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Evaluation of optical properties and protection factors of a PDLC switchable glazing for low energy building integration

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ABSTRACT

Polymer dispersed liquid crystal (PDLC) glazing is a potential electrically actuated switchable adaptive glazing for low energy building application as it become transparent in the presence of alternating current (AC) power supply and become translucent/opaque without power supply. Optical properties and protection factor for a particular type of PDLC glazing was investigated in this work. Using UV–vis–NIR (1050) spectrophotometer spectral transmittance of this glazing was measured for its both states. PDLC on state needs 20 V AC power supply to offer 41% transmission while without any supply this glazing becomes 23% transparent. In the switch off state LC particles offer forward scattering which makes this glazing translucent with high 82.6% haze. Solar factor for PDLC transparent and translucent state was found to be 0.53 and 0.39 respectively. Glazing protection factors were calculated using spectral transmittance data. Switchable transparency and switchable solar factor makes this glazing suitable to match adaptability of building occupants.

1. Introduction

Incident solar radiation on a glazing consist visible and invisible solar spectrum. Visible solar spectrum offers daylight which is essential for occupant health mood and positive working environment. However, due to excessive penetration of light through highly transparent glazing possess discomfort. Controlling of invisible part of solar spectrum is also essential as they carry considerable amount of energy which changes a building's thermo-physical properties and enhance the cooling and heating load [1–5]. Transparent nature of building's glazing allows diurnal variation of visible light which has impact on occupant health and comfortable working environment. High-energy part of the solar spectrum, i.e., ultraviolet light can damage human skin, building materials like wood, plastic and paint. A suitable glazing is thus required which can give the protection to the building occupant from vulnerable exposed solar radiation. Controlling these solar spectrums is possible by shading devices tinted film or angular selective shading device [6,7]. However these systems has drawback due to requirement of maintenance, cleaning and less potential of controlling direct or diffuse solar radiation. Modern smart glazings [8,9] such as vacuum [10–12], low emission coating [13], aerogel [14], photovoltaic [15,16] offers higher performance in terms of building energy saving. However due to constant transparency they are not suitable for occupants adaptation [17]. Switchable glazings are best suited adaptive glazing as they offer more than one transparency [18,19]. Switchable glazing is mainly electrically and non-electrically activated [20–22]. Non electrically switchable glazing includes phase change material [23], thermochromic [24], thermotropic [25,26], gasochromic [27]. These non-electrically activated switchable glazing may possess intermediate transparency between opaque and transparent state but controlling them is not possible. Electrically activated glazing gain confidence as each of their intermediate transparency level is controllable [28–30]. Three available electrically activated switchable adaptive glazings are electrochromic (EC) [31,32], suspended particle device (SPD) [33–35] and liquid crystal (LC) [36] type.

Most investigated electrically activated switchable adaptive glazing is EC due to its control over NIR solar spectrum [37,38]. Tungsten tri oxide (WO_3) is the most common EC material for glazing application due to higher stability [39–42]. EC glazing does not require continuous power supply to keep this glazing switch on condition [43–45]. It has potential to allow comfortable daylight at indoor space and glare control [29,30]. This glazing offer high modulation of transparency between opaque and transparent state (5:11) [29,30] and visible transmittance over 60% is also achievable [39]. Large scale EC devices (1.2 m × 0.8 m and 1.2 m × 0.5 m) showed potential of energy saving and offered occupant comfort while investigation was done using PASSYS cell for field test and office room [46]. Most recently web coated (plastic substrate) EC foil technology has been investigated for light weight EC device which replace the necessity of glass substrates [47].

