2011 International Conference on Intelligent Building and Management
Proc .of CSIT vol.5 (2011) © (2011) IACSIT Press, Singapore

Choosing Efficient Types of Smart Windows in Tropical Region Regarding to Their Advantages and Productivities

Mohammadjavad Mahdavinejad[1], Mohammadreza Bemanian[2], Neda Khaksar[3], Ghazal Abolvardi[4]

[1] Assistant Professor, Department of Architecture Technology, Faculty of Art & Architecture, Tarbiat Modares University, Tehran, Iran

[2]Assosiate Professor, Department of Architecture Technology, Faculty of Art & Architecture, Tarbiat Modares University, Tehran, Iran

[3], [4] M.Sc. Student, Department of Architecture Technology, Faculty of Art & Architecture, Tarbiat Modares University, Tehran, Iran

Abstract. Glazing facades are an important issue in buildings construction and design due to have different roles in building such as; control glare, control view to outside and reduce infrared radiation transmission. Nowadays, one of the new, adoptable and smart glazings is smart windows which are activated environmentally or electrically. Photochromic, thermochromic, thermotropic, electrochromic, liquid crystal device and suspended particle devices windows are different types of smart windows which can change their properties in response to input activators. Of particular importance is implementing them in a right place in order to result in thermal and visual comfort and also energy saving which is a global issue.

Due to the fact that reduction of radiation intensity and keeping living spaces cool are major needs of buildings in tropical regions, on the other hand smart windows are able of controlling thermal transmission and absorption, using smart windows would be a good option for these regions. In this regard, the efficient types smart windows and also proper position of them in buildings in tropical regions according to their direction to sun would be discussed in this paper. Research method is semi-experimental and logical argumentation through descriptive-analytical techniques.

Keywords: Smart Windows, Tropical Regions, Solar Radiation, Energy Saving, Sky Lights.

1. Introduction

Smart windows are switchable windows which have reversible behavior toward activators. The activators may be environment or electricity. These active glazing, change their characteristics due to driven activators. As smart windows have different types consequently responsive of different needs, optimizing situation for single need is unlikely to coincide with the other environmental conditions. As a result, between electrically and environmentally activated glazing, electrically activated windows –for capability to start and stop the act- and combination of different types of smart windows – for responding to different and various needs of human simultaneously- are more developed nowadays.

Of particular importance is to recognize and find what result we want in the interior. Then in next stage we should select and choose the most effective options among various types according to our desire. In this paper we want to define the types of smart windows which can be effective in tropical regions. Different types of smart windows introduced in this paper includes; photochromic, thermochromic, thermotropic, electrochromic, liquid crystal device and suspended particle devices windows.

2. Various functions of Smart Windows

+ Corresponding author. Tel.:+(98-21-82880); Fax. +(98-21-82880). E-mail address: j.mahdavinejad@gmail.com

The term ‘smart window’ has been applied to any system that purports to have an interactive or switchable surface (Addington & Schodeck, 2005, p. 167)‘Smart’ windows will typically possess one or more of the following functions (ibid, p.168):

- **Control of optical transmittance**: A shift in the transparency (the optical density) of the material may be used to manage the incident solar radiation, particularly in the visual and near ultraviolet wavelengths. The window would change from opaque or translucent for the prevention of direct sun penetration and its associated glare to transparent as incident light loses intensity.
- **Control of thermal transmittance**: This is a similar function to that above, but the wavelengths of interest extend into the near infrared region of the spectrum. Heat transmission by radiation can be minimized when appropriate (summer) and maximized for other conditions.
- **Control of thermal absorption**: Transparency and conductivity tend to correlate with each other, but are relatively independent of the incident radiation. Whenever the inside temperature is higher than the outside temperature, a bidirectional heat flow is established: radiant energy transfers in, while thermal energy transfers out. Altering the absorption of the glazing will ultimately affect the net conductivity, and thus can shift the balance in favor of one or the other direction.
- **Control of view**: The use of switchable materials to control view is currently the fastest growing application of smart materials in a building. Interior panels and partitions that switch from transparent to translucent allow light to transmit, but are able to moderate the view by altering the specularity of the material.

