IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 3 Ver. VI (May- Jun. 2016), PP 10-15
www.iosrjournals.org

Intelligent Material For Modern Age : A Review

Arvind Kaushal[1], Ajay Vardhan[2] RSS. Rawat[3]
[1]*Lecturer Department of mechanical Engineering, Indira Gandhi Engineering College Sagar(MP) , INDIA*
[2]*Assistant Professor Department of mechanical Engineering, Rajiv Gandhi Proudyogiki Vishwavidyalaya , (Bhopal), INDIA*
[3]*Professor Department of mechanical Engineering, , Indira Gandhi Engineering College Sagar(MP) , INDIA*

Abstract: *In present scenario , all the production is mostly subjected to operation of material like metals, non metals , ceramics, composites, plastics etc all kind of materials posses certain properties & characteristics such as hardness, toughness, ductility , brittleness , wear resistance , abrasion resistance etc . all those material is obtained from the nature & some are manufactured by human being as per their needs , in nature some kind of material is also available which has special properties such material is recognize as intelligent material that is defined as "A material which has built-in or intrinsic sensor(s), actuator(s) and control mechanism(s) whereby it is capable of sensing a stimulus, responding to it in a predetermined manner and extent, in a short/ appropriate time, and reverting to its original state as soon as the stimulus is removed" in this Paper we were focusing on intelligent material, their types, application & future of intelligent material.*

Keyword: *Intelligent material, Piezoelectric, Pyroelectric , Shape memory alloys, Electostictive material ,Magnetoristrictive material*

I. Introduction

Today we are living in modern age, everywhere we facing various kind of technology which simplify the human life in all aspects. It does not only depend our one dimensional motion of technology but also it covers all direction of possible motion including engineering & technology. Medical science, aerospace and so many other fields. We had been passing away the plastic age and composite age, the mid age of time adopted by smart material or intelligent material. in this review paper I would like to light up the field of material science in various material are investigated by various scientist & researchers in order to fulfill the required purpose of human being including metals , non metals , ceramics , composites , plastics , polymers etc , all the investigated metals and non metals having specific application in all field of technology , in present scenario a new metals has been investigated by the researchers that is known as intelligent metal or material it is a hidden name , and its fancy name is recognize as a smart material . These materials possess adaptive capabilities to external stimuli, such as loads or environment, with inherent intelligence. (Rogers, 1988; Rogers et al., 1988) defined smart materials as materials, which possess the ability to change their physical properties in a specific manner in response to specific stimulus input. The stimuli could be pressure, temperature, electric and magnetic fields, chemicals, hydrostatic pressure or nuclear radiation. The associated changeable physical properties could be shape, stiffness, viscosity or damping. Or it may also be expressed as Smart or intelligent materials are materials that have the intrinsic and extrinsic capabilities, first, to respond to stimuli and environmental changes and, second, to activate their functions according to these changes. Smartness describes self-adaptability, self-sensing, memory and multiple functionalities of the materials or structures. These characteristics provide numerous possible applications for these materials and structures in aerospace, manufacturing, civil infrastructure systems, biomechanics and environment. A another very close explanation may be as "A system or material which has built-in or intrinsic sensor(s), actuator(s) and control mechanism(s) whereby it is capable of sensing a stimulus, responding to it in a predetermined manner and extent, in a short/ appropriate time, and reverting to its original state as soon as the stimulus is removed"

II. Literature review

Literature review is the basic foundation of any research or review version which deals with the new technological ideas , that had been previously demonstrated by various researchers , scientist, research scholars , student of ignited mind , these ideas help us to glow our path toward the innovation & discover the futuristic ideas thus the literature review provide us a platform , following are some important literature reviews

