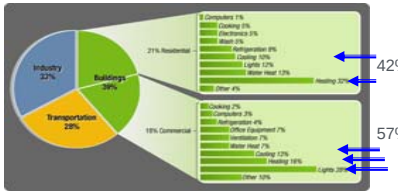
ENERGY EFFICIENT BUILDING ENVELOPE

Technologies and Facilities Supporting Net Zero Energy Building Goals



Buildings consume 40% of all US energy, and 71% of all electricity, at an annual cost of over $400B/yr. The Building Envelope – walls, roofs, windows and skylights – is responsible for about 25% of all building energy use, but can impact up to 42% of Residential use and 57% of Commercial use.

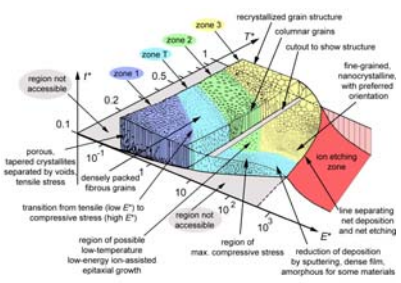
Goal: using innovative, high performance materials and smart designs, reduce the envelope energy impacts by 80%.

High Rate, Thin Film Coating Deposition

Enabling Technologies for Efficient Glazings and Building Surfaces

High Power Impulse Magnetron Sputtering (HIPIMS) (LBNL)

HIPIMS is an emerging physical vapor desorption (PVD) technology that combines traditional magnetron sputtering with pulsed power technology. It results in ionization of the sputtered atoms and provides a flux of ions assisting in the coating process. As a result, the properties of coatings can be tuned in the fabrication process. Films are usually denser, of crystalline nature, with a preferred grain orientation depending on the material and process. By tuning the kinetic energy and temperature of the substrate, a wide range of structures can be produced.



The microstructure of a coating can be tuned with ion assistance from a plasma to obtain desirable properties . Ref: A. Anders, "A structure zone diagram including plasma-based deposition and ion etching," Thin Solid Films, vol. 518, pp. 4087–4090, 2010.

High Deposition Rate, On- Line Coating (NREL)

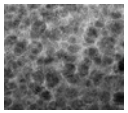
Some low-E coatings are deposited today using atmospheric CVD methods online in a glass float line. This is an approach that might be used to lower costs of more complex multilayer coatings. NREL has developed extensive capabilities focused on decreasing the cost of energy efficient glass coatings using methods that can be integrated with glass manufacturing.

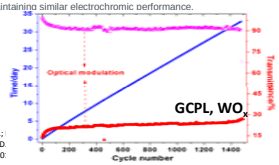
Smart Coatings for Efficient Envelope Surfaces

Dynamic Coatings with variable optical properties, including electrochromic, thermochromic, photochromic

NiO_x- and WO_x-based electrochromic electrodes (NREL)

NREL is partnering with SAGE Electrochromics to improve the current state of the art with electrochromic coatings for windows. Current work on NiO_x- and WO_x-based electrochromic electrodes have achieved superior switching speeds, improved depth of coloration with optical modulation as high as 80% and a bleached state of transmittance of 98%; enhanced coloration efficiency; greater film durability in liquid electrolyte, (stable up to 1000 cycles under constant current conditions (galvanostatic cycling with potential limitation, GCPL)); and reduced film thickness by 50% relative to previous technologies while maintaining similar electrochromic performance.



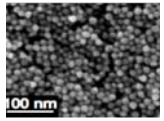


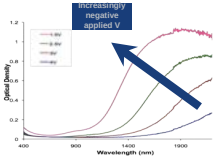
(1) Gillaspie, D.; Norman, A; Tracy, C. E.; Pitts, J. R.; Lee, S.-H.; *J. Electrochem. Soc.* **157**, 3, H328-H331 (2010); (2) Gillaspie, D. Tenent, R. C.; Dillon, A. C. *J. Mater. Chem.*, **20**, 9585–9592 (20:

Tunable Metal Oxide Nanocrystals for Dynamic Window Coatings (LBNL)

Transparent Indium Tin Oxide (ITO) nanocrystals show dynamically tunable plasmon absorption in the near infrared

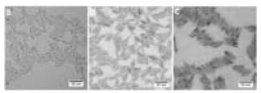
In heavily doped metal oxide nanocrystals, localized surface plasmons give rise to optical absorption in the infrared spectral range. The wavelength of this absorption peak can be modified by varying the amount of dopant incorporated into the nanocrystals during their chemical synthesis. The surface plasmon absorption of a nanocrystal film can be dynamically and reversibly tuned across the near infrared spectrum while maintaining excellent transparency for visible light. These properties are of keen interest for a new breed of carbon-saving, dynamic window coatings that can modulate solar heating while consistently supplying daylight.





