Challenges of Designing Glass Compositions for new applications

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Challenges

- Newer applications need newer glass properties
  - Satisfying customer's expected performance specifications
  - Able to commercially manufacture glass
  - Complying with environmental regulations

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Glass Quality Requirements

- Building Glass products
  - Neutral reflected and transmitted color (residential)
  - Architects aesthetic preferences
  - Low solar heat gain, e.g., <0.25 (LEED points)
  - High visible transparency – daylighting
  - Low U-value for colder climates

- Solar PV Glass products
  - Tsol > 90.2%; Reflectance should be small
  - Durable and little to no solarization

- Extra Strength glass
  - Strength also important in addition to other properties

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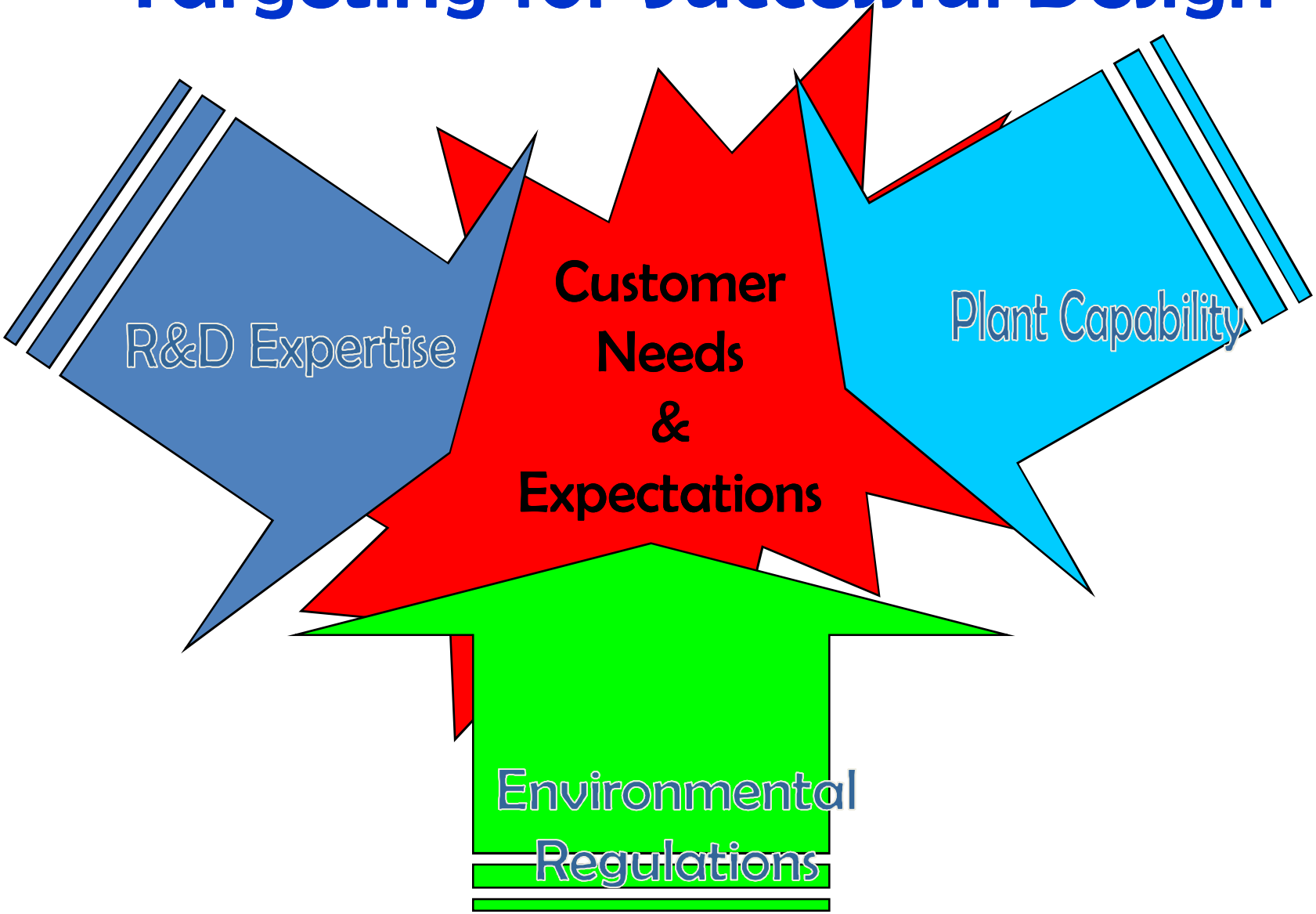
Targeting for Successful Design



