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Multifunctional Glazing System: Solution for Modern Smart Glazing

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Multifunctional Glazing System- Solution for Modern Smart Glazing

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ABSTRACT

Multifunctional glazing combines various glazing, that have potential to control solar heat gain by changing the window transmittance and low heat loss. In autonomous multifunctional glazing its function will be powered by PV layer attached to the glazing. This glazing obviates the necessity for shading devices to control the glare. Glare control for such a small scale south facing vertical surface multifunctional glazing is discussed.

INTRODUCTION

The building sector consumes 41% energy in USA, 40% EU, and 25% in China. At present, low energy buildings are gaining importance to reduce overall energy demand. A near zero energy building combines two concepts (i) the amount of energy supplied to the building must be small and (ii) that energy should be supplied from the renewable sources. In this context, windows are the most important building envelope component contributing to energy use reduction. Windows offers privacy, visual amenity, comfort and control of light and air. In a direct dynamic relation with outside atmosphere, heat gain and heat loss both ensue through a window. In addition to multiple pane glazing that includes low emittance coatings vacuum glazing, aerogel glazing, building integrated photovoltaic (BIPV) glazing and smart glazing are available. Vacuum and aerogel glazing gives low heat loss from room to environment and reducing heating load demand. BIPV glazing introduces daylight and reduces the artificial lighting load demand. Smart glazing like electrochromic (EC), liquid crystal (LC), suspended particle device (SPD) type control the solar heat gain and reduce the cooling load demand.

