The Effect of Smart Low Emission Glass Material on Reducing Energy Consumption for Office Building in Hot Arid Climate

Hiyam Siham Taha¹, Susan Abed Hassan²
¹,² Department of Architectural engineering, College of Engineering, Al- Nahrain University-Iraq

Abstract: There were massive innovations in the field of buildings materials at the beginning of the new millennium especially in the field of smart materials. There were many literatures that searched on the role of the smart materials on reduce energy consumption for buildings. This research problem that there was no obvious studies about the effect of smart low emission glass material on reducing energy consumption for office buildings in Baghdad city as an example for hot aired climate cities. Software simulations were used to comparatively estimate the energy performance model for an office building (Baghdad University office tower) after replace the glass of windows with low emission glass. The results showed that reduce of energy consumption reached to 11% as compared to typical type of glass materials.

1. Introduction
Buildings industries consume energy through construction and operation phase [1]. Last decades many attempts were made to develop building's design and materials to reduce energy consumption [2]. The invention of smart materials and it uses in building increased to develop structural efficiency and reduce energy consumption. There were many definitions for the smart materials, the technological encyclopedia defines smart materials and structures are those things that sense environmental events, a process that calls for sensory information and then works on the environment. NASA defines smart materials as materials that remember formations and can be compatible with them when giving a particular incentive [3]. Smart materials can respond to electrical, thermal and magnetic changes and have the ability to sense environmental and internal catalysts to respond and adapt by integrating functions into their structures. Catalysts and their response can be electrical, chemical, magnetic or radiological, shape-changing [4]. Also smart materials can be defined as materials and products capable of changing their shape or dimensions in reverse in response to one or more catalysts through external influences: light, temperature, pressure, electric or magnetic field or chemical catalyst. Among these materials are materials and products capable of changing the shape without changing the dimensions of intelligent materials electro-jihadi electrical and chemical are those that have the greatest interest in the field of architecture. Due to their potential to provide long-term stability expected and other factors [5]. Many recent literatures studied the relationship from different sides of view. Abdullah,et.al. 2019 explored the characteristics and
advantages achieved by smart materials systems in architecture and their impact on the process of design and architectural construction and how it can produce a more adaptive architecture with the immersion of the basics of adaptive architecture and components of the modern building system and then test the validity of the hypotheses through comparative analysis of architectural models. The research concluded a clear mechanism in achieving maximum adaptation in the built environment through the impact of smart materials systems on the design process and its outputs at the constructional, climatic and architectural levels [6]. Samy.et.al. 2017 studied the link between architecture and new materials science, including smart materials that have can feel the environment, such as living systems with an analytical study of types of smart materials. The research concludes that materials are a functional element with a method that can be formally adopted and effective at each stage of the design and the use of these materials enhances the sustainability of buildings, so an integrated approach was proposed towards a new model of innovative architectural design [7]. Alobeidi, et.al, 2019 studied the impact of the use of smart materials in the facades of contemporary buildings through the identification of smart materials, types, and importance in architecture and analysis of a series of facades of contemporary buildings and their environmental and technological effects [8].

2. Smart materials
The most distinctive characteristics of smart materials include material, composition or system. [9]

- **Immediacy**: Immediate response
- **Transiency**: means response to transient conditions
- **Self-actuation**: means intelligence inside the material and not outside (do not need actuator systems and computer system)
- **Selectivity**: Materials with a distinctive and predictable response
- **Directness**: In-place response and motivation

Smart Material Classifications based on its behaviour, smart Materials can be classified into [10]:

