Low emissivity (low-E) coating technologies for Energy saving window applications

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Intermolecular Inc.

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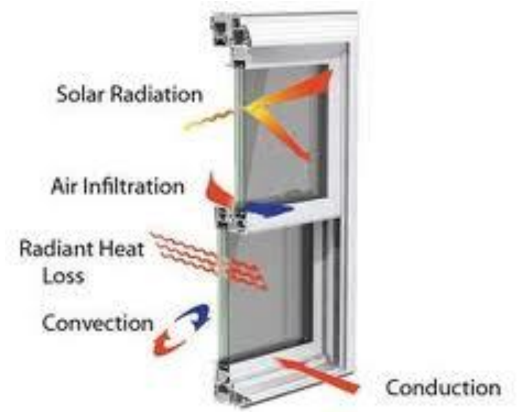
Why low-E coating window is needed

- Windows are often considered the least energy efficient component in a building.
- Radiation losses occur through the window glass and represent about 60% of total heat loss in a standard window*
- Radiative heat flow can be reduced by choosing low-emissivity (low-E) materials:
  - Emissivity is the value given to materials based on the ratio of heat emitted compared to a blackbody, on a scale from zero to one. A blackbody would have an emissivity of 1 and a perfect reflector would have a value of 0.



Materials surface**	Thermal emissivity
Aluminum foil	0.03
Asphalt	0.88
Brick	0.9
Concrete, rough	0.91
Glass, smooth (uncoated)	0.91
Limestone	0.92
Marble, Polished or white	0.89 to 0.92
Marble, Smooth	0.56
Paper, roofing or white	0.88 to 0.86
Plaster, rough	0.89
Silver, polished	0.02

- "low-E basics.ppt , Guardian Industries-NT window" http://www.ntwindow.com/uploads/Forms/Additional%20information/Low-E%20Basics.ppt
- ** Low emissivity - Wikipedia, the free encyclopedia

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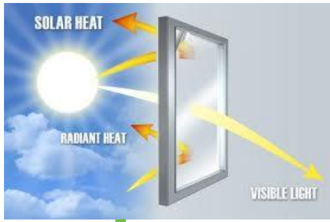
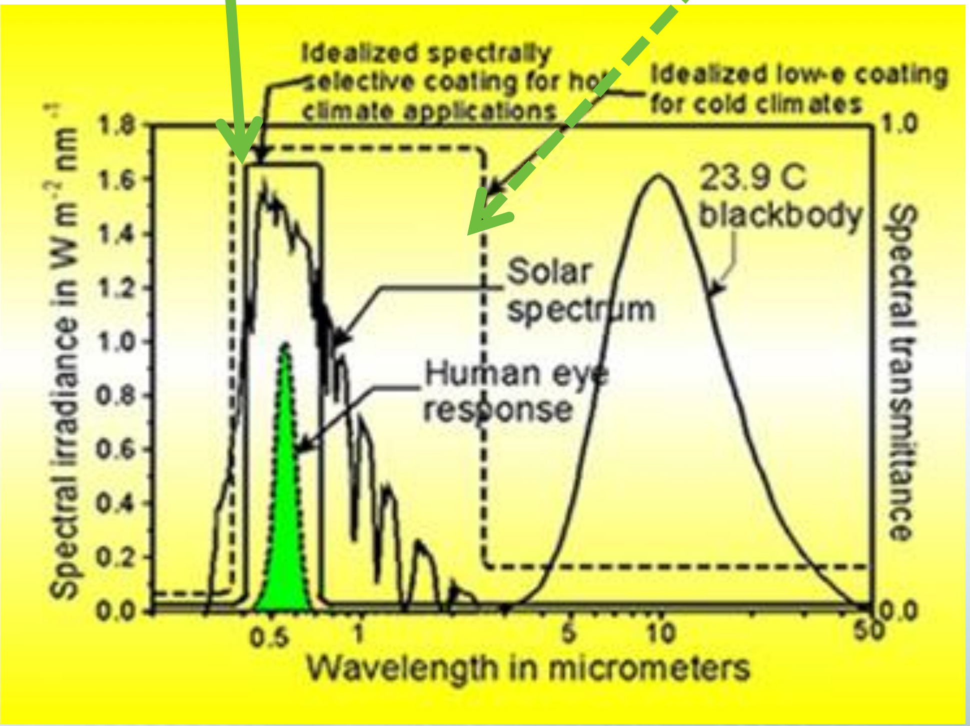
What are Ideal low-E coating window

