Application of Smart Materials in the Interior Design of Smart Houses

Mohammed Thabit Al-Baldawi
College of Architecture and Design, Al-Ahliyya Amman University, PO box 133, Amman 19328, Jordan
E-mail: dr.m.baldawi@gmail.com

Abstract

We highlight in this research the development and uses of smart materials to enhance the economical, functional, technical and aesthetic side as well. We discussed in the study the classification of materials used in the design of interior architecture, and the relationship between the environment and the impact on the health of occupants and the use of less harmful materials.

The effect of reducing the use of materials' amounts is important in economic terms, by choosing the appropriate material and put it in the right place. It is also necessary to know the specifications and properties of the physical and chemical materials for optimization of its use. The understanding of this stage can enhance interior design in the future.

Taking advantage of the types of materials used in interior design that can be recycled and re-manufactured reflects its beneficial effect on the environment and also reduces the consumption of agricultural original materials.

We pointed to the bamboo as an example of the kinds of agricultural materials used in interior design and the possibility to develop this types of which Biocomposite and Hybrid bamboo-glassfibers composites.

We addressed the subject of smart materials and their use in smart homes after the definition provided on the types of materials, and also the importance of smart materials from an environmental point of interior design. The benefits of smart materials which we considered are minimized air conditioners size, in addition to most smart materials in the interior design is sensible and invisible, which plays a big role in smart homes design.

We have defined the smart home and what are the essential parts that constitute it and its association with a computerized engineering mechatronic reflection on economic and interior design. The study is aimed at linking the use of smart materials and the possibility of energy conversion for introducing better interior design to modern homes that makes them more convenient and comfortable and energy-saving. We have given some examples of smart materials largely used in sensors, glass, coatings and heating.

Keywords: smart materials, interior design, smart house, energy, environment.

1. Introduction

Among many environmental topics in interior design; indoor environmental quality and interior materials are the topics especially related to interior design [1)].

An important part of interior design is the specification of suitable materials for the various components that make up a particular interior space [2)].

Using environmentally preferable interior materials is an important issue, to reduce the flow of non-renewable resources into interior materials and pollutants from interior materials throughout life cycle of interior materials[3)]. Therefore, environmentally sustainable interior design implies working toward the promotion of indoor environmental quality by improving indoor air quality and human comfort and the use of sustainable interior materials [1)].

The Environment-friendly internal space is to be defined as the internal space that is constructed with materials that contain the least harmful factors to human being and environment [4)].

The interior material products are classified into 3 kinds; products used in construction of floor, wall and ceiling.

The interior material products which are often used in the construction of floor are tile, polyvinyl chloride sheet, marble, granite and etc, in the construction of wall, paint, dry wall, wallpaper, in the construction of ceiling, paint, metallic material, noninflammable material and etc.

The modern mankind spends the most of time in working space as business space. City-dwellers spend about over 80% of daily life in indoor space such as working space, and such working space is used so often that it is regarded as the second living space. Therefore, to investigate actual using of the materials that contain noxious substances and pollute indoor air, we investigated the interior material products which are used in domestic business space.

Most of interior material product such as chemical paint, adhesive, tile and etc. emit VOCs and formaldehyde. Adhesive agent that emits VOCs and formaldehyde is used in adhesion of Wood manufactured products such as plywood (veneer board), particleboard. In heat isolating material, asbestos is contained. In the case of paint, it is provided to use paints that contain no lead or the least lead. And it is recommended to use natural paints that contain linseed oil instead of petroleum. Instead of plywood, particle board, fiberboard with adhesive agent from formaldehyde, low VOC adhesive, low VOS cement, and low VOC plaster can be used as an alternative. And Lignin from wood can be used. Also, environmental friendly materials such as compressed straw instead of chemical heat isolating materials can be an alternative [5)].

The interior designer who “shops” for materials based on environmental and human health concerns is in this same situation. While there is a tendency in sustainable design to view materials as “green” or not green, this kind of view is usually limited. Should a manufacturer’s claims always be taken at face value? Should a product that uses renewable resources be used if it has to be shipped over a long distance, thereby increasing air pollution?

Life-cycle Assessment LCA is an analytic method that incorporates a wide range of considerations into the decision-making process, making it much more comprehensive than simple single-issue assessment. LCA has been used for many years and offers an exciting tool for designers. It is a young field, however, so both the science itself and the tools available to designers for applying this science are evolving quickly. In addition to selection of materials using LCA, the designer can employ a variety of strategies for mitigating the environmental and health effects of building, including choosing appropriate materials for the specific needs of a space, using various strategies to reduce the amount of materials required, pursuing a design strategy that accounts for the changing needs of occupants, and choosing materials based on their environmental performance at the end of their useful lives.

The designer may also consider how materials are matched to the way a space actually is used. For instance, a harder, more cleanable surface makes sense in an entryway area that is subject to heavy foot traffic and mud, water and detritus from the outdoors. In some cases, a designer may consider combining surfaces for increased sustainability and durability. For example, ceramic tile may have a greater environmental impact than an alternative surface, such as linoleum, and yet tile may be a more durable and cleanable surface for a certain space, such as around a kitchen sink. The designer may consider using the tile only in the specific area where it is needed, and surrounding it with linoleum or another low-impact material.

