TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

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1. MAGNETORESISTANCE DEPENDENT ON DIRECTION OF ELECTRON FLOW

The phenomenon of magnetoresistance (a change in the electrical resistance of a material in response to an applied magnetic field) was initially discovered by William Thompson (Lord Kelvin) in 1856. In experimenting with ferromagnetic materials (iron and nickel), he found that the material's resistance increases when the current is in the same direction as the applied magnetic field and decreases when the current is applied at a 90 degree angle to the magnetic field or force. Over time, this anisotropic magnetoresistance (AMR) effect has become used in contemporary sensors for such applications as automobile wheel speed sensing, crankshaft sensing, or steering wheel angle sensing; compass navigation; vehicle detection; current sensing; and a range of other applications.

AMR sensors, which are comprised of a nickel-iron (Permalloy) thin film deposited on a silicon wafer in the form of a resistive strip, generally exhibit a 2% to 3% change in resistance at room temperature in response to a magnetic field. AMR sensors are quite suitable for sensing magnetic fields corresponding to the Earth's magnetic field range.

Giant magnetoresistance (GMR) refers to a larger, significant change in electrical resistance (of typically 10% to 20%, or up to 50% or possibly higher at low temperature) in thin-film ferromagnetic (such as iron, nickel, and cobalt) and non-magnetic multi-layer structures. In GMR devices, the change in electrical resistance will depend on whether the magnetization of the ferromagnetic layers is in a parallel or anti-parallel alignment. Layers with parallel magnetization will have lower resistance; while layers with anti-parallel magnetization have higher resistance. In GMR devices, the electrical resistance is influenced by the scattering of electrons, which is dependent on the orientations of the electron spins and the magnetic moments.

GMR magnetic field sensors have been used in applications such as magnetic read heads in hard disk drives, biosensors, pacemaker tuning, hearing aids (for switching modes to accommodate the source of sounds), motion and position sensing. In automotive applications GMR sensors can offer advantages such as larger working distances, more precise angular position measurement of up to 360 degrees, and a higher output signal and sensitivity. Suitable or promising automotive applications for GMR sensors include angle sensing and rotational speed sensing. However, to significantly penetrate automotive applications, GMR sensors need to be very versatile and to have a wider range of features and capabilities than existing Hall effect sensors and AMR sensors and be able to be produced at lower cost.

Typically, the magnetoresistance of an electrically conductive material is unchanged when there is a change in the direction of the electric current.

In a development that can have practical applications over time, researchers at ETH Zurich, led by Pietro Gambardella, professor for magnetism and interface physics at ETH Zurich, have discovered a new magnetoresistance effect in metal materials in which the magnetoresistance of the material changes when electron flow is reversed.

The researchers used a magnetic sensing structure consisting of a thin layer of heavy metal (such as platinum or tantalum) and a thin layer of iron or cobalt above the heavy metal layer. They measured electrical resistance at different magnetization. The two-layer structure showed typical AMR behavior in that the electrical resistance changed based on the magnetization of the ferromagnets. However, it was also discovered that the structure's electrical resistance was influenced by the direction of the flow of electrons. Such behavior is attributed to the magnetic moment, or spin, of the electrons. The researchers observed that in heavy metals electrons that have opposite spin become deflected in various directions; so that electrons that have the same direction of spin accumulate at the interface of the platinum or tantalum metals. However, when a layer of iron or cobalt is put atop the heavy metal, the overall electrical resistance depends on the alignment of the accumulated spin and the magnetization of the ferromagnetic material.

The new magnetoresistance effect has been termed unidirectional spin Hall magnetoresistance. Spin Hall effect refers to spin accumulation at the lateral boundaries of a current carrying conductor. The directions of the spins are

opposite at the opposing boundaries. The boundary spin polarization is proportional to electric current and changes sign when the direction of the current is reversed.

The unidirectional Spin Hall magnetoresistance effect is described as similar to GMR. However, this phenomenon is proportional to the amount of current flowing to the material.

