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# A review on Smart Materials: Introduction, Types and Applications

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**Abstract**

In response to external conditions smart materials changes their properties, compositions, structure, appearance, functions etc. Smart materials are also called responsive materials as they are highly responsive and respond to environmental stimuli with particular changes in some variables. Smart materials are those that change one or more of their properties such as shape, colour, size etc when subjected to an external stimulus like pressure, temperature, humidity, light, electric field, magnetic field etc. Smart materials have vast potential applications in every field. Research and development in Smart Materials gives outstanding boost to technical sphere. Specific types of smart materials are Piezoelectric materials, Electrostrictive materials, Magnetostrictive materials, Shape memory alloys, Thermo and Photo chromic materials, Thermoelectric materials, Electro and Magneto rheological fluids etc. Smart materials shows their potential applications in the fields like Engineering, Medicine, fabrics, aeronautics, civil engineering, constructions, automobiles, health monitoring, computers and electronic devices, field of defense and space, reducing waste etc. This paper highlights the brief introduction to Smart materials, types of smart materials and their applications in different areas.

**Keywords: Smart materials, piezoelectric, Electro strictive, Magneto strictive, Shape memory alloys, chromic materials**

## Introduction

Smart materials are those materials which changes in response to changing conditions with their surroundings. They changes on the application of other-directed influences such as temperature, pressure, current, magnetic field etc. Properties of Smart materials are may be altered in a controlled fashion by these stimuli. Smart materials are also called responsive materials as they are highly responsive and respond to environmental stimuli with particular changes in some variables. In response to external conditions smart materials changes their electrical or mechanical properties, compositions, structure, appearance, functions etc. A key future of Smart materials is their smart behavior includes an ability to return to the original state after the stimulus has been removed. These changes are reversible and can be repeated many times. Smart materials consist of properties like that they can respond to various stimuli, they can be in various states. They respond to external stimuli without wasting time. Their response is distinguished and predictable. They are able to receive information. They can analyze and process information. They are able to take decision and act on the decision.

**Advantages of Smart Materials**

Following are some advantages of smart materials

The main advantage of smart materials is that they give to a material new capabilities. Smart materials remember their original shape and can return to it. Smart materials have better durability and realiability. Smart materials reduces the production cost. Smart materials have high energy density. Smart materials have excellent band bandwidth. Smart materials have novel functions such as the huge volume change as a function of temperature. smart materials provide high strengths and power with low weights. Smart materials have good mechanical properties like strong and corrosion resistance that provides higher strengths. Smart materials have highest power-to-weight ratio among light-weight technologies. smart materials contribute to noiseless operation leading to removal of the vibration disturbances. Smart materials are self-repaired materials. Innovative use of smart materials has the potential to reduce waste and to simplify recycling.

**Disadvantages of Smart materials**

Smart materials are unique and having great potentials but there are some disadvantages of Smart materials of these materials such as long-term effects of Smart materials are unknown. Smart materials are expensive to produce. The availability of smart materials is low as they are not easily available. Environmental pollution and biodegradability is the challenging issue. Use of smart materials requires extra care because these materials are very sensible. The handling of smart materials requires better skills and knowledge etc.

**Classification of Smart Materials**

Smart materials are either active or passive. Active smart materials have the inherent ability to transduce energy. Active smart materials possess the capability to modifying their geometric and material properties under the application of stimuli. Examples of active smart materials are Piezoelectric materials, Magnetostrictive materials etc. Active smart materials can be used as forced transducer and actuators. There is lack of inherent capability to transducer energy in Passive smart materials. Examples of Passive smart materials are Fiber Optics. Passive smart materials can be used as sensors but not as actuators or transducers.

**Types of Smart Materials**

There are different types of smart materials includes Structural materials, Electrical materials, Bio Compatible materials, Intelligent Biological materials, dynamically tunable material etc. Specific types of smart materials are Piezoelectric materials, Electrostrictive materials, Magnetostrictive materials, Shape memory alloys, Thermo and Photo chromic materials, Thermoelectric materials, Electro and Magneto rheological fluids etc. There are number of smart materials are available and some are discussed below.

