# TECHNICAL INSIGHTS

## SENSOR

## TECHNOLOGY ALERT

**04th December 2015**

## 1. SUPER-SENSITIVE BORON GRAPHENE SENSORS

Graphene, a two-dimensional atomic-scale honeycomb lattice composed of carbon atoms, has potential for creating enhanced gas sensors, owing to the material's atom-thick 2D structure, high electrical conductivity, and large surface area. Graphene-based gas sensors could also provide very high-speed detection. Moreover, the addition of boron can improve the performance of graphene-based sensors, including their adsorption energy, selectivity, and sensitivity.

An international team of researchers has spearheaded the fabrication of graphene sensors doped with boron atoms that can detect harmful gas molecules at ultra-low concentrations, down to parts per billion levels in detection of nitrogen oxides and in the parts per billion range for ammonia. This capability translates to a 27-fold greater sensitivity to nitrogen oxides and 10,000-fold greater sensitivity to ammonia, compared to pristine graphene.

The work has been funded by the National Natural Science Foundation of China, the US Air Force Office of Scientific Research, Honda Research Institute USA Inc., Europe's Graphene Flagship, Pennsylvania State University's Center for Nanoscale Science, National Science Foundation Materials Research and Engineering Center (MRSEC), and Penn State's Materials Research Institute.

The researchers envision that the results will pave the way for high-performance sensors that can detect trace amounts of various other molecules.

Researchers were previously able to dope graphene with nitrogen atoms; however, doping with boron atoms was more difficult. Boron and nitrogen are next to carbon on the periodic table, rendering their substitution achievable. However, boron compounds are highly air sensitive and quickly decompose when exposed to the atmosphere. One-centimeter-square sheets were

 

synthesized at Penn State in a unique bubbler-assisted chemical vapor deposition system, yielding large-area, high-quality boron-doped graphene sheets.

The researchers sent the fabricated boron graphene samples to researchers at the Honda Research Institute USA Inc. (Columbus, Ohio), who tested the samples against their very sensitive gas sensors. The lab of Konstantin Novoselov, professor in the School of Physics and Astronomy at the UK-based University of Manchester studied the transport mechanism of the sensors. Collaborators in the US and Belgium matched the scanning tunneling microscopy images to experimental images, confirming the presence of the boron atoms in the graphene lattice and their effect upon interacting with the ammonia or nitrogen oxide molecules. Additional collaborators in Japan and China also contributed to the research.

The approach combines innovative nanomaterials with continuous ultraviolet light radiation in the sensor design, which have been developed at Honda Research Institute USA Inc. by Gugang Chen, lead researcher. Further development of the technology is envisioned to possibly break the parts per quadrillion level detection limit, which is up to six orders of magnitude improved sensitivity compared to current state-of-the-art sensors.

Potential applications for the sensors include laboratories or industries that use ammonia, a highly corrosive health hazard, or detection of nitrogen oxides. In addition to having opportunities to detect toxic or flammable gases, based on theoretical work, boron-doped graphene technology could contribute to enhanced lithium-ion batteries and field-effect transistors.

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## 2. NITRATE SENSOR BOOSTS AQUACULTURE

Aquaculture, or fish or shellfish farming, pertains to the breeding, rearing, and harvesting of plants or animals in various types of water environments, including ponds, rivers, lakes, and oceans. Aquaculture-based farming has been mainly conducted for fish and seaweed.

Demand for fish, a vital source of proteins, minerals, and healthy fatty acids, has been increasing. Wild catching of fish is experiencing limitations due to increasing concern for overfishing of natural fish stocks .Aquaculture has key opportunities for increased production of fish to address the depletion of the ocean's resources due to the demand for seafood.

Recirculating aquaculture systems (RAS) filter water from the fish (or shellfish) tanks, so it can be reused within the tank. This technique significantly reduces the amount of water and space required to intensively produce seafood products. The steps in theRAS process can include removal of solids, ammonia, carbon dioxide, and oxygenation.

