TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

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1. FLEXIBLE PHOTONIC METASTRUCTURE CHANGES COLOR

Key applications exist for a technology that allows for changing the color of objects on demand. Actively controlling the perceived color of materials or objects can enable advancements in applications such as camouflage (for example, color changing for camouflage clothing), sensing (for instance, sensors able to detect defects in buildings, bridges, aircraft or other structures, which would be otherwise imperceptible to detect) or displays.

Researchers at the University of California, Berkeley, in United States, have created a new, thin, flexible, high-contrast metastructure (HCM) whose color can be changed by stretching the membrane. The structure of this chameleon-like material, which can change color on demand through applying a slight amount of force to it, is fabricated using silicon metastructures in a flexible membrane.

Flexible photonic metastructures for tunable coloration, published in *Optica, Vol. 2, Issue 3*, pp. 255-258 (2015), noted that the color change is accomplished by annihilating the 0th order diffraction while enhancing the -1st order, a new phenomenon made possible with a large index contrast. The color perception of the HCM can be changed by varying its period. The researchers experimentally demonstrated brilliant colors; and, with a change in period of only 25 nanometers, created colors that could be shifted from green to orange across a 39nm range of wavelengths.

The researchers were able to select the range of colors the material would reflect, depending on how the material was flexed and bent.

The team, led by Constance Chang-Hasnain of the University of California at Berkeley's department of electrical engineering and computer science, etched rows of ridges into a layer of silicon. The ridges reflect a highly specific wavelength of light. Tuning the spaces between the silicon bars allows for selecting the specific color to be reflected.

The silicon grating bars use a 120nm thick layer of silicon. The solution's flexibility is achieved by embedding the silicon bars in a flexible layer of silicone.

As the spacing of the bars is crucial to controlling the color they reflect, the researchers found it was possible to subtly shift the period, and, therefore, the color, by flexing or bending the material. The materials are able to reflect precise and very pure colors and are highly efficient, reflecting up to 83% of incoming light. The researchers built a 1cm layer of color-changing silicon.

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2. SENSOR SYSTEM FOR SMART MONITORING OF FACTORY MACHINES

Machine downtime and production efficiency are very important and root level factors for meeting the growing demand of end users. Machine downtime is likely to occur in all types of factories due to the continuous operating load. Machine downtime can even lead to shutting down of a factory and affect production efficiency. Hence, there is a need for a reliable, robust and cost efficient sensor system which can continuously monitor machines in their operating cycle and detect and identify disturbances in the machines that can lead to machine failure.

To address the above challenge, researchers from the University of Saarland are developing a novel sensor system to continuously monitor machinery and plant equipment. They are developing the sensor system to identify the first sign which might lead to the failure of machines.

The researchers are developing a mobile tablet-based system, which will supply useful information about the state of the machinery and equipment and inform the operator if any repairs or replacements are required. The system will consist of a network of sensors such as vibration sensors, temperature sensors to continuously monitor parameters such as temperature and vibrational frequency. According to the researchers, they are correlating information from different sensor signals and are identifying patterns such as vibration and its frequency and are working on filtering relevant data, which would provide useful information about machine performance such as reduction in production, cooling, drop in pressure, and so on. With the help of sensor fusion, researchers are trying to identify smallest changes in the performance of machinery, which are not detectable with the help of a single sensor. In addition, if a particular sensor in the network of sensors is not performing properly, the data provided by the particular sensor will not be included for analysis. Therefore, the sensor system will continuously and smartly monitor the factories in the future.

Once the sensor system is successfully commercialized, it has opportunities to be employed in various industries and monitor the performance of small and large machines, such as wind turbines, valves, pumps, and cooling systems. The sensor system will continuously monitor machine conditions and recommend remedial measures in case of faults or malfunctions. The sensor system will further help reduce downtime, avoid damages, increase production efficiency, and reduce cost associated with scheduled maintenance.

The project is supported by the Center for Mechatronics and Automation Technology, German Research Center for Artificial Intelligence, and Hydraulic Group. It is partly funded by Center for Mechatronics and Automation Technology and German Research Center for Artificial Intelligence. The researchers are currently working on customizing the sensor system to meet specific requirements of particular machines or plant equipment. They are also identifying ways to reduce the cost of the system.

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3. MAGNETIC SENSORS FOR BIOLOGICAL SENSING

For imaging biomechanical conditions such as ion concentration and pH, various nanosensors are being explored at optical frequencies using light. However, nanosensors at optical frequencies can have some disadvantages, such as resolution, and the sensitivity of the optical signal decreases when the depth of the body increases. This issue can limit nanosensors from accessing the regions inside the body. There is a need of the device, which can help to achieve biological sensing with high resolution and sensitivity. In addition, the device should be easy to use and cost efficient.

