The Long-Term Evaluation of Electrochromic Glazing in an Open Plan Office under Normal Use: Project Outline

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Introduction

Electrochromic (EC) glazing is emerging on to the market as a viable alternative to fixed transmittance glazing with traditional shading devices. In a double glazed EC window, one of the panes of glass has an electrochromic coating that enables it to change transmittance in response to a small applied voltage.

EC glazing has the potential to enable users to control glare from direct sun or bright patches of sky without the use of window blinds, giving users more access to daylight with all its inherent benefits. Users could benefit from having a view through the window throughout the day, even when the glass is fully tinted. Furthermore, EC glazing could reduce energy usage through a reduction of electric lighting use and a reduction of solar heat gain.

Research background

Previous research on the use of EC glazing in buildings has been based on scale models (Piccolo et al, 2009 & 2010), computer simulations (Sullivan et al, 1994; Moeck et al, 1998; Jonsson & Roos, 2010 and others) and full scale test rooms (Lee & DiBartolomeo, 2002; Zinzi et al, 2004; Rottmann et al, 2007). Several (Lee et al, 2006; Clear et al, 2006; Zinzi, 2006) have investigated the subjective effects of EC glazing on room occupants and have involved human participants. A recent study (Lee, 2012) investigated the effects of EC glazing in a functioning conference room in Washington DC, US. However, the usage patterns of a conference room (i.e. intermittent with highly variable occupancy) tends to confound attempts to make a systematic evaluation of user acceptance. Thus, in general, the literature review carried out to date indicates that there is a lack of research in real world settings, and essentially no research has been carried out over long-term monitoring periods (i.e. greater than six months).

This study aims to address these two important dimensions, by carrying out a case study into the effects of EC glazing in two existing and continuously occupied offices, the first installation of EC glazing in the UK. This paper describes the research questions to be addressed by the study and outlines some of the methodology. The installation of the EC glazing is planned for August 2012, and we will present our initial findings at the Experiencing Light conference in Eindhoven (November, 2012).

We believe that this study will have particular relevance for the building refurbishment sector. Refurbishment projects often involve changes that are primarily to the façade of the building. Contemporary buildings with highly glazed facades often suffer from problems of visual discomfort and solar gain. This in turn can lead to poor daylighting since the blinds are regularly left closed for extended periods (Van Den Wymelenberg, 2012). EC glazing could remove or at least reduce this problem by lessening the dependence on traditional shading devices such as blinds. To establish the potential of EC glazing in real world applications, the field trial needs to assess the direct impact on the visual and thermal environment as well as end user experience of the technology.

Research questions

The main research questions are as follows:

1. What are the practicalities of implementing this technology in a retrofit situation?
2. What is the optimum control strategy?
3. Can EC glazing without blinds provide visual comfort?
4. What is the effect of the EC glazing on subjective colour perception?

Proposed methodology

A case study will be carried out in two adjacent open plan offices in a university campus building. The rooms contain large southeast facing windows, and each room accommodates a small number of administration staff (seven in total). Figure 1 shows the interior of the two rooms before the EC glazing installation. Figure 2 shows the exterior façade of the two rooms, where it can be seen that the rooms share 3 windows between them, with a partition at the centre of the middle window. The monitoring period will be approximately 18 months, sufficient to encompass a variety of seasons and sky conditions.

Fig 1. The interior of the offices that will be used in the case study

Fig 2. The exterior façade showing the windows of the two case study rooms

The glazing product that will be used in the study is a double-glazed unit with an electrochromic coating on surface 2 (inside surface of exterior pane). The visible transmittance of the glass varies from 62% in the fully bleached state to 2% in the fully tinted state, with two intermediate states (20% and 6%). The glazing can be controlled automatically or manually. The control system can be zoned so that individual panes (or pairs of panes) can be controlled independently. The set-up can be summarised as follows:

Base case

- Switched fluorescent lighting
- Clear double glazing (poor condition)
- Window blinds

Test case

- Daylight-linked fluorescent lighting with occupancy sensing
- Electrochromic double glazing
- No window blinds

Reference case

- Daylight-linked fluorescent lighting with occupancy sensing
- Electrochromic double glazing switched to a continuous fully bleached state
- Window blinds

Preliminary monitoring is being carried out on the base case to provide some useful background data. The impact of EC glazing will be assessed by comparing the test case and reference case. The main study participants are the occupants of these rooms, and therefore will be exposed to both conditions. As such, this is a within-subject enquiry.

Ideally, the existing manually switched fluorescent lighting system would be changed in advance of the EC glazing installation to isolate the effect of the lighting system upgrade. However, in order to minimise disruption to the occupants, the lighting upgrade will occur at the same time as the EC glazing installation. A preliminary study revealed that the overwhelming concern that the occupants had regarding the luminous environment was with respect to the blinds and visual discomfort, rather than the artificial lighting. A settling-in period will allow occupants to get used to the new lighting system before beginning proper assessment of the impact of the EC glazing. Thus we believe that any ‘confounding effect’ of changing both the glazing and lights together will be minimised.