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Glass Attributes

- Solar Heat absorbing – high iron content (+other absorbers)
- High visible transmittance – low iron content
- Solarization resistance
- High Strength
- Low melting temperature
- Scratch resistant
- Chemical durability
- Control over density
- Low thermal expansion

Apply computer models to predict glass properties

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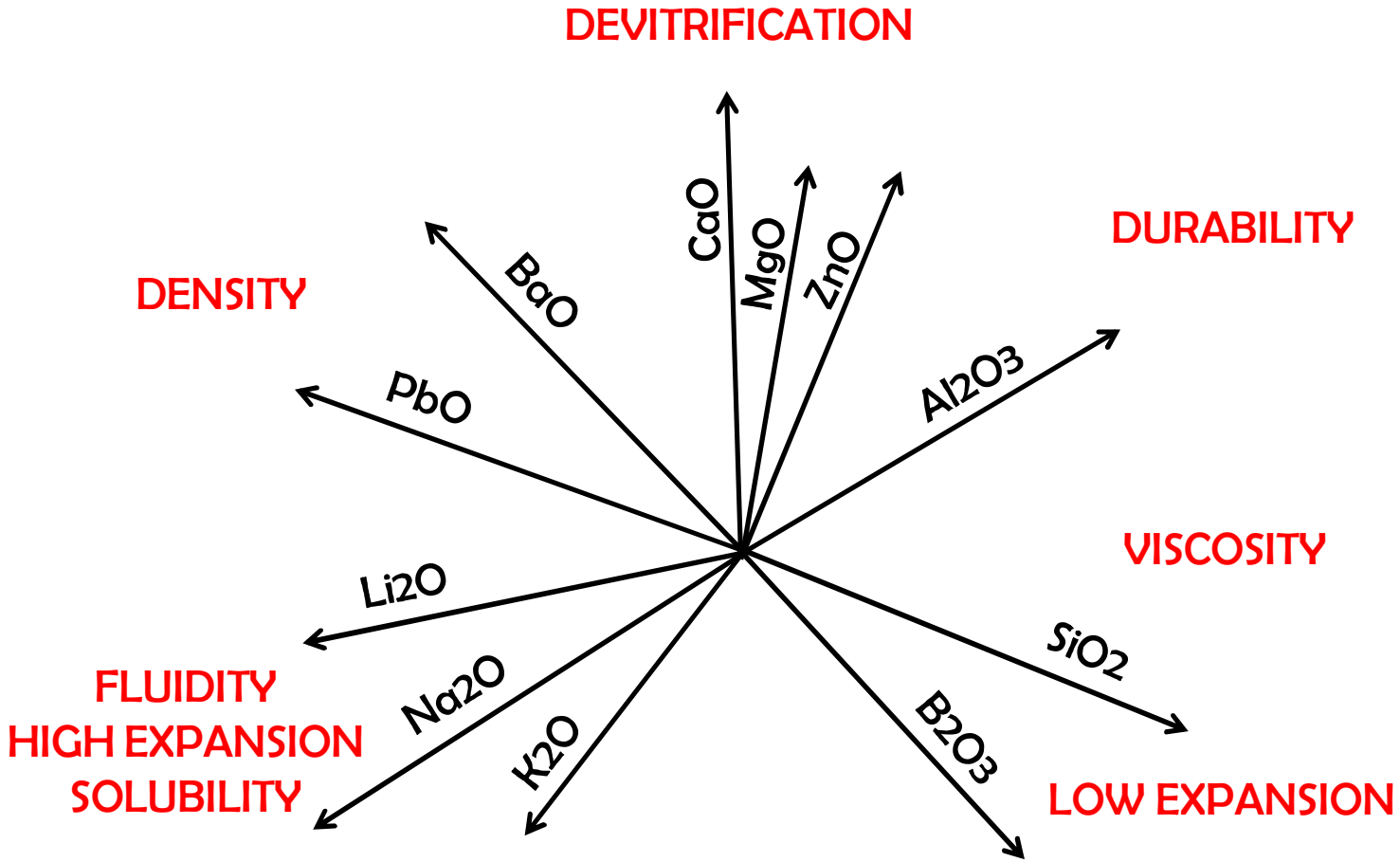
Relative Functions of the Glass-Making Oxides



