



TechCon 2021

Virtual

64th Annual Technical Conference Proceedings Virtual Event: May 3 – 7, 2021

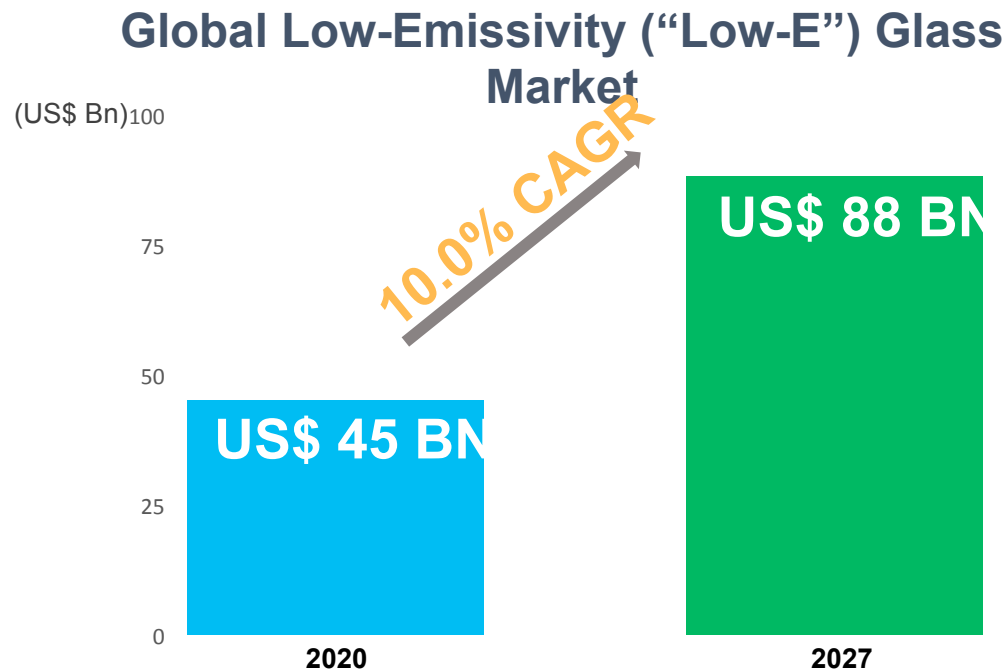
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5G Signal Penetrating Low-E Coating Technology

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Energy-efficient, low-emissivity (low-E) windows not only block infrared light radiation but also cellular signals. Signal attenuation due to low-E windows is severe (30+ dB), a problem that will get worse with the continued deployment of 5G networks. Existing solutions to overcome signal blocking consist of installing routers and antennas, which requires additional upfront investment and incur ongoing maintenance and upgrade costs. Alternatively, low-E windows can be laser scribed to enable limited signal penetration at the tradeoff of visual clarity, durability and with added costs. The optimal solution would be for low-E windows to block infrared heat while enabling cellular signals to pass through, all while maintaining low-E's optical and thermal performance at a cost competitive manufacturing level. In this presentation, we provide an overview of the market, current solutions and present our patent-pending innovation on cellular signal transmissive low-E window coating technology. Our prototype has demonstrated excellent 5G (low-band) frequency transmission and excellent visual clarity, while maintaining annealed and tempered low-E performance, including optical (transmission, reflection, color), thermal (emissivity, SHGC, U-value), and multiple durability tests.