- Ideal low-E coating window
  1. Low emissivity
     a. Blocking the IR radiation, especially the IR spectrum corresponding to the room temperature radiation
  2. High visible transmission, neutral color
     a. Good human feeling
  3. Solar spectrum
     a. High visible to solar Gain ratio for hot weather
        i. Reduce the cooling cost
     b. High solar gain for cold weather
        a. Reduce the heating cost

Low-E windows for HOT climates



Low-E windows for COLD climates



* "how window work", http://www.fsec.ucf.edu/en/consumer/buildings/basics/windows/how/solar_gain.htm

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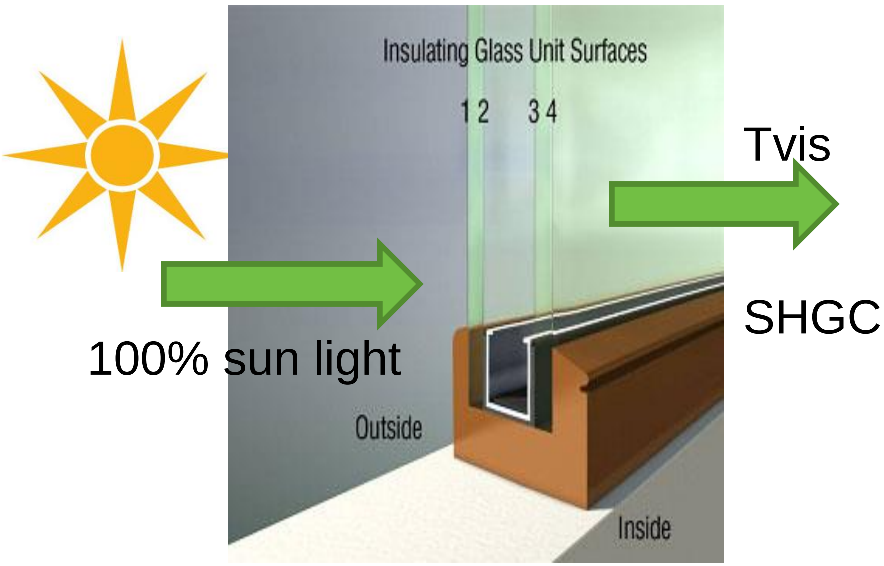
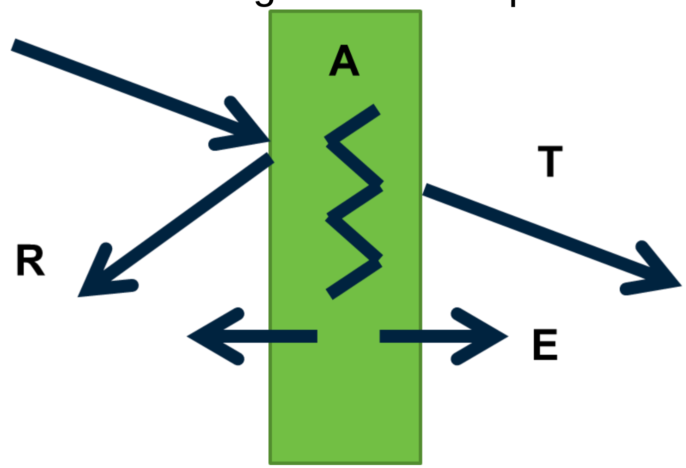
Common Terminologies in the low-E field



Schematic single substrate phenomena



- **Visible light transmittance (Tvis):** The percentage of visible light (380-780nm) within the solar spectrum that is transmitted through glass, (or Insulating Glass unit, IGU)
- **Solar Heat Gain Co-efficient (SHGC):** the ratio of the solar energy passing through the window to the incident solar energy (including direct solar transmittance and indirect re-radiation)
- **U-factor:** A measure of air-to-air heat transmission (loss or gain) due to the thermal conductance and the difference in indoor and outdoor temperatures of a 1 meter high glazing. Referred to as the overall coefficient of heat transfer.

