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TH18 - Global Megatrends and Next-Generation Architectural Glass

Presented by:
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PPG Industries

CONSTRUCT2009
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Indianapolis, IN

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Learning Objectives:

Upon completing this program, the participant should know:

1. How spectrally selective glass - and - coatings combinations, electrochromic glazing and photovoltaic applications are facilitating the drive to achieve self - sustaining, zero - energy buildings
2. How new glass technologies can help architects meet the challenge of energy conservation
3. The science behind glass technologies
4. The strategies industry technicians are pursuing to reduce energy consumption in buildings through the use of glass

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Overview

- Megatrends and Approach
- Glass Industry Focus
  - Spectrally Selective Glazing
  - Switchable Glazing
    - Electrochromic
  - Renewable Energy
    - Photovoltaics
- Industry Payback on Investment
- Summary and Conclusion

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Megatrends

- What is a megatrend?
  - A large, over-arching direction that shapes our lives for a decade or more.
  - High probability of market success and lower risk for investment

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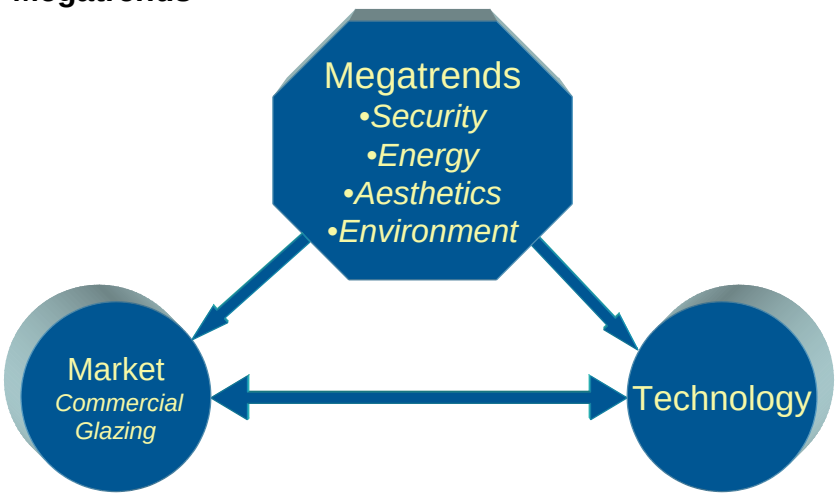
Megatrends



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Megatrends

Drivers

- Legislation Incentives — www.dsireusa.org
- Cost *Return vs. operating cost and capital*
- Megatrends
  - *Energy*
  - *Aesthetics*
  - *Environment*
- "Green" *Conserve Energy & Reduce CO_2*
- Design & Construction

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Megatrends

Role of Technology

- New Products
- New Processes
- Technology
- Modeling & Simulation
- New Materials R&D

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Megatrends

- Range of Glass Technology

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Overview

- Megatrends and Approach
- **Glass Industry Focus**
  - **Spectrally Selective Glazing**
    - **Properties and sputtered stacked silver layers**
  - Switchable Glazing
    - Electrochromic
  - Renewable Energy
    - Photovoltaics
- Industry Payback on Investment
- Summary and Conclusion

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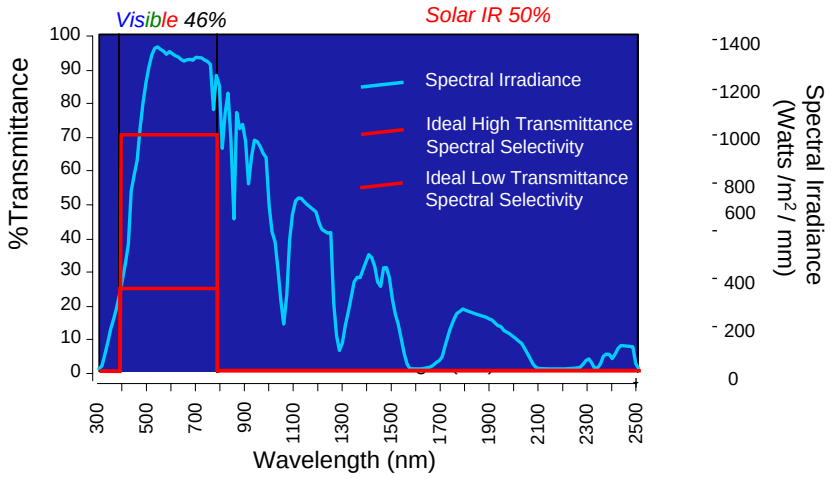
Spectrally Selective Glazings

