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A Review on Smart materials,types and applications

[1]Amaresh U, [2]Mohammed saifuddin, [3]Hassina , [3]Savitha, [3]Prajwal Suryavanshi

[1]Senior Lecturer and Head of the department,[2]Lecturer,[3]Student ,[3]Student,[3]Student
[1]Department of mechanical engineering,
[1]Sanjay Gandhi polytechnic, Ballari,India

Abstract : Materials that have been modified to respond in a predictable and reversible manner to external stimuli, such as a specific amount of mechanical stress or a specific temperature, among others, may be referred to as smart materials. The term "responsive materials" also applies to smart materials because of their responsiveness. Although "reactive" materials would be a more appropriate translation, "active" materials are more frequently used. There are many different types of smart materials, such as shape memory alloys, magnetorheological (MR), electro-rheological (ER), and piezoelectric materials. For example, the viscosity of ER and MR fluids can be changed by adjusting the electric supply, and the alignment of the particles between the electrodes can be changed by varying the strength of the electric field. For the first time, these smart materials have been deployed in the automotive and aerospace industries for a variety of applications. This paper highlights the application and use of smart materials.

IndexTerms **- Materials,responsiveness,smart materials,applications.**

I. INTRODUCTION

Humans employed materials for a variety of reasons thousands of years ago, which improved their quality of life. Civilization was divided into distinct centuries, each of which began with the discovery of a new useful materials. Materials which are metals, ceramics, polymers, and recently advanced materials. Among them, advanced materials become more attractive one because they have more technological applications. Since some of the physical characteristics of advanced materials can be modified, they serve as the foundation for the majority of the high-tech hybrid gadgets in our environment. Semiconductors have changed how computers are made, moving from vacuum tubes to smaller electronic chips. However, nano-engineered materials are more effective than their bulkier equivalents, and biomaterials have made it possible to interface with biological organs. As a result, the use of intelligent or smart materials will increase in several fields such as civil engineering, industrial appliances, medical devices, automation systems, and more.

II. CHARACTERSTICS OF SMART MATERIALS

Based on the characterstics the smart materials are grouped in different catogaries

a. Property change capability.
   The property-changing class of intelligent materials has the most potential uses in the field of architecture. These materials experience changes in one or more of their properties, such as chemical, thermal, mechanical, magnetic, optical, or electrical, in reaction to changes in their environment. . The conditions of the environment may be ambient or may be produced via a direct energy input. lncluded in this class are all colorchanging materials, such as thermochromics, electrochromics, photochromics, etc., in which the intrinsic surface or molecular spectral absorptivity of visible electromagnetic radiation is modified through an environmental change (incident solar radiation, surface temperature) or a direct energy input to the material (current, voltage).
b. Energy exchange capability
   The next class of materials that is expected to have large penetration into the field of architecture is the energyexchanging class. These materials, which can also be called 'First Law' materials, change an input energy into another form to produce an output energy in accordance with the First Law of Thermodynamics. Although the energy conversion efficiency for smart materials such as photovoltaics and thermoelectrics is typically much less than for more conventional technologies, the potential utility of the energy is much greater. For example, the direct relationship between input energy and output energy renders many of the energyexchanging smart materials, including piezoelectrics, pyroelectrics and photovoltaics, as excellent environmental sensors. The form of the output energy can further add direct actuation capabilities such as those currently demonstrated by electrostrictives, chemoluminescents and conducting polymers
c. Discrete size/location
   Many of the materials in the two above classes also exhibit the characteristic either of reversibility or of bi-directionality. Several of the electricity converting materials can reverse their input and output energy forms. For example, some piezoelectric materials can produce a current with an applied strain or can deform with an applied current. Materials with

bi-directional property change or energy exchange behaviors can often allow further exploitation of their transient change rather than only of the input and output energies and/or properties. The energy absorption characteristics of phasechanging materials can be used either to stabilize an environment or to release energy to the environment depending on in which direction the phase change is taking place. The bi-directional nature of shape memory alloys can be exploited to produce multiple or switchable outputs/ allowing the material to replace components comprised of many parts.

d. Reversibility.

Regardless of the class of smart material, one of the most fundamental characteristics that differentiate them from traditional materials is the discrete size and direct action of the material. The elimination or reduction in secondary transduction networks, additional components, and, in some cases/ even packaging and power connections allows the minimization in size of the active part of the material. A component or element composed of a smart material will not only be much smaller than a similar construction using more traditional materials but will also require less infrastructural support. The resulting component can then be deployed in the most efficacious location. The smaller size coupled with the directness of the property change or energy exchange renders these materials to be particularly effective as sensors: they are less likely to interfere with the environment that they are measuring, and they are less likely to require calibration ad justments.

