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Measured overall heat transfer coefficient of a suspended particle device switchable glazing

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HIGHLIGHTS

- Test cell experimental characterisation is performed for a suspended particle device (SPD) switchable glazing.
- The overall heat transfer coefficient of an SPD glazing has been calculated and compared with double-glazing.
- Thermal behaviour of SPD glazing was improved by adding one double-glazing.

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ABSTRACT

Suspended particle device (SPD) switchable glazing can change optical transmission from "opaque" state to "transparent" state in the presence of an alternating current (AC) power supply. It can be applied to control internal temperatures in buildings. Thermal characterisation of both SPD and same area of a double-glazing sample was accomplished using an outdoor test cell in Dublin, Ireland. The overall heat transfer coefficients (*U* value) were calculated for both systems from the experimental data. The average *U* values for SPD and double glazing samples were found to be 5.9 W/m^2 K and 2.98 W/m^2 K, respectively. Addition of double-glazing to this SPD switchable single glazing offered a *U* value of 1.99 W/m^2 K.

1. Introduction

Building's windows offer daylight, solar heat gain, privacy, visual amenity, comfort, as well as control of light and air. They interact dynamically with both internal and external environmental conditions, with either heat gains or losses occurring through them [1–3]. In warm sunny weather, solar heat gains through a window usually cause an increase in room temperature. In air-conditioned offices, to avoid the latter reaching discomfort levels, additional energy is used to provide cooling [4]. To obviate cooling loads, new window designs have been developed in recent years that enable control of solar heat gain. As illustrated in Fig. 1, those include partially opaque glazings such as photovoltaic (PV) windows [5–8] and transparent to opaque switchable windows [9–11]. In the PV window, a PV device that generates electricity is sandwiched between or laminated on to glass panes introducing a constant opacity that allow less admission of solar heat gain [12–14]. However, the constant opacity of PV glazing does not offer control over solar gains. 'Switchable' windows, on the other hand, alter their opacity [15,16] allowing active control of solar gain. Non-electrically actuated smart windows include gasochromic [17–20], thermochromic [21], and thermotropic [22].

Electrically actuated switchable include

(1) Mechanically adjusted blinds [23,24].
(2) Introduction of fluids between glazing panes [25–27] or fluids on the glazing surfaces [28,29].
(3) Glazing having solid material between two glass panes and can be in the form of electrochromic (EC), liquid crystal (LC), and suspended particle devices (SPD).

A taxonomy of such systems is shown in Fig. 1.

Electrically actuated switchable windows have the significant advantage over non-electrically actuated technologies of being controlled manually or automatically in response to the occupants' comfort levels. They also avoid operation, maintenance and durability issues associated mechanically moving parts or fluid introductions and removal.

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Nomenclature

A	aperture area of glazing (m^2)
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)
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)
Q_{in}	total energy incident on the glazing (W)
Q_{tc}	total energy available inside the test cell (W)
Q_g	heat through the glazing due to incident solar radiation (W)
Q_{loss}	heat loss through the surfaces of test cell
$T_{in,tc}$	interior temperature (°C)
$T_{out,tc}$	ambient temperature (°C)
$T_{g,s1}$	glazing outside surface temperature (°C)
$T_{g,s2}$	glazing inside surface temperature (°C)
U	overall heat transfer coefficient of glazing (W/m^2 K)
U_{spd}	overall heat transfer coefficient of SPD glazing (W/m^2 K)
U_{double}	overall heat transfer coefficient of double glazing (W/m^2 K)
$U_{spd\text{-}double}$	overall heat transfer coefficient of SPD-double glazing (W/m^2 K)
U_{wall}	overall heat transfer coefficient of test cell wall (W/m^2 K)

Greek symbols

α	absorptance
τ	transmittance
θ	incident angle

Advantages of electrochromic (EC) glazing over other electrically actuated glazing systems are their relatively low power requirements, control of near infra radiation (NIR) radiation and high luminous transmittance of the transparent state [30–33]. However, an EC glazing requires a direct current (DC) supply for colour switching [32–34]. This necessitates the inclusion of a rectifier when an EC glazing is connected to a mains alternate current (AC) power supply [35–38]. The use of EC technology in hot climates is not recommended. An opaque EC glazing absorbs heat creating a heat source inside the building. The internal surface temperature of a combined vacuum glazing and electrochromic window was found to reach in excess of 90 °C [39] in laboratory tests. Durability is a further limitation of EC glazing. To date, EC windows life spans have demonstrated consistent behaviour over 2000–25,000 switching cycles [40].

