FALL / WINTER 1997

FENESTRATION R&D

LAWRENCE BERKELEYNATIONALLABORATORY ENVIRONMENTAL ENERGYTECHNOLOGIES DIVISION

Glazings for the 21st Century

Development and Characterization of Advanced Glazing

The market for energy-efficient windows has grown considerably in just 20 years, as has the number and sophistication of products available to consumers. The most important technical advances have been new types of thin-film coatings for glazings that increase the energy performance of the window. LBNL's efforts in coating development began in 1976 with the establishment of several industrial partnerships to develop the first of these prototype coatings and a new low-cost, thin-film deposition process. This work has continued to the present day in the Building Technologies Program through a variety of projects aimed at developing and characterizing the next generation of energy-efficient glazing technology. We provide a brief overview of four current project areas.

Smart Windows: Electrochromic Coatings

DOE has supported R&D on "switchable glazings" for 15 years. The research has progressed to the stage where industry is now actively involved in the development of electrochromic coatings. DOE has launched a five-year, cost-shared, public/private effort to remove critical market barriers that impede advancement of this important technology. Two teams of companies are engaged in development of prototypes of commercially viable devices through the Electrochromics Initiative and a third company is supported through an SBIR small business grant (see page 5 for details). Mike Rubin provides overall technical coordination of the effort for DOE, and LBNL and another DOE laboratory, the National Renewable Energy Laboratory (NREL), perform a variety of measurements to evaluate the energy performance and durability of these prototypes. To assist industry researchers, current LBNL research focuses on rapid development and analysis of improved electrode materials. Among recent accomplishments was the production of a stoichiometric form of lithium nickel oxide by laser deposition and sputtering with excellent electrochromic properties. EIC Laboratories tested the films and reported that they have the highest coloration efficiency of any known anodic electrochromic material. EIC will test the films in their own devices in the near future. We also work on several binary electrodes produced by cosputtering from two targets simultaneously. For example, enhanced forms of tungsten oxide produced in this way have wide application because of the prevalence of tungsten oxide in today's devices. In addition to testing durability, NRELalso investigates the degradation mechanisms which lead to failure in the hope of being able to correlate accelerated testing to real-

(See **21st Century Glazings**, page 8)

Thin-film Coater Wins R&D 100 Award

The constricted-plasma ion source—a rugged, clean, low-cost device with potential forapplying thin films on everything from microchips to glazings—has won a prestigious R&D 100 Award forits developers, Berkeley Lab researchers Andre Anders, Mike Rubin, and Michael Dickinson.

See page 8 and the Berkeley Lab website (http://www.lbl.gov) foradditional details.

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BUILDING TECHNOLOGIES PROGRAM
WINDOWS & DAYLIGHTING GROUP

Daylighting '98
INTERNATIONAL CONFERENCE

An International
Conference on Daylighting
Technologies for Energy
Efficiency in Buildings

May 11-13, 1998
Ottawa, Ontario, Canada

iternational Daylighting Con-
rence '98 will feature advances
both the science and applica-
on of building integrated day-
ghting technologies. The con-
rence will focus on state-of-
e-art daylighting technologies,
esign tools, manufacturing pro-
esses, innovative building ap-
ications, and regulations and
odes affecting the daylighting
dustry.

he conference will bring
gether researchers, daylighting
dustry experts, regulators, gov-
nment and utility representa-
ves from North America,
urope, and Japan. Delegates
ill have an unprecedented op-
ortunity to meet leaders in the
aylighting industry, exchange
formation about the latest in-
ovations, acquire new skills
rough educational workshops,
nd debate creative approaches
future regulations and codes.

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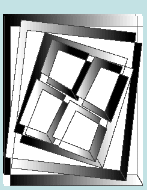

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INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme

IEA/SHC Task 18

IEATask 18 on Advanced Glazing and Associated Materials for Solar and Building Applications has concluded. Fifteen countries contributed to the Task. Prof. M.G. Hutchins from Oxford Brookes University, U.K. served as operating agent. In this final phase, 15 final project reports derived from over 300 contributions from the individual countries were submitted, including specific glazing material technologies, optical characterization, and energy performance and design assistance.

The U.S. participated in six projects and contributed two final project reports. Final reports will be submitted at the Executive Committee meeting in Australia in November.

The **9th Experts'Meeting** took place in Rome, Italy, September 23-27, 1996. The Italian National Agency for New Technology, Energy and the Environment (ENEA) sponsored the event, and the host was Mr. Augusto Maccari. Representing the U.S. were Dr. Mike Rubin of LBNL, project leader for the chromogenic glazings activity, and Mr. Robert Sullivan also of LBNL, project leader for the Modeling and Control Strategies activities. Dr. Rubin gave three presentations entitled: (1) Characterization of Electrochromic Windows from U.S. Industry Initiative, (2) New Approach to Calculate Angle-Dependent Properties from Normal Properties, and (3) New Measurement Capability and Calculation Procedure for Directional Properties. At the end of the meeting there was a tour of ENEA.

The **10th IEATask 18 Meeting**, held in Nagoya, Japan from March 10-14, 1997, was sponsored by Dr. Sakae Tanemura and Dr. Kazuki Yoshimura of the National Industrial Research Institute. Atechnical tour of Asahi Glass in Yokohama was arranged by Dr. Junichi Nagai of Asahi. Final project reports were presented. Completion of the Task report will proceed on schedule.

One day was devoted to an industry workshop. Presentations were made by IEAparticipants on the outcome of certain projects, as well as by representatives of the Japanese window and glazing industry. Mr. Sullivan, of LBNL, presented an overview of the energy performance results obtained by building simulation tools from various countries. The importance of this work prompted the task leader to request that Mr. Sullivan prepare a graphical summary of the results to guide choices of materials.

