TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

07th February 2014

1. SELF-POWERED ELECTRIC CURRENT SENSORS

The electric grid is one of the most important utilities that provide power to commercial, residential, and industrial users. The electric grid is required to function 24x7 and power outages lead to massive losses in terms of economy and also convenience. It is thus imperative to have systems, which monitor the performance of key assets of the grid to have efficient and continuous operation. For this purpose sensors play an important role. Electric current sensors are required to measure current levels in various components such as cables, conductors, bus bars, and junctions. Currently, sensors generally need an external power supply as well as signal conditioners, which have limited their usage to a large extent.

To address this challenge, researchers at Hong Kong Polytechnic University's department of electrical engineering have developed a tiny chip, which effectively senses current, and uses energy harvesting technique to generate electrical enegry. The chip measures about 1 mm in thickness and can be placed on components where current needs to be sensed. The chip uses advanced functional materials, made from rare earth multiferroics having high-magnetoelectric property. The chip detects magnetic fields generated by the electricity and uses a linear conversion technique to derive electric voltage signals. The amplitude of these converted signals is directly proportional to the measured magnetic field.

The sensors are passive and do not require any power cords and active electronic components. This makes the chips very convenient for deployment in various places that are difficult to reach. Moreover, the chips are safe and can be reliably used to detect electric faults at an early stage. This technology will aid grid operators in early detection of electric faults and enable them to take preventive measures to ensure continuity in power supply. The developed chip

can detect the condition of various kinds of electrical equipment including those carrying heavy current, strong electromagnetic fields, and high voltages. The chips produce output signals, which the research team claim have more clarity than those produced by conventional current sensors.

The sensors harvest electromagnetic radiations and convert them to electrical energy. This energy can be used for powering displays, wireless transmitters, microcontrollers, and other components that run on low-power electronics. It is important to have self-powered wireless sensors in electric power grid applications as they necessarily overcome challenges posed by wired sensors. Such challenges include deployment issues, maintenance issues, space consumption, and lifetime cost issues.

The sensors can not only be used in power grids to make them smarter, but also in other applications where electric fault detection is necessary. The developed wireless sensors are currently being tested in electrical traction systems used on trains in Hong Kong and Singapore. The sensors are being used to monitor electrical faults and traction conditions. The technology developed by the researchers has been patented. The researchers are trying to further improve the sensors by enhancing their energy harvesting capability as well as making them more sensitive and reliable. The research was supported by a € 0.5 million fund by E-T-A Elektrotechnische Apparate GmbH (E-T-A), Germany. E-T-A is working with the Hong Kong Polytechnic University to embed the wireless sensor technology into next generation electrical circuit protection devices.

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2. MINIATURIZED TEMPERATURE AND HUMIDITY SENSOR USING CHIP-SCALE PACKAGING

With the advent of wearable mobile computing, space and power consumption are two areas where a lot of research and development is happening. It is important to develop components, which consume ultra-low power, and are able to fit into tight space constraints. This is primarily important because of the host of sensors and electronic components that are

being integrated into mobile devices. Moreover, since currently available batteries have limited capacity it is important that each component draws as little power as possible. In mobile electronics, sensors are integral components and multiple applications are based on them.

Sensirion AG, Switzerland, has leveraged chip-scale packaging technology to develop an ultra-low power, miniature temperature and humidity sensor--SHTW1--that is targeted primarily toward the wearable computing market. Humidity and temperature are two key parameters that are being monitored in such wearable computing devices. The SHTW1 sensor is based on Sensirion's proven CMOSens technology. The CMOSens technology allows sensor components to be integrated with the evaluation circuit in a single semiconductor chip. The integration uses specific microsystem processes to develop the sensor structure on patented semiconductor parts. The resulting sensor chips are able to provide high reliability and precision while being cost-effective. By having wafer-level chip-scale packaging Sensirion has ensured that the SHTW1's package is not larger than the CMOSens chip itself. This results in the small size of the sensor without compromising on performance.

