TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

09th October 2015

1. ULTRA-SENSITIVE GRAPHENE-BASED MAGNETIC SENSOR

Graphene, a two-dimensional material comprised of carbon atoms, possesses certain notable properties, such as superior strength, very high conductivity, high density, transparency, and light weight. Moreover, graphene has the potential to substantially benefit sensors, owing to such attributes as a large surface-to-volume ratio, high carrier mobility, excellent electrical conductivity, small bandgap, and particular optical properties. Graphene has the potential to enable smaller, lighter, more sensitive sensors.

The Hall Effect sensor is a very well-established magnetic field sensing technology. The Hall element (typically silicon) is built from a thin sheet of conductive material with output connections perpendicular to the direction of current flow. In the presence of a magnetic field, such sensors provide an output voltage proportional to the strength of the magnetic field. Silicon Hall effect sensors are widely used in diverse industrial, commercial and automotive applications. Automotive applications for such sensors include wheel speed sensing, transmission speed sensing, camshaft position or speed sensing, current sensing, throttle angle sensing, power seats, power windows, power mirrors, and power sunroof control.

Indicative of opportunities for graphene-based sensors, researchers at Robert Bosch GmbH and at the Max Planck Institute for Solid State Research in Germany have created a graphene-based magnetic sensor capable of being 100 times more sensitive than an equivalent silicon-based sensor.

Since a top-down approach to graphene fabrication, such as mechanical and chemical exfoliation, would not be effective for commercial-scale device fabrication, the researchers focused on bottom-up methods, such as thermal decomposition of silicon carbide and chemical vapor deposition (CVD) onto metal surfaces. The researchers selected hexagonal boron nitride as the substrate for the magnetic sensor due to cost and performance factors. However, due to the lack of large-scale wafer-based and transfer-free synthesis methods, it will be about five years before graphene-based sensors can compete with entrenched techniques.

Bosch uses Hall Effect magnetic sensors in which two key performance capabilities are sensitivity (which depends on the number of charge carriers) and power consumption (which changes inversely with charge carrier mobility). In such applications, graphene's high carrier mobility is useful.

The researchers found that graphene can provide a magnetic sensor that offers high performance along with low power and a low footprint. In the worst case scenario, graphene approximately matched the silicon reference. In the best case scenario, graphene provided a considerable improvement over silicon, offering lower source current and power requirements for a specified Hall sensitivity.

A direct comparison of the sensitivity of a silicon-based Hall sensor and that of the Bosch graphene sensing device revealed significant results. The silicon sensor had a sensitivity of 70 volts per amp-tesla, whereas the boron nitride and graphene device showed a sensitivity of 7,000 volts per amp-tesla, which represented a two orders of magnitude improvement.

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2. STREAMLINED CREATION OF EPIDERMAL ELECTRONICS

Epidermal electronic systems, which enable electronic sensing devices in the form of a second skin, have key opportunities to replace more bulky, cumbersome devices for vital signs monitoring. Epidermal electronic systems feature very thin, flexible circuits that can be applied like temporary tattoos and have physical properties (including thickness) that are well matched to the epidermis. Such devices, which can be viewed as digital patches with the softness and elasticity of human skin, leverage advancements in flexible electronics to be able to be printed directly onto the skin. They can be worn for an extended period of time while an individual engages in routine activities.

Such ultra-thin wearable electronic devices that stick to the skin have the ability to detect, track, and transmit vital signals from the human body such as heart rate, muscular movement, hydration level, temperature, or brain activity. However, for such devices to gain widespread proliferation, the process for producing them needs to be less tedious, time consuming, and costly.

Addressing such key needs, in a work funded by National Science Foundation grants, researchers at the Cockrell School of Engineering at The University of Texas at Austin, led by Nanshu Lu, assistant professor, have developed an approach for producing inexpensive yet highly reliable wearable patches that are able to continuously monitor the body's vital signs for health or performance tracking, and have the potential to eclipse the performance of traditional monitoring devices, such as cardiac event monitors. The team aims to use its manufacturing technique to create disposable tattoo-like health monitoring patches for mass production of epidermal electronics.

The University of Texas at Austin researchers have devised an innovative repeatable cut-and-paste technique that reduces the time for manufacture to only 20 minutes. The team considers their method to be compatible with roll-to-roll manufacturing or processing, which creates electronic devices using a roll of flexible plastic or metal foil. The ability to make disposable epidermal electronic devices inexpensively (at around $1.00) can drive wider adoption of such epidermal electronics and create opportunities in areas such as mobile medical applications.

