USE OF
SMART MATERIALS IN INTERIORS
& ARCHITECTURE

DISSERTATION

Submitted in the partial fulfillment

Of the requirement for the award of the

Degree of

MASTER IN DESIGN

IN

INTERIOR AND FURNITURE DESIGN

By

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Under the Esteemed Guidance of

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DECEMBER 2017

CERTIFICATE

This is to certify that **PRAKHAR VERMA** bearing Registration Number **11606317** has completed his project titled, "**Use of Smart Materials in Interiors and Architecture"** under my guidance and supervision.

To the best of my knowledge, the present work is the result of the original investigation and study. No part of the project has ever been submitted for any other degree at any university. This paper is fit for submission and the partial fulfillment of the conditions for the award of the degree of Masters of Interior and Furniture Design.

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Date:

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in this research paper entitled **"Use of Smart Materials In Interiors & Architecture"** in the partial fulfillment of the requirements for the award of the **Master of Design** in **Interior and Furniture Design** and submitted in the **Department of Interior and Furniture Design** of the Lovely Professional University, Phagwara, is an authentic record of my own work carried out during period from **Aug 2017 to Dec 2017** under the supervision of Ms. Sonia Suri, Asstt. Professor, Department of Interior and Furniture Design. The matter presented in this research has not been submitted by me for the award of any other degree of this or any other University/Institute.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ACKNOWLEGMENT

I am grateful to Lovely Professional University, Phagwara for providing this opportunity to carry out the present research. Starting on logical note, I take this opportunity to express a deep sense of gratitude and thanks to **Ms. Sonia Suri**, Assistant professor, Department of Interior And Furniture Design, for supervising the research paper. Without her wise counsel and able guidance, it would have been impossible to complete the research in this manner. I am also grateful to Staff of the Interior and Furniture design department for their intellectual and administrative support during this research and am also grateful to Ms. Aditi, Mr. Gurpirnder and Mrs. Harpreet Kaur, HOL of chemical engineering who helped me during my visit for chemical experiment in the labs. I wish to express my indebtedness towards my family, who have always been my source of strength and whose affection and patience enabled me to complete this research.

Above all I express my deep regards to the almighty for his blessings and spreading pure love in all kinds of this beautiful nature.

Prakhar Verma

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ABSTRACT

Smart material is quite new terminology used for those materials or products which have changeable properties. These materials have ability to change their color or shape in reversible manner with response to chemical or physical factors i.e., light, temperature, pressure, electric or magnetic field. Smart materials are categorized into three categories on the basis of properties and shape i.e. property exchanging, energy exchanging and matter exchanging smart materials. Now days, these materials are widely used in medical, mechanical, aerospace, agriculture field. These materials made up of different chemicals which are described in detail and have some variant properties used according to stimuli. To avoid the negative impacts on human health, some alteration can be done for improvement in their properties and used as a smart material in interior. Materials like electricity generating, color changing or light emitting help to reduce the usage and cost of natural resources and artificial light which may reduce impact of artificial light on humans. Smart materials have such ability to create a building for human with ecological and sustainable environment for better living with advancement of unique materials. Present times, these materials have less scope due to cost or unavailability in market but in the future with more development, they have ability to create a futuristic building for humans.

***Keywords**: smart materials, interior design, energy, environment, stimuli, futuristic building, human health*

CHAPETR 1: INTRODUCTION

1.1 INTRODUCTION

Smart materials are the new designed materials which can significantly alter the one or more inherent properties in a controlled when external stimuli is applied, such as stress, pH, moisture , temperature, magnetic and electric field and on the removal of stimuli , it returned back to its original position. Non smart materials do not have such type of properties in it while semi smart materials have able to change the properties one or two times on the application of stimuli. Some of these materials are recognized as adaptive materials or intelligent materials because they can adapt the shape themselves according to stimuli. The following physical and chemical influence variables may act as trigging stimuli for change smart materials:

- Light or UV light
- Pressure
- Chemical environment
- Temperature
- Electric field
- Magnetic field
- pH

1.2 RESERACH QUESTIONNARE

Ques1. What do you understand by smart materials?

Ques2. In what ways do you implement these types of materials in interior and architecture?

Ques3. Are these types of materials help in increasing the efficiency of human?

Ques4. Is there any effect on the human health?

Ques5. What is the future prospect of these types of materials?

Ques6. Is there any alternative of these types of materials in present scenario?

Ques7. These types of materials are very costly but more functional so what is more important: economical or functional.

1.3 AIM:

To implement smart materials in interior and architecture field to increase the efficiency of human and reduce the usage or cost of natural resources.

1.4 OBJECTIVE:

- Detailed Study of smart materials
- Prepare a hypothetical statement
- Implementation of smart materials in interiors

1.5 SCOPE AND PARAMETERS:

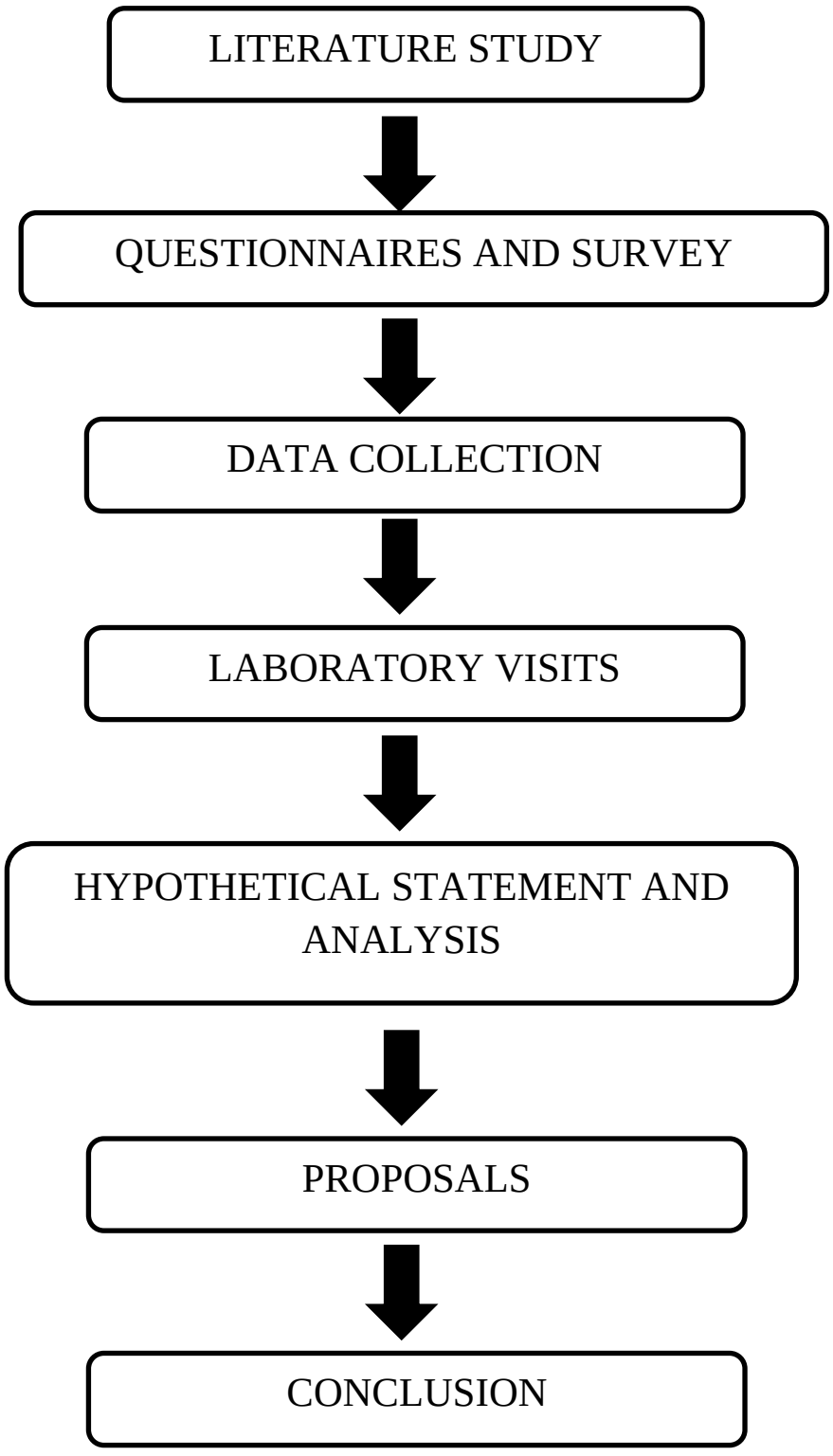
These types of materials have numerous applications in various fields so in interiors if they implemented, create a sustainable environment and reduce the usage or cost of natural resources.