2. Challenges in Interior Design

The innovative designer in general, when modifying an existing interior space, the designer can attempt to save portions of the existing interior installation, such as walls, ceilings and hard flooring materials, minimize the use of finishing materials, and simply reuse materials, including furniture and furnishings.

2.1 Reducing the use of materials

- Reduce layers in flooring – consider using polished concrete where acoustics are not of concern, or refinishing a residential wood floor rather than covering or replacing it.
- In commercial projects, consider leaving ceilings unfinished in non-critical spaces, rather than installing drywall or acoustical ceiling tile. This strategy can be successfully paired with building design approaches, such as using daylight and access floors.
- Consider incorporating visible portions of the building’s structure into the interior space as design elements, rather than covering them with additional materials.
- Sheet materials, such as drywall and plywood, come in standard sizes, usually 4 x 8 feet or 5 x 10 feet. Design the project dimensions to take advantage of product sizes to reduce material waste.
- Maximize materials conservation through partial reuse of the existing install materials.

2.2 Designing interiors to accommodate future uses

- Design multipurpose spaces that allow for adaptability, both for future uses and for several uses by the same occupants.

- Use modular design to foster adaptability.
- Open space is inherently adaptable; therefore, limit the use of permanent partitions. However, in situations where noise or privacy may be a factor, open space can make a space less usable and increase other costs, so always consider the needs of the client.
- If partitions are used, non-load bearing can be used, modular and semi-permanent partitions so the space can be reconfigured without major construction.
- Using modular or systems furniture, which allows for ongoing reconfiguration of space without major disruption to the permanent interior layout and electrical/mechanical distribution systems.
- Employ a "universal design" approach, in which designing for handicapped accessibility in a residential or corporate space takes the potential future needs of an aging population into account[6)].

3. Examples of common interior products that may contain recycled content

» Drywall

» Ceiling tile

» Insulation

» Carpet and carpet tile

» Resilient flooring

» Metal components

» Furniture

» Fabrics

» Tile

» Wall covering

» Composite wood-based products. Many are made from sawmill waste, a pre-consumer recycled material.

4. Renewable Materials

Rapidly renewable materials, such as bamboo and wool, can replace themselves within a 10-year growing cycle through agriculture or forestry. Products made from rapidly renewable sources are becoming more widely available for many interior applications, offering the environmental benefit of decreasing demands on non-renewable materials.

Reduction of agricultural waste is a further benefit of some renewable materials. Materials, such as wheat straw that might commonly be burned or used as animal bedding, are being used for interior products, saving energy and reducing pollution.

Examples of rapidly renewable resources include:

» Wheatstraw

» Corn stalks

» Polylactide (PLA) (made from corn starch)

» Cork

» Bamboo

» Sunflower seed hulls

» Soybeans

» Wool

» Linen

» Silk

» Ramie

» Linseed oil

» Quick-release vegetable oils

These materials are being used in many ways, including:

» Flooring - cork, bamboo, and linoleum made from linseed oil.

» Fabrics and carpets made from wool or PLA.

» Particleboards and medium-density fiberboards (MDFs) made with wheat straw are used in cabinetry, furniture, millwork, case goods and flooring.

» Biocomposite panels made with soybeans and sunflower seed hulls can be used for interior finish applications, such as paneling, counters and cabinets.

Interior designers need to be particularly aware of urea formaldehyde, a common binder found in interior plywood, particleboard, chipboard and medium-density fiberboard (MDF). Through research, interior designers can find urea-formaldehyde-free composite woods, and specify furniture that complies with the acceptable formaldehyde emissions levels for furniture as established by Green guard [7)].

Increment of logging activities for variety of purposes has resulted in the failing of absorption of carbon dioxide emission by the forest of which large amount of CO_2 are released into the atmosphere trapping the heat within the atmosphere (greenhouse effect) and causing the global warming.

Bamboo as the great potential to be used as solid wood substitute materials, especially in the manufacturing, design, and construction usage. Bamboo properties of being light weight and high-strength, **Figure (1)** shows the Bamboo plantations in China.

Figure (1) Bamboo plantations in China.

Figure (2) shows Bamboo flake board made from bamboo flake.

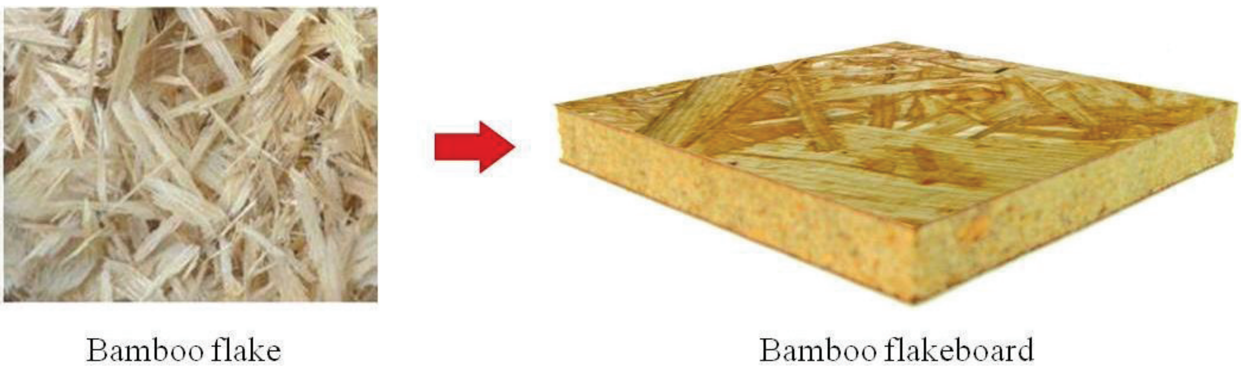

Figure (2) Bamboo flake board made from bamboo flake.

