TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

31st July 2015

1. ADVANCEMENTS IN 3D PRINTED SENSORS

Three-dimensional (3D) printing is an additive manufacturing process in which 3D objects or structures are created from a digital file by laying down (rather than removing) successive layers of material. 3D printing has been finding significantly increased opportunities in varied industries, such as healthcare, aerospace, automotive, consumer or commercial products or applications. The opportunities are driven by the ability of this manufacturing technology to fabricate parts, components, or structures more efficiently with less waste. 3D printing, which at present is mostly used for prototyping and for relatively limited-volume production, enables the creation of an agile manufacturing environment and can significantly reduce the lead time from conception to the production stage.

However, 3D printing has not been used on any significant scale to produce electronics or sensors. 3D electronic printing has the ability to produce 3D objects having circuitry embedded in the structural material; and can enable the creation of smaller, lighter, more efficient and more customized products.

One challenge in 3D printing of electronics has been the need for conductive material that could be used in, for example, desktop printers and also could be incorporated with a standard 3D printing material. It has also been challenging to match the reliability, functionality, and cost-effectiveness of 2D electronic fabrication techniques.

Advancing 3D printing of electronics and sensors, researchers at the university of California at Berkeley, collaborating with researchers at National Chiao Tung University in Taiwan, have 3D printed a wireless 'smart cap' with embedded sensors to detect spoilage in a milk carton.

The researchers are also developing such technology for healthcare applications, such as implantable devices equipped with embedded transducers to monitor blood pressure, muscle strain, and drug concentration.

The UC Berkeley researchers have created varied 3D-printed electrical components, including an electrical resistor, inductor, capacitor, and integrated inductor-capacitor system.

To circumvent the poor electrical conductivity of polymers, which are widely used in 3D printing, the researchers used polymers and wax. Then, they removed the wax left, which left hollow tubes into which liquid silver was injected and then cured. The functionality of an electrical component depended on the shape and design of the metal. For example, resistors were created from thin wires and capacitors were made from flat plates.

In addition, the electronic components were integrated into a plastic milk carton cap to monitor spoilage; and a capacitor and inductor were added to the cap to create a resonant circuit.

The circuit was able to detect changes in the electrical signals resulting from higher levels of bacteria. Changes in the milk's property result in variation in the milk's electrical characteristics. Such changes were detected wirelessly via the smart cap.

Over time, such 3D printing technology has potential for creating electronic circuits for use in packaging to provide a food safety alert; the use of a mobile device to check food freshness could be envisioned. However, 3D printing is not yet sufficiently cost-effective, compared to the cost of producing integrated circuits via high-volume batch manufacturing, for use in printing mobile devices. The researchers perceive 3D printed microelectronics to particularly have opportunities in customized products or systems.

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2. PIPELINE HEALTH MONITORING SENSOR

Corrosion, the deterioration of metal due to reaction with the environment, is a major cause of failure in oil and gas pipelines. For example, in the utility sector, due to the aging pipeline infrastructure, corrosion is a significant threat in gas transmission pipelines as well as in iron or bare steel gas distribution pipelines.

Corrosion refers to deterioration of material (typically metal) due to a reaction with the environment. In external corrosion, the environment is groundwater or moist soil. For internal corrosion, the environment is water containing sodium

chloride, hydrogen sulfide, and/or carbon dioxide. The deterioration involves the dissolution of iron into the environment, which reduces the pipeline's strength. Natural gas, which comes from a well, can contain small amounts contaminants such as water, carbon dioxide, or hydrogen sulfide. Water that condenses can react with the carbon dioxide or hydrogen sulfide to create an acid that might cause internal corrosion.

Traditional methods of preventing corrosion in pipelines have limitations. For example, conventional methods for safeguarding against external pipeline corrosion include cathodic protection and coatings. Methods to detect internal corrosion include pigging, as well as techniques such as ultrasonic inspection and magnetic flux leakage.

Cathodic protection, where current is applied to a pipeline through soil from an anode or rectifier, can be prohibitively expensive for protecting a long, bare pipeline, since the amount of current required is proportional to the exposed surface area. Coatings are used to separate the steel from an electrolyte to prevent corrosion. However, it not feasible to create a perfect coating over the entire pipeline and there can be breaks in the coating.

Pigs, which are essentially robotic snakes that travels along the line, propelled by gas or fluid flow, to check the pipe's integrity, can have varying levels of effectiveness depending on pigging velocity and distance and the target materials.