1.6 LIMITATIONS

- Some materials are very expensive and unavailability in market

- Need more technical supervision
- Detailed knowledge of usage and application
- Several materials are only available in limited colors
- Need proper handling

1.8 METHODOLGY:



CHAPTER 2: LITERATURE REVIEW

2.1 LITERATURE REVIEW:

Smart structures and materials are those systems have two operations; one is to sense the stimuli and second is react according to stimuli in real time. This intelligent property of smart materials is used in civil structure to sense the unpredicted loads on the bridges the use smart materials in civil structures have a play an interesting role for engineer for predictions undefined load to give better strength for create a better structure. In his paper, he calculates the implication which is to be come in future for improving it. **Georges akhras (1999)**

In smart buildings, smart materials or systems can be used for control of environmental, for security and health monitoring they have great impact on human ices with a numerous applications in different field. These materials are used for the treatment of pediatric patients so in his paper he focus on the smart materials applications in the of cardiovascular devices design for pediatric patients **Daniel S Levi and Nick Kusnezov(2007)**

ER fluid which is known as Electrorheological fluid is a liquid, when the electric field applied on it, changes their structures or properties. This property attracts high

attention of this fluid in use of traditional and intelligent devices. In the paper, they propose, a new techniques for the preparation of ER fluids and additionally, they introduce some new developed techniques for the advancement the performance of ER materials. **Jianbo Yin and Hong Tang (2007)**

CHAPTER3: INTRODUCTION TO SMART MATERIALS

Smart materials are the new designed materials which can significantly alter the one or more inherent properties in a controlled when external stimuli is applied, such as stress, pH, moisture , temperature, magnetic and electric field and on the removal of Stimuli , it returned back to its original position.[7]

3.1 ADVANTAGES OF USING SMART MATERIALS:

- Simultaneously act as sensors and actuators
- Easily adaptive with the environmental conditions
- Perform controlled mechanical action without any external mechanisms
- New functions development
- High level of miniaturization[6]

3.2 APPLICATION OF SMART MATERIALS:

- Aerospace
- Defence
- Automobile
- Civil
- Mechanical
- Industrial

- Medical
- Agricultural

3.3 STRUCTURE OF SMART MATERIALS:

It includes:

- Data Acquisition
- Data transmission
- Command and control unit
- Instructed data
- Action devices[7]

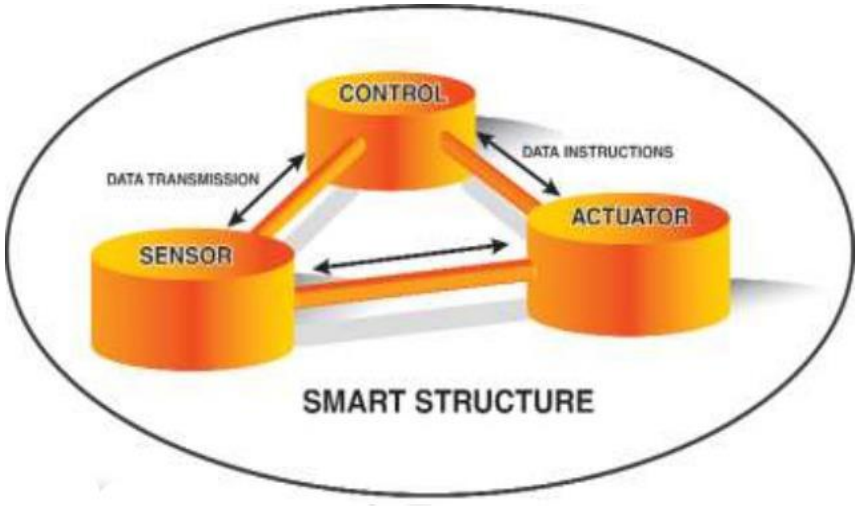


Figure 1: Structure of Smart Material (Source: Google)

3.4 CATEGORIZATION OF SMART MATERIALS:

a) Property changing SMs

b) Energy changing SMs

c) Matter changing SMs

The above entire category is again categorized into different category as follows:

a) Property changing smart materials:
    - Shape changing SMs
    - Color changing SMs
    - Adhesion changing SMs
b) Energy changing smart materials:
    - Light emitting SMs
    - Electricity changing SMs
    - Phase changing materials
c) Matter exchanging smart materials
    - Gas or water storing SMs

3.5 SHAPE CHANGING MATERIALS

Shape changing smart materials comprise those materials or products which have ability to alter their form or dimension with response to stimuli which is in a reversible manner through effect of external influences i.e., light, electric or magnetic field, temperature or pressure[6]. Some of the materials have the ability to change their shape without any change in dimension while others have the ability to change the dimension without the change in shape. While some of the materials also have the ability to change both properties at a same time [6].

The shape changing smart materials in the present market can be categorized on the basis of their stimuli as:

- **PHOTOSTRICTIVE SMART MATERIALS (light)**

- **THERMOSTRICTIVE SMART MATERIALS(temperature)**
- **MAGNETOSTRICTIVE SMART MATERIALS(magnetic field)**
- **PIEZOELECTRIC SMART MATERIALS(pressure)**
- **CHEMOSTRICTIVE SMART MATERIALS(chemical environment)**
- **ELECTROACTIVE SMART MATERIALS(electric field)**

3.5.1 THERMAL EXPANSION MATERIALS

A thermal expansion material (TEM) includes materials that have a thermal expansion coefficient that is marked as positive, negative or zero [4]. The effects may change depending on the phase change that depends on the type of material. Some materials undergo a change of volume with a continuous temperature change, while other EM undergoes a sudden change in volume with a temperature change. They are classed as phase changing materials [4].

Fig 2 show Sprinkler having EMs materials (Reece, 2006)

Materials and components usually used in EM materials:

OTHERS

Tetrachloroethylene, 1.3-dioxolane.

ALKANES (EXPANSION WAX)

Paraffin wax and paraffin oils

ALCOHOLS

Glycerin.

These EMs become area of interest in the field of architecture:

- **PARAFFIN OIL, PARAFFIN WAX**

It is colorless to whitish-yellow hydrocarbons which depend on the available state, which is liquidity to solid at +20°C [4].

Advantages:

It can be used in moderate temperature to high temperatures, it solidify at +20°C which cannot be convert it into liquid form in the presence of air[4].

Disadvantages:

If major leakage happen, it may hazard to water table[4].

3.5.2 THEMOBIMETALS

Thermobimetals (TB) are composite laminates consisting of no less than two components made of dissimilar metals having different coefficients of thermal expansion[1]. The passive component has a low thermal expansion coefficient, the highest coefficient is active. When the temperature varies over time, the components used are active or passive and their geometries adopt different shapes can be used for different purposes and applications [1].

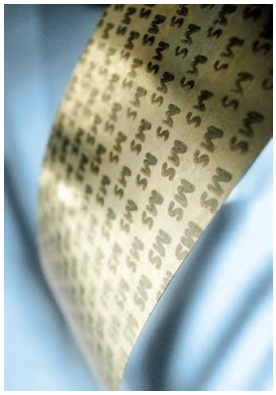


Figure 3 shows TB strips (Wayman, 2001)

The following component of TB combinations are among become the area of interest in architecture:

- **NICKEL COBALT IRON WITH IRON-NICKEL-MANGANESE AND COPPER**

Advantages:

It is appropriate for those applications which used for direct heating [1].

Disadvantages:

Expensive [1]

- **NICKEL COBALT IRON WITH MANGANESE-NICKEL COPPER**

Advantages:

It is available in market and can be prepared in huge quantities, used from long time high thermal sensitivity and variety of applications, no corrioson effecrs, can also be available in less quantities[1].

Disadvantages:

High cost [1]

3.5.3 SHAPE MEMORY ALLOYS

Shape memory alloys (SMA) consist of more than two different metal types whose properties change shape as previously reversible and temperature dependent after a thermomechanical treatment [1]. This effect can be shown among two crystalline structures on a reproducible change. The metals have a solid, austenitic, above the critical temperature, and after this temperature it becomes a flexible and deformable structure[2].

Fig 4 shows SMA springs
With Chromium coating. (Wayman, 2001)

Fig 5 show SMA springs shows
Two way effect (Wayman, 2001)

It includes:

BASIC ALLOYS

Copper-zinc-aluminum (CuZnAl), gold-cadmium (AuCd), Nickel-titanium (Nitti, e.g. Nitinol), iron-platinum (FePt),

These SMA alloys are the area of interest in the field of architecture:

- **NICKEL-TITANIUM**

Advantages:

It is available in market and can be prepared in huge quantities used for long time variety of applications, durable memory result, high strength of tensile , can also be prepared in small amount[2].

Disadvantages:

High cost as relatively to TBs [2]

- **COPPER-ZINC-ALUMINIUM (CuZnAl)**

Advantages:

Easy to use compared to others.