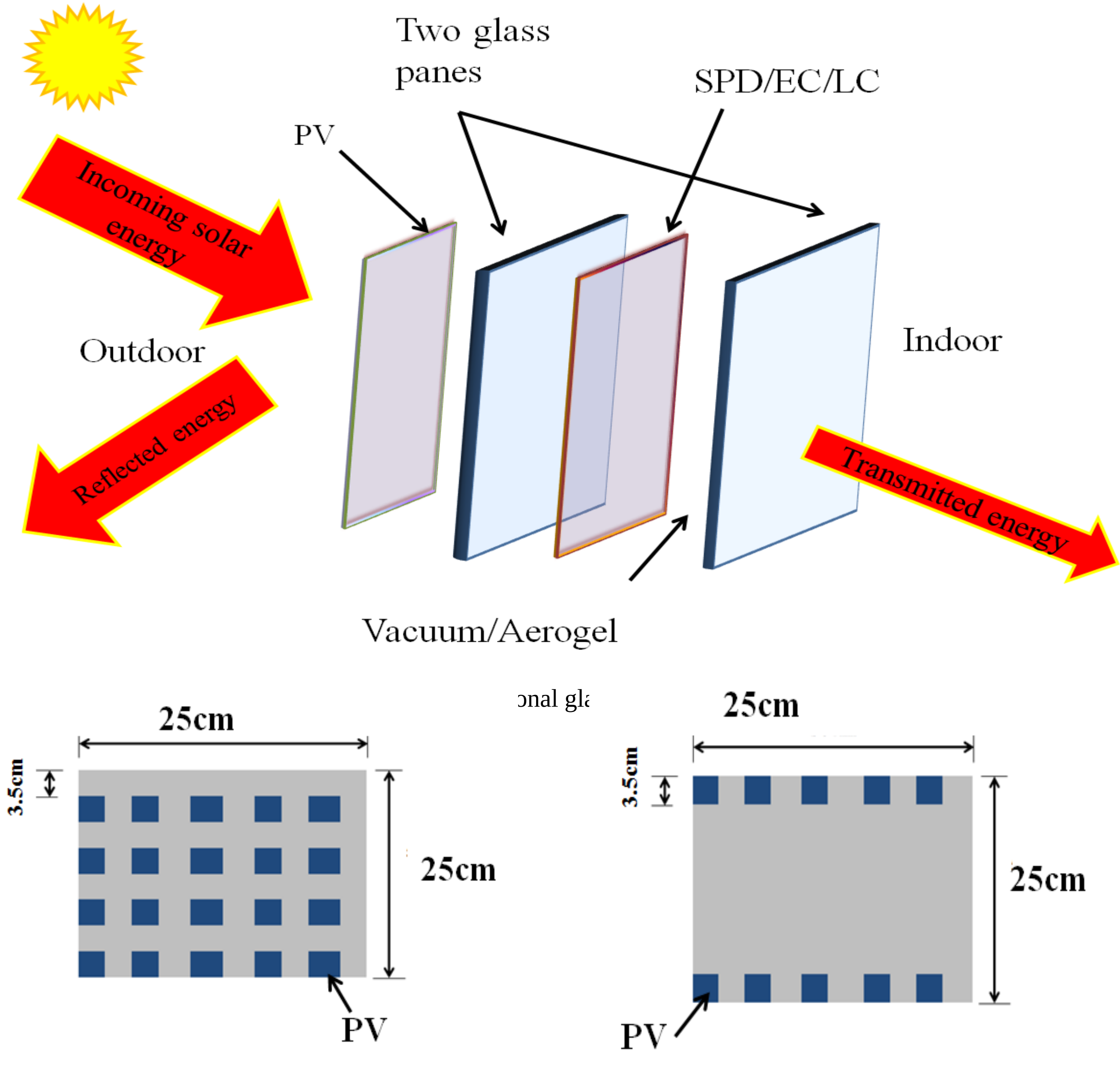
Vacuum glazing consist vacuum between two glass panes separated by small pillars to withstand the atmospheric pressure and insulated hermetic edge sealing around the periphery of the two glass sheets. This glazing shows total heat transfer coefficient (*U* value) values between 0.5-0.9 W/m^2K (Robinson and Collins 1989; Collins and Robinson 1991; Fang et.al. 2006). Highly insulating vacuum glazing can be achieved using hermetic edge sealing around the periphery of two glass sheets (Collins and Simoko 1998). Addition of transparent low emittance coatings reduces radiative heat transfer between the sheets. Use of two low- e coatings does not reduce the overall heat transfer rate over a single low e coating layer. Using one layer of low e coating also reduces the overall system cost as low e coatings are costly (Fang et.al. 2007). An aerogel is a translucent solid gel that exhibits high thermal insulation, low refractive index, and very low density (Jensen et.al. 2004). This glazing filled with aerogel can achieve a heat loss coefficient less than $0.7W/m^2K$ for 15 mm thick aerogel between two glass panes (Schultz and Jensen, 2008; Schultz et.al. 2005). In BIPV glazing transparent or semitransparent solar cells are placed on the outer facing surface of the glass panes (Miyazaki et.al. 2005, Chow et.al. 2009) which can be used as small scale electricity generation, control solar heat gain and transparency of visible light. In case of electrochromic glazing electrochromic material are placed between two glass panes. An electrochromic material is cell which changes its state from transparent to opaque state by redox reaction in the presence of applied D.C. voltage typically 0 to 5 V (Rosseinsky and Mortimer 2001). The optical properties of EC can be reversed by simple inversion of electrical polarity (Lee et.al. 2003, Granqvist 2012). The speed of this colour change process decrease at higher ambient temperatures. The bleaching to colour process take more time than colour to bleach process. EC material has potential to control transmissivity, absorptivity, reflectivity and emissivity of a glazing (Granqvist et.al.2003; Granqvist 2005). Electrcochromic glazing controls solar heat gain and daylight through a window by blocking the transmission of near infrared (NIR) and visible light (Pennisi et.al. 1999, Granqvist 2000). SPD and LC both work on AC power. Both types become clear when continuous power supply is available and a switched off condition generates an opaque state. Compare to EC glazing LC and SPD switch on response is very fast, within 2 -5ms. Another advantage of these two glazing are they produce equal transparency all over the glazing specifically when the glazing size is larger (more than $1m^2$). EC glazing colouration process takes 5-10 min depending on the size and sometimes the coloration is not uniform. The required electrical power consumption for EC glazing is much lesser than the LC and SPD glazing.

Building occupant prefer to live and work in space with good daylight distribution. Daylight in a building is preferable to saves energy from artificial lighting. Discomfort glare arises from a high or non-uniform luminance distribution with high contrast luminance between source and surroundings. Discomfort happens due to glare sources position, the part of sky seen through and the size of glare sources (Galasiu and Atif 2004; Nazzal 2005). Controlling glare while achieving maximum utilisation of daylight is one the most difficult task for present available window and shading devices. Different shading devices such as external shading, internal shading, and louvers are used to control daylight and glare (Ahmed, 2012; Freewan, 2014). Particularly overhang type shading devices cannot control the glare created from low azimuth angle direct solar radiation. Switchable glazings are capable of reducing this glare.