Plywood has been introduced in its application in 1865, since the plywood manufacturing sector began to rapidly developing era, focusing on making buildings and making the walls of the first aircraft using plywood 8). Instead of plywood, plybamboo is now being used for wall paneling, floor tiles; bamboo pulp for paper making, briquettes for fuel 9). Plybamboois a special category in the wide variety of bamboo-based panels. **Figure (3)** shows plybamboo produced from layered of bamboo veneers with certain desired thickness. Thick strips have higher rigidity; they can hardly be deformed to fill up the blank space between strips even under high pressure therefore leads to the formation of lower the Modulus of Rupture (MOR) and adhering strength. Previously, wood is used to make bottom boards over a long period of time. However, plybamboo was now identified new alternative of make bottom boards. This is because plybamboo has high quality and has great length which meets following requirements viz low weight, high rigidity, proper friction coefficient (to keep cargo and passengers from sliding) and doesn't rust. Besides, the manufacturing process of plybamboo was found to have less laborious and consumes fewer adhesive than other types of composites. The strength, wear ability and rigidity of plybamboo are higher than those of ordinary plywood, thus, plybamboo has a wide prospect in automotive, building industries and engineering construction as well [10)].

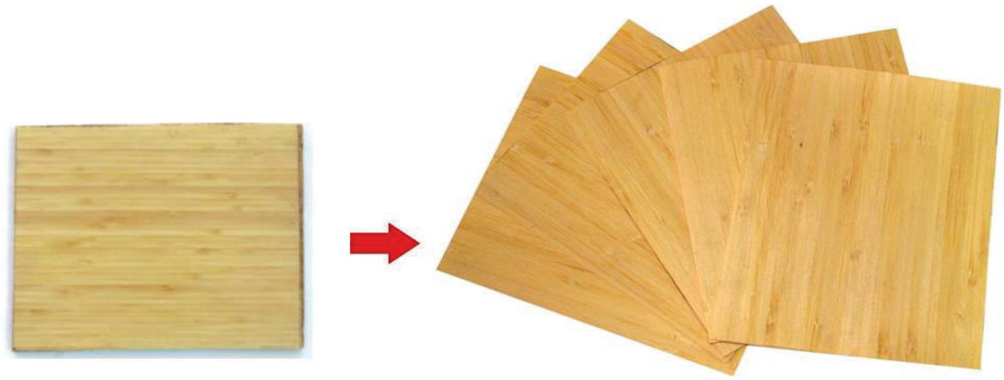

Figure (3) Plybamboo from bamboo veneer.

Mechanical properties of bamboo based laminates need to be investigated thoroughly so that the full potential of bamboo as a functionally graded composite could be utilized. This was to manufacture five types of laminated bamboo flooring (LBF) made from moso bamboo (P. edulis) laminae and investigates their physical (dimensional stability) and mechanical properties (bending properties) by ultrasonic wave techniques and a static bending method.

Hybrid bamboo-glass fibers composites exhibit enhancement in terms of stiffness, strength and moisture resistance properties.

Bamboo biocomposites has excellent impact on creating interior design that has a commercial value of its own way. Biocomposites use in the production of various bamboo products for exterior and interior which have a good demand in the global market. Most users realize the greatness of this material and support the efforts of sustainable for nature in everyday life. This is further enhanced by its excellence as an innovative material to get recognition from various quarters, proving that hybrid bamboo material can overcome other types of materials from various aspects such as physical, mechanical and aesthetic. Nowadays, various types of hybrid bamboo-based products have been produced, from the design of the ceiling, walls, floors, window frames, doors, stairs and up to the home decorative accessories.

Interior design most impact on the industry for interior decoration and architecture is Madrid Barajas International Airport, Spain also it has been recognized the world as a Sustainable Building. Richard Rogers, designer of the world's most prestigious airports that designs consist of 200,000 m^2 ceiling lath gently curved laminated bamboo, the bamboo industry's biggest project in the world. International Airport was built using laminated bamboo laths from all walks of bamboo veneer shown in **Figure (4)**. Richard Rogers has managed to apply the design process in yield designs with the use of materials and finishes that can create a unique passenger experience, exciting and the atmosphere is peaceful and quiet. Although the simplicity of the concept of architectural features terminal, it still gives comfort to passengers. Therefore, interior design use hybrid bamboo could be emulated by other designers in meeting the demands of the 21st century, so that the designs produced will be efficient, economical and functional [11]).

Figure (4) Barajas Madrid International Airport, Spain.

5. Smart materials in interior design

NASA defines smart materials as 'materials that ''remember'' configurations and can conform to them when given a specific stimulus. From the Encyclopedia of Chemical Technology: 'smart materials and structures are those objects that sense environmental events, process that sensory information, and then act on the environment [12]).

The 'discovery' of smart materials is attributed to two chemists (Jacques and Pierre Curie no less!), the disciplines of mechanical engineering and electrical engineering currently split ownership. Mechanical engineers deal with energy stimuli, kinematic (active) behavior and material structure, whereas electrical engineers are responsible for microelectronics (a fundamental component of many smart systems and assemblies), and the operational platform (packaging and circuitry).