Global demand for energy efficient (“low-E”) windows is massive and growing



- Climate Change
- Sustainability
- Net Zero
- LEED
- Cost-saving
- Ergonomics

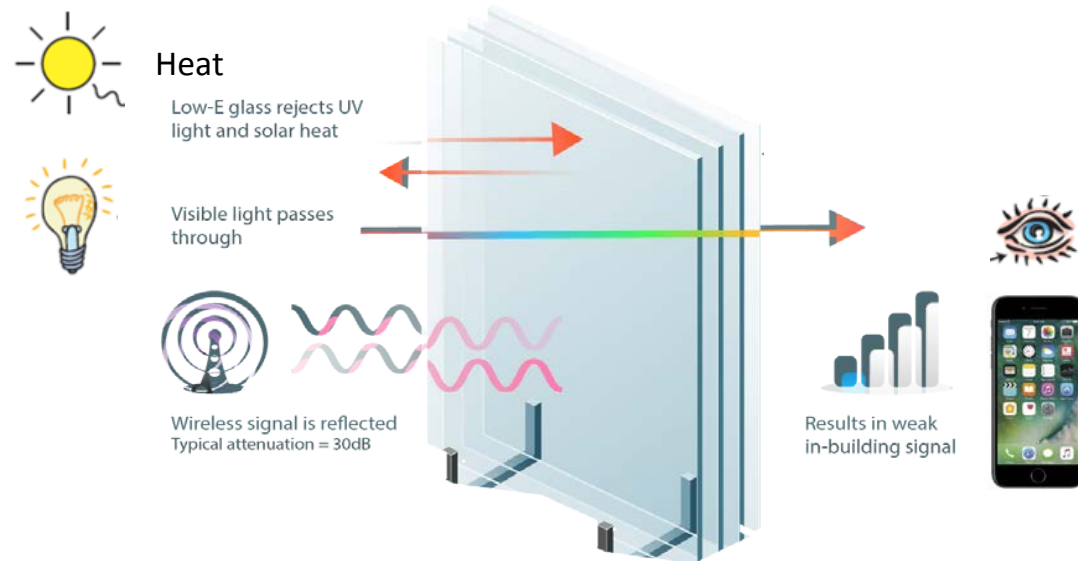
Source: Global Industry Analysts, Inc, September 2020



Yet energy efficient windows block cellular signal

Low-E windows are great thermal insulators by blocking long-wave electromagnetic energy, including cellular signal

Low-E Windows and Wireless Signal Inside LEED-Certified Buildings



Low-E window's signal blocking is severe



30+ dB



(>1000 times worse)



(Cellphone signal reduction)

MORE than 20x WORSE than a 6" concrete wall*

Note: single silver low-E under 1900 MHz PCS band; worse for higher cellular frequencies and for double and triple low-E coated windows.



Existing solutions and work-arounds are expensive with downsides

	How	Considerations
 In-door Cellular Aids	Routers, antennas, and repeaters that transmit and enhance signals into and inside of the building	<ul style="list-style-type: none">• Expensive• Carrier dependency• Quality (voice & data)• 5G readiness• Privacy• Security
 Laser Scribing	laser cuts low-E coating and breaks the “Farady Cage” enabling cellular signal to “squeeze” through otherwise electrically conductive surface	<ul style="list-style-type: none">• Throughput (manufacturing scalability)• Costs• Visual clarity (unsightly cut lines)• Durability

5G rollout significantly worsens in-door cellular coverage

US\$ 900
Mobile carrier 5G capex
BN (2020-2025)



In-door
Cellular Aids



- Costly installs, upgrades, and maintenance



Laser Scribing



- Current industrial laser technology is nonviable for mid to high-band 5G due largely to insufficient throughput

LFI's technology enables cellular signal to penetrate low-E windows at the industrial scale

Leverages proven mass production lithographic technology combined with patented structures, materials and processes to achieve a cost competitive, embedded mass manufacturing solution



Throughput

Visual clarity

5G ready

Competitive costs

Matching durability

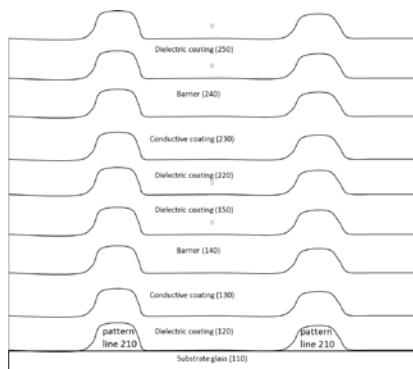


Backed by robust, comprehensive patent portfolio

14 novel **structures**, 10 **materials** / **hardware** / **process** claims

Deposition solution (US62/907,964)

- A novel deposition solution without cutting / masking to achieve a cost-competitive, in-line production



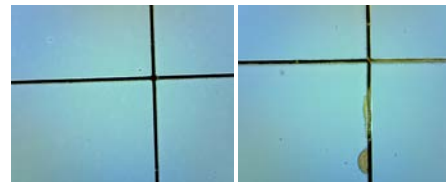
Manufacturing solution (US62/988,268)

