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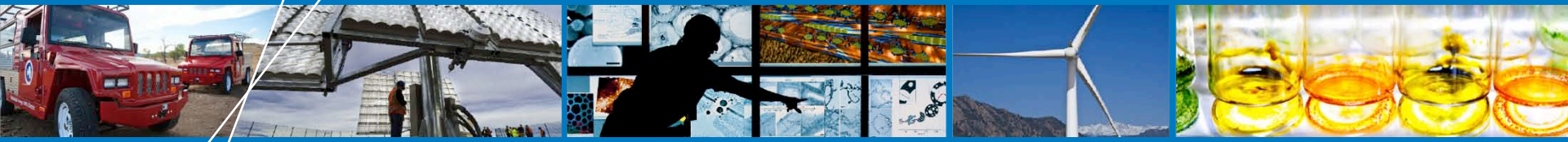
NATIONAL RENEWABLE ENERGY LABORATORY



NREL Windows Program

Chaiwat Engtrakul, Timothy Snow and Robert Tenent

Window Technology Roadmap Workshop

6/28/12

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

NREL Dynamic Windows Research Team

Multi-disciplinary team with expertise in fundamental science, engineering and technology transfer

- Buildings Technology
- Chemical and Materials Science
- Technology Transfer
- Strategic Energy Analysis

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UNIVERSITY OF DENVER
START FROM A HIGHER PLACE

Renewable Energy Materials Research Science and Engineering Center
REMRSEC

NREL Windows Team Overview

Research and support to mitigate the risk associated with the development of improved fenestration solutions.

Buildings Energy Modeling

- Modeling of building energy savings
- Estimates of price point for cost-effective deployment

Development of Improved Materials

- SAGE Electrochromics, Inc. (CRADA)
- US e-Chromic, Inc. (CRADA)

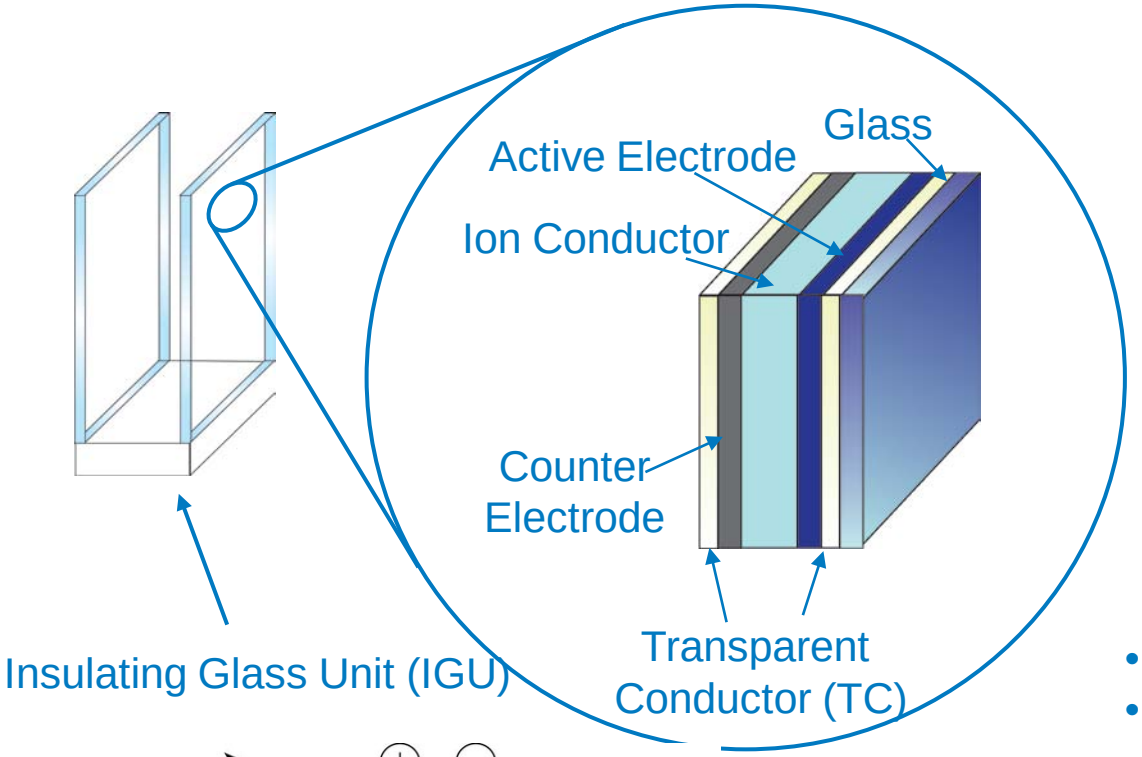
Low-cost Manufacturing Process Development

