TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

29th May 2015

1. SENSOR IMPROVES FOOD SAFETY

As biosensors or chemical sensors become increasingly compact with improved sensitivity and selectivity, they have expanding opportunities for integration in smart packaging for applications such as monitoring the quality and safety of food.

Researchers at the Massachusetts Institute of Technology (MIT) in United States have created a cost-effective, portable sensor, based on chemically modified carbon nanotubes, which is able to detect gases emitted from rotting meat. This capability allows consumers to understand whether the meat in a grocery store or refrigerator is safe to eat. Such a sensor could be implemented in smart packaging to provide more accurate safety information and reduce food wastage as a result of discarding food that is not really spoiled. The sensor could also safeguard against food-borne illness.

In this sensor, the carbon nanotubes are chemically modified. Hence, the sensor's capability to conduct electric current changes in the presence of a certain gas. The carbon nanotubes were modified using metalloporphyrins--metal-containing compounds that contain a central metal atom bound to several nitrogen-containing rings. Hemoglobin is a metalloporphyrin where iron is the central atom.

The sensor for food safety uses a metalloporphyrin with cobalt. Metalloporphyrins are very good at binding to nitrogen-containing compounds called amines. Of particular interest to the MIT researchers were biogenic amines, such as putrescine and cadaverine, which are produced by decaying meat.

The electrical resistance of the carbon nanotube is increased and can be easily measured when the cobalt-containing porphyrin binds to biogenic amines (such as putrescine and cadaverine).

The porphyrins are used to fabricate a very simple device. A potential is applied across the device and the current is monitored. The device's current is reduced when it encounters amines that are markers of decaying meat. The sensor was tested on pork, chicken, cod, and salmon. When refrigerated, all the types of meat remained fresh for four days. Without refrigeration, the samples decayed, but at different rates.

In contrast to bulky and expensive instruments that are used to detect decaying meat and which require operator expertise, the carbon nanotube sensor is inexpensive, small, easy to manufacture, and requires minimal power. The device could also be a wireless platform developed by the researchers that enables a smart phone to read the output from carbon nanotube sensors.

A patent has been filed for and the researchers are looking to license the technology for commercial development. Funding for the research was provided by the National Science Foundation and the Army Research Office through MIT's Institute for Soldier Nanotechnologies.

Details: Dr. Timothy Swager, John D. MacArthur Professor, Department of Chemistry, Massachusetts Institute of Technology, Bldg. 18-597, Cambridge, MA 02139. Phone: +1-617-253-4423. E-mail: tswager@mit.edu

2. ENHANCEMENTS IN INFRARED GAS SENSORS

Infrared (IR) gas detection is typically based on the absorption of infrared radiation at specific wavelengths as it passes through a volume of gas. The IR gas sensor based on gas absorption sensing technology uses a light source, an optical filter to allow selection of the appropriate wavelengths, and a detector to selectively measure the intensity of the wavelengths that correspond to the wavelengths absorbed by the gas of interest.

Gases that can be detected due to absorption of IR light include carbon dioxide, hydrocarbons (such as methane, propane), carbon monoxide, oxides of nitrogen, ammonia. Common types of gases that are detected by IR gas sensors include carbon dioxide and methane.

IR gas sensors are well-established for precisely measuring gas concentrations in applications such as industrial safety instruments, analytical instruments, food processing, breweries/fermentation, agriculture, healthcare, indoor air quality monitoring (e.g., measuring carbon dioxide in a space for demand-controlled ventilation), landfill gas monitoring, and so on.

Limitations of conventional infrared gas sensors can include the instability or drift of the light source, cost (which can be higher than that of, for example, catalytic gas sensors), limited temperature range, potential for particle accumulation and aging of the light source, power consumption, and the potential for somewhat impeded performance in the presence of multiple gases. The initial higher cost per point is another limitation. IR detectors, typically, are more expensive than catalytic detectors at initial purchase.

US-based Lightsense Technology Inc., launched in November 2014, with offices in Arlington, Virginia, and Tucson, Arizona, is spearheading development and commercialization of very accurate, networkable, low-power (the company's IP can enable operation at <1 W), IR gas sensors with long-term stability, which can be powered using energy harvesting. The technology platform can allow for making sensors for diverse applications, such as energy-efficient smart buildings, detection of methane gas emissions, and pollution air monitoring.

Lightsense's IR gas sensor technology platform can provide additional benefits such as high sensitivity and selectivity, the ability to operate over a long lifetime (greater than 10 years) using energy harvesting, low cost, and an unobtrusive and compact form factor. Such low-power wireless sensors can employ energy harvesting to avoid high installation costs and reduce the payback period to one year.

