	KING SAUD UNIVERSITY.	GHANNAM Thalal	Surface plasmon-based nanosensor, comprising: at least one first element of metal, preferably silver or gold, or of semiconductor, the first element being excitable to surface Plasmon resonance, in particular localized surface plasmon resonance, in the presence of electromagnetic radiation from a source, and at least one second element preferably near the first element that in the presence of the electromagnetic radiation is exciton-plasmon coupled to the first element and emits electromagnetic radiation representative of the exciton-plasmon coupling, and systems and methods for sensing photons and chemical or biological agents.
Surface plasmon-based nanosensors and systems and methods for sensing photons and chemical or biological agents	24.09.2014; EP2781909			Surface plasmon-based nanosensor (10), comprising: at least one first element of metal (14), preferably silver or gold, or of semiconductor, the first element (14), preferably a nanoparticle (14), being excitable to surface Plasmon resonance, in particular localized surface plasmon resonance, in the presence of electromagnetic radiation (16) from a source, and at least one second element (18), preferably a quantum dot (18), preferably near the first element (14) at a distance (R) that in the presence of the electromagnetic radiation (16) is exciton-plasmon coupled to the first element (14) and emits electromagnetic radiation (20) representative of the exciton-plasmon coupling, and systems and methods for sensing photons and chemical or biological agents.
Microbe Detection Via Hybridizing Magnetic Relaxation Nanosensors	07.08.2014; US20140220565	Naser Saleh	Naser Saleh	Disclosed herein are methods and materials for facilitating the detection of nucleic acid analytes of interest. Specifically exemplified herein are methods for detecting mycobacterial microorganisms, namely *Mycobacterium avium* spp. *paratuberculosis*. Also disclosed is new hybridizing magnetic relaxation nanosensor (hMRS) particularly adapted to detect a target nucleic acid analyte of interest.
Field effect based nanosensor for biopolymer manipulation and detection	05.06.2014; US20140151227	International Business Machines Corporation	Royyuru Ajay K.	A mechanism is provided for manipulating a molecule. The molecule is driven into a nanochannel filed with electrically conductive fluid. A first vertical electric field is created inside the nanochannel to slow down the molecule and/or immobilize the molecule. The molecule is stretched into non-folded linear chains by the first vertical electric field and a horizontal electric field. Monomers of the molecule are sequentially read.

Exhibit 1 lists some of the recent patents related to nanosensors.

Picture Credit: Frost & Sullivan

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