5.1 History of Smart Materials

The first recorded observation of smart material transformation was made in 1932 on gold-cadmium. In addition, in 1938 the phase transformation was observed in brass (copper-zinc).

It was not until 1962, however, that Beehler and coworkers found the transformation and attendant shape memory effect in Nickel-Titanium at the Naval Ordinance Laboratory.

They named this family of alloy Nitinol after their lab. A few years after the discovery of Nitinol, a number of other alloy systems with the shape memory effect were found.

Though product development using smart materials began to accelerate after the discovery of Nitinol, many of the smart materials contained expensive and exotic elements.

Only the copper-based alloys came close to challenging the Nitinol family as a commercially attractive system. During the 1980s and early 1990s, a number of companies began to provide Ni-Ti materials and components, and an increasing number of products, especially medical products, were developed to market [13), 14), 15)].

In order to understand the smart materials, we rely on the classification according to the phenomena of exposed materials and produce changes in exploiting the important functions.

5.2 Types of smart materials

Smart materials and systems are divided into two classes [16)]:

1. Materials undergo changes in one or more of their properties (chemical, electrical, magnetic, mechanical, or thermal) in direct response to a change in external stimuli in the surrounding environment. The energy input to a material affects the internal energy of the material by altering the material's microstructure and the input results in a property change of the material.
2. Smart materials that transforms energy from one form to another. The energy input to a material changes the energy state of the material composition, but does not alter the material, it stays the same, but the energy undergoes a change.

Type 1 materials include the following:

- Thermochromics - an input of thermal energy changes the material's color.
- Phototropics - materials that change color when exposed to light.
- Magnetorheological and electrorheological - the application of a magnetic field (or for electro-rheological - an electrical field) causes a change in micro-structural orientation, resulting in a change in viscosity of the fluid.
- Thermotropic - an input of thermal energy (or radiation for a phototropic, electricity for electrotropic and so on) to the material alters its micro-structure through a phase change. In a different phase, most materials demonstrate different properties, including conductivity, transmissivity, volumetric expansion, and solubility.
- Shape memory - an input of thermal energy (which can also be produced through resistance to an electrical current) alters themicrostructure through a crystalline phase change. This change enables multiple shapes in relationship to the environmental stimulus.
- Mechanochromics - materials that change color due to imposed stresses and/or deformations.
- Chemochromics - materials that change color when exposed to specific chemical environments.
- Electrochromics - materials that change color when a voltage is applied. Related technologies include liquid crystals and suspended particle devices that change color or transparencies when electrically activated.
- Phase-changing materials - use chemical bonds to store and release heat.
- Adhesion-changing materials - change the attraction forces of adsorption or absorption of atoms or molecules when exposed to light or electrical field.

■ **Type 2 materials** include the following:

- Light-emitting materials, that convert an input energy to an output of radiation energy in the visible spectrum, are including:
- Photoluminescents (input is radiation energy from the ultraviolet spectrum
- Electroluminescent (input is electrical energy)
- Chemoluminescent (input is chemical reaction)
- Piezoelectrics (an input of elastic energy - strain produces an electrical current. Most piezoelectrics are bi-directional in that the inputs can be switched and an applied electrical current will produce a deformation - strain).
- Thermoelectrics (an input of electrical current creates a temperature differential on opposite sides of the material)
- Photovoltaics (an input of radiation energy from the visible spectrum produces an electrical current
- Electrostrictives (the application of a current produces elastic energy - strain which deforms the shape of the material)
- Magnetostrictives (the application of a magnetic field produces elastic energy – strain

The close connection between materials and architecture has always existed. Smart materials and new technologies, due to the scale of their behavior; have to be chosen for how they perform. Material properties are determined by either molecular structure or microstructure. Any change in a material property, such as what happens in a smart material, can only occur if there is a change in one of the two structures. Change can only occur through the exchange of energy, and that energy must act at the scale of structure that determines the material property. Boundary is the region of energy change between a system and its surroundings. Architects have to understand all material behavior in relation to the phenomena and environments they create. The application of advanced technologies, based on smart materials, has the capacity to significantly improve the sustainability of buildings, by focusing on phenomena and not on the material artifact. We can reduce energy use by discretely acting only where necessary and operate discretely and locally. Then many of the advantages offered by these technologies can be appropriated by a greater diversity of designs for new and retrofitting existing buildings. Energy-exchanging materials have potential application as discrete sources, particularly for lighting delivery systems, and also as secondary energy supply sources.

6. Examples of Smart Materials

6.1 Facade systems - smart windows

□ **Control of solar radiation transmitting** through the building envelope by using spectral absorptive/transmission of envelope materials:

▫ Suspended particle panels

▫ Liquid crystal panels

▫ Photochromics

▫ Electrochromics

□ **Control of conductive heat transfer** through the building envelope by using relative position of envelope materials in louver or panel systems:

▫ Exterior and exterior radiation (light) sensors:

- Photovoltaics,

- Photoelectrics

▫ Controls / actuators:

- Shape memory alloys

-Electrorestrictive

- Magnetorestrictive

□ **Control of interior heat generation by:**

▫ Heat capacity of interior material:

- Phase-change materials

▫ Relative location of heat source:

- Thermoelectrics

▫ Lumen/watt energy conversion:

- Photoluminescents

- Electroluminescents

- Light-emitting diodes

Smart materials are often considered to be a logical extension of the trajectory in materials development toward more selective and specialized performance.