- Structure for scalable manufacturing
- Not achievable by traditional lithography
- Patented structure enables high-throughput and low-cost
- Significantly save on equipment cost

Durability solution (US63/027,111)

- Structure to improve durability
- Pass thermal durability test (650C for 8min)
- Pass boiling water test (1 hour)

Thermal Durability Test



W/ Patent structure W/o patent structure

Invisible/low cost solution (US 62/125,214)

- Structures to achieve invisibility
- New hardware/process to reduce cost and enhance performance

Visibility comparison

W patent structure
Invisible by naked eyes



W/o patent structure



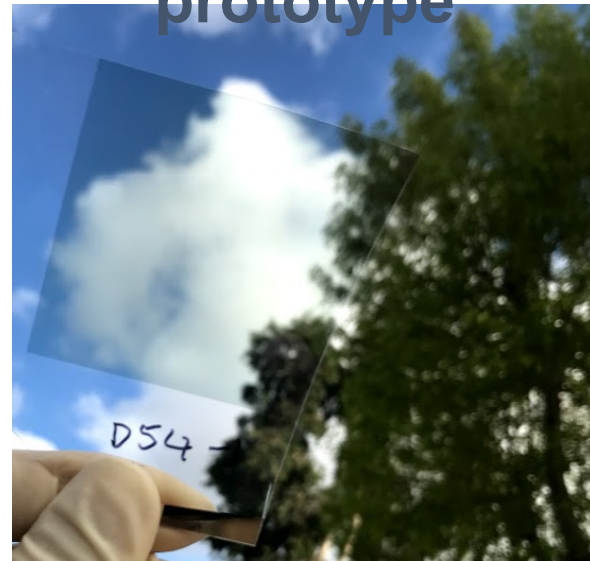
Performance



Prototype Status

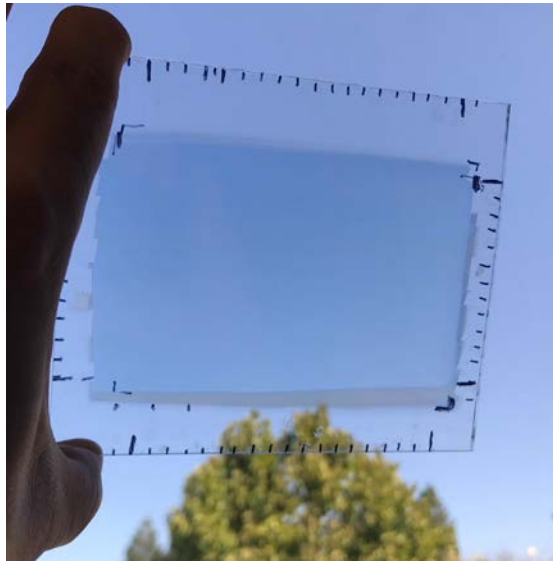
- 50 mm x 50 mm prototype
- Meet current low-E product specs, including durability
- Excellent 5G low-band frequency transmission
- Excellent visual clarity

Sample Gen2.5 prototype



Prototype

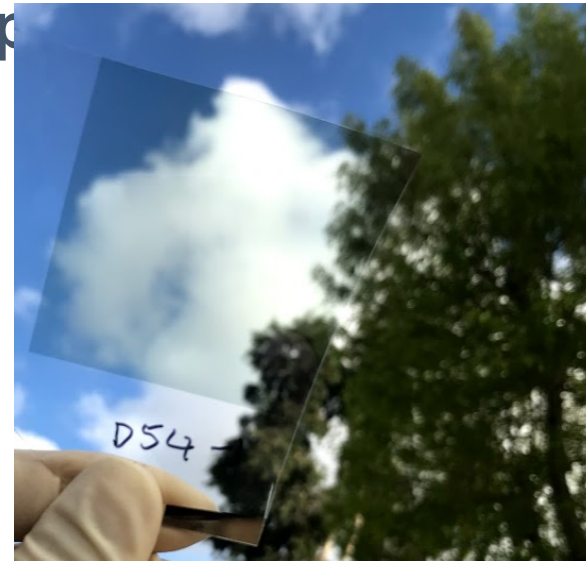
Sample Gen2 prototype



Dimensions: 60mm x 100mm
Line width: 10 μm
Pitch of the grid: 2 mm
Signal loss: ~5 dbm @ 2.4 GHz

