TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

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1. WIRELESS SIGNAL TRANSMISSION THROUGH THE HUMAN BODY

Wireless body area networks (WBANs), which transmit sensor data to and from wearable sensing devices, will find increasing opportunities as wearable sensor-based devices become more commonplace and proliferate. One logical application area for such BANs entails health monitoring, as individuals increasingly wear more smart watches and monitors to track health and fitness. Using wearable sensors for health and fitness tracking enables individuals to gain greater insight into key physiological parameters impacting their health and wellness. Individuals can use this information to lead a more healthy life style.

Sensors used in WBANs need to provide a relatively low level of complexity, a compact form factor, light weight, low-power consumption, and be convenient to use. Moreover, wearable sensing devices need very low power, user-friendly data communications technology. Bluetooth wireless communications used in wearable sensing devices can use much power for communications. Wireless communications used in sensor-based BANs should also provide security and privacy, immunity to interference, and interoperability with other wireless devices in the environment. Furthermore, the wireless sensing devices used in a BAN should be non-intrusive and transparent to the user.

In an advancement in ultra low-power, secure body area wireless communications, researchers at the University of California, San Diego (UCSD), have demonstrated a proof-of-concept of a wireless communications method that transmits magnetic signals through the human body. The technology has potential to provide a lower power and more secure communications for transmitting data among wearable electronic devices used in applications such as a body health monitoring wireless sensor network.

To be able to optimize or reduce power consumption when transmitting or receiving information, the signals from the wireless systems should easily travel form one side of the human body to another. The electromagnetic radio signals from Bluetooth wireless communication technology can not readily pass through

the human body and can require a power boost to surmount signal obstruction or path loss.

The UCSD electrical engineers have used a magnetic field human body communication technique in which the body is the conduit to provide magnetic energy between electronic devices. Since the magnetic fields can travel freely through biological tissues, the signals can be communicated with considerable lower path losses and there is potential for considerably lower power consumption. The researchers have demonstrated that the magnetic field communication link works effectively in the human body; however, the method's power consumption was not tested. In their experiments, the path losses associated with magnetic field human body communication were shown to be around 10 million times lower than the losses associated with Bluetooth radios. The researchers believe that their technique achieves the lowest path losses of any wireless human body communication system that has been, to their understanding, thus far demonstrated. It has opportunities for building wearable devices that use considerably less power.

The magnetic field human body communication system could also potentially allow battery powered wearable devices, such as smart watches, to operate longer without requiring battery recharging. The technique is free of health risks. The transmitting power of the magnetic signals sent through the body is anticipated to be considerably lower than that of MRI (magnetic resonance imaging) scanners or wireless implant devices, since the technique would be aimed at applications involved ultra low power communication systems.

The magnetic field human body communication technique could also provide enhanced security. As Bluetooth radio communicates over the air, anyone within 30 feet could possibly eavesdrop on such communications. Using the human body as a communication medium, on the other hand, renders the communications less susceptible to eavesdropping. The magnetic field communication is strong on the body, but significantly decreases off the body. In a magnetic field human body wireless communication network, information would not radiate off the body or be transmitted from one person to another.

The UCSD researchers created a prototype consisting of copper wires insulated with PVC (polyvinyl chloride) tubes. On one end, the cooper wires were connected to an external analyzer. On the other end, the wires were wrapped in coils around the head, arms, and legs. The coils provide the source of the magnetic fields and send signals from one part of the body to another. Using the prototype, the researchers demonstrated and measured low path less communication from arm to arm, arm to head, and arm to leg.

In the technique, the magnetic fields require circular geometries to propagate through the human body. Smart watches, head band devices, and belt devices will work effectively using magnetic field human body communication, but not when using, for example, a small patch on the chest to measure heart rate. The technique should work effectively when the wearable application can be wrapped around a part of the human body.

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2. ADVANCEMENTS IN ELECTRONIC NOSES FOR WATER MONITORING

Electronic noses, which mimic human olfaction capability and can be able to discriminate and recognize a variety of different gases and odors using a small number of sensors, continue to generate significant interest for a diverse applications, such as medical diagnostics, food, cosmetics, as well as environmental monitoring.