Disadvantages:

Small time of memory result and bad strength of tensile

3.6 COLOUR CHANGING MATERIALS

Color-change materials include materials or products that have the ability to modify their color and/or properties with response to influences by the effect of temperature, compression, electric or magnetic field, or temperature [4]. These can be classified on the basis of their stimuli as:

- **PHOTOCHROMIC SMART MATERIALS(light)**
- **THERMOCHROMIC SMART MATERIALS(temperature)**
- **MECHANOCHROMIC SMART MATERIALS(magnetic field)**
- **ELECTROCHROMIC SMART MATERIALS(electric field)**
- **CHEMOCHROMIC SMART MATERIALS(chemical environment)**

3.6.1 PHOTOCHROMIC MATERIALS

Photochromic (PC) materials include materials or products that are capable of reversibly altering their color by reacting with light [4].

Fig 6 shows Different colors of BR Pigments. (Kosny, 2015)

It includes:

Silver Bromide (Agbr) In INORGANIC COMPOUNDS

ORGANIC COMPOUNDS

Naphthopyranes, spirooxazines, spirodihydroindolizines,

Fig7 show Sunglasses and six plastic lenses
with light before and after excitement (schodek, 2005)

The following PCs are area of interest in the field of architecture:

- **NAPHTHOPYRANES, SPIROOXAZINES DIARYLETHENES**

Advantages:

It is available in market and can be prepared in huge quantities used long time, have variety of usage and can be used in moderate to high temperatures [6].

Disadvantages:

Insoluble in water[6].

- **SILVER BROMIDE (AgBr)**

Greenish yellow precipitate formed by an inorganic chemical compound by the reaction among silver salts, with an bromide salt liquid solution, which solidifies at +20°C [6].

Advantages:

It is available in market and can be prepared in huge quantities, used long time, have variety of usage, can be used in moderate to high temperatures [6].

Disadvantages:

Comparatively small spectrum in absorption and only available in one color in form B (various shades of grey), can be corroded, toxic in nature, cannot be recyclable [6].

- **SPIROPYRANES, SPIRODIHYDROINDOLIZINES**

It is an organic compounds which solidify at +18°C and react with visible or UV light by showing color in reversible form which modify from colorless or slightly yellow to colored. And available as powders in the market. [6].

Advantages:

It is available in market and can be prepared in huge quantities used for long time variety of usage and can be used in medium temperature [6].

Disadvantages:

Unknown

3.6.2 THERMOCHROMIC MATERIALS

Thermochromic (TC) materials include materials that have ability change their color reversibly when they react to light. Similarly, thermotropic (TT) materials and thermotropic materials include materials that have been modified to change their optical properties reversibly when they react to temperature [6].

Fig 8 show Thermo Chromic Paints (schodek, 2005)

Thermochromic materials and components generally includes:

INORGANIC COMPOUNDS

bismuth oxide (BiO), zinc oxide, Vanadium tungsten oxide (VaWO), copper oxide (CuO)),vanadium oxide (VaO),

ORGANIC COMPOUNDS

Cholesteric liquid crystals

Fig 9 show powdered microencapsulated TCs (Reece, 2006)

These TCs/TTs are the area of interest in the architecture field:

- **LIQUID CRYSTALS OF CHOLESTERIC**

It is organic compounds changing their color from black to red on continuous change in temperature. [6].

Advantages:

It is available in market and can be prepared in huge quantities used for long time , variety of usage and can be used in moderate e to medium temperatures , non-toxic in nature [6].

Disadvantages:

Special techniques are required for preparing, less color intensity, and high in cost[6].

- **LYOTROPIC LIQUID CRYSTALS**

Advantages:

It is available on the market and can be prepared in huge quantities and can be used for high temperature, of a non-toxic nature. [4].

Disadvantages:

Unavailability in market [4].

3.6.3 ELECTROCHROMIC MATERIALS

Electrochromic (EC) materials include materials or components that have the ability to change color in reversible manner when they react with light. Similarly, electro-optical (OE) materials include materials that have the ability to modify their optical properties in reversible manner with respect to light. The electrochromism phenomenon is used in which electrochemical cells are required [4].

Fig 10 show two glass panels of electrochomic materials (Reece, 2006)

It includes :

ORGANIC COMPOUNDS

Liquid crystals (stilbene derivates)

These ECs and EOs are the area of interest in the field of architecture:

- **TUNGSTEN OXIDE**

It is a metal oxide produced by the tungsten oxidation with pure oxygen and by heating of tungstic acid which can solidify at + 18° C and available as a yellow powder [4].

Fig 11 show Tungsten oxide (Source: Google)

Advantages:

It is available on the market and available in large quantities, can be manufactured by the user, can be used in moderate temperatures and non-toxic nature [4].

Disadvantages:

Cannot create neutral colors, that is only blue is formed [4].

- **NIOBIUM OXIDE (NB2O5)**

Advantages:

Can make a neutral color (brown) [4].

Disadvantages:

Not known [4].

3.7 ADHESION CHANGING SMART `MATERIALS

Adhesion changing smart materials includes those materials that have the ability to alter their surface adsorbing or reversing attraction forces with response to stimuli in solid, liquid or gaseous component. This occurs due to the effect of temperature, light, electric field or biological component[5].

Adhesion-changing smart materials can be differentiated on the basis of stimuli as:

- **PHOTOADHESIVE SMART MATERIALS**
- **THERMOADHESIVE SMART MATERIALS**
- **ELECTROADHESIVE SMART MATERIALS**
- **HYDROADHESIVE SMART MATERIALS**
- **BIOADHESIVE SMART MATERIALS**

Bio adhesive smart materials secrete adhesive substances with response to light or nutrients.

3.7.1 TITANIUM DIOXIDE MATERIALS

Titanium dioxide (TiO2) is the largest naturally occurring titanium ore in crystalline form. Titanium iron ore is a raw material used for the production of ilmenite, which is

a black mineral in luster form, and rutile, a less iron-rich titanium ore. It is not soluble in water and, it is resistant to light and temperature. [5].

Fig 13 show TiO2 Powder (Source: Google)

It includes modifications of Rutile and anatase

These materials are the area of interest in the field of architecture:

- **RUCTILE**

Advantages:

It is available on the market and can be prepared in huge quantities; use for a wide temperature range can be used as a white pigment, nontoxic. [5]

Disadvantages:

It is not unavailable in market easily, effects of this materials are light-dependent [5]

- **MODIFICATION OF ANATASES**

Advantages:

It is used as a pigment in white color for converting organic pollutants as a photo catalyst [5].

Disadvantages:

Little part of solar radiation used [5].

3.8 LIGHT EMIITING SMART MATERIALS

Light emitting materials includes those materials or items that get energized by the light or electric field to radiate light. This happens when the particles take vitality from the impermanent state before abandoning it, some piece of the vitality assimilated and produced as obvious electromagnetic radiation. This optical wonder is called as luminescence [5] .In general terms luminescence can be differentiated as:

- **PHOTOLUMINESCENCE**
- **ELECTROLUMINESCENCE**
- **CRYSTALLOLUMINESCENCE**
- **BIOLUMINESCENCE**
- **CHEMOLUMINESCENCE**
- **ELECTROLUMINESCENCE**

3.8.1 FLUORESCENCE MATERIALS

These are the materials or components with an impaired property capacity for fluorescence in the form of light by the absorption of electromagnetic radiation to emit light from the ground state from single state, in a time not greater than 10-8 seconds [4].

Fig 14 show Solid organic daylight-luminous pigments (Source: Google)

Fig 15 show day light luminous from fluorescence (Source: Google)

The materials are the area of interest to the field of architecture:

- **RHODAMINE, FLUORESCENE**

Advantages:

It is available in market and can be prepared in huge quantities, available in varied choice of colors, used for long time , more brilliance and high color intensity, cheap in cost[4].

Disadvantages:

Limited of light fastness [4].

3.8.2 PHOSPHORESCENCE MATERIALS

This happens when an atom assimilates light amid the change from an energized state to a ground state for more than 12-9 seconds. These materials or segments have this capacity to produce light are called phosphors [4].

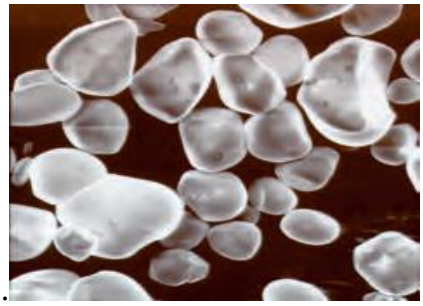


Fig 16 show alkaline earth luminate Crystals (Reece, 2006)

Fig 17 show a plastic polyacryl profile produced from it (Reece, 2006)

Fig 18 show Phosphorescent glass (Source: Google)

Fig 19 show Phosphorescent glass tiles (Reece, 2006)

The following materials currently are the area of interest to architecture:

- **ZINC SULPHIDE CRYSTALS**

Advantages:

It is available in the market and can be prepared in huge quantities, use for a long time the high color intensity, long afterglow for several hours, variety of applications; also available in smaller quantities, inexpensive compared to alkaline earth aluminate crystals [5]

Disadvantages:

Restricted to light speed [5].

