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Measured thermal performance of a combined suspended particle switchable device evacuated glazing

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HIGHLIGHTS

- Test cell experiment is performed for a combined suspended particle switchable device evacuated glazing.
- The overall heat transfer coefficient this combined glazing has been calculated in both transparent and opaque state.
- The solar heat gain coefficient of this combined glazing has been calculated in both transparent and opaque state.
- The dynamic thermal behavior of glazing has been monitored.

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ABSTRACT

A switchable suspended particle device (SPD) evacuated (vacuum) glazing has low inherent heat loss and can control solar heat gain by changing its transparency. The thermal performance of combined SPD–vacuum glazing has been investigated using a test cell. In this work two different combination of SPD–vacuum glazing was evaluated. In the first combination, SPD glazing was facing the outside ambient environment and vacuum glazing was facing the indoor test cell environment (SPD–vacuum). In the second combination, SPD glazing was facing the indoor test cell environment and vacuum glazing was facing the outdoor ambient environment (Vacuum–SPD). Variation of the SPD glazing position in a combined SPD–vacuum glazing had little impact on either the internal test cell temperature or the glazing surface temperature. This combined glazing system achieved a dynamic transmission range from 2% (opaque state) to 38% (transparent state). Low overall heat transfer coefficients between 1.00 W/m^2 K to 1.16 W/m^2 K were found for this combined glazing. Dynamic solar heat gain coefficient was possible using this glazing, which varied from 0.045 to 0.27. This type of combined glazing system is suitable for summer and winter both conditions.

1. Introduction

The building energy consumption corresponds to 30–40% of the primary energy used in the developed countries [1]. In the European Union (EU), building consumes 40% energy of total energy consumption [2]. In terms of building energy performance windows of a building has higher overall heat transfer coefficient (*U*-value) (*U*-value between 2 and 5 W/m^2 K) which possess higher heat losses compared to other building envelope walls, roof and floor (<0.3 W/m^2 K). Due to transparent in nature window also allows higher heat gain and daylight, which often create discomfort. To reduce the building energy demand, highly efficient zero energy buildings are getting priority, which will have zero carbon emission. According to the EU Directive, to improve the energy performance of buildings [3], all new buildings ought to be nearly zero-energy from 2020. To obtain this target advanced glazing for window application is essential.

Presently two types of advanced glazings are available low heat loss and solar heat gain control. Details of these two types are illustrated in Fig. 1. Low heat losses glazing possess low *U*-values, which enhances their application for reduction of building heating energy consumption in cold climate or in winter season. 21% [4] to 62% [5] of building energy consumption compared to double-glazing is possible using low heat loss windows.

Low heat loss control glazing include low emittance (low-e) coated multiple pane, silica aerogel [4–13], and evacuated (vacuum) glazing [14]. Low-e coated multiple panes [15–17] are not advantageous as presence of multiple panes make this glazing heavier and low durability of this low-e coating often create an issue. To achieve higher visibility antireflection coating is required for this type of glazing. Silica aerogel glazing has potential to offer

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Nomenclature

A	aperture area of glazing (m^2)
A_i	anisotropic index
A_{wall}	interior wall surface area (m^2)
C_{tc}	heat capacity of air (kJ/kg K)
h_0	heat transfer coefficient from test cell outer surface (W/m^2 K)
h_i	heat transfer coefficient from test cell inside surface (W/m^2 K)
I	incident solar radiation on the vertical surface of glazing (W/m^2)
$I_{beam,h}$	horizontal plane beam solar radiation
$I_{dif,h}$	horizontal plane diffuse solar radiation
$I_{global,h}$	horizontal plane global solar radiation
I_{extra}	extra-terrestrial solar radiation
k_d	diffuse factor
k_T	clearness index
K_{pl}	thermal conductivity of polystyrene (W/m K)
K_{wd}	thermal conductivity of wood (W/m K)
L_{pl}	thickness of polystyrene (m)
L_{wd}	thickness of wood (m)
M_{tc}	mass of the air inside test cell (kg)
n_{air}	refractive index of air
n_g	refractive index of SPD glazing
Q_{gain}	solar heat gain inside the test cell (W)
Q_{tc}	total energy available inside the test cell (W)
$Q_{glazing}$	heat through the glazing incident solar radiation (W)
SHGC	solar heat gain coefficient
$T_{in,tc}$	interior temperature (°C)
$T_{out,tc}$	ambient temperature (°C)
U	overall heat transfer coefficient of glazing (W/m^2 K)