- **Property change**: change of chemical, magnetic, thermal, mechanical or optical characteristics in response to changes in the conditions of the material environment maybe environmental conditions surrounding or may be produced through direct energy inputs
- **Energy exchange**: The input energy is changed to another form of output energy according to the first law of thermodynamics such as photovoltaic.
- **Size/ location**: These characteristics are the separate size and direct conduct of the material. Allowing the disposal or minimization of secondary transport networks, auxiliary components and in some cases even the packaging and energy connections reduces the volume of the active part of the material.
- **Reversibility/directionality**: Substances that have dual changeability to change properties and change energy, which allow for further exploitation of their temporary change rather than just the energies and characteristics of inputs and outputs.
- The energy absorption properties of phase change materials can be exploited either to stabilize the environment or release energy to the environment, depending on the direction in which phase change occurs. Table 1 shown the types and characteristics of the smart materials.
Table 1. shown the types and characteristics of the smart materials [10]

| Type of smart material       | input                  | output               |
|-----------------------------|------------------------|----------------------|
| Thermomochromics            | Temperature            | Color change         |
| Photochromics               | Radiation(light)       | Color change         |
| Mechanochromics             | Deformation            | Color change         |
| Chemicalochromics           | Chemical concentration | Color change         |
| Electrochromic              | Electric potential difference | Color change  |
| Liquid crystals             | Electric potential difference | Color change  |
| Suspended particle          | Electric potential difference | Color change  |
| Electrorheological          | Electric potential difference | Stiffness/viscosity change |
| Magnetorheological          | Electric potential difference | Stiffness/viscosity change |
| Electroluminescents         | Electric potential difference | Light |
| Photoluminescents           | Radiation              | Light                |
| Chemoluminescents           | Chemical concentration | Light                |
| Thermoluminescents          | Temperature difference | Light                |
| Light-emitting diodes       | Electric potential difference | Light |
| Photovoltaics               | Radiation(light)       | Electric potential difference |
| Piezoelectric               | Deformation            | Electric potential difference |
| Pyroelectric                | Temperature difference | Electric potential difference |
| Thermoelastic              | Temperature difference | Electric potential difference |
| Electrostrictive           | Electric potential difference | Deformation |
| Magnetorestrictive          | Magnetic field         | Deformation          |

Also smart materials classified according to it uses in buildings to structural and nonstructural type.

2.1 Structural smart materials

Those include smart materials which used in structural of buildings like:

- Carbon fiber reinforced: type of concrete used in locations where disasters are expected or that require a certain type of security for the building.
- Transparent concrete: it is new concrete mixture that can transmit light through it to provide transparency to a certain degree and reduce the consumption of indoor lighting
- Luminous cement: synthetic polymer material with phosphorus-coated glass granules that gives the material a glow of darkness and allows light to pass through and gives the facade decorations through reliefs.
- Anti-pollution cement: improved cement based on magnesium carbonate instead of calcium carbonate. This type of cement absorbs carbon dioxide from the atmosphere. It also has a functional life and performance greater than ordinary cement.[11,12]

2.2 Non-structural smart materials

- Aerogel Glazing: a type of glass consists of layers dictated between the material aerogel to increase the thermal and acoustic insulation of this glass in addition to the ability to disperse bright light and glare, which increases the occupant's comfort for the spaces of buildings with giving thermal insulation in the summer
- Coagulate: a type of smart glass is characterized by the presence of a layer that clots between the two layers of glass to turn from transparent to semi-transparent depending on the amount of light
falling and not the heat surrounding the material. Transparency depends on the intensity and angle of light fall. This material provides good thermal insulation $U = 1.4$ and gives good thermal performance. [13]

- **Photochromic materials:** Materials with a colorless appearance (transparent) In the case of inefficiency, this material absorbs the electromagnetic energy that comes from the ultraviolet radiation falling on its surface to change its properties, where the material changes color from transparent to semi-transparent to reflective absorption. Used to reduce brightness and glare.[5]

- **Electrochromic materials:** is a multi-layer structure of various materials that work together characterized by the ability to change color when shedding electric current on them, where the glass turns from the opaque and returns to its transparent state by the impact of shedding little electric current on them. And practical to a great degree.

