HOWSTUFFWORKS
HOME & GARDEN

How Smart Windows Work

BY KEVIN BONSOR

An exciting, cutting-edge window technology allows consumers to block either all light or just some by simply turning a knob or pressing a button. This type of light control could potentially save billions of dollars on heating, cooling and lighting costs (research indicates that approximately 2 percent of all the energy used in the United States is "consumed" by residential windows).

Competing Technologies

There are several technologies that can be used in a smart-window application:

- Thermotropics
- Photocromics or photochromatics
- Liquid Crystals
- Suspended Partical Displays
- Electrochromics
- Reflective Hydrides

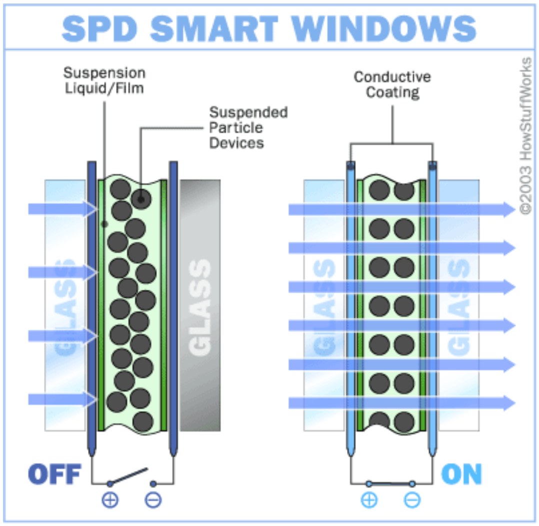
Cleaning window treatments can be a hassle. In this regard, smart windows are an easy alternative -- no more blinds to clean, or expensive drapery to be professionally cared for. Not only will smart windows cut down on your dry-cleaning bill, but they can save money on your power bill, too. When the summer sun is bathing your house in rays, things can really heat up inside your home, making your air conditioning work overtime. Smart windows can be used to block that extra heat. By blocking UV radiation, smart windows can protect paintings and furnishings in your home or office, too.

Although thermotropic and photochromic technology can be used in smart windows, both applications are ultimately impractical as energy saving devices because they cannot be manually controlled. Photochromic technology is most commonly used in sunglasses: Photochromatic material darkens in response to direct sunlight. As you can imagine, windows featuring this technology would not be entirely energy-efficient during cold winter months. On a cold but sunny day, instead of letting light in to warm a room, the windows would automatically darken instead. Thermotropic material responds to heat. So, on a beautiful, sunny summer's day, your view outside would be unavoidably diminished.

The other technologies are vying for a share of the estimated 20 billion square feet of flat glass produced worldwide each year. Currently, liquid crystals suspended particle devices (SPDs) and electrochromics are being touted as the latest and greatest window technologies -- with reflective hydrides nipping closely at their heels.

Let's take a closer look at SPD technology.

Suspended Particle Devices



Windows serve an important function in homes and commercial buildings. They not only let light in to cut down on electricity use for lighting, but the light coming through the window also provides heat. However, windows are not something people typically associate with being a cutting-edge technology. One tenacious company is trying to change that by offering a patented technology that enables a window to quickly change from clear to opaque and anywhere in between with the flip of a switch.

Conventionally, curtains and mini-blinds have been used to block out light and give us privacy, but they don't block out all of the light. Research Frontiers has developed a type of window that uses small light-absorbing microscopic particles known as **suspended particle devices** (SPD), or **light valves** to make it go from clear to dark in a matter of seconds. Here's a breakdown of the parts that make up SPD light-control windows:

- **Two panels of glass or plastic**
- **Conductive material** - used to coat the panes of glass
- **Suspended particle devices** - millions of these black particles are placed between the two panes of glass
- **Liquid suspension or film** - allows the particles to float freely between the glass
- **Control device** - automatic or manual

How the SPD windows work is very simple, if you think of SPDs as light valves. In an SPD window, millions of these SPDs are placed between two panels of glass or plastic, which is coated with a transparent conductive material. When electricity comes into contact with the SPDs via the conductive coating, they line up in a straight line and allow light to flow through. Once the electricity is taken away, they move back into a random pattern and block light. When the amount of voltage is decreased, the window darkens until it's completely dark after all electricity is taken away.

Users apply a moderate amount of voltage to the conductive material on the window panes through a control device. Several control methods are offered with the SPD light-control windows, including remote and automatic devices. The windows can be controlled manually with a **rheostat** or remote. Or, photocells and other sensing devices could be used to control the level of light automatically.

Research Frontiers holds about 470 worldwide patents on this light-control technology and has several licensees, including corporate giants like Polaroid and GE. Suspended particle devices can be used for a multitude of other consumer products, including sunroofs, sun visors, rearview mirrors, ski goggles and flat-panel displays for computers.