The lighting control system and EC glazing control system will be linked so that they can work together to provide control of the luminous environment. The monitoring campaign will capture both the response of occupants (subjective) and the impact on the physical environment (non-subjective).

Subjective measures

The subjective effects will be assessed using a combination of face-to-face interviews, questionnaires and diaries, which allow users to give regular qualitative feedback. The subjective assessment will capture the users’ experience in terms of:

(i) Visual comfort
(ii) Thermal comfort
(iii) Other subjective effects (e.g. alertness, wellbeing)
(iv) User-friendliness
(v) Colour perception

This assessment will give us an understanding of the effect of EC glazing on visual and thermal comfort, and on the wellbeing and alertness of occupants. The effect of the glazing in its tinted states on the perception of colour will be investigated in a separate experiment involving a different set of participants undertaking the Farnsworth-Munsell 100 Hue Test under controlled conditions and stable sky conditions.

In addition we will gain valuable feedback on occupants’ experience of EC glazing, for example on the speed of response of the system, and the manual control interface.

Non-subjective measures

In parallel to the subjective assessments, a set of data will be gathered to capture the impact of EC glazing on the physical environment of the offices.

High Dynamic Range (HDR) imaging will be used to capture and quantify the luminous environment. Figure 3 shows a test HDR image taken in one of the case study rooms on an overcast day. It is not practical to locate the HDR cameras at the occupants’ eye position, so the cameras will be positioned in view of the windows and will be compared with test images taken from the point of view of each occupant, to assess their validity. Additionally, when opportunities allow (e.g. weekends or when a participant is on leave), a HDR camera will be placed to match the occupant’s typical viewing position. With a sufficient number of these ‘opportunistic’ HDR captures and simultaneous ‘reference’ HDR captures we hope to be able to infer the visual conditions (from the occupant’s perspective) that triggered a manual override.

The software tool EvalGlare will be used to predict discomfort glare in the visual scene. These data will then be compared with the subjective experiences of the occupants.

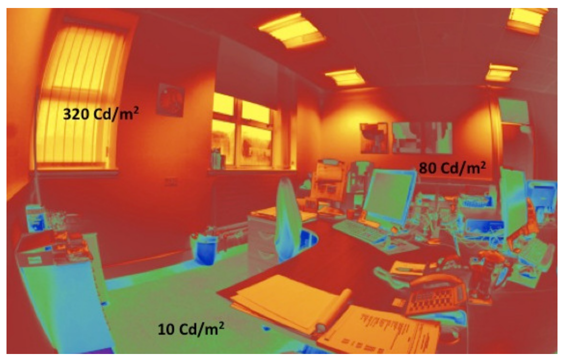

Fig 3. A test HDR image taken in one of the offices that will be used in the field trial

Other measurements will be carried out to assess the thermal conditions and the status of various key items of equipment. To summarise, the key measurements are as follows:

(i) Visual scene luminance (HDR)
(ii) Room temperature
(iii) Air conditioning status
(iv) Heating status
(v) Interior illuminance
(vi) EC window control status
(vii) Lighting control system status

In addition, external weather data will be accessed via a local weather station to give context to the interior measurements and assist with data analysis.

Preliminary data collection

A semi-structured interview was undertaken prior to any modifications to the offices' lighting and shading setup. The interview used a combination of scaled response and free text entries, and the questions were partly based on the questionnaire used in Clear et al (2006) and Osterhaus (2005). Four participants were interviewed, with the main aims as follows:

1. To gauge the occupants' current level of satisfaction with their office environment, in terms of visual comfort, thermal comfort and other relevant factors.
2. To gain insights into any particular problems experienced by occupants, e.g. recurrent glare problems at certain times of the day/year.
3. To learn about the participants' individual preferences, sensitivities and any relevant health conditions.
4. To enable the researcher and the participants to get to know each other, as part of the engagement process.

In addition, automated monitoring of the offices is being conducted in advance of the EC glass installation. This includes HDR captures, illuminance and temperature measurements. The data collected from this preliminary stage will provide useful background information on the conditions in the offices before the retrofit.

The findings of these preliminary data collection activities will be discussed at Experiencing Light 2012.

Summary

Based on physical characteristics alone – principally the wide dynamic range between clear and tinted states – EC glazing has significant potential to transform the way we use glass in architecture. This study will explore that potential by assessing the impact of the technology on end users in a real world setting. By measuring the subjective as well as the non-subjective effects in a typical office setting under normal use, a valuable data set is expected. One of the anticipated findings of this research will be to determine if occupants in a space with electrochromic glazing can control glare effectively without requiring the additional use of traditional shading devices such as blinds.

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