Novel materials for smart windows conceived as affordable multifunctional systems offering enhanced energy control. Windows are critical elements to control the energy performance of a building. There is a need to develop affordable 'smart active windows', defined as multifunctional systems offering multiple properties and functions in one single construction element.

Environmental sustainability of each developed solution should be evaluated via life cycle assessment studies carried out according to the International Reference Life Cycle Data System - ILCD Handbook); be applicable to both new built and to renovation; be applicable to both hot and cold climates; be easy to install; offer realistic solutions at areasonable price; offer adequate luminosity, adequate light transmittance, lighter weight, glare control, increased fixed or variable thermal inertia, increased thermal comfort and noise reduction. Developments should be based on new materials for new window concepts and on the better understanding and improvement of material combinations and synergies. Additional improvements to the 'smart windows' may also be included in the research, such as e.g. the application of OLEDs for lighting, adjustable infrared radiation transmission, or sensor technologies, material analysis and modeling.

Technologies, engineering materials such as aluminum and titanium can now be efficiently and easily employed as building skins, allowing an unprecedented range of building facades and forms. Materials have progressively emerged as providing the most immediately visible and thus most appropriable manifestation of a building's representation, both interior and exterior. As a result, today's architects often think of materials as part of a design palette from which materials can be chosen and applied as compositional and visual surfaces. It is in this spirit that many have approached the use of smart materials. For many centuries one had to accept and work with the properties of a standard material such as wood or stone, designing to accommodate the material's limitations, whereas during the 20th century one could begin to select or engineer the properties of a high performance material to meet a specifically defined need. Smart materials allow even a further specificity – their properties are changeable and thus responsive to transient needs. For example, photochromic materials change their color (the property of spectral transmisivity when exposed to light: the more intense the incident light, the darker the surface. This ability to respond to multiple states rather than being optimized for a single state has rendered smart materials a seductive addition to the design palette since buildings is always confronted with changing conditions. As a result, we are beginning to see many proposals speculating on how smart materials could begin to replace more conventional building materials.

Cost and availability have, on the whole, restricted widespread replacement of conventional building materials with smart materials, but the stages of implementation are tending to follow the model by which 'new' materials have traditionally been introduced into architecture: initially through highly visible showpieces (such as thermochromic chair backs and electrochromic toilet stall doors) and later through high profile 'demonstration' projects.

Whereas standard building materials are static in that they are intended to withstand building forces, smart materials are dynamic in that they behave in response to energy fields.

With a smart material, however, we should be focusing on what we want it do, not on how we want it to look. The understanding of smart materials must then reach back further than simply the understanding of material properties; one must also be cognizant of the fundamental physics and chemistry of the material's interactions with its surrounding environment.

The benefit from smart materials is replacements or substitutes for more conventional materials. For example, there have been many proposals to replace standard curtain wall glazing with an electrochromic glass that would completely wrap the building facade. The reconsideration of smart material implementation through another paradigm of material deployment has yet to fall under scrutiny.

Smart materials have been comprehensively experimented with and rapidly adopted in many other fields – finding their way into products and uses as diverse as toys and automotive components. We can replace Large **HVAC** (heating, ventilating and air conditioning) systems with discretely located micro-machines that respond directly to the heat exchange of a human body. Labels associated with building-size HVAC equipment are now routinely associated with MEMS energy devices – we now have micro-compressors, chillers, heat pumps, turbines, fuel cells and engines. The term micro-electro-mechanical systems (**MEMS**) have come to describe any tiny machine, but the more precise definition is that MEMS is a device that combines sensing, actuating and computing.

6.2 Phase-Changing Materials (PCM)

Phase change processes invariably involve the absorbing, storing or releasing of large amounts of energy in the form of latent heat. A phase change from a solid to a liquid, or liquid to a gas, and vice versa, occurs at precise temperatures. Thus, where energy is absorbed or released can be predicted based on the composition of the material. Phase-changing materials deliberately seek to take advantage of these absorption/release actions.

While most materials undergo phase changes, there are several particular compositions, such as inorganic hydrated salts, that absorb and release large amounts of heat energy. As the material changes from a solid to a liquid state, and then subsequently to a gaseous state, large amounts of energy must be absorbed. When the material reverts from a gaseous to a liquid state, and then to a solid state, large amount of energy will be released. These processes are reversible and phase-changing materials can undergo an unlimited number of cycles without degradation.

Since phase-changing materials can be designed to absorb or release energy at predictable temperatures, they have naturally been explored for use in architecture as a way of helping deal with the thermal environment in a building. One early application was the development of so-called '**phase change wallboard**' which relied on different embedded materials to impart phase change capabilities.

In many climates, radiant floor systems installed in concrete slabs can provide quite comfortable heating, but are subjected to undesired cycling and temperature swings because of the need to keep the temperature of the slab at the desired level, which typically requires a high initial temperature.

Embedding phase-changing materials in the form of encased pellets can help level out these undesirable temperature swings.

7. Smart houses

A "smart home" can be defined as a residence equipped with computing and information technology which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond [12)].

