TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

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1. ROBOTIC HAND WITH MULTIPLE FIBER OPTIC SENSORS

Force sensing is fundamental for the robotics industry. Force sensors, which sense force, pressure, or localized touch, increase the robot's intelligence and ability to perform key tasks, such as assembly, gripping, and manipulation of objects. With the amount or level of force detected, various parts of robots, such as grippers, are employed to hold different objects in diverse environments, such as manufacturing, transportation and many more.

Fiber optic sensor technology are beneficial for robotic force sensing, since such sensors are immune to electromagnetic interference and can be more conveniently configured into robotic force sensors, compared to conventional force sensing technologies.

However, the force sensors employed in robotics can have certain drawbacks. They can be incapable of measuring the weight of the objects handled and not sensitive enough to detect force that is less than a tenth of a Newton. In such a scenario, the robotic hands are not able to conform to the shape and weight of the object they are touching or handling and, furthermore, the grip is not safe and tight enough to complete the operation successfully. The robotic hands typically available do not employ enough sensors to detect small amounts of force. There is a need for robotic hands that can detect even minimal amounts of force and grip objects in such a way that the complete operation is carried out safely and successfully.

To address the above challenges, researchers from Carnegie Mellon University have developed a robotic hand with three fingers. In addition, the researchers have also developed highly stretchable fiber optic sensors that can be integrated into robotic hands.

The researchers developed three finger robotic hands with the help of four optical cables. The optical cables contain eight sensors to sense force and six sensors to sense contact with external objects. The researchers employed 3D printing to develop the robot fingers, which are covered with soft silicon rubber skin. The soft skin is developed with a soft waveguide which is further fabricated with reflective gold. The movement of the fingers of the robot stretches the silicon rubber. This phenomenon causes cracks in the reflective layer, enabling the light to escape. Thus, when the loss of light is measured, strain or total deformation can be calculated. This information further helps the finger to understand the structure of the object and thus grip it accordingly.

The project was supported by the University of Texas and US-based Intelligent Fiber Optic Systems Corporation with additional support was provided by NASA. According to the researchers, their invention is most suitable for soft robotics. At present, the researchers are also identifying different applications for the robotic hand. It is expected to be commercialized only with external funding or joint collaboration from companies.

Robots are more effectively utilized in various maintenance and safety applications where they are required to have high levels of autonomous functions. This includes mobile robots and robots that can perform autonomous tasks in harsh inaccessible environments. The highly flexible robotic system will handle a product mix at the production line and reduce costs incurred on fixtures, and manual labor costs. The robotic hand is expected to impact applications such as mobile robots, robot palletizing, bin picking, robot assisted machining, flexible feeding and many more.

Deploying multidimensional sensors or multiple sensors to measure force can be very expensive, and the production process will be very complex and time consuming. The flexible optical sensor developed by the researchers has opportunities to be successfully employed in robotics. More advances in flexible optical sensor technology are necessary for successful mass adoption. Universities are progressively researching flexible optical sensors that can sense force from three or six dimensions. In the future, multi axis flexible optical sensors have opportunities to be employed in various industries such as industrial automation, packaging, and healthcare. Partnerships or collaboration within industries will help the advanced technology to reach the market in a shorter time frame.

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2. ADVANCEMENTS IN PHOTOTRANSISTORS

A phototransistor is a solid state light detector that converts light energy into electric energy. Phototransistors possess internal gain, which renders them much more sensitive than photodiodes of comparably sized area. A phototransistor can be used in any electronic device that senses light. Applications for phototransistors include ambient light sensors, digital cameras, smoke detectors, infrared sensors, and so on.

In work supported by the US Air Force, University of Wisconsin-Madison researchers, Zhenqiang "Jack" Ma, professor of electrical and computer engineering, and research scientist Jung-Hun Seo, have created an ultra-fast, ultra-responsive flexible silicon phototransistor, which exceeds prior parameters for flexible phototransistor parameters, including sensitivity and response time. They demonstrated flexible phototransistors with a back gate configuration based on transferrable single-crystalline Si nanomembranes (Si NMs). Having the Si NM as the top layer enables complete exposure of the active region to incident light, thereby allowing for effective light sensing.

In contrast to typical phototransistors that are fabricated on rigid surfaces, and therefore are flat, the researchers have created flexible phototransistors that more easily mimic the behavior of mammalian eyes. They are able to make the curve to any shape desired to fit the optical system. The researchers use an innovative 'flip transfer' fabrication method, where, in the final step, the finished phototransistor is inverted onto a plastic substrate, leaving a reflective metal layer at the bottom. In contrast to more conventional phototransistors, in this structure, light absorption in an ultrathin silicon layer can be much more efficient, since the light is not blocked by any metal layers or other materials. Moreover, electrodes are placed under the phototransistor's ultrathin silicon nanomembrane layer, and the metal layer and electrodes each serve as reflectors and enhance light absorption without requiring an external amplifier.

