Smart Building Envelopes

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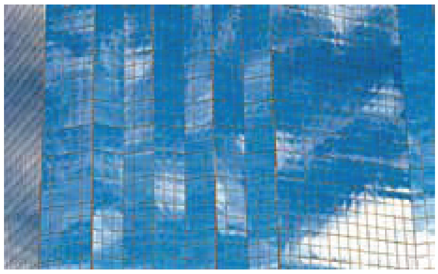

An important role of most buildings is to act as protective barrier against the outside environment, and daily climatic fluctuations. While buildings in general will have varying functions, purposes, and jobs so to speak, it is a fundamental requirement that the users inside have a comfortable environment to carry out whatever task that the building exists for. User comfort within buildings is seen as very important, with worldwide government guidelines and laws restricting the allowable temperature fluctuation within public buildings and working offices. User comfort is also very expense in terms of energy consumption as well, with heating and cooling usually required for the majority of the year in most climates.

The energy that is currently used worldwide to keep the internal building temperature at a comfortable level contributes to 40-50% of the world's carbon. This amount is quite staggering if you imagine the current global position of climate change, and push to switch to renewable energy resources. Energy reduction strategies within buildings are numerous and can consist of some of the following, energy-efficient appliances, good insulation, a smart natural ventilation strategy, heat pumps, thermal storage, intelligent solar shading, etc. In summary, these all act to reduce the undesirable heat flow in and out of a building, which is where the increased use of glass facades can cause a problem. Glass is a very lightweight building fabric in comparison to heavyweight structures like masonry that can absorb most of the daily temperature fluctuations. The high transmission properties of glass, and in particular, its solar radiation transmission properties can cause a thermally unstable and uncomfortable internal building environment. Buildings with even small amounts of building facades will experience overheating in the summer and high amounts of heat loss in the winter without the use of devices such as blinds.

Energy Transmission of Glass

Solar energy is broken into a variety of light spectrums based on the wavelength of the energy. There are three main light spectrums that are transmitted by glass and which affect the internal building environment. These spectrums are Ultra Violet, Visible Light, and Infrared Energy.

Ultra Violet – UV

UV light is broken down to three categories of which two are rejected by the earth's atmosphere, and standard float glass. UVA energy however is able to pass through standard float glass and is the primary component for fading and deterioration of fabric – this is extremely important for museums and galleries which require window materials that achieve the lowest possible UV transmission. UVA energy can be blocked by glass coatings or films that reflect or absorb this light spectrum.

Infrared – IR

This is the radiant heat energy emitted by the sun and determines the amount of heat that is added to an internal environment by the sun. Reducing this transmission will reduce the heat energy added and therefore prevent possible over-heating during summer months. The more infrared energy that a glass material is able to prevent results in the more energy and costs that can be saved due to reduced air conditioning and cooling loads for the building.

Visible Light

This spectrum of light is able to be seen by humans and consists of natural daylight as well as the color spectrum. While natural light is usually desired in an internal environment compared to the use of artificial lighting it can still generate unwanted problems such as glare and eye strain. Windows are able to reduce the visible light transmission by using 'tints' and therefore control the daylight level within a room. However it is important that the visible light is controlled enough to still allow a certain level of light to enter, in order not to become reliant on artificial lighting and thus increase utility costs.

Aims

With the need for better insulated zero-carbon buildings, a new generation of actively controlled components, are starting to replace the conventional materials. These smart devices can respond to seasonal variations in temperature/solar radiation. The foundation of this project is to address the performance of new switchable chromogenic glass. SPD glass uses suspended particle device technology which gives an electronic control of light and heat transmission by altering the 'tint' of the window.

Background into Switchable Technology

Research over the past decade has lead to the development of numerous smart adaptive materials to regulate light and energy flows through glass facades. These smart technologies primarily employ the following behaviors; thermotropic, gasotropic, and electrotropic.

Thermotropic

This is a passive technology which responds to environmental changes in temperature and can be used to control the infrared emissivity and transmittance of glass, similar to thermochromic glass as well. Thermotropic materials also have the ability to change the thermal conductivity of the glass as well as transmittance values, which holds more energy saving potential. However the thermotropic material will only change from transmissive to reflective at a certain temperature, which needs to be set within the human comfort range for it to have realistic architectural applications. Currently most activation temperatures of thermotropic materials are not in this range and so research and development is still required to alter this transition point. A general disadvantage of passive control systems are also that the performance is only optimized according to one factor, and cannot be manually overrun to take into account other variables such as the visual light levels.

