STM JOURNALS

Trends in
Mechanical Engineering & Technology

http://engineeringjournals.stmjournals.in/index.php/TMET/index

ISSN: 2231-1793 (Online)
ISSN: 2347-9965 (Print)
Volume 14, Issue 1, 2024
January–April
DOI (Journal): 10.37591/TMET

Review TMET

Application of Smart Material Technology: A Review

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Abstract

These days, smart materials are employed in every aspect of technology and human life. Much work is being done to explore their potential in different engineering applications that could benefit the average person. Shape memory alloys, piezoelectric materials, magneto rheological materials (MR), and electro rheological materials (ER) are just a few examples of the many diverse kinds of smart materials. The electric supply can be adjusted to change the viscosity of both ER and MR fluids, and the electric field's strength can be adjusted to change the particle alignment between the electrodes. These smart materials are being used for the first time in a variety of applications by the automotive and aerospace industries. These papers emphasize the use of smart materials. This paper presents the use of smart materials and structures for the development of smart cities. This paper also addresses future challenges for the development of smart cities from the standpoint of new developments in the material sciences. Additionally, the various forms of smart materials and their uses are highlighted in this paper. These include magneto strictive materials, electro-rheological materials, shape memory alloys (SMA), thermos responsive materials, electro-chromic materials, and electro-rheological fluids.

Keywords: Smart materials, piezoelectric, electro rheological, magneto rheological fluids, SMA.

INTRODUCTION

Materials that must react to stimuli and changes in their environment in order to activate their function are referred to as smart or intelligent materials. The stimuli can come from either an internal or external source. Examples of these include temperature, pressure, electric and magnetic flow, light, and mechanical. Researchers in related fields around the world are becoming more and more interested in smart materials and related technologies. One of the most forward-thinking areas of study over the last ten years has been smart materials and structures. Numerous problems in the fields of mechanical, aerospace, bionics, and medical technologies have been solved with the help of newly created materials and equipment [1].

Smart materials have revolutionized the aerospace engineering field's approach to designing and producing aircraft systems and components.

Shape memory alloys (SMAs) are utilized in adaptive wing structures to maximize maneuverability and aerodynamic efficiency through morphing capabilities. Piezoelectric materials are also used in active vibration control systems to lessen structural vibrations and enhance flight stability and passenger comfort. The aerospace industry is constantly searching for fresh and inventive approaches to employ smart materials to boost aircraft efficiency, reduce fuel expenses, and enhance safety. It's remarkable and encouraging how far we've come in creating cutting-edge materials and technology [2]. This special section's focus is on intelligent actuators and their uses. One of the areas of study for smart structures and materials that is acknowledged as being crucial to smart technologies is this one [3].

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Received Date: April 01, 2024
Accepted Date: April 09, 2024
Published Date: May 07, 2024

Citation: Mukesh Ganchi. Application Of Smart Material Technology- A Review. Trends in Mechanical Engineering & Technology. 2024; 14(1): 34–39p.

For this reason, we have arranged this particular section to encourage technological advancement and global communication in this area. The most recent advancements in intelligent materials and structures are covered in this section. The most recent discoveries in the development of diverse smart material kinds, including electro-rheological fluids, fiber-reinforced shape memory polymer composites, electro-active papers, shape memory alloys, etc.—are covered in the published papers. Applications of the materials in intelligent structures are also covered. We think that the articles included in this special section will be found to offer the most recent data and will inspire additional researchers to contribute to this area of study [4].

Today we are living in modern era of technology; everywhere peoples are facing various kind of technological innovations which simplify the life in various aspects and leads to the development of smart cities. A developed city that fosters high quality of life and sustainable economic development by streamlining various aspects of daily life while simultaneously excelling in several critical areas, including the environment, people, transportation, and economy, is referred to as a smart city, living, administration, education, and government." By robust human resources, social resources and ICT infrastructure, excellence in those key fields can be achieved [5].

The utilization of smart materials, structures, and systems with progressively higher levels of functionality will be essential to the development of smart cities. Applications in everyday life and engineering fields, including aerospace, civil, mechanical, electrical, electronics, and medical industries as well as the defense and automotive sectors, are the possible range of applications. Currently, smart metals, also referred to as intelligent metals, are being studied by researchers. These days, smart materials are employed in every aspect of technology and human life.

The field of smart materials is developing, but it is not fully structured [6]. It has developed over the past few decades, accelerating in the 1990s to reach its current state as we approach the turn of the millennium. Smart materials are also referred to as active materials or intelligent materials. Magneto strictive materials, electro-rheological materials, shape memory alloys, piezoelectric materials, and magneto-rheological fluids are a few instances of smart materials [7–10].