To address such challenges, researchers from the National Institute of Standards and Technology have developed a geometrically encoded magnetic sensor for high resolution remote biological sensing.

The researchers have designed the geometrically encoded magnetic sensor to operate in the nuclear magnetic resonance (NMR) radio frequency spectrum. In this spectrum, the distortion, signal attenuation, and background interference because of tissues are negligible. With the help of magnetic resonance imaging equipment, sensors can be easily located. The sensor is comprised of a pair of magnetic disks. The magnetic disk is tens of nanometers thick and has a diameter of 0.2 to 2 micrometers. The space between the pair of magnetic disk is filled with a swellable hydrogel material, which absorbs water and expands. There is a change in distance between the two disks because of the expanding and shrinking of the gel. This further leads to change in frequencies at which the protons in water molecule around and inside the gel vibrate with respect to the radio frequency. Current shape of nano probes can be quickly identified by scanning the sample with range of frequencies.

The project was supported by the National Institutes of Health. The researchers are working on designing a customized sensor to measure different variables or biomarkers and differentiate between different pathologies. In addition, they are also developing a large scale fabricating process to make these sensors widely available.

One the geometrically encoded magnetic sensor is commercialized, it has opportunities for use in chemical, medical, biological, and engineering research. The sensor will be used to measure different types of biomarkers such as various ion concentrations, pH, glucose, temperatures, and presence and absence of enzymes. The researchers are planning to reduce the size of the sensor (make it smaller than 100 nanometers in diameter) to enable other biomedical applications.

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4. RECENT PATENTS IN THE FIELD OF TERAHERTZ SENSORS

The terahertz (THz) region spans frequencies between the microwave and far infrared region of the electromagnetic spectrum. Terahertz sensors have gained keen interest. Terahertz imaging is a safe imaging source that can simultaneously extract extensive spectroscopic information that cannot be obtained by imaging at other frequencies. The unique rotational and vibrational responses of materials in the THz range can provide information that is generally absent in microwave, visible, infrared, and X-ray frequencies. Terahertz imaging is gaining increased momentum for security applications with initial adoption prospects envisioned high in the medium- to long-term. Other potential applications of terahertz imaging includes electronics, industrial, medical, and pharmaceuticals.

There has not been a great deal of patents in such technology published in the last few years. The most number of patents has been published in United States. Several academic institutions across Europe are also exploring the capability of terahertz. Some of the stakeholders in terahertz sensors include Teraview (UK), Advanced Photonix Inc. (USA), Raytheon (USA), Advantest Corp, among others.

A recent patent in terahertz sensing, entitled Terahertz Image Sensor (WO/2015/040316), assigned to Commissariat a l'energie atomique et aux energies alternatives, pertarins to a terahertz image sensor matrix, consisting of a matrix of pixels and an antenna to receive the terahertz signal.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
TERAHERTZ IMAGE SENSOR	26.03.2015; WO/2015/040316	COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	ROSTAING, Jean-Pierre	The invention relates to a terahertz image matrix sensor comprising a matrix of pixels and comprising, for each pixel, an antenna (32) for receiving a terahertz radiation modulated by a signal at a modulation frequency and a synchronous filter (40) with N pathways, where N is an integer greater than or equal to 4, each pathway comprising a capacitive element and at least one first breaker controlled by a first signal at said modulation frequency.
HIGH-SENSITIVITY TERAHERTZ MICROFLUIDIC CHANNEL SENSOR AND MANUFACTURING METHOD THEREOF	29.01.2015; WO/2015/010545	SUZHOU INSTITUTE OF NANO-TECH AND NANO-BIONICS OF CHINESE ACADEMY OF SCIENCE	CHEN, Qin	A high-sensitivity terahertz microfluidic channel sensor and manufacturing method thereof; the sensor comprises a substrate (1) and a cover layer (5) respectively provided with a metal plane reflector (2) and a metal microstructural layer (4); a microfluidic channel (6) is formed between the metal plane reflector (2) and the metal microstructural layer (4); and when the microfluidic channel (6) has liquid to be tested therein, a composite structure formed by the metal microstructural layer (4), the liquid to be tested, and the metal plane reflector (2) has good absorbency, in terahertz waveband, caused by resonance. The method comprises: machining to form the metal plane reflector (2) and the metal microstructural layer (4) respectively on the substrate (1) and the cover layer (5); fixedly connecting the substrate (1) to the cover layer (5), and forming a closed microfluidic channel (6) between the substrate (1) and the cover layer (5); and providing through holes (7, 8, 9, 10) on the substrate (1) and/or the cover layer (5) communicating with the microfluidic channel (6) to form a liquid flow channel for inputting/outputting the liquid to be tested into/from the sensor. The sensor has a simple structure, is easy to machine and use, and improves detection sensitivity compared with existing sensors
Terahertz frequency sensing	14.01.2015; EP2824435	FOM INST FOR ATOMIC AND MOLECULAR PHYSICS	RIVAS JAIME GOMEZ	A sensor system is described wherein the sensor system comprises a support substrate comprising a semiconductor , preferably a high mobility (intrinsic) thin-film semiconductor; and, an optical system comprising an optical source and a geometrically shaped optical mask, preferably a computer-controlled spatial light modulator, said optical system being configured for exposing at least part of said thin-film semiconductor with a geometrically shaped (pulsed) light beam, said light beam forming a shaped photon-induced THz plasmonic sensing region for sensing the THz response of a small volume sample disposed on or over said support substrate in the vicinity of said plasmonic region.
TERA HERTZ SENSOR AND IMAGING APPARATUS INCLUDING THE SAME	12.03.2014; US20140042445	TERA WAVE CO., LTD.	LEE, JIN GEUN	An imaging apparatus including a terahertz sensor is provided. The imaging apparatus comprises: an irradiation unit irradiating terahertz waves to an object; a terahertz sensor comprising sensing elements arranged in a form of a line and which generate electrical signals by detecting terahertz waves emitted by the object; and a control unit generating images from the electrical signals generated from the terahertz sensor. The tetrahertz sensor comprises: a first line detection unit composed of a plurality of sensing elements spaced at equal intervals and n line detection units respectively composed of additional sensing elements arranged in each of the positions where equal intervals between the sensing elements adjacent to the first line detection unit are divided by n. COPYRIGHT KIPO 2014