- Extensive capabilities for atmospheric pressure processing of glass coatings

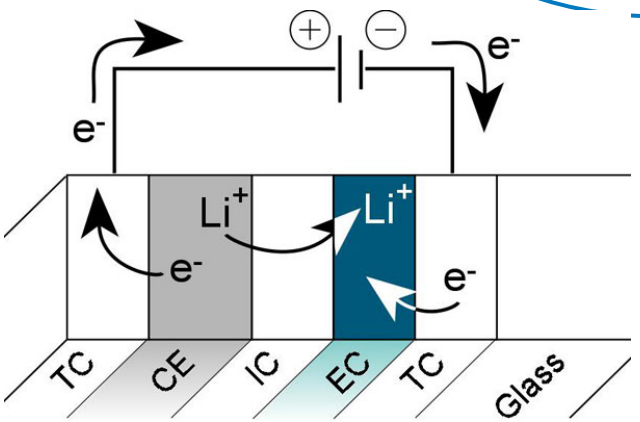
Advanced Fenestration Testing

- Provides third party durability testing of chromogenic window technologies.
- Currently expanding to include highly insulating glass units
- In-field testing of chromogenic windows

Electrochromic Dynamic Windows



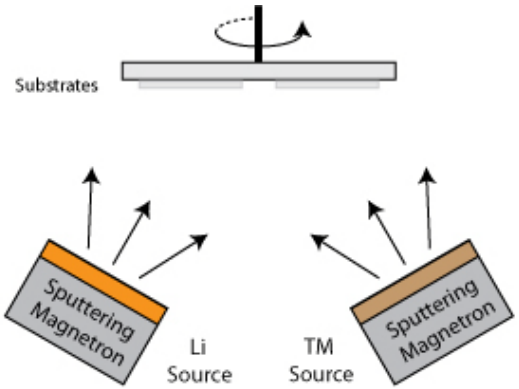
- Active Electrode Material: WO_3
- Counter Electrode Material: NiO

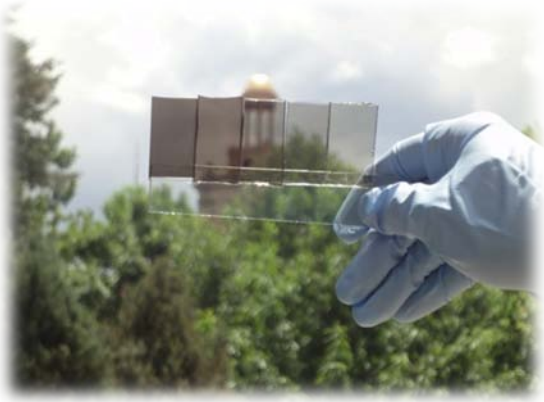


Electrochromic windows act similarly to lithium ion batteries, but change color when charged and discharged.

Improved Materials with Enhanced Electrochromic Properties

Co-Sputter Deposition



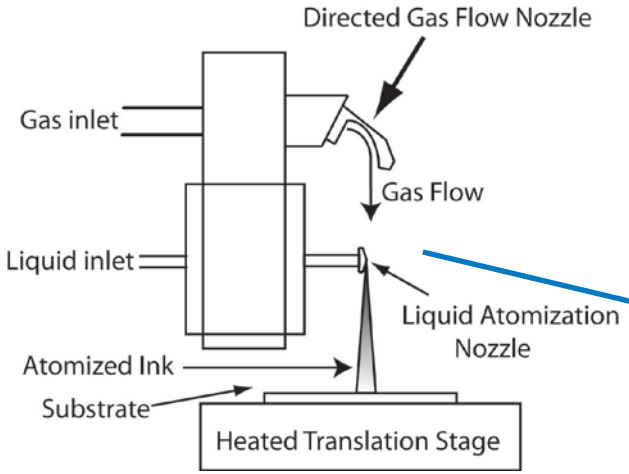


State-of-the-art NiO_x- and WO_x-based electrochromic electrodes

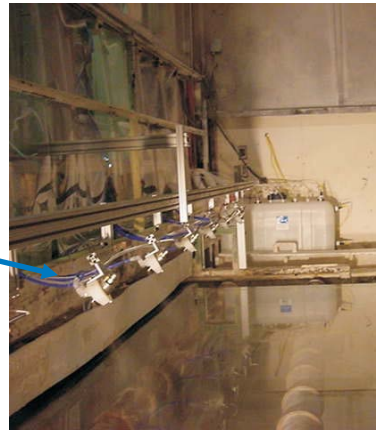
- Superior switching speeds
- Enhanced coloration efficiency
- Improved film durability
- Reduced film thickness

