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**A SURVEY OF SMART MATERIALS IN NEW ARCHITECTURE AND ITS  
EFFECTS ON INCREASING EFFICIENCY OF BUILDING**

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**ABSTRACT**

Buildings and their life are changed considerably in the past two decades. By development of materials, products and innovative construction methods, buildings are chosen with high efficiency and better costs and better adaptation with environment. Smart buildings can adapt themselves with various conditions. Somatization in our country is mostly about electric and mechanic utilities as smart lighting but intelligentization in building includes a wide range. This study deals with smart materials as a part of this issue. At first, smart materials are introduced, defined and later smart façade and smart energy systems are investigated. Finally, a solution is expressed for better use of these two systems in building and eliminating probable problems and disadvantages.

**Keywords: Smart materials, Architecture, Smart materials with the features of properties change, Smart materials with energy exchange properties, Smart façade systems, and Smart energy systems**

**INTRODUCTION**

Prediction and forecast have always been considered by engineers and researchers producing the tools to use them in future. Buildings are in varied environments. Spaces have users or they are empty. The air temperature is changing continuously.

The light in environments is varied based on different times of day and various days of year. However, buildings have fixed features. If building is designed for low-light conditions, the spaces will be highly bright in highly bright spaces. If the

windows are designed as highest thermal energy is absorbed, it is suitable at cold seasons but in hot seasons, environment temperature is increased and cooling systems should work strongly and their depreciation is increased and energy consumption is also increased.

If we design the buildings to be adapted with the surrounding environments, some of existing problems in buildings are solved. Here, intelligentization in buildings is raised. Intelligent buildings are sensitive to the environmental changes and can react to the change of conditions.

Intelligentization is raised in our country for a while and it is discussed in academic environments. In some buildings, smart systems are used as lighting systems sensitive to the presence as people enter the environment, lighting system is active and energy consumption is saved. If we discuss about intelligentization in building, discussions are restricted to utilities as mechanic and electric utilities as cooling and heat systems and lighting systems as presence sensors.

The application of intelligentization in construction industry is not only restricted to these cases and they are only a small part of applications of smart systems in building. Intelligentization of building includes various sectors as smart materials, smart façade, smart lighting systems, smart

energy systems and even smart constructs, etc. Based on the extension of this discussion, this study deals with smart materials and smart façade systems.

### **1 Definition of somatization and smart materials**

Tristan desireStark as one of the members of Robotic architecture and design of smart buildings in 2003 defined smart architecture as: A type of architecture including changes in form to react continuously to environmental conditions”.

The term “smart materials” is used freely without defining it exactly that what it is. It is difficult to give an exact definition. This word is used widely but there is no general agreement about its real meaning. A simple review of literature shows that some terms as “intelligent and Smart” are used interchangeably by many to systems and materials, but sometimes, exact differences of quality and facilities are shown. NASA defines smart materials as” Materials that remember configurations and can conform to them when given a specific stimulus, a definition that gives an indication as to how NASA intends to investigate and apply them. A more complete definition comes 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.

Interestingly, these definitions are suggestive of the qualities of many of the smart materials that are of interest to us. Common uses of the term smart materials do indeed suggest materials that have quick response capabilities.

Does smartness require special materials and advanced technologies? Most probably no, as there is nothing a smart material can do that a conventional system can't. A photochromic window that changes its transparency in relation to the amount of solar radiation could be replaced by a thermometer in a feedback control loop sending signals to a motor that through mechanical linkages repositions louvers on the surface of the glazing, thus changing the transparency. Hardly, yes, but possible to achieve with commonly used technology and materials. (Indeed, many buildings currently use such a system.) So perhaps the most unique aspects of these materials and technologies are the underlying concepts that can be collected from their behavior.

Whether a molecule, a material, a composite, an assembly, or a system, smart materials and technologies will show the following characteristics:

- Immediacy: they respond in real-time.
- Transiency: they respond to more than one environmental state.

- Self-actuation: intelligence is internal rather than external to the 'material'.

- Selectivity: their response is discrete and predictable.

- Directness: the response is local to the activating event.

