

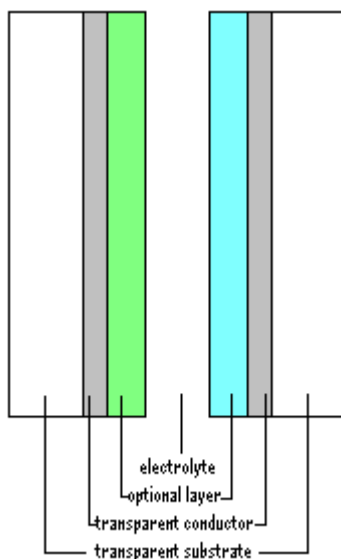
Electrochromic Systems: Now You See It Now You Don't

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Everyone has had the night-time driving experience of being momentarily “dazzled” by headlights coming up from behind, particularly with the increasing use of high-intensity discharge lamps on more vehicles. Among other challenges resulting from rapidly increasing energy costs of the early 21st century is maintaining building interior comfort while maximizing the use of renewable resources such as solar energy. **Electrochromic systems** offer some clean and affordable solutions to these and other needs of society.

The Fundamental Science

Electrochromic (EC) systems may be thought of as planar structures (e.g., windows) that provide for gradually changing the amount of light and solar heat allowed through the plane of the system over a continuum as an applied potential is adjusted. This is achieved using reduction-oxidation (redox) chemistry to change the visible color and the optical density of the system. For many solid-state EC systems, this change in optical density (i.e., the transmittance of the system) remains constant even when the applied potential is discontinued, but is reversible by applying a potential of opposite polarity. Devices may be fabricated to undergo thousands of color-bleach cycles. The color of the dark state may be selected from several options including shades of blue, green, red, and black, but the opaque color cannot be changed once a given system is established.



The figure to the left shows a generic EC system. On either side is a transparent substrate, usually glass, but sometimes certain plastics. Deposited onto the surface of each substrate is a thin film of a transparent conductor such as indium-tin oxide (ITO) or fluorine-doped tin oxide (FTO). Depending upon the specific type of EC system desired, another layer may be deposited onto the transparent conductor (and this layer may not be the same for the two “halves” of a given system as shown in the figure). Finally, the middle of this sandwich is the electrolyte. The earliest EC systems, and the ones currently most common in commercial applications, use no optional layers, and use a liquid electrolyte such as propylene carbonate-LiClO₄. More recent systems use a solid-phase electrolyte. Tungsten oxide or the analogous molybdenum oxide (WO₃ or MoO₃) are common cathodic materials, and nickel oxyhydroxide (Ni(OH)₂) is a common anodic material.

As stated above, different specialized EC systems have been developed by using different materials for the optional layers shown in the figure. Ion storage layer devices have one optional layer as a solid electrochromic material such as WO_3 . The facing electrode is coated with a layer that can reversibly insert ions or electrons upon their removal from the electrochromic material. An electrolyte having low electronic conductivity and high ionic conductivity is put between the ion storage and EC layers. When an appropriate DC potential is applied to the transparent conductor layers, ions may be exchanged between the EC layer and the ion storage layer (either inserted or extracted) by traveling through the electrolyte, to provide the desired coloration. Reversing the applied potential reverses this process and the resulting coloration. Charge in either case is compensated by electrons carried by an external circuit. The opacity of the EC system can thus be accurately and reversibly modulated by applying the correct DC potential. Other EC systems may be designed using different approaches to the redox chemistry, and thus different materials for the optional layers. These are well-described in Reference 1.

Applications

The most successful applications to date for EC systems have been automobile rear-view mirrors [1]. Gentex Corporation (Zeeland, MI) is a leader in this area, having provided over 10 million “autodimming” automobile mirrors, both interior and exterior, both OEM and after-market. Automobile windows are not a likely application anytime soon, because they must be at least 70 % transmitting (potentially a problem at night) and because their size is relatively large. Automobile sunroofs, however, have neither of these restrictions, and offer another attractive use. Architectural glass has a much larger area still than the windshield of a car, but it does not have the requirements of having to be “safety” glass or providing rapid bleaching when needed. Given rising energy costs and environmental awareness, EC systems in architecture may become more commonplace soon. EC-based display devices including large outdoor displays (signboards, message boards, clocks) may some day rival liquid crystal displays, according to Ntera, Ltd. (Dublin, Ireland), an innovator in this area with their NanoChromics™ technology. Other applications may include thermal control surfaces that do not also require optical transmission (such as space-based platforms), rapid and precise optical switches for laboratory instruments, and camouflage surfaces.

Alternative Technologies

Various other technologies have been, and continue to be, developed as alternatives to EC systems [2]. None, however, offer all of the features and advantages of ECs.

Thermochromic systems respond to changes in ambient temperature. An otherwise optically clear system becomes white beyond a certain transition temperature. Suntek, Inc. (Albuquerque, NM) offers “Cloud Gel,” a water-soluble copolymer gel sandwiched between two clear substrates. Below transition, the water molecules position themselves around the elongated polymer molecules, which become thinner than the wavelengths of

solar radiation, resulting in transmittance of 90%. Above transition, the water molecules cluster, and transmittance drops to about 10%. The transition temperature can be set anywhere between 60 °F to 150 °F [3]. Application may be skylights rather than windows.

Photochromic systems respond to changes in ambient lighting. They work well to control glare, but don't necessarily control thermal gain. The angle of the sun changes with the seasons, and sunlight strikes a window more intensely during winter. A photochromic system would reduce the resulting glare, but also would darken more deeply at a time when solar heating would be desirable. Scale-up much past the size of eyeglasses also is a challenge.

Liquid crystal (LC) systems respond to an electrical input as do EC systems. With no potential applied, the LC molecules are not aligned, light entering the system is randomly scattered, and the system becomes optically translucent. With potential applied, the LC molecules align, and light is transmitted through the system. But this requires power to be constantly applied to an LC system in order to maintain an optically clear state. Also, LC systems do not provide thermal control. Applications would be strictly for privacy needs.

Summary

Chemistry and materials science can be used to help improve products during the product development cycle. Electrochromic systems offer a versatile method of introducing optical behavior to products. Contact Bjorksten | bit 7 for more information about enhancing your product performance.

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