Another half-day in Nagoya was devoted to discussion of the next phase of work on advanced glazing materials. At the previous meeting, a working group, led by Mr. Dick van Dijk of TNO in the Netherlands, prepared a draft proposal for a new "Knowledge Base for Solar Building Envelopes" task, which the IEAExecutive Committee approved. Amajor component of Task 18 was the development and use of characterization methods for advanced glazings. The goal of the new task is seen as creating a bridge between this database and other tasks on facades and whole buildings, some of which are currently underway. Proposed elements or subtasks include (1) standards for components and systems, (2) control strategies and energy performance, (3) new and improved materials, and (4) technology transfer. The U.S., through DOE, agreed to be the lead country in defining the task definition phase with Dr. Mike Rubin in charge. The definition phase has just begun and will last for approximately one year. The first meeting is proposed for the spring of 1998 in the U.S.

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IEA/SHC Task 21

The U.S. is now formally participating in and providing the following specific contributions to IEA Task 21 on Daylight in Buildings.

Subtask A: Design, characterization, and performance information for deep-penetration window-shelf daylight systems.

Subtask C: Algorithms for simulating complex fenestration daylighting systems, and a web-page-linked network of other simulation and modeling resources.

Subtask D: The National Renewable Energy Laboratory's Solar Energy Research Facility building (SERF) in Golden, Colorado has been selected as one of the subtask case studies to be monitored and documented.

The **4th Experts'Meeting** was held in Veldhoven, Netherlands, April 21-25, and the **5th Experts'Meeting** was held in Brisbane, Australia, October 27-31. Bill Carroll presented LBNL's work on Subtask C: Daylighting Algorithms, and Steve Selkowitz participated in Subtask A: Daylighting Systems Characteristics and Subtask B: Lighting Controls. Amore detailed update will be presented in the next issue of this newsletter.

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International Conference on Building Envelope Systems

Europe Ahead in Building Application of Sophisticated Envelope Technologies

The International Conference on Building Envelope Systems and Technology, hosted by the Center for Window and Cladding Technology (CWCT), brought together 300 researchers and practitioners from 26 countries at the University of Bath, UK in April 1997 to review the state-of-the-art in building envelope technology.

Papers addressed glazing, window, and fenestration systems for the transparent element of the facade, and opaque cladding, sealants, and structure for the non-transparent elements. Although energy performance was an important theme, it was not the dominant thrust of the meeting.

Steve Selkowitz, Building Technologies program head, presented "Design and Performance of an Integrated Envelope/Lighting System," based on Berkeley Lab's work in developing, prototyping, and testing automated venetian blind systems with new lighting controls for daylight dimming.

Overall observations:

- Europe is ahead of the U.S. in the application of sophisticated new active envelope technology in commercial buildings, due to differences in costing and construction practice.
- Better design tools are needed to predict the energy performance of these state-of-the-art buildings, and to assess comfort, occupant satisfaction, and energy performance.
- RADIANCE is used widely by leading design and engineering firms in Europe. No other tools seem to be close in terms of their analysis capabilities.
- Increasing recognition that a life-cycle performance perspective is crucial to address durability and performance issues of facade systems.
- Growing interest in "green buildings" in Europe, but no clear definition of term.

The *ICBEST'97 Proceedings* are available at £75 per copy, plus £25 airmail cost. Payment should be made to CWCTServices Ltd, preferably in sterling, or direct to their bank, Barclays Bank plc, Milsom Street, Bath, UK, sort code 20 05 06, account No. 20298506.

DOE's Efficient Window Collaborative

Alliance to Save Energy Partners with Berkeley Lab

The Washington, D.C.-based Alliance to Save Energy (ASE) has joined Berkeley Lab to assist in the launch of the Efficient Window Collaborative.

The objectives of the collaborative are to work with the glass and window industry, builders, and consumers to increase the sales of efficient window technologies throughout the United States.

Berkeley Lab estimates that efficient windows sold today represent only 35% of the market. Bill Prindle, who is leading the ASE new window effort said, "Windows are a key focus for building energy efficiency; we want to double the market penetration of efficient windows." ASE brings strengths in marketing, communications, and codes and standards to the Collaborative, which complement Berkeley Lab's technical support of the EWC.

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Interoperability Alliance

IAI Seeks Window Industry Members

In the course of creating a new building, information about window products is transferred numerous times by many participants. The architect sketches a window in a CAD drawing, a colleague renders a view of the building, the engineer develops thermal performance data, a lighting designer analyzes the window impact on daylight levels, and a cost estimator adds the cost of the window to a building in a long series of steps that span months and years.

Along the way, window data is lost, recreated, modified, transferred between drawings, disks, or files in a process that increases cost, error, and liability to all members of the design team. The International Alliance for Interoperability, IAI, has the solution to this problem—a shared description of all building components that can be used by all participants to describe all the properties and behaviors of windows.

Such a common software language would enable the development of a new generation of interoperable tools. The IAI is a voluntary, open, non-profit, action-oriented alliance of over 100 companies in North America (over 400 internationally) working to create a future with interoperable software tools. The role of the IAI is to develop and publish the software specifications, called Industry Foundation Classes (IFC) that already include an initial definition of window objects. By joining the IAI you can participate in the process of refining and extending these window specifications and collaborating with the software vendors whose tools describe your products.

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Integrating Energy-Efficient Features Into a Window/Wall Panel System

To integrate or to segregate? Residential windows combine a complex set of material properties, mechanical mechanisms, and functional requirements. Windows must last many years while keeping the elements out, the occupants comfortable, allowing daylight in, and providing view out. All this in a package that can be easily and reliably installed in a building envelope.