- **ALKALINE EARTH ALUMINATE CRYSTALS**

Advantages:

It is available on the market, with a high intensity intensity, a short excitation time, a very long persistence for several hours and a various of applications available in smaller quantities [5].

Disadvantages:

High cost as compared to zinc sulphide crystals [5].

3.8.3 INJECTION ELECTROLUMINESCENCE MATERIALS

Injection Electroluminescence is the fundamental rule utilized behind semiconductor light sources, i.e. LEDs, in which charge bearers are infused all things considered, and by the recombination of electrons and electrons. Openings, the light are discharged. In this procedure, doped gallium arsenide goes about as a luminescent material in LEDs.

Fig 20 show 2W high output LED (Reece, 2006)

Fig 21 show color on demand LED (Source: Google)

It includes:

INORGANIC COMPOUNDS

Doped gallium arsenide,

The following are the area of interest in the field of architecture:

- **DOPED GALLIUM ARSENIDE**

Advantages:

It is available in market and can be prepared in huge quantities, have high color of intensity , variety range of usage depending on type, also available in less quantities in market [4].

Disadvantages:

Only produced by a few industries factory and less number of light colors available[4].

3.8.4 THICK FILM ELECTROLUMINESCENCE MATERIALS

Thick film electroluminescence is a working standard utilized for level light sources created from electroluminescent (EL) material, in view of the communication of a few utilitarian layers. The thickness of the luminescent layer is considerably thicker than that utilized as a part of thin film innovation. The stored color (phosphorus) is energized and emanates a cool light on the use of the electric field. EL movies and EL links are two of the items made from these material [4].

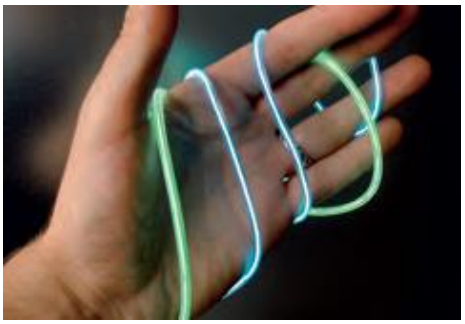


Fig 22 show EL cable (Reece, 2006)

Fig 23 show EL ink on speedometer

It includes:

INORGANIC COMPOUNDS

Doped zinc sulphide

The following are the area of interest to architecture:

- **DOPED ZINC SULPHIDE**

Advantages:

It is available in market, also available in less quantity, comparatively less cost[5].

Disadvantages:

High current is required for preparation and less number of light colors available[5].

3.8.5 ORGANIC LIGHT-EMITTING DIODES

Organic light-discharging diodes (OLEDs) are for the most part produced as level LEDs in view of natural semiconductor polymers from which the cold light emanates by electron assimilation [4].

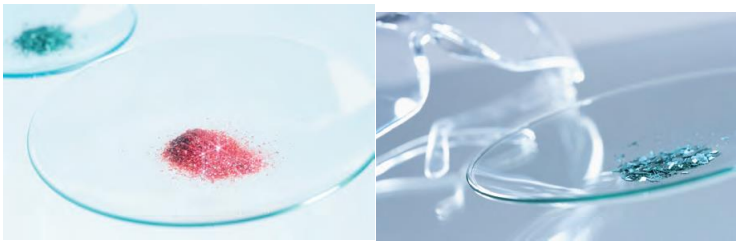


Fig 24 show Green and red crystals
for the preparation of OLEDs. (Source: Google)

It includes:

SMALL MOLECULES

E.g. aluminium-tris(8-hydroxyquinoline) (Alq3)

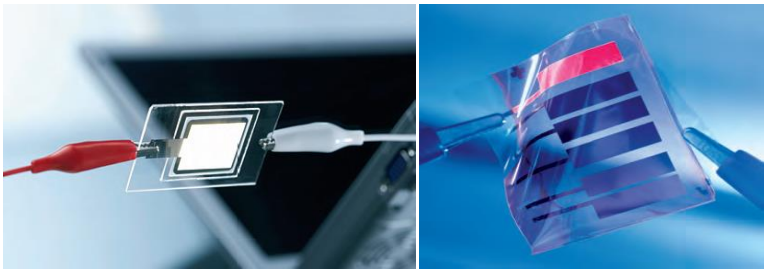


Fig 25 show light-emitting SMOLED display (Source: Google)

The following are area of interest in the field of architecture:

- **ALUMINIUM-TRIS(8-HYDROXYQUINOLINE) (ALQ3)**

Advantages:

It is available in market, also available in fewer quantities, relatively better optical properties [5].

Disadvantages:

High cost production [5].

- **POLYPHENYLENVINYLEN (PPV), POLYTHIOPHENE, POLYFLUORENE**

It is the organic semiconductor polymers luminescent, appropriate for the production of color displays and light sources, can applied in glass and plastic [5].

Advantages:

It is available in market, also available in less quantities relatively good photoconductivity and electroluminescence [5].

Disadvantages:

Limited number of colors [5].

3.9 ELECTRICITY GENERATING SMART MATERIALS

Electricity generating materials incorporate materials or items that can deliver an electrical current with a related client in light of at least one stimuli, i.e. the impact of light or changes in light or temperature [7]. Electricity-generating smart materials can be categorized according to their stimuli as

- **PHOTOELECTRIC SMART MATERIALS**
- **CHEMOELECTRIC SMART MATERIALS**
- **PIEZOELECTRIC SMART MATERIALS**
- **THERMOELECTRIC SMART MATERIALS**

3.9.1 DYE SOLAR CELLS

Dye solar cells (DSCs) are composite layers in which dyes are used to produce an electrical current with a user associated with light absorption. They are also called Grätzel cells [5].

Fig 27 shows six DSC modules and
Transparent effect of the dye used (Reece, 2006)

The following material is area of interest in the field of architecture:

- **RUTHENIUM COMPLEXES**

It is the dyes based on an organic solution and metallic element ruthenium compound.

Advantages:

It is available in market, can be used in moderate to medium temperatures ,wide range of absorption, much long life [4].

Disadvantages:

Relatively high cost as compared with anthocyanins [4].

3.9.2 THERMOELECTRIC GENERATORS

Thermoelectric generators (TEGs), made out of thermoelectric segments, deliver from two distinctive metal wires from profoundly doped semiconductors p and n which energize the electrons or create electron-opening sets by retaining the heat with response to a temperature inclination [4]. It includes:

- Bismuth telluride/iron disilicide

The following material is area of interested in the field architecture:

- **BISMUTH TELLURIDE (BI2TE3)**

It is an inorganic semiconductor composite of metallic bismuth and metallic telluride. This compound can be additionally prepared into p-and n-conductor semiconductors by doping with different outside atoms. [4].

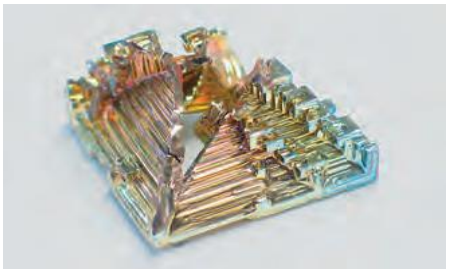


Fig 28 show Bismuth crystal

(Source: Google)

Fig 29 show Tellurium crystal

(Source: Google)

Advantages:

It is available in market and can be used in moderate to medium temperatures and have better efficiency. [4].

Disadvantages:

Cannot be used in strongly oxidizing atmospheres[4].

3.9.3 PIEZOELECTRIC CERAMICS

Piezoelectric pottery (PECs), known as piezoceramics, are inorganic or natural materials in which a mechanical load is connected, delivering electric charges on their surfaces, which adjusts the physical properties through changes in control circulation [4].

Fig 30 shows Various piezoceramic powders (Source: Google)

These materials are area of interest in the field of architecture:

- **LEAD ZIRCONATE TITANATE (PZT)**

It is an inorganic compound made out of lead (Pb), oxygen (O) and titanium (Ti) or zirconium (Zr), named hard and soft ceramic production, which can be created by doping with atom outsiders. Soft ceramic production is more effortlessly adjusted by electric fields than hard ceramic. [4].

Advantages:

It is available in Market, can be prepared in huge quantities, use for long time , can be ready into any shape [4].

Disadvantages:

Low tensile, toxic. Sensitive to moisture [4].

3.10 ENERGY-EXCHANGING SMART MATERIALS

Energy-exchange materials incorporate materials or items that can catch energy, which is either sensible and latent energy, or both, as light, electricity or heat and that has reversible properties.[7].