prototyp

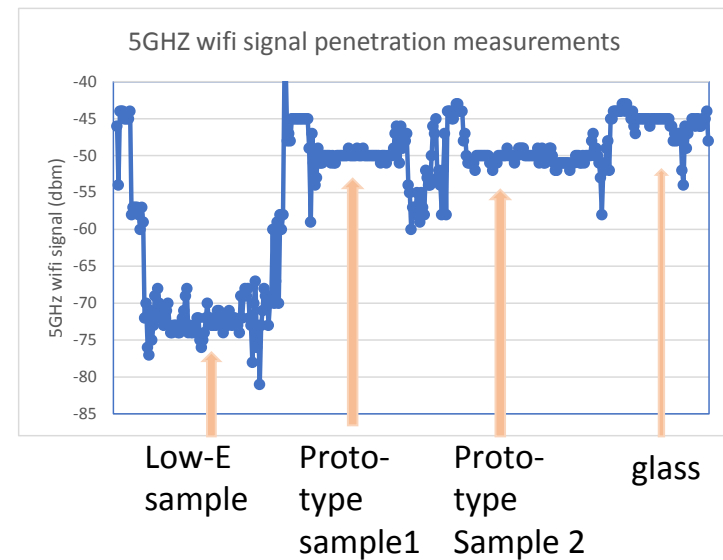
Sample Gen2.5



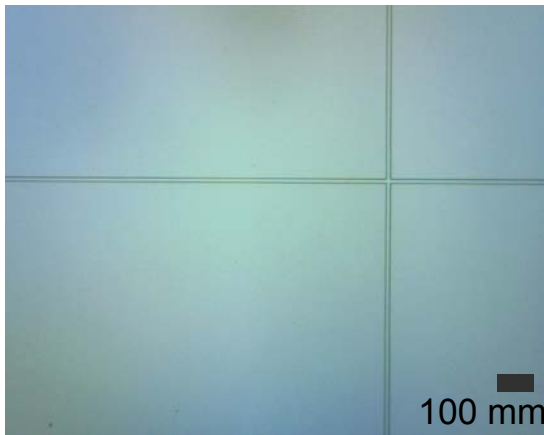
50mm x 50mm
5 μm
0.5 mm
~5 dbm @ 5GHz

Prototype shows excellent cellphone signal transmission

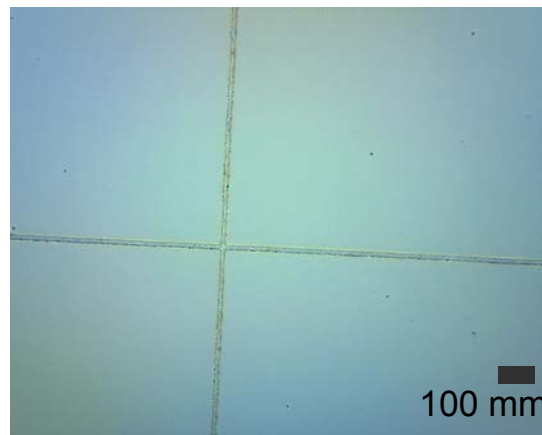
- Gen 2.5 sample (5cmx5cm) measured through
 - 5GHz Wi-Fi router
 - an iPhone with an App “AirPort Utility”
 - a heavy-duty 16 GA welded steel box with open window for signal testing
- Resulting signal loss is ~5 dB vs. ~27 dB signal loss for equivalent single silver low-E coated glass for 5GHz
- Expect further signal penetration improvement in future products



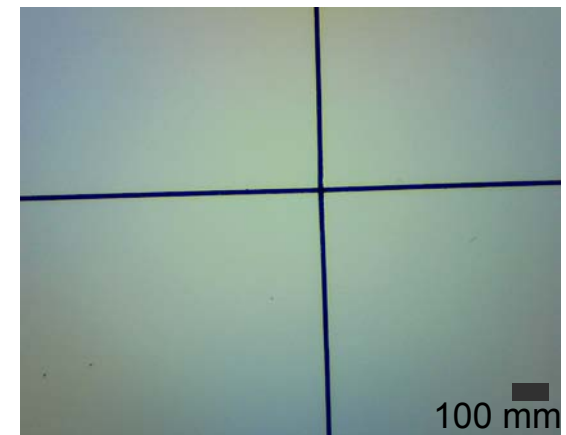
Excellent durability characteristics (microscope inspection)