The company's technology includes a chip that serves as a light source for IR gas sensors.

The company's sensors can be implemented in wireless sensor networks to cover large geographic areas for applications such as methane leak detection or measuring constituents of air pollution. Complex analytics can be applied to the sensor data due to secure aggregation of information to the cloud.

In collaboration with partner IOTA Computing (Palo Alto, California), Lightsense is launching its initial infrared MEMS (microelectromechanical systems) components and subsystems and introducing ultra low-power autonomous wireless sensor networks. The initial wireless network based on Lightsense's sensors and IOTA's cyber-secure network architecture is targeted at the smart building market and will be rolled-out in 2016. This initiative will be followed by multi-sensor networks for smart cities in 2017 and thereafter.

Details: Terje Skotheim, Chief Executive Officer, Lightsense Technology Inc., 7080 N. Cathedral Rock Pl., Tucson, AZ 85718. Phone: +1-520-955-3482. E-mail: terje.skotheim@gmail.com.

3. VANADIUM DIOXIDE MULTIFUNCTIONAL MAGNETIC SENSORS

Vanadium oxide is a key type of material (along with amorphous silicon) used in uncooled infrared microbolometers, which have impacted lower-cost infrared imaging applications such as thermography, firefighting, driver night vision, security and surveillance, as well as automotive night vision. Uncooled IR microbolometers have been undergoing performance improvements so they can encroach on more expensive cooled infrared photon detectors in certain applications, particularly those that require less resolution or range compared to their cooled IR photon detector counterparts. Spintronics pertains to technologies used in solid-state devices that take advantage of the inherent spin in electrons and their related magnetic momentum.

Magnetic field sensors that utilize spintronics can have greater sensitivity and precision. Giant magnetoresistance (GMR) magnetic sensors, comprised of ferromagnetic alloy sandwiched around a non-magnetic conducting layer, utilize spintronics. Other metal-based spintronic devices include tunnel magnetoresistance (TMR) in which current-perpendicular-to-plane (CPP) transport is realized by using quantum-mechanical tunneling of electrons through a thin insulator separating ferromagnetic layers.

Researchers at North Carolina State University in United States have driven enhancements in smart sensors by integrating vanadium oxide into a silicon chip and, furthermore, by using lasers to render the material magnetic. Such advancement can enable opportunities for smart, multifunctional spintronic sensors in application areas such as military and next-generation spintronic devices. The research efforts, which were supported by the National

Science Foundation, can fulfil key requirements for sensor technology in military applications, such as the ability to rapidly sense, manipulate, and respond to data.

Through integrating vanadium oxide material as a single crystal onto a silicon substrate, the researchers have facilitated the ability to create smart infrared sensors, with the sensor and computational functions embedded on a single chip. This integration can increase the speed and efficiency of the sensor, since data does not need to be sent to another chip to be processed. Smart sensors can also be smaller and lighter than more conventional sensors because there is no need for separate chips for the sensing and electronics.

Moreover, the researchers used high-power, nanosecond-pulsed excimer laser beams to modify the vanadium dioxide and render this material magnetic. This capability can enable the formation of smart spintronic sensors that incorporate infrared sensors and magnetic sensors on one chip. Advantages of spintronics can include higher memory capacity, faster data transfer and greater computational power on a computer chip.

As noted in "Diamagnetic to ferromagnetic switching in VO2 epitaxial thin films by nanosecond excimer laser treatment," published in *Applied Physics Letters*, 103, 252109 (2013),VO_2(010)/NiO(111) epitaxial heterostructures were integrated with Si(100) substrates using a cubic yttria-stabilized zirconia (c-YSZ) buffer. The samples were treated by a nanosecond KrF (krypton fluoride laser) excimer laser. Pristine as-deposited film exhibited diamagnetic behavior, while the laser annealed sample showed ferromagnetic behavior. The population of majority charge carriers and electrical conductivity increased about two orders of magnitude after laser annealing. Such observations were attributed to the introduction of oxygen vacancies into the vanadium dioxide (VO_2) thin films and the formation of V^{3+} (vanadium (III) ion) defects.

Diamagnetic materials create an induced magnetic field in a direction opposite to an externally applied magnetic field. Ferromagnetism refers to a mechanism by which certain materials (for example, iron) form permanent magnets or are attracted to a magnet.

