Dynamic Windows Using Reversible Metal Electrodeposition

Tynt Technologies
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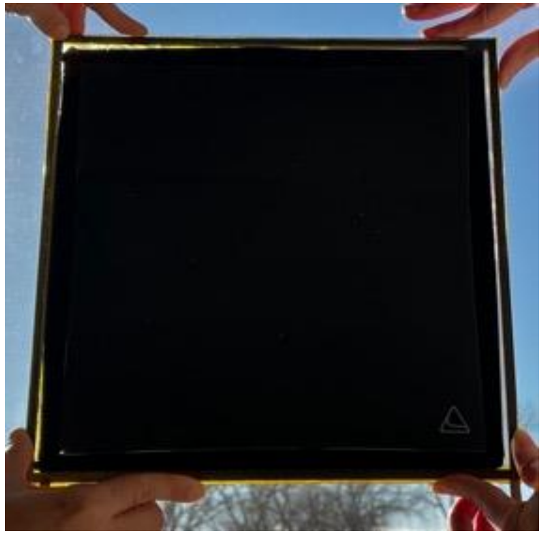
DE-EE0009701

Project Summary

Objective and outcome

Tynt Technologies is developing next-generation dynamic windows based on reversible metal electrodeposition (RME) that demonstrate fast switching with neutral color over the widest optical range for privacy applications in the residential market. These windows employ a polymer gel electrolyte and a metal mesh counter electrode for its enhanced functionality over 1000s of cycles and at large-scale (1 ft x 1 ft). Finally, these windows have already demonstrated superior performance in terms of switching speed and neutral color compared to the leading competitors' technologies.



Team and Partners

Two Subcontractors:

-Professor Mike McGehee – University of Colorado - Boulder

-Professor Chris Barile – University of Nevada – Reno

Stats

Performance Period: 10/01/2021 – 9/30/2024

DOE budget: $1.5M, Cost Share: $492,735

Milestone 1: Dynamic Window with fast (<6 min), color neutral (a*,b* | < 5) switching over widest optical dynamic range (>60% in clear state and <0.1% in dark state)

Milestone 2: Dynamic Window passing ASTM 2141

Milestone 3: Dynamic Window IGU passing ASTM 2190

Windows are stuck in the 20th century

- Huge energy loss
- Difficult to get lighting “just right”
- Manually operated
- Prevent desirable home designs
- No major innovations in decades

Windows can make up to

30%

of heating and cooling energy loss in a typical home

64%

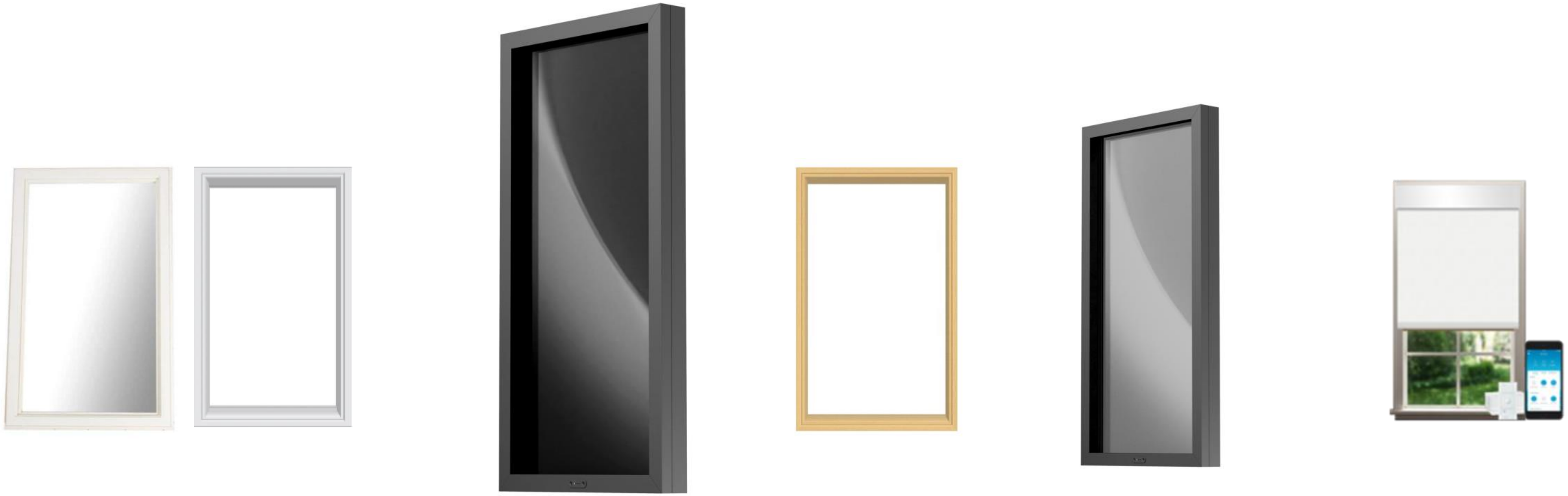
of U.S. homes have non-low-e single- or double-pane windows