Reference: S.R.Scholes, Modern Glass Practice, Industrial Publications, Inc., Chicago, IL, 1952, pg 17-18.

Production Criteria

- Glass melting and forming temperature
- Glass quality
- Glass redox control
- Glass furnace design – throughput rate, type of firing & fuel, heat penetration, convective flow velocity

- Raw material availability
- Product change times between products
- Advanced process control and automation
- Glass coating on-line vs. off-line

- Environmental permits – emissions, NO_x, SO_2, CO_2, particulate matter

Apply CFD modeling to determine compatibility with production process

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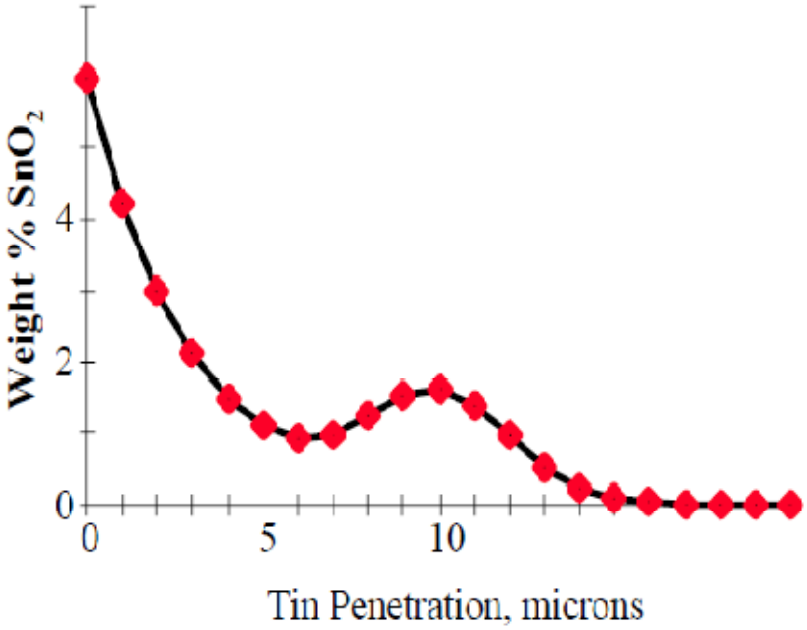
Float Glass vs. Sheet or Rolled Glass

- Float glass
  - Bottom surface enriched in tin.
  - Top surface > 10x lower tin content.
  - Effect on surface reflectance :
  - Bottom surface Rvis = 4.1%
  - Top surface Rvis = 4.0%