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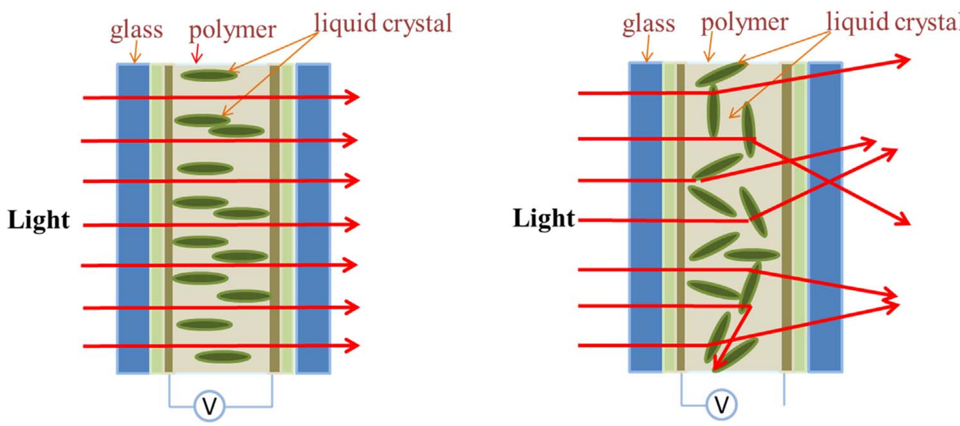

Fig. 1. Schematic presentation of PDLC glazing for its switch on transparent state and switch off translucent state.

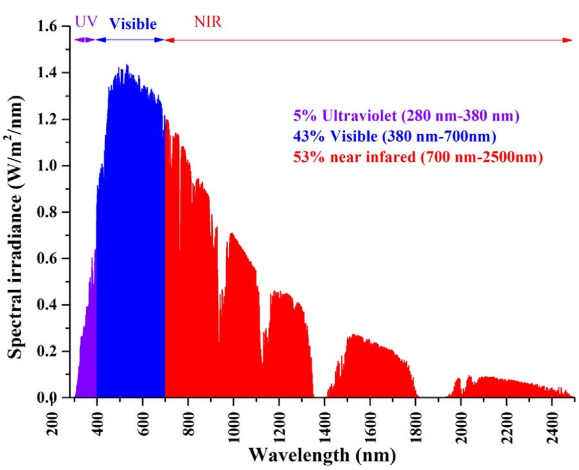

Fig. 2. Solar energy distribution.

Recently SPD glazing was also investigated for its potential application for low energy building. Daylighting [48], electrical [49] and thermal [50] performance of SPD glazing was investigated using outdoor characterisation for northern latitude climate (Dublin, Ireland) and found be a good candidate. SPD glazing suffers from high voltage requirement to obtain transparent state [11], and no control over NIR [50].

Liquid crystal (LC) is an AC powered electrically activated switchable glazing which is suitable for building glazing application [51–53]. In this glazing LC are sandwiched between two glass panes. Twisted nematic, ferroelectric, guest host, and polymer dispersed are the major liquid crystal used for LC device [54]. PDLC types are best suitable over other types for glazing as it does not require polarizer to operate [54].

In PDLC glazing liquid crystal are dispersed into the polymer matrix. In the application of electric power crystals are oriented in an order to pass light and become transparent. Without electric power crystal orientation becomes random and lights are scattered which offer translucent state as shown in Fig. 1.

Research are involved to manufacture different haze free LC material for LC glazing whereas less reports are available about its different essential parameter which is required for building application. Solar glazing factor such as glazing solar transmittance, absorbance, reflectance, UV and visible transmittance, solar material protection factor and solar skin protection factors are essential parameters to determine the glazing' suitability for building application [55–57]. The purpose of this work is to investigate these solar factors for a PDLC glazing.

2. Evaluation of solar glazing factors

Incident solar radiation on the earth surface has visible spectrum range between 380 to 780 nm. Radiation below and above this range is called ultraviolet (UV) and near infrared (NIR) as shown in Fig. 2. Solar spectrum of the radiation changes depends on the exposure level. High energy part of the solar spectrum i.e. UV light has negative impact on the glazing durability. This light can damage human skin and discolour the building interior material like wood, wall colour. Thus, knowledge of protection level of glazing is required before installing for new low energy or retrofit building.

UV transmittance, luminous (visible) transmittance and reflection, solar transmittance and reflection was calculated using Eqs. (1)–(5), respectively. $S_{uv}(\lambda)$ is relative spectral distribution of ultraviolet solar radiation. D_{65} is the relative spectral distribution of the illuminant D65, V(λ), $V(\lambda)$ is the spectral luminous efficiency of a standard photopic observer, $S(\lambda)$ relative spectral distribution of solar radiation and $\Delta\lambda$ is the wavelength interval. $T(\lambda)$ and $R(\lambda)$ are the spectral transmission

Fig. 3. Photographs of PDLC glazing for its switch on and switch off states.