Magnetic flux leakage (MFL) can have such disadvantages as susceptibility to product flow restriction or permanent magnetization of the pipe. Ultrasonic testing can have deficiencies such as difficulty in coupling to the pipe wall with a fast moving pig, and vulnerability to debris.

Indicative of opportunities to provide improved sensing of pipeline corrosion, the Corrosion Research Centre at Australia-based Deakin University has received a grant of about $1 million from the Energy Pipelines Cooperative Research Centre in Australia to develop a pipeline health monitoring system based on an innovative sensor developed by Deakin researchers. The funds will be used to advance the sensor technology via a three-year development period leading to commercialization. The researchers will also extensively model corrosion under disbanded coatings.

When the coatings used to protect high-pressure underground pipelines against corrosion become disbanded, due to chemical, electrochemical, electrical, and environmental factors, such pipelines become vulnerable to corrosion that could results in leaks or catastrophic failure.

The sensors developed by the Deakin researchers will complement smart pigs and focus on the outside of the pipe, which is a key area for underground pipeline corrosion. The sensors, which can placed in the ground, near the outside of existing pipes, will provide continuous, real-time monitoring of the efficiency of cathodic protection, coatings, and also check corrosion. The sensors will enable monitoring, modeling and prediction of when and where corrosion is likely to occur in the future, thereby facilitating enhanced and more efficient maintenance practices. The versatile sensors, which can be designed for oil and gas pipelines, underwater pipes, desalination plants, bridges, large structures, or submarines, will use wireless or satellite communications to alert companies about any corrosion-related issues.

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3. ADVANCEMENTS IN WATER SENSING

Sensing and monitoring of water quality is increasingly vital in the light of diminishing water resources coupled with the increasing population and urbanization and greater threats of contaminated water. Furthermore, many households obtain water from private wells, which do {not} assure water quality. Testing of private wells can be expensive, and it can take time to obtain the results.

There are key needs in water quality monitoring for sensors with enhanced sensitivity, selectivity, reliability, and ability to detect key contaminants swiftly and precisely in real-time. Furthermore, sensors of compact size enable ease of installation, low-power consumption, and on-site monitoring.

In a move that can address such key challenges, two types of sensors developed by researchers at the University of Wisconsin-Milwaukee have been licensed by companies, including three in Wisconsin. The sensors are a real-time sensor to continuously monitor even trace amounts of heavy metals or bacteria such as *E. coli*, and a handheld microfluidic sensing device that can identify heavy metals at very low concentrations and determine the pH (acidity) of water with a single drop. The two water sensor technologies were developed collaboratively with industry partners in the Water Equipment and Policy Center (WEP) industry

consortium. Subsequently, the intellectual property was licensed by the companies through the UWM Research Foundation.

Development of the real-time sensors that are able to withstand long-term immersion in a liquid environment to continuous monitor for trace concentrations of heavy metals or bacteria such as *E. coli* was led by Jenhong Chen, distinguished professor of mechanical engineering at the University of Wisconsin-Milwaukee. Such technology was licensed by Wisconsin companies, A.O. Smith Corp., Badger Meter and Baker Manufacturing LLC, and by Gannett Fleming Inc., of Pennsylvania.

The three Wisconsin companies also licensed the hand-held microfluidic sensor, which was created by Woo-Jin Chang, assistant professor mechanical engineering, in collaboration with Sundaram Gunasekaran, co-investor and professor, food engineering.

The sensors developed by Dr. Chen can have opportunities beyond private wells. Hundreds of such tiny sensors occupy a silicon wafer the size of a fingernail, which is a suitable size to be integrated into water equipment such as pumps, purifiers, meters, and pipes.

Chang's microfluidic device, which uses low-cost, disposable paper strips, can benefit the collection of water samples in the field.

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4. PATENT ANALYSIS OF ULTRASONIC SENSORS

Ultrasonic sensors emit high-frequency sound pulses that propagate through the air at the velocity of sound. When the pulses strike an object, they are reflected back as echo signals to the sensor. The sensor computes the distance to the target object based on the time span between emitting the sound and receiving the echo. Distance to an object is determined by time-of-flight, not by the intensity of the sound.

Piezoelectric sensors are used for sound emitter and receivers in active ultrasonic sensors that generate sound waves and evaluate the echo received by the sensor. Capacitive sensors, which use changes in electrostatic fields, are also employed in ultrasonic sensing, for example, in passive microphones that respond to ultrasonic waves.

Ultrasonic sensors are used for sensing distance, position, speed, object detection, thickness and for materials testing (including detection of cracks in material) and imaging parts of the body.

