NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Noncomposite Counterelectrode Development

Cooperative Research and Development Final Report

CRADA Number: CRD-06-203

NREL Technical Contact: Chaiwat Engtrakul

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Cooperative Research and Development Final Report

In accordance with Requirements set forth in Article XI.A(3) of the CRADA document, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

CRADA Number: CRD-06-203

CRADA Title: Nanocomposite Counterelectrode Development

Parties to the Agreement: Sage Electrochromics, Inc.

Joint Work Statement Funding Table Showing DOE Commitment:

Estimated Costs	NREL Shared Resources
Year 1-3	$ 100,000.00
Year 4-5	$ 100,000.00
Year 5-6	$ 150,000.00
TOTALS	$ 350,000.00

Abstract of CRADA Work:

New counter-electrode materials under development at the National Renewable Energy Laboratory (NREL) have the potential to positively impact electrochromic window technology. The current generation of nano-composite materials is designed to provide rapid transport of lithium ions to nanoparticles of anodic coloring materials. They may improve the coloration efficiency of the entire films stack while also improving the speed and depth of coloration. NREL expects an added benefit of greater film durability and has obtained good results in the laboratory. The objective of this collaborative work with Sage Electrochromics (Sage) is to validate the laboratory tests by constructing fully functional test articles with Sage. These will be fabricated partially at Sage facilities and partially at NREL. Performance and durability tests will be conducted to characterize any improvements obtained as a result of incorporation of the new counter-electrode materials.

Summary of Research Results:

In collaboration with Sage, NREL researchers discovered a new class of nickel oxide–based counter electrode materials that have the potential to significantly impact the dynamic glass industry. A unique approach, based on a novel co-sputtering process, was utilized by NREL researchers to enable rapid progress and improvements in the development of complementary counter electrodes for electrochromic window technologies. This co-sputtering process allowed a high degree of flexibility in creating nickel oxide materials combined with a wide variety of dopants for improved performance. The unparalleled depth and range of these newly developed

materials allowed NREL researchers to rigorously address the three main concerns hindering development and market penetration of a neutral color electrochromic device: (1) color neutrality, i.e., high vision clarity at all light transmission levels, (2) cycling durability, and (3) switching kinetics in Li-ion electrolyte systems.

State-of-the-art counter electrode materials were successfully deposited onto Sage's transparent conducting oxide substrates and Sage verified the superior electrochromic properties of the counter electrode.

In addition, the thermal stability and atmospheric stability of the NREL counter electrodes were examined to assess the impact of temperature and air exposure on electrochromic performance. Electrochemical characterization data suggested that even after various conditioning processes, NREL's thin film materials maintained a high cycling durability, high visible light transmission, and reduced yellow tint in the bleach state. The latter finding was confirmed through optical measurements that determined minimal percent absorption in the blue for the NREL counter electrodes.

Based on the demonstrated compatibility of NREL's counter electrode with Sage's proprietary processing procedures for electrochromic device fabrication, Sage was highly encouraged to continue supporting research efforts.

Subject Inventions Listing:

1. "Electrochromic Nickel Oxide Simultaneously Doped with Lithium and a Metal Dopant." *U.S. Application Nos. 13/554,144 and 14/031,573; International Application No. PCT/US12/47569*.

2. "Ternary Nickel Oxide Materials for Electrochromic Devices." *U.S. Application No. 13/961,184*.

Report Date:

April 7, 2014

Responsible Technical Contact at Alliance/NREL:

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