Electronic noses have potential to address environmental monitoring applications. Such sensors can address key needs in this sector for a convenient, reliable tool that can efficiently provide real-time information without incurring the waiting times, cumbersomeness, and cost of conventional analytical equipment such as gas chromatographs or mass spectrometers. To have optimal opportunities to impact environmental applications, electronic noses should be able to provide very high sensitivity, reliability, selectivity, while not being compromised by atmospheric conditions such as temperature or humidity.

Emblematic of advancements in electronic noses for key environmental monitoring applications, researchers at Seoul National University, under the leadership of Tai Hyun Park, have developed a bioelectronic nose that mimics the human nose to detect traces of bacteria in water via smell. The bioelectronic nose, which provides real-time assessment of water quality, was built with the human olfactory receptor (hOR) and a single-walled carbon nanotube field-effect transistor (swCNT-FET).

A traditional means of testing water for bacteria contamination with bacteria has involved taking a sample and growing the bacteria in the lab. When the bacteria grow, scientists can count the number of colonies and calculate the concentration of bacteria in the water. When the bacteria grow, a scientist can count the number of colonies and calculate the concentration of bacteria in the water.

Another method is to detect the odors directly, typically by using large scientific equipment, such as gas chromatography or mass spectroscopy. Such approaches are not conducive for field operations.

As noted in "Real-time monitoring of geosmin and 2-methylisoborneol, representative odor compounds in water pollution using bioelectronic nose with human-like performance" published in Biosensors and Bioelectronics, Volume 74, 15 December 2015, eosmin (GSM) and 2-methylisoborneol (MIB), which are primarily produced by bacteria, are representative odor compounds and indicators of contamination in the water supply. For screening of hORs (human olfactory receptors) that respond to such compounds, the researchers performed CRE-luciferase assays of the two odorants in a heterologous cell system. Human OR51S1 for GSM and OR3A4 for MIB were selected, and nanovesicles expressing the hORs on the surface were produced from HEK-293 cell. The carbon nanotube field-effect transistor was functionalized with the nanovesicles. The bioelectronic nose was able to selectively detect GSM and MIB at very low concentrations as low as a 10 ng L (nanogram/liter)$^{-1}$. Moreover, detection of such compounds from the real samples, such as tap water, bottled water and river water, was available without requiring pretreatment processes.

Two typical earthy and musty odors given off by bacteria are that contaminate water are associated with geosmin (GSM) molecules and 2-methylisoborneol (MIB) molecules. The bioelectronic nose sensor is easy to use, able to detect minute amounts of contamination in water, and can provide greater sensitivity compared to existing or conventional detection methods.

The sensing technology is able to detect the odor or flavor emitted from low levels of bacteria or other microbes. At lower concentrations, bacteria or microbes can make drinking water smell bad, dissuading individuals from drinking the water, although they do not make the water toxic.

The researchers aim to render the bioelectronic nose more like a human nose, which has around 400 distinct olfactory receptors.

Since their concern is the bad smell, Prof. Park and his colleagues naturally thought about how the human nose works and adapted its function as a sensor element. The human nose is more complicated than receptors for two smell molecules, so to make a true smelling device, the researchers will need to scale up their efforts.

The bioelectronic nose technology could have additional applications, such as detecting odors associated with perfume, cosmetics, wine or coffee; disease (such as lung cancer) detection; or security (such as drug detection). Furthermore, the

technology could facilitate the creation of a smell classification system based on detection and labeling of odors.

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3. BIOPOLYMER COATING FOR IMPLANTED MEDICAL SENSORS

Electrically conducting polymers provide certain benefits compared to traditional organic conductors and semiconductors, such as ability to be more easily processed; less expensive and safer fabrication capability; greater availability; and better performance in certain applications.

Conducting polymers possess certain excellent electronic properties that can be advantageous for biosensing, such as electrical conductivity, low energy optical transitions, low ionization potential, and high electron affinity. Biosensors based on conductive polymers have been designed to detect, for example, nitric oxide, NADH (a reduced form of nicotinamide adenine, dinucleotide), heavy metals ions, and so on. Conducting polymers can enhance the stability, speed, and selectivity of biomedical devices.

Bioactive conducting polymers can improve the chronic performance of neural prosthetic devices.

In addition, biocompatible biopolymers capable of successfully operating within the human body can have opportunities in implantable biomedical sensors and in conducting electricity and sensor communication within the human body. However, conventional conducting polymers such as those used in LEDs and solar cells are not very well-suited for medical implants, since the body will combat and reject them and shutdown the electrical connection.