Aquaculture-based farming has tended to be manually operated. Moreover, although nutrients, such as nitrates or nitrites can be now measured *in situ*, standard wet chemistry nutrient analysis has been relatively expensive.

Under the three-year EU-funded AQUALITY project, which officially concluded at the end of November 2014, researchers developed a sensor that has been calibrated to measure the nitrogen compound nitrite. Recirculating aquaculture systems have biofilters, which convert nitrogen-based waste products to nitrites and nitrates. The presence of high levels of nitrite and ammonia can indicate that the biofilter is not functioning optimally, potentially leading to toxic nitrogen compounds in the water.

The innovation, developed by partners in the Netherlands and tested in Denmark, is a key component of AQUALITY's open standardized technology platform, which is capable of measuring eight parameters simultaneously. This capability enables aquaculture staff to obtain continuous online measurements of total nitrogen compounds, pH, salinity, oxygen level, carbon dioxide level, total gas saturation and temperature, in addition to nitrite. The concentration levels are fed in real time directly to a monitoring screen. By coupling the measuring tools with an automatic, intelligent control system that contains built-in knowledge of specific farmed species, the team has facilitated automated, convenient, accurate and efficient fish farming.

 

Monitoring devices available to fish farmers have tended to be designed for general water management and, therefore, may lack sufficient accuracy for assuring the health of fish.

By improving the management and surveillance of the RAS' biofilter via a standardized, open platform technology, the AQUALITY project contributes to the development of more profitable Recirculated Aquaculture Systems, which use minimal water and enable farms to be situated anywhere, including urban environments.

The RAS method of fish production depends on recirculated water, which should be accurately monitored. By assuring water quality, the fish are kept comfortable and are more apt to achieve optimal growth.

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## 3. 3D MICROWAVE IMAGING

The demand for in-depth information about images or the environment is gaining traction in many different industry verticals, such as building and construction, healthcare, food, defense, consumer electronics, robotics and many more. Availability of in-depth information is increasing the opportunities to enable better identification and handling of materials in an industrial or warehouse environment. Such in-depth measurement is so accurate that it can separate the foreground from the background. Such accurate information about the images or the environment will enable safe and fast operation. Obtaining highly accurate reconstructed images with in-depth features remains a challenge in microwave imaging because of reflections from interfaces or barriers and the masking of in-depth features by reflections from the antennas. In addition, the use of multiple antennas increases the complexity of microwave imaging systems.

To address the above-mentioned challenges associated with in-depth sensing and better detection solutions, an Israel-based company, Vayyar Imaging Ltd., has developed a compact, low power, and efficient 3D microwave imaging sensor. The sensor has multi-antenna radar-based detection capabilities**.** Vayyar Imaging's innovative technology is designed to enable sophisticated imaging for

 

different objects. Moreover, the microwave imaging sensor technology is resilient to background and skin clutter.

Vayyar's 3D imaging technology can be integrated in a single unit to look into objects by passing through known barriers and to create highly sophisticated images. Vayyar Imaging serves an extensive range of applications with low power (power utilization=1% transmit power of a cellular call). Keeping in mind the demand for safe and fast operation, Vayyar Imaging has focused considerably on non-ionizing radio transmissions which further helps to scan objects in a few seconds and will enable new generations of products to be created over time, with increasing levels of quality and functionality. Vayyar's 3D imaging technology is also designed to operate in dark, smoky and foggy conditions with high precision and accuracy.

Vayyar Imaging has participated in a project with Agilent Technologies to develop a high-performance low-cost network analyzer. The company's partnerships have allowed them to build the working samples using its technology at very affordable costs.

The key applications that this technology will significantly impact are breast cancer screening, detecting water leakage, food safety monitoring, detecting variations in soil formation, identifying contamination in soil, detecting flow in non-metallic pipes, detecting leaks in metallic and non-metallic pipes, and many more. The company's 3D microwave imaging technology can improve the capabilities of the targeted applications.

