Responsive glazing for solar control shading

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ABSTRACT

Sunlight is necessary for life. Managing sunlight is necessary to achieve a level of comfort for living. Radiation transfer through glazing has an impact on costs for heating, cooling and lighting in a building and on environment. The energy that is gained or lost may be solar or thermal energy. Glazing materials are known to respond differently to these two types of energy. This paper provides a comfortable choice in solar design by providing an understanding of solar energy and the tools for managing the amount and type of sunlight permitted through glazing systems. In particular, new IR absorber PVB interlayers - such as Vanceva™ Solar Advanced Solutions for Glass™ by Solutia – offers solar performance superior to that of previously available laminating safety glass systems. Vanceva™ solar provides the architectural marketplace with new, cost-effective options for controlling heat and energy loads in buildings, while offering the opportunity to create truly distinctive glazing appearance.

1. INTRODUCTION

The energy that is gained or lost may be solar or thermal energy. Glazing materials are known to respond differently to these two types of energy. Solar energy is high temperature energy radiated by the sun. The sun radiates energy to earth in electromagnetic waves over a range of wavelengths known as the solar spectrum.

Amongst the different solar control systems, Saflex® and Vanceva™ Architectural Glazing Interlayers by Solutia Inc. are very effective in providing reduction in solar heat gain for energy control and in reducing ultraviolet light transmission to reduce potential fading. Latest product developments have resulted in the commercialization of new IR Absorber Polyvinylbutyral (PVB) interlayers called Vanceva™ Solar which combines superior solar performance, energy efficiency and occupant comfort with the benefits found in traditional PVB interlayers.

2. BACKGROUND ON THE ENERGY PERFORMANCE OF BUILDING

According to U.S. Department of Energy, 1/3 of building's cooling load is due to solar heat gain through the building windows. Over 50% of the windows in non-residential buildings are energy-inefficient, doing little to reduce solar heat gain into the building.

According to the European Directorate General for Energy and Transport (01/2001), 41% of energy is used in the residential/tertiary sectors. Potential energy savings in building sector could be as high as 22% by 2010. Cooling consumes 4% of total energy in the tertiary sector and energy use for air-conditioning will double by 2020. Lighting consumes 14% of total energy in the tertiary sector. Space heating consumes 52% (Tertiary) and 57% (Residential).

There is definitively a need for "Bioclimatic Design": Active and passive solar design and systems, improved daylighting and natural cooling can reduce energy demand up to 60%. The directive 2002/91/EC of the European Parliament and the Council of 16 December 2002 on the energy performance of building was finally accepted and published in the official Journal of the European Communities L1, Volume 46 of 4 January 2003, p.65-71. The directive covers the following main points:

- A common methodology for the preparation of minimum integrated energy performance.
- The application and regular updating of minimum standards based on above methodology for new buildings and for renovation in building of more than 1000m².
- The certification systems for new and existing buildings. Delivery of a certificate of energy performance with all building transaction (sales/rental).
- Obligation to have a regular inspection of boilers and air-conditioning systems.
- A period of three years for the implementation of the Directive in national law.

3. HEAT MANAGEMENT CONTROL THROUGH RESPONSIVE GLAZING

3.1 The main criteria of selection cover the following points:

- Appearance of the glazing: blue, green and gray colors are the preferred choice of architects / designers.
- Visible light reflectance below 10%, UV cut-off greater than 99% (at 380nm) and color rendering index of more than 90% are preferred.
- Visible light transmission greater than 60% and solar factor “g” less than 40% contribute to achieve the required energy performance mainly in terms of air-conditioning
- Thermal insulating properties of an Insulating Glass Unit (IGU) should result in a U-value of less than 2.2 W/m².K
- Finally, the ratio of light transmission (%Tv) on the solar factor “g” or shading coefficient “SC” should be greater or equal to 1. This ratio is called “Coolness” (USA: Tv/SC) or “Selectivity” index (EU: Tv/g)

3.2 Applicable Standards

Light and solar characteristics of glazing are defined by the following main standards:

- Europe: EN 410 or ISO 9050 (Air Mass 1) for light and solar characteristics and EN 673 for thermal calculation.
- USA: ISO 9845-13 (Air Mass 1.5) and ASTM E 903 for Solar properties, ASTM D971 for light and UV properties, NFRC/ASHRAE for Solar Heat Gain Coefficient and Shading Coefficient (SC) and ASHRAE 2001 Fundamentals Handbook, Chapter 29 for U-value

Results obtained by these different test methods may result in slightly different values. This is mainly due to the different environmental conditions used in the different standards. There is nothing wrong with this but the test method should be always stated with each values.