Solar energy distribution at sea level for air mass = 2



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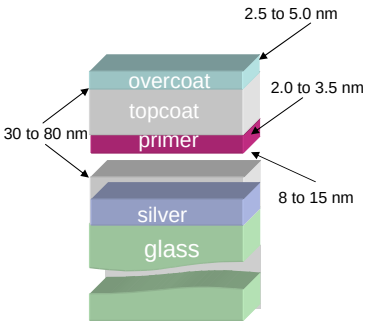
Spectrally Selective Glazing

- **Silver Layer**
  - – provides solar & thermal performance
  - – reflective in visible and IR
- **Dielectric Layers** (base and topcoat)
  - – antireflect the silver layer in the visible
  - – acts as a nucleation layer for silver
  - – protects and provides chemically & mechanically durability
  - – non-absorbing in visible spectrum
  - – low cost and non-toxic
- **Primer (sacrificial) Layer**
  - – protects silver during sputtering process
  - – provides durability
  - – stabilizes coating at high temperature
- **Overcoat Layer**
  - – (optical) extension of topcoat
  - – provides additional durability



1 Layer Silver

Dielectric/Silver/Dielectric Stack

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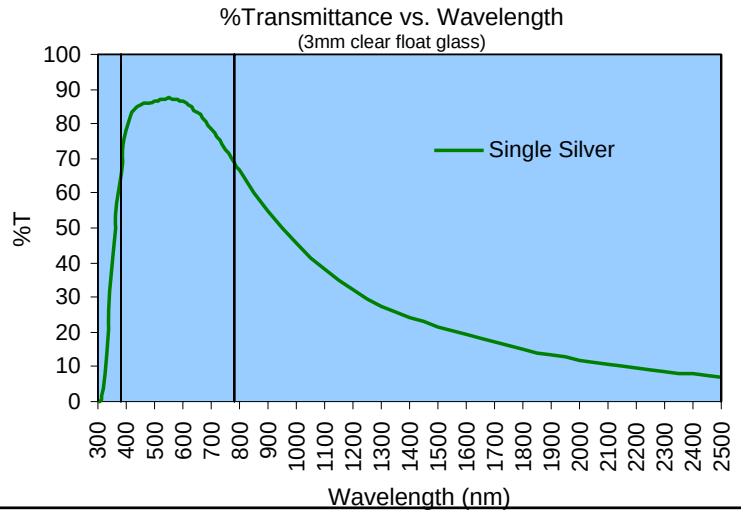
Coating Performance



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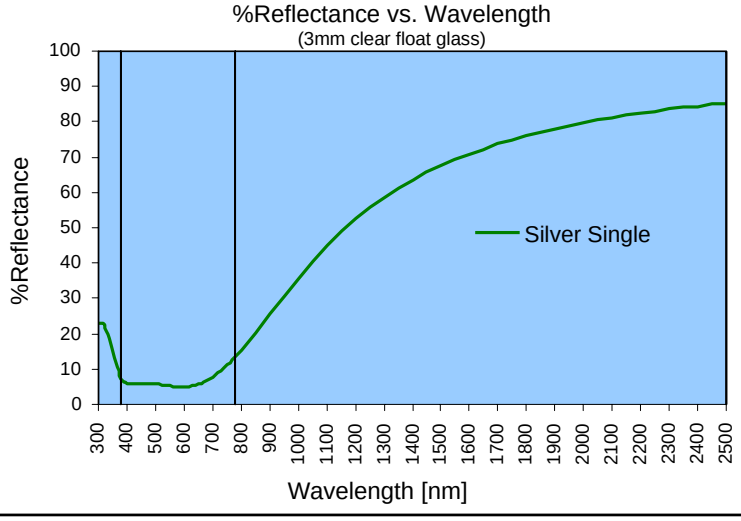
Coating Performance



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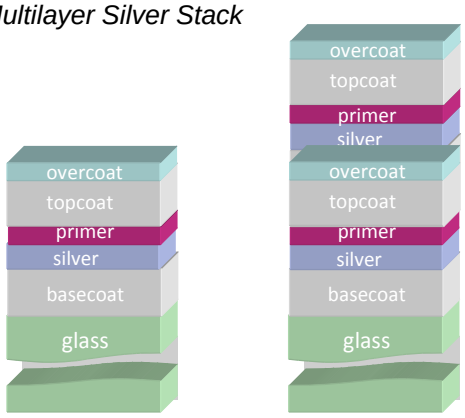
Spectrally Selective Glazing

- Building "spectrally selective"
- *Multilayer Silver Stack*



1 Layer Silver 2 Layer Silver

from J. J. Finley, PPG Industries Inc.

