TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

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1. ADVANCEMENTS IN THERMISTORS

Thermistors, or thermally sensitive resistors, are electronic devices that undergo a large change in resistance due to a change in their body temperature. Thermistors are widely used in applications such as temperature sensing, control, and compensation. A typical temperature range for existing ceramic negative temperature coefficient (NTC) thermistors is -80 degrees C to +300 degrees C.

The wealth of applications for NTC thermistors include, for example, industrial process control, home appliances (for example, rice cookers, electronic ranges, oven temperature control, thermostats), healthcare (for example, thermometers, dialysis equipment, catheters, respirators), automotive (for example, monitoring coolant temperature, engine or transmission oil temperature or intake air temperature, heated seats), HVAC (heating, ventilation, air conditioning)/climate control, liquid level detection, flow measurement, thermal switches, time delay circuits, surge suppression, and aircraft temperature.

Conventional ceramic NTC thermistors have been employed in the marketplace for over 70 years; and dominate the thermistor market. The ceramic thermistors are comprised of a metal oxide mix annealed at high temperatures. Companies around the world have used this ceramic technology to produce billions of thermistors annually.

In 2003, at Sensors Expo, a small company from Silicon Valley, AdSem, Inc. (Advanced Semiconductor Company, Mountain View, CA), revealed unique silicon and germanium high temperature NTC thermistors with very impressive characteristics. These semiconductor thermistors had better performance than their ceramic counterparts. They operated at a wider temperature range, had

higher sensitivity and interchangeability, which increases with increase of temperature, and could be made less expensively and in much smaller size than ceramic NTC thermistors.

In 2004, a technology developed by AdSem Inc., had key opportunities to disrupt the well-established ceramic NTC thermistor market. To find out what has been achieved by the company for the past decade, *Technical Insights* interviewed Dr. Michael Kozhukh, the founder and president of AdSem Inc.

Dr. Kozhukh explained that many things have happened at AdSem since the company celebrated its tenth anniversary last year; but their biggest achievement is, probably, a transition from the R&D phase to production of semiconductor NTC thermistors. "We established a manufacturing process for our products by adopting proper semiconductor device manufacturing technologies. The use of Si and Ge for NTC thermistors allows one to avoid a potential contamination created by ceramics and provides an access to semiconductor plants. These modern semiconductor plants and semiconductor packaging fabs have a giant productivity of tens of billions of devices annually," Dr. Kozhukh noted, "and they can be used for a Si and Ge thermistor packaging without any changes to the existing technology for packaging diodes, transistors or LEDs, for example."

AdSem also expanded its list of the products, which now covers cryogenic applications for low temperature, T > 1K, as well as for ultra-low temperature, T<<1K. The lowest operating temperature of theNTC thermistors is 0.9mK (900 microkelvin). In addition to semiconductor NTC themistors for a "narrow" cryogenic temperature range (77K to 400K, 20K to 400K, 1K to 400K), AdSem offers thermistors with a super-wide operating temperature range from a few mK to about 700K, thermistors with decreased sensitivity to magnetic fields up to 5T (Tesla) at helium temperatures and thermistors with increased radiation hardness.

For nuclear bolometers/X-ray spectrometry, AdSem developed thick silicon (Si) and germanium (Ge) thermistors with large surface area, which increases the operational energy and registration efficiency of these devices.

Dr. Kozhukh noted that AdSem is the only company in the world that offers inexpensive NTC thermistors with superior performance and very competitive pricing for operating temperatures from 1 mK and up to 500 degrees C. AdSem also developed and offers the smallest NTC thermistors on the market both for high and cryogenic temperatures.

Regarding the extensiveness of AdSem's intellectual property, AdSem Inc., has a number of patents in the thermistor field and a lot of "know-how." While AdSem offers an impressive list of products and has solid IP protection, Dr. Kozhukh noted that, unfortunately, the company has not yet managed to change the landscape of the NTC thermistor industry. AdSem has an amazing large scale manufacturing technology for a Si and Ge NTC thermistor production, he explained, but, regrettably, they do not use these capabilities in full.

Dr. Kozhukh explained that there is no doubt that demand for semiconductor NTC thermistors exists, and they can and will replace ceramic thermistors. Currently, AdSem sells Si and Ge high temperature and cryogenic NTC thermistors on-line to many customers all over the world, including leading international and US institutions, who are looking for high-performance NTC thermistors or unique thermistors for novel applications. Unfortunately, this is a minuscule part of AdSem's potential customer base, and it has insignificant requirements for product volume. Despite the company's intriguing and innovative products, majority of its potential customers are still unaware of inexpensive semiconductor NTC thermistors and their high performance characteristics and continue using ceramic thermistors.