3.3 Overview of Solar Control Glazing Systems

By definition, a solar control glazing system is a glazing which selectively absorbs, reflects and transmits solar energy, especially in the infrared, to aid in controlling interior environments and minimizing HVAC requirements. Measured and calculated glazing characteristics values are given under standardized environmental conditions. However, when comparing different solar glazing systems, real or actual conditions should be applied. In particular, wind speed has a direct effect on the outside heat transfer coefficient. When the wind speed increases, the outside heat transfer coefficient prevails and most of the absorbed heat is removed outward making the IR absorbing glazing technologies even more attractive.

Solar energy is high temperature energy radiated by the sun. The sun radiates energy to earth in electromagnetic waves over a range of wavelengths known as the solar spectrum Ideal solar control system (Fig. 1) should block all the UV and IR radiations

3.4 Heat Management Technologies

There are two main technologies which are based on the IR reflection or the IR absorption characteristics of the glazing systems.

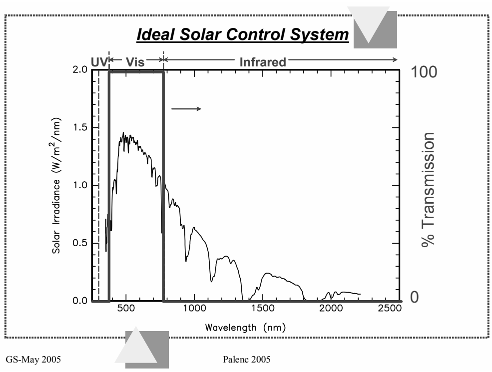

Figure 1: Ideal solar control spectrum.

3.4.1 “IR Reflecting” Technologies

These reduce the solar heat gain and lower the visible light transmission which reduces glare but diminishes daylight. It may produce exterior mirroring effects (high visible light reflection > 12%).

a) Pyrolytically applied metal oxides on glass (hard coat). These reflective coatings and films are generally used in commercial buildings, warm climates and where reduced glare inside is important. Their main advantages are their excellent rejection and the control of color with varying layer thicknesses. Their main disadvantages are the potential corrosion of stack, the variable adhesion stability (within the stack and with PVB), the fragility of stack (worse with multi layers), the manufacturing/processability complexity and cost, the high external light reflection. These metal coated glasses can be laminated with PVB. However if the coating is coming into contact with the PVB their compatibility shall be assessed.
b) Sputter-coated metal and oxide layers applied on glass.
c) Sputter-coated metal and oxide layers applied on PET film (XIR Southwall). The reflective PET film is then encapsulated between two special PVB layers. The thin transparent metallic coating reflects more than 50% of the IR wavelength (Fig. 2) that are the source of most solar heat gain while admitting up to 74% of the visible light into the building.
d) SRF: no-sputter, non metallic reflective PET film from 3M obtained by multilayer coextrusion process and then encapsulated between two PVB layers.
e) Merck bulk additives of IR reflecting compounds added in films (PET/PVB) provide interesting characteristics for translucent systems in architecture (skylight, conservatories) and horticulture (greenhouse).

IR reflecting PET glazing systems present the same performance as pyrolytically applied coated glass. Encapsulation process with PVB protects coating during processing and shipping. Potential visual defects such as wrinkles with complex curvature, cracking lines with severe bending, edge and stack corrosion, applesauce defect may be present.

3.4.2 “IR Absorbing” Technologies

Bulk additives of IR absorbing compounds are added in glass (Tinted Glass), or Mass Pigmented PVB interlayers (Laminated Safety Glass). The main advantage of these systems is their low cost relative to coated glass/PET reflecting systems.

a) Heat absorbing glass uses additional iron to absorb IR (green color), is very low cost and as durable as clear glass. These glazing reduce solar heat gain, reduce glare but diminish daylighting and alters glass color but views in daytime are not significantly diminished.
b) Heat absorbing mass pigmented (Saflex®/Vanceva™) PVB absorbs more UV and IR radiation than does the clear, tinted, or coated glass (Fig. 3).