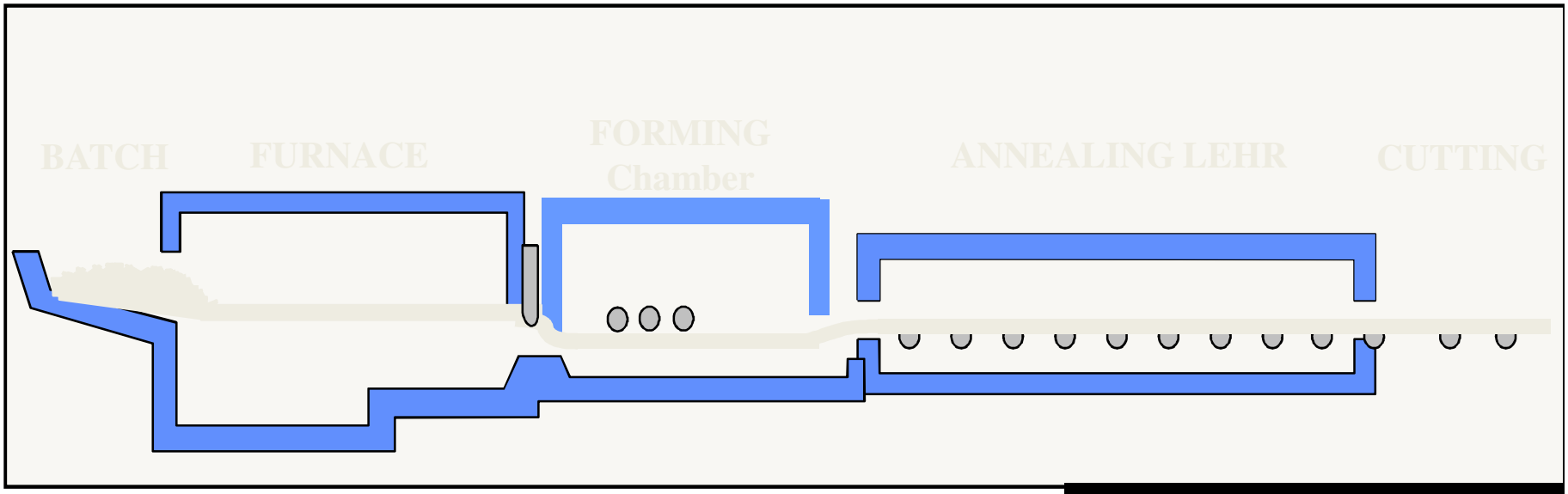


- Sheet glass
  - Down-draw or up-draw process.
  - Fire-polished surfaces

- Rolled Glass
  - Geometric pattern on one or both surfaces

Flat Glass Manufacturing

The float glass process

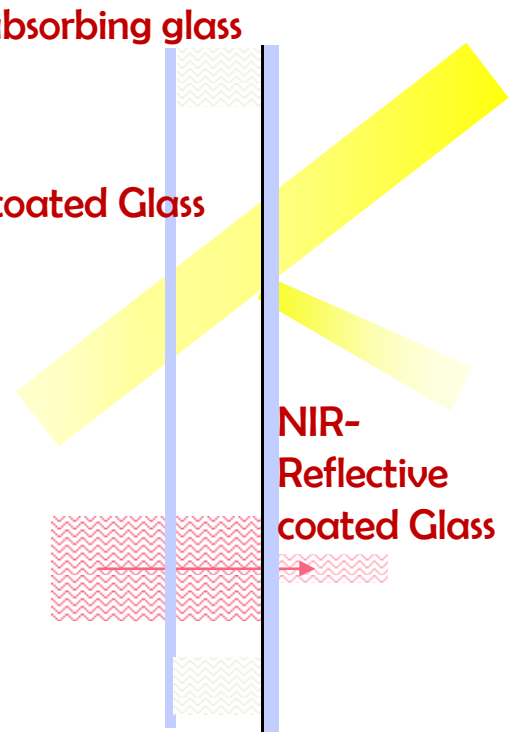


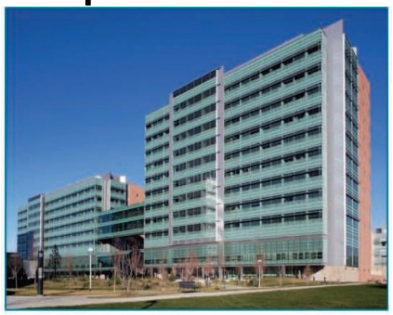
- Typical peak glass melting temperatures up to 1600 ℃
- Average throughput from 300 to 900 T/D
- Furnace melter surface area from 3000 to 4200 ft^2