Most of patents filed from June 2015 to July 2015 are about the improvement of the design and production process for increasing the efficiency of the ultrasonic sensors used for motor vehicles.

Valeo Schalter und Sensoren GmbH, an automotive technology company, has filed the most number of patents for ultrasonic sensors during this period. A patent filed by this company (US 20150198698) pertains to an ultrasonic sensor device comprising a reinforcement holder arrangement for motor vehicles. The reinforcement holder holds teh sensor housing on the back side of a trim element on the vehicle. A similar patent (US 20150192673) filed by the same company pertains to an ultrasonic sensor arrangement in the radiator grill of a motor vehicle**.**

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Ultrasonic sensor device comprising A reinforcement holder, arrangement, motor vehicle and corresponding method	July 16, 2015/ US 20150198698	Valeo Schalter und Sensoren GmbH	Hans Wilhelm Wehling	The invention relates to an ultrasonic sensor device (**1**) for a motor vehicle, comprising an ultrasonic sensor (**7**) which comprises a pot-shaped membrane (**6**) for emitting and/or receiving ultrasonic signals as well as a sensor housing (**10**), comprising a stiffening element (**3**) arranged around the membrane (**6**) and comprising a holder (**4**), which is designed for holding the sensor housing (**10**) on a back side of a trim element of the motor vehicle, wherein the stiffening element (**3**) and the holder (**4**) are designed to be integrally formed from a uniform material.
Ultrasonic sensor arrangement comprising an ultrasonic sensor in the radiator grill, motor vehicle and corresponding method	July 9, 2015/ US 20150192673	Valeo Schalter und Sensoren GmbH	Hans Wilhelm Wehling	The invention relates to an ultrasonic sensor arrangement (**2**) for a motor vehicle (**1**), comprising a trim element (**3**), in particular a bumper, comprising a radiator grill (**4**), and at least one first and one second ultrasonic sensor (**5, 6**) each comprising a membrane (**11**) for emitting and/or receiving ultrasonic signals, wherein the first ultrasonic sensor (**5**) with its membrane (**11**) is arranged on a back side of the trim element (**3**) so that the membrane (**11**) of the first ultrasonic sensor (**5**) is configured for emitting and/or receiving ultrasonic sensor signals through the trim element (**3**) and the second ultrasonic sensor (**6**) is arranged on the radiator grill (**4**). By detuning means (**7, 9**) the second ultrasonic sensor (**6**) is detuned and hereby its emission and/or receiving behaviour adapted to the emission and/or receiving behaviour of the first ultrasonic sensor (**5**).

Ultrasonic sensor device having an improved decoupling ring and motor vehicle	July 2, 2015/ US 20150185188	Valeo Schalter und Sensoren GmbH	Oliver Eidel	The invention relates to an ultrasonic sensor device (**1**) for a motor vehicle, comprising an ultrasonic sensor (**2**), which comprises a pot-shaped membrane (**21**) for emitting and/or receiving ultrasonic signals, comprising a decoupling ring (**6**), which is arranged to fit around the membrane (**21**) in contact with an outer circumference (**34**) of the membrane (**21**), and comprising a stiffening element (**13**), which is arranged around the decoupling ring (**6**), wherein the decoupling ring (**6**) comprises a circumferential first radial decoupling region (**32**) which is in contact with the outer circumference (**34**) of the membrane (**21**) as well as a second radial decoupling region (**33**) with an axial front side (**37**) which is in contact with an axial front side (**38**) of the stiffening element (**13**).
Ultrasonic sensor and method for producing the same	July 2, 2015/ US 20150187347	Seiko Epson Corporation	Chikara Kojima	Provided is an ultrasonic sensor including a piezoelectric elements arranged along a first direction and a second direction on a vibration plate, an insulation layer, and conductive lines. Each piezoelectric element including a first electrode, a piezoelectric layer, and a second electrode. The first electrode is partially removed in a regions between the piezoelectric elements. The second electrode is a separate electrode provided for each piezoelectric element. The insulation layer covers the second electrodes and has holes through which portions at opposite ends of the second electrodes along the first direction are partially exposed. Each conductive line is provided between adjacent ones of the second electrodes along the first direction and electrically connects, via the holes, the adjacent ones of the second electrodes.
Method for producing an ultrasonic sensor for a motor vehicle	July 2,2015/ WO 2015096960	Valeo Schalter und Sensoren GmbH	Wehling, Hans-Wilhelm	The invention relates to a method for producing an ultrasonic sensor (20) for a motor vehicle. According to said method, the ultrasonic sensor (20) comprises a membrane (23) for emitting ultrasonic signals in the direction of emission (21) and a sensor housing (24) in and/or which the membrane (23) is secured. Said sensor housing (24) comprises a front side (25) facing the direction of emission (21) of the membrane (23) and a rear side (26) which faces the rearward direction (27) which is counter to the direction of emission (21). On the front side (25), the sensor housing (24) has a front-sided opening (28) for the membrane (23), said front side (25) of the sensor housing (24) being connected to a flap (52) made from a film, said flap covering the front-sided opening (28) of the sensor housing (24) in the direction of emission (21). The membrane (23) is introduced at least in sections into a receiving section (53) of the flap (52) and a front side (22) of the membrane (23) facing the direction of emission (21) is connected to a base (55) of the receiving element (53) of the flap (52).