## 2- The properties and different types of smart materials

Smart materials have unique properties and they can be used in buildings more effectively than conventional materials. The materials are classified based on these properties and functions.

The properties of smart materials can potentially be used for optimization of properties of materials for transient conditions and optimization of specific behaviors to maintain static conditions in an environment. The energy fields include potential, electric, thermal, mechanic, chemical, nuclear and kinetic and based on first law of thermodynamic can be converted to each other.

The physical properties of smart materials are determined by these energy fields and mechanisms by which this input energy to materials is converted to energy. If this mechanism affects internal energy of matter via changing molecular structure or microstructure, it changes the material properties. If the mechanism changes the energy state of the material, but does not alter the material, then the input results in

an exchange of energy from one form to another.

A simple way of differentiating between the two mechanisms is that for the property change type, the material absorbs the input energy and undergoes a change, whereas for the energy exchange type, the material stays the same but the energy undergoes a change. We consider both of these changes to operate at molecular and atom scales.

To distinguish the descriptions, we can differentiate between smart materials groups as Type 1, Type 2 as discussed:

Type 1: The materials changing their properties in response to the change in environment conditions without requiring external stimulus.

Type 2: The materials are comprised of those that transform energy from one form to an output energy in another form.

### 2-1 Smart materials with properties change

These smart materials are divided into five as thermo chromic, phase change materials, liquid crystal technology, suspending particles display and other types. Briefly, some of them are explained here:

Briefly, smart materials with properties change include:

- Thermo chromic: an input of thermal energy (heat) to the material alters its molecular structure. The new molecular structure has a different reflectivity than

does the original structure; as a result, the material's color – its reflected radiation in the visible range of the electromagnetic spectrum – changes.

- Magneto rheological: the use 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.

- Thermo tropic: an input of thermal energy (or radiation for a phototropic, electricity for electro tropic 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 the microstructure through a crystalline phase change. This change enables multiple shapes in relationship to the environmental stimulus.

### 2-2 Smart materials with energy exchanging properties

Energy-environments-fields have surrounded all materials. If energy state of definite materials is balanced with surrounding environment energy, the materials are balanced and there is no energy exchange. If materials are in various stated of energy, a potential situation is

created leading to energy exchange. All materials of energy exchange deal with energy layers of atoms and input energy is increased and output energy of surface is returned to the first level. For example, if sun ray goes to photovoltaic materials, photons energy is absorbed or exactly, they are absorbed by materials atoms. As energy should be stored, extra energy in atom obliges the atom to move to high level of energy. As this level is unstable, an amount of extra energy is released. By semi-conductive and photovoltaic materials, they can transform this extra energy to electricity. It should be considered that all conventional materials should store energy as well. When extra energy is entered, energy level of matter is increased and in most materials, this input energy increases internal energy of materials and it leads to increase of temperature.

Most of energy exchanging materials can exchange input and output energy as bidirectional. The following list briefly summarizes some of the more common energy-exchanging smart materials.

- Photovoltaic: an input of radiation energy from the visible spectrum (or the infrared spectrum for a thermo-photovoltaic) produces an electrical current (the term voltaic refers more to the material which must be able to provide the voltage potential to keep the current).

- Thermoelectric: an input of electrical current creates a temperature differential on opposite sides of the material. This temperature differential produces a heat engine, essentially a heat pump, allowing thermal energy to be transferred from one junction to the other.

- Piezoelectric – an input of elastic energy (strain) produces an electrical current.

- Photo luminescent: an input of radiation energy from the ultraviolet spectrum (or electrical energy for an electroluminescent, chemical reaction for a chemo luminescent) is converted to an output of radiation energy in the visible spectrum.

- Electrostrictive: the application of a current (or a magnetic field for a magnetostrictive) alters the inter-atomic distance through polarization. A change in this distance changes the energy of the molecule, which produces elastic energy. This strain deforms or changes the shape of the material.

### **3- Systems, assemblies and intelligent components**

In the past section, classification of smart materials is defined. Now, we enter them into building technology. They should be in architecture environments and be in its own place. The materials and technologies in structure of building in foundation or electric system resist against change compared to products applied in decoration

of building and smart materials have attacked the unimportant components of building.