The UT Austin researchers use a unique dry and portable process for producing epidermal electronics. In contrast to current techniques, the researchers' process does not require a clean room, wafers and other expensive resources and equipment. Rather, the process relies on freeform manufacturing, which is similar to 3D printing but involves material removal instead of added material.

In the two-step process, inexpensive, pre-fabricated, industrial-grade metal is deposited on polymer sheets. An electronic mechanical cutter forms patterns on the metal-polymer sheets. Following the removal of excessive areas, the electronics are printed onto any type of polymer adhesive, including temporary tattoo films. Since the cutter is programmable, the size of the patch and the pattern are readily customized.

In testing, the cut-and-pasted patches produced, detected body signals that were stronger than the body signals picked up by existing medical devices, including ECG/EKG (electrocardiogram) devices that check the heart's electrical activity. Moreover, the patch conforms quite well to the skin, which can minimize motion-induced errors.

Owing to the sensitivity of the epidermal electronic patches, the team envisions the wearable patches being used to maneuver a prosthetic hand or limb without the use of muscle signals. The researchers are looking at adding different types of sensors to the patch, such as blood pressure and oxygen saturation monitors.

Lu is a co-founder and scientific advisor for Stretch Med, Inc., a medical device company involved in the development of human electrophysiological sensors for clinical applications that draws on some of the aforementioned patent-pending technologies.

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3. ELECTRONIC NOSE TO DETECT OVARIAN CANCER

An electronic nose consists of a matrix of chemical sensors that are trained, using pattern recognition algorithms, to detect and identify the key components of an odor. Electronic noses have aimed to mimic human olfaction. Efforts have been ongoing to devise smaller, less bulky, less expensive, and more sensitive electronic noses.

Electronic noses have opportunities for use in diagnosing key medical conditions by analyzing a person's exhaled breath to identify a pattern of biomarkers related to the target medical condition.

Electronic noses have potential for cost-effective, non-invasive detection of some cancers, especially where the gas samples can be sufficiently large. Volatile organic compounds (VOCs) in the breath can be analyzed by chemical techniques, but there have been challenges, since such VOCs can appear in the breath in low concentrations.

Historically, studies have indicated that in some types of cancer, electronic noses have outperformed dogs, whereas in other types of cancer, such as ovarian cancer, dogs have outperformed electronic noses in terms of sensitivity and specificity.

Furthermore, a large number of sensors are required to meaningfully diagnose cancer by analyzing breath and defining specific profiles of compounds in breath samples. This requirement can make such systems impractical for clinical use.

Researchers at the Russell Berrie Nanotechnology Institute, Technion--Israel Institute of Technology have made progress in addressing this issue. The team has developed a small array of flexible sensors that can accurately detect compounds in breath samples specific to ovarian cancer.

The researchers developed a small, breath-diagnosis array based on flexible gold-nanoparticle sensors for use in an electronic nose. As noted in "Dynamic Nanoparticle-Based Flexible Sensors: Diagnosis of Ovarian Carcinoma from Exhaled Breath," published in Nano Letters (September 9, 2015), the flexible sensors, based on molecularly modified gold nanoparticles (GNPs) were integrated into a diagnostic sensing array. Each bending state of the GNP-based flexible sensor provides a unique nanoparticle spatial organization, which changes the interaction between GNP ligands and volatile organic compounds, thereby increasing the amount of data that can be obtained from each sensor. The individual dynamic flexible sensor is able to selectively detect parts per billion (ppb) level VOCs that are linked with ovarian cancers in exhaled breath and discriminate such VOCs from extraneous environmental VOCs that exist in exhaled breath samples.

When tested on breath samples from 43 volunteers, of which 17 had ovarian cancer, the system demonstrated an accuracy rate of 82%, irrespective of confounding factors, such as tobacco consumption and comorbidities.

Further development of this technique will require clinical testing on a larger scale. The method could hold out the prospect of realizing a very streamlined, cost-efficient, non-invasive, portable system for diagnosis of cancer or other diseases.

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4. ADVANCEMENTS IN TRACKING SPORTS PERFORMANCE

There has been increasing interest in being able to accurately and unobtrusively track the performance of athletes as well as fitness buffs. Laboratory methods of tracking athletic performance are not able to provide a valid indication of an individual's physical activity in the actual training or competitive environment.

Global positioning systems (GPS) are capable of monitoring the environment in which physical activity occurs. GPS systems can triangulate their location, including elevation, by receiving radio signals broadcast from satellites orbiting the earth.. However, a major limitation of GPS units is that they are capable only of tracking location and measuring outdoor physical activity, due to their need for a clear line of sight to the satellites. The signal is interrupted when the wearer moves indoors, travels in a tunnel, or even when the line of sight is obstructed by tall buildings or heavy foliage. Other issues with GPS-based monitors can include difficulty with initial localization (typically more than 1 minute from a cold-start), limited accuracy in sensing stationary device location (error greater than 1 meter), and limited accuracy in GPS-measured distance (around 5%).