oxygen-rich → argon-rich

Solution Phase Deposition



In-line Deposition



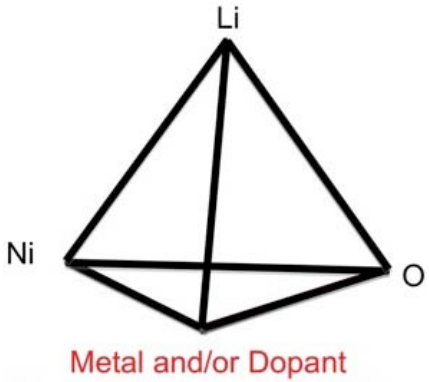
NiO **"Li^+-Doped"NiO**

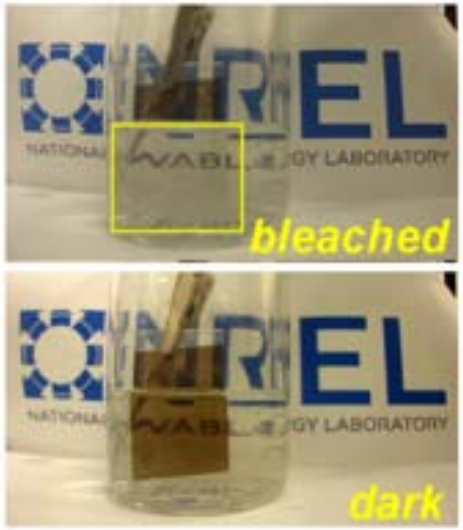
Tenent, R.C, et al. *Journal of The Electrochemical Society*, **157** 3 H318-H322 2010

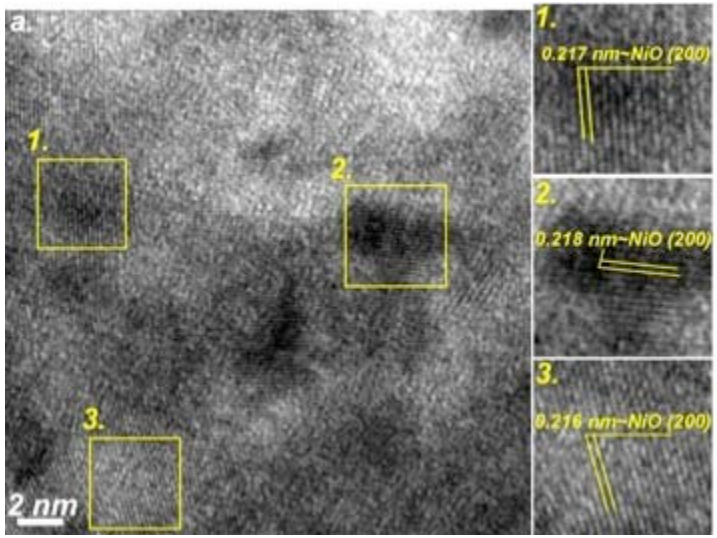
CRADA Partner SAGE Electrochromics, Patents Pending

Multidimensional Process Space - Composition Control

- Improve visual appearance
- Reduce switching speed
- Increase device efficiency and durability to simultaneously improve energy and cost savings
- Improve the basic understanding of the counter electrode, such that better performance is easily tailored







NiO d-spacing increased due to doping

Superior electrochemical performance of doped LiNiOx (optical modulation and switching speed) was attributed to the addition of metal dopants AND a dopant and Li rich matrix