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Terahertz gas sensor	20.11.2013; CN103398958	University of Shanghai for Science & Technology	Chen Lin	The invention provides a terahertz gas sensor. The terahertz gas sensor comprises a first metal plate and a second metal plate which are arranged in parallel; a clearance is formed between the two metal plates; the centers of the two metal plates are respectively provided with a groove; the two grooves are arranged in opposite; the two metal plates are arranged in a box body; the two metal plates and the box body are connected tightly; two seal plates of the box body adjacent to the two grooves are respectively internally provided with a hole; the holes are communicated with the clearance. Under a low-order transverse electric (TE) 1 mode, the polarization direction of an electromagnetic wave is parallel to planes of the parallel plates; gas enters a space between the two plates through a small hole in one side in each seal plate, gas in each plate is exhausted out from a small hole in the other side of each seal plate, and to-be-detected gas is detected. The terahertz gas sensor provided by the invention not only can be used for detecting gas, but also has high sensitivity to gas.
Terahertz porous fiber evanescent wave sensing device	25.07.2012; CN102607610	Tianjin University of Technology	Ren Guangjun	Disclosed is a terahertz fiber evanescent wave sensing device. A fiber core is made of a polymethyl methacrylate material, sub-wavelength air holes which are axially arrayed in a regular-triangularly periodic manner are uniformly distributed in the fiber core, a cladding consists of to-be-detected gas or to-be-detected liquid positioned on the outside of the fiber core, and the sensing characteristic is realized by the aid of evanescent waves at an interface of the fiber core and the cladding. The terahertz porous fiber evanescent wave sensing device has the advantages that a series of sub-wavelength air holes which are axially arrayed in the regular-triangularly periodic manner are additionally disposed in the solid fiber core of the sensing device, the effective refractivity of a fundamental mode is effectively reduced, absorption loss and waveguide dispersion of the material are reduced, relative sensitivity is improved, a fiber can be used as a sensor probe without any treatment when used for sensing the evanescent waves, mechanical reliability is high, processing cost is low, detection time is relatively shortened when the sensing device is used for a sensing area positioned on the outside of the fiber, the surface of the fiber can be treated conveniently when the fiber is used for biological fluorescent detection, and reliability of the probe cannot be affected
TERAHERTZ WAVE IMAGING DEVICE	16.06.2011; JP2011117957	FURUKAWA ELECTRIC CO LTD:THE	FUKUCHI TOSHIHIDE	PROBLEM TO BE SOLVED: To provide a terahertz imaging device capable of moving a terahertz source generating a terahertz wave having a variable frequency to the periphery of a measuring object, and measuring the terahertz wave. SOLUTION: In this terahertz imaging device 100, a sensor head part 120 is separated from a body part 110 and connected through a composite cable 130, and only the sensor head part 120 can be moved and used. The body part 110 combines each laser light having each different wavelength emitted from two wavelength variable lasers 111, 112 by an optical coupler 115, and transmits the combined wave to the sensor head part 120 via an optical waveguide 131. The sensor head part 120 allows the transmitted combined wave to enter the terahertz source 121, and generates a terahertz wave having a frequency equivalent to a beat component of the combined wave.

Exhibit 1 lists some of the patents related to terahertz sensors.

Picture Credit: Frost & Sullivan

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