The following table shows a set of smart materials and relevant properties regarding architecture. The important point in this Table is as most of these materials are used as sensors. They play important role in building systems. Even the most ordinary ventilation systems need exact determination of various environmental variables as temperature and relative humidity. The most observed type of smart materials is in windows and facades. The architects are involved mostly in this

domain. Lighting system has the highest effect on users of building. Considerable development is occurred in this field and intelligence of architects is not influenced. Energy systems are most important components as consideration to environment is increased.

One of the most interesting and tangible applications of smart materials in building is supervision and control of construct systems. Smart materials have long history in this application.

This section has a brief reference to façade and energy and the composition of these two are investigated finally.

**Table 1: building system regarding smart materials(Addington, 2005)**

Smart materials	Relevant material or system characteristics	Building system needs
Suspended particle panels, liquid crystal panels, photochromic, electrochromics	Spectral absorptivity , transmission of envelope materials	Control of solar radiation transmitting through the building envelope
Louver or panel systems, exterior and exterior radiation sensors, photovoltaics, photoelectric, controls, actuators, shape memory alloys, electron and magneto restrictive	Relative position of envelope materials	
Thermo tropics, phase change materials	Thermal conductivity of envelope materials	Control of conductive heat transfer through the building envelope
Phase change materials	Thermal capacity of interior materials	Control of interior heat
Thermoelectric	Location of heat source	
Photoluminescents Electroluminescent Light emitting diodes	Saving and optic energy consumption	
Photovoltaics, Meso energy systems (thermoelectric)	Conversion of ambient energy to electrical energy	Energy delivery
Photovoltaic, photoelectric, pyro electrics	Day light sensing IL luminance measurements Occupancy sensing	Optimization of lighting systems
Light emitting diodes (LEDs) Electroluminescent	Size, location and color of source	
Thermoelectric, pyroelectrics, biosensors, chemical sensors.	Temperature sensing Humidity sensing Occupancy sensing CO2 and chemical detection	Optimization of HVAC
Thermoelectric, phase change materials, heat pipes	Source location	
Fiber optics, piezoelectricelectrohelogicalsmagnetorhelogicals,Shape memory alloys	Stress and deformation monitoring Crack monitoring Stress and deformation control Vibration control and monitoring	Control of structural systems

### 3-1 Façade systems

Façade systems namely glass types are unsolved problems for designers. Façade

acts as mutual for energy exchange. Heat is transferred to outside until it radiates inside and light into the building should be

balanced with exterior view. Glass cutting was not emerged before 20<sup>th</sup> century and to use transparent and light facades, ventilation systems should be developed.



Figure 1- 216 two-color edge of façade (Eddington, 2005)

Smart materials are excellent for ideal technology to provide a façade. They also can be simple. Mike Davies popularized the term ‘polyvalent wall’ consisting of fine film with various layers of electro chromic, photovoltaic, conductive glasses, thermal radiation, etc and was used for final model. As windows and façade are visual components of a building, initial consideration of architects is on it. As it is expected, many innovations are performed.

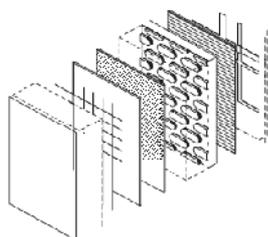


Figure 2- Schematic view of polyvalent wall (Addington, 2005)

#### ➤ Smart windows

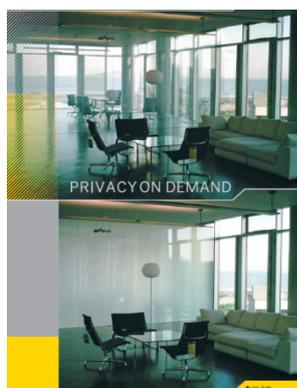
The term smart window is used for each system indicating a varied interaction or system ignoring that this surface is real,

window or virtual, interior or exterior. Here, virtual windows are in big screens and we focus on exterior glasses and interior separators.