III. TYPES OF SMART MATERIALS

There are two primary classess of smart materials

a. Type I

A material that changes one of its properties (chemical, mechanical, optical, electrical, magnetic or thermal) in response to a change in the conditions of its environment and does so without the need of external control.

b. Type II

A malerial or device that transforms energy from one form to another to effect a desired final state.

Table 1. Type of smart material and their Input & Output

TYPE OF SMART MATERIAL	INPUT		OUTPUT
Type 1 Property-changing			
Thermomochromics	Temperature difference		Color change
Photochromics	Radiation (Light)		Color change
Mechanochromics	Deformation		Color change
Chemochromics	Chemical concentration		Color change
Electrochromics	Electric potential difference		Color change
Liquid crystals	Electric potential difference		Color change
Suspended particle	Electric potential difference		Color change
Electrorheological	Electric potential difference		Stiffness/viscosity change
Magnetorheological	Electric potential difference		Stiffness/viscosity change
Type 2 Energy-exchanging			
Electroluminescents	Electric potential difference		Light
Photoluminescents	Radiation		Light
Chemoluminescents	Chemical concentration		Light
Thermoluminescents	Temperature difference		Light
Light-emitting diodes	Electric potential difference		Light
Photovoltaics	Radiation (Light)		Electric potential difference
Type 2 Energy-exchanging (reversible)			
Piezoelectric	Deformation	⟷	Electric potential difference
Pyroelectric	Temperature difference	⟷	Electric potential difference
Thermoelectric	Temperature difference	⟷	Electric potential difference
Electrorestrictive	Electric potential difference	⟷	Deformation
Magnetorestrictive	Magnetic field	⟷	Deformation

Some most commonly used smart materials are

1. Piezoelectric materials

They can convert mechanical energy into electrical energy and vice versa. For example, they change their shape in response to an electrical impulse or produce an electrical charge in response to an applied mechanical stress.

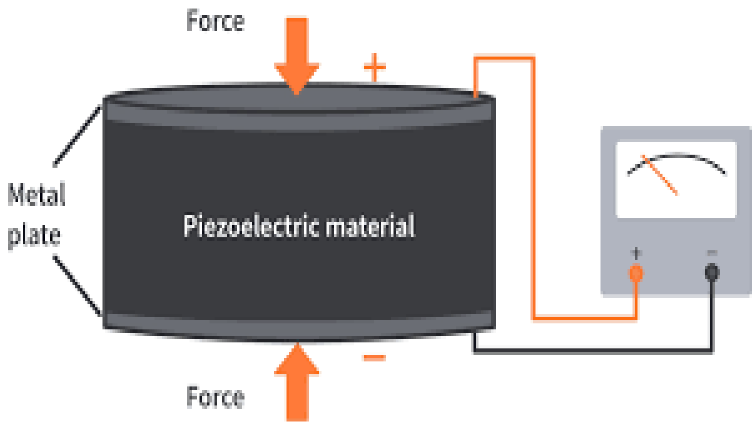

Fig 1. Piezoelectric materias

2. Shape memory materials

They have the ability to change the shape, even returning to their original shape, when exposed to a heat source, among other stimuli.

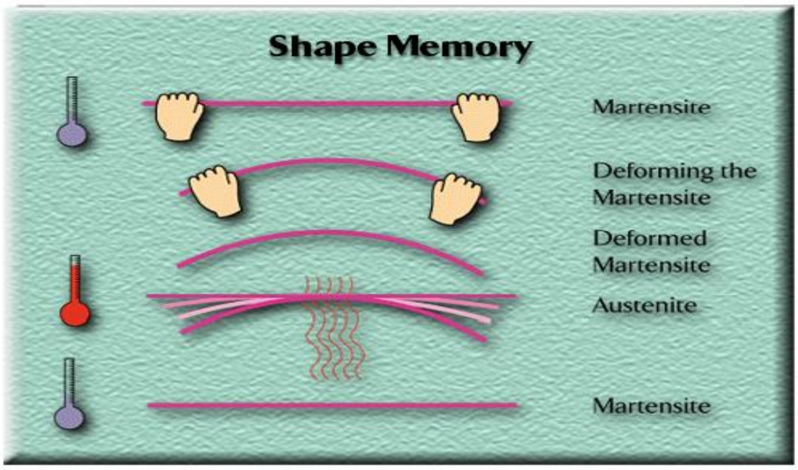

Fig 2. Shape memory materials

3. Chromoactive materials

They change colour when subjected to a certain variation in temperature, light, pressure, etc. Nowadays, they are used in sectors such as optics, among others.