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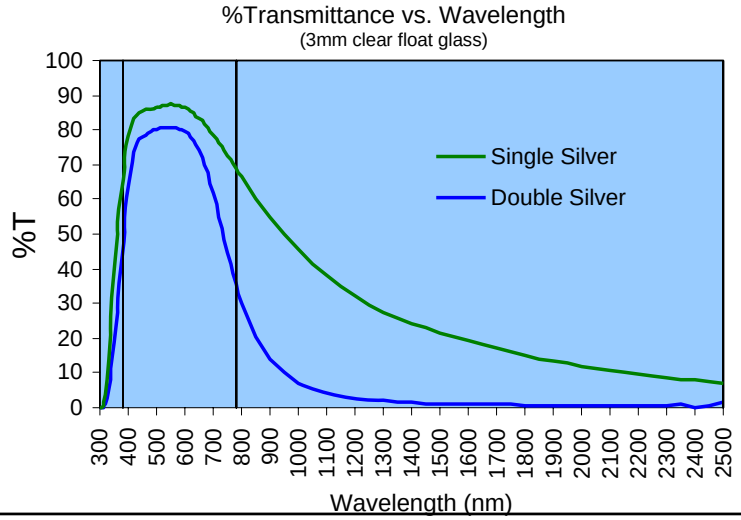
Coating Performance



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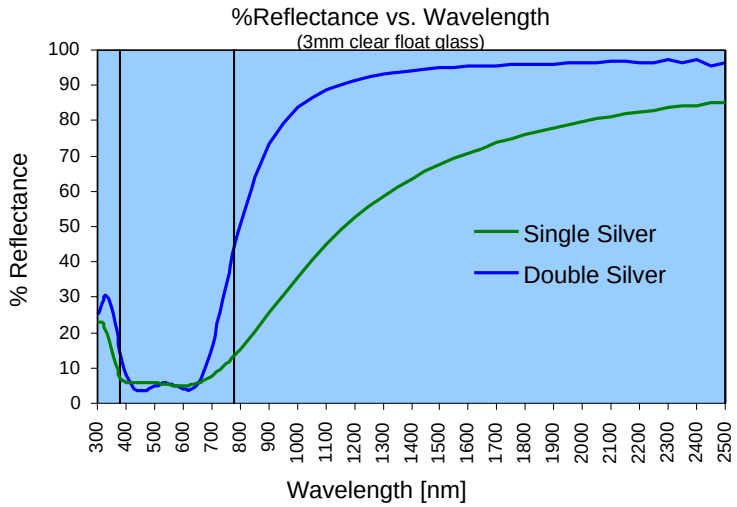
Coating Performance



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Spectrally Selective Glazing

- Building “spectrally selective”
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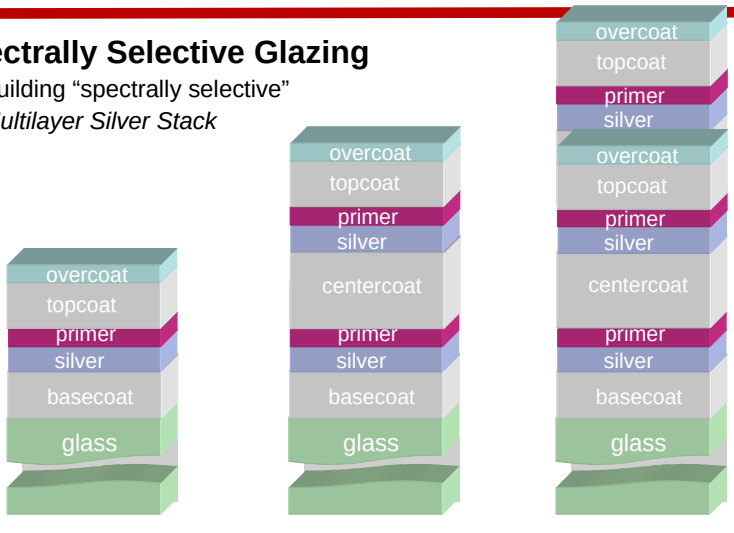

