TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

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1. INTESTINAL GAS SENSING CAPSULES FOR IMPROVED HEALTHCARE

Ongoing advancements in microsensors, nanosensors, and electronics technologies are enabling increasingly smaller sensing devices. Such sensors, moreover, can allow for personalized medical treatment, driving enhanced, more timely and efficient patient monitoring. For optimized functioning, such sensors should have very sufficient, convenient and sustainable power sources and wireless communications capabilities and be able to survive in environments within the human body.

Development of ingestible sensor technology has tended to focus on wireless patient monitoring and on diagnostic imaging. For example, ingestible sensing devices are emerging as a promising, powerful tool for monitoring or tracking the drugs a person is taking as well as key health indicators, such as sleep, activity, respiration, heart rate, temperature. Ingestible smart pills can safeguard against the patient forgetting to take their medicine or taking the incorrect dose.

Ingestible devices for imaging inside the body may also obviate the need to have invasive procedures. Ingestible sensing capsules also are drawing interest for diverse applications. For instance, ingestible sensing capsules, which leverage microsensing technology, increasingly have opportunities to provide a key means of accurately detecting and measuring intestinal gases. Such sensors have potential to provide key, real-time information about the status of important gases that exist inside the human body and about their connection to particular diseases. Key health benefits can be derived by having the ability to accurately measure intestinal gases produced by bacteria in one’s intestines.

Indicative of significant developments and opportunities in capsule sensors for measuring intestinal gases, researchers at RMIT University and Monash University in Australia have developed innovative gas sensing capsules that are able to send data from inside the stomach to a mobile phone. Intestinal gases have potential as key biomarkers for evaluating overall health. Furthermore, such gases have been associated with colon cancer and bowel disease.

The technology is able to measure the concentration of selected intestinal gases through a swallowable capsule containing a built-in gas sensor, microprocessor, and wireless high-frequency transmitter.

Breath testing, a non-invasive technique of measuring intestinal gas, can have limitations. For example, there can be potential issues in comprehending the relationship between various breath substances and physical conditions.

Microorganisms generate gases as a by-product of their metabolism. The ability to accurately measure intestinal gases could provide greater understanding about more efficient intake of food and digestion and how specific microorganisms can lead to gastrointestinal disorders. Such information can facilitate development of improved diagnostic methods and treatments.

Furthermore, the intestinal gas sensing capsules could shed knowledge on the effects of certain foods on one's stomach and enable individuals to orient their diet to enable healthy digestion.

Details: Dr. Kourosh Kalanter-zadeh, Lead Investigator and Professor, Electrical and Computer Engineering, RMIT University, 124 La Trobe Street, Melbourne VIC 3000, Australia. Phone: +61-61-3-9925-3254. Cell: +61-488-332245. E-mail: kourosh.kalantar@rmit.edu.au.

2. IMPROVED SAFETY AND INTELLIGENCE FOR DRONES

Drones, or unmanned air vehicles (UAVs), are generating increased interest for use in applications in addition to defense, such as package delivery, pipeline or crop inspection, movie making, law enforcement, journalistic initiatives.

Drones have key advantages over manned aircraft for diverse, key applications. For example, manned airborne surveys are typically expensive and the images acquired from manned aircraft can have limitations. In contrast, unmanned air vehicles allow for high flexibility which facilitates image

acquisition from diverse viewpoints, high resolution images, and reduced cost compared to traditional aerial surveys.

As UAVs or drones become more prevalent (including for commercial, non-defense applications), there will be an increasing need for enhanced orientation capability. It is important for drones to be able to travel from one point to another without being thwarted by obstacles or adverse environmental conditions.

In February 2015, the US Federal Aviation Administration (FAA) proposed rules that would allow some commercial drone flights, but not yet allow for applications such as delivering packages, inspecting crops or inspecting pipelines.

The proposed regulations for drones (small unmanned aircraft) included: drones need to be within visual line-of-sight; drones cannot fly over people not involved in the operation; daylight-only operation.

Drones have had certain limitations. For example, drones can be difficult to control because of the physical separation of the pilot from the aircraft; and, therefore, are vulnerable to being damaged or destroyed due to pilot error.