Gasotropic

The change in optical properties of gasotropic materials is caused by the chemical reaction between a special layer coated on the glass, and a gas fed into the cavity between the two glass panes. Advantages of gasotropic glass is that it is able to retain high transmission properties in the clear, 'un-reacted' state, and it also experience a fast switching ability, taking 20 seconds to change from clear to coloured, and less than a minute to switch back. Problems however arise with the complexity of the gas injection system and the build-up of water when hydrogen atoms are added for the chemical process. At this point gasotropic and gasochromic glazing is still not commercially viable but is a technology still being heavily researched in order to achieve future marketability.

Electrotropic

Within electrically activated smart glass systems there are three main devices; Liquid crystal technology, electrochromic devices, and suspended particle devices.

LC Technology

Liquid crystal glazing is made up of two sheets of glass surrounding a liquid crystal film. With the application of an electric field, the orientation of these liquid crystal chains can be altered and therefore the optical transmission of the glass also. When no voltage is applied the molecules are randomly scattered and visual light is diffused in multiple directions, giving a translucent 'opal white' effect. When a voltage is applied the molecules align with the electric field and light can pass through unobstructed.

LC power consumption is low in general – less than 5 W/m2 and the transition from opaque to clear is immediate. However LC technology is not able to reduce the amount of radiation transmission from the sun very effectively. LC glass affects the way light is transferred but does not alter the quantity of radiation, and thus heat flow through glass, making it unsatisfactory for energy saving purposes. The use of LC glass is currently popular for internal architectural designs, such as privacy partitions.

Electrochromic

Electrochromic devices are currently probably the most popular and complex of switchable glazing technology. The devices consist of a thin solid electrochromic film which is sandwiched between two layers of glass. On passing a low voltage across the thin coating the electrochromic layer is activated and changes color from clear to dark. It is with this change in color that the glass controls its optical transmission properties. Electrochromic glass is able to control solar radiation by absorbing the heat in its darkened state, though this can lead to heating of the glass. An advantage of electrochromic glazing is that the low voltage need only be applied until the desired coloration has been achieved and then the device will exhibit color memory and maintain radiation transmission for up to 48hrs.

The electric current can be either activated manually or by active sensors that respond to the external light. Darkening the glass will reduce solar transmission, and when there is little sunlight the glass can brighten, reducing the need for artificial lighting. Required time for color switching is slower than other technologies though and can take up to 30 minutes for a window size of about 2.4 m2. Durability in electrochromic glazing is a current issue with having to cope with large number of switching cycles to survive a reasonable life-time of 10-15 years.

SPD technology

SPD is a film based technology, with a uniform response throughout the film. The film contains rod-like particles suspended in billions of liquid droplets distributed

across the film. When the film has no applied voltage the particles are in random positions and block light transmission, appearing as a dark blue tint. When a voltage is then applied, the particles align and light is allowed to go through. The change in tint is instant and a user advantage to this technology is that the voltage can be varied to give a different level of tint and therefore the transmission properties can be changed to suit any particular external environment. SPD windows hold energy saving potential for the device uses solid radiation-absorbing particles in the liquid suspension. Precise optical properties depend on the thickness of the suspension film as well as the concentration of particles within. Solar radiation and visible light transmittance is reduced with the application of a voltage, which in turn reduces the heat flow into the internal environment. SPD windows allow clear sight through the glass even while fully switched on and in a state of minimum transmission, which holds a visual advantage over other glazing technologies that turn the glass 'cloudy'. The current downside of this technology is the cost as it's a very recent development. ■

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يتمثل دور معظم المباني في التصدي والحماية من البيئة الخارجية وتقلبات المناخ اليومية، وتختلف أدوار المباني وأهداف إنشائها واستعمالاتها إلا أن المتطلب الأساسي منها توفير بيئة مريحة لساكنيها. وتؤخذ راحة مستخدم المباني على محمل الأهمية وذلك مع التوجهات الحكومية والقوانين ذات العلاقة في مختلف أنحاء العالم. هذا وتشكل الطاقة المستخدمة حالياً في جميع أنحاء العالم للحفاظ على درجات الحرارة اللازمة داخل المباني بحوالي ٤٠–٥٠٪ من إجمالي حجم نسبة غاز الكربون على الأرض. ويؤدي ذلك بدوره إلى تغير المناخ والتحول إلى استخدام مصادر الطاقة المتجددة البديلة واللجوء إلى استخدام الحلول والتجهيزات الحديثة للعمل على الحد من تدفق الحرارة غير المرغوب فيها داخل وخارج المباني.