Glass Informational Bulletin **GANA 05-0911**

Dynamic Glazing for High Performance Buildings

The exterior environment of a building envelope is subject to ever-changing environmental conditions such as wind, humidity, rain, sun and ambient temperature. One of the most significant influences on the building envelope design is the sun. The sun is composed of ultraviolet, visible and infrared light that is dynamic and constantly changing relative to the building. Designs that do not take the sun's influence into account can subject the occupants of the building to conditions such as uncomfortable glare, solar heat gain, variable temperatures, and the early decay of fabrics, and surfaces that fade over time.

A dynamic glazing product is a fenestration product that has the fully reversible ability to change its optical performance properties, such as visible light and near infrared transmission and solar heat gain coefficient. These properties can be changed in different ways; some change in response to electrical stimuli, others change in response to absorbed sunlight, and some respond to ambient temperature. The ability to modulate these properties provides for a building envelope that adapts to the outside environmental conditions (or user requirements) and provides higher energy performance by capturing useful daylight while controlling glare and unwanted solar heat gain.

TYPES OF DYNAMIC GLAZING

Electrochromic (EC) Glazing

An electrical stimulus is used to change the visible light transmission (VT) and solar heat gain coefficient (SHGC) of electrochromic glazings. Tinting of the glass occurs with the application of a low voltage DC (<5V) current, which causes lithium ions to move from an ion-storage layer through an ion-conducting layer, into an electrochromic layer. The presence of ions cause this electrochromic layer to absorb visible light, in proportion to the number of ions transferred, thus making the glass appear tinted. These glazings can be switched from a highly transparent state to a highly tinted state stopping anywhere in between.

Electrocromic (EC) glazings can be configured to respond to manual control through a simple switch on the wall, or can be controlled automatically using for example sensors (e.g. for light, temperature, occupancy), or by time of day with manual override as necessary. The VT range for EC glazing can range from 3 to 62 percent and the SHGC can range from 0.09 to 0.48 in a dual pane insulating glass unit. EC glazing can be produced in dual glazed insulating glass units

as well as triple glazed units to provide good thermal insulation performance or used as part of a laminated construction for safety. The SHGC and VT can be varied to let as much light and heat into a building as desired based on environmental conditions such as glare, daylight levels, or temperature and the needs of the building occupants, without loss of view to the outside.

There are two main configurations for EC glazing – all ceramic monolithic or organic laminated.

All Ceramic Monolithic
This glazing type is made by depositing a series of very thin coatings on glass, generally using large area sputter (vacuum deposition) coating, the same process which is used to make millions of square feet of low emissivity (low-e) coatings annually. All layers in the coating are applied to one lite of glass and all materials are durable ceramic, inorganic materials. The resulting coated lite is fabricated like low-e coated glass into insulating glass units which fit into fenestration framing systems. The monolithic coating stack also has low-e properties, so additional low-e coatings are not generally required in the finished insulating glass unit.

Organic Laminated
Some of the layers are applied to one lite of glass and some to a second lite, which are then laminated together in a non-structural laminate, where the laminating material is a polymer ion conductor and forms part of the functionality of the EC. This laminated unit can be made into an insulating glass unit incorporating a low-e coating - added for insulation performance.

Photochromic Glazing
Photochromic materials, change their transparency in response to ultraviolet (UV) light. This glazing can be glass with integral photochromic compounds or a photochromic film that is laminated between or applied to glass. The main application of photochromic materials is in eyeglasses that change from clear in the dim indoor light to dark in the bright outdoors. Currently there are no cost-effective, large, durable photochromic products on the market for architectural glazing applications.

Photochromic –Electrochromic Hybrid
Lawrence Berkeley National Laboratories (LBNL) and others have conducted research on a UV-activated photochromic glazing that is electrically reversible. Currently there are no cost-effective, large, durable, hybrid photochromic products on the market for architectural glazing applications.