7.1Control systems

A typical system of sensors and actuators that are intended to accomplish specific tasks consists of elements providing a number of different functions:

* Sensors and transducers
* Signal conditioners
* Transmitters/converters/receivers
* Logic controllers
* Displays/recorders/actuators

In the traditional mechatronic (mechanical-electronic) model, several of these functions are provided by individual components that are interconnected and provide an overall desired response. The roles and operations of sensors, transducers and actuators have already been briefly explored.

The output of a sensor that is responding to some energy stimulus may or may not be in a readily usable or interpretable state. Transducers may or may not be needed to change the sensor output signal to some other energy state. The output signal is also usually in need of further conditioning to boost its amplitude, filter out unwanted 'noise' or other reasons. The conditioned signal invariably needs to be transmitted elsewhere so that it can be used directly as an input to something else, which in turn means that it has to be received elsewhere. Transmitting and receiving devices are thus obviously needed.

These processes may again require signal conversion. Actuation devices could then be directly activated. In the enhanced mechatronic model that is more sophisticated, transmitted signals that have been conditioned are first manipulated according to a logical intent and then transmitted to final actuators. Of special interest here are the logic controllers. It is here that the system is ultimately given its directions. A designer might want a motion detector to cause an alarm to go off when movement is detected, or a door to open when motion is sensed. Operations of this type can be done using actual hard-wired circuits that use common electrical devices to perform a series of operations, such as an inexpensive timer circuit where a charge builds up in a capacitor and is then periodically released, which in turn causes some action to occur. Circuits with surprisingly intricate logic capabilities can be built in this way. An advantage of the use of both property-changing and energy-exchanging smart materials within the context of sensor/actuator systems is that many of the actions described occur internally within the materials themselves. In some cases the sensor/actuation cycle is completely internalized. In other cases, additional elements may be required for certain kinds of responses, but the complexity of the system is invariably reduced.

In the door opener or slider example, there might be some type of position sensor or limit switch that detected whether the door was in the open position or that the slider moved 25mm as desired. This information would be fed back into the system and the original state compared to the final state.

7.2 Smart products

For some time smart materials found their primary use in interesting but specialized engineering and scientific applications, or, at the other end of the spectrum, in novelty applications (e.g., the endless numbers of thermochromic coffee cups that change colors when filled). Recently, a whole host of new products have found their way into the market – some interesting, some not – as designers began to 'discover' them.

A phenomenological perspective; As we have seen, most smart materials actually work at the **micro**-scale (smaller than a micron) and are thus not visible to the human eye. Nevertheless, the effects produced by these mechanisms are often at the **meso**-scale (approximately a centimeter) and **macro**-scale (larger than a meter). Whereas the physical mechanism – how the material works – is entirely dependent upon the material composition; the phenomenological effects – the results produced by the action of the material – are determined by many things independent of the material composition – including quantity, assembly construction, position and environment. As a result, very similar effects can often be produced from seemingly dissimilar materials.

We can categorize these effects in terms of their arena of action, which could be considered as analogous to an architect's intention – what do we want the material to do?

The smart materials that we use can produce direct effects on the energy environments (luminous, thermal and acoustic), or they can produce indirect effects on systems (energy generation, mechanical equipment). The following categories broadly organize smart materials according to their effects that are of direct interest to designers. Note that some materials can be deployed to have multiple effects depending on the energy input.

7.3Thermal environment; Heat transfer

The conventional means for adding heat or removing heat from an interior space is through a process known as dilution – air at a particular enthalpy is mixed in with the room air to 'dilute' it to the desired conditions. This is an extraordinarily inefficient process and it involves several levels of heat exchange.

7.4 Smart paints and coatings

Painting and coatings are ancient techniques for changing or improving the characteristics or performance of a material.

The development of smart paints and coatings gives these old approaches new capabilities. Smart paints and coatings can be generally classified into

(a) high-performance materials,

(b) property-changing materials and

(c) energy-exchanging materials.

The pigments may be insoluble or soluble finely dispersed particles, the binder forms surface films. The liquid may be volatile or nonvolatile, but does not normally become part of the dried material. Coatings are a more generic term than paints and refer to a thicker layer. Many coatings are nonvolatile.

These paints or coatings absorb energy from light, chemical or thermal sources and reemit photons to cause fluorescence, phosphorescence or afterglow lighting.

In these smart piezoelectric paints, piezoelectric ceramic particles made of PZT (lead ziconate titanate) or barium titanate (BaTIO3) are frequently used. They are dispersed in an epoxy, acrylic, or alkyd base.

7.5 Glasses

Electro-optical glass is a good example of a successful application of thin film technology in a design context. Glass is well known for use as an electrical insulator. As a dielectric material, it inherently does not conduct electricity. This very property that is so advantageous for many applications, however, becomes problematic for other applications – especially in this world of flat panel displays and other technologies that could seemingly effectively use glass for other purposes than as simply a covering material.

Electro-optical glass has been developed with these new needs in mind. Electro-optical glass consists of a glass substrate that has been covered – via a chemical deposition process – by a thin and transparent coating of an electrically conductive material. The most frequently used product uses a chemical vapor deposition system to apply a thin coating of tin oxide to a glass substrate. The chemical deposition process yields a coating that is extremely thin and visually transparent, but which is still electrically conductive.

In **architecture**, this technology can be used to create 'heated glasses'. Strip connectors are applied to either edge of a glass sheet and a voltage applied. The thin conductive deposition layer essentially becomes a resistor that heats up. The whole glass sheet can become warm. The potential uses of heat glass of this type in architecture are obvious. Difficulties include finding ways to distribute the current uniformly over the surface.