Illustration: Trevor Johnston/Paragraphics Inc., email: trevj@sympatico.ca

Integrated Window System

Ongoing research in many sectors of the building industry have created improvements in all areas of window design and function. To achieve the next step, researchers at Berkeley Lab are integrating several key energy-efficient features into a window/wall panel, an Integrated Window System (IWS).

The key elements of an Integrated Window include an exterior sun shade to block the sun's heat, and an interior insulation that covers the window at night to keep the warmth inside. A manufactured construction approach includes these energy-efficient features in a full height wall panel providing the wall structure, the structural header to transfer roof loads around the window, and a raceway for utilities run under the window.

Each of these elements adds measurable gains in comfort and thermal control to the building's occupants that are more reliable and more useful than devices installed in the field. By placing these elements in a manufactured unit they can be employed to their optimum.

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Striking Changes in Russian Window Production

Until recently, windows in Russian residential buildings were limited to three types: single glazed, double-glazed, and triple-glazed. Insulated glass units were used on rare occasion, but only in municipal buildings and in public transportation. This was of little concern when heat prices were low. In fact, the cost of energy was such that an investment to replace double-glazed with triple-glazed windows would have had a payback period of at least 20 years.

Striking changes have occurred in the field of window production in Russia within the past two years. Russia's transition to a market economy, and the sharp rises in prices of fuel and energy have stimulated interest in energy-efficient windows. Based on a review of Russian legislation on foreign investment, the most favorable course of action for foreign investors in the construction sector is probably the establishment of joint ventures with Russian partners. The following developments are indicative of the changing market environment:

- Adoped new Federal construction standards.
- Established new voluntary certification program by Ministry of Construction.
- Increased Russian companies' manufacturing of new windows by licensing foreign technology.
- Russian companies producing glass and film with low-emissivity coating with purchases of foreign equipment.
- In-country production capacity for ordinary 3-6-millimeter glass is approximately 135-140 million square meters per year, enough to meet current demand.
- More than two billion square meters of buildings constructed since 1961 need windows replaced to meet current buildings standards.
- Market potential for IGUs estimated at 24 million square feet per year. Currently, only 10 percent of this need is being met.
- New construction in Moscow area includes office buildings, business centers, and hotels, in preparation for Moscow's 850th anniversary.

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For more information, see *http://www.pnl.gov/aisu/spiridon.htm* .

Moscow Workshop Planned for May 1998

Avery successful joint meeting was held in Moscow in May 1997 between a U.S. team, comprised of DOE researchers and manufacturers, and a Russian team, comprising code officials and manufacturers. Afollow-up workshop is planned for May 1998 in Moscow.

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U.S. Department of Energy

The Electrochromics Initiative

In 1995, the U.S. Department of Energy (DOE) launched an Electrochromics Initiative to accelerate research and development on electrochromic materials that would lead ultimately to commercial products. After issuing a competitive solicitation for Phase One of the Initiative, the Department chose two manufacturers to develop electrochromic window prototypes, Optical Coating Laboratory, Inc. (OCLI) of Santa Rosa, California, and the Donnelly Corporation of Tucson, Arizona. Berkeley Lab's role in this work is to provide technical oversight of the Initiative for DOE, to supply technical assistance to these companies, to work on improved materials for the coatings, and to assess the performance of electrochromic coatings in buildings using simulation tools, field tests, and demonstration projects. Both vendors have now delivered prototype windows of about one square foot in size. Berkeley Lab has conducted optical characterization tests and Berkeley Lab researchers have also performed computer simulations of the prototypes' energy and visual performance using, respectively, the DOE-2 and RADIANCE models. Al Czanderna's group at the National Renewable Energy Laboratory (NREL) has been conducting durability tests on the samples (see article below). The results of the durability tests have proven useful in helping the Initiative's industrial partners improve their processes and define where the work will proceed in the Initiative's second phase.

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National Renewable Energy Laboratory

Developing Testing Protocol for Electrochromic Windows

The National Renewable Energy Laboratory is leading the effort to develop a testing protocol for electrochromic windows (ECWs). This protocol will be ideal for testing electrochromic samples, such as the one-foot-square specimens now under development at Optical Coating Laboratory, Inc. (OCLI) and Donnelly Corporation. Visual inspection and initial characterization for optical response properties are the first two steps of the protocol, followed by two tests, performed in parallel.

For a thermal qualification test, the samples will be cycled between 76°C and -26°C at a cycle rate of five cycles per day (4.8 hours/cycle). The samples will not be exposed to solar radiation or humidity, and they will not be switched during the test, whose purpose is to establish that ECWs will survive the thermal cycling anticipated when they are in service.

In the temperature-radiation-cyclic I-V (current voltage) test, alkali halide lamps in an Atlas XR260 four-by-six-foot accelerated testing chamber will irradiate the sample. These lamps are filtered to provide an AM 1.5 solar spectrum, including UV radiation from 290 to 400 nm. The ECWs lie in a horizontal plane, and a detector measures irradiation intensity in this plane. The chamber's air temperature is constant and is chosen to provide a mean ECW coating temperature of 60°C during the test. Each device will receive the I-V it requires for coloring and bleaching, generally in the range of one to ten minutes per cycle. Irradiation by the alkali halide lamps increases the temperature of the ECWs, especially in the colored state. Relative humidity in the chamber will be measured, but not controlled.

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Florida Solar Energy Center

Computational Analysis of Complex Fenestration Systems

Ross McCluney of the Florida Solar Energy Center, Coco, Florida, is leading the computational part of the effort to analyze complex fenestration systems.

ASAPis a design and analysis computer program for large optical systems that evaluates not only specularly reflecting and transmitting elements, but diffuse surfaces as well. An ASAPuser can enter complex shading and other fenestration system geometries, and specify a distribution, both geometric and spectral, of electromagnetic radiation incident on the system. The program generates output data that characterizes the whole fenestration system as an object, and predicts the complete angular and spectral distributions of its optical properties.