The SHTW1 has dimensions of only 1.3 mm x 0.7 mm x 0.5 mm (length x breadth x height) and thus can be easily integrated into current generation mobile devices and future applications. Such applications can include smart glasses, body worn sensors systems, smart watches, and smart clothing. The sensor has an operating voltage of 1.8 V with an ultra-low power consumption of 2 microWatts. It can take measurements at a rate of 1 per second to give a continuous data stream that can be used for analysis. The sensor measures relative humidity (RH) with an accuracy of +/- 3% across a range of 0% RH to 100% RH. The temperature sensor has an accuracy of +/- 0.3 degree C and has a wide range of -30 degree C to +100 degree C.

Sensirion is presenting the SHTW1 chip at the Mobile World Congress 2014, Barcelona, Spain, from February 24 to 27, 2014. The product is expected to be integrated into mobile devices having small form factor as well as in smartphones. Even though consumer electronics is the most promising market for the sensor, it can find application in other areas such as building management, industrial monitoring, and healthcare.

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3. E-NOSE RELYING ON SINGLE SILICON NANOWIRE FET SENSOR

Electronic noses (E-noses) are basically an array of sensors, used to selectively detect gases and volatile organic compounds (VOCs). E-noses have multiple potential applications in various industries such as disease diagnosis, environmental monitoring, and CBRNE (chemical, biological, radioactive, nuclear, and explosive) detection. It has been proven that by using nanosensors, the selectivity and sensitivity of gas sensors as well as E-noses can be improved multi-fold. Silicon nanowire field effect transistors (SiNW FETs) have shown to enable real-time, highly sensitive detection of multiple analytes when present in the liquid phase, but have so far not been able to prove their effectiveness for detecting gaseous chemical substances.

Researchers from Technion-Israel Institute of Technology, have researched on SiNW FETs and found out its applicability in VOC sensing. The researchers used molecularly modified SiNW FETs for detecting the VOCs. They found that a single SiNW FET can provide multiple signals when interacted with a VOC. The multiple signals perform similarly to a sensor array, but instead of using multiple sensors, one SiNW FET can suffice. This shows that only one sensor can possible selectively detect the VOCs in an environment. By using only one FET sensor, the overall device size of an E-nose can be reduced and at the same time reduce power consumption and cost. This can also lead to simplified circuitry in the E-Noses.

The multiple signal levels detected by the SiNW FET include voltage threshold, sub threshold swing, hole mobility, and so on. This information serves as input for an artificial neural network model. The model can be trained to enable selective detection of the VOCs. Artificial neural networks are computational models, which are capable of pattern recognition. Using the pattern recognition process, the model can selectively detect the analyte.

The researchers believe that this approach of using a single sensor and the supporting computational model can be used for detecting analytes in both gaseous and liquid phases. This can be used for applications such as environmental monitoring as well as disease diagnosis in the gaseous phase. For example, the breath of a patient can be analyzed in short times to detect

biomarkers for disease diagnosis. For real world applications, it is necessary to develop the SiNW FETs to have very fast response times and high selectivity. For the computational part the pattern recognition algorithm needs to be efficient so that it consumes minimum processing time.

The findings of this research were recently published online in the journal, *Nano Letters* on January 17, 2014, in a paper titled, Artificial Sensing Intelligence with Silicon Nanowires for Ultraselective Detection in the Gas Phase. The year of impact for commercial E-noses employing single SiNW FETs and artificial neural network models is expected to be between 2019 and 2020.

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4. PATENT ANALYSIS--TERAHERTZ SENSORS

The terahertz (THz) region is a part of the electromagnetic spectrum spanning from 100 GHz to 10 THz. T-rays have wavelength of 3 to 100 cm-1. The terahertz region is able to provide unique information that cannot be observed using techniques such as optical imaging, X-ray imaging, and nuclear magnetic resonance imaging. The key benefits of terahertz sensing includes are that the radiation is non-ionizing and safe. Terahertz waves can also pass through various materials, such as clothing, plastics, and paper that are opaque to visible light. It is possible to identify materials by using terahertz imaging. Terahertz sensing can also provide important insights into the quality of semiconductor materials.

