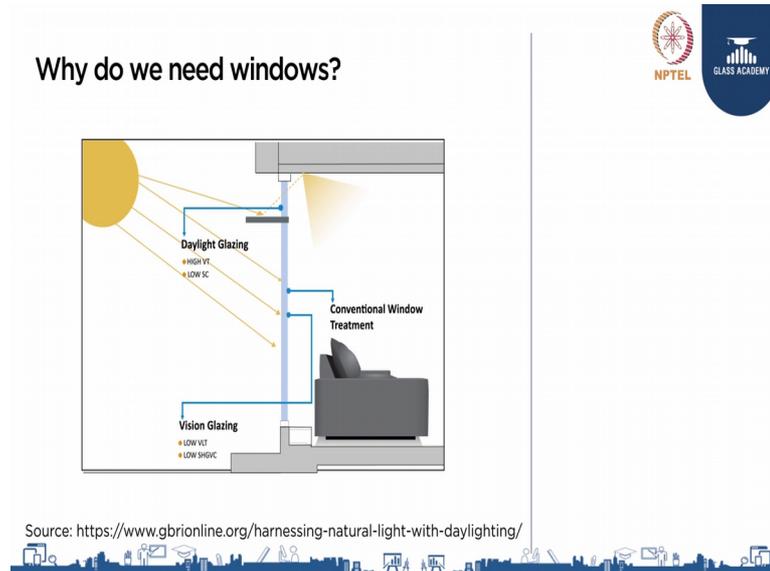


Glass in buildings Design and Application
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Lecture - 27
Daylighting Strategies-Techniques-Part II

So, let us now see what a conventional window would look like.

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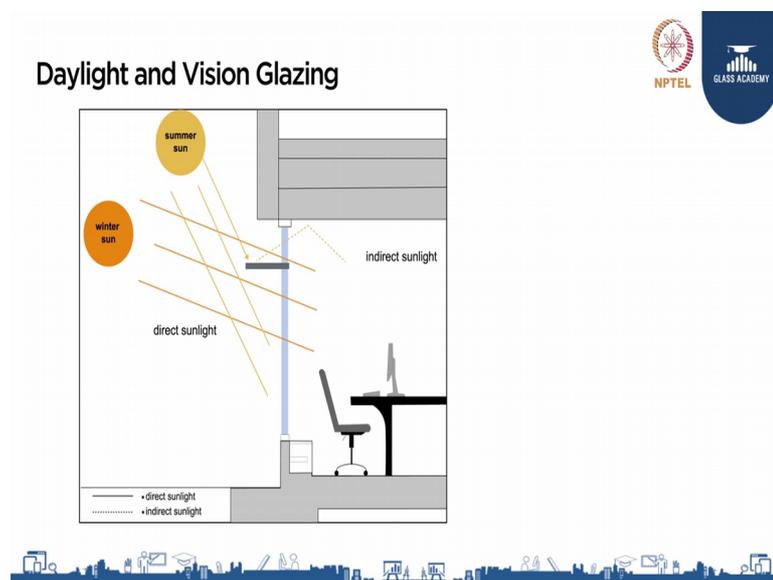
Here you see a window, which is at a sill height of two and a half feet and at a lintel height of say seven and a half feet. Through this window we can see outside and we can also get lot of daylight. However, because it is in the vision level we would like to keep the visual transmittance a little low so, that we do not get glare. Therefore, it will bring a little less daylight than what a clear glass would have brought. Further, because of this placement of this window, the daylight that enters through this window is generally focused towards the wall or towards near this window and does not penetrate deeper into the building.

So, if you want to have more daylight without getting us glare and to penetrate deeper into the building, we can put another pane on top of this pain. So, that pain that new pane which is above seven and a half feet, we can call it as the daylight glazing. So, now, we have two panes the vision glazing and the daylight glazing. The daylight glazing can

have higher visual transmittance because, it will probably not give us glare as compared to the vision glazing and it can bring daylight which will go deeper into the space.

So, the difference between the two glazings would be that the vision glazing would have a little low visual light transmittance, a good glare control mechanism and low solar heat gain coefficient. The top glazing which is the day light glazing can have high VLT, but still it should have low solar heat gain coefficient and it might not have that high controls for the glare protection.