Smart materials systems are nonliving systems that integrate the functions of sensing, actuation, logic and control to respond adaptively to changes in their condition or the environment to which they are exposed, in a useful and usually repetitive manner [Strock, 1996]. According to Vardan and Vardan (2000), *smart system* refers to a device which can sense changes in its environment and can make an optimal response by changing its material properties, geometry, mechanical or electromagnetic response. Crawley and de Luis (1987) defined 'intelligent structures' as the structures possessing highly distributed actuators, sensors and processing networks. The idea of 'smart' or 'intelligent' structures has been adopted from nature, where all the living organisms possess stimulus-response capabilities (Rogers, 1990).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 properties and functions of the materials. Fair-weather (1998) defined active smart materials as those materials which possess the capacity to modify their geometric or material properties under the application of electric, thermal or magnetic fields, thereby acquiring an inherent capacity to transduce energy. Structural and functional materials. These materials possess adaptive capabilities to external stimuli, such as loads or environment, with inherent intelligence. (Rogers, 1988; Rogers et al., 1988). In the US Army Research Office Workshop, Rogers et al. (1988) defined smart materials as *materials, which possess the ability to change their physical properties in a specific manner in response to specific stimulus input*. The stimuli could be pressure, temperature, electric and magnetic fields, chemicals or nuclear radiation. The associated changeable physical properties could be shape, stiffness, viscosity or damping Piezoelectric materials have been well-known for their use in accelerometers, strain sensors (Sirohi and Chopra, 2000b), emitters and receptors of stress waves (Giurgiutiu et al., 2000; Boller, 2002), distributed vibration sensors (Choi and Chang, 1996; Kawiecki, 1998), actuators (Sirohi and Chopra, 2000a) and pressure transducers (Zhu, 2003). 1881 G. Lippmann predicted that a crystal such as quartz would develop a mechanical strain when an electric field was applied. In the same year the Curies reported the converse pressure piezoelectric effect with quartz and Rochelle salt. They showed that if certain crystals were subjected to mechanical strain, they became electrically polarized and the degree of polarization was proportional to the applied strain. During the 1940s researchers discovered and developed the first polycrystalline , piezoelectric ceramic, barium titanate. A significant ad-vantage of piezoelectric ceramics over piezoelectric crystals is their ability to be formed in a variety of shapes and sizes.

III. Type of smart material

Smart materials can be either *active* or *passive* . active smart materials as those materials which possess the capacity to modify their geometric or material properties under the application of electric, thermal or magnetic fields, thereby acquiring an inherent capacity to transduce energy. Materials, SMAs, ER fluids and magneto-strictive materials are active smart materials. On the other hand. The material which are inactive to response and functioning are called passive smart material. Figure – 1 shows the behavior of some smart / intelligent material response

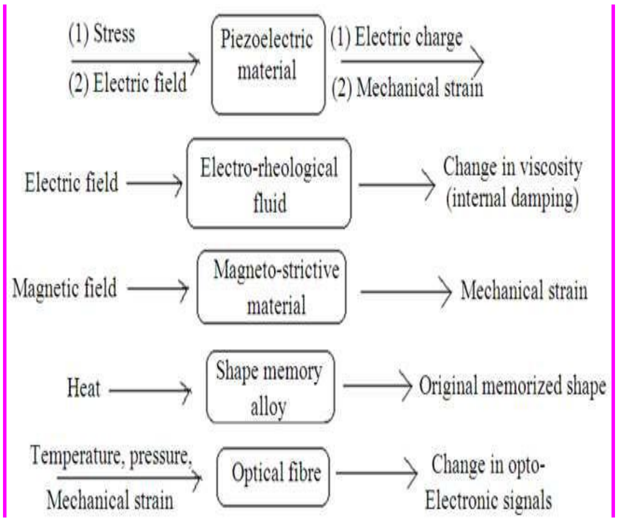


Figure -1 behavior of smart materials and their associated stimulus-response

Other important type of intelligent material is given below

3.1 Pyroelectrics material

Pyroelectrics, are materials that become electrically polarized upon an applied temperature change. Materials used as pyroelectrics include barium strontium titanate ($Ba_{1-x}Sr_xTiO_3$), lead zirconate titanate ($PbZr_{1-x}Ti_xO_3$), barium strontium niobate ($Ba_{1-x}Sr_xNb_2O_6$), triglycine sulfates (TGS), lithium tantalate ($LiTaO_3$), and polyvinylidene fluoride (PVDF). Ceramics are widely used due to their lower cost including availability and ease of processing, and good stability. Their weakness comes from their inherent brittleness. Polymers, PVDF and its copolymer with tri-fluoroethylene (PVDFTrFE), provide a non-brittle alternative but do not obtain the level of performance of ceramics. Pyroelectrics are widely used for infrared detection in surveillance and targeting applications. A pyroelectric infrared detector generally employs a thin film of pyroelectric material oriented with the electrode surfaces normal to its polarization direction. When infrared radiation is absorbed by the detector, the temperature of the pyroelectric material rises. This change in temperature alters the material's polarization causing a change in surface charges across the material which produces an electrical signal via the electrodes. The resulting signal is proportional to the incoming radiation.