   Laminated glass made with light stable, pigmented Saflex®/Vanceva™ interlayers can be combined with tinted or reflective glass to dissipate most of the heat outwardly.
c) Heat absorbing stick-on film consists of dyed

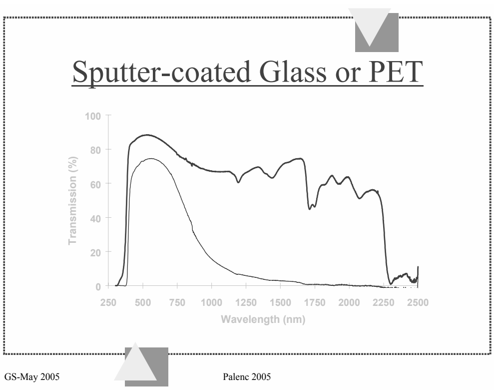

Figure 2: IR rejection.

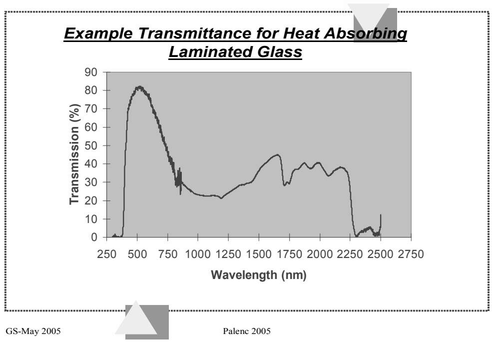

Figure 3: Heat absorbing laminated glass.

PET film with pressure sensitive adhesive. They are generally used for after-market application, are relatively price attractive but present a poor durability.

d) High Performance IR absorbers PVB Various IR absorbers were evaluated over many years but none could meet performance requirements for transmission, durability, adhesion simultaneously. Those based on organic dyes present strong absorption over narrow range of wavelengths. Typically they do not survive UV exposure and impart color. Inorganic Pigments present moderate absorption over broad range of wavelengths. Typically they result in extremely high adhesion which leads to poor impact performance.

Since nanoparticles can provide spectrally selective light absorption with minimal scattering, they can be used as additives to PVB laminated glass interlayers (Fig. 4) to reduce solar heat gain

Laminated Safety Glass based on Vanceva™ Solar PVB interlayer by Solutia Inc. contains dispersed lanthanum hexaboride (LaB6) nanoparticles (Fig. 5). These are useful in reducing solar heat gain through glazing while maintaining relatively high visible light transmission. Technology has been demonstrated both for the automotive market (moon roof, sidelights) and architectural (Guangzhou airport).

Vanceva™ Solar interlayers allow for the creation of laminated glass with a solar performance that is superior to previously available laminating systems. Alone (Table 1) or when combined with solar management glass (Table 2), this new interlayer provides the architectural marketplace with new cost effective solutions to control heat and energy loads in buildings.

Ultimately, when combined with low cost pyrolytic reflective coated glass (hard coat) it can match the solar performance of highly selective sputter metal coated glass but without corrosion, reflected color or special handling requirements.

The Figure 6 shows potential market segmentation versus Vanceva Solar configurations.

3.4.3 Other Solar Control Systems

- Any of above glazing systems combined in a standard double glazing unit to improve the

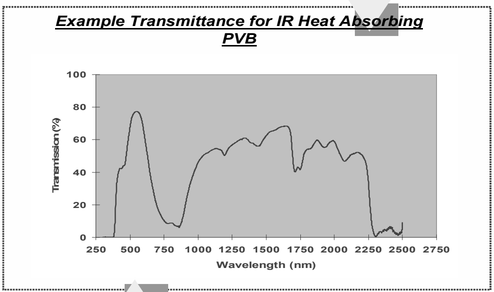

Figure 4: High performance IR absorber PVB.