Terahertz imaging has seen increased interest in recent years, primarily for applications in the field of security, inspection, and research. Key players active in patent publishing include Canon Inc. (Japan), Honeywell International Inc. (USA), and Sensor Electronic Technology (USA). However, patenting activity has not been increasing steadily and most number of patents was published in 2010. After that there has been a drop in patenting activity. Recent patents indicate the use of terahertz sensors primarily for imaging purpose. Patent CN 102794947 indicates the usage of carbon nanotube composite films for preparing a terahertz photoelectric detector.

PATENT TITLE	PUBLICATION DATE / NUMBER	APPLICANT/ ASSIGNEE	INVENTORS	ABSTRACT
SENSOR DEVICE	19.09.2013; US 20130240740	CANON KABUSHIKI KAISHA	Ouchi Toshihiko	A sensor device has an optical waveguide containing an electro-optic crystal for propagating light, a coupler provided adjacent to the optical waveguide to propagate a terahertz wave generated from the electro-optic crystal as a result of the propagation of light in the optical waveguide, and a detector for detecting the terahertz wave propagating through the coupler or the light propagating through the optical waveguide. The terahertz wave is totally reflected in a section of the coupler opposite to a section where the coupler is adjacent to the optical waveguide while passing through and propagating in the optical waveguide, and in the total reflection section, the terahertz wave interacts with a subject placed close to the total reflection section.
METHOD TO DETERMINE DEPTH OF PENETRATION OF FIELD OF TERAHERTZ SURFACE PLASMONS INTO ENVIRONMENT	27.08.2013; RU 0002491533		Sergey Kuznetsov (RU)	FIELD: measurement equipment. SUBSTANCE: invention relates to optical methods of metal and semiconductor surface control in terahertz range of the spectrum and may find application in technological processes for control of thickness and homogeneity of thin-layer coatings of metallised items and semiconductor substrates, in the methods for detection of irregularities on/of conducting surface, in infrared (IR) refractometry of metals for determination of their dielectric permeability, in IR sensor devices and inspection technology. The method includes measurement of intensity of the field of surface plasmons (SP) in the plane of drop of radiation generating a bundle of SP rays, and calculation of the value 5 by results of measurements, for this purpose the SPs are converted into a volume wave on the front line, which belongs to the selected plane of the

				bundle cross section, the wave is focused into a line lying in the drop plane, and distribution of radiation intensity is measured on this line, and the angle of inclination of wave rays to the surface, guiding the SPs. EFFECT: invention makes it possible to reduce time of measurements. 2 dwg
CALIPER COATING MEASUREMENT ON CONTINUOUS NON-UNIFORM WEB USING THZ SENSOR	15.08.2013; WO/2013/116924	HONEYWELL ASCA INC.	SAVARD, Stephane	An analytical model simulates the propagation of radiation through a coated continuous web where layer thickness and refractive index, as variables, determine the speed and direction of transmitted radiation. The model predicts characteristics of transmitted radiation based on characteristics of incident radiation and initially assigned values for layer thicknesses. Coating thickness(s) are ascertained in a process whereby incident radiation of known characteristics is directed onto a coated web and thereafter, actual measurements of transmitted radiation are compared to predicted characteristics. Using a fitting algorithm, the assigned thickness(es) of the layer(s) of the model are adjusted and the process repeated until the actual and predicted values are within desired limits at which time, the assigned thickness(es) represent the measured calipers. Radiation measurements are obtained using terahertz time-domain spectroscopy apparatus that creates a continuous reference whereby a sample pulses' phase and amplitude can be tracked and corrected.
HIGH-SPEED GIGA-TERAHERTZ IMAGING DEVICE AND METHOD	27.06.2013; WO/2013/096805	TERASENSE GROUP, INC.	KUKUSHKIN, Igor	A high-speed room-temperature imaging system, especially for electromagnetic radiation in the GHz and THz frequency range, is based on the sensor consisting of a matrix of plasmonic semiconductor detectors. The imaging system comprises a radiation source module, a terahertz beam director module, a plasmonic imaging sensor module, and a signal processing module. Entire image is formed simultaneously providing for high-speed image acquisition. Images can be

