# TECHNICAL INSIGHTS

## SENSOR

## TECHNOLOGY ALERT

**20th March 2015**

## 1. LOW COST AND FLEXIBLE NANOSENSORS

Researchers from various universities and companies are using novel materials to develop sensors. There is a need for a method which can use low-cost materials and techniques to manufacture sensors that are economical and ensure high production efficiency. In addition, the sensor should be capable of being deployed in multiple applications, such wearables, security, clinical and food monitoring, and detection of chemical substances.

To address the above challenge, researchers from Universidad Politécnica de Madrid have developed a method to manufacture nanosensors on versatile substrates that can be used for smart labels and wearable devices.

Flexible nanosensors are manufactured using low cost materials, such as polycarbonate compact disc, aluminium, and adhesive tapes. Electron beam direct pattering is used to fabricate the sensor on the substrate. The researchers manufactured the nanosensors in two stages. In the first stage, the sensors were manufactured over the compact disc, which was made of traditional polycarbonate. In the second stage, the sensors are transferred to the adhesive scotch tapes with the help of a simple stick and peel procedure. In this way, the nanosensors are passed from the surface of the compact disc to the adhesive tape. Thus, the adhesive tapes help the nanosensor to be flexible in nature. The nanosensors consist of 250 nm dimensional nanohole arrays. The arrays are drilled into an aluminum layer which is 100 nm thick. The optical nanostructure will disperse and confine light, and, according to the need of the user, the sensors can be customized. With the help of these materials and method of manufacturing it is possible to produce optical nanosensors in bulk with low cost and high production efficiency.

Once the project is successfully commercialized, the optical nanosensors will used on biological and uneven surfaces, such as human skin. The optical nanosensor will be used in wearable devices to monitor different parameters, such as body temperature and heart pressure. The nanosensors will also be used in smart labels, such as radio frequency identification (RFID) as the key means for identification. The optical nanosensors are highly suitable for general use, such as clinical and food testing and monitoring applications. They canl also be used in security labeling applications. In addition, the flexible nanosensors would also be used to detect chemical substances by measuring the refractive index variations of the surrounding medium. Such a sensor also displays iridescent colors, which can vary according to the illumination and viewing angle. This further helps the detection of surface topography and position variations.

The project was supported by Technical University of Madrid. The researchers are currently working on identifying different applications for the nanosensors. The optical flexible and thin nanosensors are expected to be commercialized in two to three years' time. Once the nanosensors are successfully commercialized, they are expected to have opportunities in wearable devices.

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## 2. WEARABLE SENSOR PATCH WITH PRESSURE SENSITIVE SENSORS

Wearable electronic devices are witnessing significant adoption in various sectors, such as consumer electronics, healthcare, and defense. among others. The devices are continuously evolving, giving users the freedom to control their key devices, such as mobile phones with ease.

Indicative of the keen activity in developing unique wearable devices, which can perform with high accuracy and precision and can be used by for long periods on the body, researchers from Saarland University have developed a flexible silicone rubber sticker with pressure-sensitive sensors that fit into the skin comfortably. The researchers have named the device iSkin.

Multiple layers of thin, flexible, and stretchable silicone are used to manufacture iSkin. Polydimethylsiloxane (PDMS) is the base material used for iSkin. PDMS is employed because of its transparent and elastic characteristics. PDMS is widely used on the human body because of its highly biocompatible characteristics. For transmitting and receiving electrodes, cPDMS (carbon-filled PDMS) is deployed. PDMS is filled with carbon black particles so that the material appears black and opaque. PDMS is very inexpensive, and, if desired, the sensor patch can be designed for one-time use. The material is fabricated with the help of the laser patterning technique. There are two levels of pressure for touch sensing--capacitive sensing is used to determine light touch and resistive sensing is used to determine firm pressure on the iSkin. To process the data and drive the sensor, the flexible sensor patch is probed with a ribbon cable to a microcontroller which is Arduino compatible. With the frequency of 17 KHz, the measurement of signals from the sensor is done with the help of time division multiplexing (TDM).

Once the iSkin project is successfully commercialized, it can enable several classes of interaction with consumer devices. The iSkin can be used to answer incoming calls and adjust the volume of mobile devices. The iSkin device will enable the human body to get in close contact with electronic devices. In the future, the device would also be used as a keyboard sticker to type and send messages. At present, the device uses probes to connect with the computer, but with the help of iSkin , the researchers are planning to create a chip which will operate without wires in the future. The iSkin device can be either wrapped around a body part or attached to the skin using biocompatible adhesives.

The project was supported by Carnegie Mellon University. The researchers are currently identifying ways to address the future challenges for touch input on the skin. Areas of interest include extending the input modalities and capabilities of the device, reduction of noise or unintentional inputs, integrating the device with mobile computers and identifying ways to provide a high level of comfort to the users. Once the iSkin device is successfully commercialized, it has potential to get a good response from the consumer electronics industry.