The ultra-rapid phototransistors have an inherent capability to sense weak light. The demonstrated technology can have opportunities in high-performance and flexible photodetection systems. The new flexible phototransistors can provide highly sensitive light detection and stable performance even under bending conditions and can be integrated into multifunctional applications. The capabilities of such phototransistors can allow opportunities in high-performance flexible optical sensor applications.

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3. NON-INVASIVE; ULTRA-RAPID BRAIN COMPUTER INTERFACE

Brain computer interfaces (BCIs) provide direct, bi-directional communication between the brain and an implanted or external device, and are used to monitor, control, repair or assist in human cognitive or sensory-motor functions. BCI can enable development of enhanced neuroprosthetics that could help individuals overcome sensor-motor and communication impairments. BCI can also lead to new modes of human-computer interaction that transcend physical interface techniques.

Electroencephalography (EEG) is a key non-invasive technique for observing and recording brain activity using electrodes attached to the scalp. EEG technology for brain activity observation can provide low cost, relative ease of use, and fine time resolution. However, EEG signals acquired through the scalp are characterized by a low signal-to-noise ratio, due to non-physiological artifacts (external noise), physiological artifacts (electrical signals from inside the human body), and EEG potentials (localized in the cerebral cortex). The low signal-to-noise ratio, moreover, leads to low rates of communication of BCI signals (the information transfer rate can be limited to about 1.0 bits per second).

One application for BCI technology entails spelling systems developed for those who cannot communicate, in which the user visually targets a letter that is read out by a computer. In some systems, the information transfer rate can be as slow as five letters per minute.

Invasive systems involving surgically implanted prosthetics have resulted in faster information transfer rates, but are deemed less practical.

A team of researchers at Beijing's Tsinghua University and the University of California, San Diego have developed an electroencephalogram-based BCI speller that can achieve information transfer rates (ITRs) up to 5.32 bits per second, the highest information transfer rates reported in BCI spellers that use either noninvasive or invasive methods.

The system is based on steady-state visual evoked potentials (SSVEPs). An SSVEP speller system detects the user's gaze direction to a target character, essentially a keyboard operated by changing eye direction rather than manual operation. Leveraging the very high consistency of frequency and phase observed between visual flickering signals and the elicited single-trial steady-state visual evoked potentials, the researchers developed a synchronous modulation and demodulation paradigm to implement the speller. They proposed a new joint frequency-phase modulation method to tag 40 characters with 0.5-s-long flickering signals and developed a user-specific target identification algorithm employing individual calibration data.

The researchers posited that the visual latency of single-trial SSVEPs as represented by neuronal population activity over the stimulation time would be highly stable across trials. Therefore, the frequency and phase of the stimulation signals can be precisely encoded in single-trial SSVEPs. Considerably enhanced performance can be expected in the SSVEP speller using a synchronous modulation and demodulation paradigm that is used in telecommunications. To further improve the system, the researchers adopted a user-specific decoding algorithm that is able to adjust to individual differences in visual latency.

Furthermore, the researchers implemented a new visual latency estimation approach to compensate for the interference in measuring visual latency from noisy EEG signals. In online spelling tests, the system showed a substantial improvement over existing non-invasive BCI spelling systems, achieving a mean spelling rate of around 50 to 60 characters per minute and an information transfer rate of about 4.5 to 5.5 bits per second. Additional investigation is required to implement systems that can handle high workloads and to determine the long-term stability of visual latency.

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4. HANDHELD NITROGEN DIOXIDE SENSOR

Nitrogen dioxide (NO2) is among the group of highly reactive gasses known as oxides of nitrogen, or nitrogen oxides (NOx). Nitrogen dioxide is created from emissions from cars, trucks, buses, power plants, and off-road equipment. Nitrogen dioxide contributes to the formation of ground-level ozone and fine particle pollution, and is also associated with adverse effects on the respiratory system.

Various techniques have been used to measure nitrogen dioxide concentration in the atmosphere, including chemiluminescent analyzers and electrochemical sensors. Chemiluminescent nitrogen dioxide sensors tend to have a high capital cost and high operating costs. Electrochemical nitrogen dioxide sensors have tended to not have a detection limit that is sufficiently low for ambient monitoring, and may be susceptible to interference from ozone. There is a pressing need for a low-power, sensitive and selective nitrogen dioxide sensor.