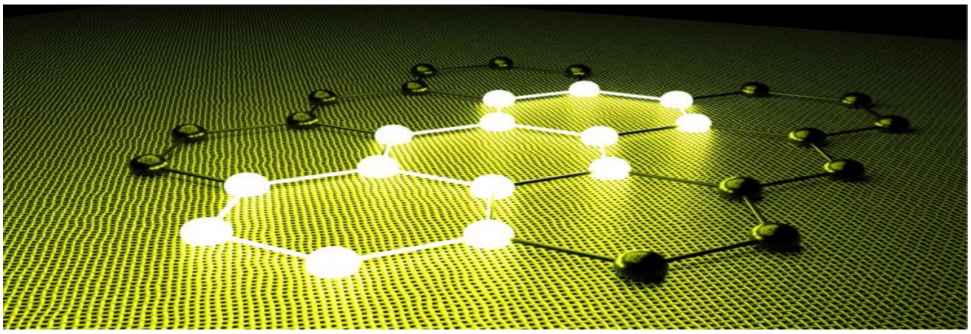

Fig 3. Chromoactive materials

4. Magnetorheological materials

Magneto-sensitive smart materials, also named as magnetorheological (MR) materials, are a class of smart composites prepared by dispersing nanometer- or micrometer-sized ferromagnetic fillers into the different carrier matrix. As the rheological properties can be controlled by an external magnetic field rapidly, reversibly, and continuously, magneto-sensitive smart materials have great application potential in construction, automotive industry, artificial intelligence, etc.

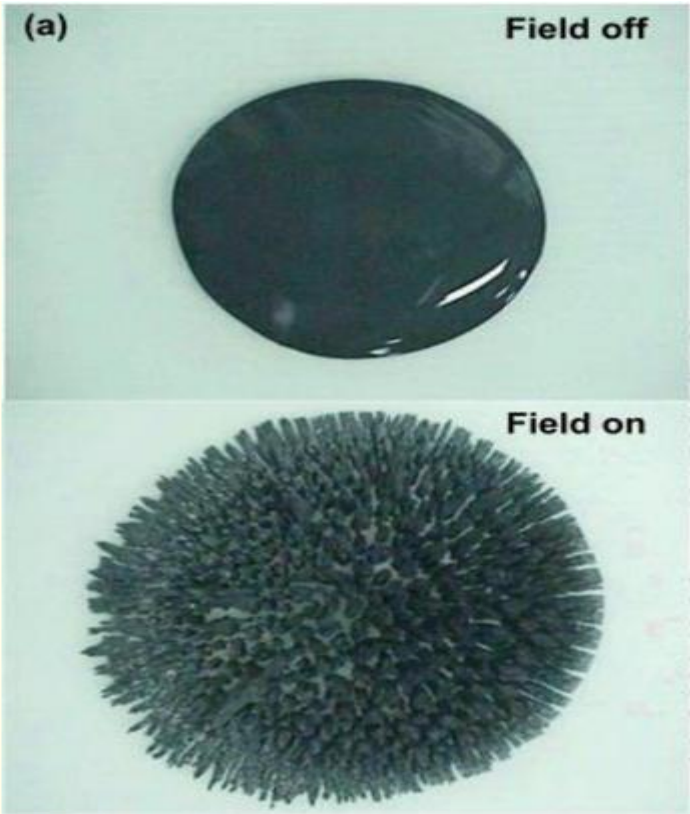

Fig 4. Magnetorheological materials

5. Photoactive materials

Photoactive materials are materials that interact with the light electromagnetic field and modify either their own properties or those of the field.

IV. APPLICATION OF SMART MATERIALS

Following are the some examples of smart materials

1. Piezoelectric materials

a. Engine knock sensors

If detonation begins in gasoline engine, piezoelectric knock sensors can be employed to sense the detonation before it becomes problematic. This gives control systems time to make the required adjustments.

b. Pressure sensors

In nearly any application requiring the measurement of dynamic pressure changes, using piezoelectric pressure sensors yields more reliable results than using conventional electromechanical pressure sensors. This is because piezoelectric devices have a high frequency response and signal conversion without requiring any bellows, diaphragm, or any type of mechanical linkage in conjunction with a strain gage or displacement sensor.

c. Diesel fuel injectors

In the last decade, regulations on emissions from diesel engines have become increasingly stringent. Additionally, customers continue to demand quieter engines with improved power and torque curves. In order to meet these stringent demands for compliance and performance, engine manufacturers have resorted to using precisely timed and metered injections of fuel during the combustion process.