Smart windows have one or more of following performances:

- Light pass control: A shift in transparency (optical density) of materials to manage solar radiation namely in visible spectrum close to ultraviolet wavelength. The window can have high density (opaque or semi-transparent) to avoid direct sunlight or low density (transparent) for low light.
- Heat pass control: This is a simile performance but its wavelengths are about infrared area of spectrum. Heat can be minimized via radiation at summer and it reaches the highest amount under other conditions.
- Heat absorption control: Transparency and conductivity are dependent on each other but are independent form radiation. If the interior temperature is higher than exterior temperature, bidirectional heath is created: Radiation energy is transferred to inside until heat energy is transmitted to outside. The change of glass surface absorption can affect specific conductivity and balance is transferred to one or another direction.
- View control: Using changing materials for view control is one of the most developed applications of smart

materials in building. The interior planes ranging from transparent to opaque as passing light but view is adjusted. For example, in front of stores as goods are shown as selective as when the store is open.



**Figure 3-** Using glasses with suspended particles technology for view control

Based on the result, the designer can select one of the diverse types as explained before. The most important difference between materials as actuated with electricity or those actuated by environment.

In the late 80s of 20<sup>th</sup> century, architects thought about smart windows and they attempted to build the glass materials responding directly to environment changes. Photo chromatic materials were developed to be used in glasses. They believed that not only this feature balanced day light, it avoided high light.

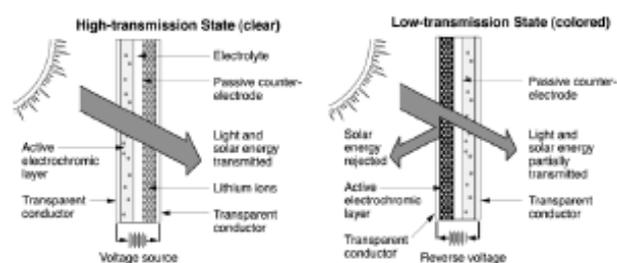
Thermo chromic materials are effective mostly on heat but they sacrifice visible light control. As heat is an input energy, thochromic transparency acts mostly in the area close to infrared region of solar

spectrum. The changing point is based on interior temperature and if radiation temperature is increased, via solar radiation or high temperature of environment outside radiation, instead of transmission, it is reflected mostly. The barrier that thermo chromic materials should overcome is low capability of transferring visible part of spectrum as 27-35%. The first aim of façade transparent surface is view and avoiding light is its secondary section and thermochromics are less developed in smart windows.

The response of thermo tropics to environment is similar to that of thermochromics and the difference is its interior structure as giving high performance to thermo chromic. As thermochromics are changed from guidance to reflection, thermo tropics are changed in reflection and the result is providing diffused light and even despite reduction of view, as electro chromic glass systems are not available economically, in most of performances can be used namely in ceiling as light is much more importance than view.

Indeed, the disadvantage of all these three technologies responding to the environment is their inability to start or stop transmission. As it was said, in most of conditions environment response . Environment response conditions are not

consistent with interior needs. Light, view and heat should pass glass facades and optimization of conditions for one of them is impossible and it is a good response for other conditions. As a result, much development is created for different types of chromic materials as actuated by electricity. All of them allow the user to control the behaviors. This control is difficult as the technologies actuated with electricity need complex support infrastructure. Electric force should be provided for each glass sector and planes and hardware should be designed and installed to guaranty specific operation. In addition, for full achievement of potential advantages of system to turn on and turn off, they need logical additional sensors. For example, a conventional scenario is using light sensors to optimize balance between artificial and naturel light. Next generation of control system-sensor for façade thermal load and determining balance between light and heat is by allowing the increase of artificial light, if other economic selections say that light transfer should be reduced to avoid thermal energy receiving and optimize the conditions. The glass surface as activated by electricity can give profit rapidly only in a decade and is used as the most visible index for smart materials in buildings.