Vayyars' 3D imaging technology has the level of accuracy and testing required for various applications, especially those in the healthcare sector. For instance, this technology could be used for the inspection of specific materials or parts that need to be tested with significantly high accuracy. This improved accuracy would in turn boost the overall efficiency and reliability of the process for which this technology is being employed. The technology has enabled products that can also be used for various testing and inspection applications in different industries to help meet the changing needs of the global market.

The company has been actively receiving feedback and suggestions from its customers through its dedicated internal team that gathers detailed feedback about its technologies and products. The feedback from the company's customers has allowed further improvements in its products to address customer requirements.

 

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## 4. PRECISION IRRIGATION USING STEM WATER POTENTIAL SENSOR

According to the Food and Agriculture Organization of the United Nations, the water consumption growth rate has been more than twice the population's growth rate. Moreover, uneven distribution, wastage, and pollution are making this precious resource even more scarce and expensive. This is a matter of concern since the access to water for farming and other economic activities has an impact on several global issues, including poverty, food safety, and food security. One of the most important challenges in the farming sector is that farmers overwater crops by approximately 20% because of the dearth of reliable systems of measurement. Overwatering crops causes wastage of this already scarce resource and makes it even more expensive. In addition, it affects the quality of crops, which reduces profits. Precision agriculture companies, therefore, face challenges in developing an easy, simple, affordable, and accurate system for measuring the stem water potential (SWP), that is, the plant water status. Conventional sensor-based water measurement techniques for irrigation, including techniques that involve measuring the leaf and soil moisture content, may not provide a solution that can combine cost efficiency, ease of use, and accuracy. Measuring SWP is extremely important for accurately determining the water status of crops.

To address the above challenge, Israel-based Saturas-AG has developed a miniature SWP sensor that can be embedded in the trunks of trees and plants as part of the automatic irrigation system. This easy-to-use sensor helps determine water status in the crops with high accuracy. It optimizes irrigation by improving crop yield and quality and provides users with excellent returns on investment by reducing water consumption.

Saturas' SWS measurement products consist of a proprietary miniature micro-electromechanical system (MEMS) pressure sensor, a membrane osmometer, a Web-integrated communication system, and a solar-powered battery. This powerful combination has resulted in an accurate and affordable SWP measurement device. The miniature SWP sensor is 20 mm in diameter. The sensor is integrated into the tree or plant by drilling a hole into the trunk. A

 

thermometer is inserted near the base of the tree sensor to collect information about environmental conditions. The measuring principle of SWP is based on membrane osmometer liquid-to-liquid contact. The membrane osmometer is filled with osmotic fluid on the membrane side and equipped with a pressure sensor on the other side. Water potential is measured by determining the difference between the pressures in the osmotic fluid and the plant fluid. Saturas' SWP sensing system automatically collects the data using a minimal number of sensors per hectare and transmits it to a central control system connected to irrigation controllers for automated irrigation. Thus, accurate information about water content in the crops is conveyed to the farmer in an easy and cost-effective manner.

Saturas is working toward gaining widespread acceptance among key participants from different markets, many of whom are already working with the company's research team. With its varied capabilities and scalability options, Saturas' technology has the potential to supersede other SWP measuring technologies.

Its scalable MEMS pressure sensor can be used in the farming of a broad range of crops. Saturas' highly scalable technology also offers enhanced quality and functionality, enabling the development of new products.

Saturas can have a competitive advantage because of its embedded sensor technology. The technology is fitted inside the trunk enables direct contact with the water tissues and provides an accurate measure of the water content. Saturas has designed a product that can add value to the business of its customers in the irrigation industry.

Over the short term, farmers in Europe and the United States planting a broad range of crops are expected to primarily account for Saturas' market revenue opportunties.