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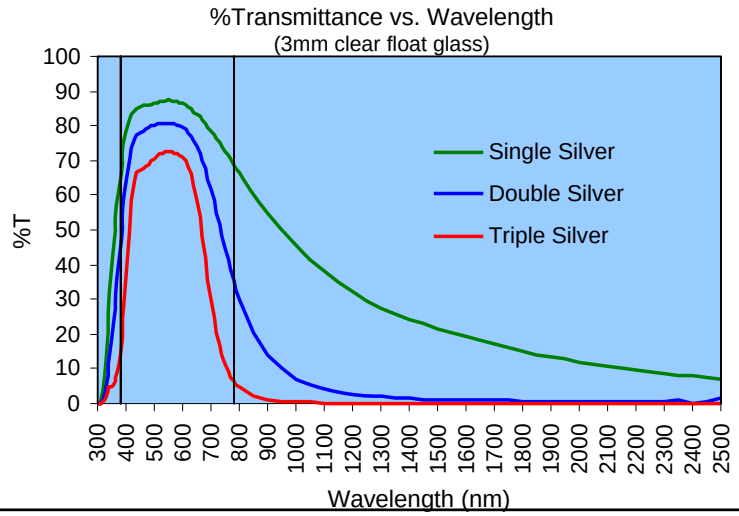
Coating Performance



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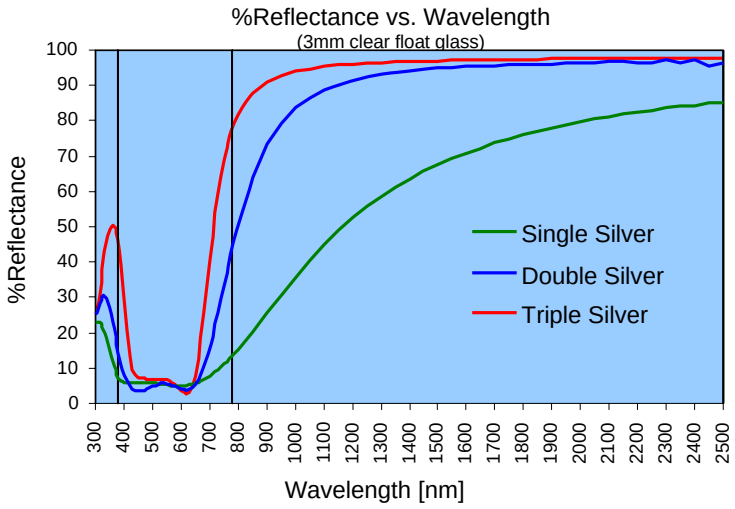
Coating Performance



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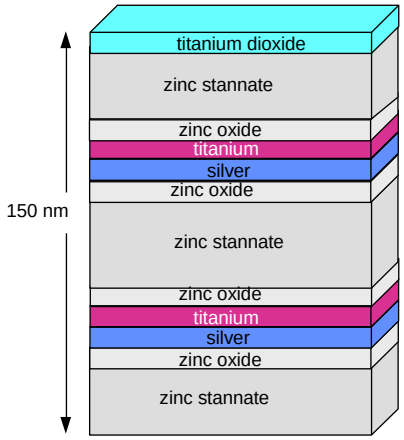
Spectrally Selective
Double-Layer Silver Coating



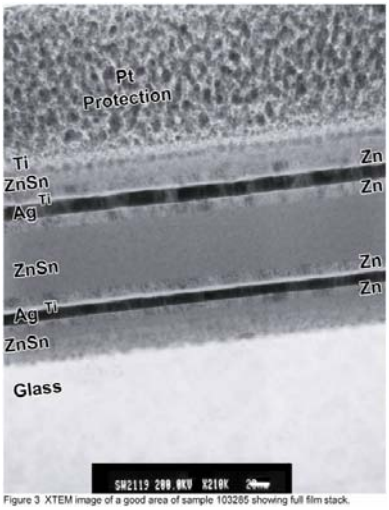


Figure 3 XTEM image of a good area of sample 103285 showing full film stack.