As incredible as this may sound, a single fuel injector may switch fuel flow with pressures exceeding 26,000 psi (1800 bar) on and off several times in rapid succession during a single power stroke. Such precise control of high-pressure fluid is made possible by using piezoelectric actuators controlling small valves within fuel injectors.

d. Ultrasound imaging

Piezoelectric transducers are often used in medical ultrasound equipment. Advances in equipment over the decades have enabled improved monitoring of pregnancies and facilitated minimally invasive surgical procedures.

e. Piezoelectric speakers

Piezoelectric speakers are featured in virtually every application that needs to efficiently produce sound from a small electronic gadget. These types of speakers are usually inexpensive and require little power to produce relatively large sound volumes. Thus, piezoelectric speakers are often found in devices such as the following:

– Cell phones
– Ear buds
– Sound-producing toys
– Musical greeting cards

2. Shape memory materials

They are used as wires and tubes in applications with hot fluids flowing through them. These materials are ideal as they can retain their shape even in a heated environment.Another application of SMAs is in civil engineering. For example, they have been used in bridge structures. SMAs can dampen vibrations, hence tuning the natural frequency of various structures. This property of vibration damping has also been used in launch vehicles and jet engines. Newer lightweight alloys have also been discovered, such as magnesium-scandium that can have a variety of potential applications such as in aerospace applications and the medical industry for biodegradable self-expanding stents.

Shape memory polymers could be inserted inside the body and react to the changes and stimulation of the body. Indeed, it could allow the creation of brand new antibiotics reacting, for example, to the body temperature changes.

Possible use of shape memory materials would be on solar panels that would be working as sensors for detecting the sun. This way, solar panels could be auto-rotating in the right direction.

3. Chromoactive materials

a. Photochromics

Photochromic materials are used in a wide range of applications. Certainly we see them used in a wide range of consumer products, such as sunglasses that change their color. ln architecture, they have been used in various window or façade treatments, albeit with varying amounts of success, to control solar gain and reduce glare. By and large, thess applications have not proven effective because of the slowness of response and heat gain problems.

b. Thermochromics

Consumer goods pieces, for example, are sensitive to body heat and show a colored 'imprint' of a person who iust sat on the furniture, The image fades with time. The notion of using thermochromic materials on the exterior of a building has similarly always aroused interest. Unfortunately, a major problem with the use of currently available thermochromic paints on the exterior is that exposure to ultraviolet wavelengths in the sun's light may cause the material to degrade and lose its color-changing capabilities.

c. Mechanochromics

Mechanochromics have altered optical properties when the material is subjected to stresses and deformations associated with external forces. Many polymers have been designed to exhibit these kinds of properties. The old household device for imprinting raised text onto plastic strips utilizes a plastic of this type. The raised text that results from a mechanical deformation shows through as a different color.

d. Chemochromics

Chemochromics include a wide range of materials whose properties are sensitive to different chemical environments. You might perhaps recall the ancient litmus paper in a basic chemistry class

e. Electrochromic

Electrochromism is broadly defined as a reversible color change of a material caused by application of an electric current or potential. An electrochromic window, for example, darkens or lightens electronically. A small voltage causes the glazing material to darken, and reversing the voltage causes it to lighten.

4. Magnetorheological materials

Magnetorehological materials are used in Vibration absorbers & Vibration isolators in order to damp the vibrations. These phenomena are beginning to be utilized in a number of products. An electrorheological fluid embedded in an automobile tire, for example, can cause the stiffness of the tire to change upon demand; thus making it possible to ,tune, tires for better cornering or more comfortable straight riding. Some devices that typically require mechanical interfaces, e.9., clutches, might conceivably use smart rheological fluids as replacements for mechanical parts. ln architecture and industrial design, little use has been made of smart rheological fluids. One can imagine, however, chairs with smart rheological fluids embedded in seats and arms so that the relative hardness or softness of the seat could be electrically adjusted.

5. Photoactive materials

Among other uses, this material can find application as an anti-counterfeiting ink since the marking can only be identified under UV light.

The magneto-optic effect can be used for the detection of biologic phenomena such as heart beat or brain activity.

V. FIELDS WHERE SMART MATERIALS ARE USED

a. Aircrafts
b. Orthopedic surgery
c. Dental braces

d. Robotics
e. Smart fabrics
f. Sporting goods
g. Smart glass

VI. PROS AND CONS OF USING SMART MATERIALS

Pros

a. High mechanical performance
b. High damping capacity
c. Large actuation force
d. Compactness
e. Lightness
f. High wear strength

Cons

a. Expensive materials
b. Complex thermo mechanical behaviour
c. Limited output
d. Not suitable for harsh enivironment

VII. CONCLUSION

The present study gives a brief summary of the stimuli-responsive smart materials followed by a complete description of the some of the smart materials. In this paper, a survey of literature discusses types of smart materials, their need, advantages, disadvantages, and applications. Piezoelectric, magnetostrictive, shape memory alloys, electro-rheological fluid, and magneto-rheological fluid are some of the smart materials.

VIII. Acknowledgment

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