CLASSIFICATION

1. *Piezoelectric materials:* Piezoelectric material will experience some mechanical change in response to an electric charge or voltage variation, and vice versa. The terms "direct and converse effects" refer to these occurrences.
2. Materials that are electro strictive have the same characteristics as piezoelectric materials, but their mechanical change is proportional to the electric field's square [11]. Displacements in the same direction are consistently produced by these characteristics (Figure 1).

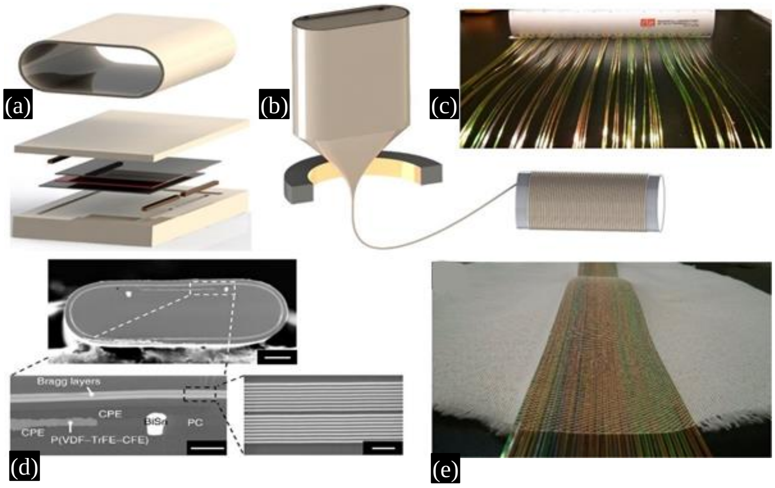

Figure 1. Electrostrictive microelectromechanical fibers and textiles.

ISSN: 2231-1793 (Online), ISSN: 2347-9965 (Print)

3. Materials that are magnetostrictive will experience mechanical strain when exposed to a magnetic field and vice versa [12]. As a result, it can function as an actuator and a sensor (Figure 2). (Terrifnol, for example).

Figure 2. Magnetostrictive materials.

4. *Rheological materials:* These are in the liquid phase and are instantly changeable in state by applying a magnetic or electric charge. These fluids might be used in the dampers for car seats, shock absorbers, and brakes [13].
5. *Thermoresponsive material:* This type of material can alter its characteristics in reaction to temperature changes [14]. They are helpful in air and automotive vehicle parts, as well as thermostats.
6. Materials that are electrochromic have the capacity to alter a material's optical characteristics. (for example, color) when a voltage is applied across them; these are employed as the cathode in lithium batteries and as LCDs (Figure 3).

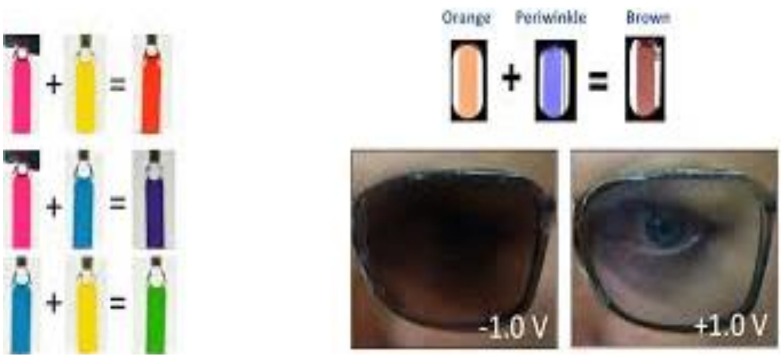

Figure 3. Electro chromic materials.

7. *Biomimetic materials:* The material and structure involved in natural systems have the capability to sense their environment, process the data and respond instantly (Figure 4).
8. Fullerenes are spherically caged molecules that have hexagonal and pentagonal carbon atoms at the corners of their polyhedral structure [15]. These are typically employed in smart system polymeric metrics. Electronic and microelectronic devices employ them (Figure 5).

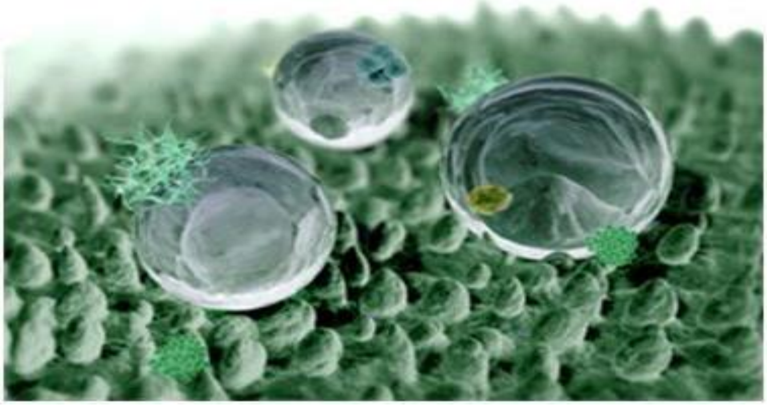

Figure 4. Biomimetic materials.

