Sensor Alert (TechVision)

Skin-based Sensors

Artificial skin poised to impact consumer electronics, robotics, health and wellness

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Contents

Sensor Technology Innovations in Skin-based Sensing

Electroluminescent Stretchable Skin, Cornell University

Stretchable Electroluminescent Actuator Can Also Emit Light and Sense Pressure

- Researchers at Cornell University, led by Robert Shepherd, assistant professor of mechanical and aerospace engineering, along with contributors from the Italian Institute of Technology's Center for Micro-Robotics, have developed an electroluminescent artificial skin that uses a hyperelastic, light-emitting capacitor (HLEC) and is able to stretch, emit light, and sense internal and external pressure (for tactile sensing).
- The multi-pixel electroluminescent displays are 5 mm thick, and each of the 64 pixels measures 4 mm.

Competing Aspects

The skin stretches to over six times its original size while emitting light. The HLEC, which uses two ionic, hydrogel electrodes embedded in a silicone matrix, is considerably more elastic than conventional stretchable light emitters based on organic semiconductors. The matrix allows for displays of different colors, because it contains zinc sulfide doped with transition metals that emit different wavelengths as electricity travels through.

Technology Readiness Level:5

The rubber sheets containing the arrays of pixels were integrated into the skin of a soft robot.

Attributes of Innovation

Layers of transparent hydrogel electrodes sandwich a zinc sulfide dielectric elastomer sheet, which changes luminance and capacitance (the ability to store an electrical charge) when it is stretched, rolled, or deformed in some way. The technology is unique in being able to sense and emit light.

Market Readiness and Commercialization Strategy

The researchers are leveraging support received from the US Army Research Office, US Air Force Office of Scientific Research, and the National Science Foundation to further develop the technology. Areas of focus are wearable electronics as well as vanishing interfaces.

Impact & Opportunities

Commercialization/Widescale Adoption Year

The technology has commercialization opportunities over the near-term. The researchers are focused on further developing the technology and do not speculate about commercialization.

Impact on Industries/Specific Apps.

- Soft robots; wearables (for example, wearable electronics, displays, and vital signs monitors)
- Transportation; Vanishing/natural interfaces that integrate with natural, everyday human function

Market Potential/Opportunity

A key opportunity is soft robots, where the color and shape of the material could improve human-robot interaction. In wearable electronics, the technology can enable devices that conform to the wearer's shape.

Technology Convergence

Wearable sensing; wearable electronics; soft robots; soft electronics

Innovative Uses of Insertable Technologies-University of Melbourne

Devices Inserted under the Skin Can Provide Greater Convenience and Accessibility in Interactions

Under the supervision of professor Frank Vetere, researchers at the University of Melbourne are investigating and field testing insertable technologies for use under one's skin: radio frequency identification (RFID) and near-field communication (NFC) microchips (encased in bio insert materials such as glass) and rare earth neodymium magnets (encased in materials such as titanium nitride).

Competing Aspects

Passive RFID chips are activated when they come into range of a transponder/scanning point. Passive RFID chips inserted under one's hands or forearms tend to have a read range of a few centimeters. NFC chips use a technology based on RFID and communicate over radio waves in NFC frequencies. Neodymium magnets are strong and durable. Magnets vibrate when in contact with electromagnetic fields. People with magnets inserted near nerve endings (e.g., on finger tips) can feel electromagnetic fields.

Technology Readiness Level

The researchers are working with commercially available insertable technologies.

Attributes of Innovation
The researchers are exploring innovative uses of insertables. They are not specializing in any particular type of insertable technology.

Market Readiness & Commercialization Strategy
The insertable technologies are available. For example, NFC chips inserted in the hand can be used for applications such as sharing contact details, launching apps, or unlocking phones, doors or cars.

Impact & Opportunities

Commercialization/Widescale Adoption Year

Insertables are envisioned to have some potential in the relatively long term, although they would compete against technologies such as wearables.

Impact on Industries/Specific Apps.