3.2 Piezoelectric material

Piezoelectric are materials that exhibit an electrical polarization with an applied mechanical stress (direct effect), or a dimensional change with an applied electric field (converse effect). They are used for both sensing and actuating devices. Lead zirconate titanate ($PbZr_{1-x}Ti_xO_3$) is the premier piezoelectric material as it may be doped to produce an n-type or p-type material with a range of dielectric constants to meet the requirements of numerous applications. Other piezoelectric materials that may be used are barium titanate ($BaTiO_3$), lead titanate ($PbTiO_3$), lead metaniobate ($PbNb_2O_6$), and PVDF. Polymers are generally favored for sensing applications while ceramics are favored for actuating. Figure-2 depicts the piezoelectric effect observed in lead zirconate titanate upon the application of compressive forces relative to the crystal structure. Piezoelectric is a nature technology with numerous applications throughout the military and commercial sectors. Devices using piezoelectric include: adaptive optics, hydrophones and sonobuoys, fuse devices, depth sounders, thickness gauging, flaw detection, level indicators, alarm systems, strain gauges, airplane beacon locators, fetal heart detectors, and tire pressure indicators among many others. Figure -2 shows the piezoelectric effect

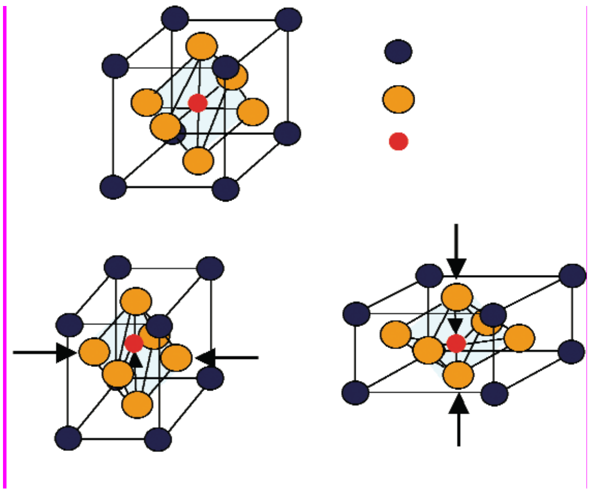
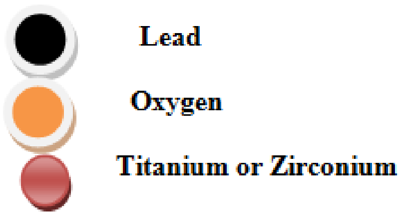


Figure -2 shows the piezoelectric effect



3.2 Electrostrictive

Piezoelectric materials are materials that exhibit a linear relationship between electric and mechanical variables. Piezoelectricity is a third-rank tensor. Electrostrictive materials also show a relationship between these two Variables. However, in this case, it is a quadratic relationship between mechanical stress and the square of electrical polarization. Electrostriction can occur in any material and is a small effect. One difference between Piezoelectric and electrostrictive materials is the ability of the electrostrictive materials to show a larger effect in the vicinity of its Curie temperature. Electrostriction is a fourth rank tensor property observed both in centric and acentric insulators. Example of electrostrictive materials include lead manganese niobate-lead titanate (PMN–PT) and lead lanthanium zirconate titanate (PLZT).

3.3 Magnetorestrictive materials

Magneto restrictive materials are materials that have the material response of mechanical deformation when Stimulated by a magnetic field. Shape changes are the largest in Ferro-magnetic and ferromagnetic materials. The Repositioning of domain walls that occurs when these solids are placed in a magnetic field leads to hysteresis Between magnetization and an applied magnetic field. When a ferromagnetic material is heated above its Curie Temperature, these effects disappear. The microscopic properties of a ferromagnetic solid are different than for a Ferromagnetic solid. The magnetic dipoles of a ferromagnetic solid are aligned parallel. The alignment of dipoles in a ferromagnetic solid can be parallel or in other directions.[10],[11],[12] the internal mechanism of magneto restrictive material is given below in figure -3