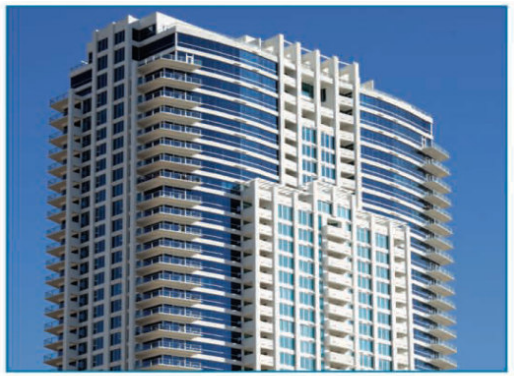
Solar Heat Absorbing Glass

Energy Management

- Building aesthetics
- Energy efficient buildings
  - Green engineering.
  - Leadership in Energy and Environmental Design (LEED) standards and certification
- New government regulations
  - Energy usage codes
- Glass Melting concerns
  - Effect on temperature gradients in melting furnace.
  - Convective flow effects due to radiative and conductive heat transfer
  - CFD modeling of tank flow patterns and temperature distributions.




Leprino Office Building
Location: Aurora, CO


Sky Las Vegas
Location: Las Vegas, NV

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High Transmittance Glass

- Requires use of low iron containing batch materials
  - Effect on temperature gradients in melting furnace.
  - Availability of raw materials
    - On-time delivery
    - Chemical consistency

- Growing demand for solar energy applications.
  - Trend towards using more Green technologies
  - Glass compositions with unique properties

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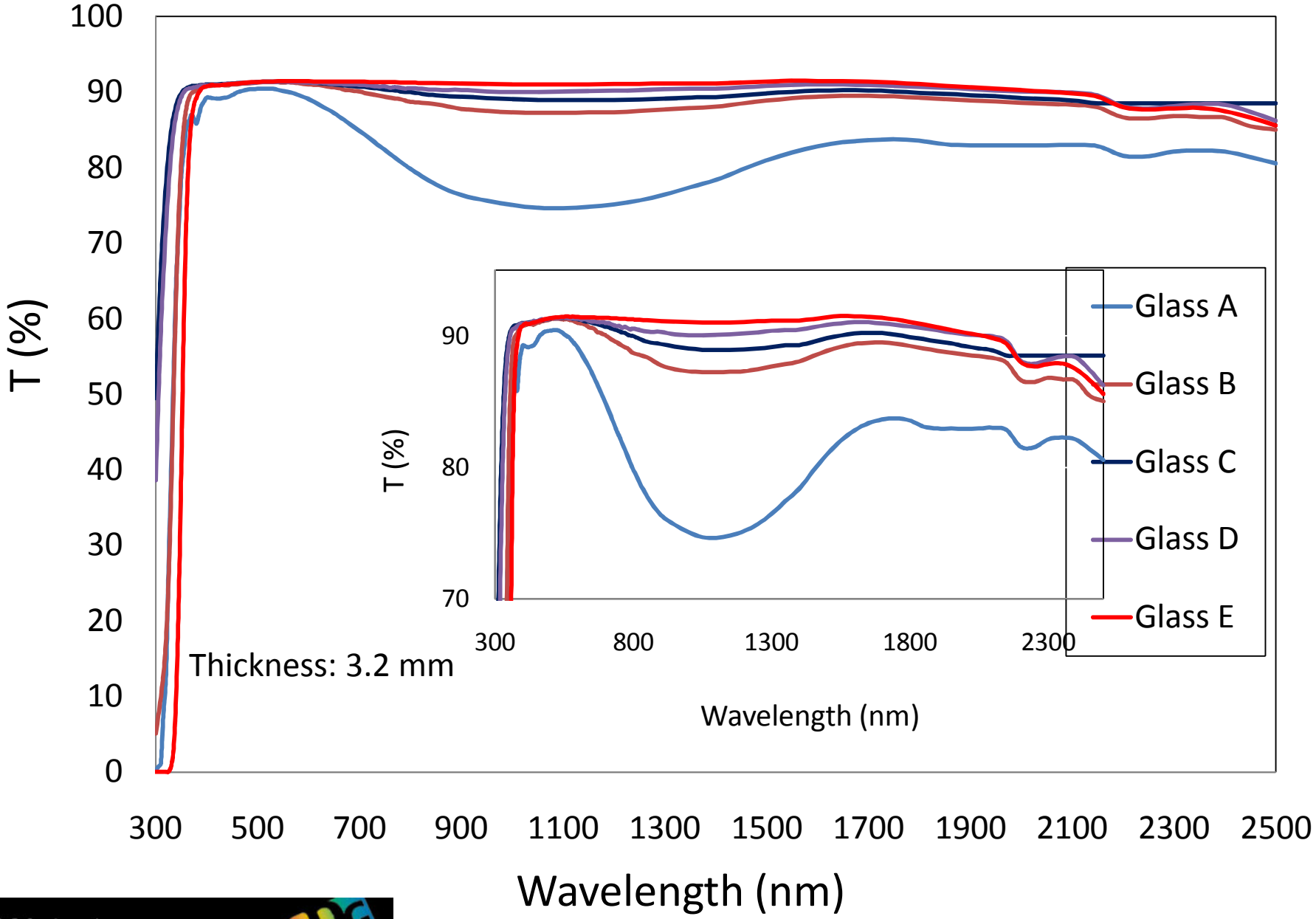
Optical Transmission in Glass