Since ASAPis an optical programming language, as well as a powerful computational tool, it should be possible to prepare a custom version adapted to the specific problem of calculating the optical properties of complex fenestration systems.

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MoWiTTTests of Electrochromic Prototype

Small-scale electrochromic prototypes from Donnelly and OCLI, participants in the DOE/Electrochromic Initiative, have recently been tested in the MoWiTT field test facility. The glazings were incorporated into skylight frames supplied by Velux. The summer test program included commercially available clear, tinted, and spectrally selective glazings as well. This project represents the first use of MoWiTTfor skylight testing and will provide valuable field experience and performance data on energy flows and temperature experienced by the skylight and their glazing assemblie

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The Glazing Optics Characterization Laboratory

Specialized Equipment Helps Accurately Determine the Energy and Visual Performance of Existing Products and Experimental Glazing Materials

Fenestration Facts

'The most promising smart window technology may be devices based on electrochromic coatings. Although not yet commercially available, they appear to have a good chance to meet performance, cost, and manufacturing requirements that would result in a marketable window system."

Residential Windows
John Carmody et al
1996

Glazing exists because of its optical clarity and light transmission properties. Increasingly important is the ability of coated glazing to control infrared and ultraviolet radiation. Dynamic coatings such as electrochromics, anisotropic and light-redirecting materials, geometrically complex insulation and shading systems will control optical radiation in new ways. Optical and radiative properties of glazing materials therefore are primary inputs for determining the energy performance of buildings. Accordingly, LBNLmaintains one of the most extensive facilities in the world for characterizing the optical properties of glazing materials, including seven specialized instruments and the analytical tools needed to interpret the results and extract useful information.

Figure 1. Ellipsometer determination of optical indices.

The optical properties of simple glazing types such as coated and uncoated glass and plastic are conventionally tested at normal incidence (light strikes the glass at 90° to the surface). The National Fenestration Rating Council (NFRC), with the technical assistance of LBNL, established procedures that provide for accurate measurement and calculation of several different optical properties. These properties are then used in a nationwide program to rate and label the energy performance of windows. As a result, all major U.S. glazing manufacturers now follow a uniform characterization procedure. LBNL has collected and validated spectral data for over 750 glazing products, and distributes the data on a diskette or by download from our web site. The 5th release occurred in September and is the first to include international data, although it is not yet NFRC certified.

The integrity of the glazing database is guaranteed both by peer comparison and by checks of each file at LBNL. Atypical operation involves the measurement of product parameters needed for calculations of SHGF, U-factor, and even annual energy performance. Standard measurements of spectral transmittance and reflectance at normal incidence are made with highly automated spectrometers. APerkin-Elmer Lambda 19 with Labsphere RSA-19 integrating sphere is used for solar range measurements on glazing products. Emittance is measured with a Nicolet FTIR with a CsI beamsplitter for extended range in the thermal infrared. Under the auspices of the NFRC, glazing manufacturers can measure their own materials using similar spectrometers. Significant error in this type of measurement, however, is common, as shown by round robin studies among the NFRC manufacturers together with the IEA Task 18. If any feature of a spectrum appears to be incorrect, more versatile and accurate equipment is employed as described below.

With the basic rating system working smoothly, the issue of properties needed to calculate annual energy performance becomes primary. Sunlight often strikes glass at oblique angles for which the transmittance and reflectance are significantly different from their values at normal incidence. Areliable procedure for extrapolating from normal properties to oblique properties is thus needed for accurate annual energy performance calculations. Several instruments are available to measure angle-dependent properties with high accuracy. Asingle-beam goniophotometer employing a feedback-stabilized laser diode with a short coherence length in conjunction with a large-area silicon detector provides absolute verification at 670 nm and any angle of incidence. We also have a goniospectroradiometer described in more detail below in connection with complex glazing. In principle, this instrument can measure all required angle-dependent properties, but accuracy is still an open issue. No standard procedures or reference materials yet exist. Finally, we have a variable-angle spectroscopic ellipsometer (Fig. 1) which is used to determine fundamental optical constants of the glazings. These capabilities, however, do not exist in most industrial

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Figure 2. Angular motion stage of bidirectional spectroradiometer.

laboratories. Therefore we have used the advanced capabilities of the optics lab to develop simple correlation models for angle dependence that rely only on readily available normal incidence data from the database.

Glazing manufacturers need other analytical tools for a variety of purposes. Prediction of the properties of composite systems such as applied flexible films and laminated glazing can not be directly obtained from measurements on isolated components with air on each side. Acalculation procedure to circumvent this difficulty has been developed. Also, from a single careful measurement, it is possible to simulate the properties of families of similar products. For example, the properties of a sheet of glass with a standard substrate thickness can be measured, and then the properties could be calculated for all other available substrate thicknesses. Similarly, a coating could be transferred to an entirely different type of substrate. Not only would such procedures reduce the measurements on existing products but they would also allow the creation of "virtual" products without the trouble of manufacturing prototypes. The first version of a new optical engine for Window 5, incorporating all of the capabilities mentioned above, is nearing completion.

Research on the coating deposition process and improvements to the materials often require an analysis of more fundamental optical properties. Furthermore, as mentioned above, methods for determining some optical properties such as transmittance and reflectance at oblique incidence, or the properties of coated laminates, cannot be developed or verified with standard equipment only. One important source for this information is a J.A. Woolam variable-angle spectroscopic ellipsometer operating over the ultraviolet, visible, and near infrared range from 250-1700 nm. Supplementary radiometric data are taken on one of the Lambda 19 spectroradiometers which also extend the range of the ellipsometric measurements so that the entire solar spectrum is covered to 2500 nm.

