



Juntos, Vemos Más Allá

---

**Vitro Flat Glass, LLC  
Company Overview**

October 2022

## Company summary



- Vitro is the largest **glass manufacturing company** in North America and one of the largest in the world.
- **+110 years of experience.** Founded in 1909 in Mexico, the company offers quality products and reliable services to serve 3 segments: **Flat Glass, Glass Containers and Chemicals.**
- In 2016 and 2017, Vitro **acquired PPG & PGW** respectively, to consolidate, expand and strengthen the architectural and automotive businesses.
- Vitro's companies produce, process, distribute and market a wide range of glass products to multiple markets like **architectural and automotive glass**, as well as the **cosmetics, fragrances, pharmaceuticals and liquors.** It also supplies **chemicals and raw materials, machinery and equipment** for industrial use.



# Architectural Business

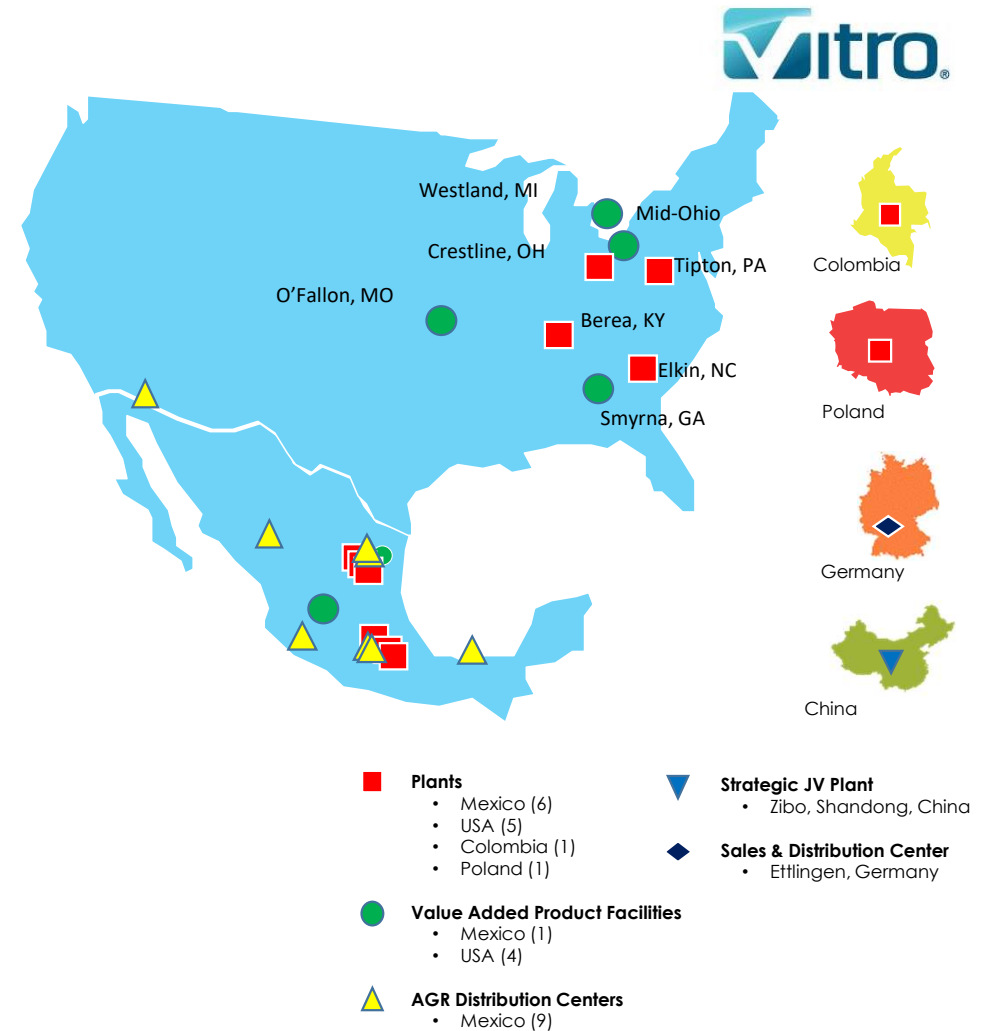


- We are the **largest flat glass manufacturer** in North America in installed capacity, with furnaces, plants and value-added process centers in the U.S., Mexico and Canada.
- Manufacture and distribution of glass for the **construction, residential, industrial and automotive** segments.
- Wide range of value-added glass products, such as Solarban<sup>®</sup>, Starphire<sup>®</sup>, Intercept<sup>®</sup> IGU Spacer, Solarphire<sup>®</sup> PV, Solarphire<sup>®</sup> AR