Exploratory Research in Alternate Production Methods

FTO on glass

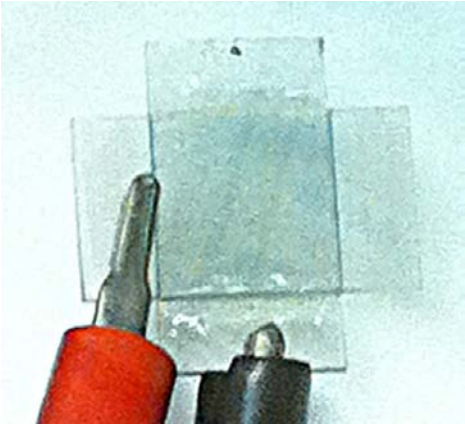
Spray WO_3

Gel Electrolyte

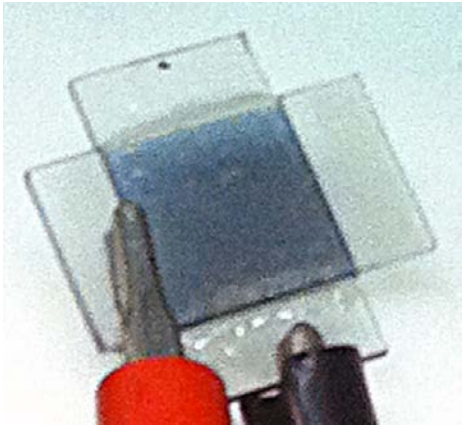
Spray LiNiO

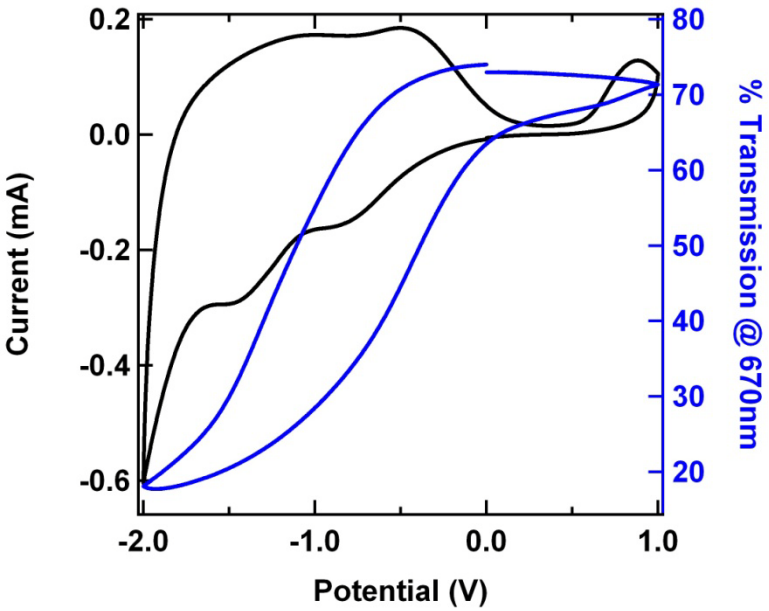
FTO on glass

Bleached Device



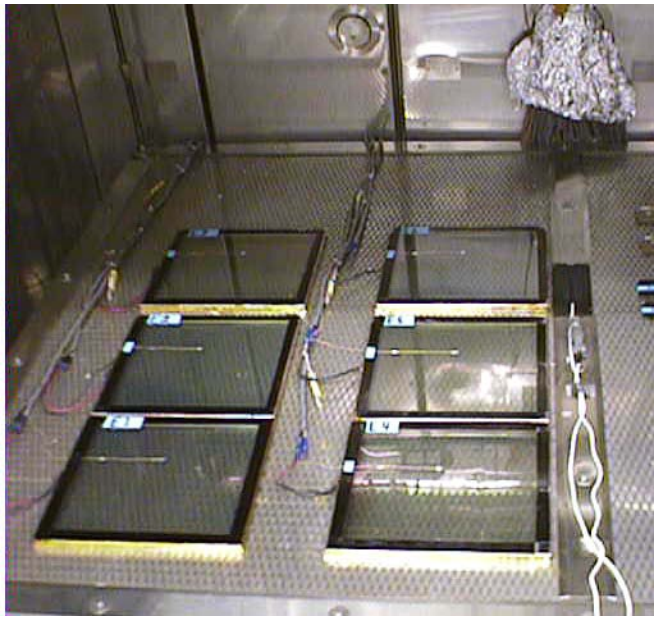
Colored Device





- Possible path to dramatic cost reduction.
- Device modulation from 70%T to 20%T
- Currently scaled to 3” by 3”
- Expect 6” by 6” device by Sept 2012.

Dynamic and Highly Insulating Windows Testing



Durability testing of electochromic windows to the ASTM E2141-02 method

Field installation and evaluation of dynamic windows

New Highly Insulating Fenestration Test System

NTS Differential Thermal Cycling Unit

Environmental Conditions

2 - Independent Chambers

Sample Temperature Range: -50° C to 110° C

Humidity: 5–95% (20° C to 85° C)

Thermal ramp rate up to 5° C/min

Sample Max: 45” x 45” x 8”

Supporting rapid thermal cycling of emerging technology IG prototypes

Capable of thermal cycling building wall sections up to 8 inches in thickness.

Windows Standards Updates

- **ASTM E2141-10 approved for release**

  Credit: Erin Whitney

- **Possible ASTM E2188 enhancements**
  - ***Strengthen standard while decreasing time***
  - Extend temperature, UV on time and ramp rate
  - Working Task Group within IGMA

- **ASTM VIG Standard Subcommittee**
  - To be formed by October 2012 ASTM Meeting
  - Working Task Group within IGMA
  - Collaboration with the Bavarian Center for Applied Energy Research

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