Simulated Building Model and energy Savings

- **Locations:** **Chicago & Miami**
- **Floor Area:** **120,000 sq. ft.**
- **Number of Stories: 6**
- **Floor/-Floor Height: 12 ft.**
- **Foundation:** **Slab on grade**
- **Window Type:** **Strip Windows**
- **Window Area:** **20,000 sq. ft.**
- **Ceiling Insulation:** **R-19 in Chicago**
  R-15 in Miami
- **Wall Insulation:** **R-13**
- **Energy Source:** **Heat – Natural Gas**
  A/C - Electric

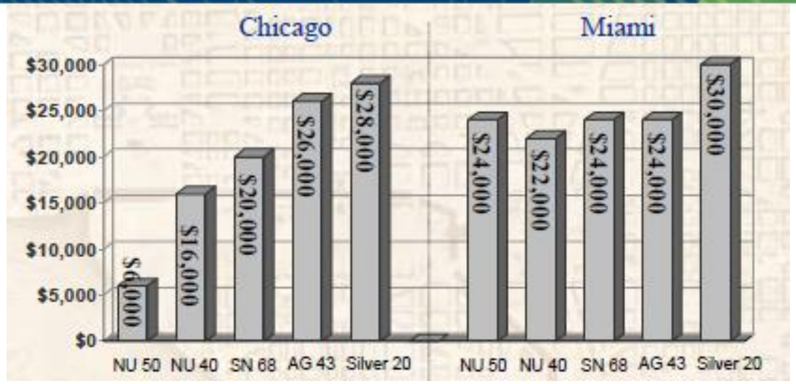
glazing	type	%Tvis	SHGC	U-value
clear glass	Mono	89%	81.8%	1.1
no coating	I.G. U	80%	71.3%	0.48
SN 68	I.G. U	68%	37.4%	0.29
Nu 50	I.G. U	50%	39.2%	0.34
AC 43	I.G. U	43%	29.6%	0.31
NU 40	I.G. U	40%	31.3%	0.33
silver 20	I.G. U	18%	20.0%	0.41

(6mm clear/ 12mm as / 6mm clear, coating #2 surface)

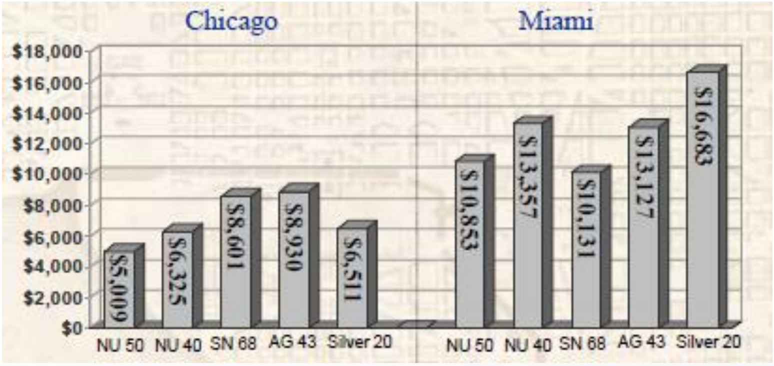
EX118 "THE EVOLUTION OF GLASS AND HIGH-PERFORMANCE COATINGS" JOHN WILSON, GUARDIAN INDUSTRIES
AIA 2012 national convention and design exposition
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http%3A%2F%2Fwww.aia.org%2Faiaucmp%2Fgroups%2Faia%2Fdocuments%2Fpdf%2Faiab094232.pdf&ei=pv55VM-3G-mDiwLPtoAQ&usg=AFQjCNHf5fS74aWoKuICzL9cxOwk0vxngw