# Automotive Fabrication Business

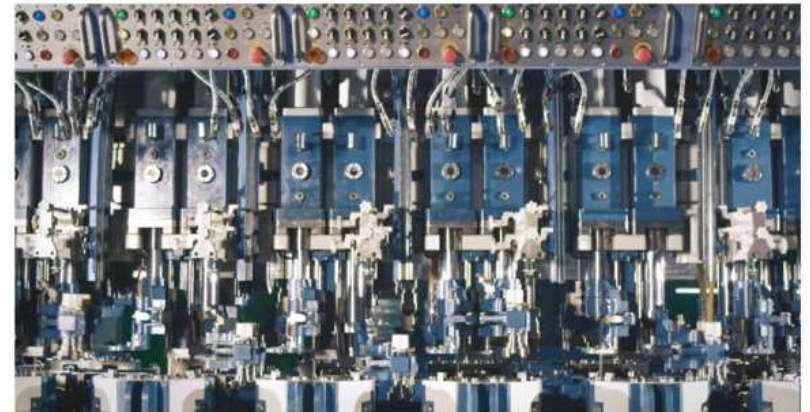
- **# 1 producer for the OEM** market in North America and a leader in the distribution and installation of automotive glass replacement (AGR).
- AGR with **9 distribution centers**, **+160 stores** and presence in **+120 cities**. Currently our operations are expanding in North America, South America, Europe and Asia.
- In 2020, a **new line of state-of-the-art windshields** began operations in Mexico, increasing production capacity.



# FAMA - Equipment & Automation Business



- Founded in 1943 as a Vitro subsidiary for in-house machinery manufacturing technology and specialized machines
- +250 machines and furnaces produced, plus the design and production of our own engineering parts
- FAMA offers a wide array of design and manufacturing solutions for toolings, structures and parts for various industries
- Generate added value to each customer requirement, using computer systems to create automation solutions that can be applied to many industries



Our wide experience in the glass container industry allows us to provide solutions through products and services for Machinery & Equipment, FAMA Services and Spare Parts for the glass industry.



We offer control and automation solutions in turnkey projects, precision manufacturing and specialized application development



We develop gray and ductile iron casting for wide variety of industries, we design and manufacture toolings, machine parts that enhance the processes for various industries by taking advantage of our foundry capabilities, well - equipped infrastructure and quality processes.