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Now, to make the vision glazing even better, we would like to provide an overhang. This overhang would protect the solar radiation from directly falling onto the glazing and coming inside the space. Now, imagine if this overhang top surface is more reflecting then not only it will protect the window below, it will also reflect the solar radiation towards the ceiling inside the space. We can even extend this overhang inside the building and make it a large piece, which will redirect the incoming solar radiation and take it towards the ceiling we call it light shelf.

So, it gives both the advantages as an overhang it protects the vision glazing, and as a reflective surface on top of it redirects the sunlight towards the ceiling and why do you want to redirect the sunlight towards the ceiling? We want to do that so, that the light which is redirected and hits the ceiling and if the ceiling is reflective in nature, it will be

reflected from the ceiling it will get diffused and it will enter deeper into the building spaces, like this we are able to bring daylight more into the spaces by redirecting it.

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Light Redirecting Systems

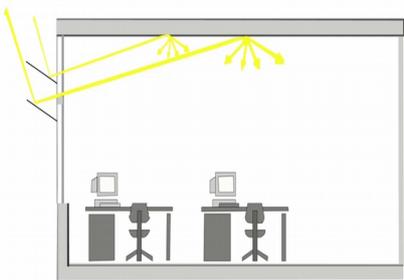
- Exterior systems
- Interior systems
- Interior louver systems
- In-pane systems



So, redirecting the daylight can be achieved by many ways, we can have exterior systems to redirect the sunlight we can have interior systems, interior louver systems and in pane systems; let us have a quick look at these systems.

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Exterior systems



Exterior Reflectors

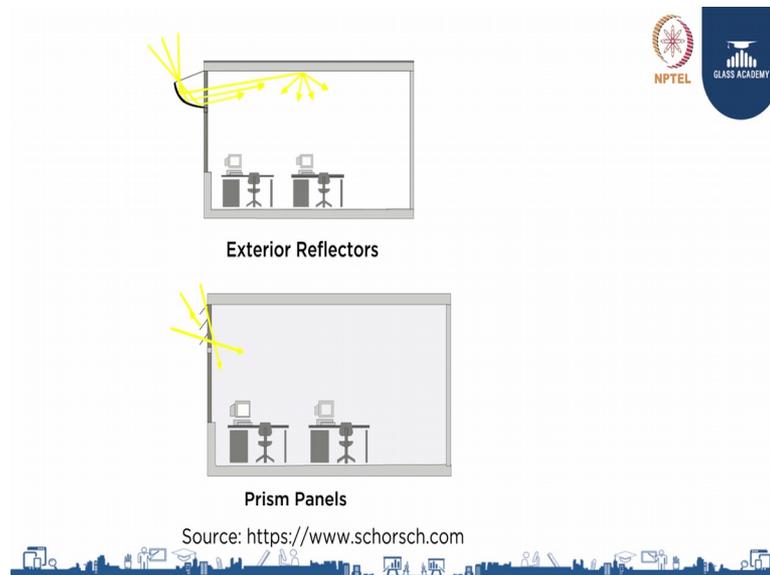
Source: <https://www.schorsch.com>



The exterior system is the most effective way to bring daylight into the building besides opening in the roof, and basically they are reflecting elements in front of the facade. So,

the light is reflected from these and it goes into the building through the daylight glazing. The exterior surfaces need not be straight they can also be curved why do we want to make it curve?

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Because the sun altitude changes with the season; so, in the summer it is at a higher altitude in the winter it is at a lower altitude. So, if I want to redirect this towards the same spot inside the ceiling, then I would need a curved reflector. We can also have prismatic panels which can reflect some of the angles, which can which can redirect other angles and therefore, they can also prevent some of the harsh solar angles which we do not want them to come inside the building.