Energy saving break down

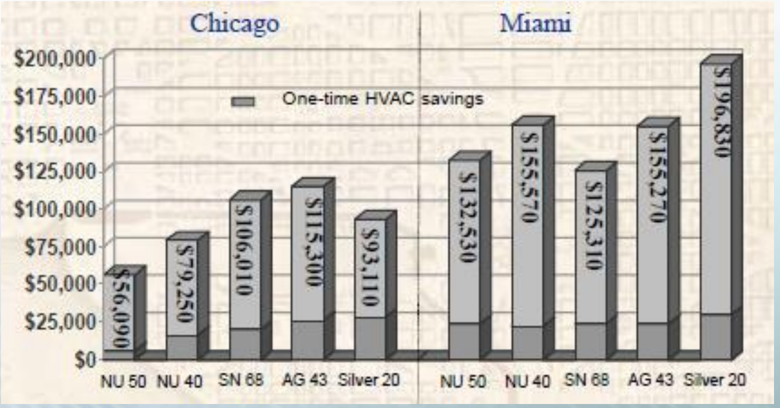
1. One-Time Savings from Reduction in HVAC System Cooling Capacity (compared to a non coating unit)



2. Annual Savings from Reduced Energy Consumption for Cooling and heating Requirements,



3. 10 year energy saving:



EX118 "THE EVOLUTION OF GLASS AND HIGH-PERFORMANCE COATINGS"
AIA 2012 national convention and design exposition

What materials can make Transparent low-emissivity coating

- There is a relationship between emissivity ε and conductivity σ at frequency ω, *
  - The higher conductivity σ, the lower the emissivity ε

$$\varepsilon = \sqrt{\frac{8\varepsilon_0\omega}{\sigma}}$$

- There is an estimation relationship between emissivity ε and sheet resistance $R_\square$

$$\varepsilon = 0.0106\, R_\square$$

- There are two type of materials for transparent low-emissivity coating
  - Semi-conductive coating, i.e. ITO, FTO
    - the extinction co-efficient k is very small such as 0.01 at 550nm, so that typical thickness is micro-meter with acceptable absorptions
  - Metallic coating, i.e. Ag and Au
    - the extinction co-efficient k is very high such as 3.5 at 550nm, so that typical thickness is below 20nm for acceptable absorptions

Typical transparent low-E coating materials comparison

- Only at early stages, there were gold film low-E
- Currently, silver based low-E dominates
- FTO is excellent on abrasion and chemical resistance. It's widely used as monolithic low-E

technical specifications of the trasparent condutive coating	Indium Oxide (ITO) coatings	Tin oxide (TO) coatings	Zinc Oxide coatins	gold layer systems	silver layer systems
layer thickness (nm)	>20	>20	>20	>6	>6
sheet resistance R (Ω)	>8	>8	>8	>5	>1
light transmittance (5)	>75	>75	>85	>25	>75
abrasion resistance	very good	very good	very good	good	good
chemical resistance	good	very good	adequate	adequate	adequate
thermal stability of technical parameters	adequate	adequate to good	adequate	adequate	good
adherence to the glass surface	very good	very good	very good	good	good
preferred coating technique for deposition onto flat glass	sputter process	APCVD Pyrolytic process	sputter process	sputter process	sputter process
pane thickness for coating (mm)	>0.3	>2	>0.3	>0.3	>0.3
planess of coated pane	as uncoated flate glass	poorer than uncoated flat glass	as uncoated flate glass	as uncoated flate glass	as uncoated flate glass

** "large area glass coating", Hans Joachim Gläser, Von Ardenne Anlagen Technik, 2000*

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How to make Low-E glass coating: type I: Pyrolytic low-E

- There are two major types of low-E glass coating types
- Pyrolytic low-E (also called, on-line low-E), sometimes referred as hard-coated, could be used in mono-lithic low-E windows, typical emissivity is below 0.15. Highly durable.