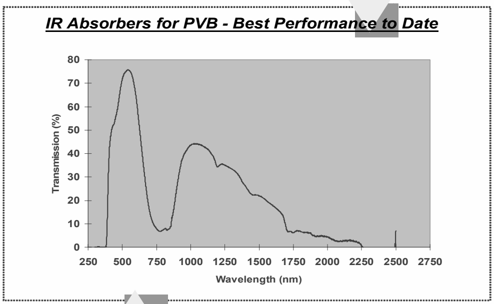

Figure 5: Best IR performance (Grey)

Table 1: Vanceva Solar Control

Vanceva™ Solar Characteristics

Color	% Tv	%Rv	% Ts	% As	"g"	Δ g
Non-Solar	89	8.6	73	20	0.78	-
Clear-Solar	82	8.1	62	31	0.70	10%
Green	71	7.1	49	46	0.60	23%
Blue	48	6.4	36	58	0.51	35%
Gray	49	5.8	34	60	0.50	36%
"Best V.S"	34	5.8	15	80	0.27	65%

(Note with 3mm clear glass)

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Table 2: Grey Products Comparison

Grey Products Comparison

	SHGC	Tvis
Pyrolitic	0.39	36
Sputter coated	0.29	35
Vanceva™ Solar Grey	0.27	34

1 - Pyrolytic product = 1" IGU with Pilkington Energy Advantage and Grey tint.
2 - Sputter coated product = 1" IGU with PPG Solarban 60 and Grey tint.
3 - Vanceva product = 6mm laminated with Vanceva™ Solar Grey plus EA and tint.

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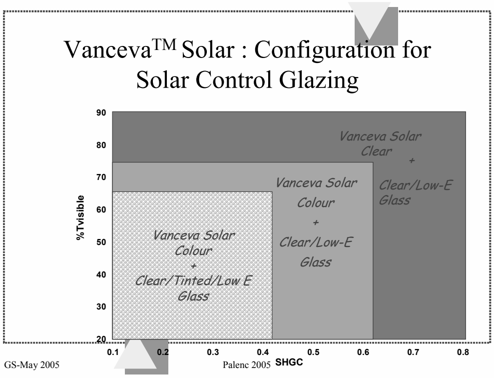

Figure 6: Market positioning.

thermal performance.
- Any above glazing systems combined in a gas fills insulating glazing unit (IGU) to further improve the thermal performance.
- Low-e and spectrally Selective Coatings to be combined in IGU in order to achieve a selectivity index superior to 1.5 (Tv/SF > 60/40 up to 70/30).
- Double skin facades are suited for moderate and cold climate. We find this building technology mainly in France and Germany. Double skin façade technology allows to get high visible transmission, very low U-value (up to 1.1) and extremely very low solar factor when stores are incorporated in the facades (“g” value as low as 0.04).

4. DISCUSSION

The solar heat gain through a glazing is expressed in Watts per square meter (W/m^2) or British Thermal Unit per hour per square foot ($BTU/hr/ft^2$). In the depicted 6mm clear glass example, the SHG is 630 W/m^2 (or 200 $BTU/hr.ft^2$). This is equivalent to the heat gain from a 60-watt light bulb. If you have 200 m^2 (or 2000 ft^2) of glass, the solar heat gain would be equivalent to the heat gain from 2000-60 watt light bulbs being turned on at one time and heating the surroundings. Think of it as one 60 watt light bulb to generate heat for each square foot of glass. For laminated safety glass based on Saflex or Vanceva™® colored PVB or better with Vanceva™ Solar and its potential synergy with metal coated glass, the solar heat gain will be reduced by up to 2/3d which means around 600-60 watt bulbs rather than 2000-60 watt bulbs. This will result in substantial energy saving in terms of air-conditioning requirement or dimensioning

5. CONCLUSIONS

Several commercial responsive glazing for solar control shading are currently available on the market place. The choice and specification of a given system depend on several criteria including not only the light and solar characteristics of the glazing but also the color of the glazing, the construction place of the building (geography) and the location of the glazing in the building. In most cold climate, thermal control (heat loss through glazing) is the most important criteria. Highly selective metal coated glass should be used in IGU. In temperate climate, both solar and thermal control glazing will help to save energy. IR Reflective or IR absorbing glazing in standard IGU will perform adequately. Vanceva™ Solar interlayers based laminated safety glass fit most hot (latitudes 33° from Equator) and moderately hot climates (up to latitudes 40°) in monolithic laminated glazing constructions. In particular this includes ALL Mediterranean countries.

Vanceva™ Solar in laminated safety glass enhances the solar properties of clear, tinted and/or reflective coated glass providing value on:

- Avoiding cost and complexity of IR reflecting technologies (also no corrosion, reflectivity),
- Greater flexibility in using glass in building design,
- Energy saving (lower air conditioning and reduced indoor lighting)
- Increased occupant comfort from reduced “hot” sensation from direct sunlight.