10 Eco-efficiency analysis of an electrochromic smart window prototype

Spiros Papaefthimiou, Elleni Syrrakou and Panayiotis Yianoulis
Solar Energy Laboratory, Physics Department, University of Patras, Greece

Abstract

The environmental efficiency of a prototype electrochromic window was studied using eco-efficiency methodology, combined with life cycle assessment. The data obtained on the specified eco-efficiency indicators provide significant information that could be used in decision-making for the optimisation of the window's energy and environmental performance. The energy efficiency of the product is affected by its life expectancy and the climatic zone. It was found that in cooling-dominated areas the energy needs of buildings can be reduced by more than 55%, while the total energy saved can be 30 times the energy consumed during an expected 25 years life cycle. The corresponding CO_2 and human toxic emissions reductions were estimated to be 6 times those achieved with a conventional double-glazed unit. An expected retail price of 200 euros per m^2 for an electrochromic window would result in a cost of less than 0.10 euros for each kWh saved over a 20-year lifetime. Consequently, purchase cost reduction will be necessary if such devices are to meet market expectations for solar control window products.

10.1 Introduction

Windows incorporating electrochromic (EC) films have been evaluated as a promising subject for research into advanced glazing materials

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(Grandqvist 1995; Karlsson et al. 2001; Sbar et al. 1999; Selkowitz 1994). An EC window is an active solar control device whose transmittance in the visible and near IR parts of the spectrum can be reversibly modulated by applying a low voltage (typically 3–5 V DC). A typical EC device has a 5-layer structure consisting of (1) a transparent and electrically conductive film (ITO) deposited on glass, (2) an electrochromic film (usually tungsten oxide – WO_3), (3) an ion-conducting electrolyte (either a polymer or a solid state compound), (4) an ion storage layer and (5) a second transparent conductive film (Grandqvist 1995). Devices using polymer electrolytes require two glass sheets, one with the ITO/electrochromic oxide and the other with the ITO/ion storage layer. The polymer electrolyte can serve as the laminating medium that holds together the two coated glass sheets. When the external voltage is applied, the lithium ions move into the electrochromic oxide matrix, thus altering its optical properties. The general characteristics, energy benefits and potential savings ensuing from the use of EC windows are summarised in Figure 10.1 (Granqvist 1995; Papaefthimiou et al. 2006; Syrrakou et al. 2005).

An EC window:

- ⇨ has infinite coloration stages
- ⇨ ensures acceptable visual transmittance
- ⇨ can block both direct and diffuse solar radiation
- ⇨ reduces glare and thermal losses
- ⇨ has no maintenance costs (no moving parts)
- ⇨ requires low voltage power supply
- ⇨ provides architects a choice for a "living" building envelope
- ⇨ reduces cooling, heating and ventilating loads
- ⇨ reduces electric lighting
- ⇨ reduces *GHG* emissions

Figure 10.1 Electrochromic window prototype in the coloured state

The system we studied is a 40 × 40 cm EC device, which comprises the five typical layers. Two Pilkington K-Glass^{TM} sheets (called K-Glass hereafter) serve as the transparent conductor. One is coated with the optically active layer, a 350 nm thick WO_3 film deposited by electron gun deposition, while the ion storage layer, a lithium-doped vanadium pentoxide film