7.5.1Dichroic glass

A dichroic material exhibits color changes to the viewer as a function of either the angle of incident light or the angle of the viewer. The varying color changes can be very striking and unexpected. Similar visual effects have long been seen in the iridescent wings of dragonflies and in certain bird feathers; or in oil films on water surfaces. Recent innovations in thin layer deposition techniques have been employed to produce coatings on glasses to exhibit dichroic characteristics.

In dichroic glass, certain color wavelengths – those seen as a reflection to the viewer – are reflected away while others are absorbed and seen as transmitted light. The colors perceived change with light direction and view angle.

The dichroic (originally referring to two-color) effect has been technically understood for many years. In new dichroic glass, a glass substrate is coated with multiple layers of very thin transparent metal oxide coatings, each with different optical properties.

Figure (5) 'Diochroic Light Field' – an installation by James Carpenter, New York

When light impinges upon or is passed through these layers, various complex optical effects occur. Fundamentally, reflections are created when light passing through a layer of one optical index of refraction meets a layer with a different optical index of refraction. When multiple transparent layers are present, different reflection directions can develop at different material change points.

7.6 Polymer dispersed liquid crystal devices in smart windows

There are several classes of electro-optic devices that can be formed using liquid crystals, but only two classes: guest-host systems and polymer dispersed liquid crystals (PDLC) are used in smart windows. In guest-host type of device dichroic dye molecules mixed with liquid crystals are used with the aim of achieving higher absorption. In the colesteric - nematic structure the direction of the long axis of the molecules is slightly displaced with the liquid crystals displaying a different alignment. The advantage of those systems is their functionality up to 1000°C.

The most promising solution is presented by micro-encapsulation polymer dispersed liquid crystals (PDLC). The principal liquid crystal devices are known under the name **"Privacy Film.**" This device consists of a PDLC film sandwiched between ITO-coated sheets of glass, as illustrated in **Figure (6**). The PDLC film consists of spherical liquid crystal droplets embedded in a polymer matrix. The typical droplet diameter is about 1μm or less, of the same order of magnitude as light wavelengths.

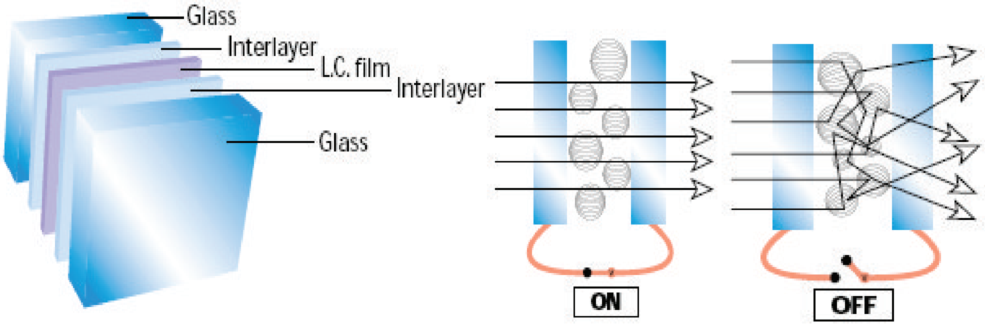

Figure (6). Components and functioning of liquid crystal devices (http://www. Saint Gobain.com)

When a voltage is applied to the ITO electrodes, the liquid crystal molecules are oriented in the field direction, resulting in index matching between the droplets and the matrix, and thus high transmittance for light propagating parallel to the applied field. When the field is switched off, the liquid crystal molecules reorient randomly; the (unmatched) value of the extraordinary refractive index also becomes effective and causes scattering at the droplet surfaces, and the film appears milky.

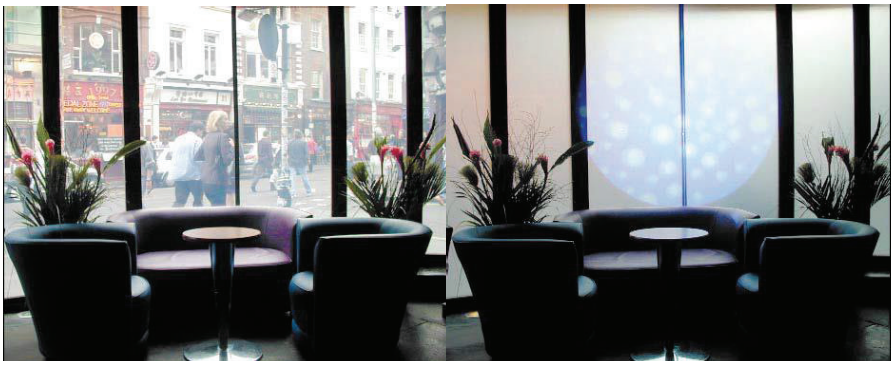

Figure (7) Liquid crystal device makes the room private or public at will. (http://www. Saint Gobain.com)

Although PDLC devices act very effectively as privacy screens and have essentially zero specular transmittance in the zero voltage state and good transmittance but some diffuse scattering in the "on" state, the devices are not particularly effective for energy conservation because the majority of the scattered radiation is forward scattered. So liquid crystal is used for discretionary projects, particularly high end residences and interior partitions where privacy and ample light are more important than energy.