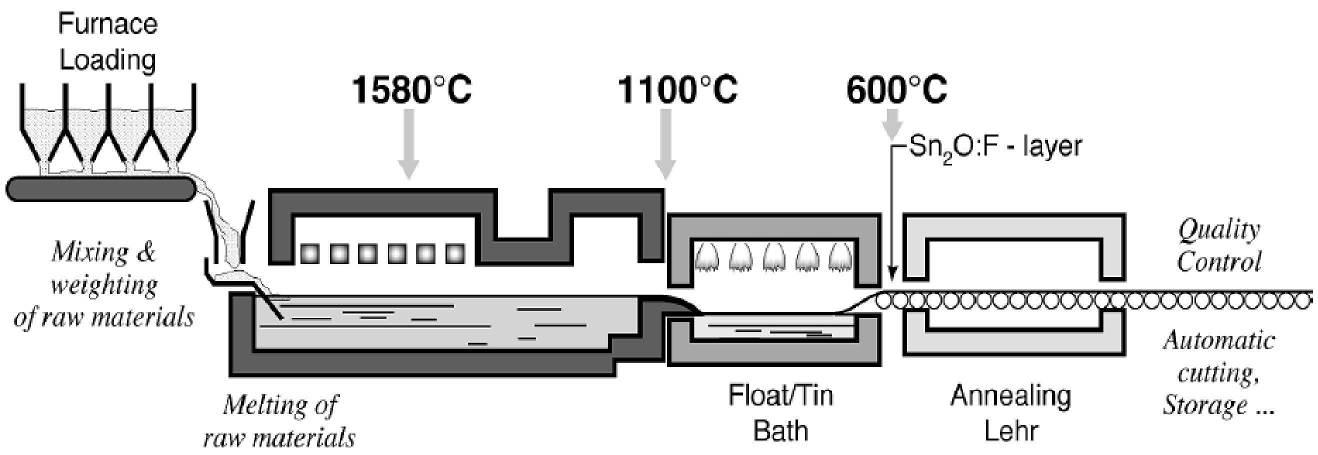

Figure 2-2. Schematic of a float bath production line showing one possible online coating reactor used to deposit fluorine-doped tin oxide.

***Coating on Glass workshop, Livermore 2000,**
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&cad=rja&uact=8&ved=0CEwQFjAE&url=http%3A%2F%2Fall-experts.com%2Fassets%2Froadmaps%2F318__GlsCoatRptweb.pdf&ei=Wyl6VL_AA4_1iQLV3oG4Bg&usg=AFQjCNFgtMds8qPiT3InDp7Tl92ut4fxsA

How to make Low-E glass coating type II: sputtered low-E

- Sputtered low-E glass coating (also called as off-line low-E, soft coating), is produced by depositing a thin metallic coating onto the surface of glass in a vacuum chamber. Currently dominates the low-E market,
  - because it provides better emissivity (below 0.06), therefore better heat radiation control, better solar heat control, and better optical performance
  - The coating price is affordable ~$2/ft^2$

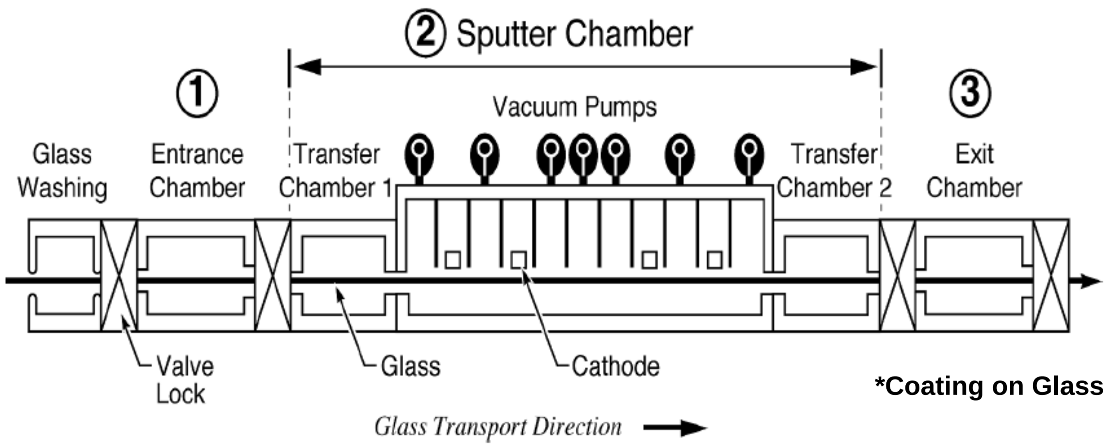

Figure 2-1. Schematic of a continuous-batch sputter-coating reactor.

***Coating on Glass workshop, Livermore 2000.**

Brief Low-E coating history

- Low-E industry history is short, but growth is fast since the first energy crisis of 1974, combined modern science and technologies.