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## 3. SELF-POWERED SENSOR FOR STRUCTURAL HEALTH MONITORING

The structural health monitoring (SHM) market is evolving steadily and there has been particular interest in monitoring aging structures. At present, researchers are working on smart materials, smart composites, bio-inspired sensors, and nanosensors among others. Wireless sensor networks are gaining significant traction in structural health monitoring. With respect to the coverage area, the sensors are very efficient but they are not especially efficient in terms of powering the device. In addition, battery-powered devices need scheduled maintenance, which further increases the cost of maintaining the device. There is a need for improved technologies for self-powering a device with the help of mechanical parameters, such as vibrations. In addition, the device should be easy to use and provide accurate results.

To address the above challenges, researchers from Michigan State University are developing a self-powered sensor enabled by a new technology called substrate computing. The researchers are currently working on the smart, modular substrates which can be embedded with properties, such as communications, sensing, and computing and which further uses ultrasound communications and mechanical energy harvesting. The main aim of the research is to integrate all of these functions in a tiny 3 millimeter-by-3 millimeter electronic chip, which can be further embedded within the material of the structure. This electronic chip when implanted in the structure will be able to detect the nature of a fault, send the information about the nature of the fault through the structure's material and then compute the fault pattern across the entire structure. The chip will be cost effective in monitoring structures and will be able to power itself with the help of mechanical forces.

The chip is expected to be used for structural health monitoring purposes in dams, tunnels, and bridges, where scheduled maintenance is not cost efficient and can be unreliable. The self-powered sensor will help perform real-time monitoring of the structures, which will further help to diagnose issues and address them in time. In the future, the self-powered sensors are expected to have advanced capabilities, such as self-sensing, self-healing or self-learning. In addition, the researchers will also try to identify applications of their self-powered sensors in different industries, such as aerospace, transport, and energy among others. In the future, the self-powered sensor will offer features such as robustness and flexibility. According to the current market scenario, there is strong demand for the self-powered sensors in SHM. Self-powered sensors will have an impact of megatrends, such as smart is the new green, convergence and connectivity, and innovating to zero.

The project is being funded by the National Science Foundation. The researchers are currently working on the challenge of battery replacement for battery-powered sensors. The research is being supported by the civil and environmental engineering department of Michigan State University. The product is expected to get a good response from the civil engineering industry, especially for structural health monitoring. Commercialization is expected in around six years.

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## 4. RECENT PATENTS IN THE FIELD OF NANOSENSORS

A nanosensor is a very miniature sensor built on the nanoscale, which is capable of obtaining data on the atomic scale and detecting stimuli such as biological or chemical substances and physical stimuli such as pressure. Such sensors are ultra-sensitive.

The different methods for manufacturing nanosensors are lithography, bottom-up assembly, and molecular self-assembly among others. The different material platforms used for nanosensors include nanoparticles, carbon nanotubes, nanoelectromechanical systems (NEMS), spintronics, biological/organic systems, nanowires, nano coatings and molecular electronics. Carbon nanotubes (CNTs) can have exceptional properties, such as high mechanical strength and a high length-to-radius ratio; but nanosensors based on changes in electrical conductance can be limited by poor charge transfer with CNTs.

Nanosensors are used to sense at the molecular scale, for instance, as an array of sensors that can be used in applications such as electronic noses. Nanosensor technology also enables the creation of highly reliable, exquisitely sensitive, and selective sensors, with lower detection limits and miniaturized, ultra-low power sensors and detection systems, which are able to analyze very small quantities.

Nanosensors have been under development and deployed in CBRNE (chemical, biological radiation, nuclear, explosives) detection, where a single device can detect multiple threats. Nanosensors can benefit military or homeland security applications by providing highly sensitive and selective sensors, and large-scale sensor arrays for broader detection coverage. In addition, nanosensors will enable enhancements in applications, such as healthcare and environmental monitoring, automobile and aerospace among others.

 

The most number of patents have been published in China, followed by the Republic of Korea. This shows a strong focus on nanosensors and nanotechnology in the APAC region. Mostly, research institutes and universities are publishing patents in this field. Among corporations, Samsung Electronics Co has the most number of patents. Nanotechnology research has been quite strong in North America, in areas, such as, chemical and biological agent detection. European universities and organizations are actively involved in developing and commercializing nanotechnology-based sensing devices. Among them, the Fraunhofer Institutes are researching various nanosensor technologies. Technology research in this region is underway. A*STAR is a key organization that has been conducting research on nanosensors.

Government agencies play an important role in the development of nanosensors, including, supporting university or industry research. Adequate funding is required to develop nanoscale sensors and increase the adoption rate.