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Interior Systems

Effective way to bring daylight into a building with reflecting elements inside the facade



Light Shelf

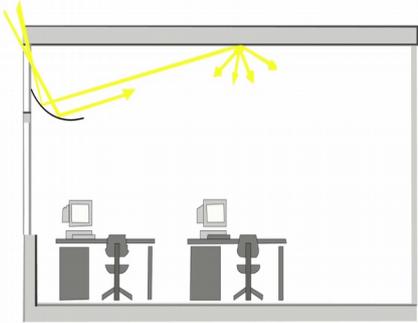
source: <https://www.schorsch.com>



The other mechanism is interior systems just like we discussed, we can have light shelf which can redirect the light towards the ceiling.

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Interior Systems



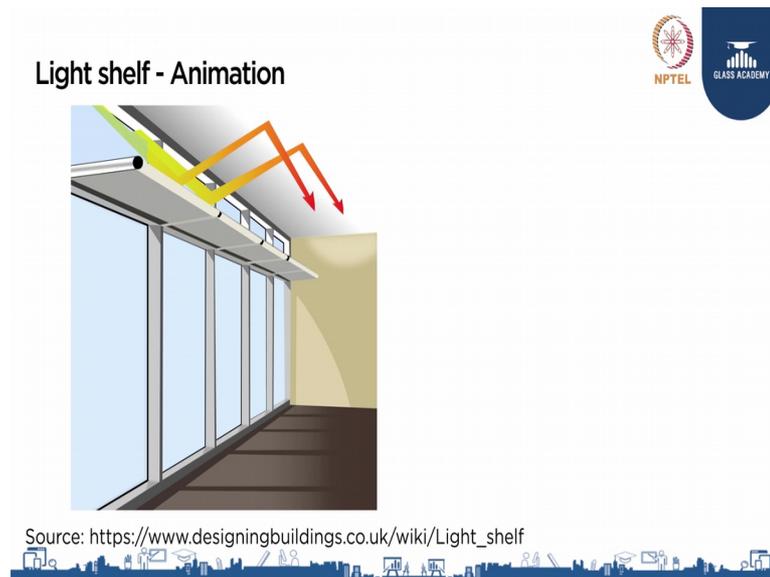
Anidolic Mirrors

Source: <https://www.schorsch.com>



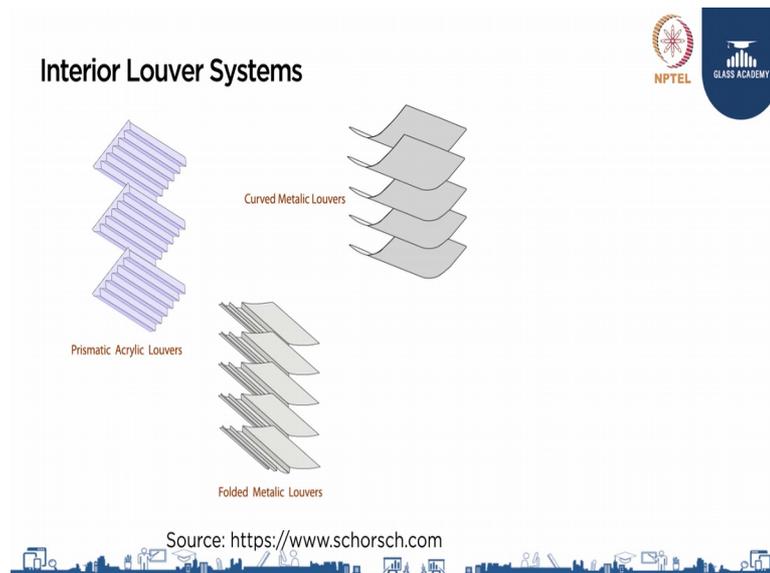
The light shelf need not be a horizontal piece, it can also be a curved one and again why do we want to have it curved? Because, the solar altitude changes with the season.

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So, here you see how the light shelf works. Light shelf is between the vision pin panel and the daylight panel and it extends inside, the sun light falls onto the top surface of the light shelf which is reflecting, it redirects the light towards the ceiling it hits the reflective ceiling and get diffused nicely soft top lighting available into the deeper spaces at the building.