Juntos, Vemos Más Allá

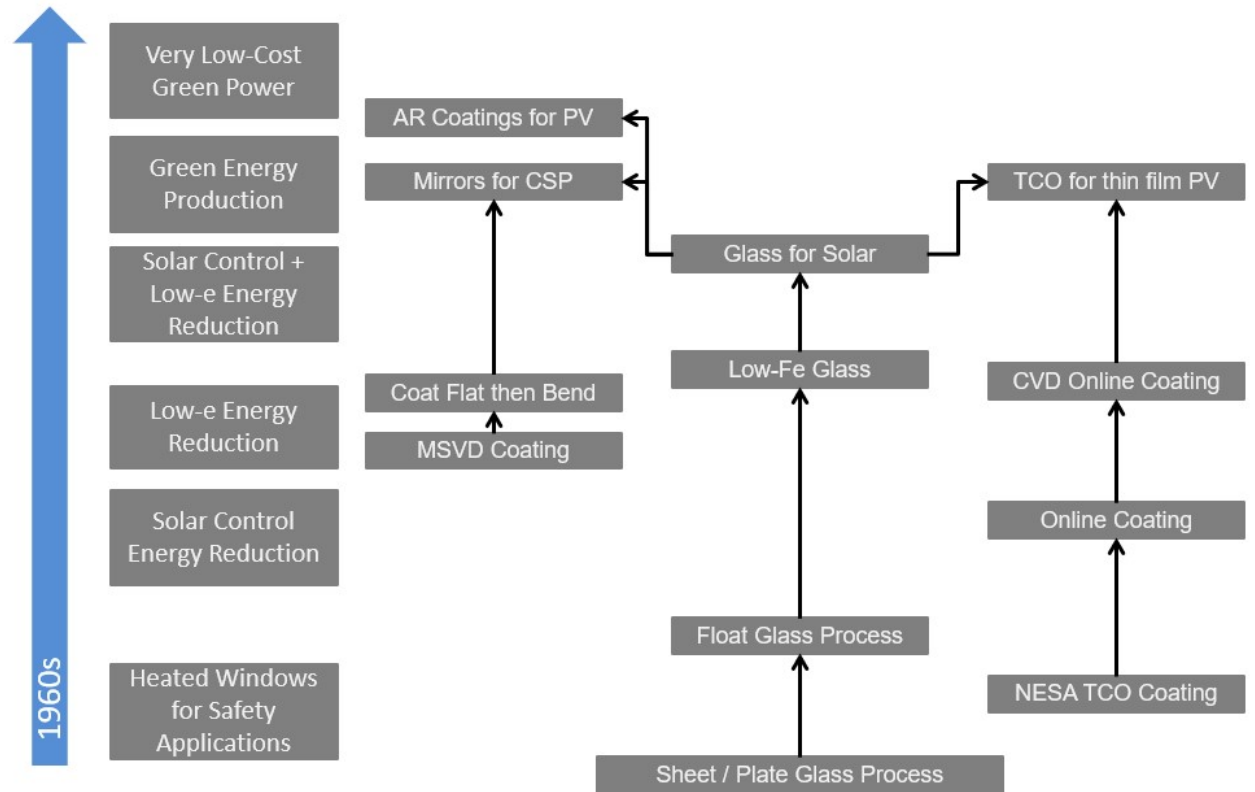
---

## **Vitro Technology Capability for Solar Applications**

# Vitro Strategy in Developing Products for Solar



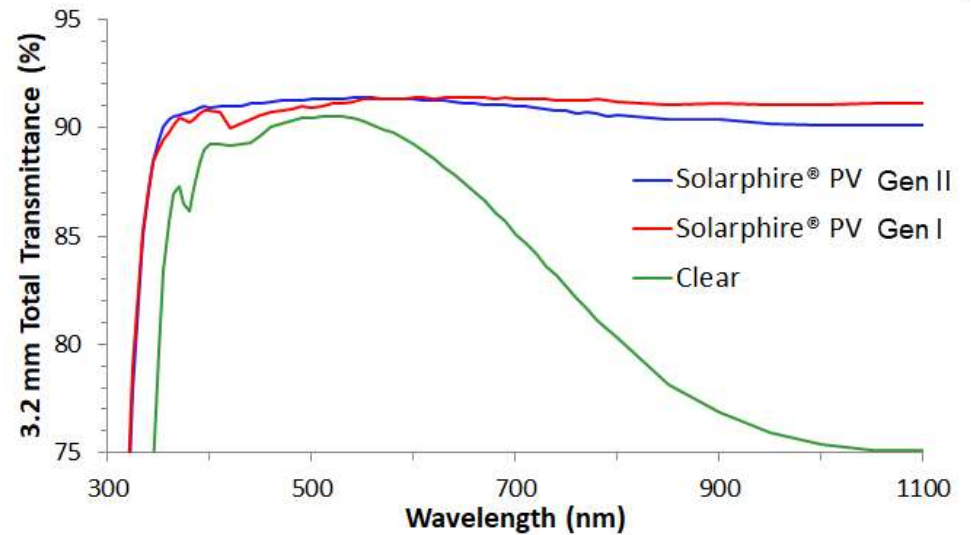
- Materials
  - Performance
  - Durability
- Process
  - High volume
  - Drive yields and costs
- Device
  - Focus on minimized  $\$/W_p$  and LCOE
  - Collaborative development