CONCEPT of MULTIFUCNTIONAL GLAZING

Combining vacuum and EC device gives both low heat loss and switching characteristics to get both effects together (Papaefthimiou et.al. 2006; Fang et.al. 2008). An EC /LC/SPD device needs an external supply to change colour which can be supplied by PV added to the EC (Deb et.al. 2001; Huang et.al. 2012; Huang et.al. 2012). Using EC window and overhang shading in combination (Lee and Tavil 2007) has been studied.

A new multifunctional glazing, shown in figure 1 integrates of all these different existing EC/LC/SPD system, Vacuum/Aerogel, and Photovoltaics (PV). PV generates the power necessary to change the colour of smart material (EC, LC, and SPD). Multifunctional glazing can be solution for new fenestration devices that control the direct solar radiation, improve daylight quality, control daylight and glare. The location of PV layer will have an influential contribution in multifunctional glazing. Different positions of the PV layer will produce different PV outputs that will be used to switch the smart material.



(a) (b)

Figure 2 Schematic diagram of semitransparent PV device for multifunctional glazing

Transparency reduces when PV cells are applied to the glass. Organic PV cells have a high transparency compare to inorganic PV cell but durability and efficiency of this type of cells are very lower. Keeping in consideration the cost and durability of the PV cells, silicon PV cells are considered in this study. Figure 2 illustrated two different options of placing PV cells are placed to glazing space to provide a semitransparent glazing. In the figure 2 (a) shows a 20% transparency while figure 2 (b) has 40% transparency. For the multifunctional glazing as shown in figure 1 different transparency level of each and layers are , glass 90%, PV 20% or 40%, EC clear 50% , EC opaque 10%, SPD opaque 5% and clear 58%. Different positions for the PV will result in different PV outputs available for switching the multifunctional window. PV arrays produce maximum power when inclined at the local latitude angle. As windows are usually vertical surfaces most the PV will also be inclined vertically. Depending on the different position of window east west south north the incident solar radiation intensity will also be different. It will be evaluated that how much light and solar radiation will be available for multifunctional glazing and also for different orientation.

Different possible positions of different layers are;

Type 1- Glass, SPD/EC/LC, PV, Vacuum/aerogel, and Glass (here we consider only EC, PV 20% transparent)

Type 2- PV, Glass, EC/LC/SPD, Vacuum/aerogel, and Glass

Type 3- EC/LC/SPD, Glass, PV, Vacuum/aerogel, and Glass

Type 4-PV will be on the frame of glazing, Glass, EC, Vacuum/aerogel, and Glass

This Study considers Type1

METHODOLOGY

Glare index calculation is provided for a 25cm ×25cm multifunctional glazing for a sunny day on 1st of June 2014 in Dublin (53.3478° N, 6.2597° W). The glazing is considered to be on a vertical south façade. Dimension of the room and glazing position and measuring points are shown in figure 3.