AdSem has a limited internal funding, and because of that they do not have a significant sales and marketing force to convert the ceramic thermistor users into its customers. The company focusses on new technology development and establishing a cost-effective manufacturing process, which it considers as its strongest side, and it chose to direct almost all available funds into these areas. AdSem is trying to find the right solution to its current problems.

AdSem did have a number of offers from venture capitalists (VCs), but they were unacceptable. Cooperation with thermistor manufacturers has not happened because they are not interested in supporting semiconductor NTC thermistors, which have better performance than their ceramic thermistors.

Nevertheless, AdSem continues working on improvement of its sales and marketing departments and on finding suitable cooperation.

Dr. Kozhukh noted that, fortunately, there are many companies in different industries, to which cooperation with AdSem is attractive. For example, there are companies from the temperature measurement industry--thermocouple companies, semiconductor temperature IC manufacturers, platinum and other metal RTD manufacturing companies, infrared temperature sensor manufacturing companies. There are also discreet device (diodes, transistors, light-emitting diode [LED]) and passive device (resistors and capacitors) manufacturing companies, big semiconductor packaging fabs, large instrumentation and semiconductor materials companies, large auto- and medical companies, which use thermistors in their products, and so on. Companies with established temperature sensor sales channels would benefit from extension of their product lines, and consumers of the temperature sensors would get access to AdSem's inventions, advanced products, and cost effective large scale manufacturing technologies.

One of the strongest aspects of AdSem is new product development. Dr. Kozhukh noted they developed the first multifunctional (dual function) sensor. In this device the same semiconductor sensor measures two different characteristics at different conditions. Further details about this sensor cannot be disclosed because AdSem is under proper patent law requirements.

AdSem is working on a development of its first PTC (positive temperature coefficient) thermistor with an extended operating temperature range (in comparison with existing PTC thermistors) both at its low- and high ends. This thermistor will have significantly higher sensitivity than platinum (Pt) RTD in the whole operating temperature range and will be less expensive than the Pt sensor.

For many years, AdSem has been interested in neutron physics, specifically, in mosaic slow neutron monochromator development. During last few years they reached amazing results with Ge mosaic crystals,Dr. Kozhukh explained. NIST (US National Institute of Standards and Technology) tested AdSem’s monochromators at its slow neutron facility and measured 80% to 89% slow neutron reflectivity for Ge monochromators, with mosaicity in the range of 15 to 25 arc minutes. This is an extremly large reflectivity value, it even exceeds the reflectivity of graphite monochromators, which are considered

a benchmark for these devices. This is a "dream" result in 70+ years existence of crystal neutron optics, Dr. Kozhukh noted. Such mosaic crystal monochromators are of interest also for gamma- and X-ray optics, specifically, in some medical and astrophysics applications.

Technical Insights plans to continue to follow the progress in semiconductor NTC thermistor market development, which could be very important for the temperature sensor industry and its evolution.

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2. GRAPHENE-BASED GAS SENSORS

Gas sensors constitute a subclass of chemical sensors that are used for detection and measurement of concentration of gas in the vicinity. There are many gas sensing technologies available in the market, such as optical/infrared, electrochemical, calorimetric, metal oxide semiconductor, and so on. However, these gas sensing technologies may not be sensitive enough to detect a single gas molecule in several different environments. These technologies can show a gas detection response curve only when a specific amount of gas is detected. There is a need for highly sensitive, efficient, and robust gas sensors to detect even a single gas molecule in the environment.

To address the above challenge, researchers from the University of Illinois (UIC) at Chicago have developed an innovative chemical gas sensor. This graphene-based gas sensor is based on crystalline flaws in graphene sheets. Polycrystalline properties, such as mechanical, thermal, optical, and electronics scatter electrons and weaken lattice because of the grain boundaries. The research team at UIC created a graphene grain micrometer-sized boundary. The electrical property of grain boundary attracts gas molecules to the surface of the sheet. Hundreds of electron transport gaps are produced in the grain boundaries with different sensitivities. There is a charge transfer when the gas molecules are accumulated on the grain boundary, which results in a sharp response in detecting the gas molecules. Thus, it is expected that this process can detect even a single gas molecule. .

Once the project is fully developed, the gas sensor developed by UIC has opportunities to be used in environmental monitoring, process control industries, boiler control, fire detection, and detection of harmful gases in mines. The properties of the gas sensor would allow it to absorb gas molecules 300 times more than traditional gas sensors.

