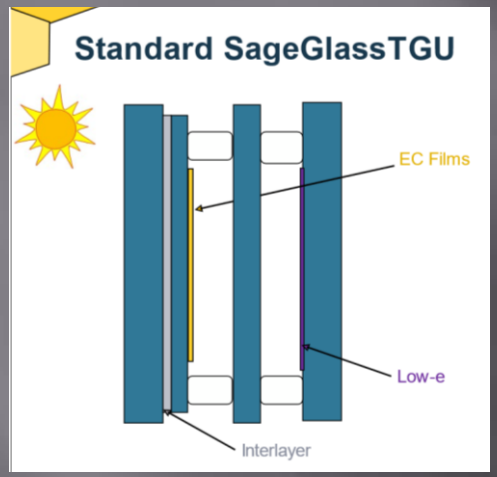
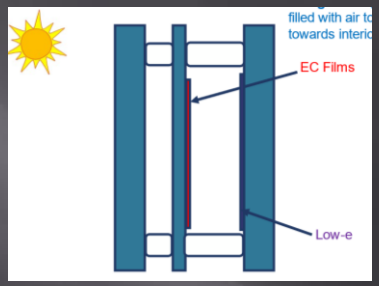
Cost Effective Electrochromic Glazing Repositioning For Insulating Glass & Secondary Windows

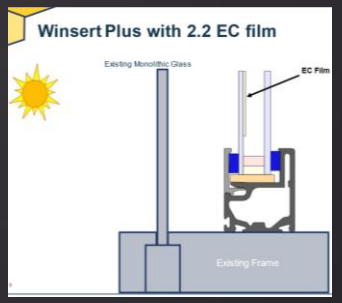
BEFORE: Standard TGU (Triple Glass Unit) ElectroChromic Configuration



AFTER OPTION #1: EC Device Layer Central To IGU Surface #2 Freed For Heat Strengthened Low-e



AFTER OPTION #2: EC Device Layer Integrated Into Interior Secondary Window



Alpen/Sage Project Thin-Glass Triple EC
Central EC Device Layer – Installed Prototype
Empire State Building 32nd Floor WSW Orientation

Primary Contractor: Alpen High Performance Products, Inc.
ThinkAlpen.com

Subcontractor: Sage Electrochromics, Inc.
SageGlass.com

Principal Investigator: Robert Clarke, Alpen Founder
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Project Assignment Number: DE - EE0009704

Project Summary

OBJECTIVES

#1: Reduce Commercial Installed EC Cost by 50-75%.

#2: Enable Quick, Interior Installation Of Lightweight, Economic & Self-Powered EC Glazing

#3: Provide Minimum Triple-Glazing U-Value Thermal Insulation

#4: Race To Market With A Fully Certified Alpenglass/SAGE-EC Product Line

#5: Facilitate *Super* Low-Conductivity (Non-Aluminum) Framing.

NREL Chamber Temperature Testing Of Both EC Thin Triple & EC WinSert

METHODOLOGY

#1: In Parallel - Race Development Of Both: 1) EC Thin-Glass Triple & 2) EC WinSert

#2: Correlate NREL-Chamber And Field Measurement & Verification Test Data

#3: Transfer Device Layer Vacuum Coated EC Thin-Glass Sheets From SAGE To Alpen For Automated IG Production

GENERIC PRIMARY BIG-CITY TARGET

Single-Glazed, Leaky, Non-Thermally Broken Curtainwall High Rises
($100M Market In NYC Alone)

Performance Period: 9/1/22- 10/312024

DOE Budget: $1.5M Cost Share: 300K

Milestone 1: Identify optimal Tvis, SHGC & U-Value & select prototype IG spacer.

Milestone 2: Select optimal IGU materials including spacers & extend material choice to frames

Milestone 3: Install NYC, MN & CO Prototypes & revise optimal material specifications

Team & Partners

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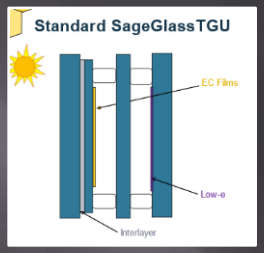
Problem: Electrochromic Architectural Glass Is Critical Toward Empowering Windows As Net Positive Contributors To The Built Environment

George H. Heilmeier
DARPA – Defense Advanced Research Projects Agency

1) **Wh**at are you trying to do?

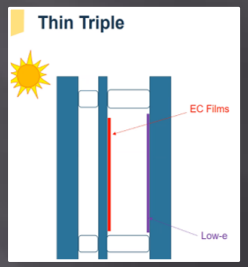
1) Alpen & SAGE are trying to reduce the installed cost of electrochromic architectural glass by 50-75%.

2) How is it done today, and what are the limits of current practice?



