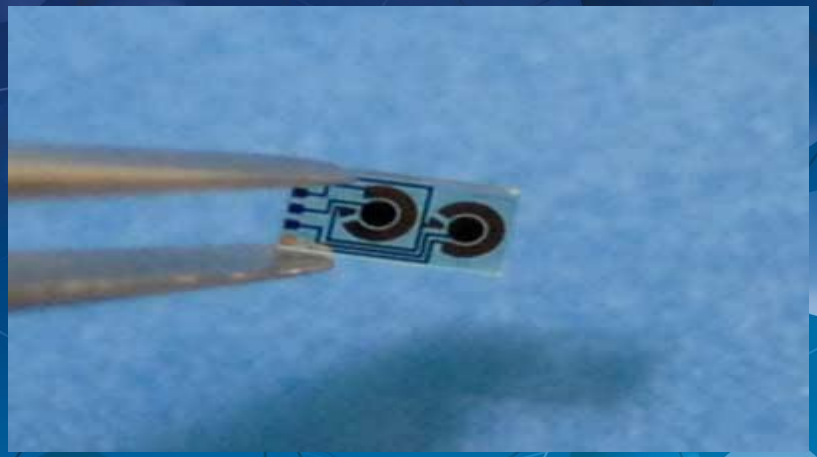
Sensor Technology (TechVision)



Bioinspired Sensors

Smart materials poised to impact different applications

D727-TV

March 04, 2016

FROST & SULLIVAN

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Sensor Technology Innovations in Bio-inspired Sensors

Economical, Robust MEMS Fluid Flow Sensor

MIT Alliance for Research and Technology (SMART) Centre for Environmental Sensing and Modeling, Singapore

Bioinspired MEMS Flow Sensor to Benefit Medical Applications

SMART researchers have developed a bioinspired, tiny, highly sensitive MEMS (microelectromechanical systems) flow sensor inspired by the blind cave fish. This fish can swim adeptly underwater at high speed.

Competing Aspects

- The superficial neuromast-inspired flow sensors use biomimetic soft polymer materials (e.g., a biomimetic acid-based hydrogen cupula dressing) allowing for high sensitivity and resolution. Blind cave fish have neuromasts outside their body that allow formation of 3D flow and objects maps for improved maneuvering.
- The flow sensor is small enough for integration in an IV or intravenous set-up for regulating the velocity of fluid flow to increase nurse productivity by 30%.

Technology Readiness Level:3

The researchers are working on rendering the technology suitable for such applications as biomedicals.

Attributes of Innovation

- The artificial nanosensors, based on nanoengineered sensors in nature, can attain an accuracy below the deep-vein velocity.
- Such sensors combine the inexpensive fabrication and accuracy of MEMS sensors with a robust design.

Market Readiness and Commercialization Strategy

The CENSAM team has worked on such sensors since 2014 and anticipates having robust sensors ready for routine use in biomedical applications .

Impact & Opportunities

Commercialization/Widescale Adoption Year

The technology has key adoption opportunities over the longer term.

Impact on Industries/Specific Apps.

- Heathcare (for example, IV or intravenous applications)
- Marine (navigation of underwater robots)

Market Potential/Opportunity

The technology has opportunities particularly in healthcare. For low-cost IV tubes or alarms.

Technology Convergence

Bioinspired sensors

Bio-inspired Nanofabricated Photonic Vapor Sensors

General Electric Company–Bio-inspired colorimetric sensor for gas detection

Tech. Profile

Researchers from General Electric Global Research and other organizations have constructed an enhanced bio-inspired colorimetric sensor comprised of a multilayer interferometric nanostructure and horizontal lamella which is supported by the vertical ridge. The structure and functioning of the sensor is inspired by the Morpho butterfly wing scales. The wings scales are highly selective to vapors.