	1950's	1960's	1960's	1970's	1974	1975-1980s	1980's	1981	1988	1990's	2006
notes	market for heat reflection glass	first solar control glass to reduce the cooling cost of the building		heat insulating glass units of building	1st energy crisis				asymmetrical silver layer system	double silver	tripple silver
firm:	BOC Edwards	Flaverbel	Heraeus / DETAG	Philips (NL)		flashglas /DELOG	Pilkington	Interpane	interrpane	Cardinal etc,	PPG
film stack	BiOx/Au /BiOx	BiOx/Au	ZnS/Au /ZnS	Tin oxide		BiOx/Au, IGU filled Ar	Tin oxide	BiOx/PbOx /Ag/PbOx /BiOx	silver based coating	oxide /Ag/ oxide /Ag/ oxide	3 cycles of oxide/Ag/ oxide
trade name		"Stop ray"	"infrastop"	Thermoplus		Thermoplus	k-glass	iplus neutral		double silver	solarban glass
new features	high transmittance /high heat reflection	high IR reflection, low thermal emissivity, good transmittance	high IR reflection, low thermal emissivity, good transmittance	high transmittance low-e coating		transmission form 40%==>60%, U: 1.3W/m2k, Jumbo glass	highly durable chemical/ mechanical resistance	ageing resistant and color neutral better than greenish color by Au coating	higher transmission, better neutral color	better solar gain control, higher LSG up to 2.0	better solar gain control, higher LSG up to 2.3
deposition method	sputter/ evaporation	sputter	evaporation	pyrolysis		sputter	APCVD on-line	sputter	sputter	sputter	sputter

History of the development and industrial production of low-e coatings for high heat insulating glass units
by Hans J. Gläser, “http://www.interpane.com/m/en/history_of_low-e_coatings_123.87.html”

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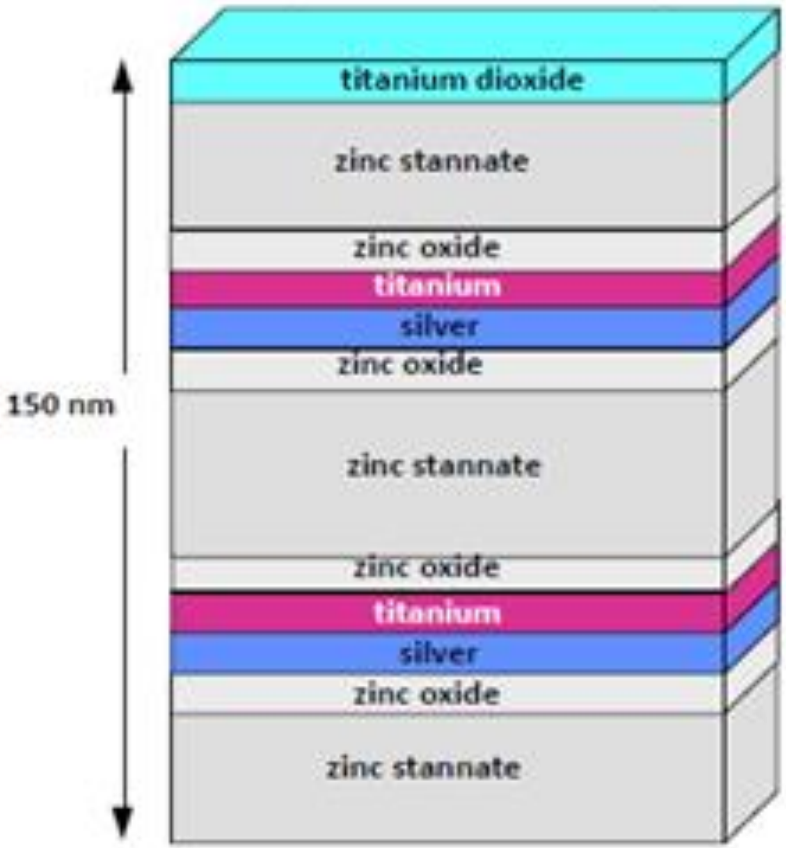
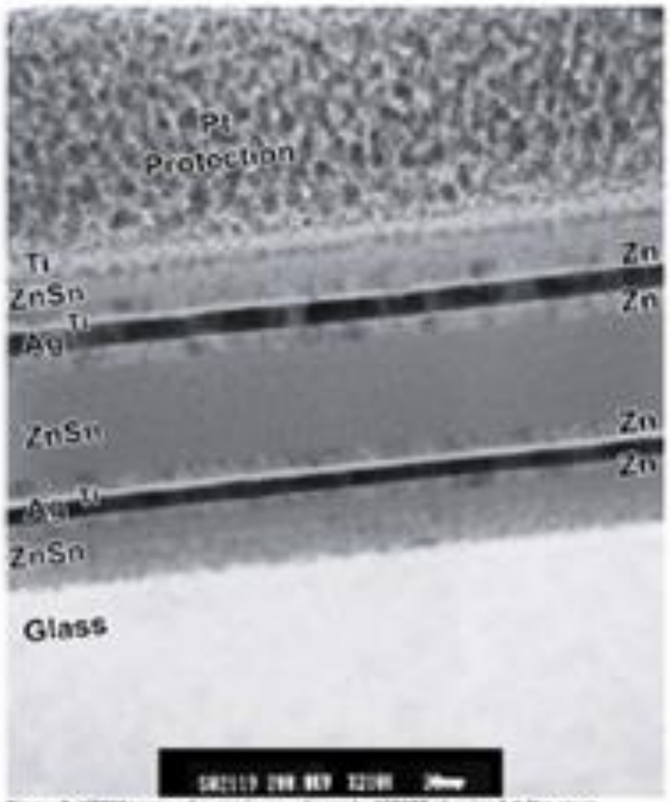
Example of low-E coating