As-coated



**Post 650C
8 minutes test**

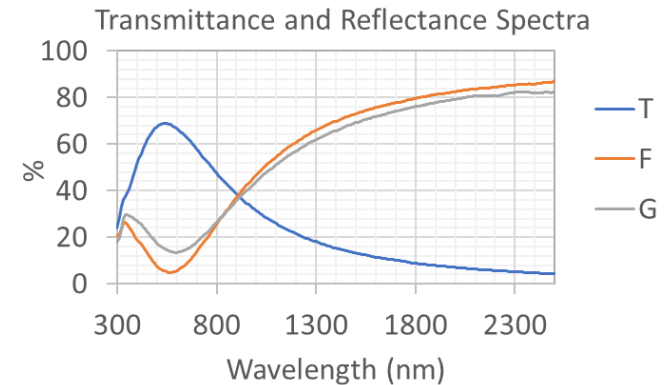


**Post
boiling 1-
hour test**

Meet major low-E product performance specifications

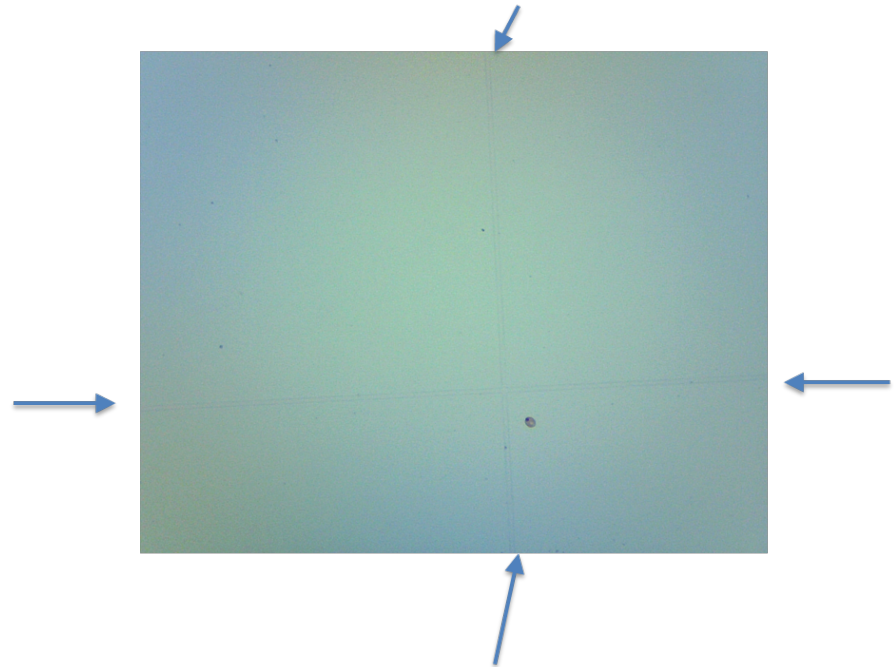
- **Meet all major low-E performance specs:**
 - Color
 - Visible transmission
 - Visible reflection
 - Thermal energy saving
 - Thermal durability
 - Environmental durability
 - Mechanical durability

monolithic glass coating	T _Y	67.6
	T _a *	-4.4
	T _b *	4.9
	G _Y	14.9
	G _a *	4.7
	G _b *	-14.6
	F _Y	6.1
	F _a *	14.4
	F _b *	-21.8
	haze	0.3
Emissivity	0.05	
AGU (1 mm glass/ 12 mm gap Ar /3mm glass) NFRC	T _{vis}	61.8%
	T _{sol}	40.1%
	U-value	0.250
	SHGC	0.42
	LSG	1.44



Visual clarity as normal low-E coating

- Human eyes cannot detect lines on LFI low-E coating glass at any distance, any angles.
- Unless under microscope in special light conditions.
- => picture under microscope, very faint lines may be seen along the direction of the arrows.





Thank You!

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