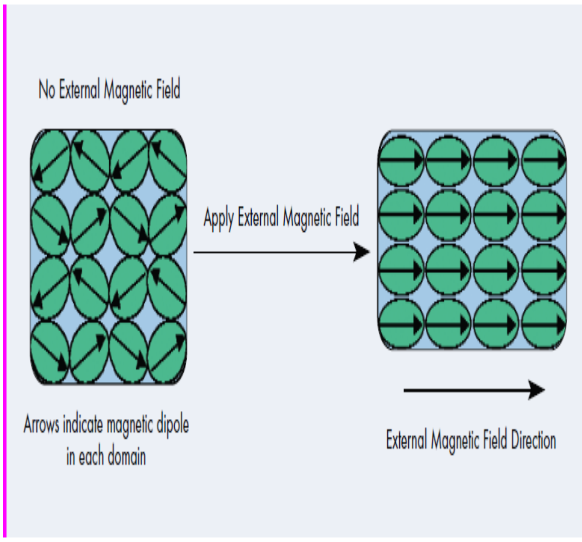


Figure -3 The internal mechanism of magneto Restrictive material

3.5 Shape memory alloys

Shape memory alloys are very special type of alloys whose behavior is just a magic , consider a metal upon which some kind of deformation force is applied & their effect is metal become deformed , and heat supplied is perform on it , its return back to original shape & size this phenomenon is called shape memory effect . These materials undergo a thermo mechanical change as they pass from one phase to another

- When metals are cooled below the Curie temperature it passes through the martensitic phase.
- On the other hand if the temperature of metal increases above the critical temperature the transformation of martensitic into austenitic phase takes place , finally metal behave like originally as a previous state Figure -4 shows a complete mechanism of shape memory effect

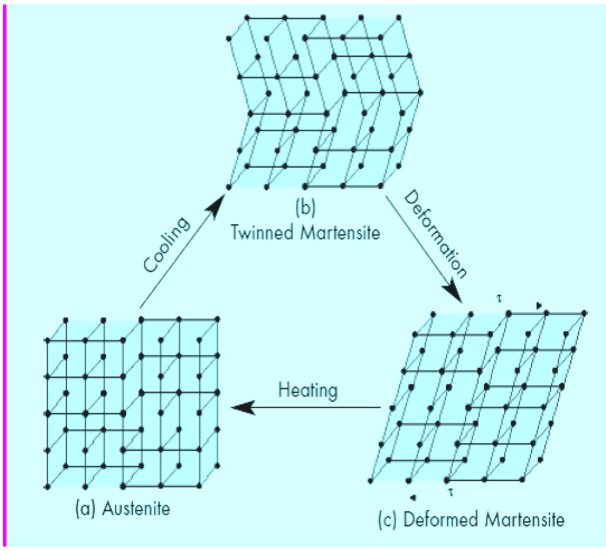


Figure -4 Mechanism of shape memory effect

- "a" Represent the Austenitin phase of metal
- "b" Represent the Deformed pattern of metal
- "c" also represent the Deformed Martensite structure of pattern

- " a" Represent original regained position after heating

Following are the very important types of shape memory alloys which generally used in various applicationsNickel–titanium (nitinol family) , silver–cadmium, gold–cadmium, copper–aluminum–nickel, copper–tin, copper–zinc, combinations of copper–zinc with silicon or tin or aluminum, indium–thallium, nickel–aluminum, iron–Platinum, manganese–copper, and iron–manganese–silicon. [16]

IV. Improvement in intelligent material / smart material

Following futuristic improvement may be possible regarding the above context

- Restraining the crack propagation in material that is developed by stress intensity around the damaged point (damage recovery)
- Either load may satatic or dynamic ,material should create resistance for that action as well as detection automatically (shock behavior detection)
- Material having capability of self reparability & maintainability (self- healing characteristics)
- Materials which are usable up to ultra-high temperatures by suitably changing composition through transformation (thermal mitigation).

V. Applications

Smart materials find a wide range of applications due to their varied response to external stimuli. The different areas of application can be in our day to day life, aerospace, civil engineering applications and mechatronics to name a few. The scope of application of smart material includes solving engineering problems with unfeasible efficiency and provides an opportunity for creation of new products that generate revenue. Important feature related to smart materials and structures is that they encompass all fields of science and engineering. As far as the technical applications of smart materials is concerned, it involves composite materials embedded with fiber optics, actuators, sensors, Micro- Electro Mechanical Systems (MEMSs), vibration control, sound control, shape control, product health or lifetime monitoring, cure monitoring, intelligent processing, active and passive controls, self-repair (healing), artificial organs, novel indicating devices, designed magnets, damping aero elastic stability and stress distributions. Smart structures are found in automobiles, space systems, fixed-and rotary-wing aircrafts, naval vessels, civil structures, machine tools, recreation and medical devices.

5.1 In the field of defense and space

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

5.2 In nuclear industries

Smart technology offers new opportunities in nuclear industrial sector for safety enhancement, personal exposure reduction, life-cycle cost reduction and performance improvement. However, the radiation environments associated with nuclear operations represent a unique challenge to the testing, qualification and use of smart materials. 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.