Patents pertaining to nanosensors are geared toward improving methods of operation, materials used, and the ability to detect varied analytes of interest. For example, WO/2015/035271, assigned to Virginia Commonwealth University, pertains to highly sensitive nanosensors that inhibit glycosaminoglycan (CAG)-cleaving enzymes.

| Title | Publication Date/ Publication Number | Assignee | Inventor | Abstract |
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| NANOSENSOR FOR DETECTING THE ACTIVITY OF GLYCOSAMINOGLYCAN-CLEAVING ENZYMES AND USES THEREOF | 12.03.2015; WO/2015/035279 | VIRGINIA COMMONWEALTH UNIVERSITY | DESAI, Umesh, R.. | High sensitivity nanosensors for detecting the inhibition of glycosaminoglycan (GAG)-cleaving enzymes are provided. Methods of using the nanosensors include detecting contaminants in commercial GAG preparations (e.g. heparin preparations) by measuring the activity levels of a GAG)-cleaving enzyme in the presence of a sample which may contain a contaminant that inhibits the GAG-cleaving enzyme. |
| SURFACE PLASMON-BASED NANOSENSORS AND SYSTEMS AND METHODS FOR SENSING PHOTONS AND CHEMICAL OR BIOLOGICAL AGENTS | 25.09.2014; US20140285809 | | | Surface plasmon-based nanosensor, comprising: at least one first element of metal, preferably silver or gold, or of semiconductor, the first element being excitable to surface Plasmon resonance, in particular localized surface plasmon resonance, in the presence of electromagnetic radiation from a source, and at least one second element preferably near the first element that in the presence of the electromagnetic radiation is exciton-plasmon coupled to the first element and emits electromagnetic radiation representative of the exciton-plasmon coupling, and systems and methods for sensing photons and chemical or biological agents. |

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| NANOMAGNETIC DETECTOR ARRAY FOR BIOMOLECULAR RECOGNITION | 14.08.2014; US20140228227 | Litvinov Dmitri | Litvinov Dmitri | A biomolecular sensor system includes an array of magnetoresistive nanosensors designed for sensing biomolecule-conjugated superparamagnetic nanoparticles. Materials and geometry of each sensor element are designed for optimized sensitivity. The system includes magnetic field generators to apply forces to superparamagnetic nanoparticles for 1) nanoparticle manipulation, 2) sensor magnetic biasing, 3) magnetic pull-off measurement for differentiation against non-specific association, and 4) removal of all particles from the sensor array surface |
| Microbe Detection Via Hybridizing Magnetic Relaxation Nanosensors | 07.08.2014; CN103427150 | Naser Saleh | Naser Saleh | Disclosed herein are methods and materials for facilitating the detection of nucleic acid analytes of interest. Specifically exemplified herein are methods for detecting mycobacterial microorganisms, namely *Mycobacterium avium* spp. *paratuberculosis*. Also disclosed is new hybridizing magnetic relaxation nanosensor (hMRS) particularly adapted to detect a target nucleic acid analyte of interest. |
| Nanosensors and methods of operating nanosensors | 16.07.2014; EP2755022 | HONEYWELL INT INC | MIHAILA MIHAI N | Nanosensors and method of operating nanosensors are described herein. One nanosensor (100) includes a nanomaterial (110), such as nanowire, nanoribbon or graphene materials , a nanogap (112) in the nanomaterial, and an instrument (114) configured to measure a current or resistance of the nanogap. One method includes passing a molecule (118),such as DNA, through a nanogap in a nanomaterial, measuring a current or resistance of the nanogap while the molecule is passing through the nanogap, and identifying the molecule based on the measured current or resistance of the nanogap. |
| Optical Nanosensors Comprising Photoluminescent Nanostructures | 20.03.2014; US20140080122 | Massachusetts Institute of Technology | Strano Michael S. | Systems and methods related to optical nanosensors comprising photoluminescent nanostructures are generally described. Generally, the nanosensors comprise a photoluminescent nanostructure and a polymer that interacts with the photoluminescent nanostructure. In some cases, the interaction between the polymer and the nanostructure can be non-covalent (e.g., via van der Waals interactions). The nanosensors comprising a polymer and a photoluminescent nanostructure may be particularly useful in determining the presence and/or concentration of relatively small molecules, in some embodiments. In addition, in some instances the nanosensors may be capable of determining relatively low concentrations of analytes, in some cases determining as little as a single molecule. In some embodiments, the interaction between the analyte and the nanosensor (e.g., between the analyte and the photoluminescent nanostructure) can be reversible, which may allow, for example, for the reuse of a nanosensor after it has been exposed to an analyte. |

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| NANOSENSORS INCLUDING GRAPHENE AND METHODS OF MANUFACTURING THE SAME | 06.03.2014; US20140062454 | SAMSUNG ELECTRONICS CO., LTD. | JEON Tae-han | Nanosensors including graphene and methods of manufacturing the same. A nanosensor includes a first insulating layer in which a first nanopore is formed; a graphene layer that is disposed on the first insulating layer and having a second nanopore or a nanogap formed therein adjacent to the first nanopore; and a marker element that is disposed adjacent to the graphene layer and identifies a position of the graphene layer. |

**Exhibit 1 lists some of the patents related to nanosensors.**

*Picture Credit: Frost & Sullivan*

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