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Spectrally Selective Glazing

Basic Performance – Low Emissivity Coatings

Number of Silver Layers *[metal oxide–silver–metal oxide]*	VLT	SHGC	LSG	U-Value
Uncoated	79	0.70	1.13	0.48
1 Layer	73	0.52	1.40	0.31
2 Layers	70	0.38	1.84	0.29
3 Layers	64	0.27	2.37	0.28

Commercial IG Unit: 1-inch units with ½-inch airspace and two 1/4-inch clear lites



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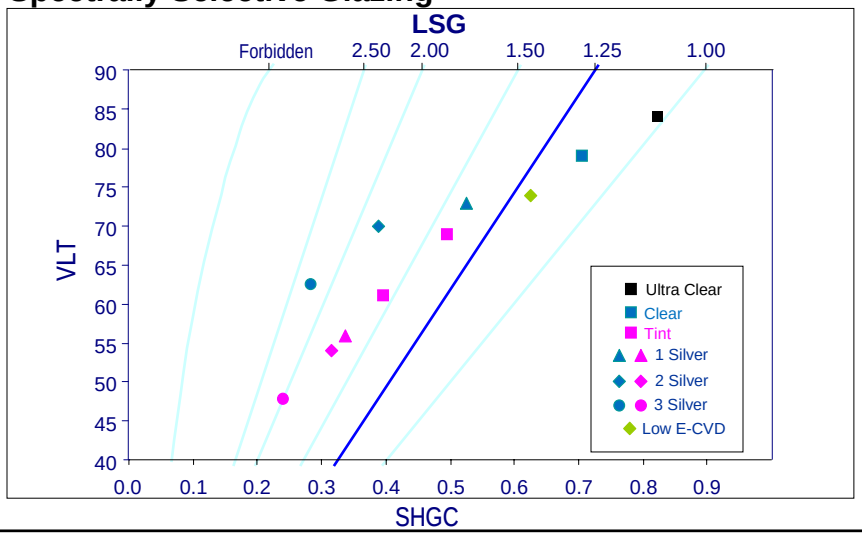
Spectrally Selective Glazing





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Economic Impact

City - Boston	Total Operating Cost	Total Capital Cooling HVAC Costs	Annual Operating Cost Savings of vs. Tinted	Initial Capital Cost Savings vs. Tinted
Tinted	$853,540	$2,326,967	0	0
2 layer-silver	$793,066	$2,123,627	$60,474	$203,341
3 layer-silver	$756,001	$1,928,086	$97,539	$398,881

See *A Comparison of Energy, Economic and Environmental Benefits of Transparent Low-E Glasses*
Based on eight-story glass-walled office building
Total Glass Area: 50,967 ft²
Total Floor Area: 270,000 ft²

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Cooling-Related CO_2 Emissions Reductions

City - Boston	Annual CO_2 Savings vs. Tinted (Tons)	40 Year Building Life CO_2 Savings vs. Tinted (Tons)
Tinted	0	0
2 layer-silver	228	9,120
3 layer-silver	354	14,160

See *A Comparison of Energy, Economic and Environmental Benefits of Transparent Low-E Glasses*
Based on eight-story glass-walled office building
Total Glass Area: 50,967 ft²
Total Floor Area: 270,000 ft²

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Spectrally Selective Glazing

Advantages of high LSG ratio
(Tvis /SHGC) Product

- Allows more daylighting
- Reduces
  - utility costs
  - capital costs
  - carbon footprint
- Enhances design through use of glass

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Spectrally Selective Glazing

Current and Future Status

	Current Status	Future Status
Commercial Applications	Growth of high LSG based products with immediate energy and environmental payback.	• Continue growth of high LSG • Increase utilization of BIM to optimize energy efficient green buildings. • In-building monitoring to provide real world performance.
Glass Industry	Significant R&D and capital asset investment.	• Continue to leverage assets to reduce cost and time to market.
Manufacturing Process	• Employ MSVD process for environmentally friendly, flexible, cost effective production of low-E. • Expand TCO capability with CVD	• Integrate non low-E products (PV) into manufacturing process. • Emphasize process control and modeling.

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Overview

- Megatrends and Approach
- **Glass Industry Focus**
  - Spectrally Selective Glazing
  - **Switchable Glazing**
    - **Electrochromic**
  - Renewable Energy
    - Photovoltaics
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Switchable Glazings