Growth Potential

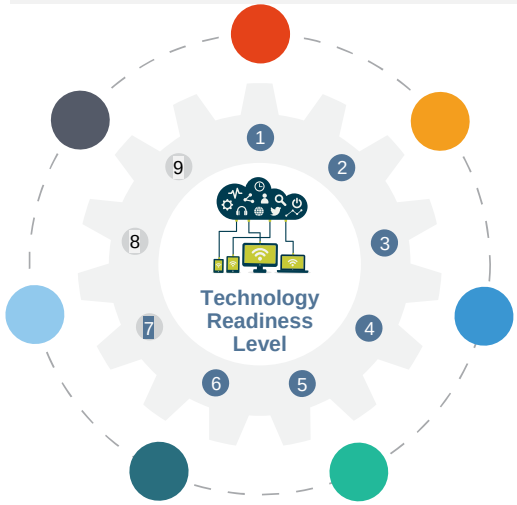
Conventional gas sensor arrays have limited selectivity and gas chromatographs and mass spectrometers have limitations in field use with regard to power, cost, size, vacuum or carrier gas requirements. The very selective colorimetric sensor can represent significant advancement in gas leak detection, with potential for diverse applications and field use.

Market Opportunity

- Industrial inspection; distributed monitoring
- Home Health Care
- Wearable units for monitoring, medical patients, chronically ill individuals, workplaces and athletes.
- Military /defense

Competing Aspects

The sensors are able to detect separate gases, and are also capable of quantifying gases and high selectively when they are blended in different chemical backgrounds.



Technology Convergence

The technology has the potential to converge with wearables and IOT, to send real-time information about the health of individuals in remote locations.

Innovation Attributes

The design of the sensor involves diffraction and optical interference. In addition, it uses optical loss in the nanostructure to bring about distinct signatures of reflectance spectra induced by optical attenuation.

Market Entry Strategies

Under a completed USDARPA (Defense Advanced Research Projects Agency) program on Bio Inspired Photonics, General Electric Global Research has collaborated with the State University at Albany, University of Exeter, and Air Force Research Laboratory. Achieving cost-effective fabrication of the photonic sensors could enable commercial applications in the next 5 years.

Bio-inspired Stretchable Sensor Network in Composite Structures

Structures and Composites Laboratory, Stanford–Developing a way to integrate large-scale sensor structures

Tech. Profile

Researchers at Stanford University have been working towards integrating large- scale stretchable sensor networks with wires thinner than human hair. The material used by the researchers has included polymers, piezoceramic/piezoelectric, and silicon MEMS technology on a flexible polymer substrate material to detect parameters, such as pressure, temperature, strain, vibration, and so on.

Year of Impact

Such a sensor network is expected to have opportunities for commercialization within circa 5-7 years. In addition, the technology will elicit interest from the aerospace and defense sector.

Market Opportunity

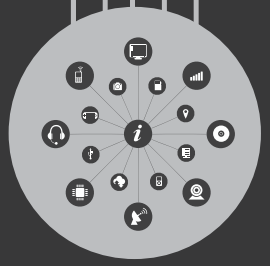
- ✓ The sensor could be employed in the manufacture of smart wings for unmanned aerial vehicles or, over time, in other structural monitoring applications.

Competing Aspects

The sensor network will sense the state/health of the structure and current damage, and predict damage propagation throughout the material during its lifetime.

Innovation Attributes

The stretchable sensor network will add to the intelligence in the composite structure. The fabrication of the sensor network can be done from the nano to micro scale.



Market Entry Strategies

The project was funded by the U.S. Air Force Office of Research (AFOSR) MURI program, Bio-Inspired Intelligent Sensing Materials for Fly-by-Feel Autonomous Vehicles.

Progress

The researchers have worked on investigating the feasibility of integrating the sensors to monitor the composite curing process to check network survivability and response.

Technology Readiness Level 1 2 3 4 5 6 **7** 8 9

Bio-inspired Artificial Skin Mechanoreceptor

Stanford University–Developed organic digital mechanoreceptor

Stanford University

Tech Profile

Thousands of sensors, also called mechanoreceptors, are distributed in the skin to accomplish the sense of touch. To develop an artificial skin, the researchers employed sensors made of plastic with carbon nanotubes scattered through the plastic. Such sensors can sense touch or pressure and generate an electrical signal which is further used to communicate with the brain.

Competing Aspects

Pressure on the plastic squeezes the CNTs closer together, enabling them to conduct electricity. Increased pressure results in more electricity flowing through the sensor. Pulses will cease when there is pressure. Small electrical pulses induce only few pulses per second while larger pulses produce electrical pulses more frequently--about several hundred pulses per second, Artificial mechanoreceptors mimic this process by coupling the pressure sensor with the flexible circuit layer that produces the electrical pulses.

