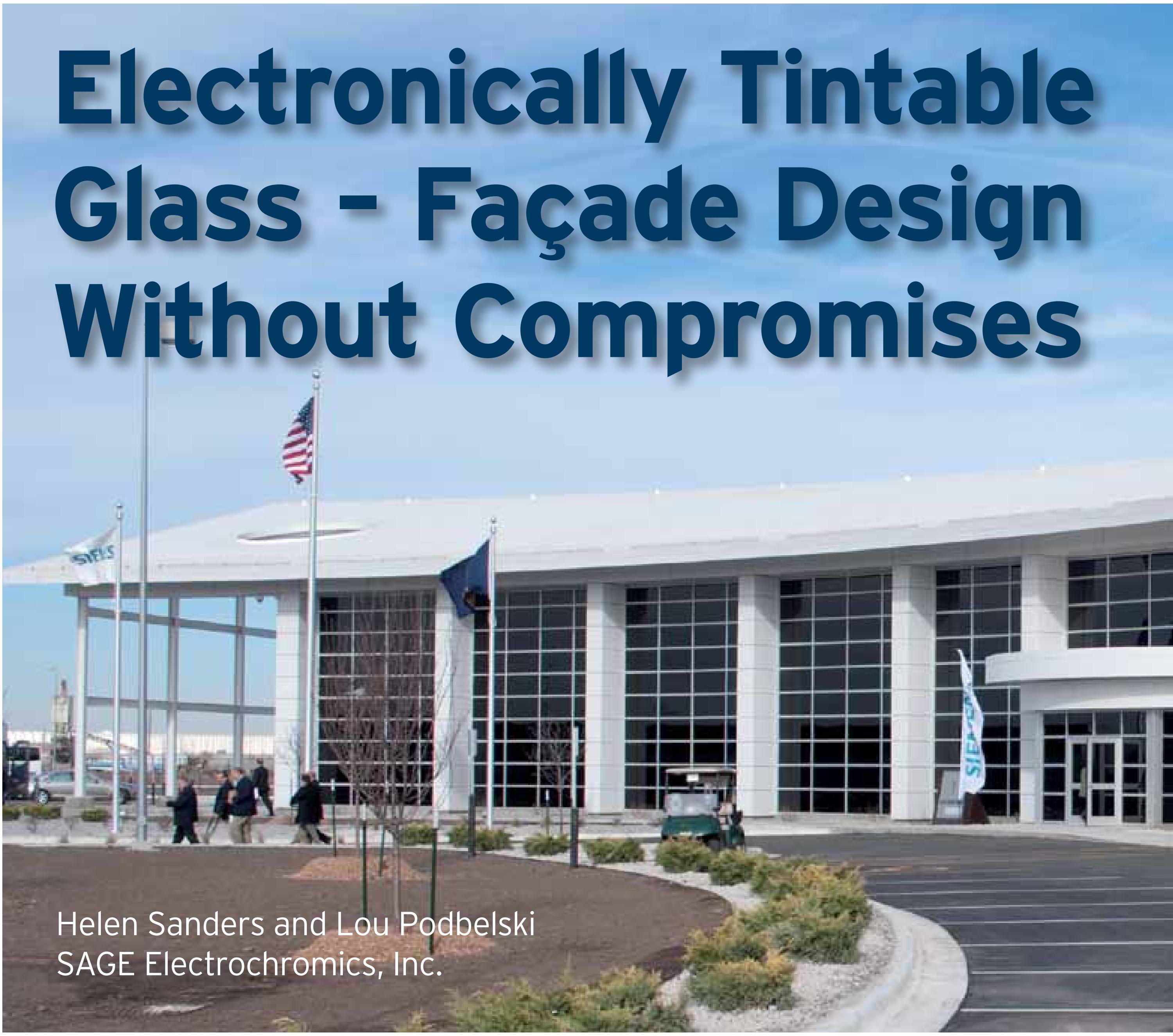

Electronically Tintable Glass - Façade Design Without Compromises

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The Current Debate

Will ever more stringent energy codes mean that highly glazed buildings are a thing of the past? And will architectural design freedom using glass be constrained as we move towards zero net energy buildings?

These are questions being asked more often now as windows are increasingly viewed as the weak energy link in the building envelope [1, 2].

Glass is an important tool for daylighting and having the right amount of glass in the right place on the façade can offset electric lighting usage significantly if used in conjunction with dimmable lighting controls. However, with insulating values lower than walls and at times the cause of unwanted solar heat gain, there is an upper limit in glass area beyond which the additional HVAC loads due to heat gains and losses begin to outweigh the electrical lighting savings, even with an optimum daylighting design.