**Figure 4- Diagram of function of electro chromic glasses**

The three types of chromic as actuated by electricity need external stimulus and the main difference between them is due to light transmission as dispersed, absorbed or reflected. Electrochromics are the first technologies as considered by producers of façade and glass. Four-layer structure of electrodes and conductors as electrochromics can be extended from a heavy system as damaged easily to a thin film on a standard glass surface. The need to maximum passing with minimum receiving heat developed electrochromics and high initial severity against short source waves and low severity have high wavelength in the region and the glass is inclined to blue as electrochromics can have spectrum change. There are materials that are used mostly in façade for the reason of passing spectrum and view from white to colored ones.



**Figure 5- A view of interior and exterior of electro chromic windows and its spectrum performance**

Liquid crystal glasses apply great developments in liquid crystals. As liquid crystals is primary chromatic technology as used in screens. They have received much attention for their development in great exterior surfaces. Despite development of electrochromics as ranging from desire to application in building façade, liquid crystal glasses are tested and filtered. This issue is considered regarding durability, maintenance, installation and packaging and is solved. The architects are obliged to use it. Despite these benefits, these liquid crystals have great disadvantages, first when they are changed from white to colored, passing energy is not changed and is only dispersed. If we remember that the primary reason for colors is reduction of unwanted infrared, liquid crystals are hardly satisfactory. Despite electrochromics needing force only in phase change, liquid crystals need continuous force in transparent case and linear regulation of crystals as transparent can reduce oblique angles. Despite these disadvantages, liquid crystals are used mostly in required projects namely in costly houses and interior separators in which domain and light were more important than energy.



Figure 6- Experience of design-Wall is changed with temperature change (Addington, 2005).

Suspended particles equipment is an alternative for liquid crystals for separating applications. With similar disadvantages, they are not effective on reduction of infrared transmission and they need continuous force to remain transparent. Their main advantage compared to liquid crystals is their ability to have view of oblique angles.

The problem of all chromic activated with electricity is providing electricity. Despite actuated chromic via environment, actuated chromic by electricity are turned on and off mostly. Although great tests are performed to determine the number of cycles before great loss is occurred in terms of optical properties, they are not studied really. In addition to normal application, transparent surfaces are exposed to climatic conditions and windows should be washed. It seems that actuated chromic of environment have high durability but we should consider that their chemical properties are less stable and fixed. Electric function is also important as

we should consider that voltage should be provided. As electrochromics need force only in phase change and doesn't need any force to state in a phase, this force can be provided by battery. Liquid crystals and suspended particles need continuous force to stay at transparent phase. Thus, they need an electric infrastructure to provide electricity. Continuous force rejects any saving of energy.

The following Table, shows a summary of important features of design of different

chromic. The first question is what is the result inside? Do we want reduction of infrared radiation passing without losing view? Does we avoid view but we want light? Is control of dazzling light important? If privatization with providing maximum light is possible, liquid crystals are the best choice. If minimum thermal energy is received, thermo tropics are the best choice.

Table 2- Comparison of features of smart windows (Addington, 2005)

Smart windows					
Input energy	Internal thermal result	Internal visual result	Mirror response	Type of system	
Ultraviolet	Reduced passing light	Reduced severity but remaining transparent	Mirror-to mirror Passing at above ultraviolet	Photochromic	
Heat (high temperature of surface)	Reduced passing light	Reduced severity but remaining transparent	Mirror-to mirror Passing at above ultraviolet	Thermo chromic	
Heat (high or low temperature of surface)	Reduced radiation, dispersed radiation and conductivity	Reduced severity view, and dispersion	Mirror to dispersed Passing at high and low temperatures	Thermo tropic	
Voltage or pulse	Relative reduction of radiation pass	Reduced severity	Mirror to mirror Radiation passing with short wave	Electro chromic	
Voltage	Minimum compression in radiation	Minimum reduction in severity, reduced view and dispersion	Mirror to dispersed passing	Liquid crystals	
Current	Minimum compression in radiation	Reduction of view severity and dispersion	Mirror to dispersed passing	Suspended particles	

### 2-3 Energy systems

Three types of energy are required in building: Mechanic, thermal and electric. Thermal energy is used for cooling, heating the space, heating water and cooking. Mechanic energy is used for fans, engines, compressors, pumps and other equipment. Electric energy is used directly for lighting and additional equipment as TV, computer.