Fig 31 Show Light Glazing System With Salt Hydrate materials

(Kosny, 2015)

These materials can be categorized as follows:

- **LIGHT-STORING SMART MATERIALS**
- **HEAT-STORING SMART MATERIALS**
- **ELECTRICITY-STORING SMART MATERIALS**
- **HYDROGEN-STORING SMART MATERIALS**

3.10.1 PHASE CHANGING MATERIALS

All materials that can switch their state in light of outer impacts are named stage change materials or PCMs. The greater part of the notable materials of this class demonstrates temperature-dependent stage changes. Addition, the accompanying states, in particular solid, fluid or vaporous, there are different states known as middle of the states, e.g. colloidal state that is produced using gels [8].

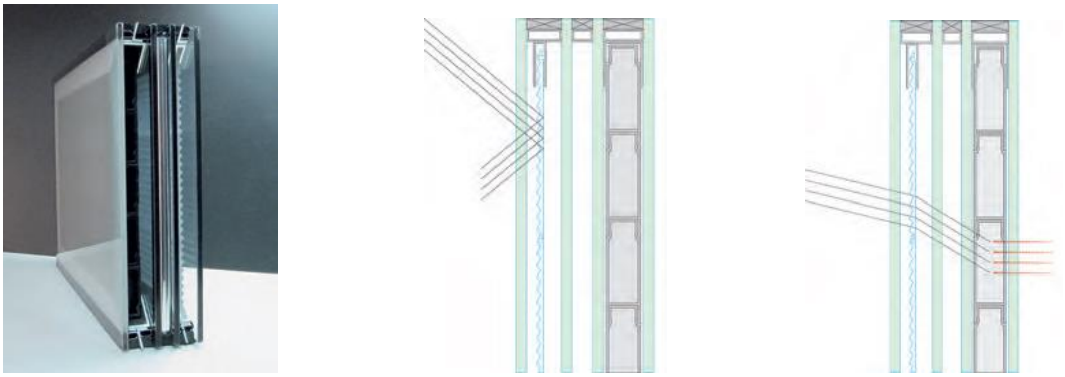


Fig 32 show section through light-directing insulation
Operating at high and low solar positions.
(Kosny, 2015)

The following PCMs are area of interest in the field of architecture:

- **PARAFFINS, PARAFFIN MIXTURES**

Advantages:

It is accessible in the market that can be set up in substantial amounts, utilized for a long time, can be utilized for huge temperatures having an assortment of utilizations. [8].

Disadvantages:

Profoundly combustible and change in volume at stage change, generally costly contrasted with water based PCM[8].

- **SALT HYDRATE, SALT HYDRATE MIXTURES**

Fig 33 show Microscopic photo of salt hydrate Crystals(Source: Google)

Advantages:

Non-flammable can be used over a large range of temperature, relatively less cost as compared to paraffin PCMs [8].

Disadvantages:

Vary at phase change and can be corroded at certain points [8].

- **SILICATE**

It is available in the form of powder

Advantages:

Comparatively less change in volume at phase change [8].

Disadvantages:

None known [8].

3.11 MATTER – EXCHANGING SMART MATERIALS

Material exchanging materials incorporates materials or items that can adopt or bind and discharge the material taken as atoms, in particular vaporous, fluid or strong segments utilizing methods physical or synthetic [4].

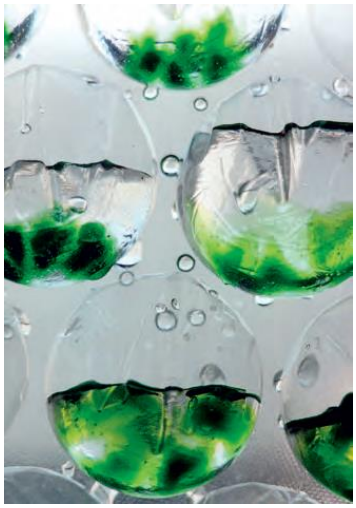


Fig 34 show hydroabsorber foils

3.11.1 MINERAL ADSORBENTS

Mineral adsorbents (MAd) incorporate materials or parts that have a fluid or strong stage and can embrace vaporous segments in their inward surfaces and reversibly change their volume, thickness, or optical properties. Thus, mineral absorbers (MAb) incorporate materials or parts that have a fluid or strong stage and can take fluid segments into their inner surfaces and reversibly cover their thickness. These fluid segments ought not be discharged under pressure. [5].

These MAds and MAbs are area of interest in the field of architecture:

- **SILICA GELS**

It is a manufactured gel arranged by sodium silicate and silicic corrosive mixes in different molecule shapes, either unpredictable or circular, having an extensive variety of utilizations. [4].

Fig 35 show silica gel granule with or Without indicator

(Source: Google)

Fig 36 show silica gel granule methyl orange as indicator in active or inactive

Advantages:

It is available in market can be prepared in huge quantities, having large temperature range from others , non-flammable, not responsive with mechanical vibrations, zero maintenance cost [4].

Disadvantages:

Short replacement life, huge dust is released during preparation, poor air circulation, can be burst when contact with water or any aqueous solution [4].

- **LOAMS**

Advantages:

It is usable over high temperature range, suitable as Moisture buffers, non-hazardous [4].

Disadvantages:

Relatively poor adsorption capacity[4].

- **ZEOLITES**

Naturally prepared zeolites can be utilized for heat-emitting materials; falsely arranged zeolites utilized for gas drying exist as powder and granules which can be additionally handled by different techniques [5].

Fig 37 show zeolites prepared gypsum board

Advantages:

Long life of replacement which can be used over a wide range of temperature[5].

Disadvantages:

Relatively high regeneration temperatures required [5].

3.11.2 ABSORBENT POLYMERS

Absorbent polymers are the arranged manufactured hydrophilic 3d cross-connected polymer that can embrace fluid parts that are fluid or water on their interior surfaces and that come in their volume, and that change their volume or thickness reversibly. These fluid parts not discharged even under high weight can assimilate a lot of water or watery arrangements rapidly which makes these sorts of items appealing in the field of engineering. [5].

Fig 38 show SAP in varying states of saturation. (Source: Google)

These APs and SAPs are area of interest in the field of architecture:

- **CROSS-LINKED SODIUM POLYACRYLATE**

These are 3D cross-connected polymers which is hydrophilic in nature altered agreeing their applications; produced artificially by the polymerization of different components and again treated into powders and crushes which accessible for a colossal assortment of utilizations. [5].

Advantages:

It is available in Market which can be prepared in huge quantities, used for long time, have wide range of temperature , unresponsive with mechanical vibrations, zero maintenance cost [5].

Disadvantages:

As compared to others having short replacement lives[5].

CHAPTER 4: ANALYSIS

4.1 HYPOTHETICAL STATEMENT AND ANALYSIS:

As we know, smart have the variety of applications in various field now the main focus is to study how they impact on human lives and functionality of building envelope. These type of materials have numerous properties which can be used in various zones in interior field which may be proved a better way of designing the suitable of humans lives .due to less knowledge or need a technical knowledge for

installation purpose they didn't get a proper eye-catching in traditional practices of interior designs. As these type help to reduce the use of natural resources so these buildings prove a sustainable building which may be more focus on these materials only of because of human health. So these materials have beneficial in following ways if they implemented in interior field:

- Provide sustainable environment
- No negative effect on human health
- Help to reduce use of natural resource
- Low electricity usage
- Comparatively inexpensive

With the ever growing the need and greed, Sustainable Development become aa important concern for the designing the building and defined as use of natural resource to fulfill their need without any compromising the future need.

Sustainable development deals to maintain the balance between energy and development. It maintains a life better for present and future generations.

When these of type of materials in interior, they didn't have any negative impact on human lives in terms of any visible effects or with they have more functionality and aesthetic in various interiors or architectural building. Some materials have negative impacts with deal with ground water on leakage so; some alternation is needed for use in interiors.

In market, they are available in large amount which affect the cost of smart materials. Some are available at low cost with variant properties required for smart materials. A

large number of colors are available in color a changing material which gives more ways to use in interiors as comparison to traditional design.

Electricity generation smart materials help to reduce the usage of electricity which affects the over cost and usage of natural resources.

4.2 QUESTIONNARE SURVEY:

Ques1. What do you think by smart materials?

- They act as smart materials
- A technical term
- Any other, specify
- Don't have any idea

Ques2. In what ways do you implement these types of materials in interior and architecture?

- For aesthetic purpose
- For the maintain the interior environment
- For health
- Conservation of electricity

Ques3. Do you think these types of materials help in increasing the efficiency of human?

- Yes
- no

Ques4. In which form it may affect the affect the human health?

- Anybody side effect
- Mental issue
- Health issue

Ques5. What is the future prospect of these type of materials?