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## 5. RECENT PATENTS IN THE FIELD OF SENSORS FOR WEARABLE ELECTRONICS

Wearables will be increasingly incorporated with more complex electronics and sensors to collect varied types of information about the wearer in an unobtrusive manner. Sensors have already found their way into many objects, such as blood pressure monitors, activity monitors, wrist bands, watches, glasses, heads-up displays, patches, brain computer interfaces, and glucose monitoring. Further sensor integration into textiles and shoes would open up a new and expanding avenue of opportunities for participants across the entire ecosystem.

The different types of wearable devices render the wearables market complex and diverse, encompassing products and applications beyond a mobile phone or television ecosystem. Wearable electronics with sensors are finding their way into diverse sectors, such as consumer electronics, industrial, healthcare, fitness and wellness, military, and others. Sensor-based wearable products are also diverse, encompassing, for example, hearing aids, head bands, apparel, smart watches, and so on.

A key growth driver in the wearable sensors market entails innovation and successful introduction of new wearables. Moreover, sensors for wearables must provide low power, a small form factor, ease of integration with associated electronics, and sensor fusion capability. Rising average life expectancy and increasing awareness for health and fitness monitoring from different end-user groups and enhanced user experience are further driving the market.

There are also expected to be opportunities for low-cost and disposable paper-based sensors for glucose detection and other chemical sensing applications.

Some of the companies involved in sensors for wearable electronics include Samsung, Google, Apple, Philips, Microvision, Adidas, and Fitbit.

A recent patent in sensors for wearable electronics (US20150268729), assigned to Thomas G. Cehelnk, pertains to electric field sensor arrays for applications such as interactive gaming, computer interfaces, machine vision, healthcare, imaging, geographical exploration. The 3D motional command system is able to perform standoff (at a distance) gesture recognition and to also serev as a touch screen.

 

| Title | Publication Date/Publication Number | Assignee | Inventor | Abstract |
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| Electric field sensor arrays for interactive gaming, computer interfaces, machine vision, medical, imaging, and geological exploration CIP | 24.09.2015; US20150268729 | Thomas G. Cehelnk | Thomas G. Cehelnk | A 3D Motional Command System (MCS) is disclosed for interactive gaming, computer interfaces, communications, imaging, and geological exploration. The system can perform standoff gesture recognition and also function as touch-screens. E-field sensors and array topologies are disclosed comprised of FET discrete transistors. The designs facilitate the fabrication of high density sensor arrays similar to LCD displays. The system can be used in portable and wearable electronic devices. Uses are for PC computers, portable devices, and gaming systems such as the Wii. Other applications include wireless connection of sensor and audio data from a simple headphone jack output. |
| Determining physiological characteristics from sensor signals including motion artifacts | 20.08.2015; US20150230756 | Michael Edward Smith Luna | Michael Edward Smith Luna | Embodiments relate generally to electrical and electronic hardware, computer software, wired and wireless network communications, and wearable computing devices in capturing and deriving physiological characteristic data. More specifically, disdosed are one or more electrodes and methods to determine physiological characteristics using a wearable device (or carried device) and one or more sensors that can be subject to motion. In one embodiment, a method includes receiving a sensor signal during one or more portions of a time interval in which the wearable device is in motion, and receiving a motion sensor signal. The method includes decomposing at a processor the sensor signal to determine physiological signal components. An analysis of the physiological signal components can yield a physiological characteristic, whereby a physiological characteristic signal that includes data representing the physiological characteristic can be generated during at least one of the one or more portions of the time interval. |
| Determining physiological characteristics from sensor signals including motion artifacts | 05.08.2015; EP2900136 | AliphCom | Luna Michael Edward Smith | Embodiments relate generally to electrical and electronic hardware, computer software, wired and wireless network communications, and wearable computing devices in capturing and deriving physiological characteristic data. More specifically, disdosed are one or more electrodes and methods to determine physiological characteristics using a wearable device (or carried device) and one or more sensors that can be subject to motion. In one embodiment, a method includes receiving a sensor signal during one or more portions of a time interval in which the wearable device is in motion, and receiving a motion sensor signal. The method includes decomposing at a processor the sensor signal to determine physiological signal components. An analysis of the physiological signal components can yield a physiological characteristic, whereby a physiological characteristic signal that includes data representing the physiological characteristic can be generated during at least one of the one or more portions of the time interval. |