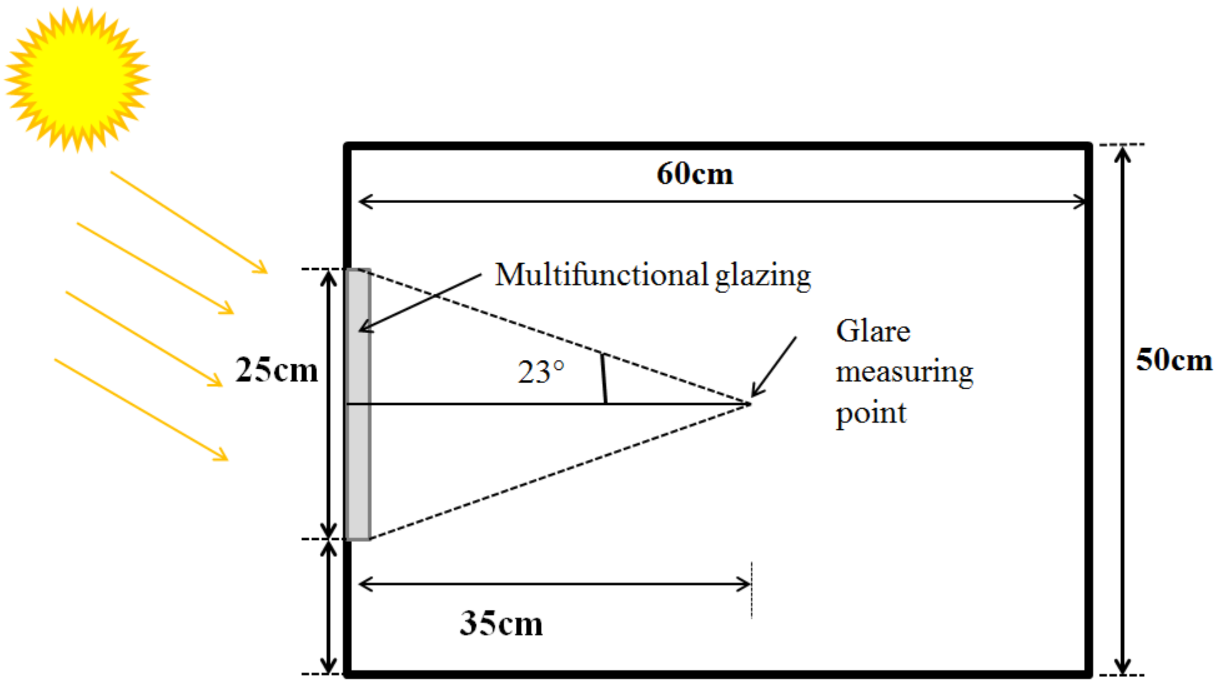


Figure 3 Schematic cross section of a room with multifunctional glazing place on vertical south facade

The available solar radiation I_{g20} inside the room will be

$$I_{g20} = \tau_{g1}\tau_{pv}\tau_{ec}\tau_{vaccum}\tau_{g2}I_{vinci} \quad (1)$$

Solar radiation incident on the vertical surface is calculated from horizontal direct and diffuse solar radiation using equation 2 (Liu and Jordan, 1960) for vertical surfaces orientated, east, west, north and south.

$$I_{vinci} = I_b R_b + I_d R_d + \rho R_r (I_b + I_d) \quad (2)$$

$$R_b = \frac{\cos\theta_i}{\cos\theta_z} \quad (3)$$

$$R_d = \frac{1+\cos\beta}{2} \tag{4}$$

$$R_r = \frac{1-\cos\beta}{2} \tag{5}$$

Angle of incidence are given by

$$\cos\theta_i = \sin\delta\sin\phi\cos\beta - \sin\delta\cos\phi\sin\beta\cos\gamma + \cos\delta\cos\phi\cos\beta\cos\omega + \cos\delta\sin\phi\sin\beta\cos\gamma\cos\omega + \cos\delta\sin\beta\sin\gamma\sin\omega \tag{6}$$

Global illuminance from the global incident solar radiation can be calculated from (Perez, 1990)

$$L = I_{vinci}\left[a_i + b_i W + c_i\cos(Z) + d_i\ln(\Delta)\right] \tag{7}$$

Discomfort glare is represented by glare index (GI) described by (Hopkinson and Collins 1970; Hopkinson and Bradley 1960)

$$GI = 10\log_{10} 0.478\left(\frac{L_s^{1.6}\Omega^{0.8}}{L_{ba} + \left(0.07\omega^{0.5}L_s\right)}\right) \tag{8}$$

The standard glare values are 10 for just perceptible, 16 for just acceptable, 18.5 for borderline between comfort and discomfort 22 for just uncomfortable and 28 for just intolerable.

RESULT & ANALYSIS

Vertical surface global solar radiation is illustrated for different orientation in figure 4. It can be seen that receiving solar radiation on multifunctional glazing is possible during all the day in south facing building. East facing and west facing glazing receive more solar radiation before 12 am and after 12am respectively. For an East facing window in the morning variable transmission control of glazing is essential whereas west facing windows needs control in the afternoon. South facing window needs maintenance of glare and daylitghiting throughout the day

