TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

26th June 2015

1. ORGANIC SEMICONDUCTORS ENHANCE IMAGE SENSORS

Organic semiconductors (organic materials with semiconductor properties) can offer key benefits for image sensing compared to conventional silicon semiconductors, such as the ability to absorb more light (which can boost sensitivity and image capture even in low-light conditions); lightweight; robustness; streamlined design; ability to function on flexible substrates; and ability to be produced at relatively low cost and to sense color. However, organic electronics can have limited electrical conductivity; and organic photodiodes should have sufficient photosensitivity for use in image sensors.

Researchers at the University of Queensland in Australia achieved key progress in the design of more cost-efficient image sensors with improved ability to recognize colors.

As noted in "Narrowband light detection via internal quantum efficiency manipulation of organic photodiodes" (Nature Communications 6, Article number 6343, published on February 27, 2015), the researchers used broadband-absorbing organic semiconductors and the electro-optical properties of the junction "to create the narrowest NIR (near infrared)-band photoresponses yet demonstrated." The photodiodes are found to outperform incumbent technology (input filtered inorganic semiconductor diodes) and emerging technologies (for example, narrow absorber organic semiconductors or quantum nanocrystals. The design concept enables response tuning, and the desired color can be selected by adjusting the thickness of the light-absorbing layer of the sensor. The concept is also generic with respect to other spectral windows and is material agnostic and suitable for other disordered or polycrystalline semiconductors.

The researchers noted that spectrally-selective light detection is crucial for full-color NIR (near infrared) imaging and machine vision. However, this is not achievable using traditional broadband-absorbing inorganic semiconductors without input filtering and has yet to be realized for narrowband absorbing organic semiconductors. The researchers claim to have demonstrated the first sub-100 nm full-width-at-half-maximum visible-blind red and NIR photodetectors exhibiting state-of-the-art performance across key response metrics.

The organic photodiodes (that these devices are based on) have optically thick junctions. Broadband-absorbing organic semiconductors are used and electro-optical properties of the junction to create the narrowest NIR-band photoresponses. The photodiodes outperform input filtered inorganic semiconductor diodes and emerging technologies such as narrow absorber organic semiconductors or quantum nanocrystals. The design enables response tuning, is generic for other spectral windows, is material-agnostic, and applicable to other disordered and polycrystalline semiconductors.

Their innovative approach can open the field of image sensing to a number of potential new-generation applications in technologies such as medical imaging, robotics and intelligent surveillance.

The image sensor uses organic plastic semiconductors, rather than conventional inorganic silicon semiconductors to absorb light. It eliminates any need for a color filter system, which silicon-based technologies using silicon can require.

The technology can be particularly important for use in outdoor settings since colour filters are unable to cope under situations with extreme light conditions. In the design, the desired color can be selected by adjusting the thickness of the light-absorbing layer of the sensor, a capability that renders the design distinctive with respect to organic semiconductors for imaging technologies.

The organic light-absorbing layers of the new image sensors are inherently able to operate on large and flexible surfaces. With reduced design complexity, such sensors could enable production of simpler and less expensive device structures in the future.

The new design can enable the sensors to outperform conventional silicon image sensors over a range of metrics, including the ability to cope with larger light extremes (or the dynamic range), image sensitivity, capacity to rapidly respond to light signals, and the ability to select and sense particular colors.

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2. FIBER OPTIC SENSOR RAPIDLY DETECTS SMALL TEMPERATURE CHANGE

Fiber optic sensors use optical fiber as the sensing element or to relay signals from the sensor to remote electronics where signal processing occurs. Such sensors can be used in environments with high-voltage electricity or flammable materials, and can endure high temperatures. Fiber optic temperature sensors are able to function effectively in environments with high levels of electronic or electromagnetic interference or where intrinsic safety is an issue.

Researchers at the University of Nebraska-Lincoln and the US Naval Research Laboratory have designed a next-generation fiber optic temperature sensor for enhanced measurement of ocean dynamics that can affect marine biology, climate, and military operations.

By attaching a small silicon pillar to the tip of the fused silica glass used in optical fibers, the researchers enabled the sensor to register substantially smaller temperature changes at around 30 times the speed of existing commercial counterparts.

Co-designer Ming Han, associate professor of electrical and computer engineering, University of Nebraska-Lincoln, noted that the optical density of silicon naturally changes when exposed to even slight temperature shifts, rendering it a sensitive material especially suited for thermometry. The ease in which it transfers heat, combined with the sensor's small size, can enable the silicon to register such changes at very rapid rates.

The team also developed an innovative signal-processing technique that averages multiple wavelength peaks to help decrease signal noise, which can create artificial temperature fluctuations and impede the sensor's precision.

The fiber optic sensor's capabilities will help advance the measurement of the constantly shifting and subtle temperature changes in the underwater environment. The ocean's temperature can undergo a small change very quickly in a turbulent setting. A sensor with a very rapid response speed is needed to accurately detect such minute changes and to distinguish a signal from unwanted noise.