Potential in access applications, such as opening secure entrances, accessing accounts, work places, gaining access to homes or even public transport.

Market Potential/Opportunity

If issues such as fear of use for tracking purposes and interfacing the technology inside the human body can be addressed, insertable technologies could have some market opportunity by offering greater convenience.

Technology Convergence

- Trend toward the quantified self
- Miniaturization of electronic devices

Low-Cost Artificial Skin Multisensor Platform-King Abdullah University of Science and Technology (KAUST), Saudi Arabia

Paper Skin System Capable of Enhancing Wearables, Flexible Electronics

Researchers at KAUST's Nanotechnology Lab, under the direction of Muhammad Mustafa Hussain, associate professor of electrical engineering, have developed an artificial skin, which uses low-cost household materials to simultaneously detect external stimuli such as pressure, temperature, humidity, proximity, pH (acidity), and flow. Increasing humidity increased the system's capacitance. Exposure to an acidic solution increased the sensor's resistance. Exposure to an alkaline solution decreased it. Voltage changes were associated with temperature changes. When a finger came closer to the platform, its capacitance decreased.

Competing Aspects

Chemically functionalized, inkjet printed or vacuum-technology processed papers have exhibited limited performance and functionality relative to cost. In contrast, the KAUST researchers used everyday materials to develop the multisensor.

The properties of the sensing materials, such as their porosity, adsorption, elasticity, and dimensions, were exploited to develop a low-cost sensor platform and demonstrate an integrated platform capable of simultaneous, real-time detection of multiple stimuli.

Technology Readiness Level:4

Paper skin manufacturing can be achieved with slight tweaking. But, before an autonomous, flexible, multifunctional sensing platform is commercially attainable, development of wireless interaction with the paper skin needs to be achieved and testing is needed to assess the sensor's longevity and performance under severe bending conditions.

Attributes of Innovation

Sticky note paper was used to detect humidity, and sponges and wipes to detect pressure, and aluminum foil to detect motion. By coloring a sticky note with a HB graphite grading scale pencil, the paper could detect acidity levels, while temperature was detected using aluminum foil and conductive silver inks.

Market Readiness and Commercialization Strategy

Sensor integration must be optimized on the platform for medical monitoring system applications. Target applications include medical monitoring (for instance, heart rate, blood pressure, skin hydration, body temperature), robotics and large surface area coverage, and food quality monitoring.

Impact & Opportunities

Commercialization/Widescale Adoption Year

The initial version of the technology can be in the market in about 18 months. A US patent is pending, and the first prototype has been developed for vital signs monitoring. Investors are being sought.

Impact on Industries/Specific Apps.

Wearables/flexible electronics for wireless vital sign monitoring (for example, heart rate, blood pressure, breathing, skin hydration, and temperature), and touch-free computer interfaces. Other applications include assisting burn victims, robotics, vehicles, and environmental surveys.

Market Potential/Opportunity

Has opportunities to enable high-performance, multiparameter sensing in areas such as wearables. It integrates a very high number of sensing functionalities in one platform and uses recyclable, low-cost, and widely used materials.

Technology Convergence

Wearable sensing and electronics, quantified self.

Silicone-based Rubber Sticker

Saarland University–Artificial skin with pressure sensing capabilities

Tech. Profile

Researchers from Saarland University, in collaboration with the Max Planck Institute and Carnegie Mellon University, have developed a flexible silicone rubber sticker with pressure-sensitive sensors that can be fitted into the skin without any discomfort.

Wide-scale Adoption

The iSkin sensor, which uses capacitive touch sensing, has opportunities to enable various types of interaction with consumer devices. It could be used to answer incoming calls and adjust the volume of mobile devices. It has opportunities to enable the human body to get in close contact with electronic devices. While there have been no plans to release a commercial version of iSkin, it has potential to be commercialized in circa 3-5 years.