MEMS-based inertial sensors (accelerometers as well as gyros) have been gaining increased adoption and proliferation for human activity monitoring and sports performance monitoring and analysis. The development of such smaller, low power, durable sensors that can be readily packaged with microelectronics and are conducive to sending sensor data wirelessly from compact portable systems is enabling more accurate and convenient measurement of physical activity and athletic performance.

The use of inertial sensors for human activity monitoring and sports performance analysis has enjoyed considerable attention in recent years. The increasing availability of micro or microelectromechanical systems (MEMS) sensors coupled with increasingly powerful wearable computing power has allowed such solutions to be applied to a number of sports in both training and competition environments. MEMS sensors can offer higher sensitivity along with lower power consumption for activity monitoring or sports performance monitoring compared to conventional macro sensors.

Furthermore, magnetometers, which can measure the strength and direction of a magnetic field, can help provide compassing and correct tracking of orientation in physical activity monitoring.

Indicative of the keen interest and advancements in human activity monitoring, Australia-based Griffith University's SABEL Labs has developed SABEL Sense, a wearable inertial sensor that collects data from digital MEMS sensors (a 3-axis accelerometer 3-axis gyro, and 3-axis magnetometer). The user has freedom to move outside the laboratory environment, indoors or outdoors. Data is stored on the sensor and controlled wirelessly from one's PC.

In contrast to GPS, SABEL Sense is able to accurately record and track performance data for elite athletes (for example, running speed and distance). A model that enables accelerometers to be a viable alternative to GPS in athletic assessment was developed by Jonathon Neville, project manager of SABEL Labs and a research fellow. Neville compared inertial sensor data with GPS data, which was collected from Brisbane Lions AFL players during 2009, to create a model that is highly accurate for running speeds.

GPS has limitations when there are frequent and quick changes in speed and distance. SABEL Labs researchers discovered a data processing technique that facilitates extracting data from an athlete and creating an individualized model. The technology, which can automatically create individualized models for tracking speed and distance, can prevent over-training, which can lead to injuries.

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5. RECENT PATENTS IN THE FIELD OF BIOSENSORS

Biosensors use a biological element (such as tissue, antibodies, enzymes, and so on) and a detector to detect an analyte. The signal resulting from the interaction of the analyte and the biological component is transduced into one that can be measured.

There are a number of biosensor technologies available for detection, including electrochemical (potentiometrc or amperometric), optical, piezoelectric, pyroelectric, thermistor, and magnetic type sensors. Well-established technologies include electrochemical and optical, while thermistor and magnetic type biosensors are not that common. Advances in microfabrication, signal processing, and nanotechnology are being applied to enhance biosensors. There is also a focus is on developing low-cost rapid detection biosensor devices to be able to detect specific viruses without requiring a skilled operator. Key performance attributes for biosensors are their sensitivity and selectivity.

University laboratories, academic and research institutions as well as biotechnology and pharmaceutical companies are working toward the development of new biosensors. Research for innovation in biosensors is encouraging the establishment of startups for bio sensing devices.

Patent filing trends under biosensors can also be analyzed with respect to the focus area or the applications such as point-of-care diagnostics and health monitoring devices. Point-of-care diagnostics is the major application focus area for biosensor patent filings. Security and biodefense are emerging fields, witnessing growth. In addition, biosensors are penetrating home diagnostics, as well as the environmental, and process industry market segments. The research laboratories segment is expected to maintain stable growth. In agriculture and plant biology, current uses are limited, but mobile platform applications are expected to increase in the coming years. Moreover, sensors that detect biological activity such as stress, heart rate, skin conductance, are expected to be integrated into advanced driver assistance systems (ADAS) in emerging automotive applications.

Biosensors are moving toward preventive health and penetrating into new markets, such as mobile platforms and automotive.

North America is the largest market and will continue to dominate because of large R&D investments. The Asia-Pacific region has been exhibiting the most growth.

