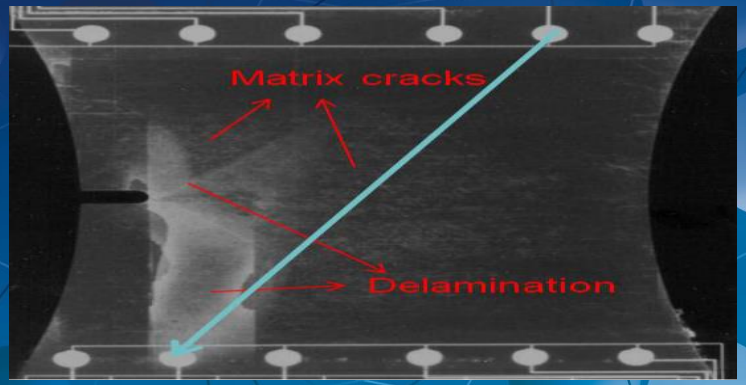
Sensor Technology (TechVision)



Structural Health Monitoring

Sensors Poised to Impact Structural Health Monitoring

D727-TV

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FROST & SULLIVAN

Contents

Sensor Technology Innovations in Structural Health Monitoring

Wireless Sensing System for Structural Health Monitoring

Lord MicroStrain – Provides and develops sensing systems for Aerospace Applications

Tech. Profile

Wireless solution permits scalable sensing at a fraction of the size. Integration of different sensing technologies in one platform enhances the monitoring capability by offering data -rich information about the structure. This enables comprehensive monitoring in a cost-effective manner.

Innovation Attributes

Low-power wireless sensors can use ambient energy harvesting from strain, vibration or temperature to offer long-term monitoring without replacing or maintaining the battery.

LORD MicroStrain® SENSING SYSTEMS

Competing Aspects

- *Scalable wireless sensor network*
- *Easy to Integrate*
- *Ease in data processing*
- *Eliminates heavy wiring*

Market Entry Strategies

Lord MicroStrain has collaborated with Curtiss-Wright Corp. to develop wireless sensing solutions for defense flight test instrumentation applications. This collaboration will open up new markets for Lord Microstrain.

Impact & Opportunities

Product Portfolio

✓Wireless sensing system for rotorcraft health monitoring and high-speed trains
✓Wireless bridge monitoring solution
✓Vibration energy harvester
✓Wireless sensor data aggregator
✓Wireless analog input sensor node
✓Miniature displacement sensors

Market Opportunity

The presence of several sensing solutions in one single platform saves space in different applications, including aircraft and bridge health monitoring and enables opportunities in various market segments such as

✓Aerospace and Defence
✓Automotive
✓Civil engineering
✓Machine health monitoring
✓Environmental
✓UAVs

Technology Convergence

The wireless sensing solution is a combination of both software and hardware. The wireless sensing platform can be converged with the cloud based platform for remote management, data storage and visualization. It also enables condition-based maintenance and predictive maintenance of critical assets.

Self-powered Wireless Vibration Control and Monitoring

WiBRATE Consortium–Self-Powered Wireless Vibration Sensing System

Tech Profile

Self-powered wireless vibration control and monitoring platform consists of innovative, smart sensors which can be fitted in structures, and software which can be used to compare the data in future to predict the health of the structure

Innovation Attributes

- *Identifying the premature failures*
- *Monitoring wear and tear of, for example, axles and wheels*
- *Real-time information about tracks*
- *Eliminates Heavy Wiring*

WiBRATE

Wireless, Self-Powered Vibration Monitoring and Control for Complex Industrial Systems

Competing Aspects

- *Early Damage Detection*
- *Cost Effective*
- *High Sensitivity*
- *Maximizes uptime*
- *Minimizes risk*
- *High ROI*

Consortium Profile

Under the project WIBRATE, researchers from various universities, coordinated by the University of Twente, have collectively developed a self-powered wireless vibration control and monitoring platform. The WIBRATE project (2007-2013) was supported by the European Commission under the 7th Framework program.