For deployment in practical applications, the newly discovered magnetoresistance effect would need to achieve a higher change in resistance. The researchers envision custom materials as having promise, such as semiconductor materials or topological insulators in which the electrons confined at the interfaces of the materials could have amplified magnetoresistance.

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2. ZBLAN FIBER PROVIDES A BROADBAND LIGHT SOURCE

Photonic crystal fibers (PCFs), consisting of pure silica core optical fibers with tiny air holes embedded in the host silica matrix, have key benefits, such as providing single-mode operation over very short operating wavelengths, remaining single-mode for large-scale fibers, ability to achieve high birefringence (the optical property of a material whose refractive index depends on the light's polarization and direction of propagation), and controllable dispersion characteristics.

Photonic crystal fibers are, moreover, well-suited for supercontinuum generation (the formation of broad continuous spectra via propagation of short laser pulses through non-linear media), since the dispersion can be designed to facilitate continuum generation in a specific region. Therefore, light can be converted to both a higher and lower wavelength. Applications that can benefit from broadband PCFs include biomedical research or other medical applications including optical coherence tomography (OCT). PCFs can also be employed in very sensitive gas sensors. PCFs have typically been fabricated in silica glass.

Researchers at the Max Planck Institute for the Science of Light in Erlangen, Germany, have enhanced the capabilities of PCFs by creating broadband PCF microstructured glass fibers from ZBLAN, a very stable fluoride glass with

superior infrared (IR) transmittance properties. In contrast to conventional quartz glass, ZBLAN is also very resistant to ultraviolet (UV) light. Prior to the achievement by the researchers, it has not been extremely challenging and deemed essentially impossible to draw photonic crystal fibers from ZBLAN.

The researchers have succeeded in creating a PCF that consists of a 2D periodic structure comprised of hollow channels that surrounds the fiber core and spans the length of the fiber. The hollow channels are arranged in a 2D periodic structure in the fiber end face, and restrict light to the fiber core. Moreover, the fiber microstructure is able to manipulate the chromatic dispersion of the photonic crystal fiber. The PCF's design allows for controlling the interplay between light and the photonic crystal fiber. The refractive index is altered based on the light's intensity; and the speed of the light waves changes in accordance with their color.

The broadband PCF is created by coupling a pulse from a low-energy IR laser into a photonic crystal fiber that is designed so that the spectrum generated becomes white light (a combination of light of different wavelengths in the electromagnetic spectrum, in this case a uniquely broad spectrum spanning from the deep ultraviolet wavelength region to the mid-infrared portion of the electromagnetic spectrum). The researchers sent very short, relatively low energy infrared pulses through the PCF to enable white light that was able to cover a large portion of the UV spectral range.

This ultra-broadband light source, which also provides other characteristics desired in a light source, such as optical coherence and high brightness, can have opportunities in areas such as biomedical research (for example, investigating biochemical processes in cancer cells), as well as physics or chemistry. Moreover, the light from the PCF is able to retain much of its brightness across the entire covered spectrum as opposed to losing its brightness due to optical filtering.

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3. DEVELOPMENTS IN IN-VEHICLE AUTOMOTIVE ALCOHOL SENSING

Drunk drivers are a menace on the roads and a major source of vehicular deaths and accidents. For example, according to the US National Highway Traffic Safety

Administration (NHTSA, 2008), in 2007, there were nearly 13,000 fatalities in accidents involving blood alcohol concentrations of 0.08 g/dl (grams per deciliter) or higher. The number of such deaths accounted for 32% of the overall traffic fatalities in that year. A significant portion of alcohol-impaired traffic fatalities involve drivers who do not have previous DWI (driving while intoxicated) convictions.

To combat the problem of alcohol-impaired driving, in 2008, the Driver Alcohol Detection System for Safety (DADSS) collaborative research program was launched. DADSS represents a research collaboration between the Automotive Coalition for Traffic Safety (ACTS), which represents 17 automakers, and NHTSA to evaluate and develop in-vehicle alcohol-detection technologies, which would prevent a vehicle from being driven (prevent a car from starting) when a driver's blood alcohol concentration exceeds the legal limit of 0.08%.