In an environment of ever increasing building energy performance goals, constraining the amount of glass area in buildings is being widely debated. Indeed, in both Europe and North America we are seeing an increasing trend to reduce window to wall ratio in new building energy codes and standards through either increasing stringency for insulation values and whole building energy efficiency targets [3] or through additional specific window area limits [4].

However, glass is also a key architectural design tool and is ubiquitous in buildings today because of the design flexibility it provides and the positive impact that natural daylight and the connection with the outdoors have on people's health and well-being. Constraining

Figure 1: Siemens Wind Turbine Facility, Hutchinson, Kansas. The façade design features EC glass for a clean aesthetic, instead of a horizontal mechanical louvre system.

the amount of glass that can be used certainly puts limitations on an architect's design freedom.

However, it is also true that too much glass or glass in the wrong location on the building can cause uncomfortable glare and heat for the occupants, as well as a large air conditioning load.

Moreover, because we live in a dynamic environment which changes season-by-season, day-by-day, and hour-by-hour, a traditional "static" building envelope cannot respond effectively to these ever-changing conditions, even if glass is strategically placed around the façade and overhangs employed. Indeed, a static envelope is increasingly becoming a constraint when balancing architectural design with occupant comfort and the rising demands of energy efficiency.

> "Electronically tintable glass can provide the architect with more design flexibility and the ability to use more glass in the face of ever more stringent building codes"

The US Department of Energy has identified three key façade elements required in order to achieve net zero energy commercial buildings [5]: Low U-factor fenestration (reduce conductive losses), dynamic solar control (admit or block solar heat gain and light as needed)

Figure 2: EC glass installed in the Student Services Center at Chabot College, Hayward, CA (exterior view) which is an example of how EC glass can provide additional design freedom to architects. In this case the use of EC glass enabled the use of a natural ventilation system while maintaining a fully glazed south and west facing atrium.

and integrated façades in which dimmable lighting controls are used in combination with fenestration to offset electric lighting with natural daylighting.

Dynamic solar control can be achieved conventionally with mechanical moveable louvre systems or automated Venetian blinds integrated into double skin curtainwalls, and such systems are becoming increasingly more popular in Europe.

Alternatively, electronically tintable glass (also known as electrochromic or EC glass) can be used to provide variable solar control. EC glass can, at the touch of a button or command from a building automation system, modulate its solar heat gain coefficient (g-value) and visible light transmission over a wide range stopping anywhere in between (See graph on page 84 for an example of the performance of an EC product).

By achieving a visible light transmission as low as 2% in the tinted state, EC glass also provides the ability to block uncomfortable glare while maintaining the view to the outside, unlike the mechanical alternatives which block or obstruct the view. The ability to modulate the solar heat gain coefficient (g-value) also provides the designer with a controllable heat and light valve for their building; the amount of light and heat coming into the space can be tuned depending on the exterior environmental conditions and the needs of the occupants.

By dynamically controlling the light and heat flow, significantly more energy savings can be captured than when using a static solution and enhanced occupant comfort with maintained exterior views can be realized. In fact, the use of EC glass provides an architect with the ability to design with more glass without energy penalty.

In this article we explore through three case studies how dynamic glass has been used to provide architects with a tool that can expand design possibilities for the use of glass and enable the creation of exceptionally energy efficient and comfortable daylit spaces that would otherwise not be possible.

Figure 3: Interior view of the EC glass installed in the Student Services Center at Chabot College, Hayward, CA. The glass can be tinted to control the amount of solar heat entering the space to allow effective use of the natural ventilation system.

HVAC-Free Design

The first case study is illustrated in figures 2 and 3 which show exterior and interior images respectively of a two story atrium space at Chabot College Student Services Center in Hayward, California which has been glazed with EC glass. This highly glazed space faces south and west in a cooling dominated climate zone and as such presents significant challenges for glare and heat gain control.

Furthermore, as part of the energy efficiency strategy to meet the US Green Building Council's LEED certification, the architect created this atrium as an HVAC-free, naturally ventilated space, implementing a novel natural air cooling and heating strategy. The temperature of the atrium is controlled by radiant heating and cooling in the concrete slab, combined with roof and ceiling air scoops to provide natural air flow. Implementation of

Figure 4: Dehority Hall at Ball State University. A fully EC glazed roof with clerestory encloses a courtyard to provide a multiuse space. This image shows the EC glass in the clear state condition with the clerestory in the fully tinted state.

Figure 5: Dehority Hall at Ball State University (as in figure 4). The EC glass is in an intermediate state of transmission between fully clear and fully tinted maintaining a set light level in the space.

EC glass gave the architect sufficient range of solar control that he was able to implement his design strategy without needing to reduce the glazed area in the space.