Under the direction of professor Kourosh Kalantar-Zadeh of Australia-based RMIT University's Centre for Advanced Electronics and Sensors (CADES), researchers have developed an innovative method toward creating a handheld, economical, personalized, sensitive and selective nitrogen dioxide sensor that has opportunities to be incorporated into smart phones. The technology has promise for use in smartphones to detect harmful levels of nitrogen dioxide at an early stage, thereby combating and preventing the negative or catastrophic impact of nitrogen dioxide and helping to avoid illnesses arising from nitrogen dioxide poisoning.

A key barrier to early detection and mitigation of the effects of nitrogen dioxide has been the lack of effective monitoring tools available to the public. The researchers have developed a low-cost method for detecting nitrogen dioxide that can also provide performance benefits compared to certain existing, conventional techniques.

The sensors operate by absorbing nitrogen dioxide gas molecules onto flakes of tin disulphide (a yellowish-brown pigment generally used in varnish for gilding). This method not only increases the level of sensitivity to accepted EPA (Environmental Protection Agency) standards, but can outperform other nitrogen dioxide sensing solutions. To fabricate the sensors, the researchers transformed the tin disulphide into flakes of only a few atoms thick. The large surface area of the flakes has a high affinity to nitrogen dioxide molecules, which allows the highly selective absorption of this material.

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5. RECENT PATENTS IN THE FIELD OF BIOSENSORS FOR FOOD SAFETY

Food poisoning is mostly caused by the growth of bacteria, viruses, and parasites in food products rather than the presence of toxic substances in food. Unfortunately, some cases of food poisoning can be caused either by the presence of natural toxins or by chemical contamination.

Many different variations of pasteurization and other technologies enhancing food safety have been invented to treat a variety of foods. Recent years have witnessed the establishment of a wide variety of technologies enabling food safety to ensure that food is safe for customers. The technologies can be categorized into two sets--primary and supplementary technologies. The different methods of primary technologies are physical separation of contaminants, biosensors, automated food processing, packaging and protection coatings. Methods for supplementary technologies are electronic traceability, smartphone and mobile applications, real-time scanning and monitoring.

The key growth driver in this market is the increase in consumer interest in quality and hygiene of food products, spurring demand for stricter food safety standards in order to increase consumer confidence. This trend is a major factor boosting innovation and patent filing in food safety technologies.

Legislation and new standards for microbial monitoring are important growth drivers for biosensors. Increasing concerns over food safety and security are also driving the demand for biosensors. Novel technologies and materials, such as those based on nanomaterials, are likely to change the structure of the food safety market in the near future

Some of the companies in the biosensors for food safety market are Bayer CropScience, 3M, Ecolab, Neogen, PURE Bioscience, Birko, Honeywell, and many more.

From the patent filing scenario, it can be seen that the demand for biosensors is growing in the food and beverage industry in areas such as microbial food safety, anti-bioterrorism,, pesticide residue screening, and pathogen detection. They will also witness high demand from government inspection agencies.