7.7Phase-changing pellets

These products are targeted for architectural applications. The storing and releasing of large amounts of energy via the phase change effect makes their potential use in helping control and maintain thermal environments in a building very attractive. There have been a number of experiments in trying to find an effective way of incorporating phase change capabilities into common building products, including experiments with wallboard products. The problem of containing and distributing the materials has always been problematic. An interesting current approach uses relatively large encapsulated pellets. These pellets can be placed in common floors or walls. They are particularly useful in connection with radiant floor heating approaches. Common techniques of burying hot water pipes into concrete floors can be problematic due to the time-lag problems associated with heat storage and release in concrete. Concrete is slow to heat up and slow to cool down, with the consequence that heat is often being released at the wrong time. Encapsulated phase changing pellets can respond in a much more timely way and can be incorporated in a light framing system. The positive attributes of radiant floor heating can be achieved without many of the problems associated with heavy mass systems. They are used in radiant heating floor systems [16)].

Figure (8) pellets contain encapsulated Phase-changing materials

8. Conclusions

Recently, architectural materials consist of several of complicated compounds and contain much hazardous articles. Especially, new interior material products have bad influence on human body, also decline amenity.

Though we are exposed to various indoor pollutants, the recognition is low and there is still no appropriate standard for using architectural material and interior material.

The followings are expected through this study;

Constructing the informational system about hazardous substances of interior material products, it can be used as the standard of selection for appropriate architectural materials. By constructing such information, it can be expected to be used as standard for architects and designer. Smart materials in addition to the importance of environmentally but economically also have an important role. Using recyclable materials also plays an important role in reducing the losses in material sourcing.

Note for us to use new sources of materials including bamboo, such as agricultural development has an important role in the renewal of the architectural designs and optimal exploitation of the material, especially in the exploitation even remnants manufacturing materials as in the design of the Madrid International Airport in Spain.

Smart materials through their behavior and their properties have a significant role in the smart home is economic and environmental best. The application of advanced technologies, based on smart materials, has the capacity to significantly improve the sustainability of buildings.

So the development of smart materials reflected on the existing sensors and smart actuators for the home and saving of energy in order to reach the standard of the situation or optimized for energy saving in addition to the comfort and convenience for residents. The greatest with smart materials in interior design (Color-changing materials that respond to light, temperature, mechanical strain, or electric voltages).

References

[1] Mihyun Kang, Denise A. Guerin, (2009), "The State of Environmentally Sustainable Interior Design Practice", American Journal of Environmental Sciences 5 (2), pp.179-186.

[2]Pile, J.F.,(2003), "Interior Design", 3rd Edn., Prentice Hall, Englewood Cliffs, New Jersey, ISBN: 10:0130991325.

[3] Kim, J. , B. Rigdon,(1998), "Sustainable architecture module: Introduction to sustainable design" Ann Arbor, MI: National Pollution Prevention Center for Higher Education.

[4] Seungmo Kang, Ja in Kwon, (2001), "A semantic study on Environment-friendly of interior architecture materials", Korea institute of interior design.

[5] Kwang-woo Kim, (1995), "Technology of global environment and building environment" Architectural

Institute of Korea.

[6] www.greenguard.org

[7] Tristan Roberts,(2006), “Materials and Products Interior Design and Global Impacts”, Allyson Wendt, Building Green, Inc., American Society of Interior Designers.

[8] Sen, H. N. T, & Reddy, J. Application of Sisal, (2011), “Bamboo, Coir and Jute Natural Composites in Structural Up gradation”, International Journal of Innovation, Management and Technology, 2(3), 186-91.

[9] Makinejad, M. D, Salit, M. S, Ahmad, D, Ali, A, &Abdan, K. (2009), “A Review of Natural Fibre Composites in Automotive Industry”, Research on Natural Fibre Reinforced Polymer Composites.

[10] Mahdavi, M, Clouston, P. L, Arwade, S. R, & Low-technology, (2012), “A Approach Toward Fabrication of Laminated Bamboo Lumber”. Construction and Building Materials, 29(0), 257-62.

[11] S. SitiSuhaily, H.P.S. Abdul Khalil, W.O. Wan Nadirah, M. Jawaid, (2013), “Bamboo Based BiocompositesMaterial,Design and Applications”, Suhaily et al.; licensee InTech.

[12] Richard Harper, (2003), “Inside the Smart Home”, Springer-Verlag London Limited.

[13]Hodgson, D.E., and Brown, J.W. (2000), “Using Nitinol Alloys” Report of Shape Memory Applications Inc.

[14] Maji, A.K., and Negret, I., (1998), “Smart Prestressing with Shape-memory Alloy” Journal of Engineering Mechanics, Vol.124, No.10, pp.1121-1128.

[15] DesRoches, R., (2002), “Application of Shape Memory Alloys inSeismic Rehabilitation of Bridges,” Technical Report NCHRP-IDEA project 65.

[16] D. Michelle Addington Daniel L.Schodek, (2005), “Smart Materials and New Technologies for the architecture and design professions”, Harvard University.

[17]Mihyun Kang, Denise A. Guerin, (2009), “The State of Environmentally Sustainable Interior Design Practice”, American Journal of Environmental Sciences 5 (2): 179-186.

[18] www.csm.linst.ac.uk

[19] Sherif M.S. Elattar, (2013), “Smart structures and material technologies in architecture applications”, academic Journals, Vol. 8(31), pp. 1512-1521.