Spurred by a grant of $499,995 awarded from the National Science Foundation, researchers at The University of Akron (US), led by Gang Cheng, assistant professor of chemical and biomolecular engineering, are further investigating and developing polymer coatings for medical implants. Chang has been investigating biologically compatible polymers for a significant amount of time. The five-year grant will boost the ability of the researchers to understand the structure and functionality of water soluable polymers and to search for such polymers that are safe to implant and would have the ability to conduct electricity and communicate with sensors while implanted within the human body.

Sensors coated with a biocompatible conducting polymer can have opportunities for use in monitoring biomarkers, such as blood sugar, continuously on a 24/7 basis. When used in conjunction with a drug-delivery system, such sensors could activate medication doses when needed. Such polymers also could have opportunities for use in pacemakers and in more sophisticated implantable devices that need to communicate with the body.

The researchers will build polymer-coated sensors for testing in the lab. Additional funding will then be sought for the next phase involving testing of the sensors in rats.

The researchers envision other application opportunities for biocompatible conducting polymers, such as biofuel cells capable of transforming bodily sugars into a source of energy. In the future, such biofuel cells may be able to power implanted medical devices, instead of using batteries as a power source.

In addition, researchers at other institutions, such as US-based Brown University, have investigated using polypyrrole, a conductive polymer, as a coating on an implantable carbon nanotube sensor to release drugs to treat implant-related infection or inflammation.

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4. ELISA ON-A-CHIP STREAMLINES ANALYSIS OF DISEASES

Lab-on-a-chip (LOC) technology miniaturizes and integrates laboratory functions on a tiny chip to achieve automated, high-throughput screening. LOC scales lab processes to a chip-scale format, and is associated with microfluidics technology, which pertains to the integration of the overall sequence of laboratory processes for conducting chemical analysis.

LOC devices provide greater accuracy and reproducibility by being able to control fluidics and manipulate them through narrow channels, as well as due to the miniaturization of sensors for biological components. Additional benefits afforded by LOCs include lower consumption of fluid volume resulting in less waste and reduced cost of reagents; and more rapid analysis and response time due to a high surface-to-volume ratio; compact size and high throughput analysis; reduced fabrication costs, facilitating mass production.

Enzyme-linked immunosorbent assay (ELISA) is a test that utilizes antibodies and color change to identify a substance, usually an antigen in a liquid or wet sample.

Antigens from the sample are attached to the surface, and a further specific antibody is applied over the surface in order for it to bind to the antigen. The antibody is linked to an enzyme, and a substance containing the enzyme's substrate is added. The reaction produces a signal, typically a color change in the substrate.

LOC technology has keen prospects for enhancing efficiency, throughput, and sensitivity of ELISA-based detection and medical diagnostics. LOC technology for ELISA-based detection, moreover, can significantly reduce the cost and processing time for analysis, as such technology is able to perform an analysis using considerably less fluid, and enables small reagent consumption compared to traditional ELISA instruments or devices. An LOC-based ELISA platform also provides greater portability. Furthermore, it is conducive to creating a point-of-care system for performing complex medical assays without the laboratory equipment required for conventional ELISA analysis.

With finding from the National Institutes of Health, National Science Foundation, and the New Jersey Commission on Brain Injury Research, researchers at US-based Rutgers, The State University of New Jersey have developed an innovative ELISA-on-a-chip device that has potential to boost the throughput and substantially reduce the cost for lab tests for medical conditions, such as HIV (human immunodeficiency virus), Lime disease, or syphilis. The LOC-based ELISA device, which uses miniaturized channels and valves to replace benchtop assays requiring a large sample of blood or other fluids and expensive chemicals mixed in trays of tubes or plates, is capable of analyzing 32 samples simultaneously. It can measure the concentrations of up to six proteins in a sample.

The ELISA-on-a-chip device requires one-tenth of the chemicals used in a conventional multiplex immunoassay, which could cost up to about $1500.