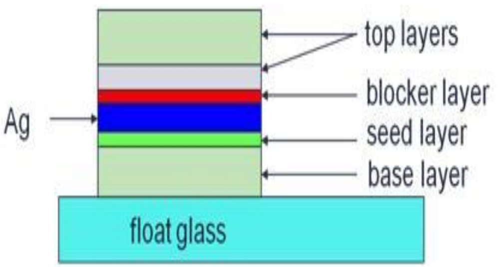
Spectrally Selective
Double Layer Silver Coating

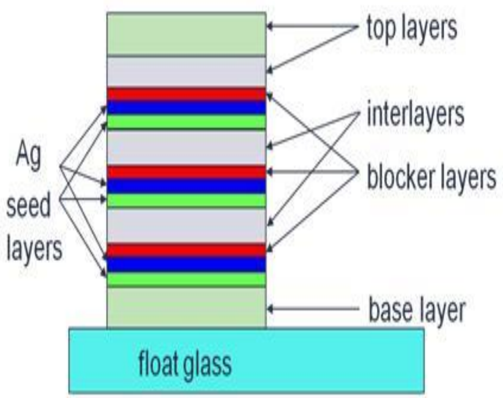




"The future high performance Glazing in commercial buildings", James, Finley, PPG Industries, Inc.