The project was supported by the startup budget of UIC, National Science Foundation, National Energy Research Scientific Computing Center and the US Department of Energy Office of Science. The research was also supported by Purdue University. The researchers are working on fabricating a chip-scale sensor array using grain boundaries and detecting different gas molecules. Once the project is fully developed, the gas sensor has opportunities to receive a good response in suitable applications because of its highly sensitive ability to detect even a single gas molecule.

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3. TACTILE SENSING FOR THE ROBOTICS INDUSTRY

Tactile sensing is a vital fundamental technology for the robotics industry. It enables robots to have a sense an object's structure; and based on the structure, robotics parts such as robotic hands modulate operations to hold different objects. Robots with tactile sensors are being used in varied industrial applications, such as grasping or lifting objects and helping to determine the characteristics of objects. However, the tactile sensing equipment used in the market can be subject to certain challenges--the equipment may not have the accuracy to localize the pose of the object that is being handled. These sensors cannot conform themselves according to the shape of the object. Hence, there is a need for an accurate device, which can sense the structure of the object; is easy to use, cost-efficient; and can accurately perform complete tasks such as holding a USB plug and inserting it in the correct slot.

To address the above challenge, researchers from the Massachusetts Institute of Technology (MIT) and the Northeastern University have developed an innovative solution. The device is in the prototype phase and is capable of operating in the robotics industry. This novel tactile sensor is called as GelSight.

The GelSight device is cubicle in shape and is comprised of a transparent slab and synthetic rubber. On one side, the synthetic rubber is coated with metallic paint. The rubber conforms when it pressed against any object. The metallic paint covered face is exposed to the gel mounted on the device. The four walls of the cube conduct different colors of light such as white, green, blue, and red with the help of a light-emitting diode. Light bounces off the metallic paint when the gel is deformed, and the camera placed on the cube captures the process. The researchers have developed a computer vision algorithm for different color lights and different intensities. The algorithm can gather three-dimensional (3D) information about the surface to which the sensor is pressed and about the structure of ridges. Thus the GelSight sensor determines the tangible acuity of the device and tightens the grip of the robotic hand on which the sensor is placed.

Once the project is fully developed, GelSight can be used in industrial robots and also in optical measurement applications. While testing the sensor with the Baxter robot from Rethink Robotics, 3 millimeter variation was recorded in grasping a device. Researcher are working on enhancing the computer vision algorithm of the device.

The project was self-funded by MIT and it was supported by the Northeastern University. Researchers are working on implementing the GelSight with different application domains in robotics and improving its sensitivity. GelSight is expected to get commercialized in two to three years' time. The GelSight sensor ihas potential to garner good response from the robotics industry because of its accuracy in performing tasks and its cost efficiency.

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4. RECENT PATENTS IN THE FIELD OF FINGERPRINT SENSORS

To secure data and other assets from hackers, corporations are increasingly using biometric authentication. Some of the biometric authentication technologies are fingerprint, iris, facial recognition, and so on. Among these, finger print recognition is an efficient and widely used method for identification/authentication of people. Sensors such as optical, thermal, and

capacitive and used in finger print recognition. Fingerprint sensors can be used in offices for tracking employee attendance. They can also be used on safety boxes, lockers, and so on. Fingerprint sensors help users secure their data and assets.

From 1976 to September 2014, approximately 33,905 patents have been registered under biometric sensing. The biometric sensors are classified under fingerprint sensing. From 2009 to September 2014, approximately 40 patents for fingerprint sensing have been assigned to Apple Inc. Apple is significantly investing in finger print sensing for safe and trouble-free performance of its products. A recent patent in fingerprint biometric sensing (WO/2014/149655) was assigned to Apple Inc., which was classified under "acquiring finger biometric data and spoof detection." It pertains to an electronic device that may include an array of finger sensing pixels and data acquisition circuitry coupled to the array.

Fingerprint sensors are significantly getting incorporated in mobile phones. It is also expected that other Apple products, such as the IPod and IPad, can become deployed with fingerprint sensors. Samsung is also investing in fingerprint sensors. It had filed for a patent under fingerprint sensing in April 2014.