Potential to save

***1.8 $GtCO_2$**

*US Department of Energy

Cost enables Tynt to become standard



Standard
$500

TYNT @ SCALE
$750
(COST = $400)

Premium
$900

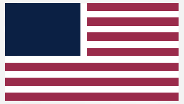
TYNT @ PILOT
$1000
(COST = $900)

Auto blinds
$2000

Additional Savings

- Window Treatments: $100+
- Energy Savings: $500 (over 10 years)
- Tax Credits: $250

Opportunity - Tynt Every Home in US + EU


+


New Homes	2.3M HOMES
Existing Homes	440.9M HOMES
Existing Windows	10.5B WINDOWS
Windows Sold Today	130.9M WINDOWS

Windows haven't changed in 100 years

Energy efficient solutions are shunned for "cheap and pretty" windows

1 Billion sq ft of windows installed in US every year

Serviceable Available Market

$65B

~4% reduction in global GHG emissions

Competing Technologies

view Dynamic Glass

SageGlass SAINT-GOBAIN

HALIO

LUTRON

HunterDouglas

All competitors require costly replacements and add-ons to achieve what Tynt can do in one product.

Their limitations: Cost, automation, color, light control range

"Dynamic Windows will be ubiquitous at $20-$25/sq ft" – Consensus among Glass and Window Executives

GENTEX CORPORATION

Furcifer

CLICK MATERIALS

MIRU smart technologies

eLstar

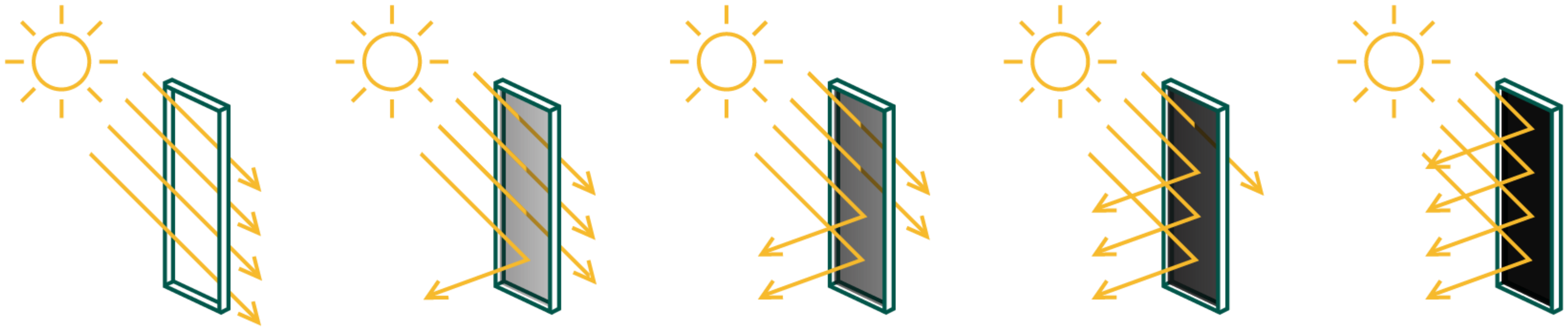
CROWN

Gauzy

Color Neutral Tinting to Blackout Privacy

Dynamically control the visible light and solar heat gain to optimize comfort and energy.

Take control by toggling the system from automatic to manual.

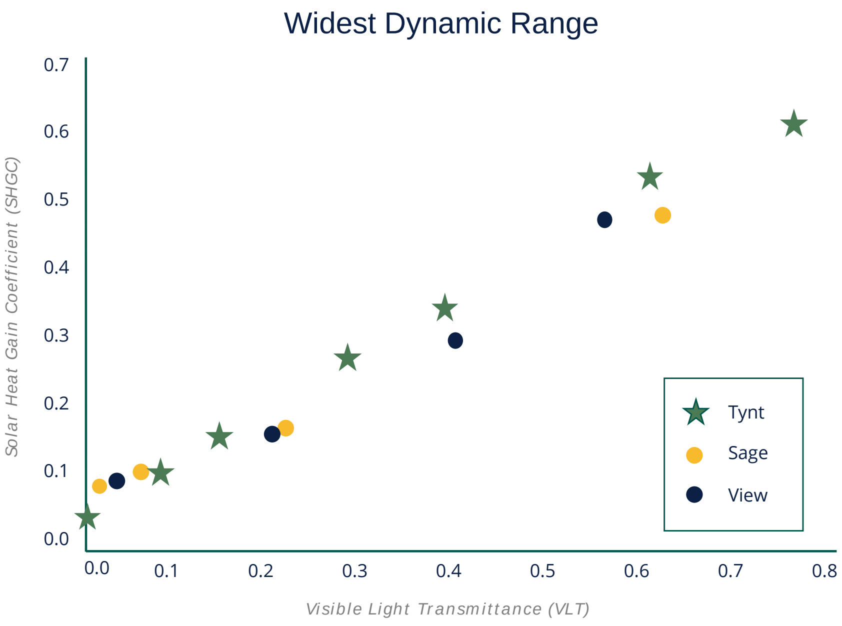


In clearer states, let the sun in and utilize natural energy to light and warm the space.