Three Barriers to Market

- Cost
- Functionality
- Aesthetics

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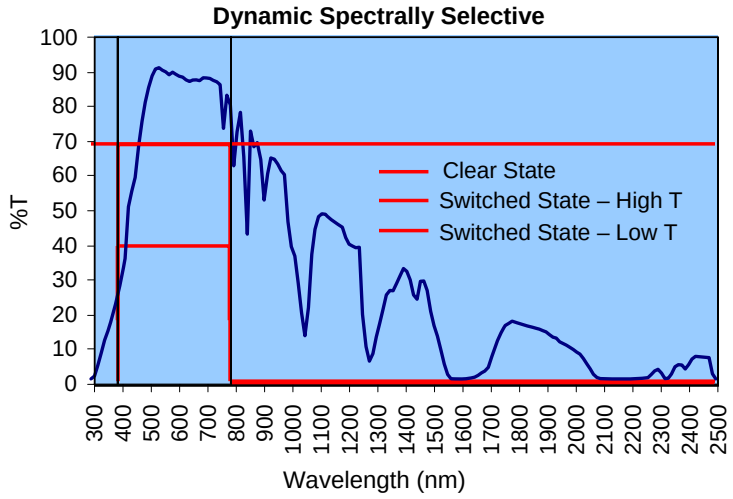
Switchable Glazing



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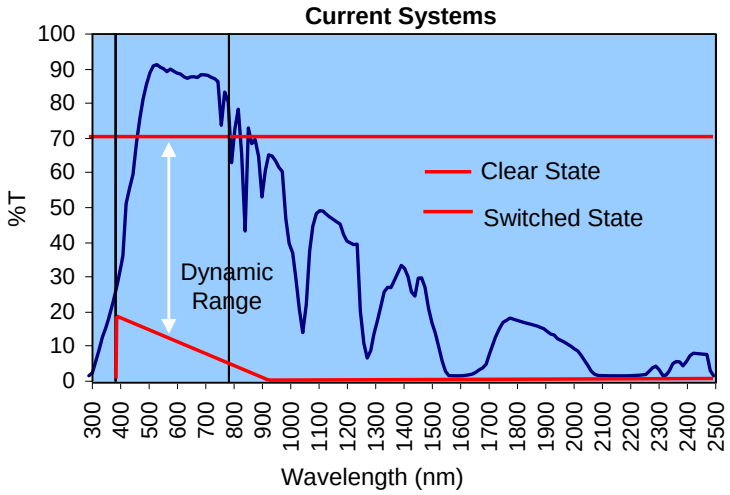
Switchable Glazing



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Switchable Glazing – WO_3 Based

- Excellent performance
- Wide dynamic range
- Response time - size dependent
- Enhanced performance when combined with Low-E coatings
  - SHGC; VLT
- No independent spectral region (IR/Vis) capability/control
- Niche market due to cost & properties
- Limited aesthetic appeal
- Status of development is mature
- Breakthrough in either product or process required for widespread use

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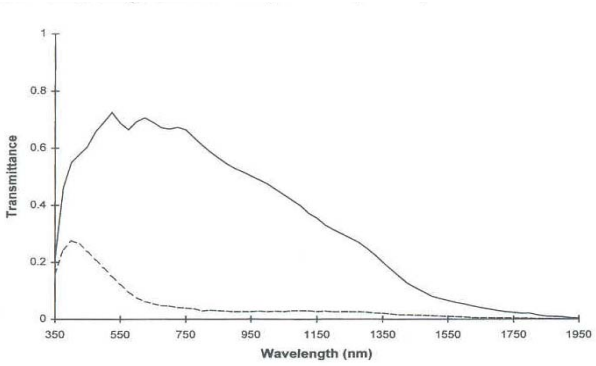
Switchable Glazing – WO_3 Based

(Greenberg 2001)



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Switchable Glazing - Organic Systems

- Potential less costly electrochromic system
  - Inexpensive polymer materials
  - Low capital investment for EC layer deposition
- Application of well understood conjugated polymers
- Faster switching and lower voltage
- Functional with variety of electrolyte systems
  - e.g., Ionic Liquid Electrolytes
- Long term durability issues
  - Long term field exposure unknown and suspect
    - Current testing shows limited functionality
  - Issues virtually ignored in polymer R&D labs
    - Polymers have fundamental physical limitations
- Limited spectral response
  - Functional mostly in visible
- More focus on polymer R&D required to address durability and performance issues.

