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Multi-functional and adaptive Smart material

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Abstract

Smartness describes self-adaptability, self-sensing, memory and multiple functionalities of the materials orstructures. These characteristics provide numerous possible applications for these materials and structures inaerospace, manufacturing, civil infrastructure systems, biomechanics and environment. Self-adaptation characteristics of smart structures are a great benefit that utilizes the embedded adaptation of smart materials like shape memory alloys. By changing their properties, smart materials can detect faults and cracks and therefore are useful as a diagnostic tool. This characteristic can be utilized to activate the smart material embedded in thehost material in a proper way to compensate for the fault. This phenomenon is called self-repairing effect.in this paper we are trying to showcase all the aspects of smart materials

Introduction:

In material science development, many new, high-quality and cost-efficient materials came into use in various engineeringfields. In last ten decades, the materials became multifunctional and required the optimization of differentproperties and characterization. Withevolution, the concept has been driving towards composite materials and now, the next evolutionary step is being contemplated with smart materialsconcept. New generationSmart materials surpassing the conventionalfunctional and structural materials. Adaptive capabilitiesof these materials possess to external stimuli, such as environment or loads, with inherent intelligence. (Rogers 1988; Rogers et al., 1988) explained as smart materials, the ability to change their physical properties in particular way in reaction to particular stimulus input. The stimuli could be temperature, pressure, magnetic and electric fields, chemicals, hydrostatic pressure or nuclear radiation. The adjustable associated physical properties can be stiffness, shape, viscosity or damping. Takagi (1990) described it as intelligent materials that respond to environmental adjustment at according to the environment best conditions and reveal their own functions.

Definition:

Smart materials or intelligent materials that have the intrinsic and extrinsic capabilities, according to these changes environmental changes to respond stimuli andto activate their functions,Internally or externally stimuli could originate since its beginnings, materials science has undergone a distinct evolution from the use of inert structural materials to materials built for a particular function for active or adaptive materials, and finally to smart materials with more acute recognition, discrimination and reaction capabilities. To satisfy a number of fundamental specifications to encompass this last transformation, new materials and alloys, Smart materials combining two or more single the ultimate objective of any new smart material compositeto utilize synergistically the best properties of their individual constituents is the ultimate objective of any new smart material composite. So smart composite materials are very close to fulfilling all the above specifications. Their benefits and adaptability to design requirements are given above have led to a profusion of new products. They are two types:

1) A tailored man-made composite materialcompletely. The motive of this material is to enhance or add strength or stiffness. The succeeding examples will give your insight into the field. One product is made by incorporating a powerful fibrous material with boron or silicon into a matrix of aluminum or titanium, mixing with a solid minuteanother byspheres of glass, polymer, orceramic, and a third by turning polymer, glass and some metals into sturdy foams. Bubbles of syntactic foams used are mechanically joined with composite materialas a resin to form. To make laminated composite or sandwich construction these foams can be integrated with thin panels or outer skins. Another example that contains of a non-metallic material launch into a powder alloy to form a metal matrix composite.
2) Materials with Fiber/Reinforced Polymers (FRPs) an amalgamation of a single/composite. For concrete, steel or other construction materials fiber reinforced polymers have been used as reinforcementfor the last two decades. The selection of FRP as an alternative to other materials, particularly steel, economically handling and transportation are very attractive and it is possible because the tradeoffs between costs, weight. Another significant advantage isdesign configurations are flexible. If the FRP is combined with fiber optic sensors, the resulting product will be smart composite particularly cost effective and attractive.

Material Requirements:

To achieve a specific objective for a particular function or application,the following 5 propertiesmust be satisfied by specific qualifications related to a new material:

- Technical properties, such as mechanical characteristics such as plastic flow, fatigue and yield strength; and behavioral characteristics including damage electrical andtolerance, fire resistance andheat.
- Manufacturing technologicalencompassing, properties,welding abilities, forming, thermal processing,workability, waste level,repair capacities andautomation.
- Related to raw material economic criteria, and production costs, availabilityand supply expenses.
- Including features such as environmental characteristics, toxicity and pollution.
- Recycling capacities and implying reuse of Sustainable development criteria.

To the list functions of sensing and actuation are added, then the new material/alloy is considered as a smart material.