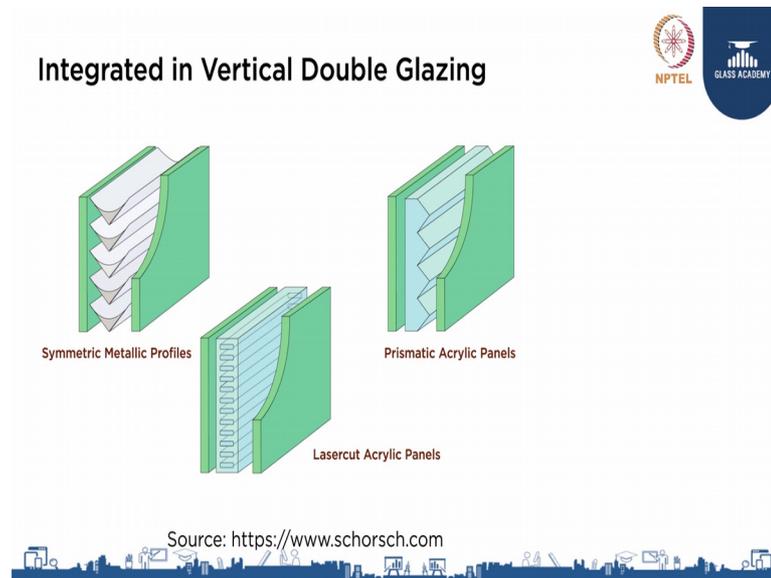
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Now, we can also redirect the light using interior louver systems these can be prismatic acrylic louvers, these can be curved metallic louvers or folded metallic louvers the basic

idea is same. Some of the angles you might allow them to come straight inside some of the angles you would like them to be reflected towards the ceiling and some of the angles we might even reject and reflect them outside.

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We can also have these louvers which are integrated into the panels. So, we can have two glass panels and these louvers can be between the panels, why would we like to integrate them between the double glazing? Because, then they are easy to maintain they are not getting exposed to the pollution and the dust and the reflectivity of the material can be easily maintained. The purpose is same they have to reflect the solar radiation towards the ceiling.

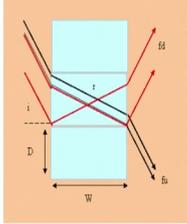
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Laser Cut Panels

Sunlight is incident on a window at a wide range of angles depending on the time of day and season and for each incident angle a corresponding fraction will be redirected. As some sunlight passes directly into the room careful design is required to ensure the sunlight does not result in over heating or glare.



An automatic laser cutting machine is programmed to make an array of parallel cuts through or partly through a transparent sheet of acrylic plastic. The air to material interface at the walls of the cuts become internal mirrors that reflect by total internal reflection.



Source: <http://www.solartran.com.au/lasercutpanel.html>



There is another interesting technology for achieving the same thing, which is called laser cut panels. In laser cut panels there is an automatic laser cutting machine which is programmed to make an array of parallel cuts through a transparent acrylic sheet. What happens when we make these cuts? These cuts become internal mirrors that reflect the sunlight that falls onto these cuts.

So, whatever light falls onto this cut it gets reflected whatever light does not fall onto this cut it passes through the glass. So, some part of the light comes inside like normal and some part gets reflected toward the ceiling. So, here in this picture you will see that when you see through this glass it is not a very clear transparent glass, you will see some lines there, but it still it gives you a good view to outdoors and these lines are the ones where the sunlight is getting reflected.

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Another picture showing you view to the outside and the reflected light.

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Angle Selective Glazing

The angle selective function is obtained from the very high light deflecting power of the laser cut panel. When closed the panels admit high elevation light and deflect it towards the ceiling - low elevation light is also admitted retaining the view through the window. This is the optimum winter position. As the panels are tilted high elevation light is deflected more deeply into the room. When the panels are tilted to the near horizontal high elevation light is deflected back out the window while low elevation light is admitted. This is the optimum summer position.

Source: http://www.labeee.ufsc.br/antigo/pos-graduacao/ecv_4247/arquivos/10_Arq_Sustentavel_inovacoes.pdf

NPTEL GLASS ACADEMY

The slide features a central photograph of a window with horizontal laser-cut panels. The panels are tilted upwards, reflecting light onto the ceiling. The slide also contains the NPTEL and GLASS ACADEMY logos in the top right corner and a decorative blue bar with white icons at the bottom.