For the characterization of complex window systems, an approach has been adopted that has many similarities to the successful method for simple glazings. Rather than make measurements on full-sized windows that may have shading devices, measurements are made on small samples of each layer only and then the resultant properties of the system are calculated. Fewer permutations need to be measured, less data is collected and stored, and much of the work is done with inexpensive computer time. We are now testing a new goniospectroradiometer (Fig. 2) designed to measure the bidirectional properties of any glazing material. Four angular degrees of freedom are sufficient to cover the angular variations of the most asymmetric sample. Atranslational degree of freedom is also built in to account for small-scale inhomogeneities in samples such as rough glass. A commercial ray tracing program is then used to simulate the system properties. The computational aspect of the process will be more fully developed at the Florida Solar Energy Center (see page 5).

Amultichannel optical test station for electrochromics allows continuous monitoring of optical and electrochemical properties during cyclic testing (Fig. 3). Both devices and electrodes in solution can be tested either inside or outside of a dry box. Remote access has been built into this system because experiments of this type tend to run unattended for days or weeks. Tests can be monitored and if desired the testing protocol can be altered from an office PC on the LBNLnetwork. Off-site access is also possible. Optical indices needed for design of electrochromic systems are not widely available. With the instruments described above, we have embarked on a long-term project to catalog the basic optical parameters of electrochromic materials. Data for a variety of materials is available on the web site, *http://windows.lbl.gov.*

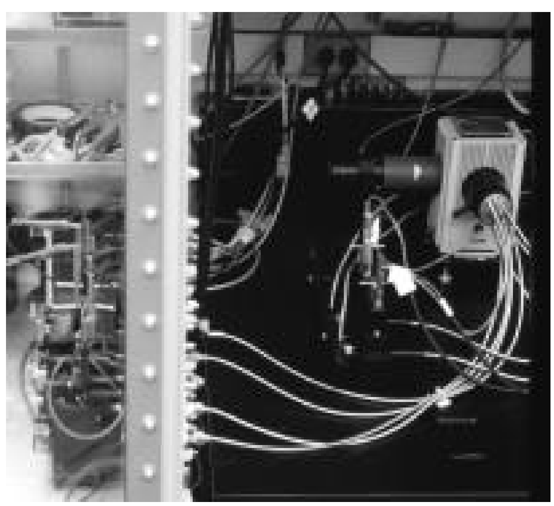

Figure 3. Simultaneous collection of cyclic voltammograms and optical changes of electrochromic materials.

Fenestration Facts

"'Smart windows are able to dynamically change their solar-optical properties in response to changing performance requirements. There are two basic types of smart windows—passive devices that respond directly to environmental conditions such as light level or temperature, and active devices that can be directly controlled in response to occupant preferences or heating and cooling system requirements."

Residential Windows
John Carmody et al
1996

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Fenestration Facts

‘Avariant of the liquid crystal display technology used in wristwatches is now serving as a privacy glazing for new windows. Avery thin layer of liquid crystals is sandwiched between two transparent electrical conductors on thin plastic films and the entire package is laminated between two layers of glass. When the power is off, the liquid crystals are in a random and unaligned state. When power is applied, the electric field in the device aligns the liquid crystals and the glazing becomes clear in a fraction of a second, permitting view in both directions.”

Residential Windows
John Carmody et al
1996

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21st Century Glazings ...

(continued from page 1)

time failure as well as to diagnose and correct device problems (see page 5).

Thin Film Deposition Processes

Process modification for development of improved low-emittance and solar control coatings can be achieved through the use of advanced plasma technology developed at LBNL. Anew type of constricted glow-discharge plasma source was recently selected for the prestigious R&D 100 Award. Invented by LBNL researchers Andre Anders, Mike Rubin, and Mike Dickenson, the source was designed to be compatible with industrial vacuum deposition equipment and practice. Construction is simple, rugged, and inexpensive. The source can operate indefinitely over a wide range of chamber pressure without any consumable parts such as filaments or grids. Among the uses of the source are densification of coatings for greater durability, crystallization at low temperatures for increased reflectivity or electrical conductivity, enhancement of reactivity to produce an otherwise unstable phase or increase deposition rate, and control over composition. Several of these sources have been fabricated for specific uses by glazing manufacturers. LBNL will assist these manufacturers to optimize the source characteristics and to develop new coating types. Recently, a linear configuration was successfully tested. Consisting of an array of miniaturized versions of the original source, this linear source is extendible to a deposition system of any width.

International Collaboration on Optical Materials

LBNLstaff continue to participate actively in several international forums under the auspices of the International Energy

Simulation tools, such as these RADIANCE ray tracing images, compare visibility of a computer screen with conventional clear glass (lower left), tinted glass (lower right), and electrochromic glass (top left), using two different control strategies.

Agency (IEA). LBNL led the subtask on Chromogenics under IEATask 18 which concluded in March. Switchable glazing technologies such as liquid crystals and thermochromics, as well as electrochromics, were investigated and compared. Asurvey was made of the companies involved worldwide and the status of their technology. Test methods and results were compared for a variety of small sample types and some large electrochromics. Energy performance of these technologies was evaluated in another subtask led by Bob Sullivan of LBNL. Reports were produced on various specific technologies and a final report will be available later this year. One new study used DOE-2 to evaluate the performance of angle-selective prototypes developed by Prof. Geoff Smith of the University of Technology at Sydney. (See the regular update on IEATask 18 on page 2).