Technology Readiness Level

1 2 3 4 5 6 7 8 9

Impact & Opportunities

Wide-scale Adoption

As the system is wireless, the technology further reduces the cost of maintenance without the need for complex retrofit wiring and batteries. The train operators are updated with real-time information about the condition of the train. This enables the technology to gain traction among different industries

Market Opportunity

Southeastern Railways, UK was the first to deploy the sensor system on their trains. The technology is gaining traction in a number of countries in Europe, including Germany, Italy, Ireland, Sweden, and Spain. The sensors can be used to monitor structures in different applications, such as in petrochemical plants, and civil engineering.

Technology Convergence

Wireless sensors are emerging as one of the strongest options for SHM applications. Wireless sensors, along with energy harvesting technology, is gaining market recognition and traction.

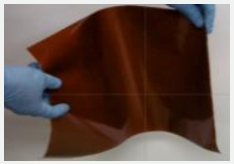
Intelligent Bio-Inspired Stretchable Sensor Network

Stanford University–Manufacturing a smart UAV wing using the embedding technique

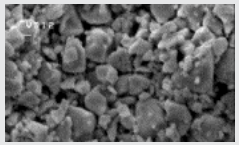
Expandable networks comprised multiple sensors around a structure can provide improved condition monitoring

MEMS & CMOS Processing

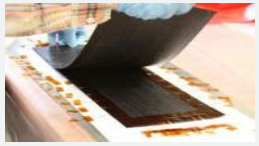
Polymer Substrate

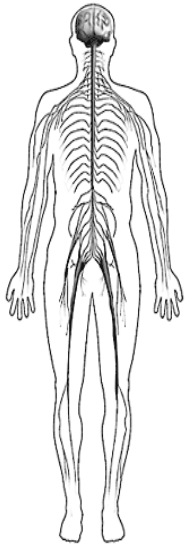


Piezoceramic Material



Embedded Systems in Composites





- Piezoelectric high frequency Strain
- Strain Gauge Low frequency Strain
- RTD - Temperature
- ChemFET chemicals

2013 2014 2015 2016 2017 2018 2019 2020

Over the next five years, the demand for advanced materials is expected to escalate and along with it, there will likely be an increase of interest in the Bio inspired, Biomimetics, and Bio replication materials.

Industry Initiatives

Bio inspired materials are gaining traction among OEMs such as The Boeing Company as well as research laboratories such as the US Air Force Research Lab and academic institutions that are developing intelligent materials. Stanford University has developed a bio-inspired absolute pressure sensor network for applications such as UAVs.

Working Principle

- A sensor network will be integrated in large-scale structures with thin wires. The sensor network will be stretched to the macro level. Multi-scale fabrication processes will be employed to fabricate a sensor network on a silicon wafer.
- Intelligent composite materials with embedded sensors that can monitor manufacturing processes and material quality, sense the state of the structure and current damage, and predict damage propagation throughout the material during its lifetime.

Wireless Sensing System to Monitor Large Infrastructure

GENESI Consortium–Focused on Energy harvesting enabled sensing system to monitor civil structures

Tech. Profile

In the Genesi project (2010-2013), a wireless sensor network that includes a low-power flexible sensing platform, multi-source energy harvesting, low-power requirements and wake up radio capabilities, is further able to support infrastructures by providing reliable monitoring, for very long periods of time in an energy- neutral way

Wide-scale Adoption

The sensor would be deployed, for example, next to a tunnel boring machine to measure and monitor parameters, such as temperature and deformation in real time. The sensors will be used to measure different parameters; this will further help the sensing system to be employed in different industries.

Market Opportunity

Across the world, civil and industrial infrastructure is aging; many public assets, such as roads and rail networks, power stations and water supply plants, are decaying to such a degree that there are now concerns about their stability and ever-increasing maintenance costs. The aging infrastructure has gneerated the need for structural health monitoring. The need to manage the serviceability of the infrastructures creates opportunities for wireless sensing.