In fact, the architect, Phil Newsome from tBP Architecture, is quoted as saying that the natural ventilation technology implemented in this project would not have been possible without the use of dynamic glass. "This revolutionary dynamic glass controls the amount of sunlight entering the two story space. As a result it has become an architectural enabler that has allowed us to create an HVAC free space."

The EC glass is automatically controlled in three zones through the building automation system based on temperature control points with manual over-ride, providing glare control for the occupants of the private office spaces on the second floor as well as a comfortable temperature in the atrium.

Figure 6: Dehority Hall at Ball State University. In this image, the glass is in the fully tinted state ready to provide the necessary light control for AV presentations.

More Glass Without Compromising Comfort, Functionality or Energy Efficiency

Electronically tintable glass can also provide greater architectural design freedom by allowing the use of glass where otherwise it would be impossible due to too much heat and light admission and the inability to create a comfortable environment.

The application shown in Figures 4, 5 and 6 demonstrates this capability. In this project, dynamic glass has been used in a fully glazed roof to create a very open environment, capturing all the benefits of natural daylight, yet controlling unwanted heat gain, to create a thermally comfortable environment and at the same time providing the ability to darken the space for audio visual presentations.

Dehority Hall at Ball State University in Indiana, USA, features a large skylight (~150 sq.m.) with clerestory glazing around the perimeter. Converted from an open central courtyard into an enclosed space, the university wanted to preserve the open feel of the space and to create a general purpose area serving as a lounge, entryway, and a venue for large group audio visual presentations.

Working in the background using light sensors, the dynamic glass solution in this application provides variable levels of tint in order to maintain a constant user determined light level in the space.

This automatic control can be manually over-ridden to, for example, fully tint the glass when darkening the room for presentations or when full glare control is required.

When considering solutions for the heat and light control problem that they knew they would have, the architects, Schmidt Associates, investigated alternative options involving mechanical shading solutions.

According to the design architect Ryan Benson, EC Glass was a more eco-friendly and aesthetically pleasing alternative to using conventional skylights and architectural controls such as shades, exterior fins or louvres. It enabled him to incorporate more glass into the project without compromising energy efficiency and a view to the natural outdoors.

He said "students perform better with daylighting and views. EC Glass was the best option for the Ball State project because it enabled us to maximize natural light and a view to the outdoors, while creating a space that's thermally and visually comfortable for the students inside".

In addition Gary Canaday, Ball State's Manager of Campus Construction, Facilities Planning and Management, is quoted to have said "we previously had regular glass skylights, but blinding glare and heat was a problem. We looked at installing mechanized shades and blinds, but that option was not attractive and would have created on-going maintenance issues. EC Glass controls the sunlight and heat that enters and leaves the building, reducing our energy use while enhancing and increasing students' use of the space".

Based on this feedback it is clear that the provision of a comfortable space which met both the "open feel" design intent and the full range of occupant needs would not have been possible without the use of EC glass.

Louvre-Free Façade Design Solution

The third case study illustrates how EC glass can provide more architectural design freedom and a more elegant façade solution relative to conventional mechanical dynamic solar control alternatives.

The main photo across pages 80 & 81 shows the application of EC glass integrated into a full building façade in the Siemens Wind Turbine Facility in Hutchinson, Kansas, and is the largest installation of EC glass in the world today. The interior view is shown on the right in figure 7.