In more opaque states, block sunlight and reflect unwanted energy back, resulting in a cooler interior.

CLEAR — BLACKOUT (TYNT EXCLUSIVE)

Tynt Advantages



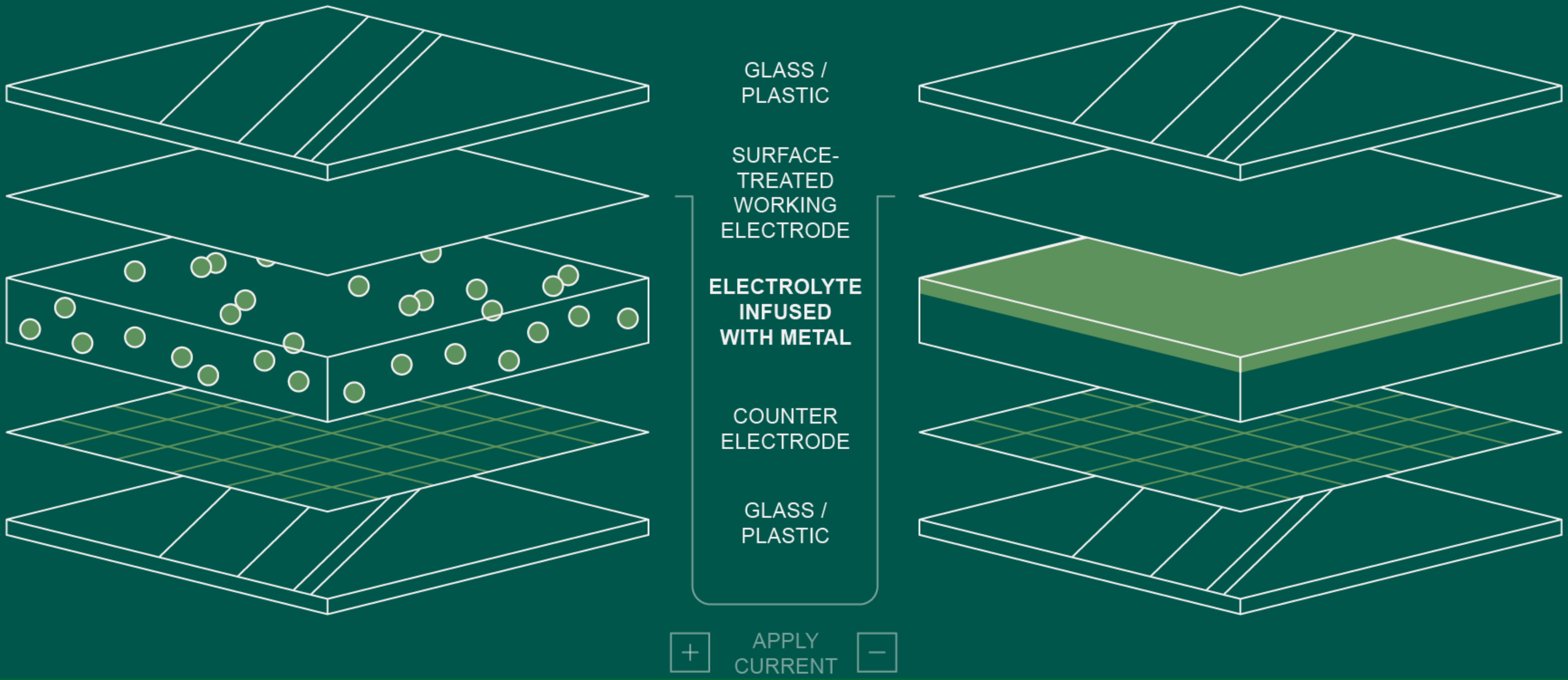
	SageGlass SAINT-GOBAIN	view	HALIO	tynt
Clear State VLT (%)	56	52	65	>60
Dark State VLT (%)	1.2	1.0	2.0	<0.1
Clear State Color (L*a*b*)	(79.8,-6.3,13.8)	(77.0,-6.4,11.2)	(83.4,-2.7,6.8)	(85.9,-0.7,2.1)
Dark State Color (L*a*b*)	(10.69,-5.64,-7.84)	(8.86,-4.01,-5.59)	(15.82,-6.41,-4.02)	(1.72,-0.32, 3.28)
Switching Time to 1%	~15-20 mins	~20 mins (*varies by window size)	N/A (2% VLT < 3 min)	< 5 min

Fast Switching with Neutral Color over the Widest Optical Dynamic Range

Technology:

Reversible Metal Electrodeposition

- Uses electric current to *dynamically* form a metal film inside the window to tint to any level
- Low temperature, low-cost processing
- 6 patents licensed from Stanford and CU Boulder