				acquired either at a single frequency (discrete spectrum) or wide frequency bands (continuous spectrum). The imaging system can be used in defectoscopy, inspection, medical and other applications.
ARRAY SENSOR OF TERAHERTZ RADIATION (VERSIONS)	20.05.2013; RU 0002482527		Sergey Kuznetsov	FIELD: instrumentation. SUBSTANCE: proposed device consists of dielectric film with partially selective surface made at the side of terahertz radiation incidence while continuous layer with metallic conductance is applied on opposite side. In compliance with first version, said partial selective surface is composed of array of fragments with different topological patterns to provided for different spectral and/or polarisation sensitivities while thin layer of high IR emittance material is applied on opposite side, over said continuous layer with metallic conductivity. In compliance with second version, second dielectric layer is applied on that with metallic conductivity whereat metalised topological pattern is formed to make second frequency-selective surface. Note here that thickness of second dielectric layer and topological pattern of second frequency-selective surface are selected so that to allow resonance absorption of IR radiation. EFFECT: integrated multispectral or polarisation-sensitive detection of terahertz radiation. 14 cl, 6 dwg
OSCILLATOR FOR GENERATING A SIGNAL COMPRISING A TERAHERTZ-ORDER FREQUENCY USING THE BEAT OF TWO OPTICAL	10.04.2013; EP 2577864	UNIV RENNES	ALOUINI MEHDI	The invention relates to an oscillator for generating a wave including a terahertz-order frequency from the beat of two optical waves generated by a dual-frequency optical source (10). The oscillator comprises: a modulator (12) having a non-linear transfer function for generating harmonics at a frequency lower than one terahertz for each of the optical waves generated by the dual-frequency optical source; an optical sensor (14) capable of detecting at least one harmonic for each of the optical waves generated by the dual-

WAVES				frequency optical source, and of converting the detected harmonics into an electric signal; a comparator (15) for comparing the electric signal to a setpoint electric signal; and control means (16) for controlling at least one member of the dual-frequency optical source from a signal obtained from the signal resulting from the comparison
MILLIMETER WAVE ENERGY SENSING WAND AND METHOD	24.01.2013; US 20130021192	Daly Robert Patrick	Daly Robert Patrick	A millimeter wave energy sensing wand includes a housing adapted to be grasped by a hand of an operator. A number of sensors may be coupled with the housing and include comprising at least one millimeter or terahertz wave energy sensor. A controller coupled with the housing and electrically coupled with the sensors receives signals from the sensors in two or more sensing modes, including an active sending mode and a passive sensing mode, and generates feedback when an anomaly is detected in the received signals. The sensors may also operate in a metal detection sensing mode, and the controller may further generate feedback based on the metal detection sensing mode. The sensors may further be configured to operate in a proximity sensing mode. One or more LEDs may illuminate a portion of a scanning area

DAST-carbon nano tube composite film and preparation method thereof	28.11.2012; CN 102794947	University of Electronic Science and Technology of China	Xu Xiangdong	The invention discloses a 4-(4-dimethylaminostyryl)methylpyridine p-toluenesulfonate (DAST)-carbon nano tube composite film and a preparation method thereof. The film is formed by compounding a carbon nano tube and a DAST film. According to the invention, the DAST-carbon nano tube composite film is used for manufacturing the devices such as infrared or terahertz photoelectric detector, temperature sensor and gas sensor, the shortcomings of the pure carbon nano tube or pure DAST material in the performance of electrics, optics and the like can be overcome, and the comprehensive performance of the device is improved. The preparation method of the DAST-carbon nano tube composite film disclosed by the invention does not need complicated and expensive film forming equipment, reduces the manufacturing cost, improves the working performance of the device, and is suitable for large-scale industrial production.

Exhibit 1 lists some of the recent published patents on terahertz sensors.

Picture Credit:USPTO /Frost & Sullivan

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