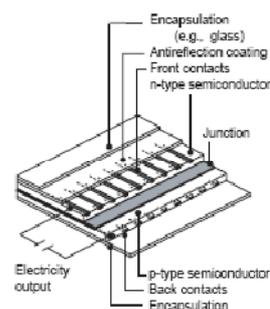
These needs exist but providing source for them can be of different types of energy. There is no logical reason that mechanic energy of building is provided directly in building. Electric energy as smaller need is turned into one of the energy providers in building as the only source for mechanic tools. Thus, 2/3 of energy is provided via electric and almost 2/3 of electricity of US

is due to buildings. Reduction of electricity consumption in building is one of the main goals of reduction of greenhouse gas.

Indeed, development and investment in systems reducing electricity is logical and unique energy transfer features can make most of their smart materials for construction as ideal. No major studies have been conducted in this field. It is mostly regarding replacing electricity energy and fossil fuels with photovoltaic instead of searching new methods reducing energy consumption.

#### ➤ photovoltaic

The origin of photovoltaic is NASA about two decades ago in which facilities of big size photovoltaic generations were built. High cost and low efficiency avoided the extension of using photovoltaic and at first instead of electricity generation were used to generate steam by solar energy. At the same time, photovoltaic cells were replaced by batteries in calculators and clocks. Also, photovoltaic were used to provide electricity of MOder in remote areas and until electricity industry was dependent on state, it was not used as a network of houses. Energy department of US encouraged people to use this network via discount in tax in 1997. The term building – integrated photovoltaic (BIPV) is a part of dictionary of architects.



**Figure 7- Schematic plan of a photovoltaic cell (Addington, 2005)**

A photovoltaic cell produces 2 watts and the cell is connected in some rows and unit is formed and by connection of units, arrays are formed. The connection of series is required to increase operating voltage but is vulnerable to weak connections.

Self-sufficient systems store generated energy in battery and system balance is called suitable adjustment of photovoltaic with suitability.

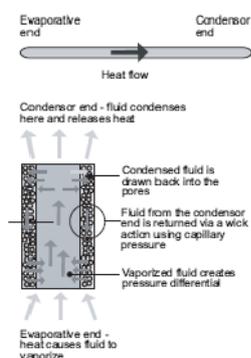
The increase of efficiency of single cells has received much attention. Efficiency is increased as ranging 8% for thin films to 18% for abstract silicon crystals. As solar energy is high, low efficiency shouldn't seem an important issue except cost but according to "energy", energy loss leads to heat generation due to efficiency. The calculation of efficiency shows that a part of it is reflected and it doesn't generate heat but 40-45% of solar radiation is converted to heat in a unit. Photovoltaic are sensitive to heat and increase of temperature decreases efficiency and it also increases temperature. Silicon-based cells are sensitive to heat and their efficiency is at

temperature  $0-8^{\circ}\text{C}$  and their efficiency is half at room temperature.

Ignoring the type of cells, they are sensitive in a common aspect, pollution and orientation. The damage due to pollution is ranging 5-10% in a year. Optimal deviation angle is  $90^{\circ}$  to latitude of site and azimuth optimal angle from south to west is ranging as load production is high or not. The application of Photovoltaic is a challenging issue for architects. Depending on the fact that they are connected as thin films on glass surface to be installed on ceiling, we should ask how building establishment can have highest efficiency and we need participation with electricity and energy engineers to get the best answer of development.

#### ➤ Micro meso systems of energy

These new systems try to have direct relationship with heat system of building as heating or cooling of building instead of providing the tools. These studies started from electric cooling and development of miniature batteries.



**Figure 8- Thermal pipe. This equipment is used to transfer heat from a location to another one (Addington, 2005).**

Primary researches were mostly regarding movement of HVAC big systems with macro and meso technologies. Some researchers design thermoelectric with placing beside each other to design a system with low dimensions as replaced directly with thermal pump of building. Another group selected other ways and they placed meso scale thermochromics as micro dimension films and their idea was interesting. They produced sheets of thermal pumps as being installed in the room as wallpapers. The researchers found that conventional HVAC systems were despite the rule and the small equipment can be used effectively. If they are directly installed on thermal management, they can do indirectly via surrounding environment. However, they are not available in building consumption and affect our thermal environment.