Moreover, drones can run out of power, in which case they must land immediately. The drones should be able to identify safe landing spots and carry through landing operations with accuracy. In the event that drone's GPS signal is compromised, it is crucial for the drone to have a back-up system to regain flight stability.

Researchers from the University of Zurich have employed a camera, acceleration sensors, and computer vision software to allow safer operation of drones beyond the operator's line-of-sight. The work enables drones to be able to recover flight stability from any position and to land autonomously in the event of a system failure. The drones equipped with such technology would be able to identify safe landing sites and to land automatically, if necessary.

The orientation system of the research group's drones emulates the human visual system and sense of balance. Upon detection of instability or a failure, computer-vision software analyzes the images to identify distinctive landmarks in the environment and regain balance. Image processing and control run on a smartphone processor aboard the drone. The software constructs a three dimensional (3D) model of the environment, which is utilized to categorize the terrain beneath the drone into risky and safe landing sites. In

the event an emergency landing is required because of a low battery or system failure, the drone can automatically detect and land on a flat, safe location without requiring human intervention.

Details: Dr. Davide Scaramuzza, Co-Inventor and Professor and Director of the Robotics and Perception Group, University of Zurich, Andreasstrasse 15, Office 2.26, 8050 Zurich, Switzerland. Phone: +41-44-635-24-09. E-mail: sdavide@ifi.uzh.ch.

3. RAPID DETECTION OF CHARGE OF A SINGLE ELECTRON

Single electronics offers key advantages of small size and low power operation. For example, single-electron transistors (SETs) have opportunities to be a key component for very large-scale integrated circuits due to their ultra-low power consumption and small size.

Quantum computers use particles such as atoms or electrons to conduct processing and memory tasks. Such computers differ from digital computers, which are based on transistors. The latter require data to be encoded in binary digits or bits, where each bit represents a 1 or a 0. In contrast, quantum computing uses a sequence of qubits or quantum bits that can represent superpositions of certain states. A single qubit can represent a 1, 0, or any quantum superposition of such two qubit states. A pair of qubits may be represented in any supposition of four states; and three qubits can be in any supposition of eight states. Quantum computers could provide tremendous increases in computer power based on their ability to execute score of calculations simultaneously.

Researchers at the University of Cambridge in UK have created an extremely accurate electronic device that is able to detect the charge of a single electron in less than one microsecond. This is the best value thus far obtained for this type of system. Such a device, termed the gate sensor, has potential to be applied in future quantum computers to read information stored in the charge or spin of a single electron.

The ultra-sensitive electrical charge sensor was developed in the same Cambridge laboratory in UK where British physicist J.J. Thomson discovered the electron in 1897. M. Fernando González Zalba, from the Hitachi Cambridge Laboratory and Cavendish Laboratory, is the leader of the research team.

The super-sensitive electrical charge sensor is more compact and accurate than prior versions. The device has been termed a gate sensor, since, in addition to being able to detect the movement of individual electrons, the device is capable of controlling the flow of electrons in the fashion of an electronic gate that opens or closes.

With this device, the researchers achieved the possibility of detecting the charge of an electron in about one nanosecond by coupling a gate sensor to a silicon nanotransistor where the electrons flow individually.

Typically, the electrical current that powers telephones, refrigerators or other electrical equipment is composed of numerous electrons. However, the electronic functionality of advanced, leading-edge or next-generation devices, such as ultra-precise biosensors, single electron transistors, molecular circuits and quantum computers, is based on the charge of a single electron, where the new gate sensor can provide key benefits.

Details: Dr. M. Fernando Gonzalez-Zalba, Research Scientist, Hitachi Cambridge Laboratory, J J Thomson Avenue, Cambridge CB3 0HE UK. Phone: +44-1223-4429-16. E-mail: mg507@cam.ac.uk

4. RECENT PATENTS IN THE FIELD OF THERMOELECTRIC SENSORS

The thermoelectric sensor utilizes the thermoelectric effect in which the change in temperature is measured and the resulting heat is converted into electrical signal. The 'Seebeck' effect is the term used to describe current that is generated due to the temperature difference between two junctions of conducting materials. Heat flow occurs between n-type and p- type materials, electrically joined at a high temperature junction, and hence there is flow of charge from the high-temperature end to the low-temperature end. This establishes a voltage difference across base electrodes, which will be proportional to the temperature difference.