Polymer Dispersed Liquid Crystal (PDLC) Glazing
This glazing is made by encapsulating a liquid-like layer in which organic particles are suspended between two sheets of polyethylene terephthalate (PET) plastic, coated with a transparent conducting oxide, then laminated between two lites of glass using two adhesive layers. Liquid crystal technology has been used for over 20 years as privacy glazing because it transitions from an opaque to transparent state. When power is off, the liquid crystals are in a random and unaligned state. They scatter light, which makes the glass appear translucent, thus

obscuring direct views and providing privacy. When the voltage is applied the crystals align, allowing light to pass through and thus appearing transparent.

The light transmission and the solar heat gain coefficient are not modulated in this product (the light is scattered not blocked), so it provides little energy or glare control performance. As a result, this type of dynamic glazing is used most often for privacy in interior applications, such as bathrooms, conference rooms, and changing rooms in retail stores.

Sunlight-Activated Glazing

Sunlight-activated glazing changes its VT and SHGC properties based on absorbed sunlight. These products continuously change their tint level based on the amount of the sun's energy incident to the window.

A sunlight-activated glazing is constructed with an extruded thermochromic polyvinyl butyral (PVB) film utilizing existing PVB film lamination equipment used worldwide. Additives in the film respond to increasing temperature to slowly vary the VT and SHGC, as well as fading factors when laminated between two lites of glass and exposed to the sun. The change in glass characteristics is based on the directness of the sunlight on the window and thus responds based on sun angle. The absorbed sunlight warms the glass and causes the change in light transmission (proportional to the temperature), the warmer the window gets the darker it gets, the cooler the window gets, the more transparent it gets. In an insulating glass unit with a double silver low-e, for good thermal performance, the VT ranges from 60% down to less than 10% based on absorbed sunlight and window construction. Tinted glass can be used on the outboard of an insulating glass unit. The outboard lite of the laminated unit-can be tinted. Tinted glass and a variety of low-e coatings can be used in this laminated glass product.

Suspended Particle Device (SPD) Glazing

In a similar way to PDLC glazings, SPD's are constructed utilizing two electrically conductive coated plastic layers with an emulsion containing suspended particles placed between the plastic layers forming a film or sheet. This is then laminated between two lites of glass utilizing two adhesive interlayers, one on either side of the plastic-film. SPDs are electronically controlled to provide variable tinting. When a voltage (~80V) is applied to the SPD, the suspended particles align and allow light to flow through unhindered (the clear state). Once the electricity is turned off, the particles revert to a random pattern and block light (the tinted state). SPD can be in the form of a monolithic glass-plastic laminate or this laminate can be incorporated into insulating glass units with the addition of a low-e glass for improved insulation value. For specific ranges of VT and SHGC, contact the manufacturer.

Thermotropic Glazing

Thermotropic glazing is constructed with the active thermal component between lites of glass or plastic. If it is between plastic, it then has an adhesive applied to the glass. If it is between two lites of glass it can be a monolithic laminate or combined into an insulating glass unit. There are three types of thermotropic glazing: reflective, absorbing, and light scattering. The visible light transmission of a thermotropic glazing changes when the ambient temperature exceeds a fixed

activating temperature set point. The VT changes from a highly transparent state to a tinted reflective or light scattering state (depending on the type) when this temperature threshold is exceeded. Contact the manufacturer for specific performance data.

BENEFITS OF DYNAMIC GLAZING

Dynamic glazing products can provide energy savings through optimized use of natural daylight and reduced need for air-conditioning, resulting in increased occupant comfort by controlling unwanted daylighting and glare. With the exception of PDLC (privacy glass), dynamic glazing can control daylighting without additional appendages to the façade and, while also preserving the view to the exterior through the glazing.

Energy Savings

The US Department of Energy (DOE) states that dynamic solar control on the building envelope is a critical component in achieving net zero commercial buildings. In combination with two other key façade related technologies, low U-factor fenestration (to reduce thermal energy losses), and addressable, dimmable lighting controls (to maximize the use of natural daylight and allow electric lights to be turned off or dimmed), an integrated solution can be provided to maximize energy efficiency and provide a clear path to achieving net zero[1].

The Windows and Daylighting Group at LBNL have studied the performance of electrochromic glass. Its studies have shown that electrochromic windows can save up to 60% of daily lighting energy and predicted that commercial buildings relying on electrochromic window systems could save up to 28% in energy costs when compared to buildings with static, spectrally selective, low-e windows[2]. Additional studies by LBNL[3] show that electrochromic glass can help achieve:

- 10-20% operating cost savings;
- 15-24% peak demand reduction; and
- Up to 25% decrease in HVAC system size.