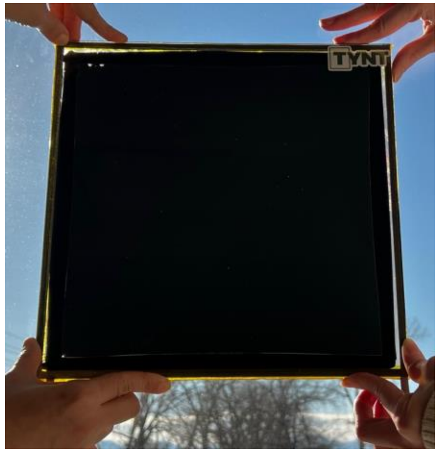


Other Potential Partnership Options

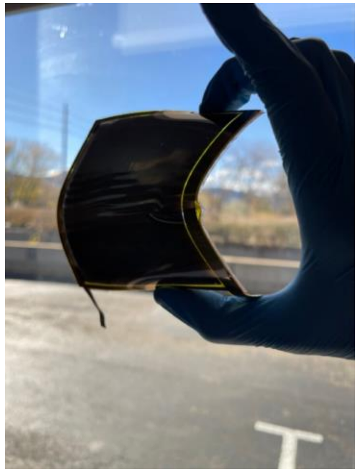
Skylight / OEM

Aftermarket

Window OEM



Automotive



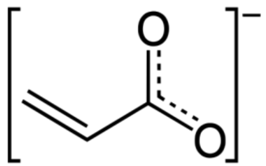
IGU & Commercial

IGU Partnerships enable commercial façade market and Tynt Residential Window

Gel Polymer Electrolyte

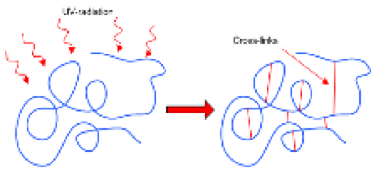
Radical Polymerization

Acrylates



AND

Chemically (covalent) cross-linked

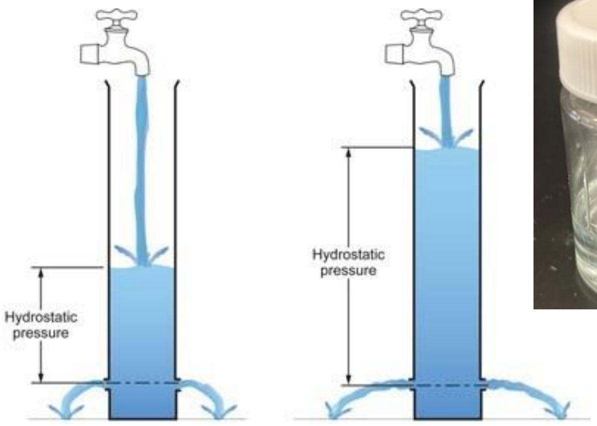


Improved Functionality

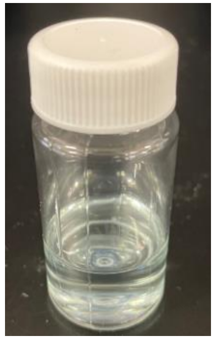
- Cross-link polymers with metal ions already present in gel composition to allow for in-situ processing and ease of integration

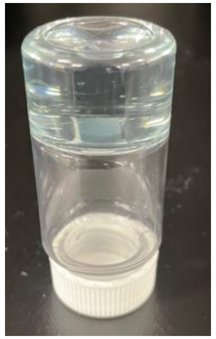
Improved Durability

- Chemical cross-links by strong covalent bonding will be stable at 85^{0}C and 1-sun UV (ASTM standard conditions)