5.3 Biomedical applications

In the field of biomedicine and medical diagnostics, still investigations are being carried out. Certain materials like poly-electrolyte gels are being experimented for artificial-muscle applications, where a polymer matrix swollen with a solvent that can expand or contract when exposed to an electric field or other stimulation. In addition, due to biodegradability of these materials, it may make it useful as a drug-delivery system.

5.4 In structural engineering

These materials also find application in the field of structural engineering. They are used to monitor the civil engineering structures to evaluate their durability. Not only the smart materials or structures are restricted to sensing but also they adapt to their surrounding environment such as the ability to move, vibrate and demonstrate various other responses.

5.5 Reducing waste

All over the world, the electronic wastes are the fastest growing components of domestic waste. During disposal and processing of such wastes, hazardous and recyclable materials should be removed first. Manual disassembly is expensive and time consuming but the use of smart materials could help to automate the process. Recently fasteners constructed from shape memory materials are used that can self release on heating. Once the fasteners have been released, components can be separated simply by shaking the product. By using fasteners that react to different temperatures, products could be disassembled hierarchically so that materials can be sorted automatically.

5.6 Health

Biosensors made from smart materials can be used to monitor blood sugar levels in diabetics and communicate with a pump that administers insulin as required. However, the human body is a hostile environment and sensors are easily damaged. Some researches on barrier materials are going to protect these sensors. 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.

VI. Conclusion

Intelligent material is differentiated by other metals or material due to its inherent natural characteristics, "the definition of intelligent materials has been expanded to the materials that receive, transmit, or process a stimulus and respond by producing a useful effect that may include a signal that the materials are acting upon it". Intelligent material have a wide range of variety as well as wide range of application in various field like aero space engineering , bio medical engineering , mechanical engineering , physics , chemistry , electronics etc. finally we can say that it is a multidisciplinary material , there should be a possible improvement for new generation of material as per their broad application

Acknowledgment

This work is carried out by the support of Indira Gandhi Engineering College Sagar (MP) India , I also thanks to all the faculty members and colleagues for their valuable guidance & constant motivation for completing the tasks

References

[1]. Amato,Sci. News,137(10), 152–155 (Mar. 10, 1990).
[2]. Port, Business Week, No. 3224, 48–55 (Mar, 10, 1990).
[3]. Committee on New Sensor Technologies, Materials and Applications, National Materials Advisory Board Commission on Engineering and Technical Systems, National Research Council Report, Expanding the Washington, DC, 1995, pp. 33–45.
[4]. C. A. Rogers,Sci. Am.,273(3), 122–126 (Sept. 1995).
[5]. S. Ramamurthy, M.V. Gandhi, and B.S. Thompson, Smart Materials for Army Structures
[6]. Dosch, J. J., Inman, D. J. and Garcia, E. (1992), "A Self Sensing Piezoelectric Actuator for Collocated Control", Structures, Vol. 3, pp. 166-185.\
[7]. LAMSS (2003), Laboratory for Active Materials Journal of Intelligent Material Systems and Smart Structures, University of South Carolina, http://www.me.sc.edu/Research/lamss (date of access: 9 September, 2003)
[8]. Ahmad, I. (1988), "Smart Structures and Materials", Proceedings of U.S. Army Research Office Workshop on Smart Materials, Structures and Mathematical Issues, edited by C. A. Rogers, September 15-16, Virginia Polytechnic Institute & State University, Technomic Publishing Co., Inc, pp. 13-16.
[9]. Dosch, J. J., Inman, D. J. and Garcia, E. (1992), "A Self Sensing Piezoelectric Actuator for Collocated Control" Journal of Intelligent Material Systems and Structures, Vol. 3, pp. 166-185
[10]. Takagi, T., 1990. A concept of intelligent materials. J. Intell. Mater. Syst. Struct., 1: 149-156. DOI: 10.1177/1045389X9000100201
[11]. Vardan, V.K. and V.V. Vardan, 2002. Microsensors, Microelectromechanical Systems (MEMS) and electronics for smart structures and systems. Smart Mater. Struct., 9: 953-972
[12]. Fairweather, J.A., 1998. Designing with Active Materials: An Impedance Based Approach. 1st Edn.,UMI, New York, pp: 196.
[13]. Kumar, S., 1991. Smart materials for accoustic or vibration control. Ph.D. Thesis,
[14]. Susitna Kamala, Introduction, Classification and, applications of Smart materials: An OverviewAmerican Journal of Applied Sciences 10 (8): 876-880, 2013
[15]. Shailendra Kumar Bohidar, smart materials for future, International Journal of Advance Research In Science And Engineering IJARSE, Vol. No.4, Special Issue (02), February 2015