2) EC glass today is laminated to thick, (heavy) annealed glass then combined with one or two additional layers of standard-dimension glass. Today's limits are a) interior IG EC (dark state) temperatures, b) limited thin-glass IG knowledge, and c) a total absence of an interior secondary EC window.

3) What is new in your approach and why do you think it will be successful?



3) New in our approach is a) the repositioning of the thin EC layer, b) introducing thin glass IG processing, c) integrating the device layer into a WinSert secondary-window ,and c) powering both configurations in the absence of any grid connection.

4) Who cares? If you are successful, what difference will it make?

4) Two discrete groups will embrace the market availability of technologies emerging from this Project's success:1) new-construction developers of leadership ZNE / ZNC buildings, and 2) energy-focused architects, HVAC engineers, chief engineers and owners of all buildings with any but the latest high-performance glazing .

Heilmeier Continued: Alignment & Impact

George H. Heilmeier

5) What are the risks?

5) a) glass breakage from differential thermal stress: b) safe handling of EC coated sheets from MN to CO, c) keeping EC WinSert Plus sufficiently low in weight for high rise curtainwall re-skinning, and d) providing sufficient wireless power to enable frequent dynamic cycling.

6) How much will it cost?

6) Installed institutional/commercial EC architectural glass will be available at 40-60% below 2023 levels.

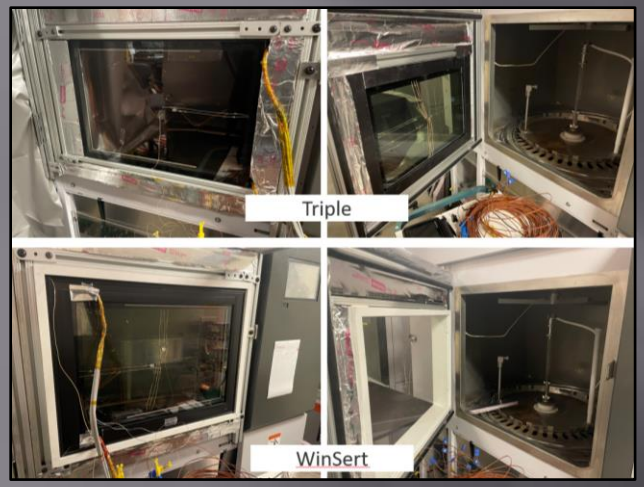
7) How long will it take?

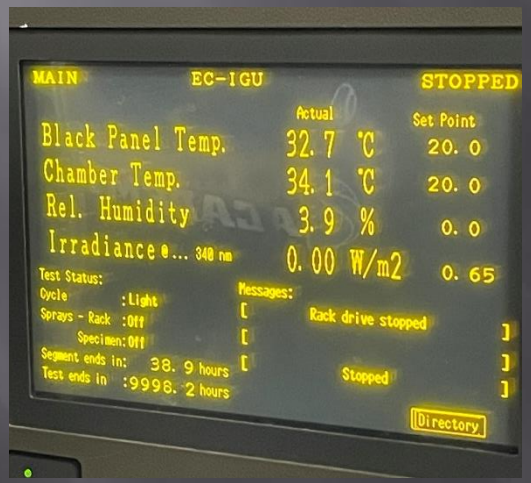
7) All prototypes scheduled to be in place by December 1, 2023; select thin EC triple IG and EC WinSert Plus units ready for limited release by January 31, 2025

8) What are the mid-term and final “exams” to check for success?

8) Mid-term: a) Maintenance of all interior-surface material temperatures below the limit to emerge from NREL-chamber and WinSert monitored prototype installations in the highest temperature environments, b) consistent wireless control of full-range EC darkening with sensitivity to battery level, and c) sufficient self-contained (non-grid) power supply to ensure darkening cycling to occupant and building-owner satisfaction
Final : a) Alpen CNC edge grinding success of SAGE EC cut-size device layer, b) consistent safe MN to CO transfer of full-size (1.8 x 3.2 M) EC thin glass, c) ongoing success in long-term IG hermetic-seal durability testing (zero condensation at -70F), and d) 100% ongoing passage of all Mid-term tests .

NREL Test Results
1) EC Thin Triple IG 2) EC WinSert Plus





RESULTS

1) EC Thin Triple Insulating Glass units can be configured with a balanced mix of internal low-e vacuum coatings & gas filling to maintain all spacer, sealant & glass temperatures below a determined safe threshold 180F (82 C)

2) EC WinSert Plus units with the EC device layer behind clear glass reached levels of some concern, but can be cooled by some combination of convective cooling and solar-control film applied to the existing outer glass.

3) Center-glass stress/strain sensors further quantified glass convex/concave displacement through high/low chamber temperature cycling.