Competing Aspects

- ✓ Reliable
- ✓ Less Response Time
- ✓ Easy to Integrate
- ✓ Cost Effective

Technology Convergence

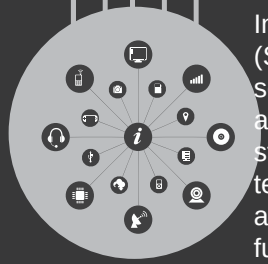
Data analytics is challenged by the presence of heterogeneous data. The data becomes too large and complex to be stored, managed and processed by traditional database management techniques. The wireless sensing system is expected to converge with cloud storage and big data analytics.

Innovation Attributes

The wireless sensor network is designed to be installed in a new structure during the construction phase. To detect long-term changes in the structure, the wireless sensor network will remain in place to monitor parameters such as aging, accidents or other changes.

Market Entry Strategies

In the Pont de la Poya Bridge (Switzerland), a prototype GENESI senor network was used to monitor and measure parameters, such as strain, bearing displacement, temperature, wind, pull on the pylon, and water levels. The technology is further expected to be licensed by the consortium.



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

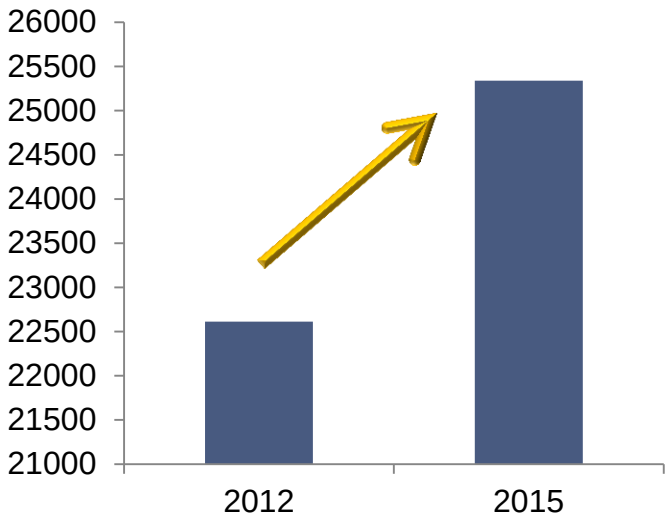
Strategic Perspectives

Strategic Insights

Technology Roadmap

2016	2017	2018	2019	2020
Research is still needed to identify effective energy harvesting technique(s) that make sensors self-reliant with a long life to meet service needs.	Nanosensors are still largely in the development stage. Carbon nanotube (CNT)-based nanosensors are being explored, and offered for applications such as biosensing, but would need another 7 to 8 years or so to begin to impact the commercial market.		MEMS (micro-electromechanical systems) sensor technology is well-established in the market. With regard to SHM applications, MEMS sensors have opportunities to be integrated with ever smaller radios and processors on a single chip for further reduction in power consumption.	

Intellectual Property (IP)



- According to the patent filing trends, researchers are moving towards detecting multiple types of damage. More vital and prominent technologies are sensor based because of certain advantages such as reliability, low cost, durability and enable easy integration into the existing structure.
- In the civil engineering and aerospace domain for structural health monitoring, R&D and patent activities are gaining lot of traction. Other sectors, such as geophysics, automotive, and energy among others, are witnessing growth in predictive maintenance of structures. In the coming years, these sectors are expected to experience a significant number of patent filings. The highest concentration of structural health monitoring patent activity is in the US, followed by Canada, Europe, China and Japan.
- Some of the participants investing in R&D for structural health monitoring include Smart Fibers Ltd., Micron Optics Inc., and many more.

Strategic Insights

Drivers

- ✓ Aging Infrastructure
- ✓ Low Downtime
- ✓ Return on investment
- ✓ Government Regulations
- ✓ Advancements in wireless sensing and energy harvesting technologies
- ✓ Advancement in smart materials
- ✓ Convergence with cloud storage
- ✓ Big data analytics to analyze past data

Restraints

- Ẋ High initial investment
- Ẋ Integration of Systems
- Ẋ Wireless sensor requirements for SHM such as high data rates, large data size, relatively high duty cycle, accurate sampling of many measurement points, synchronization and communication of sensed data.
- Ẋ Lack of Standardization
- Ẋ Heterogeneity of Data

Funding

- Funding support by government and venture capitalists is expected to accelerate the commercialization of prototypes and products. Technology developers would be able to bring innovative ideas to the market with financial support.
- The government and defense sectors from different countries are funding R&D activities in structural health monitoring.