The high-speed fiber optic temperature sensor has opportunities to enhance underwater transmission of optical and acoustic signals and to aid in forecasting climatic events. For example, efforts have been focused on tools to quantify how heat flows from one direction to another at high rates yet on a small scale. Such information would help predict the circulation of ocean currents and the atmosphere by shedding insight on how energies (heat energy and heat flux) mix.

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3. QUANTUM TECHNIQUE IMPROVES MICROCANTILEVER SENSORS

Microcantilever-based sensors can provide benefits for sensing physical, chemical, or biological parameters by detecting changes in the bending or vibrational frequency of the cantilever. Key advantages of microcantilever sensors include the ability to be configured in arrays for multi-analyte detection, to possess miniature size, have rapid response time, and possess high sensitivity.

A quantum sensor is a device that exploits quantum correlations, such as quantum entanglement, to achieve superior sensitivity or resolution. Quantum entanglement occurs when pairs or groups of particles are generated or interact in ways so that the quantum state of each particle cannot be described independently. Instead, the quantum state may be given for the system as a whole.

Researchers at the US Department of Energy's Oak Ridge National Laboratory have leveraged quantum correlated light beams to achieve extraordinary or uncommon levels of detection from microcantilever-based sensors. They used quantum correlated beams of light to surmount the basic detection limit of microcantilever sensors due to fluctuations in intensity. The

technique could substantially enhance applications such as thermal imaging, microscopy, or ultra-trace chemical detection.

By reducing the low noise to an unprecedented level, the researchers allowed the microcantilever sensors to provide images with considerably improved, detailed and discernible features

The researchers focused their efforts to surmount basic limitations of detection derived from the Heisenberg uncertainty principle, which stipulates that a particle's position and momentum cannot be measured with absolute precision. The more accurately one of the values is known, the less accurately the other value can be ascertained.

The researchers noted that a similar Heisenberg uncertainty relation exists with respect to the intensity and phase of light. They were able to exceed the quantum limit without violating the uncertainty principle by moving the noise out of the variable of interest and into an area that is not of interest and is not detected.

The technique, using two beams of light to cancel noise, can achieve a 60% error reduction, enabling higher contrast imaging and detection of lower concentrations of particle, compared to conventional sensors.

The researchers declared that the work represents the first time that quantum states have been applied to practical micro-electromechanical systems (MEMS) devices, which include sensors to measure temperature, pressure, inertial forces, chemicals, magnetic fields and radiation. The researchers used an off-the-shelf cantilever, similar to a miniature diving board. The technique for improving the cantilever's sensitivity is in sync with existing sensing and imaging platforms.

The development also provides a base for integrating the sensor into an existing device, such as very high resolution atomic force microscopes, which are capable of imaging, detecting, and manipulating matter at the nanoscale level.

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4. RECENT PATENTS IN THE FIELD OF BIOSENSORS

A biosensor (also called as biological sensor, or in certain applications referred to as an immunosensor) is a chemical sensing device composed of a sensor and a biological element (such as an enzyme, antibody, and so on). The bioelement interacts with the target analyte, and the sensor converts the biological response into an electrical signal.

To monitor health and warn people about disease, various companies are developing low-cost biosensing devices. Printing on plastic or paper can enable such sensors to be manufactured at a low cost. Biosensors are penetrating various industry segments such as environmental, security, biodefense, home diagnostic, point of care, and many more. Point of care (POC) will enable biosensor devices for diabetes management, cardiac monitoring, blood analyzers, and several others. Home-based health monitoring biosensor devices include blood glucose monitoring devices, pregnancy test kits, blood cholesterol monitoring devices, and wearable biosensors for monitoring health.

Since 2012, the number of patents published in the domain of biosensors is increasing every year, which further indicates growing interest and increase in possibilities of application from near to medium term. Key growth areas expected for biosensors include POC biosensor devices, home-based health monitoring devices, and biodefense devices.

Biosensors are insensitive to the temperature and electrical interference, providing an output signal with high reliability. Biosensing devices will be cost efficient because of the advancement in printed and flexible electronics and printing techniques, which will further help to manufacture low-cost biosensor devices. Thus, the ability to provide accurate output signal with high reliability and enhanced speed of response makes biosensors highly feasible for non-clinical and clinical applications.

