Smart Windows: Energy Efficiency with a View

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NREL research scientist Dane Gillaspie holds a sample of an electrochromic, or color-changing. window inside an accelerated weathering chamber at the Field Test Laboratory Building. Prototype windows are subjected to extreme simulated conditions to determine their performance and durability. Credit: Pat Corkery

(PhysOrg.com) -- Buildings consume 40 percent of our nation's energy. NREL is testing and researching electrochromic windows that could knock that back significantly.

Imagine wrapping a giant pair of Wayfarers or Aviators around your house on a sunny day. Wouldn't that be cool?

NREL researchers are trying to do the high-tech equivalent of putting sunglasses on buildings with a new generation of insulated "dynamic windows" that change color to modulate interior temperatures and lighting.

Buildings consume 40 percent of the nearly 100 quadrillion Btus (quads) of energy the United States consumes annually. Conventional clear windows account for about one-tenth of the buildings' share of that energy load, or four quads. That's because they allow precious heat to leak out on chilly days or allow the incoming sun to warm a room to uncomfortable levels, and building's climate system struggles to adjust.

Using dynamic windows to compensate for some of the electric lighting used inside buildings could save another quad of energy, according to NREL research scientist Dane Gillaspie.

"Combined, a broad installation of these highly insulating, color-changing windows could save about one-eighth of all the energy used by buildings in the U.S. every year," Gillaspie said, "and about 5 percent of the nation's total energy budget."

Torture Tested

Color-changing windows have been available for more than two decades. While they have attracted widespread interest — NREL provided a prototype in 1998 for a solar home exhibit at Walt Disney's Epcot Center — they have not become widely available or commercially successful.

Since the 1980s, NREL has tested various window technologies and helped establish technical standards for the industry with the American Society for Testing and Materials.

Researchers put window samples into accelerated weathering chambers for 20,000 light-dark cycles, or the equivalent of 20 years of service. Conditions inside the chamber are calibrated at the intensity of one sun (or the amount of light that typically hits Earth on a sunny day) and 176 degrees F (80 degrees C.)

"We call it our torture chamber," said Erin Whitney, NREL's dynamic window testing coordinator.

Many products and prototypes tested in the NREL chamber have performed poorly and their color-changing properties degraded sooner-than-expected. Among contemporary designs, NREL has verified the performance of one technology developed by Sage Electrochromics — which has a cooperative research agreement with the Laboratory. Sage predicts its technology will drop in price by as much as 70 percent over the next five years as performance improves, volume increases and production becomes more efficient.

However, today's dynamic windows still cost up to $1,000 per square meter of glass.

"That's a problem," said NREL senior scientist Anne Dillon, who manages the dynamic windows program. "They are too expensive."

How They Work

Insulated windows are made from multiple layers of glass. Typically the spaces between the panes are filled with a gas. Electrochromic windows are made with a very thin stack of dynamic materials deposited on the outside pane.

The dynamic portion consists of three layers: active and counter electrodes separated by an ion conductor layer. NREL researchers are experimenting with electrode layers made of nickel and tungsten oxides; the ions are lithium.

The window changes from clear to tinted when a small electric field is applied and the lithium ions move into the working electrode layers. The change can be triggered by sensors in an automated building management system, or by a flick of a switch. Electrochromic windows can block as much as 98 percent of the direct sunlight. Reversing the polarity of the applied voltage causes the ions to migrate back to their original layer, and the glass returns to clear.

Gillaspie said NREL researchers are using metal oxides because light does not degrade them. While current manufacturer warranties typically extend for 10 years, NREL is aiming to develop windows that perform for 20 years or more.

Although electrochromic windows add yet another powered device to a modern building, they should save far more energy than they consume. Powering 1,500 square feet of color-changing glass (about 100 windows) would require less power than a 75 watt light bulb.

And because the windows modulate the building's interior climate, the rest of the heating, cooling and illumination systems can be smaller, leading to lower construction costs and lower monthly energy bills.

In computer simulations of building performance, the electrochromic windows:

• reduce electricity consumption for cooling by up to 49 percent;
• lower peak electrical power demand by up to 16 percent; and
• decrease lighting costs by up to 51 percent.

"The brilliant thing is that not only do you save energy with these windows," Gillaspie said, "but they allow you to scale back the HVAC, so you save money."

Learning from Photovoltaics

If the dynamic layers of the electrochromic window remind you of an advanced solar cell, it's no coincidence. The entire dynamic stack between the glass panes measures about a micron thick. That's about the same as thin-film photovoltaic cells.

The dynamic layers of electrochromic windows are manufactured with a vacuum deposition process called "sputtering." The process also is used in PV and semiconductor manufacturing because it provides a high degree of control and creates uniform results when depositing materials in ultrathin coatings. However, sputtering is relatively slow and energy-intensive.

NREL researchers are working to drive down high manufacturing costs by creating the dynamic layers using inexpensive printing technologies and metallic inks similar to research into high-volume thin-film PV manufacturing already taking place at NREL.

NREL's smart window engineers will be using some of the same equipment with window manufacturers in the advanced Science and Technology Facility, including the Atmospheric Processing Platform in the Process Development and Integration Laboratory.

NREL researchers also are investigating ways to rapidly make electrochromic films on cheaper, flexible plastic substrates instead of glass. This will allow development of so-called "roll to roll" (R2R) processing methods similar to those currently used to print newspapers.

An electrochromic device made of flexible materials could be retro-fit to existing windows, NREL research scientist Robert Tenent said.

Expanding into the retrofit market would expand the windows' use and accelerate energy savings, he said.

"By and large, high manufacturing costs are limiting the implementation of these dynamic materials," Tenent said. "A significant portion of our research efforts are directly focused on eliminating that expense through manufacturing improvements and allowing us to realize the tremendous potential energy savings that this technology holds"

The PV connection doesn't end there. Dynamic windows typically are hardwired into a building's electrical system. But in a wireless version, the power for the color change could come from a small PV cell installed in the window's casement.

When sunlight hits the PV cell, it converts the sunlight to power, which ionizes the electrode layers and darkens the window

Eventually, dynamic windows may produce more energy than they consume so power generation would not be limited to a rooftop PV system.

NREL research supports the U.S. Department of Energy's goal to deploy energy saving windows for residential construction by 2015 and commercial buildings by 2020.

More information: Learn more about DOE's Electrochromic Initiative and Windows Technology program: www.eere.energy.gov/buildings/ … dows_technology.html

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