#### 4- Combination of façade systems and energy systems

As it was said, photochromic, thermochromics and thermo tropics are good materials for façade, they have a major problem as the start and end of their change are not controlled. Always, external and internal needs are consistent in a building. Assume that to control input energy to a building, photochromic glasses are used and these glasses get dark in sunlight. Assume that we need the view at

the same time, as something is occurred outside and we should see.

In smart materials as actuated electricity, electrochromics, suspending particles and liquid crystal, this problem is eliminated and changes can be controlled. These smart materials have a major disadvantage and it is their need to electricity. Thus, we need complex infrastructures as should be provided and they are not suitable in terms of energy consumption namely if they are used to control heat energy from sun for saving energy consumption and required electricity of these systems can reject any saving in energy consumption. Thus, they need complex infrastructure as provided and in addition, they are not suitable in terms of energy consumption namely if the aim of using them is control of thermal energy control of sun to save energy consumption and required electricity of these systems can reject any saving in energy consumption.

What is the solution? The best way is combination of energy systems as Photovoltaic with these three types as electrochromics, suspended particles and liquid crystals. If the aim is control of view in interior sectors of building, two types of suspended particles and liquid crystals are used. To solve the energy problem of these two types of materials, we can install solar cells in suitable locations and transfer

required electric energy (without increasing the costs of building energy and environment pollution) to these walls and eliminate the problem of these materials.

If these materials are used with climatic goals and the goal of using them is avoiding solar energy absorption, combination of these two materials types is efficient. If highest energy radiation and highest thermal energy receiving of sun are occurred, we need maximum opacity in glass surface and at the same time energy smart systems like Photovoltaic have high energy production. Thus, by combining these two systems, without consuming energy and environment pollution, if we need opacity of smart windows in case of sunlight, by producing electric energy from solar energy by Photovoltaic, this is easily possible and the problem of control of changes is eliminated.

Perhaps, it seems that in a part of building, we can use solar planes to generate electricity and we can transmit this energy to smart windows but there is a simple way. Photovoltaic materials are recognized as solar cells installed in the roof or body to building but by progress of technology of these materials as thin and transparent films, they can be installed on glass planes without avoiding view and they can produce electric energy. Today, some of factories producing smart glasses applied

this technology and some windows were built composed of various layers including electro chromic and Photovoltaic film. It means that electro chromic materials needing electric energy to control the entrance of energy into the building, this energy are received by neighboring Photovoltaic film. It can be controlled and don't need support equipment and external electric energy.

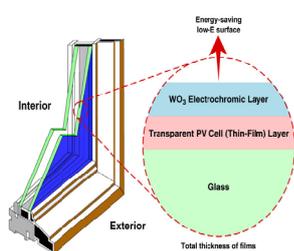
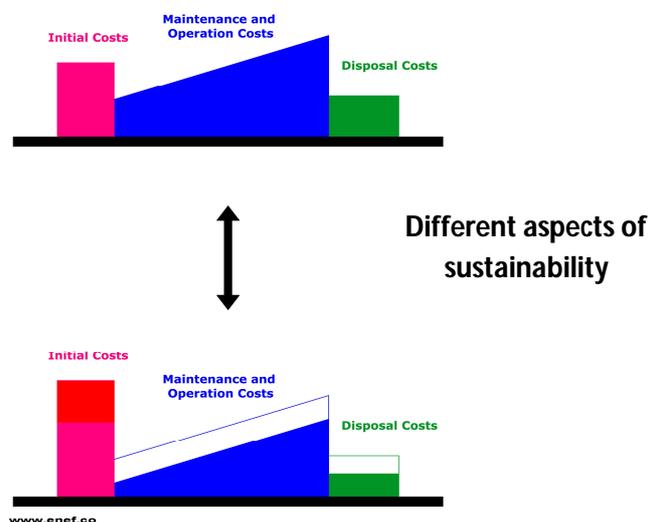


Figure 9- Combination of Photovoltaic film and electro chromic layer

5- Life cycle costs of building

One of the sustainability and architectural sustainability aspects are its economic aspect. Economic sustainability deals with the issue that construction of a building is sustainable and economical. This issue deals with life cycle costs and is one of the important aspects of sustainability. This issue is of great importance in Iran with economic and social conditions. Although economic aspects of constructions and reduced executive costs are of great importance, this issue shouldn't include only executive costs of building and it refers to all costs of a building from construction to the end of building construction and it deals with costs of life cycle of building.