Market Opportunity

At present, the iSkin uses wires or cables to connect with the computer, but with the help of this skin, the researchers are planning to create a microchip which will operate without wires in the future. The device can be either wrapped around a body part or attached to the skin using biocompatible adhesives. In the future, it would also be used as a keyboard sticker to type and send messages.

Competing Aspects

- ✓ Reliable
- ✓ Robust
- ✓ Longer lifetime
- ✓ Easy to integrate

Technology Convergence

- Energy Harvesting
- Human-Computer Interaction
- Wearable Electronics

Innovation Attributes

An organic polymer called Polydimethylsiloxane (PDMS) is employed as a substrate in the manufacturing process. PDMS is ideal material because of its characteristics such as biocompatibility and elasticity. Thin, stretchable silicone is piled up in multiple layers and fabricated with the help of the laser patterning technique. Conductive carbon black particles are added to the silicone, which allows it to become a conductor and used for touch input.

Market Entry Strategies

The device will either be wrapped around a body part or will attached to the skin using biocompatible adhesives and form a close contact with electronic devices. There can be opportunities to license iSkin technology to wearables, consumer electronics, or robotics companies.

Strategic Insights

Strategic Insights

Applications

- Flexible displays and bendable phones
- Fitness tracking bands, smart watches, patient monitoring devices
- RFIDs, sensors for industrial purposes and for packaging purposes
- smart sensors, motion sensors, occupancy sensors
- AR glasses, leading to heads-up display for military purposes

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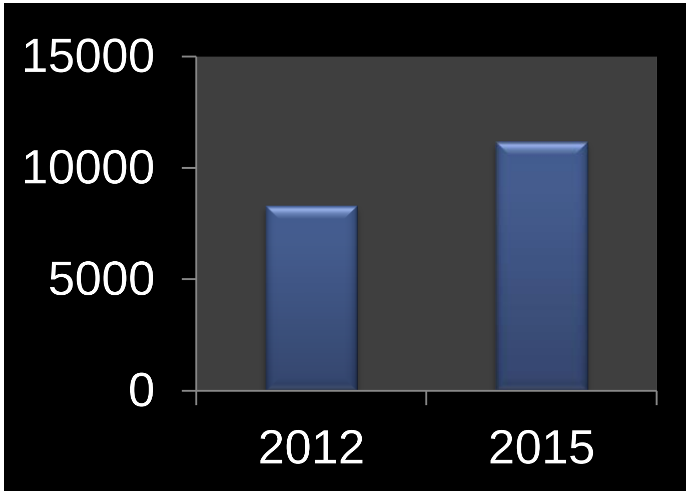
Intellectual Property (IP)



- According to the patent filing trends, the largest number of applications for stretchable sensors are in the consumer electronics and healthcare domains. Stretchable sensors are currently driven by applications, such as mobile phones and health, wellness and sports. In the medium term, it is projected that Internet-of-Things (IoT) will spur the growth of the market.
- In the consumer electronics and healthcare domains, stretchable sensor patent activities are gaining significant traction. In the coming years, wearable stretchable sensors are expected to witness significant patent filing activity. The highest concentration of patent activity can be seen in the US, followed by Japan, China, and Korea.

Strategic Insights

Drivers

- ✓ Design flexibility
- ✓ Low-power consumption
- ✓ New product development
- ✓ Strong R&D efforts
- ✓ Technology advancements
- ✓ Greater demand for enhanced user experience
- ✓ Application extension
- ✓ Bio compatibility
- ✓ Ease of usage
- ✓ Enhanced product line

Restraints

- Ẋ Technological barriers such as batteries, wireless, processing limitations
- Ẋ Security and privacy concerns
- Ẋ Operational reliability
- Ẋ Operational efficiency

Focus Areas

- Light Weight Material
- System-on-Chip ICs
- Flexible and Stretchable Materials
- Energy Harvesting
- Sound Absorbers

Funding

- To help develop flexible electronics, the UK Technology Strategy Board, now operating as Innovate UK) allocated up to 4.75 M pounds (about US$6.7 M at the current exchange rate) for R&D in the manufacture of future electronic systems.
- Funding support by governments and venture capitalists is expected to accelerate the commercialization of devices.