If we put this type of laser cut panels as slats, then we can rotate these slats and control the way the light is getting reflected. So, we have three things now which are possible one we are able to see outdoors irrespective of the angle of the slats, two we are able to reflect the light and three we are also able to control the direction of the reflection of the light and; obviously, why do we want to control is because the solar altitude changes across the seasons.

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Need for Glazing Controls and Methods



Privacy

Glare control

Illuminance control

Heat control



Now, the basic question is why do we want to control the light. Why do we want to sometimes reduce it or sometimes increase it, is there a necessity to control? Yes there is a necessity to control and there are various reasons some of the reasons are privacy. Say for example, if you have a building a nice clear glass and it is being occupied in a night. So, in the night time when there are internal lights which are on, the inside of the building will be visible to outdoors people from outside would be able to see inside the building.

So, if you want to have privacy, you would like to control the transmittivity of the window system. Another reason can be glare control, there can be too much light coming from the window and it might give glare to the occupants and we might like to control it. The third reason can be that we want to control the illumination levels indoors for different tasks that we are performing.

Say for example, if we are using a projector into a space, we would like to reduce the light levels. So, we might like to shut the windows put some curtains or whatever ways so, that less light comes inside the space. Then we might also like to control the amount of radiation that is coming through the window because we want to save on the energy consumed by the air conditioning system.

So, if it is summer and its becoming too hot the building is getting overheated, even if it is when if it is not been occupied you might like to reduce the heating gas and control the

windows. So, there are some of these reasons because of which we would like to control the glazing.

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So, let us see a simple example, when we use these controls is when we talk about photochromatic glasses. I am sure most of you would have seen these glasses. So, these glasses are special in the sense that when you go outdoors and you expose these glasses to solar radiation, they become dark and when you are indoors they become more transparent they become light. So, these glasses automatically change their visible transmittance based on the energy the based on the solar energy that is falling onto this glass, they are called photo chromatic glass because this change happened because of the photons that are striking the glass.

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Another kind of glass is thermochromic glass, in this glass the transmittivity of the glass changes because of the temperature. So, here you can see in the morning, the glass is reasonably transparent in the afternoon it is very dark and the night it becomes very clear. So, it is automatically changing the transmittivity based on the temperature. Both these glasses are great, but we want something beyond it why? We do not want the glass to change its properties on its own we would like to control it because we just saw that there are various reasons why we would like to control the transmittivity of the glass.

Imagine if I am using a thermochromic glazing and in the night I want to reduce the visible transmittance I cannot do it because the glass has become very clear because of the temperature or for that matter even if I am using a photochromatic glass, and I want it to be dark in the night time I cannot do that. So, we want to have a glass where we can control the transmittivity as per our liking.

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Smart glass - Electrically switchable

- Suspended-particle devices
- Polymer-dispersed liquid-crystal devices
- Electrochromic devices



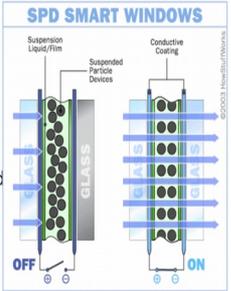
So, there are three ways of achieving it; one is the suspended particle devices based glass another is polymer dispersed liquid crystal devices, and the third one which is the most popular one is the electrochromic devices.

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Suspended Particle Devices

In suspended-particle devices (SPDs), a thin film laminate of rod-like nano-scale particles is suspended in a liquid and placed between two pieces of glass or plastic, or attached to one layer. When no voltage is applied, the suspended particles are randomly organized, thus blocking and absorbing light.

When voltage is applied, the suspended particles align and let light pass. Varying the voltage of the film varies the orientation of the suspended particles, thereby regulating the tint of the glazing and the amount of light transmitted



So, let us see how they work suspended particle devices or SPDs. In suspended particle devices a thin film laminate of rod like nanoscale particles is suspended in a liquid and placed between two pieces of glass or plastic or it can be attached to one layer.