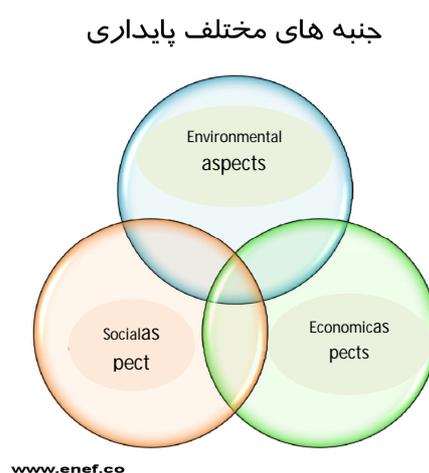


Application of life cycle costs of building is not new as the idea of life cycle costs in construction sector dates back to 60s. The costs of life cycle of building include building construction costs and its current costs and maintenance cost. Reduction of

initial investment costs and building execution without further costs of building and without proper planning can lead to the increase of current costs of building (operation costs and maintenance) and total costs of life cycle of building is increased.

This issue is important namely when reduction of costs of execution of a building leads to the increase of imposed costs of building on environment and nature. In national planning, we should go beyond it and to reduce costs of a building, we can reduce all costs of building as production, transportation of materials, costs of eliminate of negative effects of materials on environment and people, cost of building execution (materials and human resources), current costs of building (water, electricity and wastewater), operation costs and building maintenance, materials recycle costs after destruction ignoring the building costs based on the problems of construction and housing sector in Iran and low quality of materials and entire building, low life cycle of buildings and high energy consumption, dealing with these issues

should be on priority. Not only these issues have great importance compared to economic aspects of building construction, the mentioned aspects of construction in Iran are low compared to other countries. In most cases, reduction of building construction is not provided with proper planning to reduce the costs and can be provided by reduction of quality of building. Before, the buildings achieve good level in quality of materials and increase of life cycle of building and reduced energy consumption, only economic aspects can add the problems of building and housing. Economic aspects of building have high importance but importance of dealing with it is after the increase of quality of building and reduced energy consumption.



## CONCLUSION

Architecture in our country has a long history. In the past years, architects by the

most advanced construction methods built buildings adaptable with climate.

The only existing materials on that time were soil in some areas. By soil as dried

mud and brick as tolerating compressive forces, architects cover many openings by arch and dome. This method was an advanced technology on its time. On the other hand, in various climatic areas, buildings were built as were consistent with climate and without mechanic equipment, comfort conditions were provided in spaces.

Indeed, our traditional architecture is valuable and can give great lessons for current architects. The lessons that not only refer to the appearance of our past architecture (despite most of designers who consider referring to past architecture only limited to arch and dome forms) and the origin of each of them is introduced for us. Some lessons as using new technologies and considering climatic issues and environment, without damaging environment and polluting it, we can provide good conditions inside the building.

Smart materials are new technologies as applied in most of issues as climate and energy. In the past architecture of our country, architects with advanced technologies of that time solved climatic issues inside the building. If we want to take example from the past, one of the methods is using smart materials. These materials bring perception of surrounding

stimuli and adaptation with various conditions.

These materials have not been used in construction industry for a long time and now are used as case in buildings. There are some problems in using these materials and suitable solutions are not found. In the close future, with more progresses in this regard and finding some solutions for various problems (as it was mentioned in the paper, with the combination of two intelligent systems, the disadvantages are eliminated) and these materials can enter construction as commercial and we can proceed with the world to keep up with architecture.

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