The LOC device, which is 3 in. long by 1 in. wide, is able to conduct complex analyses using 90% less sample fluid than that is required for conventional ELISA tests. The LOC ELISA platform, leveraging microfluidics technology, can facilitate expanded research activities and initiatives, since research can be hindered by the inability to extract a sufficient amount of fluid. For example, research on central nervous system disorders of animals, such as spinal cord injury and Parkinson's disease, has been thwarted by the inability of researchers to extract a sufficient amount of cerebrospinal fluid to conduct a conventional analysis. The Rutgers LOC-based ELISA technology will be capable of conducting large-scale controlled studies while providing accuracy similar to conventional assays.

Since the amount of joint fluid or synovial fluid that can be collected from farm animals using conventional assays is also minute, the LOC-based ELISA

technology could enable more comprehensive research concerning autoimmune joint diseases, such as rheumatoid arthritis, via animal investigations. Commercial opportunities for the technology are being explored.

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5. PATENT ANALYSIS FOR LIGHT REFLECTIVE SENSORS

A light reflective sensor can be considered a type of photoelectric sensor, which detects infrared or visible light beams emitted by transmitters and reflected by objects or surfaces. A photoelectric sensor consists of a light source (emitter) and a receiver (photodiode or phototransistor) for the received light.

When emitted light is interrupted or reflected by the sensing object, it changes the amount of light that arrives at the receiver. The receiver detects the change and converts it to an electrical output. The change in light enables the sensor to detect the presence or absence of an object, the object's size, shape, color, reflectivity, opacity, or translucence.

Photoelectric sensors tend to use a light-emitting diode (LED) as the light source. The light detector is a solid-state component that provides a change in conducted current depending on the amount of light detected. Light detectors are more sensitive to certain wavelengths of light; and their spectral response determines their sensitivity to different wavelengths in the light spectrum

From the patent analysis for light reflective sensors, it is evident that most of the patents filed are based on methodologies for creating or designing light reflective sensors and their applications**.** A patent (WO2013173237) filed by Redox Biomedical Inc. (United States) pertains to monitoring a laser safety system that uses a light reflective sensor to sense light reflected from a sample. Omron Corporation (Japan) has filed a patent (WO2013136825) that pertains to a reflective light sensor with a light receiving element and a light transmitting element.

Title	Publication Date/ Publication Number	Assignee	Inventor	Abstract
Sensor-type electronic musical instrument based on freely movable light reflection and photoreceptor sensor (photoreceptor element)	April 02, 2015/ WO 2015046179	Watarai Hiroshi	Watarai Hiroshi	An objective of the present invention is to provide a system wherein a light source to be converted to music is set, light or a light beam from the light source enters a freely rotatable light reflection plate via an entry aperture, and the reflection plate is controlled so that the entering light is projected upon a photoreceptor sensor (photoreceptor element) keyboard and sound is played. Furthermore, information of this system is digitally converted (3DCG, etc.) and installed in hardware such as a personal computer or a smartphone, such that it is possible to combine and synthesize said information into a signal which is to be converted into an image which is sent from a CCD or CMOS image sensor, run a simulation thereof on a screen, and control a projection of the light or the light beam upon the screen to play a sound or a melody using the reflection upon the photoreceptor sensor keyboard which is connected to the simulated electronic musical instrument.
System for positioning a reflective surface in relation to the sun, using a solar sensor and the reflected light	Dec 31, 2014/ EP 2818806	Univ Sevilla	Quero Reboul, José Manuel	The invention relates to a method for positioning a reflective surface in relation to the sun, so that the reflected light falls on a target point, using a solar sensor and a two-axes angular mechanism. The method can be used to position a reflective surface (R) in relation to the sun (S), said reflective surface being mounted on a mechanical system having two axes of rotation (azimuth-elevation), using a solar sensor (1) that is positioned facing the reflective surface in a fixed orientation. The solar sensor measures the angles (2) formed by the projected incident light vectors in relation to two orthogonal planes (4). The method is applied independently and simultaneously to both axes of rotation and can be used to calculate the relative position of the ray (3) reflected from the reflective surface in relation to the orthogonal planes (4) of the solar sensor (1). Once the relative position is known, the position of the reflective surface (R) is altered in both independent axes, by means of a suitable movement of two motors, until the relative position (2) of the reflected ray (3) coincides with the perpendicular of the solar sensor (1).
Atomic sensor physics package with integrated transmissive and reflective portions along light paths	Dec 18, 2014/ EP 2674820	Honeywell Int Inc	Schober Chistina Marie	In one embodiment, a block for a physics package of an atomic sensor is provided. The block comprises one or more sections of optically transparent material defining a vacuum sealed chamber, and including a plurality of transmissive and reflective surfaces to define a plurality of light paths intersecting the vacuum sealed chamber. The one or more sections of optically transparent material include a first monolithic section defining at least a portion of the vacuum sealed chamber. The first monolithic section includes a first portion disposed across a first light path of the plurality of light paths such that light in the first light path is incident on the first portion of the first monolithic section.