Details: Dr. Jagdish Narayan, John C. Fan Distinguished Chair Professor of Materials Science and Engineering, North Carolina State University, Department of Materials Science and Engineering, North Carolina State University, 911 Partners Way, EBI, Room 3030, Raleigh, NC 27695. Phone: +1-919-515-7874. E-mail: j_narayan@ncsu.edu

4. RECENT PATENTS IN THE FIELD OF BIOSENSOR

A biosensor is an analytical device, which is used to pick up electrical signals from a biological response. An electrical signal is picked up with the help of a transducer. The biological response is achieved when biological elements such as microorganisms, enzymes, tissues, and nucleic acid interact with an analyte. The ability of a biosensor to provide an output signal corresponding to the environment and the speed of its response make biosensors extremely viable for both clinical and non-clinical applications.

Point-of-care biosensor devices, such as diabetes management, cardiac monitoring, blood analyzer and several others constitute the largest market segment for biosensors. Security and biodefense is a smaller market, but it is growing at an increasing rate. Biosensors are penetrating into home diagnostics, environmental, and process industry market segments. The research laboratories segment is estimated to maintain stable growth.

The United States is leading in the number of patents published in biosensors, followed by Europe and Asia Pacific. North America is the biggest market for biosensors, including different segments such as home based monitoring, point of care and environment monitoring devices. Some of the companies focusing on biosensing in North American are, for example, Vital Connect, Lifescan, and Telcare. Revenue in the European region is expected to increase because of the growing demand from aging populations. There is a high focus on printed wearable and implantable biosensors.

Developments in nanotechnology have facilitated nano-engineered biosensors. The improvement in process techniques and enhancement in biosensor functionalities have resulted in the expansion of applications. To achieve compatibility with integrated circuits, the sensors have been downsized to micro and nano scales. Clinical diagnostics, medical home diagnostics, environmental monitoring, biotechnological process control, and food and beverage are the beneficiaries of nanotechnology research into biosensors.

A recent patent (US20150125965). in biosensors, assigned to Intel Corporation, involves a resonator enabled by piezoelectric material. The functionalized surface of the piezoelectric resonator reacts with the target biomolecules by changing the mass or charge of the resonator, which alters the resonator's frequency response.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
BIOSENSOR UTILIZING A RESONATOR HAVING A FUNCTIONALIZED SURFACE	07.05.2015; US20150125965	Intel Corporation	Yuegang Zhang	Systems and methods for detecting the presence of biomolecules in a sample using biosensors that incorporate resonators which have functionalized surfaces for reacting with target biomolecules. In one embodiment, a device includes a piezoelectric resonator having a functionalized surface configured to react with target molecules, thereby changing the mass and/or charge of the resonator which consequently changes the frequency response of the resonator. The resonator's frequency response after exposure to a sample is compared to a reference, such as the frequency response before exposure to the sample, a stored baseline frequency response or a control resonator's frequency response.
TRANSPORTER BIOSENSORS	07.05.2015; US20150125893	Carnegie Institute of Washington	Wolf B. Frommer	The invention provides fusion proteins comprising at least one fluorescent protein that is linked to at least one transporter protein that changes three-dimensional conformation upon specifically transporting its substrate. The transporter protein may be a nitrate transporter, a peptide transporter, or a hormone transporter. The invention provides fusion proteins comprising at least one fluorescent protein that is linked to at least one mechanosensitive ion channel protein. The invention also provides for methods of using the fusion proteins of the present invention and nucleic acids encoding the fusion proteins.
CARBON NANOTUBE BIOSENSORS AND RELATED METHODS	30.04.2015; US20150119263	Alan T. Johnson, JR.	Alan T. Johnson, JR.	Disclosed are devices that comprise a protein, such as an antibody, placed into electronic communication with a semiconductor material, such as a carbon nanotube. The devices are useful in assessing the presence or concentration of analytes contacted to the devices, including the presence of markers for prostate cancer and Lyme disease.
HIGH SENSITIVITY BIOSENSOR USING PIXEL ANALYSIS OF CMOS IMAGE SENSOR	30.04.2015; US20150116484	GWANGJU INSTITUTE OF SCIENCE AND TECHNOLOGY	Min-Gon Kim	Provided are a method of analyzing a target substance to be measured, the method including: dividing a surface of a measuring unit of a CMOS image sensor into a plurality of pixels, directly fixing a bioreceptor onto the surface of the measuring unit of the CMOS image sensor, and measuring chemiluminescent signals depending on concentrations of the target substance to be measured, and a CMOS image sensor applied to the same.
PORTABLE POCKET-SIZED BIOSENSOR	30.04.2015; US20150118695	Korea University Research and Business Foundation	Sehwan Paek	Disclosed herein is a portable biosensor, wherein a fluidic channel, comprising a porous solid matrix on which a capture recognition material of an analyte is fixed, is in contact with a signal detection sensor, wherein the signal detection sensor is a lens-free complementary metal oxide-semiconductor (CMOS) image sensors (CISs) for measuring a light signal generated by the reaction between the analyte and the capture recognition material.
PROCESS FOR BIOSENSOR WELL FORMATION	30.04.2015; WO/2015/061511	GENIA TECHNOLOGIES, INC.	DAVIS, Randall, W.	A biochip for molecular detection and sensing is disclosed. The biochip includes a substrate. The biochip includes a plurality of discrete sites formed on the substrate having a density of greater than five hundred wells per square millimeter. Each discrete site includes sidewalls disposed on the substrate to form a well. Each discrete site includes an electrode disposed at the bottom of the well. In some embodiments, the wells are formed such that cross-talk between the wells is reduced. In some embodiments, the electrodes disposed at the bottom of the wells are organized into groups of electrodes, wherein each group of electrodes shares a common counter electrode. In some embodiments, the electrode disposed at the bottom of the well has a dedicated counter electrode. In some embodiments, surfaces of the sidewalls are silanized such that the surfaces facilitate the forming of a membrane in or adjacent to the well.
BIOCOATED PIEZOELECTRIC BIOSENSOR PLATFORM FOR POINT-OF-CARE DIAGNOSTIC USE	23.04.2015; US20150111765	Lisa Laury-Kleintop	Lisa Laury-Kleintop	Biosensor components (chips) are described based on direct biocoating processes that result in the tenacious and stable, noncovalent (believed to be chemisorptive) binding of anchor substances such as avidin(s) other proteins having specific binding partners or oligo- or poly-nucleotides onto any piezo-electrically active crystal surface. The resulting platform technology can be developed for a variety of biosensors with specific applications in biological assays. The table mono layers of the anchor substances forms reactive layers, ready to bind a capture reagent such as a biot-inylated antibody for capture and detection of analytes in biologic fluid samples. Although the processes described herein can be performed on any type of piezoelectric material in any number of configurations, some embodiments are directed to a biosensor with the foregoing biocoating onto a particular acoustic plate mode biosensor and where the interdigitated transducers (IDTs) are present on the opposite side of the crystal's biocoated film.