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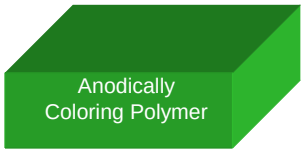
Organic Coloring Electrodes



- PANI [Polyaniline]
- PPy [Polypyrrole]

- PDOT [poly(3,4-ethylene dioxythiophene]
- PEDOT-PSS [poly(styrene sulfonate)]
- POT [polyoctyl-3-thiopnene]
- WO_3

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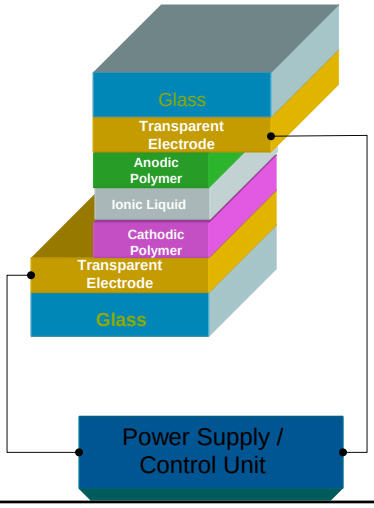
EC Device & Circuit

- Power Supply provides voltage to power and switch device
  - Low voltage (< 3V required) for polymer
  - Power Supply is cost factor
- Control Unit functions to regulate voltage to
  - Avoid overvoltage conditions
  - Ramp up and down voltage
  - Adjust to environmental conditions

Polymer Device



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Switchable Glazing

- Future technology will require
  - independent switching in visible and solar infrared regions of the spectrum
  - smart control of spectrum to optimize energy savings

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Switchable Glazing – Dye-Based

- Currently, a non-window-based system
- Developed for dimmable aircraft cabin windows and automotive mirrors
- Simple construction
  - *Electrochromic dye between transparent conductive electrodes*
    - Technical hurdles for large-scale applications

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Switchable Glazing

Current and Future Status

System	Application	Current Status	Future Status
Thin Film Inorganic, (WO^3)	Window glazing, sunroofs	• Niche product • Optimum for direct shading applications	Requires manufacturing efficiencies for price point and growth
Dye Based (Viologin)	Small Area Applications	Scale up to cabin windows	Small probability for large area commercial product in next five years
Organic (Conjugated Polymer)	Window glazing (?), internal partitions	• Concept stage • Less than 5 years product lifetime	No commercial window product in foreseeable future

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  - Spectrally Selective Glazing
  - Switchable Glazing
    - Electrochromic
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    - **Photovoltaics**
- Industry Payback on Investment
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Photovoltaics (PV)

- Global Solar Power Generation continues to grow at accelerated rate
- Focus area for glass industry
  - Transparent conductive oxide coatings (TCO's)
  - High-transmission/low-iron glass
  - Anti-reflective coatings
  - Glazing products for BIPV
    - Optimize efficiency with SSG, EC
    - PV module building integration
- Explore low-cost organic and dye-based systems

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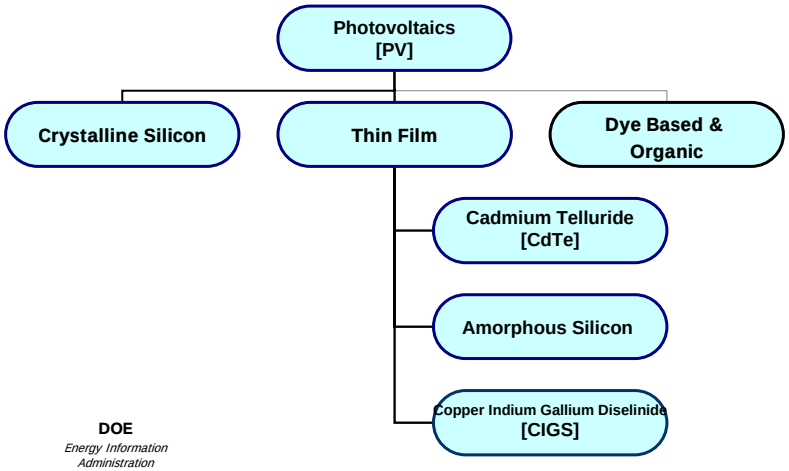
Photovoltaics

Solar Industry Market Structure



DOE
Energy Information Administration

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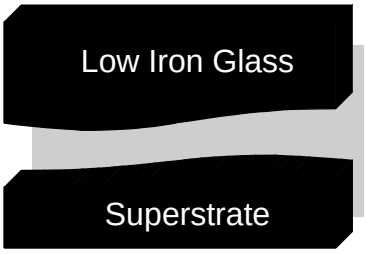
Photovoltaics

- **High-Transmission/Low-Iron Glass**
  - Traditional markets
  - High volume capability
  - Modified for PV
  - Increases transmittance of PV cell over clear