Greek symbols

α	absorptance
τ	transmittance
τ_v	vertical global transmittance
τ_{dir}	direct transmittance
τ_{diff}	diffuse transmittance
θ	incident angle

low U value. However, this silica aerogel inside the glazing does not absorb the visible light but scatters, which makes it haze. The scattering is most visible if the aerogel glazing is exposed to direct sunlight. This strong diffusion of the light makes the glazing almost impossible to see through [8,9]. Thus, they are not suitable for building glazing application due to low visibility. Vacuum glazing is a potential low heat loss glazing which consists of two sheets of glass sealed together hermetically separated by a narrow evacuated space. An array of small support pillars ensures that the glass sheets do not come into contact under the large atmospheric pressure forces. Internal transparent low emittance coatings (low-e coating) reduce radiative heat transfer to a sufficiently low level [14–47]. A detail of vacuum glazing is shown in Fig. 2.

Solar heat gain control glazings are suitable for hot climatic condition or in summer season. This type of glazing can save cooling energy consumption up to 9.4% for a residential room [48]. These solar heat gain control glazing are mainly switchable type and constant transparency type. Constant transparency [49–56] types are not preferable, as they do not offer control over the transparency and solar heat gain after installation in a building based on occupant demands. Switchable glazing can save up to 50% of the total energy by retrofitting it with only 18% of the total window

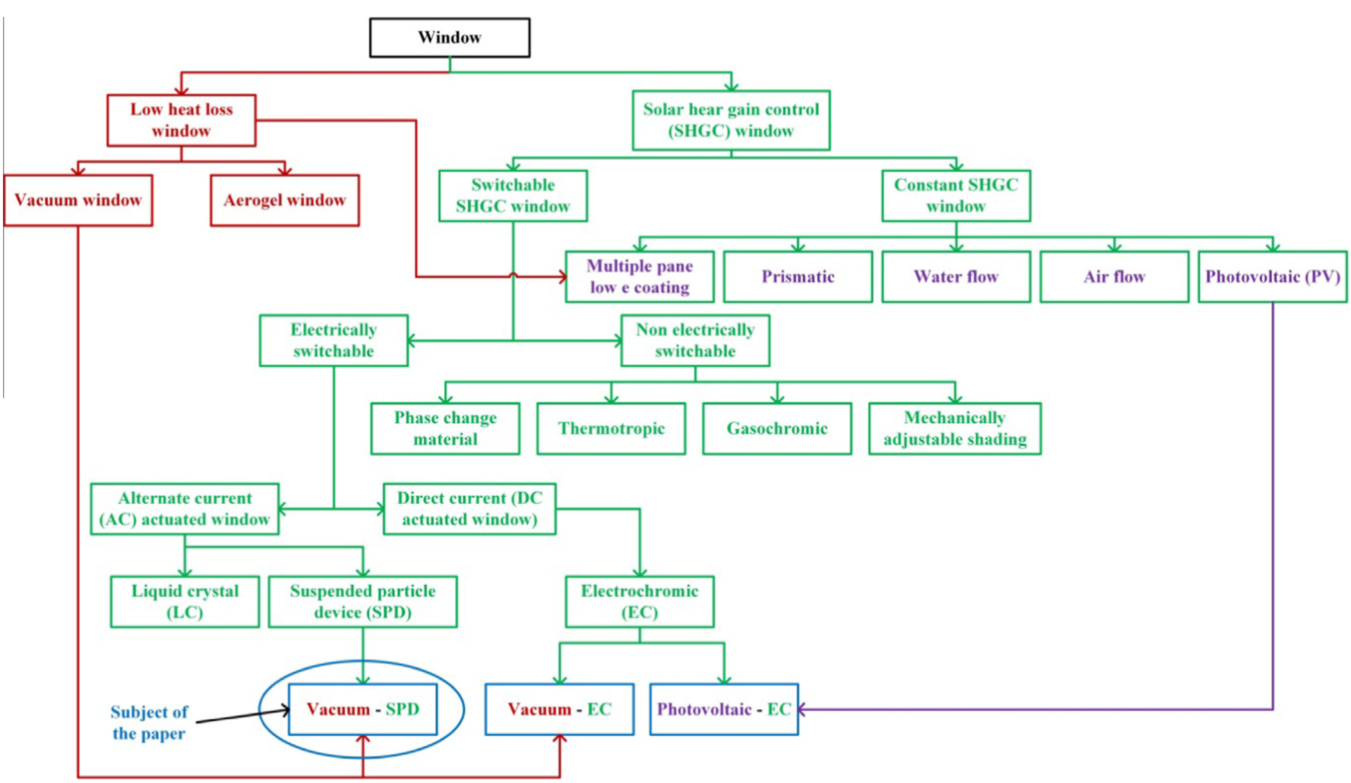

Fig. 1. Taxonomy of window system.