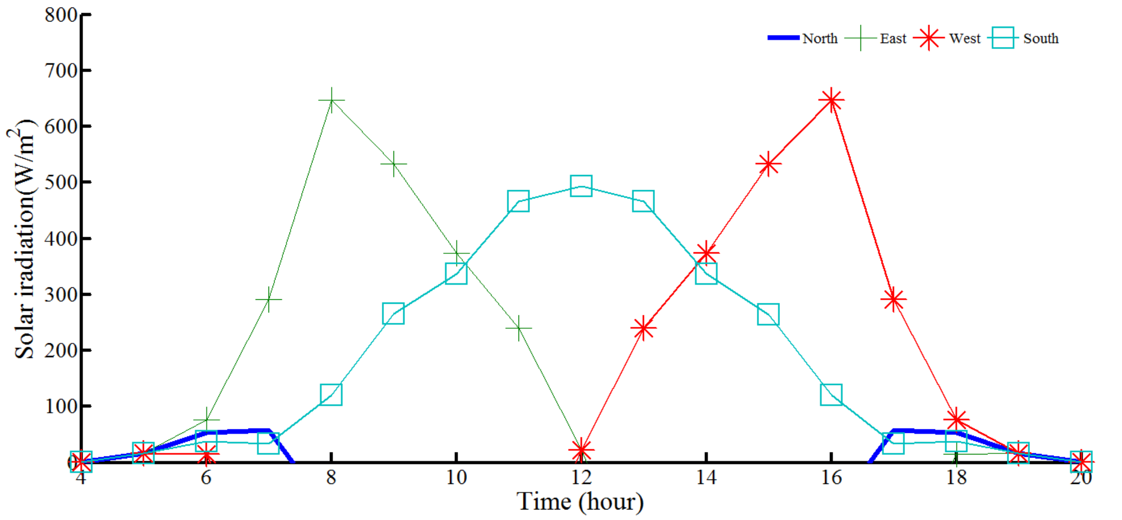
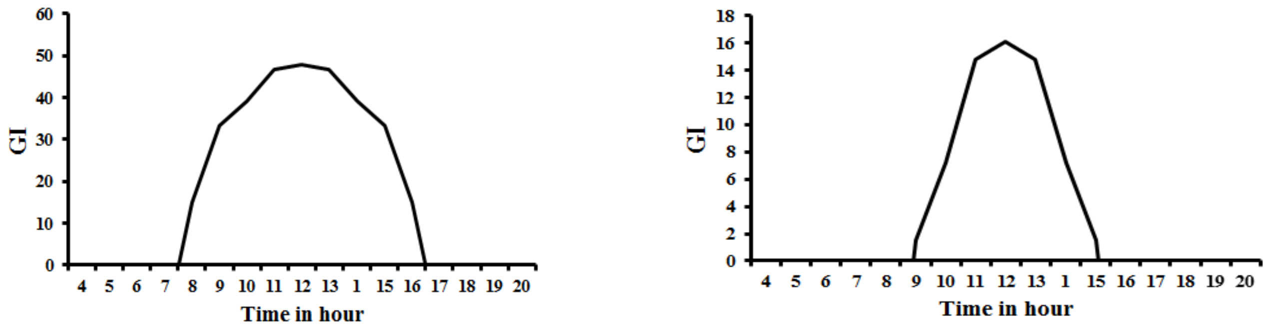


Figure 4 Incident global solar radiations for north east west and south on vertical surface

Glare index (GI) for south façade multifunctional glazing for switch off and switched on conditions are shown in figure 5. When EC was switched off its 50% transparency allowed excessive light inside the room. It can be seen that after 8am it crossed the limit of intolerable limit range of 28. At 12am it was nearly 50. This excessive glare can be controlled using the switched on EC with10% transparency rendering the glare acceptable range. At 12 am the maximum glare was 16 just in the acceptable range. In both case the PV transparency was 20%.



(a) **(b)**

Figure 5 Glare indices when EC was switched off clear (a) and switched on opaque condition (b)

CONCLUSION

Multifunctional glazing has potential to control heat loss and heat gain and generate electricity to switch a switchable material. This glazing has the potential to control glare. Glare control of a particular room has been found to be provided was theoretically calculated using standard glare index equation. It was found that when EC device was switched off condition the glare was nearly 50 at 12 am which was more than intolerable limit of 28. During the switched on condition the glare was nearly the acceptable range 16 at 12 am.

NOMENCLATURE

I = Incident solar radiation (W/m^2)
τ = Transmittance
L = luminance (lux)
R = conversion factor
Ω = solid angular subtense for modified position index (sr)
ω = solid angular subtense for source (sr)
ϕ = latitude angle (deg)
δ = declination angle (deg)
β = title angle (deg)

Subscripts

T = vertical
b = beam
d = diffuse
s = source
ba = background
r = radiative

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