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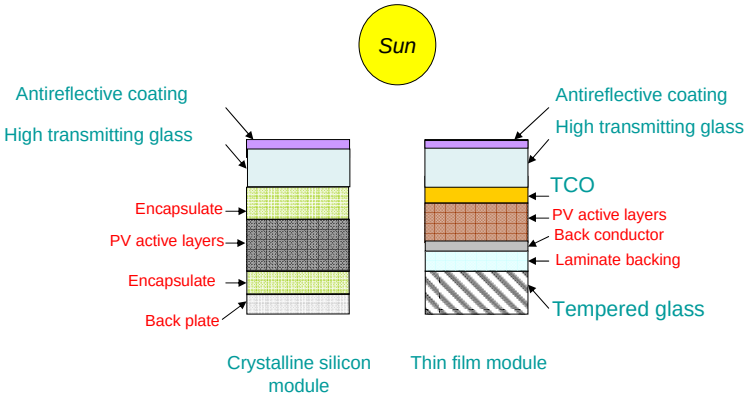
Photovoltaics

- **Modules**



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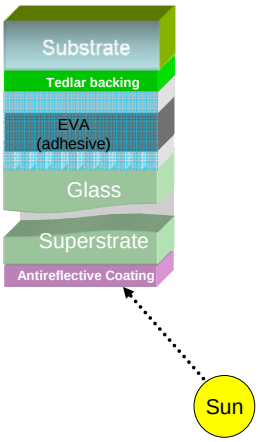
Photovoltaics

c – Silicon Photovoltaic Cell

- Application for crystalline silicon
  - 90% of PV industry market share
- Glass industry supplies
  - Ultra-high transmittance glass
  - Anti-reflective coating



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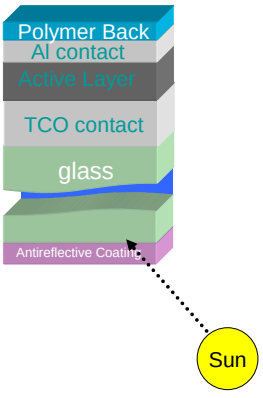
Photovoltaics

- Application for thin film PV
  - 10% of market share
  - Amorphous silicon
  - CdTe
  - CIGS (CuInGaSe)
- Glass industry supplies
  - High-transmittance/low-iron glass substrate
  - Low-sheet-resistance TCO coating on substrate
    - F:SnO, ITO, CdSnO4
    - Amorphous Si – rough surface
    - CdTe & CIGS – smooth



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Photovoltaics

Glass Technology Needs for PV Technology Segments

PV Technology	Low-Iron/Hi-T Glass Substrate	AR Coated Glass	TCO Coated Glass (rough)	TCO Coated Glass (smooth)
Crystalline Silicon				
Amorphous Silicon				
CdTe, CIGS Thin Film				

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Building Integrated Photovoltaics (BIPV)

- 4,000+ square feet solar cells roof installation
- Maximum theoretical output of 60 kilowatts

Adam Joseph Lewis Center for Environmental Studies Oberlin College, Oberlin, Ohio

Renewable Energy: An Energy Destination for the West June 21-22, 2002

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Building Integrated Photovoltaics (BIPV)

Kiss + Cathcart, Architects

Coney Island's Stillwell Ave Terminal

Kiss + Cathcart, Architects

The 2020 Tower

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Industry Payback on Investment

- To alleviate costs, reduce risks and accelerate progress, the glass industry will
  - Form partnerships
    - government agencies and labs, academic institutions, and core technology industries (e.g., PV)
  - Leverage - as far as possible - existing assets
  - Focus investment in key areas dictated by the macrotrends

- The rate and degree of development will depend on
  - Legislation/incentives to drive investment
  - Increasing price for traditional forms of energy
  - Net positive effect on the environment
    - reducing carbon footprint

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Summary

- The glass industry is addressing the megatrends - energy, the environment and aesthetics.
- Advanced coatings and high performance glass will further enhance spectrally selective glazing
- Modeling applications such as Building Information Modeling (BIM) and measurements of real world systems will optimize the use of spectrally selective glazing and EC
- Electrochromic glazing will require advances in manufacturing efficiencies; alternative technologies will be explored to create the all-in-one window product independent
- PV development will grow dramatically and employ significant resources; BIPV will grow with integration of PV modules into glazing systems
- Industrial-academic-government partnerships will be necessary to alleviate development costs and accelerate progress

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Conclusion

- The glass industry's future path will see more change than any time in its long history
- The opportunity for growth will be great and driven primarily by energy, environmental, and aesthetic megatrends



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Thank you!

This concludes the American Institute of Architects Continuing Education Systems Program.

Any Questions?

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