The operating temperature and figure of merit (denoted by ZT; the conversion efficiency of the material) are important parameters to enable wide-scale application of thermoelectricity. The other most important parameters for assessing thermoelectric ability are current and voltage, that is, output power. Thus, it is important to understand the issues related to the output power and the ways of optimizing the thermoelectricity or thermoelectric effect. In high temperatures, electronics and materials can malfunction or be completely

destroyed. Conflicting material characteristics of hot and cold parts can lead to limited efficiency of conversion.

Thermoelectricity is expected to play a leading role in making sensor systems self-sufficient in terms of their energy needs. Smart intelligent homes, industries, and automotive will be key target vertical markets for thermoelectric energy harvesting. Moreover, infrared thermopile sensors (consisting of connected thermocouples) that can detect temperature, presence, or position, are well-established in applications such as ear thermometers, consumer electronics (e.g., microwave ovens, hair dryers), automotive (climate control), gas detection, and so on.

The number of patents published under the thermoelectric sensors domain is increasing every year, which further indicates the growing interest in and increasing opportunities for cost-effective applications in the near term. Thermoelectric sensors are expected to find expanding opportunities in sectors such as consumer electronics (including smart phones, laptops); military/aerospace; automobiles; industrial gas detection or temperature detection heating, ventilation, and air conditioning; and so on

A recent patent (WO/2015/039919) pertaining to a thermoelectric sensor that includes a pyroelectric layer and Seeback coefficients is assigned to Siemens Aktiengesellschaft