A recent trend in fingerprint sensing market suggests that both investors and inventors are focusing on preventing fraudulent activities such as identity theft. In the future, fingerprint sensors are expected to be deployed in smart cards, mobile phones, tablets, laptop, office, security boxes, and many more. Fingerprint sensing and its applications are gaining lot of attention across various sectors; and the market potential of finger print sensors has potential to significantly expand going forward.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
ELECTRONIC FINGERPRINT ACQUISITION WITH INTERLEAVED SPOOF DETECTION	25.09.2014; WO/2014/149655	APPLE INC.	MINTEER, Gregory, T.	An electronic device may include an array of finger sensing pixels and data acquisition circuitry coupled to the array. The data acquisition circuitry may be capable of acquiring finger biometric data from each sub-array of the array, and acquiring spoof detection data from at least one of the sub-arrays in an interleaved fashion with the finger biometric data.
AN AUTHENTICATION SYSTEM AND METHOD	25.09.2014; WO/2014/146684	QATAR FOUNDATION	FILIPPI, Raymond	An authentication system for authenticating an authorised user at a respective electronic device, the system comprising a device-specific identifier (101) (di) operable to identify the respective electronic device; a biometric data sensor (102) operable to sample biometric data (bd) from the authorised user of the respective device identified by the device-specific identifier (101) and provide reference biometric data (rb) for the authorised user; a storage unit (103) operable to hold the reference biometric data (rb) derived from the biometric data of the authorised user of the respective device identified by the device-specific identifier (101) for delivery to a processor (104) operable to perform a one-way function F on a data pair comprising or derived from: the device identifier (di) (101); and the biometric data (bd/rb), the one way function having an output comprising F(di, bd/rb).
BIOMETRIC AUTHENTICATION SYSTEM AND BIOMETRIC SENSOR CONFIGURED FOR SINGLE USER AUTHENTICATION	21.08.2014; US20140232526	Tec Solutions, Inc.	CARPER Todd Alan	A biometric authentication system comprises a biometric sensor configured for single user authentication. The biometric sensor can be configured for single user authentication through an enrollment procedure in which one or more sensing parameters are adjusted based on unique characteristics of the user. Thereafter, the user can be authenticated by capturing biometric data using the adjusted sensing parameters and comparing the captured biometric data against stored template data.
DERMATOGLYPHIC HAND SENSOR	21.08.2014; US20140233810	LUMIDIGM, INC	Spence William J.	Methods and systems are disclosed for performing a biometric function. A means is provided for positioning a hand of an individual in a substantially repeatable manner. An optical direct-imaging sensor is disposed relative to the means for positioning to image a portion of the hand when the hand is positioned by the means for positioning. A computational unit in communication with the optical direct-imaging sensor has instructions to operate the optical direct-imaging sensor to generate an image of the portion of the hand, and instructions to perform the biometric function with the generated image.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
FINGERPRINTING APPARATUS, SYSTEM, AND METHOD	14.08.2014 US20140225712	Longo Leonard P.	Longo Leonard P.	An apparatus, system and method for biometric acquisition are disclosed. In one embodiment, a sensor is configured to detect a biometric signature of a subject. The sensor is configured to be mounted to a surface. Various sensors are disclosed as being operative with the biometric acquisition apparatus. A vehicle with a mounted biometric acquisition apparatus is disclosed. A method for identification of suspects is also disclosed.
APPARATUS AND METHOD FOR FINGERPRINTING SENSING	07.08.2014; US20140219523	SYNAPTICS INCORPORATED	PEREZSELSKY Armando Leon	A biometric sensor apparatus and method are disclosed, which may comprise a flexible substrate comprising a first side surface and a second side surface opposing the first side surface; a biometric sensor portion comprising biometric image sensing elements formed on the second side surface forming at least part of a biometric sensor array sensing capacitively induced changes induced by a biometric in the vicinity of the biometric image sensing elements; a biometric sensor controller integrated circuit mounted to the flexible substrate on one of the first side surface and the second side surface of the flexible substrate; an edge surface of the flexible substrate including at least one conductively plated perforation in the flexible substrate; and an electro-static discharge element formed on or as part of the flexible substrate and electrically connected to the at least one conductively plated perforation.
BIOMETRIC IMAGING DEVICES AND ASSOCIATED METHODS	24.07.2014; WO/2014/113728	SIONYX, INC.	SAYLOR, Stephen D.	Systems, devices, and methods for authenticating an individual or user using biometric features is provided. In one aspect, for example, a system for authenticating a user through identification of at least one biometric feature can include an active light source capable of emitting electromagnetic radiation having a peak emission wavelength at from about 700 nm to about 1200 nm, where the active light source is positioned to emit the electromagnetic radiation to impinge on at least one biometric feature of the user, and an image sensor having infrared light-trapping pixels positioned relative to the active light source to receive and detect the electromagnetic radiation upon reflection from the at least one biometric feature of the user. The system can further include a processing module functionally coupled to the image sensor and operable to generate an electronic representation of the at least one biometric feature of the user from detected electromagnetic radiation, and an authentication module functionally coupled to the processing module that is operable to receive and compare the electronic representation to an authenticated standard of the at least one biometric feature of the user to provide authentication of the user.

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

Picture Credit: Frost & Sullivan

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