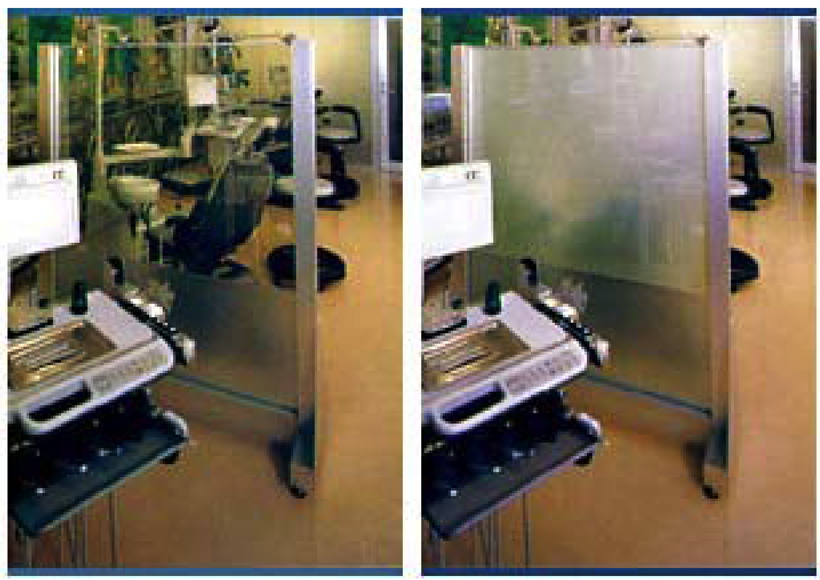
Now, you may be thinking, "Well, this sounds great, but I don't want to have to replace all the windows in my home." You might not have to. Research Frontiers has a patent -- No. 6,429,961 entitled, "Methods for Retrofitting Windows with Switchable and Non-Switchable Window Enhancements" -- that will enable homeowners to upfit their existing windows with SPD technology. And, if you're wondering "How energy efficient can it be to have windows that you essentially have to turn on for a clear view outside?" Reportedly, you can power about 15 large SPD smart windows in your home for less electricity than it takes to operate a simple night-light.

SPD technology isn't the only smart-window technology on the block. **Liquid crystals** have been in use for years, and **electrochromics** essentially performs the same functions as suspended particles. In the next sections, we will look at these two technologies.

A Chance Discovery
Although Edwin Land, inventor of the **Polaroid** camera, was the first to build a device using suspended particle devices (SPDs), the actual discovery of light-absorbing crystals can be credited to a dog. SPD technology was first discovered more than 100 years ago. As the story goes, the dog of an English chemist had been fed some quinine bisulfate to settle an upset stomach. When the dog accidentally urinated on a tray of iodine, the chemist noticed that green crystals formed in the tray. Somehow, the chemist discovered that these crystals had the ability to filter out light. Land later used these light-absorbing crystals to make a pair of glasses that could block out light.

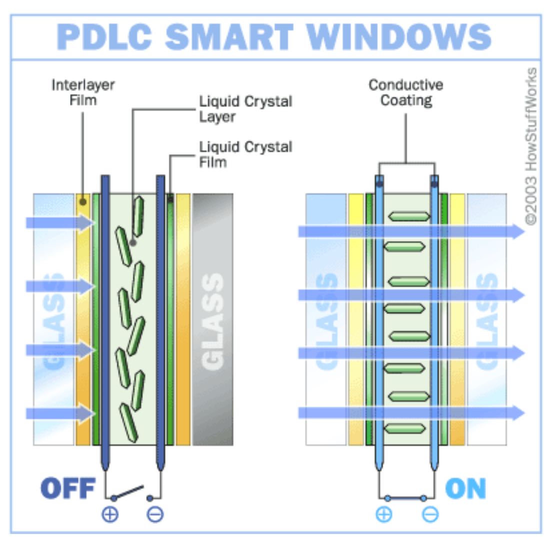
Liquid Crystals

Windows are undergoing a change the likes of which haven't been seen since the horizontal mini-blind was developed 50 years ago. Soon, curtains and window blinds could be obsolete. SPD technology is certainly one of the reasons for this window revolution, but other competing technologies like liquid crystals are responsible, too.



Using liquid crystal technology, the SwitchLite Privacy Glass™ in this screen goes from clear to translucent in an instant.
PHOTO COURTESY **SWITCHLITE PRIVACY GLASS™**

You are probably familiar with liquid crystals, which are found in many of the products you use every day. Portable computers, calculators, digital clocks and watches, and microwave ovens all use liquid crystal displays (LCDs). In these displays, electricity is used to change the shape of the liquid crystals to allow light to pass through, thus forming figures and numbers on the display.



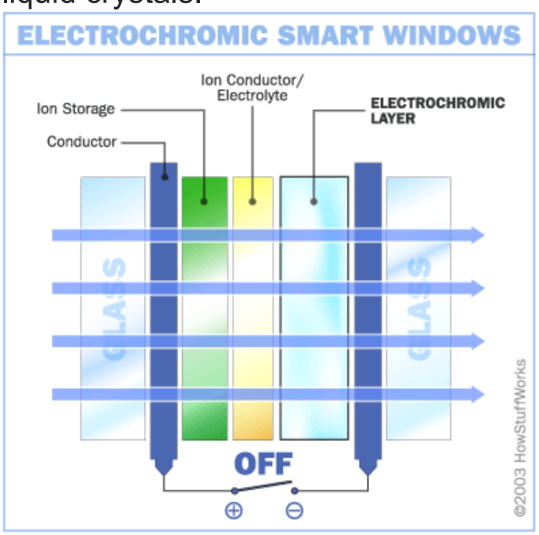
The technology behind an LCD is similar to the **polymer dispersed liquid crystals** (PDLCs) used in some smart-window applications. In these windows, the liquid crystals respond to an electrical charge by aligning parallel and letting light through. When the electrical charge is absent, the liquid crystals in the window are randomly oriented. With liquid crystals, the glass is either clear or translucent. There are no intermediate settings.