Different types of smart windows, as would be mentioned follow, have one or more of above functions.

2.1. Photochromic Windows:

Photochromic windows change from clear state to transparent colored state when subjected to light or ultraviolet radiations (Lampert, 2004). They can control glare, reduce transmitted radiation and the most important feature of them is to obstruct UV radiation. Nevertheless, they have not proven effective because of the slowness of response and heat gain problems (Addington & Schodeck, 2005, p. 86). Besides that, a photochromic window in northern latitudes would darken more in the winter than in the summer although winter is the time when solar heat would be beneficial (ibid, p. 168). Therefore they can be effective for skylights.

2.2. Electrochromic Windows

Electrochromic smart windows are able to vary throughput of radiant energy by low voltage electrical pulse (Granqvist, 1998). So fliping a switch, change them from clear to fully darken or any level of tint in-between. They are developed widely for reduction of heat transmissivity whilst remain transparent.

Fig.1- Electrochromic window in large surfaces

2.3. Thermochromic Windows

They are activated by heat but do so by sacrificing control in the visual part of the spectrum. it operates best in the near infrared region of solar spectrum(Manfredi, 2010, p. 16672). The application hurdle that thermochromic glazing must overcome is its low transmissivity in the visual part of the spectrum, which currently ranges from 27-35% (Addington & Schodeck, 2005, p. 169).

Fig.2- Thermochromic window with semi-opauqe view to outside

2.4. Thermotropic Windows

Thermotropic respond to the same environmental input as do thermochromics. Whereas thermochromics switch from transmissive to reflective, thermo tropics undergo a change in specularity, resulting in the ability to provide diffuse daylight even as the view is diminished (Addington & Schodeck, 2005, p. 169). Two kinds of more current thermotropic windows are thermotropic hydrogels and polymers with some

Fig.3- Thermotropic window without any view to outside, reduction of glare exclusively.

different features and different applications. Thermotropic hydrogels undergo changes from highly transmitting state to a highly reflective state at temperature between 5-60 °c, where as the thermotropic polymer blends do so at 30-130 °c (Resch, 2009, p.124).

2.5. Liquid crystal device windows

Liquid crystal device windows are in the group of electrically activated smart windows in which normal "off" condition of the glazing is a translucent milky white. When an electric current is applied, it turns clear. Liquid crystal systems allow controlling their transmittance by electrical-driven director reorientation (Cupelli, 2009) Liquid crystal windows are used for privacy control but they do not provide energy savings.

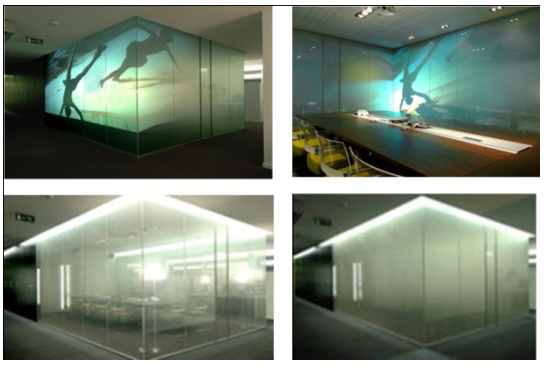

Fig.4- Liquid crystal device windows used in interior and act as advertisement board and provision of private space simultaneously without reduction of light

2.6. Suspended particles device windows

Suspended particles device windows in a group of eletrochromics that change transparency when electrically activated. They are an alternative to liquid crystals with similar draw backs, but their primary advantage over liquid crystals is their ability to permit much more oblique viewing (Addington, 2005, 185).

In implementing smart windows the first question that should be asked is what result we want in the interior. According to our desire, we can choose between different types.