The DADSS program has three phases. Phase I, completed in 2011, involved research and analysis of two alcohol detection technologies: a touch-based approach and a breath-based approach. Phase II entails further research and testing of both types of alcohol detection sensors for improved accuracy and more rapid measurement. This phase has been anticipated to be completed in early 2016. Phase III, which began in 2013 and is occurring simultaneously with Phase II, is geared toward further refining the alcohol detection technology and gaining further understanding of the human-sensor interaction and the operation of the alcohol detection technologies in a vehicle.

On June 4, 2015, NHTSA unveiled advancements in the two DADSS alcohol detection prototypes.

The breath-based breathalyzer system, under development by Sweden-based Autoliv, located on the steering wheel or the driver's side door, or possibly dispersed in the vehicle cabin, is based on distant spectroscopy, in which infrared light is transmitted on the breath sample from a source that receives and analyzes the reflected and absorbed light to determine the concentration of alcohol. The sensor measures concentration of alcohol and carbon dioxide. The quantity of carbon dioxide in human breath indicates the degree of dilution of the alcohol concentration in exhaled air. This system detects alcohol in the surrounding air particles, and can work even if the driver does not blow into the device.

Japan-based Takata has partnered with TruTouch Technologies (USA) to develop the touch-based approach based on tissue spectrometry that measures alcohol concentration in the driver's tissue. The touch-based system measures blood alcohol levels (blood alcohol content in the capillaries) beneath the skin's surface by shining infrared light on the driver's skin (through the fingertip). A portion of the light is reflected back to the skin's surface and collected by a touch pad. The reflected and collected light provides information about the skin's chemical properties, including alcohol concentration. The touch sensor is expected to be installed in a natural place with respect to the driver, such as the vehicle ignition button, steering wheel, or gear shift. DADSS will be available as a voluntary safety option on new vehicle.

Ignition interlock devices that prevent the engine from starting if the driver's blood alcohol level is greater than the programmed blood alcohol concentration, have tended to use electrochemical sensors or metal oxide semiconductor (MOS) sensor. Although electrochemical and MOS sensors can be less expensive than sensors based on infrared spectrospcopy, and the former can be alcohol specific, IR spectroscopy can be more accurate, reliable and may not be as susceptible to long-term drift and stability concerns.

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4. RECENT PATENTS IN THE FIELD OF TOUCHLESS SENSING

The basic definition of touchless sensing is the interaction between humans and machines without touching. One of the key applications for touchless sensing is gesture recognition, which provides a natural, intuitive way of interaction with devices.

The types of key enabling technologies for touchless sensing include two-dimensional image sensors, three- dimensional imaging, optical sensors, voice recognition, ultrasonic sensing, and electric field sensing. Electric field sensing is an emerging area, which focuses on determining changes in ambient electric field. While an earlier application of touchless sensing was in sanitary equipment, it is currently being used across various industries. . In the consumer electronics segment (including gaming), touchless sensing is gaining a lot of traction. In

addition, touchless sensing also is finding opportunities in industrial, automotive, and health care applications.

Key efforts in camera-based touchless sensing can be seen in the North American region by companies such as Leap Motion, GestureTek, Apple, and Microsoft. In recent times, several startups from Israel are also entering the consumer electronics market with touchless sensing technologies.

The key drivers for adoption of touchless sensing include ease of interaction, intense competition in consumer electronics, and continuous advancement in technology. In the near term, a key source of the revenue opportunities will be from the consumer electronics sector, especially from mobile devices.