Ultrasonic sensor	July 2,2015/ WO 2015096962	Valeo Schalter und Sensoren GmbH	Ludwig, Michael	An ultrasonic sensor (1) comprises a housing (2), a membrane (4) to which a piezo element (6) is secured, and an electrical connection zone (8) that includes a connection to ground (24). The membrane (4) is electroconductively connected to the connection to ground (24) in such a way that an arm (15) extending within the housing (2) acts as an electrical conductor between the membrane (4) and a male grounding contact (9).
Method for producing an ultrasonic sensor for a motor vehicle	July 2,2015/ WO 2015096959	Valeo Schalter und Sensoren GmbH	Wehling, Hans-Wilhelm	The invention relates to a method for producing an ultrasonic sensor (20) for a motor vehicle. A membrane (23) for emitting ultrasonic signals in a transmission direction (21) and a sensor housing (24) are provided for the ultrasonic sensor (20), said membrane (23) being secured in and/or on the sensor housing. The sensor housing (24) has a front face (25) which faces in the transmission direction (21) of the membrane (23) and a rear face (26) which faces in a backwards direction (27) opposite the transmission direction (21). The rear face (26) of the sensor housing (24) is formed with a rear-face assembly opening (29) for components of the ultrasonic sensor (20), and the membrane (23) is introduced into the sensor housing (24) through the rear-face assembly opening (29) in the transmission direction (21), brought into an assembly position on the front face (25) of the sensor housing (24) through an interior (30) of the sensor housing (24), and secured in the assembly position.
Method for the improved activation of ultrasonic sensors, driver assistance device and motor vehicle	July 1,2015/ EP 2888602	Valeo Schalter und Sensoren GmbH	Heimberger Markus	The invention relates to a method for operating an ultrasonic system (3) with a plurality of ultrasonic sensors (5 to 10), which are arranged in a distributed manner on a motor vehicle (1) and are activated in measuring cycles for the emission of an ultrasonic signal, wherein the measuring cycles are repeated. By means of a detection device (4) of the motor vehicle (1) that is separate from the ultrasonic system (3), an object (21, 24) in the surrounding area (13) of the motor vehicle (1) is detected, and a relative position of the object (21, 24) in relation to the motor vehicle (1) is determined. Depending on the relative position at the given time, the number of ultrasonic sensors (5 to 10) that are activated within a measuring cycle is then decided.
System for detecting inoperative inkjets in three-dimensional object printing using a test pattern and an ultrasonic sensor	June 30,2015/ US 09067446	Xerox Corporation	Aaron M. Moore	A printer detects inoperative inkjets during printing of three dimensional objects. The printer includes a substrate onto which a printhead ejects building and support material in a test pattern. An ultrasonic sensor scans the substrate on the unprinted side and measures thicknesses at a plurality of locations on the substrate. The thickness measurements are used to identify inoperative inkjets in the printhead and the printing of an object can be suspended to take remedial action with regard to the printhead before formation of the object is completed.

Alternative installation of a concealed ultrasonic sensor in the motor vehicle	June 25,2015/ US 20150177378	Valeo Schalter and Sensoren GmbH	Paul-David Rostocki	The invention relates to an ultrasonic sensor arrangement (2) for a motor vehicle (1) with a cladding component (4, 5, 8, 9) and a first ultrasonic sensor (10 to 13), which with its membrane is disposed on a rear side of the cladding component (4, 5, 8, 9), so that the membrane is designed for transmitting and/or receiving ultrasonic signals through the cladding component (4, 5, 8, 9), wherein the cladding component (4, 5, 8, 9) is a wing (4, 5, 8, 9) for the motor vehicle (1).

Exhibit 1 lists some of the patents related to ultrasonic 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 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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