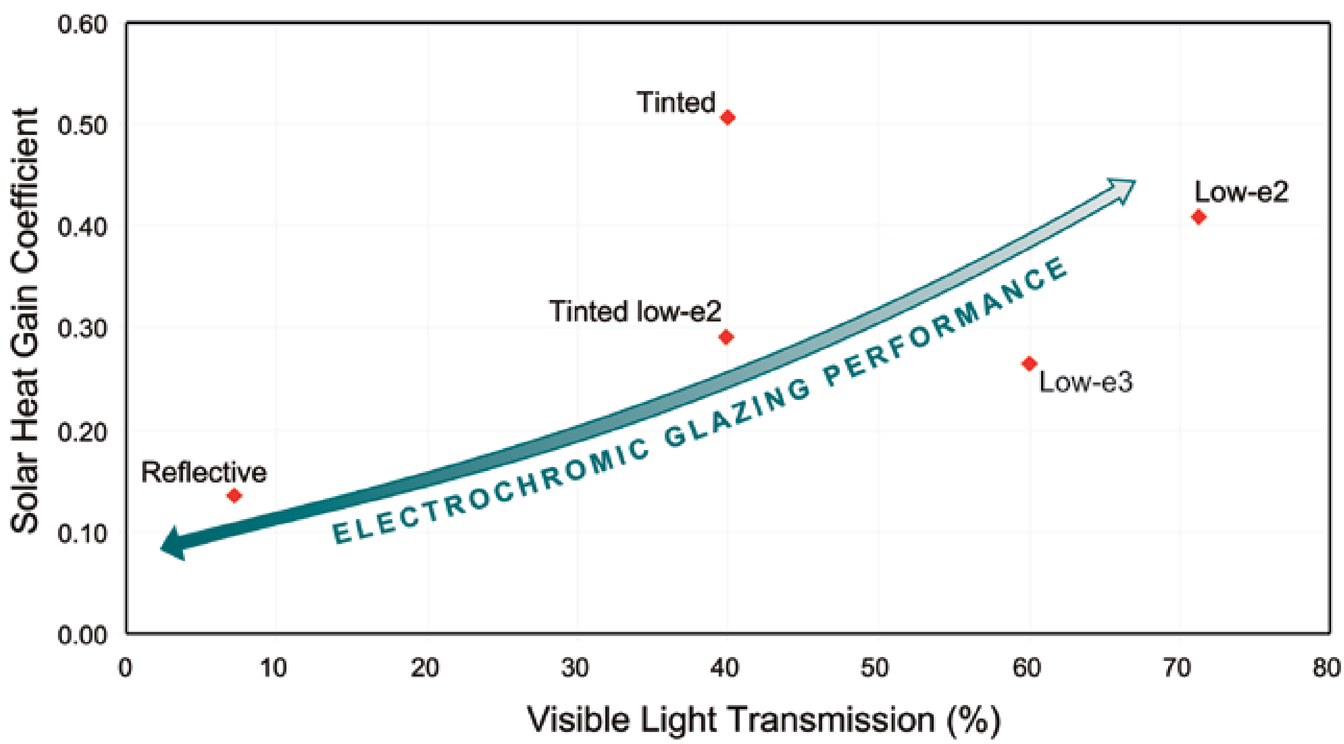
The original renderings of this building design showed the use of automatically controlled external horizontal louvres spanning between columnar elements on the façade which were to provide dynamic solar control.

After investigating alternative options, the architects decided to specify electronically tintable glass for a number of reasons.

Firstly, on an initial upfront cost basis, the EC solution was less expensive than the mechanical louvre system originally envisioned and secondly there would be no additional maintenance costs.

Moreover, the EC glass also presented a more elegant façade solution which provided a clean look to the building with unobstructed views to the outside. The ability to zone the glass on the façade and to variably tint the glass between the fully clear and fully tinted states allows for different control strategies for private offices compared to multiuse spaces such as the cafeteria, entryway and meeting areas.

The EC control system is connected via BacNet interface to the Siemens building management system. Based on whether the building is



Graph of visible light transmission (Tvis) versus solar heat gain coefficient (SHGC): This chart shows the heat gain and light transmission range of a high performance EC product compared with some examples of standard static glass.

Figure 7: View from the inside of the Siemens Wind Turbine Facility. The EC glass is in the clear state flooding the interior with natural daylight on a cloudy day.

occupied or not, the EC glass is switched to either optimize for energy efficiency or for occupant comfort.

The Future of Glazing

The case studies described above clearly demonstrate why EC glass can be considered an architectural enabler and the importance of dynamic glass in the future of façade design. Electronically tintable glass can provide the architect with more design flexibility and the ability to use more glass in the face of ever more stringent building codes as well as facilitating the use of other sustainable technologies which together support the movement towards zero energy buildings.

Electrochromic glazings represent a simple and elegant solution for the control of heat and light incident on the building envelope. Today, even though manufacturing economies of scale are not yet leveraged, EC systems are comparable in cost to – and in an increasing number of cases, lower cost than – today's conventional solutions, which combine high performance static low-e glass, interior and exterior mechanical shading and larger HVAC capacity.

This is especially true when comparing the EC glass solution to automated mechanical shading systems such as exterior louvres, interior automated blinds or double skin curtain wall with integrated automated Venetian blinds. Employing single skin dynamic façades rather than a double skin provides more rentable or usable space too.

With a static envelope system, the building owner also has the potential reduction in productivity due to comfort issues and worst of all the loss of the primary reason we put windows in a building in the first place – to see out.

With the advent of high volume manufacturing and the efficiencies afforded by the use of large area magnetron sputtering, the manufacturing costs of the EC glass solution are being driven increasingly lower and lower.

In a similar way to the advancement of low-e products over the past 20 years, electronically tintable glass will evolve in terms of price reduction, performance enhancements and breadth of product range, thus driving increasing market adoption until ultimately EC products will become the de-facto standard for building envelopes.