Smart windows	Input	Visual limitedly	Visual characteristic (after responding to input)			Thermal characteristic (after responding to input)	
			Reduction in intensity	Reduction in visibility	Colored/bleached	Reduction in transmitted radiation	Reduction in Emitted radiation
Photochromic	UV	-	*	-	Colored and transparent	*	-
Thermochromic	Heat(high)	*	*	-	Colored and semi-opaque	*	-
Thermotropic	Heat(high or low)	*	*	*	Colored and opaque	*	*
Electrochromic	Voltage or current	-	*	-	Colored and transparent	proportional *	-
Liquid crystal	Voltage	*	(minimal) *	*	bleached	minimal*	-

Table 1- features of smart windows

Suspended particle	current	*	*	*	bleached	minimal*	-

3. Tropical region

The tropic area is region of the Earth by the Equator. It is limited in latitude by the Tropic of Cancer in the northern hemisphere. In this region the sun can be directly overhead. The mean monthly temperature is over 20°C/68°F. They have two defined seasons: the rainy season from May to August and the dry season for the rest of the year. Discomfort is found most of the time due to high temperatures and humidity levels (Tenorio, 2007, p.609)

4. Discussion

Smart windows divided to two main groups; environmentally activated and electrically activated. Each group has special application according to their weakness and their strength.

As the major function of windows is to provide visibility to outside, on the other hand smart environmentally –driven windows are unable to control start and stop transition and therefore mat obstruct view, they should be used in places where view to outside is not important; such as sunroofs or sky lights or upper windows or overhanging shelves.

Among environmentally activated materials, photochromic windows, which darken on the exposure of light and UV are able to protect UV but not effective for energy saving as much as thermochromic and thermotropics. They would be mostly effective for skylights due to the fact that the sun angel should be high in order to be activated. also their main usage of them is for obstructing UV radiation.

Fig.5- thermotropic polymer laminate glasses be applied as overhanging shelves on the outside

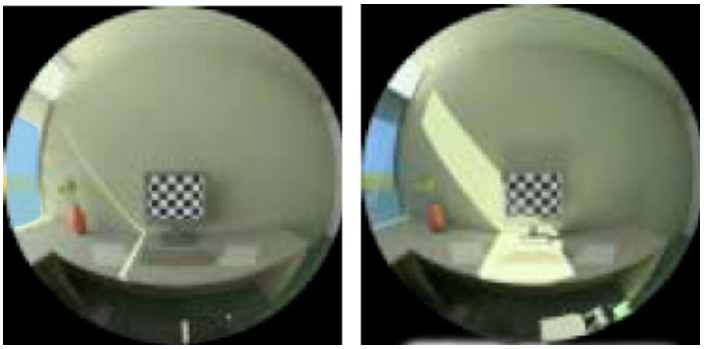

Fig.6- thermotropic polymer laminate glasses be applied as overhanging shelves on the outside

Application of thermochromic and thermotropic windows result in thermal comfort but do so by sacrificing view. They respond to heat by changing their color to white and reduce the transition of heat, but difference of them is that thermotropic obstruct view completely but thermochromic does not. On the other hand thermotropic are more effective for overheating protection and reducing energy consumption.

As discussed, the two major kinds of thermotropic windows are polymer and hydrogels. Each has been applied in different situation. As thermotropic polymers are susceptible to heat at high temperature, they can be utilized in west windows, where thermal comfort of the space is more significant than having visibility to outside, meanwhile in moderate temperature view to outside is possible. On the other hand thermotropic polymer laminate glasses can be applied as overhanging shelves on the outside; as a result both proper view and heat protection will occur simultaneously (fig.5). The last prototype of environmentally activated windows that would be discussed is thermochromic windows which change to semi-opaque states on the activation of heat. As they provide semi- opaque view meanwhile controlling heat gain of the building, they can be utilized in upper windows.(fig.6) due to high temperature in summer time, thermochromic windows will be activated and act as a insulator and in winter, in spite of low angle of sun, it would not be translucent and let incident solar radiation.