# Glass Composition Development



- Absorption control
  - $\text{Fe}_2\text{O}_3$  concentration at the ppm level – drives overall level
  - Redox controls spectral response
- Durability
  - Alkali modification for 30+ year exposure
  - Adjust dopants for redox control without solarization
- Commercial sales to major US solar module manufacturer



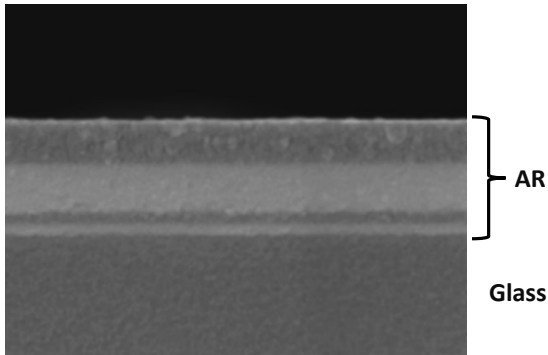
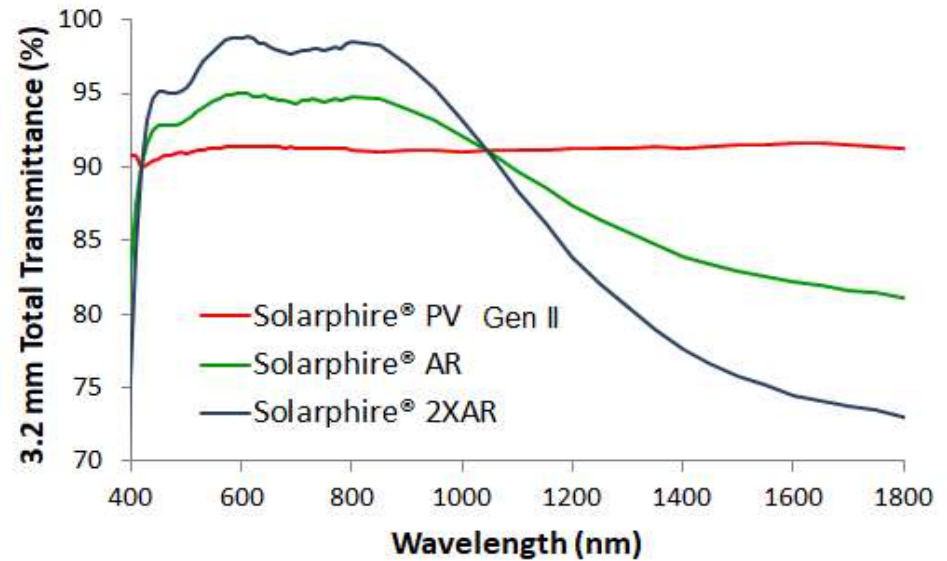
	3.2 mm	4.0 mm
	$T_{\text{sol}}$ ISO9050 (300-2500nm)	$T_{\text{sol}}$ ISO9050 (300-2500nm)
Clear	83.4%	81.7%
Solarphire® PV Gen I	90.7	90.4
Solarphire® PV Gen II	91.0	90.8



# Anti-reflective Coatings on Glass



- Performance
  - Optimized multi-layer stack
  - Designed to minimize LCOE
- Durability
  - Able to run AR side down in downstream process steps
  - Far Exceeds IEC spec for HF and 85/85
  - Taber test results *comparable to glass*
- Commercial sales to major US solar module manufacturer