Materials Characterization Studies

Characterization of these new glazing materials is an important part of our research. Structural and compositional analysis is performed using a variety of facilites available at LBNL. These techniques range from standard techniques such as x-ray diffraction, or less common techniques such as Nuclear Reaction Analysis for detection of lithium in electrochromics, to exotic and unique applications of atomic resolution electron microscopy or the syncrotron at LBNL's Advanced Light Source. Amore complete listing and description of these general materials science capabilities may be found on LBNL's web site, *http://www.lbl.gov*. Optical and thermal characterization of windows are of particular importance to our energy efficiency program, so we maintain specialized facilites in these areas. Thermal facilites were highlighted in previous issues. The Optical Characterization Facility for glazing is described in detail in a separate article on page 6.

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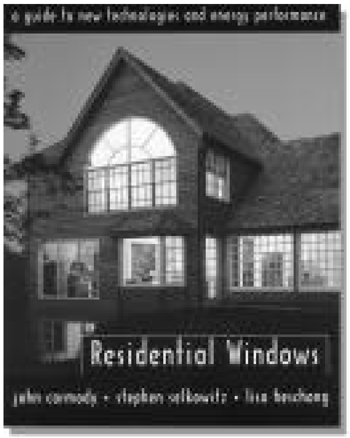
Exciting New Publications for the Building Industry



Residential Windows, A Guide to New Technologies and Energy Performance

John Carmody, Stephen Selkowitz, Lisa Heschong

Available from W. W. Norton & Company, paperback, 214 pp, 1996, $22.00. Website orders:

http://www.wwnorton.com/catalog/spring96/073004.htm

Acomprehensive overview of design principles, applications guide for windows and skylights, description of latest technology innovations and their energy impacts, and resource materials.

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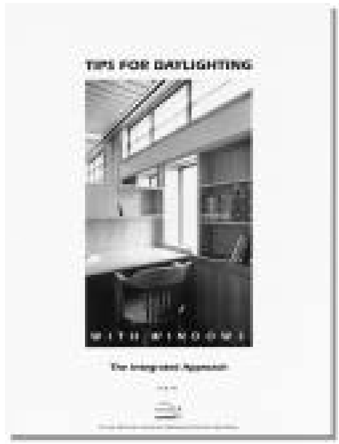

Tips for Daylighting with Windows: The Integrated Approach

Jennifer O'Connor, Eleanor Lee, Francis Rubinstein, Stephen Selkowitz, Building Technologies Program, Lawrence Berkeley National Laboratory, 1997.

Apractical "how-to" guide for applying daylighting strategies in commercial buildings, with a systems integration perspective. Chapters include Daylight Feasibility, Envelope and Room Decisions, Glazing Selections, Shading Strategy, Mechanical Coordination, Lighting Coordination, Sensors and Controls, Calibration and Commissioning, Maintenance, and Cost-Benefit Analysis.

Review the table of contents and sample chapter under Publications at Building Technologies Program's web site: *http://eande.lbl.gov/btp*. Single copies of the document can be downloaded in PDF format from the web site. If you are interested in reprinting the document, please contact us.

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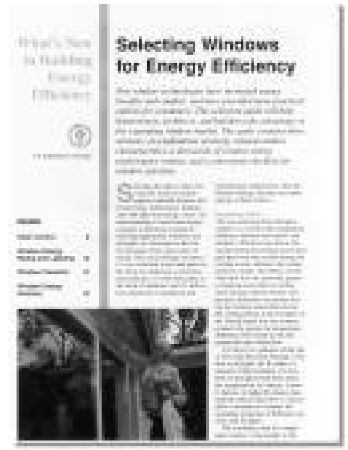

Selecting Windows for Energy Efficiency

This 16-page brochure discusses the new residential window technologies that have increased energy benefits and comfort, providing more practical options for consumers. Written as a guide for homeowners, architects, and builders, the brochure provides guidance on the National Fenestration Rating Council's window energy rating and labeling, design recommendations, and a valuable window checklist for design, specification, and installation.

Review the table of contents and download the document in PDF format from the Building Technologies Program web site: *http://eande.lbl.gov/btp.*

Copies are available from EREC/Energy Efficiency and Renewable Energy Clearinghouse, P.O. Box 3048, Merrifield, VA22116 or call (800) 363-3732, fax (703) 893-0440. If you are interested in reprinting the brochure to include your organization's identification, please contact us directly.

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Fenestration Facts

"Adopt a holistic design approach, where the building is viewed as a whole and not just a collection of parts. Common practice often fails to address the critical interactions between the building facade (which admits heat and light) and the electric lighting system, resulting in an uncomfortable and ineffecient building that is expensive and difficult to retrofit."

Tips for Daylighting with Windows, The Integrated Approach
Jennifer O'Connor et al
1997

FALL
WINTER
1997

LAWRENCE BERKELEY NATIONALLABORATORY

ENVIRONMENTALENERGY TECHNOLOGIES DIVISION

BUILDING TECHNOLOGIES PROGRAM
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Recent Research Publications

Electrochromic Lithium Nickel Oxide by Pulsed LaserDeposition and Sputtering. 1996. Rubin M., Wen S-H., Richardson T., Kerr J., von Rottkay K., Slack J. SPIE International Symposium on Optical Materials Technology for Energy Efficiency and Solar Energy Conversion XV, Freiburg, Germany. To be published in *Solar Energy Materials and Solar Cells.*

Abstract: Thin films of lithium nickel oxide were deposited by sputtering and pulsed laser deposition (PLD) from targets of pressed $LiNiO_2$ powder. The composition and structure of these films were analyzed using a variety of techniques, such as nuclear-reaction analysis, Rutherford backscattering spectrometry (RBS), x-ray diffraction, infrared spectroscopy, and atomic force microscopy. Crystalline structure, surface morphology and chemical composition of $Li_xNi_{1-x}O$ thin films depend strongly on deposition oxygen pressure, temperature, as well as substrate-target distance. The films produced at temperatures lower than 600°C spontaneously absorb CO_2 and H_2O at their surface once they are exposed to the air. The films deposited at 600°C proved to be stable in air over a long period. Even at room temperature the PLD films are denser and more stable than sputtered films. RBS determined the composition of the best films to be $Li_{0.5}Ni_{0.5}O$ deposited by PLD at 60 mTorr O_2 pressure. Electrochemical tests show that the films exhibit excellent reversibility in the range 1.0 Vto 3.4 Vversus lithium. Electrochemical formatting which is used to develop electrochromism in other films is not needed for the stoichiometric films. The optical transmission range is almost 70% at 550 nm for 150-nm thick films. Devices made from these films were analyzed using novel reference electrodes and by disassembly after cycling.