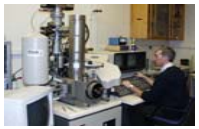
Luminescent Solar Concentrators (LSC) (ANL)

LSCs are based on novel semiconductor nanocrystals, which absorb sunlight over a large area and re-emit lower-energy radiation that is efficiently directed towards a small-area solar cell. These LSCs are also promising candidates for wavelength-selective window materials; they could collect infrared radiation from sunlight and allow visible light to pass - reducing cooling requirements at the same time as producing electricity. The performance of LSCs has been limited by the availability of suitable light-emitting materials. In particular, efficient solar energy conversion requires that the emitting material have nearly 100% quantum yield, that it re-absorbs very little of the emitted light, and that it emits at near-infrared wavelengths. The organic molecules that have generally been investigated for use in LSCs have not been able to meet all these criteria simultaneously but inorganic nanomaterials should overcome these limitations. Detailed simulations based on Monte-Carlo ray tracing are being used to optimize the LSC performance.

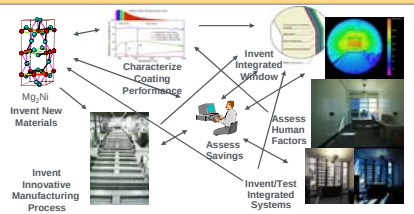


Materials Characterization:

National Labs have extensive basic materials science capabilities to allow characterization of structural, chemical, electronic, optical properties of novel materials from macro to molecular to nano/atomic levels. Some equipment is uniquely suited to specialized purposes.



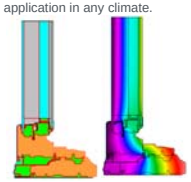
Technology Innovation -> Marketable Building Systems: Integrated RD&D Program to Cross the "Valley of Death"



Field Testing of Materials, Components, Systems

National Lab Test Facilities: the National Labs have unique field test facilities and instrumentation to evaluate the detailed component and system level energy performance of early prototypes, emerging technologies and integrated systems with smart controls. These are available to industry partners and research collaborators.

Performance Simulation: the National Labs have extensive modeling, simulation and optimization tools to explore properties of new material, guide virtual designs, support rapid prototyping, and predict energy, load shape, thermal and visual comfort in virtually any building application in any climate.

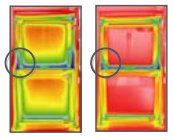


Isotherms in triple glazed, energy efficient window (THERM software)

Physically-based lighting simulations (Radiance software) to explore alternative designs and controls

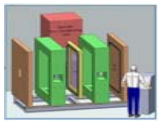
IR Thermography Lab (LBNL)

This lab supports detailed studies of the thermal performance of windows systems. It can be used for design optimization, software validation, diagnostics and new technology development. An accurately controlled interior and exterior environment and calibration protocols makes it possible to accurately measurement a wide range of building products.



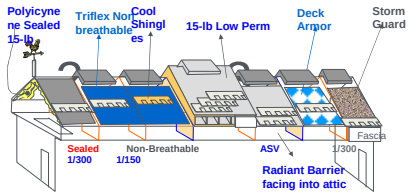
Accelerated Durability Testing (NREL)

The thermal performance of new highly insulating triple glazings and vacuum glazings with gas fills and low-E coatings depends on the long term integrity of the edge seals. This new facility will allow researchers to conduct differential thermal cycling over a wide temperature range to verify the performance of seals.



Roof and Attic Test Facility (ORNL)

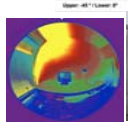
Evaluates energy, durability, moisture of materials and complete roof and attic systems in facilities in diverse US climates.



An element of **the Building Envelopes Research program at ORNL**:
Goal: Develop affordable envelope technologies that improve energy efficiency, durability and environmental sustainability of buildings, focusing on multifunctional solutions to minimize peak energy demands and overheating from solar gain.
Research focus:
- **Systems**: Walls, roofs, foundations
- **Components**: sheathing, membranes, coatings
- **Materials**
- **Fundamentals** of heat, air and moisture transfer

Window, Façade and Daylighting Field Tests (LBNL)

LBNL operates a series of unique field test facilities with specialized instrumentation to measure the full range of thermal and optical performance of glazing, shading and daylighting solutions. Occupant studies can also be performed. A key focus has been the ability of dynamic, smart glazings to control cooling and moderate peak demand.



Points of Contact: LBNL- Stephen Selkowitz, seselkowitz@lbl.gov NREL – Anne Dillon, Anne.Dillion@nrel.gov ORNL - Edgar Lara-Curzio, laracurzioe@ornl.gov ANL – Matthew Pelton, pelton@anl.gov