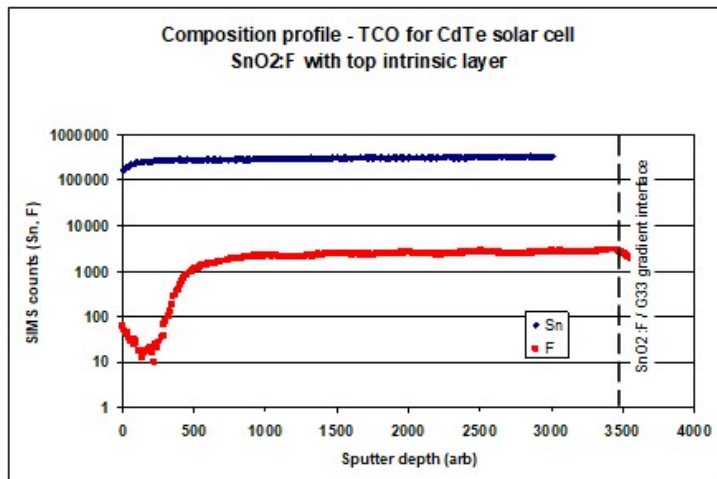


Glass Type (3.2 mm)	ISO 9050 Transmittance (400-1100 nm)* (%)
Solarphire® PV Gen II	91.1 (±0.2)
Solarphire® AR	93.6 (±0.2)
Solarphire® 2XAR	<b>96.3 (±0.2)</b>
Solarphire® PV Gen I	90.8 (±0.2)

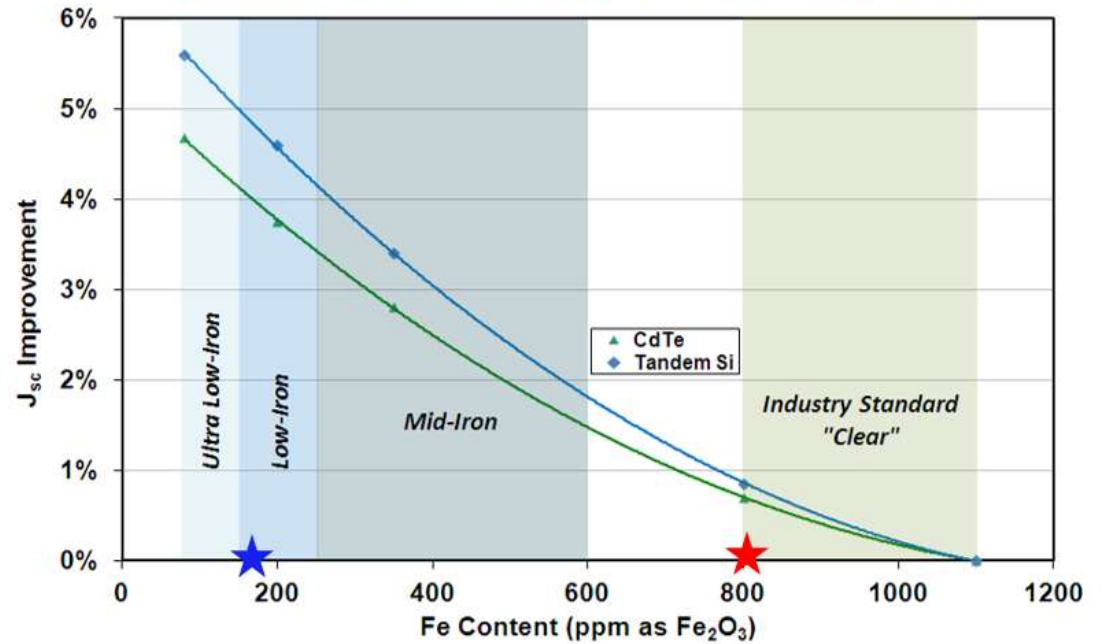
# TCO Coated Glass



- Focus on device physics
  - Light management
  - $I^2R$  series resistance
  - Surface morphology
  - TCO / active layer interface
- Production scale
  - Produced low sheet resistance, high transmission coating structure
  - Demonstrated with CdTe module fabrication



Thin Film Photovoltaic Device  
 $J_{sc}$  Performance vs. Iron Content of Glass Superstrate



Product	Rsheet ( $\Omega/SQ$ )	$T_{pv}(CdTe)$	$T_{pv}(a-Si)$
Solar TCO (R12H1) <span style="color:red">★</span>	11.2	77.6	79.3
Solar TCO (R8H1) <span style="color:red">★</span>	8.2	77.2	75.2
Solarphire™ TCO (R8H1) <span style="color:blue">★</span>	8.4	80.4	79.7
"Standard" TCO Coated Glass	13.2	77.5	79.7