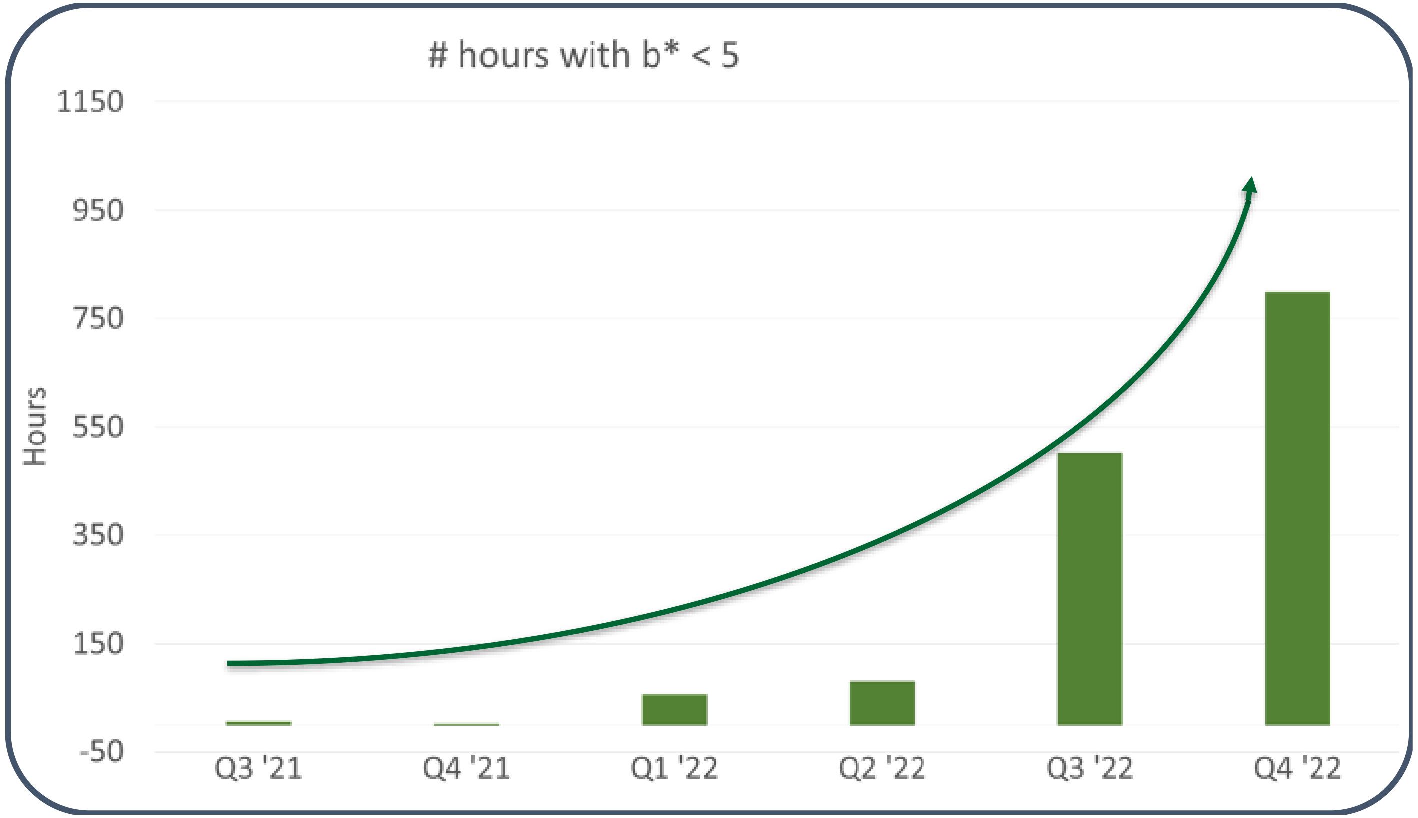
$$P_{hydrostatic} = P_o + \rho g h$$



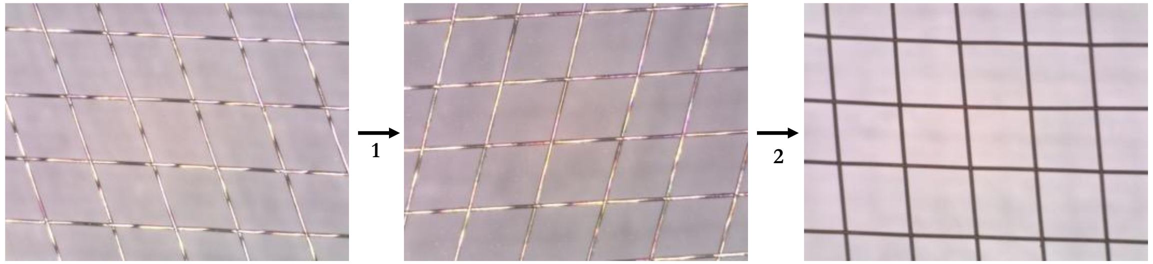


Continued improvement on electrolyte formulation to slow down yellowing (i.e. b* evolution) under high temperature and UV exposure

Goal for Year 1: 100 hours (Currently over 800 hours)



Metal Mesh Counter Electrode



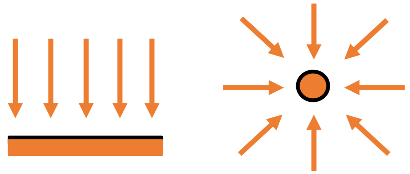
Inert Core

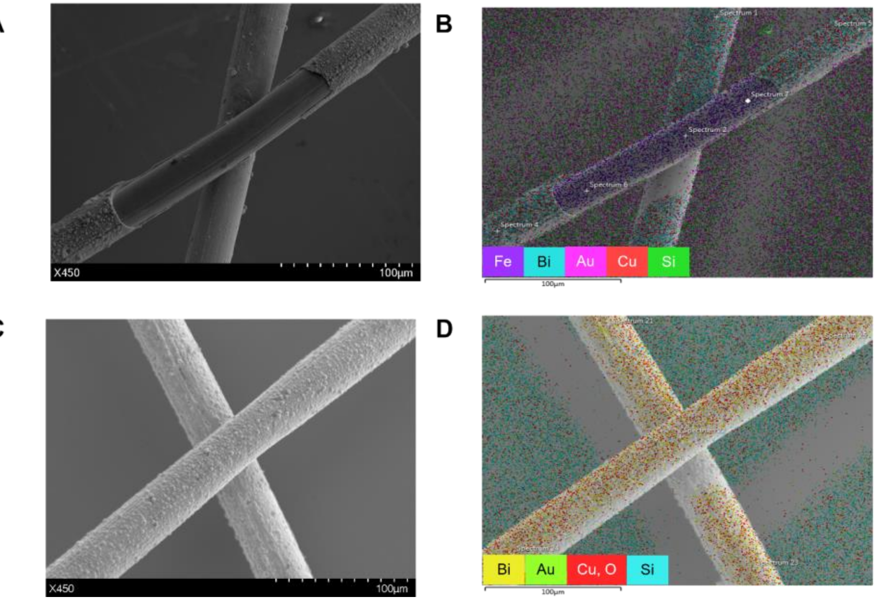
Noble Metal Adhesion Coat

Top RME Coat

Electrode	Geometry	% area per square
Pt-ITO	Planar	100
Cu Mesh	Cylindrical (woven wires)	75
Au-SS Mesh	Cylindrical (woven wires)	37