Types or classification

Smart Materials Classification:

Smart materials can be classified into two categories i.e., either active or passive. Fair-weather (1998) explained active smart materials as materials which acquire the capability to change their geometric or material properties under the approach of electric, thermal or magnetic fields, thereby acquiring an inherent capability to transduce energy. Piezoelectric materials, SMAs, ER fluids and magneto-stricture materials are contemplate to be the active smart materials and therefore, they can be used as force transducers and actuators. Kumar (1991) showed that SMA has large recovery force, of 700 MPa (105 psi)of the order, which can be exploit for actuation. Similarly piezoelectric materials, which transform electric energy into mechanical forces, are also 'active'. On the other part, the materials, which are not energetic, are called passive smart materials. Even though they are smart, they lack the inherent transduce energycapacity. A good example of a passive smart material isfiber optic material. Such materials can respond as sensors but not as actuators or transducers.

Following categoriesgrouped into the Smart materials:

- Piezoelectric:Piezoelectric material will undergo some mechanical change when subjected to an electric charge or a variation in voltage and vice versa. These events are also called as the direct and converse effects.
- Electrostrictive:These materials have the similar properties as piezoelectric material, but according to the mechanical change in proportional to the square of the electric field.They will alwaysgenerate displacements in the same direction of characteristic.
- Magnetostrictive: When they are subjected to a magnetic field, and vice versa (direct and converse effects), thisMagnetostrictive material will undergo an induced mechanical strain. Accordingly, it can be utilize as sensors or actuators.
- Shape Memory Alloys: When subjected to a thermal field, shape modificationswill appear whenthis material will undergo phase transformations. It will recover its original shape in its 'austenite' condition when heated (high temperature) and at low temperatureitchanges to its 'martensitic' condition.
- Optical Fibers: Fibers that use intensity, phase, frequency or polarization of modulation to measure strain, temperature, electrical or magnetic fields, pressure and other measurable quantities. These sensors are excellent.

Materials with Added Functions

- All around sensor material that can detect certain signals, and adjust sensitivity according to environmental changes, or restore degraded sensitivity.
- Catalytic material that can recognize the progress of a response or distinguish the reaction of a product.
- Textile material that can detect a variety of signals from the human body and weather conditions so as to allow for greater comfort. (Example: the smart T-shirt.)

Smart Composites:

Applications

A wide range of Smart materials find applications due to theirresponse varied to external stimuli. The different application areas can be in our day to day life, aerospace, civil engineering applications and mechatronics to few names. The range ofsmart material applicationsincorporate solving engineering problems with an unfeasible origination and produce an chance of creating a new product that produce revenue. Related to smart materials important feature and structures is that they enclose all science and engineeringfields. It involves composite materials attach with fiber optics, sensors,actuators, Micro-Electro Mechanical Systems (MEMSs),shape control, vibration control, sound control,active and passive controls, product health or lifetime monitoring, cure monitoring,novel indicating devices, intelligent processing, artificial organs,self-repair (healing), designed magnets, damping aero elastic stability and stress distributionsas far as the technical applications of smart materials is distressed. Smart structures are found inspace systems, automobiles,naval vessels, fixed-and rotary-wing aircrafts,machine tools,civil structures, recreation and medical devices.To adapt to the various levels of stimuli in a controlled fashion The kind of 'smartness' shown by these materials is generally programmed byspecial processing, material composition, introduction of defects or by modifying the micro-structure. The terms 'smart and 'intelligent' are used interchangeably for smart materialslike smart structures, Takagi (1990) defined intelligent materials as the materials which respond to environmental changes at the most optimum conditions and manifest their own functions according to the environment. The feedback functions within the material are combined with functions of the materials andproperties.

In Nuclear Industries:

In nuclear industrial sector for safety enhancement smart technology offers new opportunities, personal exposure reduction, life-cycle performance improvement and cost reduction. The radiation in environment associated with nuclear operations represents a unique challenge to the testing, use of smart materials and qualification. However, the use of such smart materials in nuclear facilities requires knowledge about the materials respond to irradiation and how this response is influenced by the radiation dose.

Self-Repair:

One method is in development involves embedding thin tubes that containing uncured resin into materials. When damage occurs, exposing the resin which fills any damage and setswhen these tubes break.In inaccessible environments self-repair could be important such as in space orunderwater.

Structural Health Monitoring:

Embedding sensors within structures to monitor stress and damage can reduce maintenance costs and increase lifespan. Worldwide this is already used in over forty bridges.