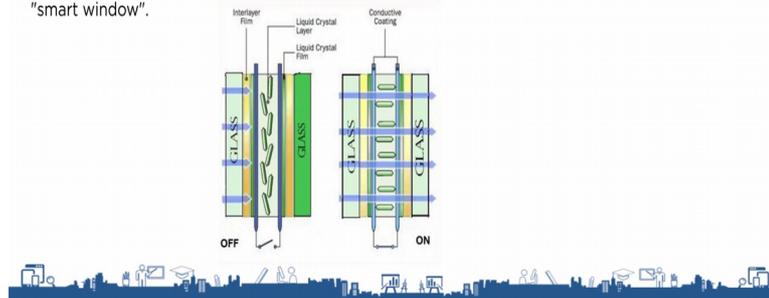
When no voltage is applied the suspended particles are randomly organized thus blocking and absorbing the light. When voltage is applied the suspended particles align and let the light pass. Varying the voltage of the film varies the orientation of suspended particles, thereby regulating the tint of the glazing and amount of light that is transmitted. So, by the voltage we can make these devices from opaque to transparent and depending on the voltage, we can attain any degree of transmittivity in between.

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Polymer Dispersed Liquid Crystal Devices



In polymer-dispersed liquid-crystal devices (PDLCs), liquid crystals are dissolved or dispersed into a liquid polymer followed by solidification or curing of the polymer. During the change of the polymer from a liquid to solid, the liquid crystals become incompatible with the solid polymer and form droplets throughout the solid polymer. The curing conditions affect the size of the droplets that in turn affect the final operating properties of the "smart window".



The other kind of devices, are polymer dispersed liquid crystal devices. In polymer dispersed liquid crystal devices liquid crystals are dissolved and dispersed into a liquid polymer followed by solidification of or curing of the polymer. Just like the previous one here also when we apply the voltage, the crystals align and they allow the light to pass through.

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Polymer Dispersed Liquid Crystal Devices



In the OFF state, the droplets are randomly aligned and the light is scattered or reflected in a large angle towards the viewer. In the ON state, the LC molecules orient uniformly along the direction of the applied field.



The black/off state appears milky opaque, it is a poor black state, as a result, the contrast ratio of PDLC is relatively low.

Source: https://continuingeducation.bnpmmedia.com/article_print.php?C=1199&L=5

Now, let us look at one application here you see the facade is having polymer dispersed liquid crystal devices. In the off state the droplets are randomly aligned and the light is scattered or reflected on a large angle towards the viewer. In the on state the LC molecules orient uniformly along the direction of the applied field therefore, in the off state it appears milky opaque and in the on state it appears transparent.

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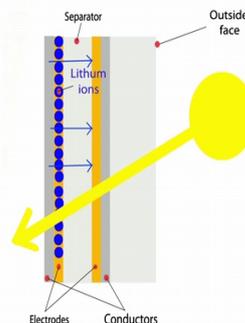
Electrochromic Glazing



Electrochromic devices change light transmission properties in response to voltage and thus allow control over the amount of light and heat passing through. In electrochromic windows, the electrochromic material changes its **opacity**: it changes between a **transparent** and a tinted state.

A burst of electricity is required for changing its opacity, but once the change has been effected, no electricity is needed for maintaining the particular shade which has been reached.

Electrochromic glass provides visibility even in the darkened state and thus preserves visible contact with the outside environment.



Now, let us look at electrochromic glazing. Electrochromic devices change light transmittance properties in response to voltage and thus allow control over the amount of

light and heat that passes through them. In electrochromic window the electrochromic material changes its opacity it changes between transparent and tinted state.

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Electrochromic Glazing

Electrochromic devices change light transmission properties in response to voltage and thus allow control over the amount of light and heat passing through. In electrochromic windows, the electrochromic material changes its **opacity**: it changes between a **transparent** and a tinted state.

A burst of electricity is required for changing its opacity, but once the change has been effected, no electricity is needed for maintaining the particular shade which has been reached.

Electrochromic glass provides visibility even in the darkened state and thus preserves visible contact with the outside environment.