Innovation Attributes

The sensations from the detected pressure are sent to the brain cells as short pulses of electricity which are very easy to read and interpret. The sensors are very thin, flexible and stretchable and can be mounted on the skin to detect vital signs such as heartbeat and blood pressure

Market Entry Strategies

The researchers envision that this artificial mechanoreceptor concept will inspire a technology that can be utilized for enabling brain responsive prosthetics, providing the most important sense of touch. The university will adopt the collaboration model to enter the market.

Technology Readiness Level

1 2 3 4 5 6 7 8 9

Impact & Opportunities

Wide Scale Adoption

Over time, the technology has opportunities to detect different types of sensations in artificial skin. In the future, stem cell technology could generate an optogenetic interface for technologies such as the new sensors. Companies and universities are working toward developing soft electrodes exploring optogenetics (a combination of genetics and optics) as an alternative to electrical stimulation which will offer better bio-interfaces.

Market Opportunity

For wearable artificial skin sensors to become more widespread, they need to be affordable. Hence, it is essential to ensure that the product and all associated technologies are extremely economical. Sacrificing profit for market penetration will be critical at least initially. The industry will need to focus on driving adoption and affecting a paradigm shift before turning attention on revenue.

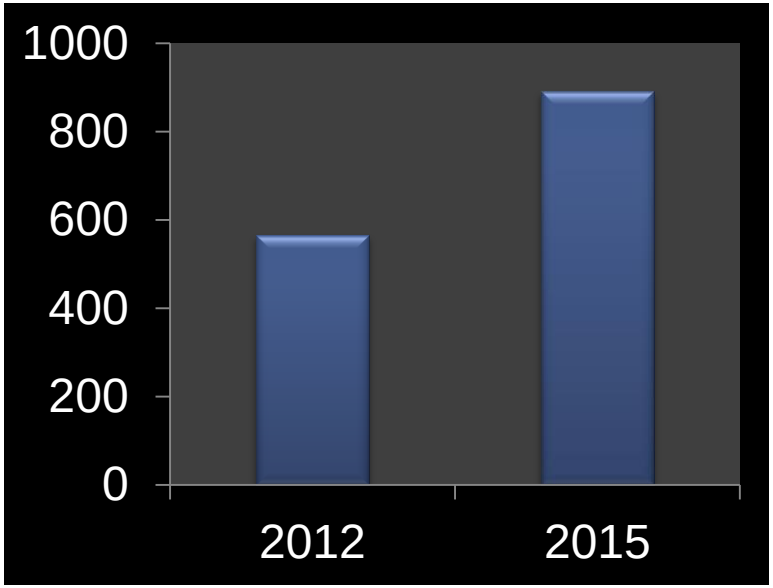
Strategic Insights

Strategic Insights

Key Participants in Bio Inspired Sensing

The Pennsylvania State University (USA), Jet Propulsion Lab (USA), University of Wyoming (USA), The University of Utah (USA), Defense Science and Technology Organization (Australia), University degli Studi di Salerno (Italy), NASA Ames Research Center (USA), Universito de Buenos Aires (Argentina), Seoul National University (Republic of Korea), University Autónoma de Madrid (Spain), Polytechnic Institute of New York Univ. (USA), Osaka University (Japan), The University of Texas at Austin (USA).

Intellectual Property (IP)



Source: WIPO/Frost & Sullivan

- Bio inspired materials are gaining traction among OEMs such as The Boeing Company as well as research laboratories such as US Air Force Lab and academic institutions that are working towards developing intelligent materials.
- Over the next five years, the demand for advanced materials is expected to escalate and along with it, there will likely be increased interest in the bio inspired biomimetics, and bio replication materials.

Strategic Insights

Drivers

- ✓ Diverse Application Areas of Bioinspired sensors boosts adoption and leads to new product development
- ✓ Strong R&D efforts
- ✓ Technology advancements
- ✓ Compact sensor design decreases production cost
- ✓ Advancements in smart materials
- ✓ More detailed monitoring of structures or better ability to give sensing capabilities to human skin

Restraints

- Ẋ Miniaturization of sensors
- Ẋ Detection limit
- Ẋ High initial investment.
- Ẋ Integration of systems
- Ẋ Funding Issues
- Ẋ Increased complexity of large-scale sensor networks

Funding

- The majority of start ups depend on bank financing, angel investors and strategic tie-ups for funding.
- The government intends to increase the uptake of these cost-effective devices and promote the use of devices based on breakthrough technologies for easier and quicker results.
- Funding support by government and venture capitalists is expected to accelerate the commercialization of prototypes. Technology developers would be able to bring innovative ideas to the market with financial support.