Planar vs Spherical Diffusion





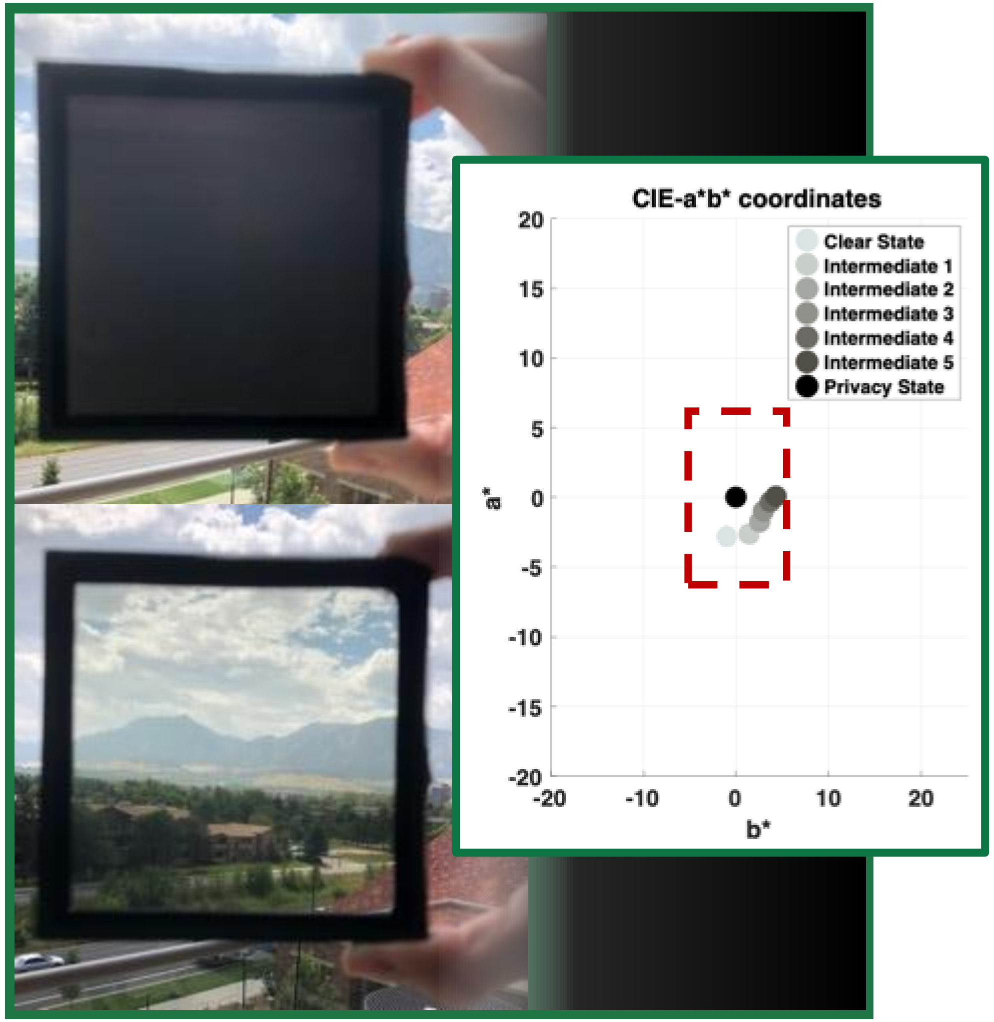
Substrate	Minimum Transmission State of Window	Charge Capacity (mC cm^{-2})	Transmission (%)	Haze (%)
Stainless Steel Mesh	N/A	0	88.3	1.7
Au Strike on SS Mesh	N/A	0	88.0	1.6
Privacy	0.1%	150	87.4	1.0
10x Privacy	<<0.1%	1500	86.6	0.8

< 3% drop in transmission!

Reduction in haze!

Metal Mesh Counter Electrode with <2% and >85% transparency with enough capacity and surface area to current match the working electrode for blackout privacy switching.