Energy Performance of Evacuated Glazings in Residential Buildings. 1995. Sullivan R., Beck F., Arasteh D., Selkowitz S. ASHRAE Transactions 102(2) (1996). (LBL-37130 Rev.)

Abstract: This paper presents the results of a study investigating the energy performance of evacuated glazings or glazings which maintain a vacuum between two panes of glass. Their performance is measured by comparing results to prototype highly insulated superwindows as well as a more conventional insulating glass unit with a low-E coating and argon gas fill. We used the DOE-2.1E energy analysis simulation program to analyze the annual and hourly heating energy use due to the windows of a prototypical single-story house located in Madison, Wisconsin. Cooling energy performance was also investigated. Our results show that for highly insulating windows, the solar heat gain coefficient is as important as the window's U-factor in determining heating performance for window orientations facing west-south-east. For other orientations in which there is not much direct solar radiation, the window's U-factor primarily governs performance. The vacuum glazings had lower heating requirements than the superwindows for most window orientations. The conventional low-E window outperformed the superwindows for southwest-south-southeast orientations. These performance differences are directly related to the solar heat gain coefficients of the various windows analyzed. The cooling performance of the windows was inversely related to the heating performance. The low solar heat gain coefficients of the superwindows resulted in the best cooling performance. However, we were able to mitigate the cooling differences of the windows by using an interior shading device that reduced the amount of solar gain.

Advanced Optical Daylighting Systems: Light Shelves and Light Pipes. 1995. Beltrán L.O., Lee E.S., and Selkowitz S.E. 1996. IESNAAnnual Conference, August 4-7, 1996, Cleveland, OH, and to be considered for publication in the Journal of the IES and Lighting Design and Application. (LBL-38133)

Abstract: We present two perimeter daylighting systems that passively redirect beam sunlight further from the window wall using special optical films, an optimized geometry, and a small glazing aperture. The objectives of these systems are (1) to increase daylight illuminance levels at 4.6-9.1 m (15-30 ft) from the window aperture with minimum solar heat gains and (2) to improve the uniformity of the daylighting luminance gradient across the room under variable solar conditions throughout the year. The designs were developed through a series of computer-assisted ray-tracing studies, laser visualization techniques, and photometric measurements and observations using physical scale models. Bidirectional illuminance measurements in combination with analytical routines were then used to simulate daylight performance for any solar position, and were incorporated into the DOE-2.1E building energy analysis computer program to evaluate energy savings. Results show increased daylight levels and an improved luminance gradient throughout the year compared to conventional daylighting systems.

Surface Temperatures of Insulated Glazing Units: Infrared Thermography Laboratory Measurements. 1995. Griffith B.T., Türler D., and Arasteh D. 1996 ASHRAE Transactions 102(2), San Antonio, TX. (LBL-38117)

Abstract: Data are presented for the distribution of surface temperatures on the warm-side surface of seven different insulated glazing units. Surface temperatures are measured using infrared thermography and an external referencing technique. This technique allows detailed mapping of surface temperatures that is non-intrusive. The glazings were placed between warm and cold environmental chambers that were operated at conditions corresponding to standard design conditions for winter heating. The temperature conditions are 21.1°C (70°F) and -17.8°C (0°F) on the warm and cold sides, respectively. Film coefficients varied somewhat with average conditions of about 7.6 $W/m^2 \cdot K$ (1.34 $Btu/h \cdot ft^2 \cdot °F$) for the warm-side and 28.9 $W/m^2 \cdot K$ (5.1 $Btu/h \cdot ft^2 \cdot °F$) for the cold-side. Surface temperature data are plotted for the vertical distribution along the centerline of the IG and for the horizontal distribution along the centerline. This paper is part of a larger collaborative effort that studied the same set of glazings.

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Fenestration Facts

"When shopping for windows and skylights, pay close attention to whether the U-factor listed by the manufacturer applies to the glazing only or to the entire unit. If it is for the glazing only, the overall U-factor may be considerably higher because of the frame and spacer effects. These effects increase with decreasing total window area."

Selecting Windows for Energy Efficiency
U.S. Department of Energy
1997

FALL
WINTER
1997

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User Facilities

Industry is invited to collaborate in the use of these facilities. In each issue of **Fenestration R&D** we will take a closer look at one of our user facilities. Please contact the individual researcher listed under each facility to discuss potential use.

❒ ***Mobile Window Thermal Test Facility (MoWiTT)*** The MoWiTT facility contains two highly instrumented, side-by-side calorimetric test chambers that are used to test window and wall elements under actual outdoor conditions. The facility may be rotated to face in any direction and is currently located in Reno, Nevada, which experiences both summer and winter extreme climate conditions. It can directly measure solar heat gain and can be used to determine window and shading system properties for a wide variety of solar control options. With 200 data channels collecting data every few seconds, the facility can directly measure cooling load shapes on peak summer days with excellent time resolution. The facility can also be used to validate computer models and to compare various technologies in real time. Industry has used MoWiTT results to justify new product development.