PDLCs are not a developing technology. In fact, they can already be found in offices and homes around the globe. Because it can achieve a translucent setting, PDLC technology is great for homes and offices -- you get privacy without sacrificing all light. PDLCs and suspended particle devices require power for their smart windows to be transparent. A different smart window technology is in development that would reverse the process. So what else is in store for the future of smart windows?

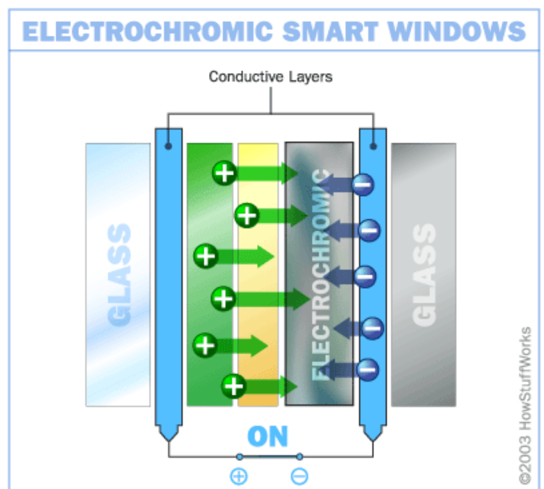
These roof panels are fitted with SwitchLite Privacy Glass ™.
PHOTO COURTESY SWITCHLITE PRIVACY GLASS ™

A Bright Future

Electrochromic windows darken when voltage is added and are transparent when voltage is taken away. Like suspended particle devices, electrochromic windows can be adjusted to allow varying levels of visibility. They are not an all-or-nothing technology like liquid crystals.



When switched off, an electrochromic window remains transparent.



When switched on, a low volt of electricity makes the electrochromic window translucent.

Electrochromic windows center around special materials that have **electrochromic** properties. "Electrochromic" describes materials that can change color when energized by an electrical current. Essentially, electricity kicks off a chemical reaction in this sort of material. This reaction (like any chemical reaction) changes the properties of the material. In this case, the reaction changes the way the material reflects and absorbs light. In some electrochromic materials, the change is between different colors. In electrochromic windows, the material changes between colored (reflecting light of some color) and transparent (not reflecting any light).

At its most basic level, an electrochromic window needs this sort of electrochromic material and an electrode system to change its chemical state from colored to transparent and back again. There are several different ways to do this, employing different materials and electrode systems.

Like other smart windows, electrochromic windows are made by sandwiching certain materials between two panes of glass. Here are the materials inside one basic electrochromic window system and the order you will find them in:

- Glass or plastic panel
- Conducting oxide
- Electrochromic layer, such as tungsten oxide
- Ion conductor/electrolyte
- Ion storage
- A second layer of conducting oxide
- A second glass or plastic panel

In this design, the chemical reaction at work is an **oxidation reaction** -- a reaction in which molecules in a compound lose an electron. Ions in the sandwiched electrochromic layer are what allow it to change from opaque to transparent. It's these ions that allow it to absorb light. A power source is wired to the two conducting oxide layers, and a voltage drives the ions from the ion storage layer, through the ion conducting layer and into the electrochromic layer. This makes the glass opaque. By shutting off the voltage, the ions are driven out of the electrochromic layers and into the ion storage layer. When the ions leave the electrochromic layer, the window regains its transparency.

With an electrochromic smart window, it only requires electricity to make the initial change in opacity. Maintaining a particular shade does not require constant voltage. You merely need to apply enough voltage to make the change, and then enough to reverse the change -- making this pretty energy-efficient. In fact, according to Sage Electronics, you can run a house full of electrochromic windows for about the same amount of money that it takes to power a single 75-watt light bulb.

Although they can technically be classified as electrochromic materials, the new reflective hydrides that are being developed behave in a noticibly different way. Instead of absorbing light, they reflect it. Thin films made of nickel-magnesium alloy are able to switch back and forth from a transparent to a reflective state. The switch can be powered by low-voltage electricity (electrochromic technology) or by the injection of hydrogen and oxygen gases (gas-chromic technology). Furthermore, this material has the potential to be even more energy efficient than other electrochromic materials.

The 2004 Chrysler Pacifica features an auto dim electrochromic rearview mirror.
PHOTO COURTESY DAIMLERCHRYSLER

We're surrounded by windows every day, but we probably don't stop to think about them very often. With advances in smart window technologies, we will start to see windows in a whole new light.