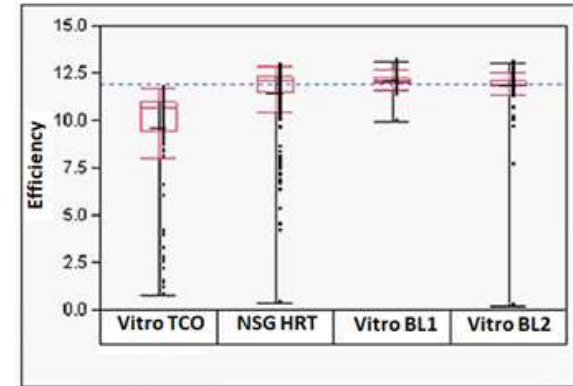
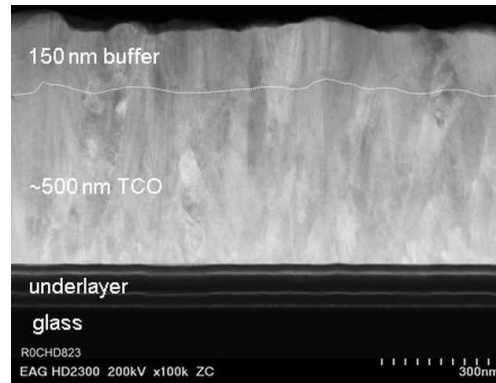
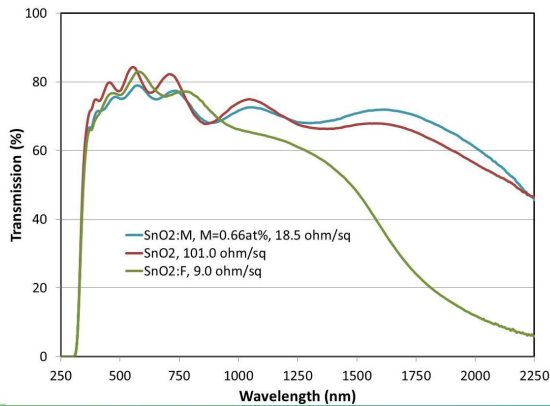
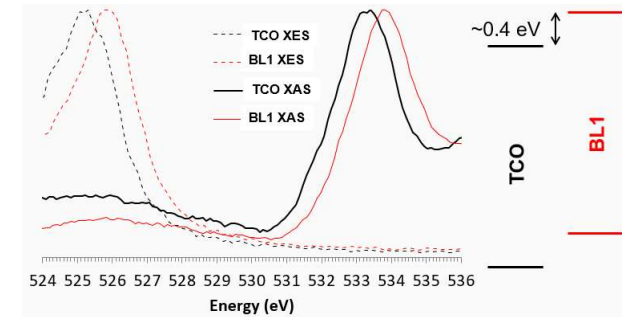
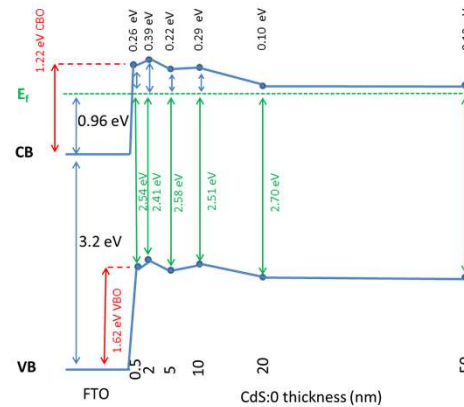
\* $T_{pv}$  is a weighted transmission = Solar Spectrum (ISO 9050) x QE(CdTe or mc-Si cell) x %T (measured)

# TCO Design and Active Layer Interface Engineering



- Focus on device physics
  - Band structure engineering at interface by materials design of buffer layer
  - TCO mobility modification through modification of matrix
- Performance impact
  - Reduced variations in efficiency while maintaining high output
  - Increase in  $J_{sc}$  with no degradation of  $V_{oc}$
  - Engineered buffer layer required for 'window layer free' device

Band Diagram of F:SnO<sub>2</sub> with variable CdS:O thickness





**Thank You**