Among electrically activated materials, liquid crystal windows are not able to response to desired outcome which are reduction of light intensity and reduction of transmitted heat besides that need energy to change to transparent states. Consequently, they are not suggested in tropical regions. Their widespread and exclusive usage of them is for architectural market.

Between two other technologies, suspended particle device and electrochromic windows, electrochromic windows are more proper due to cause reduction in transmitted radiation whilst remain transparent and not

have visibility limitation, on the other hand, they need less energy to function and can be used in large exterior surfaces.

Suspended particle device windows are intrinsically dark and provide obstructed view, so they can be used for private spaces. On the other hand, they have impact on reduction of transmission radiation. Their weaknesses are size limitation and their need to continuous power to be activated. So application of suspended particle device and electrochromic windows are in different cases but both of them can be effective and utilized in tropical regions. However, combination of them with coatings can significantly optimize their efficiency for heat protection.

Smart windows		**description**	**Efficiency**	**Appropriate place**	
Environmentally activated	Photochromic	-	*	skylights	skylights
	Thermochromic	-	*	Windows(combined)	In upper windows
	Thermotropic	-	*	Windows(combined)	In west windows In overhanging shelves
Electrically activated	Electrochromic	Used with coating	*	windows	East and south window
	Liquid crystal	-	-	-	-
	Suspended particle	Used with coating	*	windows	East and south window

Table 2- study efficiency of smart windows in tropical regions

5. Conclusion

All types of smart windows can be effective in tropical regions except liquid crystal device glazing, which come into architectural markets. Of particular importance is know that the efficiency of smart windows due mostly to its place in building. Being utilized in appropriate place, they can be considerably impressive for energy saving and thermal and visual comfort. Smart windows come to two types of electrically and environmentally activated ones.

Basically the major drawback of all three environmentally-activated windows is their inability to 'stop' or 'start' the transition. So they would be utilized in where view is not important such as skylights or sunroofs in order to provide view to outside. On the other hand, electrically activated chronics, all of which give the user opportunity to control and balance the often-conflicting behaviours, have found wide-spread usage in windows. Based on the desired outcome, permanent visibility to outside where as transmission of radiant energy reduced or having privacy besides control heat gain, electro chromic and suspended particle device windows will be utilized respectively.

6. References

- Addington M. & Shodek, D. *Smart materials and new technologies (for architecture and design professions).* Harvard University, U.S.A. 2005.
- Cupelli, D., Nicoletta, F. P., Manfred, S., Vivacqua, M., Formoso, P., De filpo, G., and Chidichimo, G. self-adjusting smart windows based on polymer dispersed liquid crystal. *solar energy material and cells,* 2009*,* 93, pp. 2008-2012.
- Granqvist, C G., Azens, A. & Hjlem, A., Kullmam, L., Niklasson, G. A., Ronnow, D., Stromme Matsson, M., Veszelei, M., and Vivars, G. (1998). Recent advances in electrochromism for smart windows applications**.** *Solar energy material and cells*. 1982, vol. 63 (4), pp. 199-216.
- Groat, L. & wang, D .*Architectural Research Method*. John Weily & Sons, Inc., United States of American, 2002.
- Lampert, C. M. *Choromogenic smart materials*. Material study, march 2004, pp.28-35.
- Tenorio, R. Enabling the hybrid use of air conditioning: A prototype on sustainable housing in tropical regions. *Building and Environment*. 2007, (42), pp.605–613.
- Manfredi S. & others, Energy modelling studies of thermochromic glazing, Energy and Buildings. 2010, (42), 1666-1673.
- Resch, K. the thermotropic layers for flat plate collectors. *solar energy materials and solar cells. 2009, (93)*, pp. 119-128.