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❒ ***IR Camera Test Facility*** This facility includes a high-resolution, infrared imaging camera, a computer processor/printer, and a cold/hot chamber to hold samples for testing. The camera system is portable and can measure surface temperatures that can then be correlated to various heat loss or gain parameters. The IR camera is useful for assessing heat loss from existing buildings in the field as well as from building components and appliances in the laboratory setting.

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❒ ***Thin-Film Materials Laboratory*** This laboratory includes a wide range of apparatus to deposit and analyze thin-film coatings for energy control purposes. The laboratory's thin-film deposition systems are used to make new types of selective and electrochromic coatings. The laboratory also includes spectrophotometers to measure solar, near IR, and far IR properties.

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❒ ***Sky Simulator*** The 24-foot-diameter sky simulator is a hemispherical facility used to test daylighting performance in scale-model buildings under controlled and reproducible conditions. Computerized control of light sources within the hemisphere can create luminous distributions typical of clear, uniform, or overcast skies representative of any desired location, orientation, climate, and season on Earth. It can also be used as a sun simulator to test shading strategies in scale models up to 1.5 square meters in size. Light levels within the models are measured by 60 photosensors and the measurements are used to predict daylight illuminance conditions within full-sized buildings.

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❒ ***Solar Heat Gain Scanner*** This device is used to characterize the complex optical properties of glazings and shading systems that are geometrically complex, such as venetian blinds. The system measures transmitted and reflected energy and light at all incidence and outgoing angles. The scanner has been used to develop a new procedure to predict solar heat gain through complex shading systems.

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Software Available

❒ **ADELINE 2.0** analyzes lighting energy savings in buildings that utilize daylighting. Its unique collection of software tools for the MS-DOS platform includes Radiance v2.4, Superlite 2.0 IEA, Scribe (a 3D editor for simple scenes), and a Windows-like graphical user interface that ties these tools together. The package comes with an extensive 475 page manual in a loose-leaf 3-ring binder, context-sensitive help menus, online hyper-text help, and installs from CD-ROM.

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❒ **RESFEN 3.0** is a WINDOWS 95 (or NT)-based PC program for calculating residential fenestration heating and cooling energy use and costs. This new program (which uses the DOE-2 calculation engine) is currently being evaluated for possible use as part of a window rating system being developed by the National Fenestration Rating Council (NFRC).

❒ **SUPERLITE 2.0** is a PC program that calculates daylight illuminance distributions for complex room and light source geometries with tested accuracy. SUPERLITE will model daylight coming through as many as five openings and being reflected from as many as 20 opaque surfaces oriented in any direction.

❒ **WINDOW 4.1** is a thermal analysis PC program that is the de facto standard used by U.S. manufacturers to characterize product performance. The program is used by the National Fenestration Rating Council as the basis for development of energy rating labels for windows.

❒ **THERM 1.0** is a Microsoft Windows-based 2D heat transfer analysis tool, based on finite element analysis and can model two-dimensional heat transfer with a minimum of simplifications to exact cross-section geometries.

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The **Fenestration R&D** newsletter provides a periodic update on U.S. Department of Energy-sponsored windows and glazings research at Lawrence Berkeley National Laboratory, as well as other DOE-supported activities at Florida Solar Energy Center, National Renewable Energy Laboratory, Oak Ridge National Laboratory, University of Massachusetts, and Tufts University.

Fenestration R&D is made possible with support from the U.S. Department of Energy, Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technology, State and Community Programs, Office of Building Systems.

Samuel J. Taylor Program Manager, Building Systems and Materials Division

LBNL's **Windows and Daylighting Group** develops advanced optical materials, studies fenestration performance, and creates computer-based tools and applications guides for improving the energy-related performance of windows.

Stephen E. Selkowitz Program Head, Building Technologies

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BUILDING TECHNOLOGIES PROGRAM
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'UB-762 Fall/Winter 1997-5000

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ity Programs, Office of Building
Systems, Building Systems and Ma-
erials Division, **Samuel J. Taylor,**
program manager.

NFRC Update

National Fenestration Rating Council

New Image for NFRC

It's official! The NFRC membership overwhelmingly adopted a new logo at the Spring 1997 Membership Meeting in Nashville, Tennessee.

The new multi-faceted logo reflects the many different aspects of NFRC's mission. The new logo emphasizes the importance of both heating and cooling performance of fenestration. The quadrant design gives the appearance of a window, while symbolizing different climate regions.

The new logo will begin to appear immediately on all NFRC promotional and marketing materials.

NFRC-100 Revised

In an effort to streamline certification procedures, NFRC has revised NFRC-100: Procedure for Determining Fenestration Product Thermal Properties. Instead of requiring two separate tests to determine U-Factor values, manufacturers can now validate their values through one initial test. U-Factor measures a product's entire ability to transfer heat from inside the home to the outside.

New Heating and Cooling Ratings Under Development

At its spring, summer, and fall 1997 meetings, NFRC continued its efforts to develop consumer-friendly heating and cooling ratings. The ratings will make window shopping easier for consumers and builders, without sacrificing technological excellence.

These ratings will provide energy performance information in just two numbers—one describing performance during the winter heating season, and the other during the summer cooling season. The numbers, given on a scale from 0 to 10, will allow quick, accurate comparisons of the energy performance of different products.

NFRC Meeting Schedule

January 21-22, 1998
NFRC Task Group Meetings
Holiday Inn San Francisco Airport
San Francisco, California

March 29-April 2, 1998
NFRC Spring Meeting
Loews Annapolis Hotel
Annapolis, Maryland

For more information on:
- Administrative & Membership
- Certification Agency Program
- Communication and Education
- Compliance Assurance Program
- Laboratory Accreditation Program
- Meetings/Newsletters
- Product Certification Program
- Publication Orders

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