In Structural Engineering:

These materials also discover application in the field of structural engineering.To evaluate their toughness they used for monitoring the civil engineering structures. Not just the smart materials or structures are cramped to sensing but also they change to their surrounding environment such as the capability tovibrate, move and demonstrate various responses.To decrease the pull and increase operational efficiency the applications of such adaptive materials necessitatein the capability to control the aero elastic form of the aircraft wing, to observe structural integrity in aircraft and space structures smart structures are also being expanded, to control the vibration of satellites lightweight structures. To decrease noise in air conditioners attempt has been made to investigate certain piezoelectric materials. In

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civil engineering, to observe the integrity of bridges, dams, offshore oil-drilling towers where fiber-optic sensors embedded in the structures are utilized to identify the trouble areasthese materials are used.

Biomedical Applications:

In the field of biomedicine and medical diagnostics, still investigations are being carried out.

Certain materials like poly-electrolyte gels are being carryout trails for artificial-muscle applications,when reveal to an electric field or other stimulationwhere a polymer matrix swollen with a solvent that can enlarge or contract. In addition to biodegradability of these materials, it may make it useful as a drug-delivery system.

Reducing Waste:

The fastest growing components of domestic waste all over the world, the electronic wastes are. During disposal and processing of such wastes,first we mustremovehazardous and recyclable materials.The use of smart materials could help to automate the processbut Manual disassembly is expensive and time consuming.On heating recently fasteners constructed from shape memory materials are used that can self-release. Simply by shaking the product once the fasteners have been released, components can be separated. By using fasteners that react to different temperatures,materials can be sorted automatically when the products could be disassembled hierarchically.

In the Field of Defense and Space:

To suppress vibrations and change shape in helicopter rotor blades smart materials have been developed. Shape-memory-alloy devices are also being developed that are capable of achieving accelerated breakup of vortex waves in submarines and similarly different adaptive control surfaces are developed for airplane wings. For placement of actuators and sensors present research is on its way to focus on new control technologies for smart materials and design methods.

Health:

To monitor blood sugar levels in diabetics and communicate with a pump that administers insulin as requiredBiosensors made from smart materials are used. However the human body is a hostile environment and sensors are easily damaged. Toprotect these sensors some researches on barrier materials are going on. Now-a-days different companies are developing smart orthopedic implants such as fracture plates that can sense whether bones are healing and communicate data to the surgeon. Within the next five years small scale clinical trials of such implants have been successful and they could be available. Other possible devices include replacement joints that communicate when they become loose or if there is an infection.In present technology limits the reactionin the future these devices to transmitting data but, they could respond directly by releasing antibiotics or self-tightening. The requirement for invasive surgerycould decrease.

Reducing Food Waste:

Between all others food makes up maximum squander. Due to their reaching of termination date most of the food grown for consumption is thrown away without consumption. Product life may be longer these dates are conservative estimates and actual. To extend product life with packaging by utilizing smart materials the manufacturers are now looking for ways.

Bacteria build up as food becomes less fresh, chemical reactions take place within the packaging. Smart labels have been developed that change color to indicate the presence of an increased level of a chemical or bacteria in it. Time on the degradation of most products storage temperature has a much greater effect. Dependent on temperature some companies have developed time-temperature indicators that change color over time at a speed.

The Ageing Population:

There are moreaged people over 60than childrenin almost every part of universe, making life easier for the elderly creating a new market for products. Lot of these could use smart materials and systems to incorporate added functionality. For example, shape memory materials are used in food packaging that automatically open on warm for people with arthritis. Smart homes have been expanding by experimentationfor people with dementia that uses sensors to monitor behavior and to ensure that the resident is safe.

Merits and demerits

Merits:

The Smart structure Benefits:

- Performance of the new advanced composite materials can be monitored.
- Less time and expenses in inspections.
- Bio-compatibility.
- Good mechanical properties.
- Compactness.
- Simplicity.
- The response of the structure can be monitored remotely in real time.
- Safety mechanism.

The advanced composite materials oflong-term performance can be compared to conventional girders in the bridge also outfitted with fiber optic sensors.

Demerits:

- More expensive.
- Limited bandwidth.
- Complex control.
- Low energy efficiency.

Conclusion

With monitor able properties, good bio-compatibility and ability to monitorremotely smart materials will sure rule the engineering industry in near future, high cost will eventually come down with development of new technologies, but low energy efficiency is a major draw back.in this paper we tried to give you a glance about smart materials, their properties and applications. This area is very preferable for both post graduates and PhD scholars to carry their research work.

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