Focus Areas

- Nanotechnology
- Compact design
- Multifunctional composite material
- Nano-structured composite material
- Bio-functional material and structures
- Composite materials with built-in sensors
- Material with a micro fabricated stretchable sensor network

The 2020 Scenario

- ❑ Sensor manufacturers will try and incorporate multiple features in single products by collaborating with third parties during the development stage to produce bio inspired materials.
- ❑ Technology developers will develop versatile sensing platforms that would be capable of measuring several structural responses through a single solution. That would reduce the system cost considerably and also facilitate comprehensive information about structural health.

Key Patents and Industry Interactions

Key Patents

No.	Patent No.	Publication Date	Title	Assignee
1	**JP2012194969**	11.10.2012	Bioinspired system for featuring through processing on color attribute of digital image	Fundacion Tecnalia Research & Innovation
	PROBLEM TO BE SOLVED: To provide a computer-mountable bioinspired system for processing color attributes of a digital image. SOLUTION: There is provided the computer-mountable bioinspired system for processing color attributes of the digital image. The bioinspired system includes an order structure which emulates functions of retinas of the primates, analyzes the original digital image received by a data input part to detect color attributes in the original digital image, and generates output information formed of a set of data representing the color attributes in the original digital image and prescribed with respective pixels of the original digital image. The system has an emulator group constituting virtual retinas, each emulator is parameterized and generates a first color channel (a) and a second color channel (b) of an output signal group, and a bipolar cell emulator group generates a third channel (A) of the output signal group through a horizontal cell emulator group. COPYRIGHT: (C)2013,JPO&INPIT			
2	**US 20120207376**	16.08.2012	Bioinspired system for image processing	Garrote Contreras Estibaliz
	A method for digital image processing is bioinspired and includes an architecture that emulates the functions of photoreceptors, horizontal cells, bipolar cells and ganglion cells of a primate retina based on an image as input. The method detects edges and properties of the surfaces present in the digital image. The output is a data set that includes photoreceptor emulators that emulate photoreceptor cells and connected to the data input. Each emulator includes a cellular base structure with a modulated data input, a calculation center to process the modulated data and an output of the data processed by the calculation center, and the emulators forming a virtual retina in which each emulator is parameterized.			

Key Patents

No.	Patent No.	Publication Date	Title	Assignee
3	**US20100232533**	16.09.2010	Methods of selecting signal transmitting, receiving, and/or sensing devices with probabilistic evolutionary algorithms in information conveyance systems	Lee Daniel
	Methods are described for near optimal Antenna and/or sensor selection via population-based probabilistic evolutionary algorithms such as estimation of distribution algorithm (EDA) and bio-inspired Optimization (BIO). The aspects of the invention includes a method for joint transmit and receive antenna selection using EDA; and an enhanced EDA, which uses cyclic shift register and biased estimation of distribution; and methods for joint transmit and receive antenna selection using improved population-based optimization. The proposed EDA-based and bio-inspired selection methods results in performances that are close to the ESA (exhaustive search algorithm) and yet impose mush less computational burden than ESA. Another advantage of our methods is that they can be easily implemented on parallel processors.			
4	**US 20070285040**	13.12.2007	Synthetic nervous system for robotics	New School Technologies LLC
	A synthetic nervous system (**10**) capable of rudimental learning and self-organization for robotic applications having a control circuit (**190**) and servo actuators (**224**) using oscillating continuously variable analog voltages to mimic natural bio-neural processes. Simple oscillators (**1**-**8**) capable of being modulated in frequency, phase, amplitude, and DC offset act as analog processing elements or oscillating infinite state machines. A central pattern generator (**140**) utilizing periodic, quasi-periodic, or chaotic oscillators or phase shifters, or a combination thereof, along with a basic motor neuron circuit (**314**) enables multiple servos to coordinate their behavior to enable bio-inspired locomotion such as walking, swimming, flapping, crawling, and the like. Sensors (**200**) interfaced to the control circuit (**190**) provide a wide range of adaptive behavior such as following a light source, avoiding an obstacle, and shifting balance point. Overlapping or concurrent sensor input can provide complex behavior with minimal circuitry.			

Industry Interactions

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