In a SPD glazing, a cross-linked polymer matrix with droplets of polyhalide particles is suspended in a liquid suspension located between two glass panes [41,42]. The polyhalide particles, which are less than 200 nm in size for optical clarity, are normally free to rotate but become aligned in the presence of an electromagnetic field.

An SPD glazing has two main advantages over EC systems:

- It can be connected directly to an AC power supply.
- No power is required to control the solar heat gain in sunny day, as an SPD remains opaque in its un-powered condition.

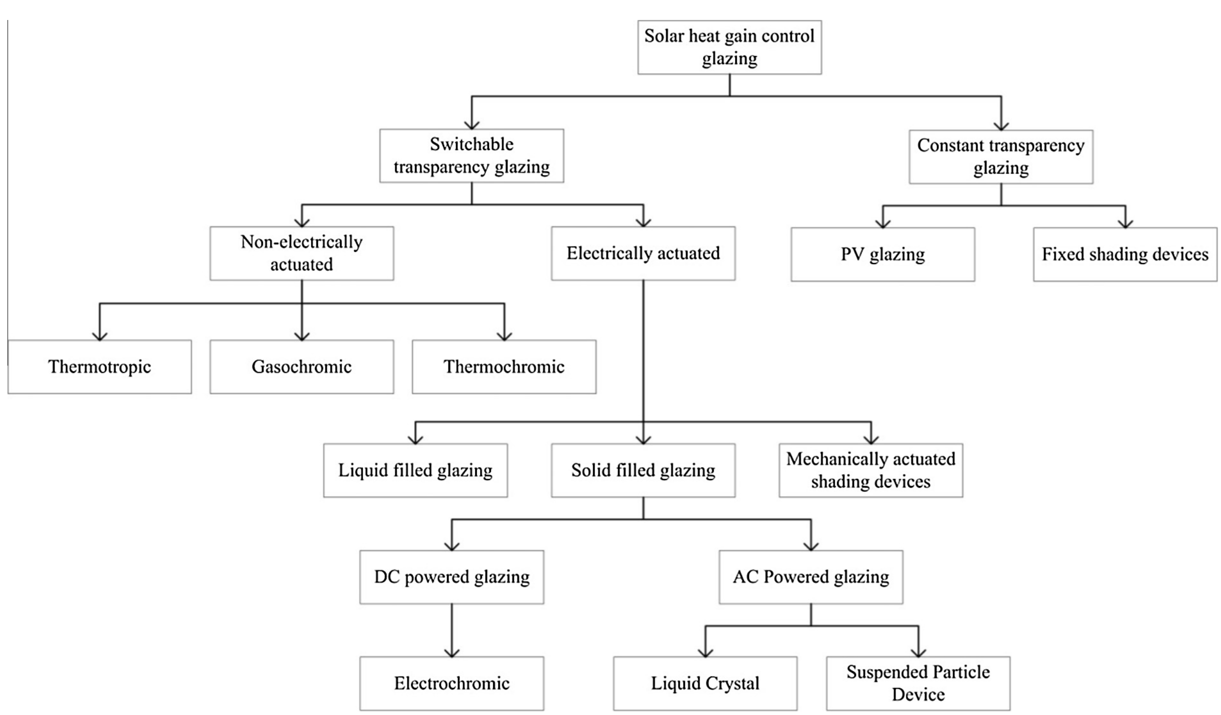

Fig. 1. Taxonomy of solar heat gain control glazings.