The diagram illustrates the internal structure of an electrochromic glazing unit. It consists of a central electrochromic layer sandwiched between two electrodes. These electrodes are connected to conductors. A separator is placed between the electrodes. The diagram shows lithium ions moving from the left electrode through the separator into the electrochromic layer. On the right side, there is an 'Outside face' and a yellow sun icon. Yellow arrows represent light passing through the glass. Labels include 'Separator', 'Outside face', 'Lithium ions move', 'Electrodes', and 'Conductors'.

Interesting thing about electrochromic glazing is that we need not continue to apply the voltage to maintain the state. Once the voltage has been applied and the state has been achieved, there is no need to continue to apply the voltage.

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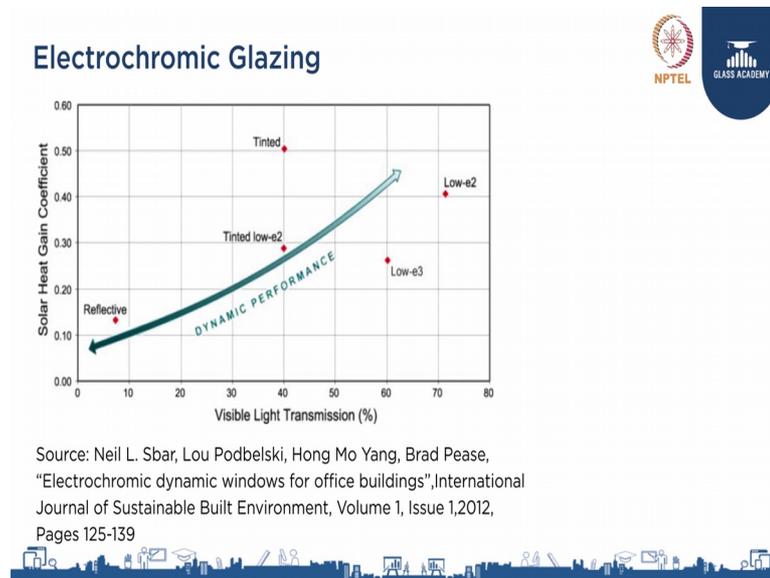
Electrochromic Glazing

- Considered to be the most suitable chromogenic technology for energy control in buildings
- Electrochromic materials undergo a reversible change in optical properties upon injection of light ions
- Typically they consist of two electrodes separated by an ion conductor.
- Transparent conductors form the contacts.

The diagram illustrates the internal structure of an electrochromic glazing unit. It consists of a central electrochromic layer sandwiched between two electrodes. These electrodes are connected to conductors. A separator is placed between the electrodes. The diagram shows lithium ions moving from the left electrode through the separator into the electrochromic layer. On the right side, there is an 'Outside face' and a yellow sun icon. Yellow arrows represent light passing through the glass. Labels include 'Separator', 'Outside face', 'Lithium ions move', 'Electrodes', and 'Conductors'.

Now, these are considered to be most suitable chromogenic technology for energy control in buildings, and they undergo a reversible change in optical properties upon injection of the light ions.

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By use of electrochromic glazing, we can change the property of the glazing from high visual light transmittance to low as well as high solar heat gain coefficient to low. So, this is a dynamic glazing we can change its property in this spectrum.

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Here is a photograph which is showing electrochromic glazing, when it is in the on state you can see lot of light is coming from the glass and illuminating the space, when it is in the off space off state it is dark and very little light is coming. This is commercially being used in the New Boeing Dreamliner and they have replaced the windows with this kind of glazing so, by touch of a button we can make a dark or we can make it light. Now, let us see: what are the other ways of getting the daylight into the building. All these things that all these techniques that we saw are applicable to the windows now let us look at skylights.

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Summary:

By the end of this video, you have learnt about the:

- Need for windows
- Daylight and vision glazing
- Light redirecting systems
 - Exterior systems
 - Interior systems
 - Interior louver systems
 - In-pane systems
- Laser cut panels
- Angle selective glazing
- Need for glazing controls and methods
- Photochromic glasses
- Thermochromic glazing
- Suspended particle devices
- Polymer dispersed liquid crystal devices
- Electrochromic glazing