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
THERMOELECTRIC SENSOR	26.03.2015; WO/2015/039919	SIEMENS AKTIENGESELLSCHAFT	HEDLER, Harry	The invention relates to a thermoelectric sensor (1,1i) comprising at least one sensor element (1) comprising a head electrode (6), a foot electrode (8) and a pyroelectric layer (16). Said head electrode (6) is arranged on a first side (15) and the foot electrode (8) on a second side (17) of the pyroelectric layer (16) facing away from the first side (15); said sensor element (1) also comprises at least one first and one second electric foot conductor (12,14) and at least one electric head conductor (10); the first and second foot conductors (12,14) are in contact on the foot electrode (8) and the head conductor (10) is in contact on the head electrode (6); the head conductor(10) and the first foot conductor (12) have essentially the same first Seebeck-coefficients and the second foot conductor (14) has a second Seebeck coefficient which is different from the first.
THERMOELECTRIC CONVERSION MATERIAL, THERMOELECTRIC CONVERSION ELEMENT, ARTICLE FOR THERMOELECTRIC GENERATION, AND POWER SOURCE FOR SENSOR	12.03.2015; WO/2015/033832	FUJIFILM CORPORATION	NISHIO, Ryo	Provided are the following: a thermoelectric conversion element, comprising on a substrate a first electrode, a thermoelectric conversion layer, and a second electrode, wherein the thermoelectric conversion layer contains a thermally stimulated polymer compound comprising a nano-conductive material with a mean long axis length of at least 5 nm and repeating units represented by the formula (1); an article for thermoelectric power generation and a power source for a sensor using this thermoelectric conversion element; and a thermoelectric conversion material for forming the thermoelectric conversion layer, wherein the thermoelectric conversion material contains a thermally stimulated polymer compound comprising the nano-conductive material and repeating units represented by the formula (1). In the formula (1), "A ring" represents a conjugated hydrocarbon ring or a conjugated hetero-ring. "X" represents a group in which one or more atoms selected from the group consisting of a carbon atom, an oxygen atom, a sulfur atom, a nitrogen atom, a phosphorus atom, and a silicon atom are used as a ring-constituent atom of the A ring. The mean inter-unit distance of the A rings is 1.42 Å or less. "R11" and "R12" each independently represent substituent groups and may be mutually linked to form a ring. "*" represents a bonding position for the repeated groups.
THERMOELECTRIC SENSOR FOR ANALYTES IN A GAS AND RELATED METHOD	05.03.2015; US20150065365	Invoy Technologies, L.L.C	Lubna Ahmad	An apparatus is provided for sensing an analyte in a fluid. The apparatus includes a fluid collecting device configured to collect the fluid containing the analyte; a fluid input in fluid communication with the fluid collecting device configured to input the fluid containing the analyte into the fluid collecting device, an analyte interactant in fluid communication with the fluid collecting device, wherein the analyte interactant, when contacted by the analyte, reacts to cause a first change in thermal energy within the fluid collecting device; a modulator that causes a second change in thermal energy; a thermal sensing device comprising at least one pyroelectric device thermally coupled to the fluid collecting device to generate a first signal in response to at least one of the first change in thermal energy and the second change in thermal energy; a control device operatively coupled to the thermal sensing device and the modulator that generates a second signal, wherein the second signal comprises information useful in characterizing the analyte. A related method also is disclosed.
INFRARED SENSOR, THERMAL IMAGING CAMERA AND METHOD FOR PRODUCING A MICROSTRUCTURE FROM THERMOELECTRIC SENSOR RODS	19.02.2015; US20150048249	SIEMENS AKTIENGESELLSCHAFT	Hedler Harry	An infrared sensor with a microstructure has a multiplicity of sensor rods protruding from a sensor base and arranged axially parallel to one another. Each of the sensor rods is designed as a thermocouple, in that a first rod end, arranged on the sensor base, is electrically connected to an opposite free second rod end by both a first and a second electrically conductive rod element. The two rod elements have a different Seebeck coefficient, and the first rod element is formed as a hollow profile and the second rod element is arranged in the first rod element such that each thermocouple is formed as a single rod with a small standing area on the sensor base.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
COOLING DEVICE EQUIPED WITH A THERMOELECTRIC SENSOR	21.08.2014; US20140233186	Savelli Guillaume	Savelli Guillaume	A cooling device of a component includes at least one channel in which a first cooling fluid flows designed to cool a hot area of the component. It further includes a thermoelectric module configured to measure a temperature difference between the hot area of the component and the channel, and a control circuit configured to modulate the flowrate of the first cooling fluid in the channel according to the temperature difference.
Silicon thermoelectric and photoelectric sensor in self-powered radio-frequency transceiver module	09.07.2014; CN103910326	SOUTHEAST UNIVERSITY	LIAO XIAOPING	The invention discloses a silicon thermoelectric and photoelectric sensor in a self-powered radio-frequency transceiver module which is placed at the top of a radio-frequency power amplifier and is of an array structure composed of multiple same sensor modules. The sensor modules are serially connected through multiple groups of thermocouples. The thermal side of the sensor is placed on the position (a thermal dissipating plate) where heat of the power amplifier is concentrated, and the cold side is away from the position where heat is concentrated and is tightly close to a metal shell (a thermal sink plate), so that larger temperature difference at two ends of the thermal side can be achieved. Output of direct-current voltage is generated from the array structure of the sensor on the basis of Seebeck effect, and the direct-current voltage performs charge storage upon a rechargeable battery. Energy of optical energy and thermal energy can be simultaneously collected to be self-powered, and compared with a conventional self-powered sensor capable of collecting single energy, the silicon thermoelectric and photoelectric sensor is small in size and high in power supply capacity.
COOLING DEVICE PROVIDED WITH A THERMOELECTRIC SENSOR	11.06.2014; EP2740153	COMMISSARIAT L ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES	SAVELLI GUILLAUME	The invention relates to a device for cooling a component (24), including at least one channel (18) in which a heat-transport fluid for cooling a hot area of the component circulates. The device further comprises a thermoelectric module (20) configured so as to measure a temperature differential between the hot area of the component and the channel, and a control circuit (32) configured to modulate the flow rate of the first heat-transport fluid in the channel according to the temperature differential.

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

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.

Rajiv Kumar
Senior Partner

For more information contact:
techvision@frost.com

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