Color-Neutral, Fast Switching



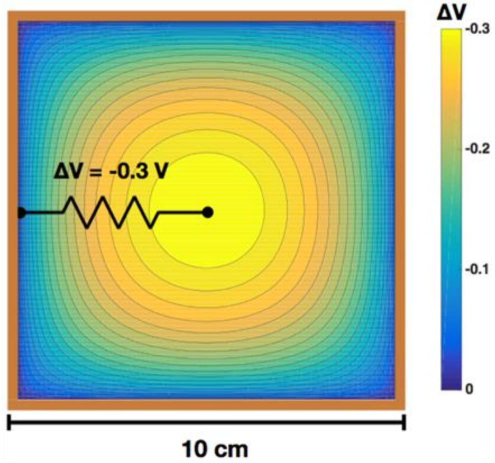
VLT % (@550nm)	Switching Speed (s)	A*	B*
70	0	-1.37	2.13
10	58		
3	105 (Goal: <180)		
1	168		
0.1	353 (Goal: <360)	0.07	1.21
0.01	487	-0.44	1.41
0	600	-0.43	1.31

VLT > 65% VLT ~10% VLT ~1% VLT ~0.1% VLT ~0.01%

Industry desires neutral color, defined as absolute value of a* and b* <5

Full dynamic window with gel polymer electrolyte and metal mesh with <3 min to <3% VLT and <6 min to <0.1% VLT with neutral color in clear and dark states

Scaling with Similar Performance



- Voltage Drop: $\Delta V = \frac{J R_{SH} L^2}{8}$
- Uniformity limit: $\Delta V < \Delta V_{\mathrm{U}}$ ("voltage tolerance")

<u>With our understanding:</u>

- Voltage Drop: $\Delta V = (\frac{OD}{CE * t}) \frac{R_{SH} L^2}{8}$

To lower voltage drop:

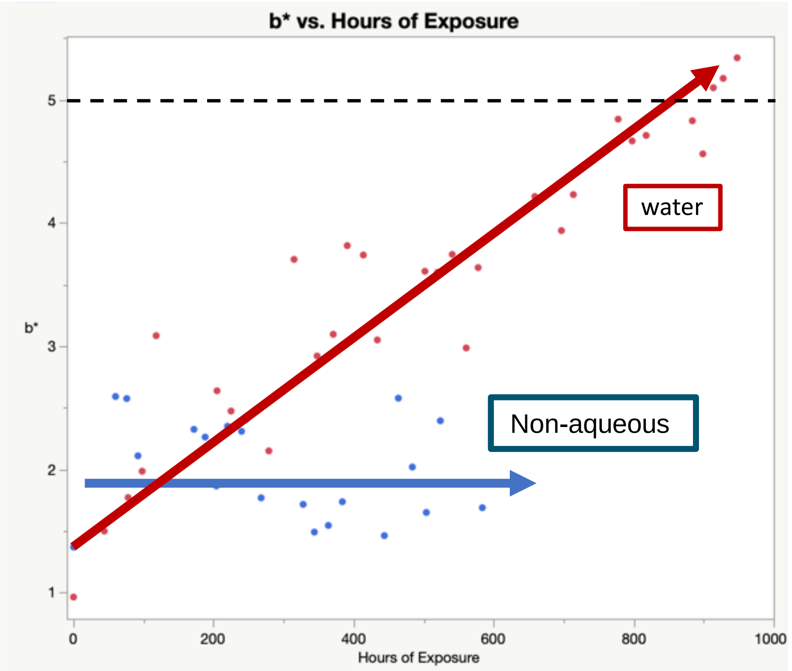
- Slow down the switching speed (increase t)
- Increase coloration efficiency (increase CE)
- Decrease sheet resistance (decrease R_{SH})

Proof of Concept 1 ft x 1 ft Dynamic Window with uniform switching

*Note: we are ahead of schedule on scaling as this is not a milestone until Year 2