- Help in conservation of natural resource
- Human health
- Don't know

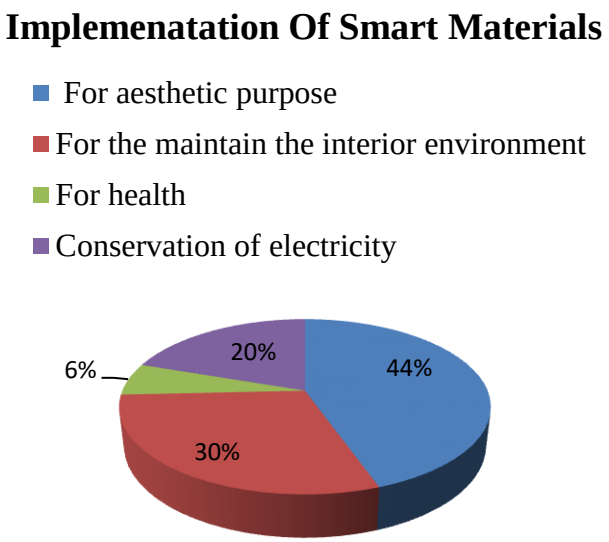
Ques6. Is there any alternative of these types of materials in present scenario?

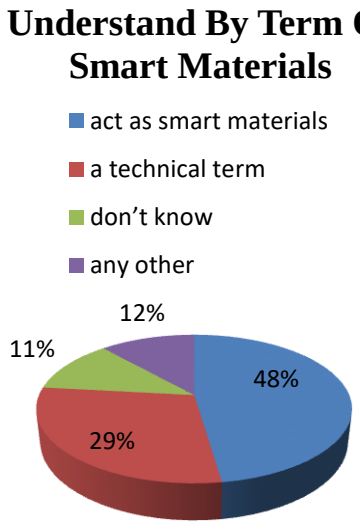
- LED Units
- Solar techniques
- Any other, specify

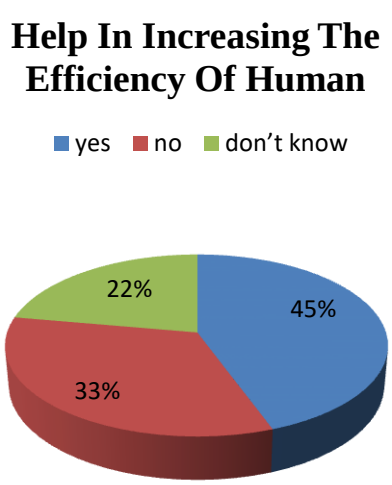
Ques7. These types of materials are very costly but more functional so what is more important: economical or functional.

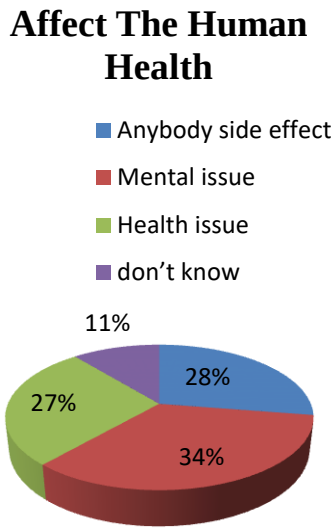
- Economical
- Functional

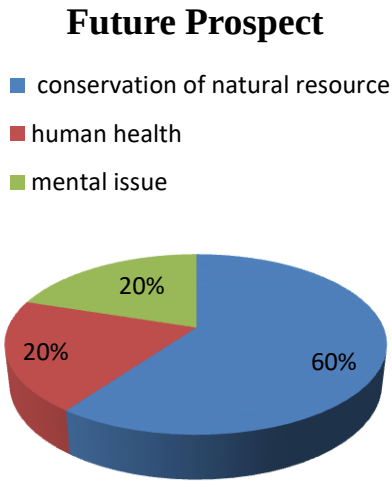
2.3 ANALYSIS OF QUESTIONAARE SURVEY:











CHAPTER 5: CASE STUDY

5.1 NET CASE STUDY:

Kinetic facade for a meeting center at Hinzert, Germany

This is an architectural composition constructed in Germany in 2004; it is made in circular shape of the existing building which is completely renovation purely into futuristic building with great functionality. The architect gives this rounded shape as the main theme for designing the structure principle of his dynamic presentation.

Building have four ring connected to each other have a some cornered and tapper angle. First two rings have a library and conference room and remaining two exhibition areas with different atmospheres. The remaining area between these two rings acts a foyer for both. The walls inside the foyer is constructed in circular form , with frameless glass facade which stores amounts of light and divided panels diagonally for opening it on suitable degree. The solar cells are used inside the building to collect the amount of sunlight that falls on the glass facade. To control the effect of thermal energy, element housings are enclosed separately for thermal insulation. At the same time, each corner of the facade slabs moves over a large area to collect light. Furthermore collectors around roofs or on the glass exterior representable another vitality idea for sun oriented vitality gathering. (Reece, 2006)

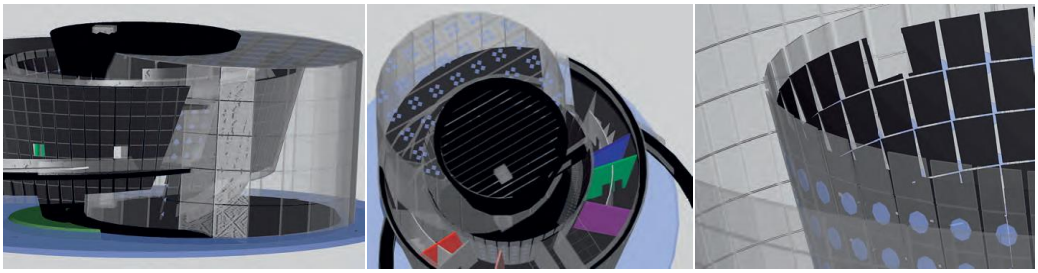


Fig 39 show the installation of thin solar cells on the interior face of building

(Source: Google)

High rise facade | Tokyo, Japan (2004)

A design one assembly Chanel headquarter might have been constructed another building clinched alongside 2004 in the Tokyo. It may be ten-stored high-determination building hosting a shopping Centre, a show lobby furthermore an restaurant. The stature of the structure may be 56 m Hosting 910 shows which permit on make another building plan and example All around those day, may be a standout amongst the from claiming this kind about advanced mobile building everywhere the planet. Exterior will be committed up about overlay Hosting a few practical layers.

Principle façade is constructed for ash glass which will be associated with stainless steel structure Hosting rhombus honeycombed structure which provides for a rich presence of the structure. Throughout the day, those whole exterior is changed over should An transparent state because of the utilization for electro-active glass. Those perspective outside the building will be reasonable and during night, the glass will be changed over under hazy and the exterior provides for An surface Hosting 700000 LEDs, which need aid controlled Furthermore directed Toward three primary workstations Also 65 000 microcomputers. The exterior could show at present pictures and also feature presentations on the shown headed divider. (Reece, 2006)

Fig 40 show the outside and interior face of building

(Source: Google)

5.2 LIVE CASE STUDY:

5.2.1 SMART T-SHIRT:

The ‘smart t-Shirt’ is prepared with sensors of special fabric which maintain to record your heart rate, body temperature and daily basis routine alarm. The garment is lightweight and washable which send the information to an app on your smartphone via chips installed in the shirt.

Fig 41 shows Smart T-shirt (Source: author)

How this smart shirt works:

The shirt may be committed of a advanced mobile sensing fabric for micro-sensors. They send those majority of the data should an little separable transmitter appended of the inside of the shirt, which sends data of the smartphone. Data transmissions could main a chance to be settled on 10 meters out from the phone. At those phone may be associated with those transmitter, it saves those information and provides for majority of the data appropriately. It could identify mankind's temperature to muscle to control it may be associated with LPU provision to showing the vital subtle elements without opening the provision.

CHAPTER 6: INFERENCES

Smart materials can be used in various parts of interior zones and having wide properties which can help for improve the present scenario. Each category of materials has different or unique properties which are totally variant from other through it acts as smart. Smart materials are not smart until it react with external stimuli. In this, stimuli play an important role to make it smart. But they required a

certain condition for reacting in smart way i.e., temperature, pressure, light, electric or magnetic field. Case study shows implement of solar cells and LED on the interior or exterior faces of building to enhance the properties and functionality with reduction usage of natural resources and in the literature view , we can understand that smart materials is not used in the interiors they have more scope in medical and engineering to manufacture their respective devices for various applications.

CHAPTER 7: PROPOSAL

Smart materials have wide variety of usage in various field but how these materials is implemented in interiors and its application is described in table and how this materials is installed with the main materials is also discussed before in the chapter1 .