A recent patent (WO/2015/089092), assigned to Illumina Inc., is for a biosensor for biological and chemical analysis, which has an array of light sensors and an array of light guides.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
BIOSENSORS FOR BIOLOGICAL OR CHEMICAL ANALYSIS AND METHODS OF MANUFACTURING THE SAME	18.06.2015; WO/2015/089092	ILLUMINA, INC.	ZHONG, Cheng, Frank	Biosensor including a device base having a sensor array of light sensors and a guide array of light guides. The light guides have input regions that are configured to receive excitation light and light emissions generated by biological or chemical substances. The light guides extend into the device base toward corresponding light sensors and have a filter material. The device base includes device circuitry electrically coupled to the light sensors and configured to transmit data signals. The biosensor also includes a shield layer having apertures that are positioned relative to the input regions of corresponding light guides such that the light emissions propagate through the apertures into the corresponding input regions. The shield layer extends between adjacent apertures and is configured to block the excitation light and the light emissions incident on the shield layer between the adjacent apertures.
GAS EVACUATION SYSTEM FOR NANOFLUIDIC BIOSENSOR	18.06.2015; WO/2015/087178	ABIONIC SA	DURAND, Nicolas	A nanofluidic biosensor system (200) comprising a bottom substrate (120) and a top substrate (110) between which are defined an input lateral aperture (210), a nanoslit (230) which contains at least one functionalized area (231) and an output lateral aperture (220) or an internal reservoir (221), said biosensor system (200) being adapted to let a solution containing biomolecules (320) enter the input lateral aperture (210) and successively pass through said nanoslit (230) and said output lateral aperture (220) or internal reservoir (221); said biosensor system (200) furthermore comprising a gas evacuation subsystem (150-155) which is located between said nanoslit (230) and the biosensor external environment.
SENSOR CHIP AND BIOSENSOR SYSTEM	11.06.2015; WO/2015/083749	SHARP KABUSHIKI KAISHA	YASHIRO Yuhji	In order to detect substances derived from living organisms with high accuracy, this sensor chip comprises: an insulation film (2) having a capture surface (2a) on which a capture substance is fixed that reacts with or binds to the substance being measured derived from a living organism; and multiple electrode groups (S1-S6, D1-D5) provided on the side of the insulation film (2) opposite of the capture surface (2a) and arranged side by side in at least one direction. A supplementary substance (R) is formed on the capture surface (2a) in a region that overlaps with the multiple electrodes in planar view and/or in a region between at least two of the aforementioned multiple electrodes in planar view.
BIOSENSOR COMPRISING WAVEGUIDE	11.06.2015; WO/2015/082247	KONINKLIJKE PHILIPS N.V.	SCHLEIPEN, Johannes Joseph Hubertina Barbara	The invention relates to an optical device (110) and a corresponding detection apparatus (100) that may for example be used for monitoring the replication of nucleotide sequences at a surface. In a preferred embodiment, the optical device (110) comprises a waveguide substrate (130) with a wiregrid (140) on a bottom surface (132), wherein apertures (141) of the wiregrid are in at least one direction (x) smaller than a characteristic wavelength (λ) of input light (IL). Moreover, a diffractive structure (120) is disposed on the opposite surface (131) of the substrate (130) for coupling input light (IL) into the substrate (130) such that constructive interference occurs at the apertures (141). Thus evanescent waves can be generated with high efficiency in these apertures, allowing for example for a surface-specific excitation of fluorescence (FL) that can be sensed by a detector (160).
IMPLANTABLE BIOSENSOR	11.06.2015; WO/2015/084269	PANG, Dexing	PANG, Dexing	The present invention provides a fully implantable device for monitoring at least one physiological parameter of an individual. The device comprises at least one sensor configured to generate a sensor signal representative of the physiological parameter, where each sensor has at least one electrode and at least one membrane adapted to separate the electrode from a medium external to the device. The device also has a programmable chip configured to receive, process and transmit the sensor signal, and a housing adapted to accommodate the sensor and the programmable chip. The present invention further includes a transponder for working with the device and a kit including the device and a means for implantation of the device. Furthermore, the present invention includes a system for monitoring at least one physiological parameter of an individual, the system including a fully implantable device.
ELECTRICAL BIOSENSOR FOR DETECTING A SUBSTANCE IN A BODILY FLUID, AND METHOD AND SYSTEM FOR SAME	28.05.2015; WO/2015/077632	AVAILS MEDICAL, INC.	KNOPFMACHER, Oren S.	An electrical biosensor for use with a reader is provided and can include an electrical component configured such that the coupling of a targeted substance to a surface of the electrical component changes an electrical characteristic of the electrical component. A protein immobilization structure can be disposed on the surface and can include an array of functionalized structures for interacting with a substance in a sample of a bodily fluid. Each functionalized structure can include a protein capable of binding to a targeted chemical substance or substance in the sample whereby an electrical reading can be obtained by a reader to determine the concentration level of the targeted substance in the sample.
BIOCHIP WITH BIOSENSORS AND FLUIDIC DEVICES	21.05.2015; US20150139857	TAIWAN SEMICONDUCTOR MANUFACTURING COMPANY, LTD	Yi-Shao LIU	A biochip includes a substrate, where the substrate includes at least one hole extending from a first surface of the substrate to a second surface of the substrate opposite the first surface, and where the substrate comprises a microfluidic channel pattern. The biochip further includes a surface modification layer over the substrate. Additionally, the biochip includes a sensing wafer bonded to the substrate, where the sensing wafer has one or more modified surface patterns having different surface properties from each other.

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.

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Back to TOC