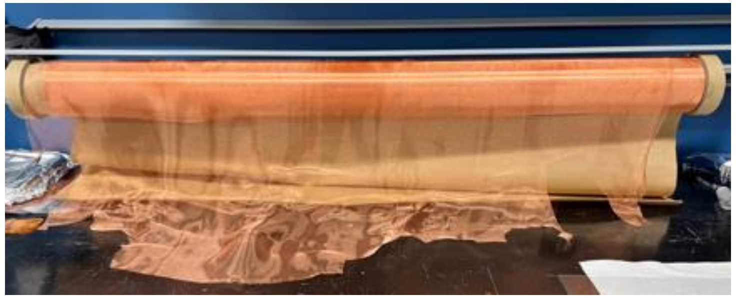
Next Steps and Challenges

1. Polymers in Water Turn Yellow

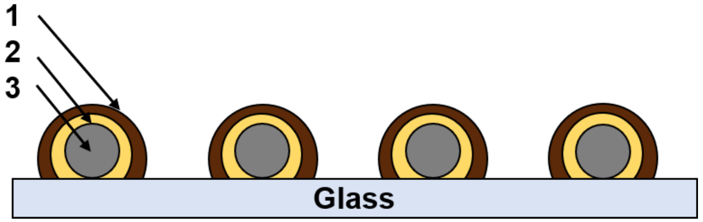


Internal development of non-aqueous gel polymer electrolyte

2. Large-Scale Mesh

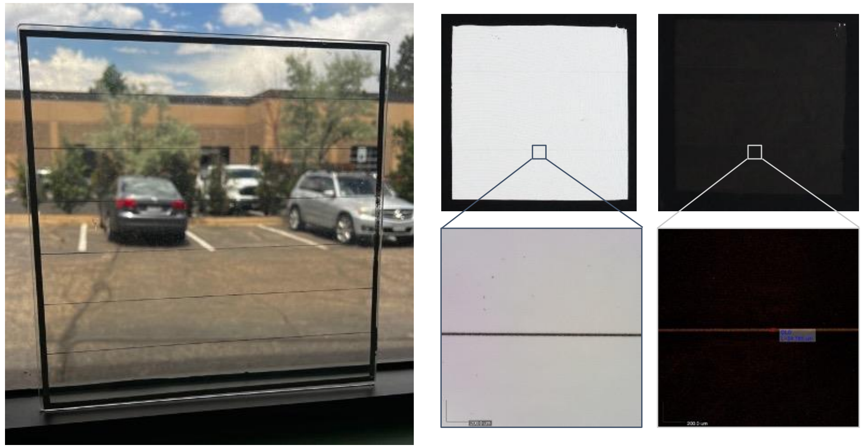


Customize material, diameter, and pitch



Ongoing development of sub-30-micron electroplated wire-based meshes

3. Path Towards "Invisible" Busbars

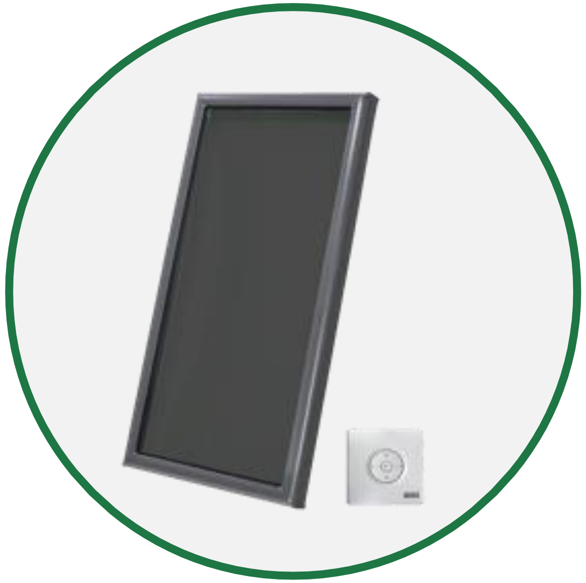


Ongoing development of sub-20-micron conductive metallic traces

Plans After The Project

Launch - OEM

- Partner with VELUX to deliver premium skylights



Scale - TYNT Windows

- Develop and sell complete window solution
- New construction AND retrofit

Future - Aftermarket

- Affordable solutions for all existing windows

Thank You

Tynt Technologies

Tyler Hernandez, Co-Founder/Director of Technology

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DE-EE0009701

REFERENCE SLIDES

Project Execution

	FY2022				FY2023			
Planned Budget	$698,674				$585,834			
Spent Budget	$638,696.52				in progress			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work								
Q1 Milestone: 100 hours of electrolyte stability								
Q2 Milestone: Highly transparent metal mesh counter electrode								
Q4 Milestone: Fast switching, color-neutral device								
Current/Future Work								
Q2 Milestone: 1 ft x 1 ft dynamic window with uniform fast switching and color neutrality								
Q4 Milestone: 5000 cycles under elevated temperature and UV								

- Hit all 3x Go/No-Go's for BP1
- Current working towards 2x Go/No-Go's for BP2

Team

Ameen K. Saafir

CEO

Former Halio Chief Engineer

Also commercialized OLEDs with Samsung and Dupont

John Dwyer

COO/CPO

18 years at Flex. Started and ran connective audio and wearables businesses.

25+ years leading manufacturing operations

Dr. Michael Strand

Director of Engineering

Co-inventor of RME technology and scale-up lead.

Forbes 30 Under 30

Prof. Michael McGehee

CU Boulder PI/Chief Scientist

Ranked #11 materials scientist in the world.

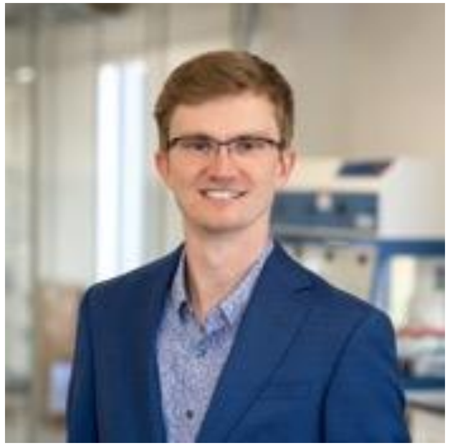
13 technology spinouts worth over $2.5B.

Prof. Christopher Barile

UN Reno PI

Co-inventor of RME technology.

Published first paper on RME dynamic window



Dr. Tyler Hernandez

Director of Technology

Co-inventor of RME technology and durability lead.

Forbes 30 Under 30

EERE/BTO goals

(Not a template slide – for informational purposes only)

The nation's ambitious climate mitigation goals

Greenhouse gas emissions reductions

50-52% reduction by 2030 vs. 2005 levels

Net-zero emissions economy by 2050

Power system decarbonization

100% carbon pollution-free electricity by 2035

Energy justice

40% of benefits from federal climate and clean energy investments flow to disadvantaged communities

EERE/BTO's vision for a net-zero U.S. building sector by 2050