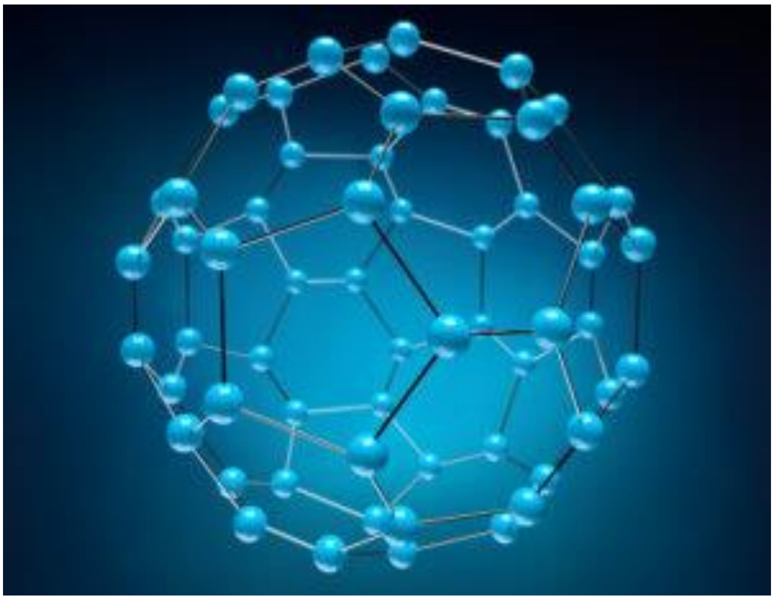

Figure 5. Fullerenes Product.

WHY SMART MATERIAL?

1. Because it's environmentally friendly
2. By adding smart material, mechanical properties like fatigue and corrosion can be increased.
3. Taking less time to identify.
4. Its durability is longer than that of other materials.
5. Greater energy density.
6. Maintenance expenses go down.

PROPERTIES

When detecting alterations in their surroundings, intelligent materials have the potential to react predictably. Typically, a few of the characteristics of smart materials are:

1. *Eco-Friendly:* Smart materials are very helpful in creating an eco-friendly, sustainable environment that leads to reduced energy use, which is advantageous for our society [16].
2. *High Energy Density:* The material's higher energy density increases the quantity of energy contained in its mass.
3. *Self-Sensing:* It is capable of sensing its own conditions, including pressure, temperature, stress, strain, and so forth.
4. *Self-Vibration Damping: Noise reduction:* Vibration and noise reduction are crucial for maritime defense.

5. *Increasing Material Durability:* To make materials more durable and still useful in the environment and for material life, a wide range of materials have been employed.
6. *Increasing Mechanical Properties:* The addition of smart material will improve mechanical properties like strength, fatigue, stress, and strain as well as noise reduction.

APPLICATION OF SMART MATERIAL

1. *Aerospace:* Smart materials like shape memory polymers (SMP), shape memory alloys (SSA), and shape memory material (SSM) are used in aviation. These materials will aid in its storage, serve as a means of helping to remember its shape, and prevent it from deforming [17].
2. *Robotics:* Material plays a crucial role in sensor detection, communication, and actuators. Smart material can introduce new technologies to robotics.
3. *Self-Controlling:* Smart materials possess the capacity to regulate their own behavior in order to reclaim their original position. This includes the ability to control external stimuli like strain, temperature, pressure, stiffness, and stress.
4. *Medical:* Super elasticity, light weight, and shape memory alloys are just a few applications for smart material in the biomedical field. Other applications include orthopedics, cardiovascular, bone fracture, and orthodontic wires.
5. *Eco-Friendly:* The building's roof is covered and protected with intelligent materials that help to control temperature and absorb water.
6. *Sturdy Bricks:* Using smarter materials, bricks can be built that are useful in the event of an earthquake, tornado, hurricane, etc.

CONCLUSION

Using small constructions and materials is one of the most promising technologies that can be used to increase lifetime effectiveness as well as dependability.

The ultimate goals of research in these areas are to comprehend and control the composition and microstructure of any new material, as this is essential to the creation of high-quality smart materials.

In this chapter, we reported a short overview about the smart materials technology, their types, their specific properties, as well as some general examples for applications of smart materials which may prove useful for us.

The multipurpose use of smart materials includes long-term durability, reduced costs, efficient performance, dependability, maintenance, and the capacity for self-control, self-curing, self-healing, etc. Research is being done on smart materials that will be useful for our evolving lifestyle, technology, and smart goods that will improve our quality of life. Innovative and cutting-edge materials will undoubtedly improve our quality of life.

Additionally, practically every field is covered by smart materials technology, including applied engineering, mechanical and electrical, computer science, chemistry, physics, and automotive, among others. Ultimately, we can state that without the assistance of smart materials, the vision of a smart city is unattainable.

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