Testing is also taking place on other types of dynamic glazing; however, results were not available at the time of this document's publishing. One would expect to see greater energy savings compared to the ASHRAE 90.1 standard for these other types of dynamic glass.

Human Factors

Natural daylight through glass benefits peoples' health and well-being; however, glazing can also cause thermal and visual discomfort. Indeed, interior building temperature is a primary occupant complaint. Perimeter offices have a tendency to be cold in the winter and hot in the summer. In addition, occupants may be affected by significant glare on their computer screens.

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[1] Arasteh, D., Selkowitz, S., Apte, J., LaFrance, M., Zero Energy Windows, Proceedings of the 2006 ACEEE Summer Study on Energy Efficiency in Buildings, August 13-18, 2006. LBNL report number 60049

[2] Lee, E., Lawrence Berkeley National Laboratory (LBNL), IEA Task 31/45, *Daylighting/Lighting Seminar on Research and Practice*, Pacific Energy Center, San Francisco, April 21, 2005

[3] http://windows.lbl.gov/

Dynamic glazing can significantly improve thermal and visual comfort while preserving the view and connection to the outside. Studies[4] have shown productivity increasing by 0.5-5 percent annually with increased daylight and better control of office temperatures.

Privacy

Because they do not become opaque, these glazing products do not provide complete privacy, however, they do give some measure of privacy in that the more tinted the glass is, the harder it is to see through from the exterior of the building. It should be understood that, when light levels are substantially higher on one side of the dynamic glazing than the other side, one will still be able to see through them. PDLC glazing is the only switchable glazing that provides strict privacy by switching from clear to opaque, by scattering the light, but it does not provide light and heat attenuation. Dynamic glazing for use on the building envelope generally switches from a highly transparent state to a more tinted state, preserving a clear view to the outside.

For additional information on dynamic glazing, please visit the LBNL website at http://windows.lbl.gov/

INDUSTRY STANDARDS

Glass used in dynamic glazing systems conforms to the following ASTM Standards:

ASTM C1036	*Standard Specification for Flat Glass*
ASTM C1048	*Standard Specification for Heat-Treated Flat Glass—Kind HS, Kind FT Coated and Uncoated*
ASTM C1172	*Standard Specification for Laminated Architectural Flat Glass*
ASTM C1376	*Standard Specification for Pyrolytic and Vacuum Deposition Coatings on Flat Glass*
ASTM E2141	*Standard Test Methods for Assessing the Durability of Absorptive Electrochromic Coatings on Sealed Insulating Glass Units*
ASTM E2188	*Standard Test Method for Insulating Glass Unit Performance*
ASTM E2189	*Standard Test Method for Testing Resistance to Fogging in Insulating Glass Units*
ASTM E2190	*Standard Specification for Insulating Glass Unit Performance and Evaluation*
ASTM E2354	*Standard Guide for Assessing the Durability of Absorptive Electrochromic Coatings within Sealed Insulating Glass Units*

LABELING DYNAMIC GLAZING

The National Fenestration Rating Council (NFRC)[5] has adopted labeling requirements for dynamic glazing products. The label utilizes an arrow between the "on" and "off" positions (eg. between "clear" and "tinted" states) to represent the end point values of a dynamic glazing for VT, U-value, and SHGC. Thermal and optical properties for some dynamic glass can be found

[4] http://www.iaqscience.lbl.gov/performance-summary.html
[5] National Fenestration Rating Council, 8484 Georgia Avenue, Suite 320, Silver Spring, MD 20910; www.nfrc.org

in the International Glazing Database and the performance values can be modeled in different fenestration systems using Window 5 and 6. For other dynamic glazing, please contact the manufacturer for the optical performance values.

INSTALLATION

Specific instructions on installation and compatibility should be obtained from the manufacturer before any installation of dynamic glazing.

Consult the *Tech Center* section of the Glass Association of North America (GANA) website (www.glasswebsite.com) for additional Glass Informational Bulletins and flat glass industry reference resources.

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