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Daylight characteristics of a polymer dispersed liquid crystal switchable glazing

Aritra Ghosh[a,b,*], Brian Norton[b], Tapas K. Mallick[a]

[a] Environmental and Sustainability Institute, University of Exeter, Penryn, Cornwall, UK
[b] Dublin Energy Lab, Dublin Institute of Technology, Dublin, Ireland

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ABSTRACT

The daylighting performance of a polymer dispersed liquid crystal (PDLC) switchable glazing has been evaluated using an unfurnished outdoor south-facing test cell with a glazing-to-wall ratio of 1:9. Useful daylight illuminance levels (UDI) were determined for clear sunny, intermittent cloudy and overcast cloudy days. Daylight glare indexes (DGI_N) was calculated for the PDLC glazing in its transparent and translucent states. An electrically-actuated adaptive PDLC switchable glazing with transparency that varied between 27% and 71% was able to control daylight glare.

1. Introduction

Replacing artificial light with daylight (i) reduces the building energy consumption [1] (ii) enhances visual comfort [2] (iii) prevents or reduces eyes tiredness and fatigue [3] and (iv) achieves natural daylight colour rendering [4,5]. Reducing artificial lighting energy demand in building during the day requires appropriate daylighting design [6–8]. Occupant visual comfort can be maintained via the use of curtains, blinds and adaptive glazings that actively or passively adjust their optical properties [9–11].

Acceptable illuminances for work and study inside a room can vary between 100 and 2000 lx as shown in Table 1 [12].

Switchable glazing includes electrochromic (EC) [17–19], gasochromic [20], thermochromic [21], thermotropic [22,23], liquid crystal (LC) [24], suspended particle device (SPD) [25–28] and phase change materials (PCM) [29]. These glazing can be electrically, thermally, or chemically actuated. Electrical actuation of switchable glazings EC, SPD, and LC gives control of the switchability of glazing [30–34]. EC glazing changes its transparency from transparent to opaque state in the presence of direct current power supply. EC glazing can control NIR [35,36]. Higher switching time of EC glazing can be mitigated using suitable powering [37]. Degraded EC films (both based on W oxide and Ti oxide) can be rejuvenated by galvanostatic treatment [38–40]. Large scale (1.2 m × 0.8 m and 1.2 m × 0.5 m) EC device was also investigated using PASSYS test cell [41]. Daylight and glare performance of EC glazing has been evaluated theoretically in a hot climate in a west orientated wall [42–44] and evaluated experimentally performed for computer tasks [45]. Operated by an alternating current power supply, SPD glazing changes its state from opaque to transparent [46]. SPD glazing has a low switching time [47] intermediate transmission states between opaque and transparent state and high stability [48]. However controlling thermal comfort with SPD requires additional coated panes as the near infrared transmission is high [49]. Daylight and glare performance of SPD glazing has been evaluated [50]. In a liquid crystal (LC) glazing, LC films are sandwiched between two glass panes as shown in Fig. 1. Due to the anisotropic electrooptic properties of the LC material, transmitted light through the cell is controllable by applying appropriate voltages [51–54]. Polymer dispersed liquid crystals (PDLC) types are suitable compared to twisted nematic, ferroelectric and guest host type LC as they don't need polarizer to operate [55]. Liquid crystal droplets with diameters in the range of 1–20 μm in a polymer matrix form a PDLC. In the presence of an electric field LC droplets are aligned with electric field so allowing light passes through it. In the absence of an electric field LC droplets orient isotropically, scattering incident beam so becoming white translucent.

2. Methodology

Daylight glare index (DGI) [56,57] has been used to characterise EC glazing [42,43] and for SPD glazing [50] using data from a test cell. The DGI_N is given by

$$DGI_N = 10\log_{10}0.478\sum_{i=1}^{n}\frac{L_{ext}^{1.6}\Omega_{pN}^{0.8}}{L_{adp}+0.07\omega_N^{0.5}L_{win}} \quad (1)$$

* Corresponding author at: Environmental and Sustainability Institute, University of Exeter, Penryn, Cornwall, UK.
E-mail address: aritraghosh_9@yahoo.co.in (A. Ghosh).

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Table 1
Acceptability of illumination.

		Acceptability	Activity	Reference
Illuminance level (Lux)	≥ 150	Comfort	Working space	[13]
	500	Comfortable	Office work	[14]
	500	Comfortable	Office work	[15]
	840–2146 (morning)	Comfortable	Office work	[4,5,15]
	782–1278 (afternoon)	Comfortable		
	700–1800	Comfortable	Computer work	[16]
	100–2000	Useful Daylight Illuminance	Any types of work	[12]

where L_{ext} is the exterior luminance of the outdoor source including direct sunlight, diffuse skylight and reflected light from the ground and other external surfaces (cd/m2), L_{win} is window luminance (cd/m2), L_{adp} is adaptation luminance of the surroundings including reflections from internal surface (cd/m2), ω_N is solid angle subtended by the window, Ω_N is solid angle subtended by the glare source. Schematic diagram showing DGI_N is given in Fig. 2. The luminance level 5 provided by glazing, adaptation and exterior are calculated from Eqs. (2)–(4).