A recent patent (EP2829959), assigned to Blackberry Ltd., pertains to a gesture recognition method that uses two or more ambient light sensors and one or more processors.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Backlight for touchless gesture detection	28.01.2015; EP2829959	BLACKBERRY LTD	IDZIK JACEK S	A device and method to detect a gesture performed by an object in touchless communication with the device are described. The device includes two or more ambient light sensors arranged at respective first surface locations of the device, each of the two or more ambient light sensors sensing light intensity at the respective first surface location. The device also includes one or more processors to operate one or more light sources at respective second surface locations of the device based on the light intensity sensed by the two or more ambient light sensors, and detect the gesture based on the light intensity sensed by each of the two or more ambient light sensors.
GAMING MACHINE WITH PROXIMITY SENSING TOUCHLESS DISPLAY	15.05.2014; US20140135130	KONAMI GAMING, INC.	George Jeffrey	A device for providing a proximity sensing touchless display to a gaming machine is provided. The device includes a processor, a display coupled to the processor, and a touchless input interface coupled to the processor and being implemented by the display for receiving input from the player. The input interface employs proximity sensing technology, such as but not limited to proximity button activation. For example, the display can be operable to sense a player's approaching finger entering an electrical field (e.g., corresponding to one or more electrodes) such that a particular button or function on the interface can be activated without the player's finger having to ever physically contact a button, push pad, keypad, touch screen, and/or the like.

TOUCHLESS SENSING AND GESTURE RECOGNITION USING CONTINUOUS WAVE ULTRASOUND SIGNALS	08.05.2013; EP2588939	QUALCOMM INC	LI REN	The embodiments provide systems and methods for touchless sensing and gesture recognition using continuous wave sound signals. Continuous wave sound, such as ultrasound, emitted by a transmitter may reflect from an object, and be received by one or more sound receivers. Sound signals may be temporally encoded. Received sound signals may be processed to determine a channel impulse response or calculate time of flight. Determined channel impulse responses may be processed to extract recognizable features or angles. Extracted features may be compared to a database of features to identify a user input gesture associated with the matched feature. Angles of channel impulse response curves may be associated with an input gesture. Time of flight values from each receiver may be used to determine coordinates of the reflecting object. Embodiments may be implemented as part of a graphical user interface. Embodiments may be used to determine a location of an emitter.
MOTION SENSING SWITCH	28.02.2013; WO/2013/027889	HYSONIC.CO.,LTD.	JUNG, He Won	Systems, methods, and devices for cooperative intrusion detection are described herein. For example, one or more embodiments include completing a radar scan with a network of outer perimeter radar nodes, detecting an intrusion event with the network of outer perimeter radar nodes, notifying at least one inner perimeter radar node in a network of inner perimeter radar nodes of the intrusion event, activating the at least one inner perimeter radar node from an idle mode in response to the notification of the intrusion event, and completing a radar scan with the at least one inner perimeter radar node upon activation.
Low Cost Embedded Touchless Gesture Sensor	22.11.2012; US20120293404	Federico Jacob	Federico Jacob	An array of independently addressable optical emitters, and an array of independently addressable detectors, energized according to an optimized sequence sensing a performed gesture to generate feature vector frames that are compressed by a projection matrix and processed by a trained model to perform touchless gesture recognition.
COMPUTER MOUSE PROVIDING A TOUCHLESS INPUT INTERFACE	08.11.2012; US20120280912	Westphal Geoffry A.	Westphal Geoffry A.	A computer input device, such as a mouse, has a surface movement sensor in communication with a processing circuit for providing to the processing circuit first signals indicative of sensed movement of the computer input device upon a surface, and one or more touchless sensor subsystems in communication with the processing circuit for providing to the processing circuit second signals indicative of sensed surface movements relative to the computer input device. A transmission circuit under control of the processing circuit issues transmissions to a computer representative of the first and second signals.

Electronic device and method of controlling electronic device	19.09.2012; CN102687498	Sony Corp.	Fukuda Kenichiro	An electronic device and a method of controlling the electronic device in which the electronic device includes a digital camera function. A touchless screen is configured to display an image. A control unit is configured to sense an operation member held over an area of the touchless screen without the operation member touching the touchless screen, and the control unit is further configured to determine at least one of a size or a position of the operation member held over the area of the touchless screen, and to control at least one digital camera operation based on the sensed at least one of size or position.

Exhibit 1 lists some of the patents related to touchless sensing.

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 analyse 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 catalyse 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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