The 2020 Scenario

- ❑ Strategic partnerships between research institutes and companies across the value chain will increase the commercialization and market penetration of flexible, skin sensors for applications such as bioacoustic sensing and touch interfaces, as well as human motion capture.
- ❑ The rising application scope ensures more types of artificial skin-based sensing devices and will demand research work in all spheres as the applications differentiate the types of sensing devices and their functionalities. The higher the application opportunities, the better the market prospects.

Key Patents and Industry Interactions

Key Patents

No.	Patent No.	Publication Date	Title	Assignee
1	**WO/2015/184072**	03.12.2015	Advanced sweat sensor adhesion, sealing, and fluidic strategies	University of Cincinnati
	A sweat sensor device (200) includes one or more sweat sensors (220) and a seal (280) covering the one or more sweat sensors (220). The seal (280) is adapted to protect the sweat sensors (220) from outside contaminants when the device (200) is placed on the skin (12). The sweat sensor device (200) may include an absorbing medium (230) to absorb sweat from the skin (12) that is covered by the seal (280). The seal (280) can be permeable to gas, permeable to water and impermeable to at least one aqueous solute, or selectively permeable to at least one aqueous solute. The sweat sensor device (200) may include an artificial sweat stimulation mechanism (345) for stimulating sweat when the device (200) is placed on the skin (12).			
2	**CN104713824**	17.06.2015	Horizontal type testing device and testing method for attachment between fabrics and liquid-penetrating skin	Zhejiang Sci-tech University
	The invention provides a device and method for testing the attachment between fabrics and liquid-penetrating skin. The testing device comprises a sample clamping system, a universal joint, a force-measuring sensor, a lifting and falling machine, porous artificial skin, a liquid containing cavity, a trace injection pump and a control and processing system, wherein the sample clamping system is used for carrying out horizontal-direction circumferential clamping on a sample; the universal joint, the force-measuring sensor and a telescopic rod are arranged above the sample clamping system in sequence; the porous artificial skin is positioned below the sample clamping system, and longitudinal micropores are densely distributed in the porous artificial skin; liquid in the liquid containing cavity can emerge along the longitudinal micropores; and the trace injection pump can inject liquid into the liquid containing cavity. The method provided by the invention comprises the following steps of: when the horizontally-clamped sample is gradually separated from the porous artificial skin, the acting force of a liquid bridge formed between the horizontally-clamped sample and the porous artificial skin is tested, and the control and processing system outputs characteristic curves, token indexes and test data. The device and method provided by the invention can be used for testing and evaluating the attachment between woven fabrics, knitted fabrics, non-woven cloth and braided fabrics and the like and the liquid-penetrating skin.			

Key Patents

No.	Patent No.	Publication Date	Title	Assignee
3	**WO/2015/084061**	11.06.2015	High-sensitivity sensor comprising conductive thin film containing cracks and method for manufacturing same	Global Frontier Center for Multiscale Energy Systems
	A high-sensitivity sensor containing cracks is provided. The high-sensitivity sensor is obtained by forming microcracks on a conductive thin film, which is formed on top of a support, wherein the microcracks form a micro-joining structure in which the microcracks are electrically changed, short-circuited or open, thereby converting external stimuli into electric signals by generating a change in a resistance value. The high-sensitivity sensor can be useful in a displacement sensor, a pressure sensor, a vibration sensor, artificial skin, a voice recognition system, and the like.			
4	**US20150082920**	26.03.2015	Platform unit for combined sensing of pressure, temperature and humidity	Technion Research & Development Foundation Limited
	The present invention provides a modular platform unit comprising a plurality of sensors for the combined sensing of pressure, temperature and humidity. In particular, the sensors are composed of a layer of metallic-capped nanoparticles (MCNP) casted on a flexible substrate or a rigid substrate. Integration of the platform unit for artificial or electronic skin applications is disclosed.			

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