R&D Focus Areas

- Smart Structures and Materials
- Multifunctional Composite Material
- Nano-structured Composite Material
- Bio-Functional Material and Structures
- Composite Materials with Built-in Sensor
- Material with Micro fabricated stretchable sensor network
- Elastic and Acoustic Metal Material
- Seismic Wallpaper with Built in Sensors
- Energy harvesting
- Wireless sensor networks

The 2020 Scenario

- ❑ Proper functioning of sensors throughout the operating period is confirmed through self-diagnostic features. It is important to incorporate self-diagnostics into the sensors because current systems may not differentiate between signal changes due to sensor failures from changes caused by damage.
- ❑ The technology developers will develop versatile sensing platforms that would be capable of measuring several structural responses through a single solution. That would reduce system cost considerably and also facilitate comprehensive information about structural health.

Appendix

Key Patents

No.	Patent No.	Publication Date	Title	Assignee
1	**WO/2015/192194**	23.12.2015	STRUCTURAL HEALTH MONITORING SENSORY ARRANGEMENT INTEGRATED WITHIN A SELF-HEALING SYSTEM	EMBRAER S.A.
	An integrated system and method to acquire the health state of a structure identifying the presence of damage, and to self- repair the damage in the considered structure. A sensor network installed in the structure is interrogated by a dedicated hardware for damage detection. In case of damage is detected by the sensor network in the structure, the sensor network is triggered and generates harmonic excitation in the structure. Due to the excitation, the natural frequency of vascular microtubes and /or capsules presented in the structure is reached, promoting their disruption. The vascular microtubes and/or capsules disruption along the damage releases the healing compound, repairing the damaged portion of the structure.			
2	**WO/2015/181516**	03.12.2015	IMPROVED STRUCTURAL HEALTH MONITORING	BAE SYSTEMS PLC
	The invention relates to improved structural health monitoring, particularly to structural health monitoring of fibre reinforced polymer composites, more particularly at bonded joints and methods thereof. There is provided a method of structural health monitoring a composite structure (12), wherein said structure (12) comprises at least one non-reinforcing thermal element (18), such as electrically conductive fibres, comprising the steps of applying a stimulus to cause heating of said thermal element (18), removing the stimulus, and measuring the electrical resistance of said element (18) as a function of time, to provide a thermal decay profile (41, 42) indicating whether damage has occured in the composite structure (12).			

Key Patents (continued)

No.	Patent No.	Publication Date	Title	Assignee
3	**US20150338344**	26.11.2015	METHODS AND OPTICAL INTERROGATION SYSTEM FOR MONITORING STRUCTURAL HEALTH OF A STRUCTURE	THE BOEING COMPANY
	Methods and an optical interrogation system for monitoring structural health of a structure are provided. The method includes generating an optical signal using an optical signal generator, and directing the optical signal towards at least one optical sensor located remotely from the optical signal generator. The optical sensor includes a photonic crystal wafer optically interacting with the optical signal and an environmental condition. The method also includes capturing, by an optical signal receiving apparatus, a reflected optical signal reflected from the at least one optical sensor, and analyzing the reflected optical signal to determine a change in the environmental condition.			
4	**WO/2015/160945**	22.10.2015	SYSTEMS AND METHODS FOR STRUCTURAL HEALTH MONITORING AND PROTECTION	LORD CORPORATION
	Structural health monitoring and protection systems and methods are provided. System and methods utilize structural information and/or enhanced built in testing capabilities for detecting failure modes that may cause damage to a structure. Systems and methods herein may protect a structure by mitigating one or more incorrect forces. The structure may be an aircraft, a rotary wing aircraft, or any other physical structure subject to vibrations and receptive to canceling of those vibrations.			

Industry Interactions

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