| Title | Publication Date/Publication Number | Assignee | Inventor | Abstract |
|---|---|---|---|---|
| Wearable inductive-force sensor | 20.08.2015; US20150233776 | JiangZhe | JiangZhe | A wearable inductive-force sensor, which provides high-sensitivity dynamic measurements of both normal force and shear force, utilizes three spiral planar force sensing coils. These spiral planar coils allow the measurement of shear force in the x and y directions and the measurement of a normal force in the z direction. The force sensor is configured to be mounted in various locations, such as an insole of a shoe, so as to provide real-time force sensing of forces that are applied to a patient's feet as they move. In addition, force-measurement electronics used with the force sensor are configured to use resonance-frequency division signal multiplexing to monitor the response of the force sensing coils, which allows the sensor to have minimal complexity, while still being highly sensitive. |
| Olfactory receptor-functionalized transistors for highly selective bioelectronic nose and biosensor using the same | 10.03.2011; US20110059544 | Hong Seung-Hun | Hong Seung-Hun | In accordance with an aspect of the present invention, there is provided a transistor including: a substrate; a source electrode and a drain electrode formed being spaced apart from each other on the substrate; a nanostructure electrically contacted with and formed between the source electrode and the drain electrode; and a lipid membrane having an olfactory receptor protein which is formed to cover surfaces of the source electrode, the drain electrode, and the nanostructure. The olfactory receptor-functionalized transistor in accordance with an aspect of the present invention is useful for a bioelectronic nose which can detect odorants highly specifically with femtomolar sensitivity, and may be applied in various fields requiring the rapid detection of specific odorants, for example, anti-bioterrorism, disease diagnostics, and food safety. |
| Systems, artides, and methods for electromyography sensors | 04.06.2015; WO/2015/081113 | Morun, Cezar | Morun, Cezar | Systems, articles, and methods for surface electromyography ("EMG") sensors that combine elements from traditional capacitive and resistive EMG sensors are described. For example, capacitive EMG sensors that are adapted to resistively couple to a user's skin are described. Resistive coupling between a sensor electrode and the user's skin is galvanically isolated from the sensor circuitry by a discrete component capacitor included downstream from the sensor electrode. The combination of a resistively coupled electrode and a discrete component capacitor provides the respective benefits of traditional resistive and capacitive (respectively) EMG sensor designs while mitigating respective drawbacks of each approach. A wearable EMG device that provides a component of a human-electronics interface and incorporates such capacitive EMG sensors is also described. |
| Single-surface position sensor and positioning method thereof | 20.05.2015; CN104635984 | Peking University | Zhang Haixia | The invention relates to a single-surface position sensor and a positioning method of the single-surface position sensor. The single-surface position sensor comprises a substrate layer and induction electrodes, wherein the induction electrodes are located on the substrate layer; the sensor further contains a friction layer; the friction layer is located on the substrate layer and located among the induction electrodes; the independent induction electrodes are grounded through the same load resistors, so that at least one time of contact and separation happens between a measured object and the friction layer, and the load resistors produce different voltage outputs; the position of the measured object is determined by analyzing the ratio of voltages of all the electrodes. The single-surface position sensor and the positioning method of the single-surface position sensor have the advantages that the single-surface position sensor is an active sensor, and compared with a traditional sensor, energy consumption of the single-surface position sensor is reduced; the single-surface position sensor can be manufactured into a flexible transparent thin film and widely applied to portable electronic equipment and wearable equipment; the single-surface position sensor is simple in process, low in cost and beneficial to mass production. |

**Exhibit 1 lists some of the patents related to sensors for wearable electronics.**

*Picture Credit: Frost & Sullivan*

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