Exhibit 1 lists some of the patents related to biosensors.

Picture Credit: Frost & Sullivan

5. TECHVISION 2015

The TechVision program is the premier offering of Technical Insights, the global technology innovation-, disruption-, and convergence-focused practice of Frost & Sullivan. TechVision embodies a very selective collection of emerging and disruptive technologies that will shape our world in the near future. This body of work is a culmination of thousands of hours of focused effort put in by over 60 global technology analysts based in six continents.

A unique feature of the TechVision program is an annual selection of 50 technologies that are driving visionary innovation and stimulating global growth. The selected technologies are spread across nine Technology Clusters that represent the bulk of R&D and innovation activity today. Each Cluster represents a unique group of game-changing and disruptive technologies that attract huge investments, demonstrate cutting-edge developments, and drive the creation of new products and services through convergence.

Our technology analysts regularly collect deep-dive intelligence on several emerging and disruptive technologies and innovations from around the globe. Interviews are conducted every day with innovators, technology developers, funders, and others who are a part of various technology ecosystems. The respondents are spread across public and private sectors, universities, research institutions, and government R&D agencies. Each technology is rated and compared across several parameters, such as global R&D footprint, year of impact, global IP patenting activity, private and public funding, current and emerging applications, potential adoption rate, market potential, and so on. This organic and continuous research effort spread across several technologies, regions, organizations, applications, and industries is used to generate an annual list of Top 50 technologies that have the maximum potential to spawn innovative products, services, and business models.

Furthermore, we analyze several possible convergence scenarios where two or more of the Top 50 technologies can potentially come together to disrupt, collapse, and transform the status quo. Driven by IP interactivity emanating from each of the top technologies, a whole range of innovative business models, products, and services will be launched at unprecedented speed in the future. We have come up with over 25 such unique convergence scenarios.

The Top 50 technologies we have selected for TechVision 2015 have the power to drive unique convergence and catalyze wide-scale industry disruptions. Frost and Sullivan's TechVision program empowers you with ideas and strategies to leverage the innovations and disruptive technologies that can drive the transformational growth of your organization.

Rajiv Kumar
Senior Partner

For more information contact:
techvision@frost.com

Visit us at:
www.frost.com/techvision

Follow us on:
@TechVision_FS
www.frost.com/techvisionlinkedin

Back to TOC