Proximity sensor and proximity sensing method using light quantity of reflection light	Jan 29, 2014/ KR 1020140011690	Samsung Electronics Co. Ltd.	Lee, Jun Haeng	Disclosed are a proximity sensor and a proximity sensing method using the amount of reflected light. The proximity sensor comprises a sensing unit detecting changes in the amount of reflected light, wherein emitted light able to change its brightness is reflected from an object, and a proximity determining unit which determines whether the object is approaching by changes in the brightness of emitted light and the amount of reflected light. COPYRIGHT KIPO 2014 [Reference numerals] (100) Proximity sensor; (101) Light source; (110) Light amount change detecting unit; (120) Proximity determining unit; (130) Motion recognition unit
Proximity sensor and proximity sensing method using light quantity of reflection light	Jan 23, 2014/ US 20140022528	Samsung Electronics Co. Ltd.	Lee, Jun Haeng	A proximity sensor and proximity sensing method using a change in light quantity of a reflected light are disclosed. The proximity sensor may include a quantity change detection unit which detects a change in a quantity of reflected light which is output light which has been reflected by an object, where an intensity of the output light changes, and a proximity determination unit which determines a proximity of the object to the quantity change detection unit based on a change in the intensity of the output light and the detected change in the quantity of the reflected light.
Systems having a reflected light sensor and methods of use	Nov 21, 2013/ WO 2013173237	Redox Biomedical Inc.	Lipson, Jan	Various systems and methods of monitoring laser safety by sensing contact of the system with a sample are provided. The system includes a focusing element for focusing an incident light from a laser light source onto a sample, an optical element having a collection zone for collecting a signal from the sample, a reflected light sensor for sensing a reflected light from the sample, wherein the reflected light sensor is located outside the collection zone of the optical element and on an inner surface of a housing of the system, an electrical circuit operably connected to the reflected light sensor and the laser light source and configured to control power to the laser light source in accordance with the reflected light sensed by the reflected light sensor and a spectral analyzer for processing the signal. Methods and other systems are also described and illustrated.
Reflective light sensor	Sept 19, 2013/ WO 2013136825	Omron Corporation	Uetsuji Yasuhito	A reflective light sensor in which a light projecting element and a light receiving element (1) which receives reflected light from an object to be detected that has received light from the light projecting element by a light receiving surface elongated in one direction are disposed to have a relationship in which the image formation position of the reflected light in the length direction of the light receiving surface changes according to the distance from the object to be detected. In order to reduce the amount of noise light that enters the light receiving element, the light receiving element receives the light in a light receiving area having a width that becomes narrower toward the direction in which the image formation position of the reflected light moves when the object to be detected approaches the sensor. In an embodiment, the light receiving element is a two-split light receiving element, and a shielding member (11) having an opening (10) is disposed in front thereof. In the opening, an open portion corresponding to a Near-side light receiving element (1N) which receives strong reflected light from a place relatively closer to the sensor has a width that becomes narrower away from a boundary with the other Far-side light receiving element (1F).

Optical sensor and image forming apparatus configured to detect inside diffusely-reflected light	Sept 05, 2013/ US 20130228674	Yoshihiro Oba	Yoshihiro Oba	An optical sensor includes an irradiation system emitting linearly polarized light of a first polarization direction toward a surface of an object from an incident direction inclined with respect to a normal to the surface; a first light detection system including a first light detector placed on a light path of light emitted from the irradiation system and specularly reflected by the object; and a second light detection system including a separation optical element placed on a light path of light diffusely reflected by the object, on a plane of incidence of the object, and extracting a linearly polarized light component of the first polarization direction included in the light diffusely reflected by the object, a second light detector receiving the linearly polarized light component of the first polarization direction extracted by the separation optical element and a third light detector receiving the light diffusely reflected by the object.

Exhibit 1 depicts patents on light reflective sensors.

Picture Credit: Frost & Sullivan, WIPO

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