A recent patent in biosensors (WO/2015/147594), assigned to SK Innovation Co., Ltd., is about an electrochemical biosensor that uses two electrodes to retain excellent stability and sensitivity. The patent pertains to an electrochemical biosensor with a working electrode with a modified active surface and an auxiliary electrode.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Electrochemical biosensor using dual electrode pair	01.10.2015; WO/2015/147594	SK Innovation Co. Ltd.	Shin, Heung Joo	The present invention relates to an electrochemical sensor and, more specifically, to an electrochemical biosensor using a sensing system comprising a working electrode including an active surface modified through a linker; and an auxiliary electrode. The sensor of the present invention has a high current value compared with an existing sensor and retains excellent stability and sensitivity, and thus can be expected to be easily used for sensing various kinds of biomaterials.
Microdevices and biosensor cartridges for biological or chemical analysis and systems and methods for the same	10.06.2015; EP2880423	Illumina Inc.	Helmy A. Eltoukhy	A flow cell including inlet and outlet ports in fluid communication with each other through a flow channel that extends therebetween. The flow channel includes a diffuser region and a field region that is located downstream from the diffuser region. The field region of the flow channel directs fluid along reaction sites where desired reactions occur. The fluid flows through the diffuser region in a first flow direction and through the field region in a second flow direction. The first and second flow directions being substantially perpendicular.
Implantable biosensor and methods of use thereof	24.09.2015; US20150265182	Optoelectronics Systems Consulting, Inc.	Faquir Jain	Disclosed herein is an analyte sensing device capable of continuously monitoring metabolic levels of a plurality of analytes. The device comprises an external unit, which, for example, could be worn around the wrist like a wristwatch or could be incorporated into a cell phone or PDA device, and an implantable sensor platform that is suitable, for example, for implantation under the skin. The external device and the internal device are in wireless communication. In one embodiment, the external device and the internal device are operationally linked by a feedback system. In one embodiment, the internal device is encapsulated in a biocompatible coating capable of controlling the local tissue environment in order to prevent/minimize inflammation and fibrosis, promote neo-angiogenesis and wound healing and this facilitate device functionality.
Biosensor chip having precise count function and method of sensing amount of cells	24.09.2015; EP2899128	Kun Shan University	Hung-Wei Wu	Disclosure is a biosensor chip having precise count function comprising: a substrate, a plurality of ground wire waveguide layers, a signal waveguide layer and a protective layer. Wherein, the plurality of ground wire waveguide layers are located on two sides of the substrate, the signal waveguide layer is located on the substrate and between the plurality of ground wire waveguide layers, wherein the signal waveguide layer has a recess which forms a cell sensing region; and the protective layer covers a portion of the ground wire waveguide layers and a portion of the signal waveguide layer to expose the recess.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Systems and methods of sensing and analyzing antibody blocking interactions	24.09.2015; US20150269312	Wasatch Microfluidics Inc.	Adam Miles	A system and method for sensing and analyzing antibody blocking interactions is described. A biosensor can be used to identify interactions between antibodies to generate interaction profiles for the antibodies. A processor can be used to assign the antibodies to one or more bins, with the antibodies sharing a common interaction profile assigned to a common bin, and each antibody only being assigned to one bin. The antibodies can be represented by displaying nodes grouped together for antibodies in a common bin. Connections between the nodes can be displayed, representing interactions between the antibodies.
Device and method for detecting biomarkers	24.09.2015; WO/2015/140362	Universidad de Cantabria	Moreno Gracia, Fernando	The invention relates to a biosensor for detecting the concentration or quantity of at least one biomarker present in a sample of fluid, said biosensor comprising: a chip (410, 510) having a substrate (411, 518) on which a metal layer has been deposited, said metal layer having at least one nanostructure (414, 514) designed to produce LSPR when subjected to optical radiation of a determined spectral range; and a resonant cavity delimited by two surfaces that act as a mirror, wherein one of the two surfaces is the metal layer having the nanostructuring (414, 514). The metal layer having at least one nanostructure (414, 514) is biofunctionalised using at least one biomolecule that recognises the at least one biomarker. In exposing the chip (410, 510) to optical radiation when the sample is in contact with the chip, the concentration or quantity of the biomarker present in the sample in measured, by comparing the spectral response of the light at the output of the chip (410, 510) with a previously determined spectral pattern. The spectral response responds to the combined effect of LSPR in the plasmonic nanostructure (414, 514) and the resonance of the resonant cavity.
Biosensor compositions and methods of their use	17.09.2015; US20150259722	Cirle	Richard Awdeh	Embodiments of the present disclosure provide for biosensors that include a material such as polydiacetylene (PDA) material, where the material is used for detection of a microbe or microbial product present in a fluid present in the container. Embodiments of the present disclosure provide for containers, or structures used in conjunction with the containers, that include a polydiacetylene (PDA) material, where the PDA material is used for detection of a microbe or microbial product present in a fluid present in the container. In an embodiment, a change of PDA color (e.g., blue to red) indicates detection of the microbe or microbial product in the fluid within the container. In an embodiment, the PDA material can be selected and/or the container or structure designed so that only certain types of microbes can be detected or so that a plurality of types of microbes is detected.

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

Picture Credit : Frost & Sullivan

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