4) Test-chamber thermal results closely correlated with LBNL Window simulations

Milestones Passed ("Mid Term) & Remaining ("Final Exam")

ALPEN-SAGE PROJECT MILESTONES	STATUS AS OF APRIL 25,2023
12/31/21 • Identify optimal T, SHGC & U-value in clear / tinted state • Identify and model all prototype configurations / components	100% Complete
6/30/22 • Model thermal conductivity of materials used at scale production • Confirm low-cost manufacturing & aesthetic architectural approval	100% Complete
12/31/22 • CO, MN & NYC prototypes with instrumentation / monitoring • Select optimal %T, SHGC & U-values in clear / tinted state	95% Complete – finishing up modeling and factory prototyping
6/30/23 • Datalogging in diverse climates: a) insulating value (interior glass-surface temperatures) b) Tvis Daylight Transmission & c) solar-heat transmission • Modeling to show annual energy consumption and peak loads using NREL empirical measurements • Performance & durability validation of thin-EC IGU and WinSert	80% Complete – as of 4/25/23
12/31/23 Prototype thin-EC triple pane configuration meeting the following: • %T varying from at least 55% to 1% • SHGC varying from at least 0.4 down to at least 0.15 • Verified >R-6 full window performance • EC manufacturing costs within $10-$14 $/sq ft over current thin triple glazing • Pass regulatory (ASTM-2190; ASTM E-2141 in process)	10% Complete

2023 "Thin Glass Triple"

Plans Moving Forward

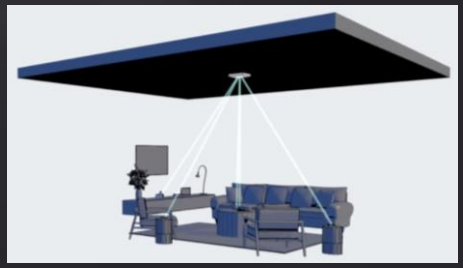
Facility Expansion: Alpen to extend its facility to accommodate glass-processing operations unique to electrochromic and thin-glass technology.

New IG-Configuration Certification: Standard NFRC certifications will be expanded to include emerging unique thin-glass EC IG, and secondary-window EC configurations.

Thin Glass Novel Procedures: Traditional glass handling, cutting, insulating-glass spacing, and perimeter sealing will be upgraded to encompass "cellphone thin" glass to reduce embodied energy, weight, and cost.

Market Research: Alpen and Sage will in parallel study the 19.5 B SF market of installed U.S. vision glass to identify a TAM (Total Addressable Market) of perhaps $500M for new EC configurations.

Wireless Power Integration:
BIPV, WiFi, RF, and Ethernet (POE) will be closely tracked to enable self powered" Alpen-Sage EC windows.



Overall ALPEN-SAGE-DOE 36-Month Timeline

October 1, 2021 To October 31, 2024 Alpen-SAGE Thin Glass EC & Secondary EC WinSert Research & Pre-Production Schedule

10/21	11/21	12/21	1/22	2/22	3/22	4/22	5/22	6/22	7/22	8/22	9/22	10/22	11/22	12/22	1/23	2/23	3/23	4/23	5/23	6/23	7/23/	8/23	9/23	10/23	11/23	12/23	1/24	2/24	3/24	4/24	5/24	6/24	7/24	8/24	9/24	10/24
Simulate NFRC specifications & cross-section temps.																																				
		Determine cross-section makeup of both Thin-Glass EC Triple and EC WinSert units.. Finalized spacer, sealant and glass components. Specify WinSert frame.																																		
									Determine NREL test protocol and configuration of all IG and WinSert units. Construct prototypes.																												
												Refine search & evaluation of four potential methods of providing battery-charging power to each Thin Glass EC IG and secondary Winsert Plus.																							
															Affirm market including assessment of urban environment constraints. Assess WinSert implications of being interior to an existing commercial window																				
															Locate, purchase & install additional glass-handling and edge-conditioning equipment to be installed in Alpen's Colorado facility																				
																		Research solar panel & PV integration. Wireless power transfer assistance for the interior.																			
																				Experiment with all feasible types of wireless power.																	
																								Prove concepts. Control each pane. Verify power supplied to each unit.													
																										Install additional prototypes ; instrument & monitors.											
																										Commission to verify all aspects of performance among both Thin Glass EC IG and EC WinSert prototypes installed nationwide.											
																										Finalize cross-section configuration of both Thin Glass IG EC and WinSert Plus units for market introduction.. Modify select prototypes accordingly & accelerate Measurement & Verification commissioning.											
																											Verify system architecture									

Summary

As of April 25, 2023, this project is 49% through its (10/1/21 – 10/31/24) term. Within original time and budget constraints, Project Objectives have evolved from research to a commercial commitment to market a radically improved electrochromic technology at significantly reduced cost. This enhanced goal now embodies the assimilation of novel glass-industry thin-material handling & CNC edge conditioning .

All time-critical thresholds have been cleared, and all indications are that even an expanded, aggressive commitment to transfer EC insulating-glass fabrication from a vacuum coating location to nearly 1000-mile distant automated IG facility remain on track.

Thank You

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