- **Liquid Crystal technology:** is a layer of glass, including the liquid crystal material, which works to control the amount of light through which by shedding an electric current on the liquid crystals to become transparent glass allows the passage of light and vision in both directions

- **Low-Emissivity Glass:** The addition of a metal oxide coating to stained or transparent glass so that the appearance and performance are the same regardless of the thickness of the glass. This costs about 15% more than ordinary glass, but reduces energy by up to 30-50% depending on the climate. [14]

3. **The effect of smart glass material on the energy of the building**

   The unique power transmission properties of many smart materials make it ideal for use in building facade and lighting systems especially glazing, which considered major problem for designers as energy travels in both directions. The architect had to choose the right smart materials to reduce energy, also, to provide transparency and lighting for the building, so the term smart windows emerged, which had a convertible interactive surface and provides one or more of the following functions:

   - Control of optical transmittance: a gradient in transparency to prevent direct penetration of sunlight and associated glare
   - Control of thermal permeability: reduce the transfer of thermal energy through the windows by reducing radiation transmitted in the summer and benefit from it in winter.
   - Control of thermal conductivity: The change of thermal conductivity of windows affects the total thermal conductivity of the building and thus creates a balance between the inside and outside
   - Control of vision: through the gradual transparency of glass.

4. **Methodology**

   Research studied the effect of smart low emission glass material on reducing energy consumption for office buildings the selected chosen sample was (University of Baghdad head courter tower). It designed in 1957 by (Walter Gropuis) as a part of the University of Baghdad, at the south of Baghdad city in Al-Jadiriyah, it consist from 16 floors, the picture of the tower with typical floor plan and section showed in Figure 1. Software simulations for cooling loads was made using software, Hourly analysis Program HAP4.9 software was used to comparatively estimate the energy performance model, after replace the glass of the windows with low emission glass. The tested samples for measurement include two wings for offices with 184 m$^2$, the elevations face south and north. Both wings windows had compost louvers. The
cooling loads calculated in 6 months (4,5,6,7,8, and 9). The effects were addressed by comparing the energy of it. Percentage variation was calculated and matched consequently.

Figure1. The tower of head quarter with typical floor plan and window section

5. Results and Discussions
The results show the effect of the use of the smart low emission glass material on reducing energy consumption for office buildings.

5.1 The effect of window glass on energy consumption glass types on cooling energy consumption for south elevation
The comparison tested window glass cooling energy consumption results, for south elevation offices, and for only one story is shown in Tables 2 and Figure 2.

**Table 2.** The effect of window glass types on cooling energy consumption for south elevation

| Energy consumption for cooling in Wh | 5mm | 5mm clear low-e |
|-------------------------------------|-----|----------------|
| Max. Month                          | 347409.7 | 321890.1 |
| Max. Hour                           | 26013.5  | 23728.2  |
| Total                               | 1927811  | 1807857  |
| Per. M²                             | 10774.2  | 9825.3   |

**Figure 2.** The monthly cooling load for the tested window glass samples at south direction

5.2 *The effect of window glass on energy consumption glass types on cooling energy consumption for north elevation*

The comparison tested window glass cooling energy consumption results, for south elevation offices, and for only one story is shown in Tables 3 and Figure 3.

**Table 3.** The effect of window glass types on cooling energy consumption for north elevation

| Energy consumption for cooling in Wh | 5mm  | 5mm clear low-e |
|-------------------------------------|------|----------------|
| Max. Month                          | 281349.8 | 274462.6 |
| Max. Hour                           | 17832.6  | 17445.7  |
| Total                               | 1483508  | 1442650  |
| Per. M²                             | 8062.5   | 7840.4   |
6. Conclusion

The developments of smart materials technologies raised widely in this century. There were many advantages for smart materials from different sides of buildings construction to occupy. Smart glasses highly considered in buildings design cause it multiple advantages from the control of optical transmission to thermal, vision and thermal comfort. As on the level of energy reduction this research results showed the effect of use low emission glass on reduction of energy consumption that reached to 7.3% for 5mm clear low-e glass as compared to the same clear glass one for the south direction for the tested office south wing, and for only one story. And the reduction of energy consumption reached to 3.7% for 5mm clear low-e glass as compared to the same clear glass one for the north direction, and for only one story. This means that the total energy consumption for one story reached to 11%. The opportunities of low emission glasses in reduction of cooling energy encourage the architectures and owners of buildings to depend on it.

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