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Solarization of glass

- Loss of light transmittance after prolonged exposure to sunlight

  → number of photons available to the cell decreases

  - Of great important for solar energy applications

Causes:

- Certain additives in the composition of the glass
- Non-bridging oxygen in the structure

Solarization Science

One species is oxidized (Loss of e^-)

$$X^{+2} + h\nu \leftrightarrow X^{+3} + e^-$$

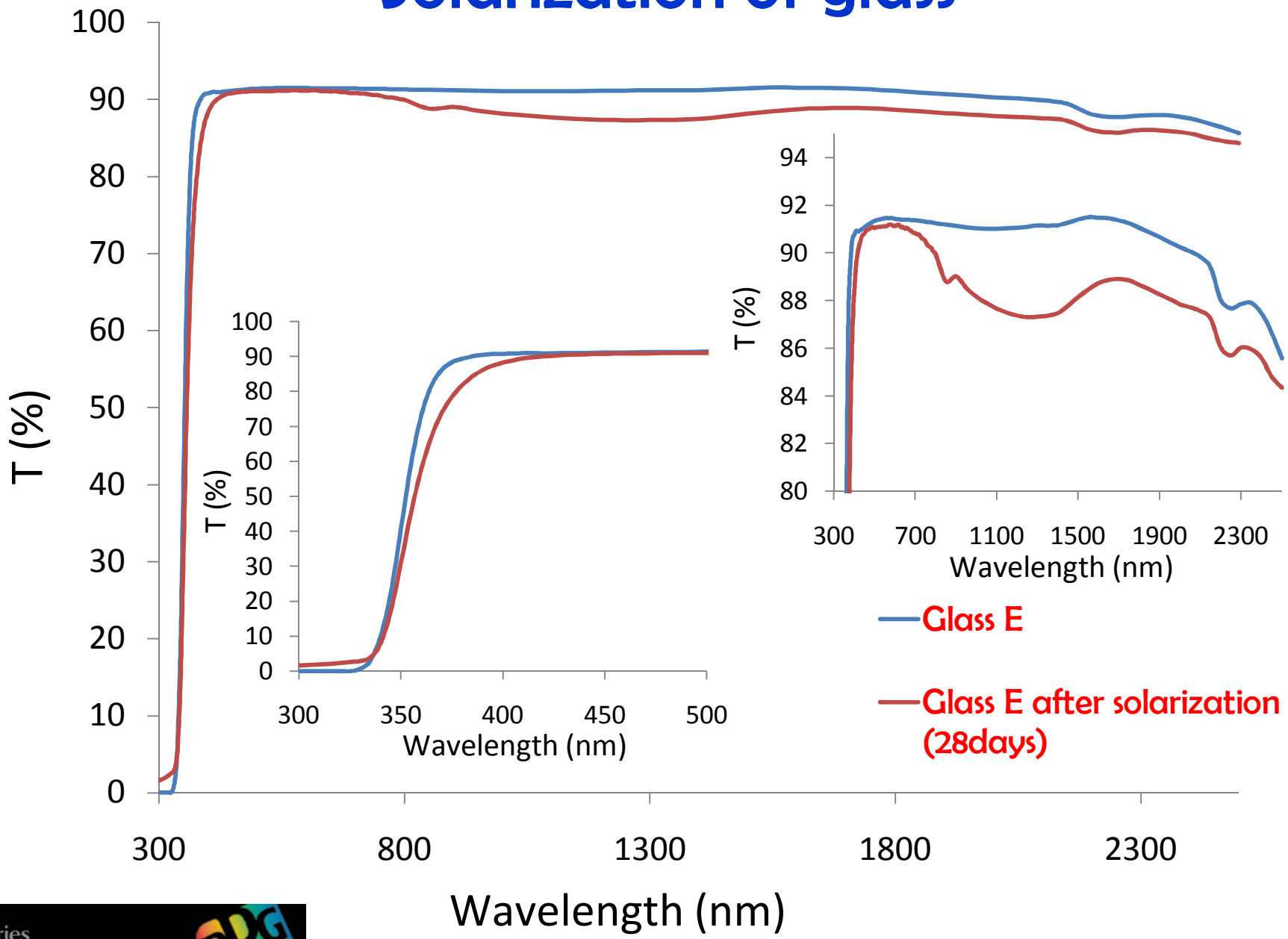
Another species is reduced (Gain of e^-)

$$Y^{+3} + e^- \leftrightarrow Y^{+2}$$

A known solarization equation is:

$$4MnO + As_2O_5 \leftrightarrow 2Mn_2O_3 + As_2O_3$$

Solarization of glass



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Chemical Durability

An important attribute for outdoor applications

- Surface corrosion (due to water induced ion-exchange)

- Challenges:
  - Improve resistance to water/moisture attack
  - Withstand large temperature variations
  - Withstand large humidity variations
  - Corrosion resistance in other chemical environments.

High Strength Glass

- Maintain pristine glass surface.
- Avoid surface flaws.
- Surface strengthening methods
  - Thermal tempering
  - Chemical tempering.
- Trend towards using thinner glass, lighter weight but strength cannot be compromised

Will Rogers Airport
Location: Oklahoma City, OK

Environmental Stewardship

GE Healthcare Technologies
Location: Waukesha, WI

- Comply with Green Engineering manufacturing process.
- Air emissions. CO_2, NO_x, SO_x, etc.
- Water emissions.
- Employee health and safety. Dust, noise, heat exposure.
- Glass with ENERGY STAR solar energy performance attributes
  - High efficiency buildings and houses to lower operating costs for lighting, heating and air conditioning.

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Summary

- Challenges to design variety of glass compositions to meet customers needs which requires compromises in performance and manufacturing while maintaining the cost.
- New glasses will continue to be made commercially over a large range of possible compositions and properties.
- Computer modeling will play a larger role in further development of compositions of glasses