$$L_{win} = \frac{E^{in}_{V,win}}{2\pi\phi} \tag{2}$$

$$L_{adp} = \frac{E^{in}_{V,adpt}}{\pi} \tag{3}$$

$$L_{neag} = \frac{E^{in}_{V,neag}}{2(\pi - 1)} \tag{4}$$

where

$$L_{ext} = L_{neag}$$

$$\omega_N = \frac{[ab\cos(\tan^{-1}X)\cos(\tan^{-1}Y)]}{d^2} \tag{5}$$

$$\Omega_N = 2\pi\phi \tag{6}$$

The configuration factor ϕ was calculated from the Eq. (7) using (Fig. 2)

where

$$\phi = \frac{(A\tan^{-1}B + C\tan^{-1}D)}{\pi} \tag{7}$$

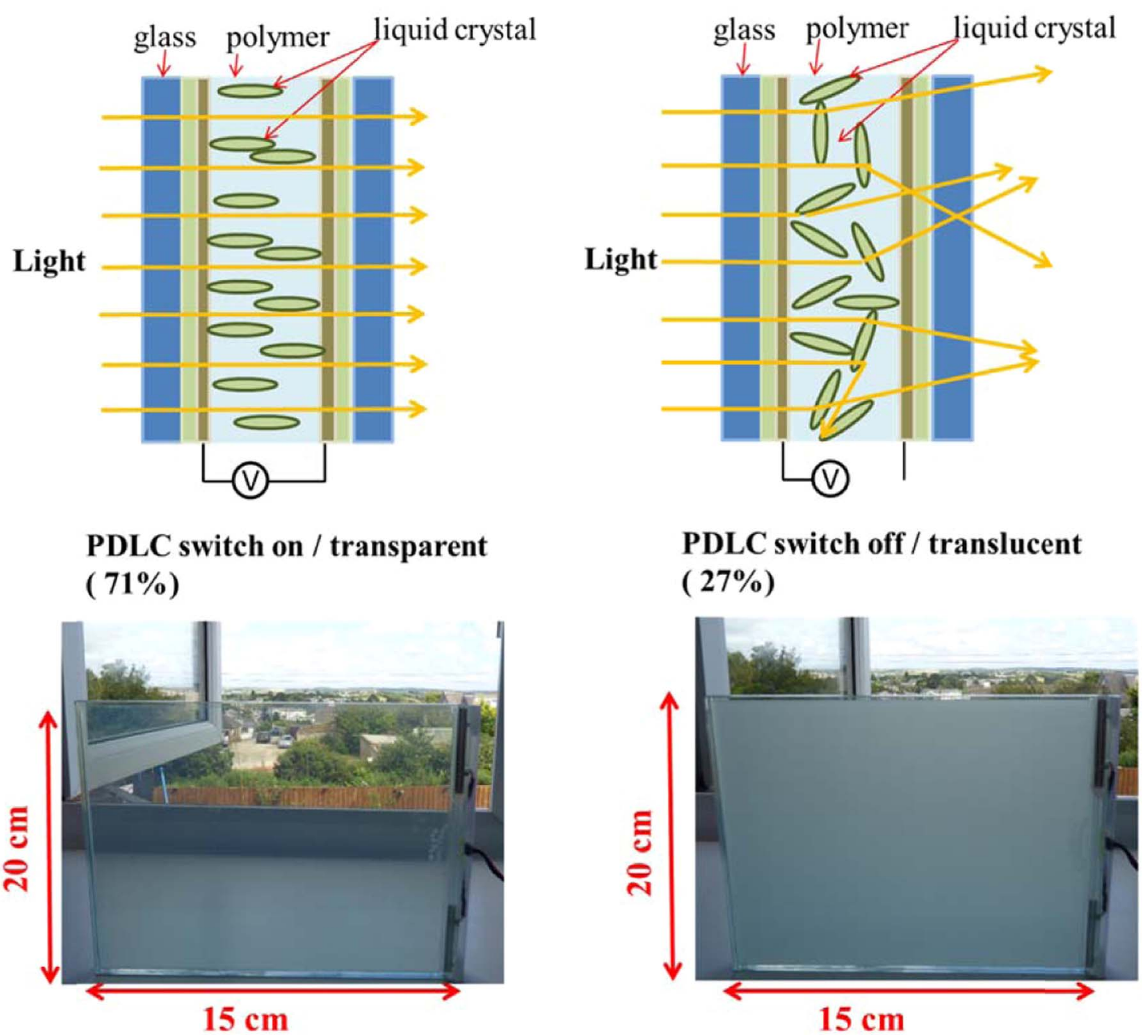

Fig. 1. The “transparent” and “translucent” states of a PDLC glazing. As PDLC glazings are intended for architectural applications, thus PDLC glazing daylight and glare results are essential information for building integrated PDLC switchable glazing. In this work first outdoor characterisation of PDLC glazing using test cell was performed to find out its glare and daylight control potential.