7.1 RESDIENTIAL BUIDINGS:

Materials	Properties	Applications	Benefits	Hypothesis verified
Color changing smart materials	Change The Color Properties With The Influence Of Light, Temperature ,Electric Or Magnetic Field	Used in wallpaper, Furniture design, exterior facades, Utensils for hot or cold storage, Swimming pools, Wall clock	Less construction cost, increase functionality of building envelope,	Inexpensive materials with more functionality
Light emitting smart materials	Excited due to the effect of energy part of the energy absorbed and the light emitted in the form of visible electromagnetic radiation.	For special design on walls, hidden cove lights, night pathways, night light lamps, wallpaper, Exterior facades, partition walls,	Reduce the cost of artificial light, provide a better luminance , suitable environment for humans	Provide a sustainable Environment for human,
Adhesive smart materials	This is due to the effect of temperature, light electric	For exterior facades for control the action of bacterial effects , interior walls,	Help in the control of bacterial action on the various	Suitable environment For human, help to maintain odor

	field or biological component and provides adhesion for different use.	swimming pools, ceiling treatments, wall exposed walls like water tanks, water curtain	elements of building which is still in research	
Energy exchanging smart materials	Store energy in the form of light, heat and cold electricity or hydrogen and used in various products	Heat storing facades, Water installations, For maintain the interior environment.	Better way to use natural resources, low cost us ,better functionality, suitable for human health,	Reduce in the cost of electricity usage, better environment For human with no Effects on body, More functionality
Matter exchanging smart materials	Absorb the liquid or gaseous components and can be used under high pressure	Odor maintenance , Gas detection , Sound absorption, in thermal industries to regulate the gas or odor prevention	Prevention of bad or harmful odors which helps to reduce the breath disease, odor free environment	Suitable environment For human, Lost cost maintenance
Shape changing materials	Change the shape on the application of light, temperature, Electric or magnetic field	Used in sprinklers, various products of interiors, furniture, length adjusting lamps	Comparatively Inexpensive materials, used in wide variety of interior products,	Variety of usage, inexpensive products
Electricity Exchanging Smart Materials	generate electricity with a user connected by the effect of light, temperature, pressure, electric or magnetic field	Solar cells, generating pattern on facades due to variation in light and temperature, thermoelectric generator generate electricity from heat,	Reduce cost and more efficient	Less cost

7.2 EDUCATIONAL AND INSTITUTIONAL BUILDINGS:

Materials	Properties	Applications	Benefits	Hypothesis verified
Color changing smart materials	Change The Color Properties With The Influence Of Light, Temperature ,Electric Or Magnetic Field	Used in wallpaper, Furniture design, exterior facades, Utensils for hot or cold storage, Swimming pools,	Less construction cost, increase functionality of building envelope,	Inexpensive materials with more functionality
Light emitting smart materials	Excited due to the effect of energy part of the energy absorbed and the light emitted in the form of visible electromagnetic radiation.	For special design on walls, hidden cove lights, night pathways, night light lamps, wallpaper, Exterior facades, partition walls,	Reduce the cost of artificial light, provide a better luminance , suitable environment for humans	Provide a sustainable Environment for human,
Adhesive smart materials	This is due to the effect of temperature, light electric field or biological component and provides adhesion for different use	For exterior facades for control the action of bacterial effects , interior walls, swimming pools, ceiling treatments, wall exposed walls like water tanks, water curtain	Help in the control of bacterial action on the various elements of building which is still in research	Suitable environment For human, help to maintain odor
Energy exchanging smart materials	Store energy in the form of light, heat and cold, electricity or hydrogen and used in various products	Heat storing facades, Water installations, For maintain the interior environment.	Better way to use natural resources, low cost us ,better functionality, suitable for human health,	Reduce in the cost of electricity usage, better environment For human with no Effects on body, More functionality
Electricity	generate electric	Solar cells,	Reduce cost and	Less cost

Exchanging Smart Materials	current with a connected user by the effect of light, temperature, pressure, electric or magnetic field	generating pattern on facades due to variation in light and temperature, thermoelectric generator generate electricity from heat,	more efficient	

7.3 ASSEMBLY BUIDINGS:

Materials	Properties	Applications	Benefits	Hypothesis verified
Color changing smart materials	Change The Color Properties With The Influence Of Light, Temperature ,Electric Or Magnetic Field	Used in wallpaper, Furniture design, exterior facades, Utensils for hot or cold storage, Swimming pools, Wall clock	Less construction cost, increase functionality of building envelope,	Inexpensive materials with more functionality
Light emitting smart materials	Excited due to the effect of energy part of the energy absorbed and the light emitted in the form of visible electromagnetic radiation.	For special design on walls, hidden cove lights, night pathways, night light lamps, wallpaper, Exterior facades, partition walls,	Reduce the cost of artificial light, provide a better luminance , suitable environment for humans	Provide a sustainable Environment for human,
Energy exchanging smart materials	Store energy in the form of light, heat and cold, electricity or hydrogen and used in various products	Heat storing facades, Water installations, For maintain the interior environment.	Better way to use natural resources, low cost us ,better functionality, suitable for human health,	Reduce in the cost of electricity usage, better environment For human with no Effects on body, More functionality
Electricity	generate electric	Solar cells,	Reduce cost and	Less cost

Exchanging Smart Materials	current with a connected user by the effect of light, temperature, pressure, electric or magnetic field	generating pattern on facades due to variation in light and temperature, thermoelectric generator generate electricity from heat,	more efficient	

7.4 BUSINESS BUIDING:

Materials	Properties	Applications	Benefits	Hypothesis verified
Color changing smart materials	Change The Color Properties With The Influence Of Light, Temperature ,Electric Or Magnetic Field	Used in wallpaper, Furniture design, exterior facades, Utensils for hot or cold storage, Swimming pools, Wall clock	Less construction cost, increase functionality of building envelope,	Inexpensive materials with more functionality
Light emitting smart materials	Excited due to the effect of energy part of the energy absorbed and the light emitted in the form of visible electromagnetic radiation.	For special design on walls, hidden cove lights, night pathways, night light lamps, wallpaper, Exterior facades, partition walls,	Reduce the cost of artificial light, provide a better luminance , suitable environment for humans	Provide a sustainable Environment for human,
Energy exchanging smart materials	Store energy in the form of light, heat and cold, electricity or hydrogen and used in various products	Heat storing facades, Water installations, For maintain the interior environment.	Better way to use natural resources, low cost us ,better functionality, suitable for human health,	Reduce in the cost of electricity usage, better environment For human with no Effects on body, More functionality
Electricity Exchanging Smart	generate electric current with a connected user	Solar cells, generating pattern on facades due to	Reduce cost and more efficient	Less cost

Materials	by the effect of light, temperature, pressure, electric or magnetic field	variation in light and temperature, thermoelectric generator generate electricity from heat,		

7.5 MERCHANTILE BUIDINGS:

Materials	Properties	Applications	Benefits	Hypothesis verified
Color changing smart materials	Change The Color Properties With The Influence Of Light, Temperature ,Electric Or Magnetic Field	Used in wallpaper, Furniture design, exterior facades, Utensils for hot or cold storage, Swimming pools, Wall clock	Less construction cost, increase functionality of building envelope,	Inexpensive materials with more functionality
Light emitting smart materials	Excited due to the effect of energy part of the energy absorbed and the light emitted in the form of visible electromagnetic radiation.	For special design on walls, hidden cove lights, night pathways, night light lamps, wallpaper, Exterior facades, partition walls,	Reduce the cost of artificial light, provide a better luminance , suitable environment for humans	Provide a sustainable Environment for human,
Energy exchanging smart materials	Store energy in the form of light, heat and cold, electricity or hydrogen and used in various products	Heat storing facades, Water installations, For maintain the interior environment.	Better way to use natural resources, low cost us ,better functionality, suitable for human health,	Reduce in the cost of electricity usage, better environment For human with no Effects on body, More functionality
Shape changing materials	Change the shape on the application of	Used in sprinklers, various products of interiors, furniture,	Comparatively Inexpensive materials, used	Variety of usage, inexpensive products

	light, temperature, Electric or magnetic field	length adjusting lamps	in wide variety of interior products,	
Electricity Exchanging Smart Materials	generate electric current with a connected user by the effect of light, temperature, pressure, electric	Solar cells, generating pattern on facades due to variation in light and temperature, thermoelectric generator.		Less cost

7.6 STORAGE BUILDINGS:

Materials	Properties	Applications	Benefits	Hypothesis verified
Color changing smart materials	Change The Color Properties With The Influence Of Light, Temp	Used in wallpaper, Furniture design, exterior facades, Utensils for hot or cold storage,	Less construction cost, increase functionality of building	Inexpensive materials with more functionality
Light emitting smart materials	Excited due to the effect of energy part of the energy absorbed and the light emitted in the form of visible electromagnetic radiation.	For special design on walls, hidden cove lights, night pathways, night light lamps, wallpaper, Exterior facades, partition walls,	Reduce the cost of artificial light, provide a better luminance , suitable environment for humans	Provide a sustainable Environment for human,
Energy exchanging smart materials	Store energy in the form of light, heat and cold, electricity or hydrogen and used in various products	Heat storing facades, Water installations, For maintain the interior environment.	Better way to use natural resources, low cost us ,better functionality, suitable for human health,	Reduce in the cost of electricity usage, better environment For human with no Effects on body, More functionality
Matter exchanging smart materials	Absorb the liquid or gaseous components and can be used under high	Odor maintenance , Gas detection , Sound absorption, in thermal industries to regulate the gas or	Prevention of bad or harmful odors which helps to reduce the breath	Suitable environment For human, Lost cost maintenance

	pressure	odor for prevention	disease, odor free environment	

7.7 HAZARDOUS BUILDINGS:

Materials	Properties	Applications	Benefits	Hypothesis verified
Adhesive smart materials	This is due to the effect of temperature, light electric field or biological component and provides adhesion for different use	For exterior facades for control the action of bacterial effects , interior walls, swimming pools, ceiling treatments, wall exposed walls like water tanks, water curtain	Help in the control of bacterial action on the various elements of building which is still in research	Suitable environment For human, help to maintain odor
Matter exchanging smart materials	Absorb the liquid or gaseous components and can be used under high pressure	Odor maintenance , Gas detection , Sound absorption, in thermal industries to regulate the gas or odor for prevention	Prevention of bad or harmful odors which helps to reduce the breath disease, odor free environment	Suitable environment For human, Lost cost maintenance