**Piezoelectric materials**: Materials which produce a voltage when stress is applied. Example of Piezoelectric materials is Quartz. The same process can happen in reversible manner. The structures made with this materials can bend, expand and compress.

**Thermo responsive materials: These** types of smart materials have ability to hold different shapes at different temperature.

**Electrostrictive materials: If** the dielectric material is suspended in electric field, then it experiences a strain which is proportional to strength of electric field.

**Magnetostrictive materials-** These smart materials can alter shape when subjected to magnetic field. This is a reversible process. Magneto striction is a property of ferromagnetic materials that causes them to change their shape or dimension during the process of magnetization.

**Chromic materials-** These smart materials have property to change their colour when subjected to external stimuli such as temperature, light, electric field. The different chromic materials are Thermo chromic materials, Photo chromic materials and Halo chromic materials.

**pH sensitive materials-** These smart materials have properties to change their colour when there will be change in acidity of the liquid.

**Thermo electric materials-** These materials when subjected to any temperature difference produces proportional voltage output. The reverse effect is also true.

**Shape memory alloys –** These are metal alloys which can undergo solid to solid phase transformation and can recover completely when heated to specific temperature. These alloys remember their original shapes.

**Magneto rheostatic fluid-** This is a type of smart material in which a fluid who has viscosity almost to the oil will solidifies when brings in to magnetic field. This type of material is much stronger.

| Types of Smart Material | Input | Output |
|---|---|---|
| Piezoelectric | Deformation | Electric Potential Difference |
| Thermoelctric | Temperature | Electric Potential Difference |
| Pyroelctric | Temperature Difference | Electric Potential Difference |
| Photovoltaics | Radiation | Electric Potential Difference |
| Electrostrictive | Electric Potential Difference | Deformation |
| Magnetostrictive | Magnetic Field | Deformation |
| Shape Memory Alloys | Temperature | Deformation |
| Electroheological | Electric Potential Difference | Stiffness/Viscosity change |
| magnetoheological | Electric Potential Difference | Stiffness/Viscosity change |
| Photochromic | Radiation | Colour Change |
| Therochromics | Temperature | Colour Change |
| Mechanochromics | Deformation | Colour Change |
| Chemochromics | Chemical concentration | Colour Change |
| Electrochromics | Electric Potential Difference | Colour Change |
| Liquid Crystals | Electric Potential Difference | Colour Change |
| Suspended Particle Change | Electric Potential Difference | Colour Change |
| Electroluminescents | Electric Potential Difference | Light |
| Photoluminescents | Radiation | Light |
| Chemoluminescents | Chemical concentration | Light |
| Thermoluminescents | Temperature Difference | Light |
| Light Emitting Diodes | Electric Potential Difference | Light |

**Applications of Smart Materials**

There are numerous applications of Smart materials which includes technology in the automotive, aerospace, appliance, medical, Computers and other electronic devices. Smart fabrics, Smart Aircraft, Sporting Goods, Robotics, Medical Surgery, Security, Consumer goods applications, Civil engineering, Medical equipment applications, Rotating machinery applications. With future advances, smart materials are also likely to be useful for fabricating insulin pumps and drug delivery devices. In civil structures they were widely employed in construction of smart buildings, for environmental control, security and structural health monitoring etc.

**Conclusion**

Smart materials have vast potential applications in every field. Research and development in Smart Materials gives outstanding boost to technical sphere. Technology of smart materials is highly interdisciplinary including basic and applied sciences and engineering. Technology relies on the materials that are sensitive and responsive to environmental changes and can change their functions according to optimum condition. Smart materials can change their properties and functions with surrounding conditions. At present smart materials shows there great applications in the field of Engineering, Medicine, fabrics, aeronautics, civil engineering, constructions, automobiles, health monitoring etc. In future smart materials will be used to meet the minute needs and to enhance quality of our life.

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