A recent patent in biosensors for food safety, (CN104359870), assigned to Beijing Zhonglongyicheng Technology Co. Ltd., pertains to an efficient preparation method for a surface plasma resonance (SPR) biosensor chip, capable of detecting multiple trace small molecular substances such as cyanurotriamide, clenbuterol hydrochloride, ampicillin.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Preparation method of surface plasma resonance (SPR) biosensor chip	18.02.2015; CN104359870	BEIJING ZHONGLONGYICHENG TECHNOLOGY CO., LTD.	SU HUI	The invention discloses a preparation method of a surface plasma resonance (SPR) biosensor chip. L-cysteine, nanogold and bovine serum albumin coupled antigen molecules are sequentially assembled on a substrate glass sheet plated with a gold membrane with the thickness of 50nm, so that the SPR biosensor chip is obtained. The preparation method of the SPR biosensor chip is simple, rapid and low in cost, no fussy activating treatment needs to be carried out, the SPR biosensor chip is applicable to detection of multiple trace small molecular substances of cyanurotriamide, clenbuterol hydrochloride, ampicillin and the like, the regenerability is good, and the SPR biosensor chip can be widely applied to the fields of food safety, environments, biological science and the like.
Organic phosphorus electrochemical biosensor based on adsorption of nano particles	23.04.2014; CN103743804	HUNAN PROVINCE INSTITUTE OF TEA	LIU SHUJUAN	The invention particularly relates to an electrochemical biosensor capable of directly detecting an organic phosphorus pesticide in a water phase. The sensor comprises a glassy carbon electrode, a nano gold particle layer and a ZrO_2 nano particle layer. A production method of the sensor comprises the following steps of firstly electro-plating a layer of nano gold particles on the surface of the glassy carbon electrode, and then electro-plating a layer of zirconium dioxide nano particles on the nano gold particles. After the produced sensor fully adsorbs in a prepared organic phosphorus solution, and quantitative detection of the organic phosphorus is realized through the dissolution peak current detected by an electrochemical workstation. The sensor takes full advantage of special performances of the nano gold particles and the ZrO_2 nano particles in structure, is low in production cost, high in sensitivity, wide in linear detection range, good in reproducibility, small in nonspecific adsorption, and simple and fast in detection process, and has great application potential in food safety monitoring field.
Biosensor based on aptamer and manufacturing method and application thereof	22.01.2014; CN103529113	Zhengzhou University of Light Industry	Zhang Zhihong	The invention discloses a biosensor based on an aptamer and a manufacturing method and application thereof and belongs to the field of biochemical technique. According to the biosensor based on the aptamer, n-octadecyl mercaptan is automatically assembled on a gold film, the n-octadecyl mercaptan is combined with carboxyl group graphene oxide through intermolecular force, activating treatment is carried out on the carboxyl group graphene oxide to enable carboxyl to be converted into an active ester group, and an amido bond is formed through the active ester group and amino acid on molecule of the aptamer to enable the aptamer to be fixed on the surface of the carboxyl group graphene oxide. According to the biosensor based on the aptamer, the electrochemical activity is good, the aptamer can be well fixed, and the biosensor can be used for detection of various kinds of target protein and can be applied to the fields such as biomedicine, food safety and environmental monitoring. The manufacturing method of the biosensor based on the aptamer is simple and easy to operate. Due to the fact that hydroxyl and epoxy group which are on the graphene oxide are converted into the carboxyl due to the adoption of NaOH and $ClCH_2COONa$, the COOH functional group content is high, the good electrochemical activity is achieved, and the aptamer can be well fixed.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Surface treated TiO2 nano lattice array based working electrode for electrochemical biosensor	28.10.2015; EP2936279	Zhejiang University	Weng Wenjian	The invention discloses a surface treated TiO2 nano lattice array based working electrode for an electrochemical biosensor. A uniformly distributed TiO2 nano lattice array is obtained on a conducting substrate through a phase separation self-assembly method; after CO atmosphere heat treatment, the working electrode for the electrochemical biosensor can be obtained through Nafion and enzyme modification. The prepared working electrode for the electrochemical biosensor has high sensitivity, the linearity test time can be regulated through change of time of the CO atmosphere heat treatment so that different test requirements can be met. The working electrode for the electrochemical biosensor can be widely used in fields such as medical treatment detection, environment monitoring and food safety.
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.
Piezoelectric biosensor and biosensor array for parallel detection of multiple biomarkers	21.01.2009; EP2017613	GENETEL PHARMACEUTICALS LTD	YANG MENGSU	Biosensors are analytical devices composed of a recognition element coupled to a physical transducer (mass, optical, electrochemical and thermal) for qualitative and / or quantitative detection of biological analytes. Biosensors have wide applications in Medical & Technology; Food & Technology; Industrial & Technology; Environment Measurement & Technology and BioDefense. The invention is about a novel biosensor and biosensor array using piezoelectric ceramic resonators as the core component of the biosensor, and to develop a biosensor platform for simultaneous detection of multiple biomarkers including but not limited to detection of multiple cancer markers for screening and early diagnosis of the most common types of cancers; detection of multiple heart disease markers for early diagnosis and prognosis of heart disease; detection of multiple food contaminants for improvement of food safety; detection of multiple environmental toxins for monitoring environmental pollution and detection of multiple bio-warfare agents for military and civil defence applications. The piezoelectric ceramic-based biosensor and the technology platform established will create an exciting new market in various sectors with tremendous growth potential.
Conductimetric biosensor device, method and system	11.12.2008; US20080305963	Board of Trustees of Michigan State University	Alocilja Evangelyn C	A multi-array membrane strip biosensor device (**10, 20**) using a fluid mobile conductive polymer as reporter is described. The biosensor device (**20**) is designed to detect multiple analytes at low concentrations in near real-time with an electronic data collection system. The biosensor device can be small. The device can be used to detect pathogens, proteins, and other biological materials of interest in food, water, and environmental samples. The device can also be used for on-site diagnosis and against potential bioterrorism. Potential users include food processing plants, meat packaging facilities, fruit and vegetable packers, restaurants, food and water safety inspectors, food wholesalers and retailers, farms, homes, medical profession, import border crossing personnel, and the police force, military, space habitation and national security.

Exhibit 1 lists some of the patents related to biosensors for food safety.

Picture Credit: Frost & Sullivan

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