7.8 Design proposal in interior buildings:

7.8.1Color changing materials:

Fig 42 show the color of silver bromide as fluorescence (source: Google)

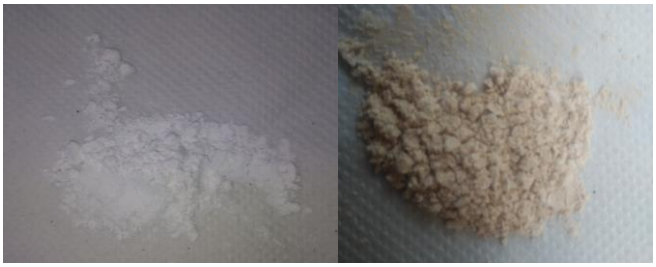


Fig 43 show the real experiment of silver bromide when react with light and heat (Source: author)

When the light and heat passes, it changes color during the light and in night, so it can be used on the celling or walls for change the color during the day or in night according the requirement. It is available in the various colors in the market.it can be regain color by adding egg yolk and sugar solution in paint.

Fig 44 shows the changes in color of the wall with variation in temperature (Source: author)

Figures shows color changes with respect to variation in temperature. As the temperature of room increases the color of room varies in tones of blue color. Mainly Silver Bromide (Agbr) is used for the application of color changing smart materials under the thermo chromic materials. The temperature range for this variation is -20°C to +250°C. It is used for the functional purpose for change the color in building of ceiling, walls and exterior facades.

7.8.2 Light emitting smart materials:

Fig 45 show the raw zinc (Source: Google)

When the zinc sulphate react with UV light or artificial light under the presence of copper sulphate, it emits or radiate a light according to temperature, it can be used for different purposes.

$$Zn(s) + CuSO_{4\,(aq.)} \rightarrow ZnSO_{4(aq.)} + Cu(s)$$

Reaction of copper sultphate and zinc

Fig 46 show the change of light in wallpaper during day and night (Source: author)

Figure shows change the wallpaper color in day and in night. Rhodamine and cyclam is used for this application. It is mixed in the paint composition which illuminate in day and night in different ways. The temperature required this illumination is –40°C to +80°C. This light helps to reduce the cost of electricity in night time and can be used in those building which works in 24 hours like BPO.

7.8.3 Electricity generating smart materials:

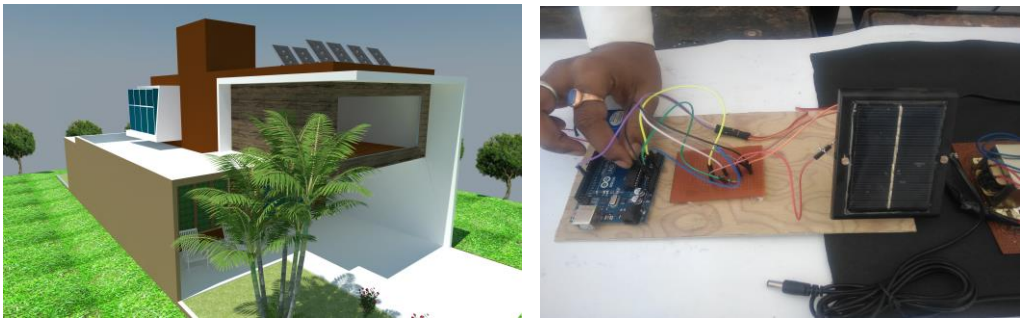


Figure 47 show installation of dye solar cells in interiors building and the arrangement of the solar cell at low cost method
(Source: author)

In this, thin size of solar cells is used with rotatable technique which moves towards the direction of sun. dye used in the manufacturing of cells acts as smart material which absorb the solar rays in it , desorb in the form of electricity which reduces the cost of electricity and promote the use of natural resources for maintaining the human health and ecological balance. This kind of cells can be used in those areas where sun rays fall in opposite direction for collecting more heat.

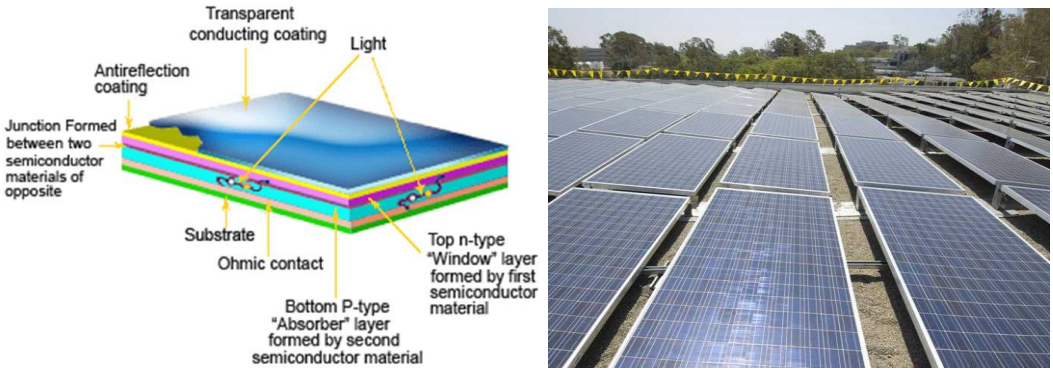


Fig 48 show the section of DSCs and the installation of solar cells

(Source: Google)

The main processes that occur in a DSSC

1. The incident photon is absorbed by Ru complex photosensitizers adsorbed on the TiO2 surface.

2. The photosensitizers are excited from the ground state (S) to the excited state (S∗). The excited electrons are injected into the conduction band of the TiO2 electrode. This results in the oxidation of the photosensitizer (S+).

$$S + h\nu \rightarrow S*$$

$$S* \rightarrow S+ + e- (TiO2)$$

3. The injected electrons in the conduction band of TiO2 are transported between TiO2 nanoparticles with diffusion toward the back contact (TCO). And the electrons finally reach the counter electrode through the circuit.

4. The oxidized photosensitizer (S+) accepts electrons from the I− ion redox mediator leading to regeneration of the ground state (S), and the I− is oxidized to the oxidized state, I3 −.

$$S+ + e- \rightarrow S$$

5. The oxidized redox mediator, I3 −, diffuses toward the counter electrode and then it is reduced to I− ions.

$$I3- + 2\ e- \rightarrow 3\ I-$$

7.8.4 Matter exchanging smart materials:

Fig 49 show the chemical compound of a) activated alumina and b) silica gels (Source: author)

These mixes are utilized for controlling the scent display in the region. It can be utilized as a part of compound production lines, gas location and clinics where the scent presents which influence the human wellbeing. It is utilized as a desiccant to control nearby mugginess to maintain a strategic distance from waste or corruption of a few products. Since silica gel can have included synthetic markers and assimilates dampness exceptionally well.

CHAPTER 8: CONCLUSION

Although, smart materials do not have such popularity in preset scenario due to some limitations but with the development in these materials for improving their performance, it can be prove a better way for construct a futuristic building for human with sustainable or ecological balance. They need a proper handling and technical supervision, a technical knowledge is required for used in application form. They have wide usage not only in interiors but also in many fields. So they have capability to create a better environment.

CHAPTER 9: FUTURE RESEARCH AND SCOPE

With the development of unique or smart materials or products, we move to a building that has different functions and properties which is clearly different from past few decades. We are just at end of traditional building or say a start of new generation of building which have unique functions which is sustainable or ecological efficient, they have intelligent building which is easily adaptable to the environment and have ability to response from direct or indirect environment and adjust themselves to it. This creates a new task for engineers and designers to create a building with such of functionality. Smart materials have such ability to create a building for human with ecological and sustainable environment for better living with advancement of unique materials. Present times, these materials have less scope due to cost or unavailability in market but in the future with more development they have ability to create a futuristic building for humans Future scope of smart materials usage depends and their effects on architectural building, it is totally different what we are used to see present scenario..