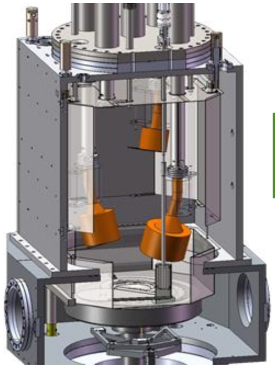
How low-E stacks were developed

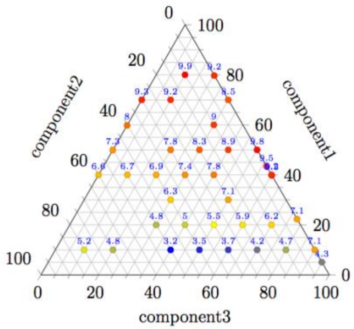




Low-E Stack

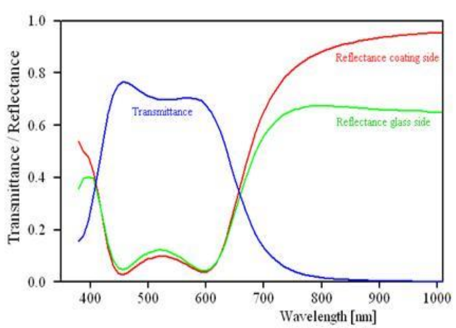
A. Advanced Material Investigation



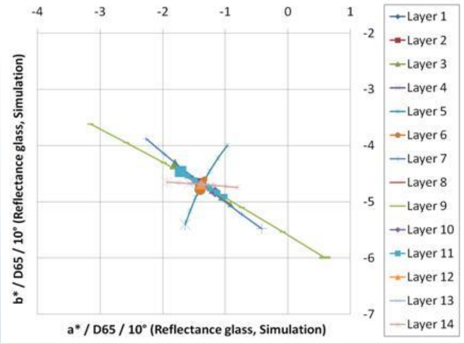


B. Iterative optical modeling provides predictive capabilities to optimize the stack

Optical simulation



Trends prediction



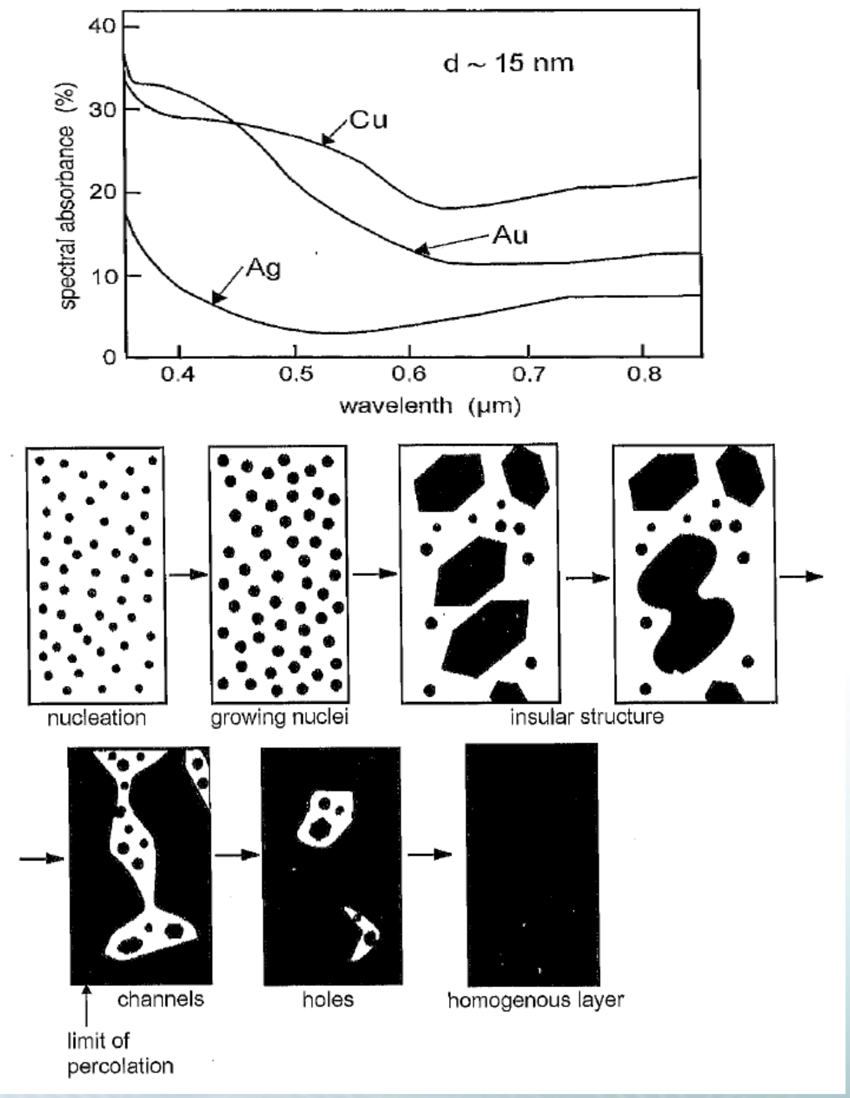
spec

Innovative materials are the key to the low-E performance

- Au versus Ag in history
  - Au is the first low-E product
  - Once the Ag process was developed, much better performance was achieved
  - Au is no longer important in the low-E products today

- Thin Ag film could be much different from different growth methods, that could significantly impact the low-E performance.

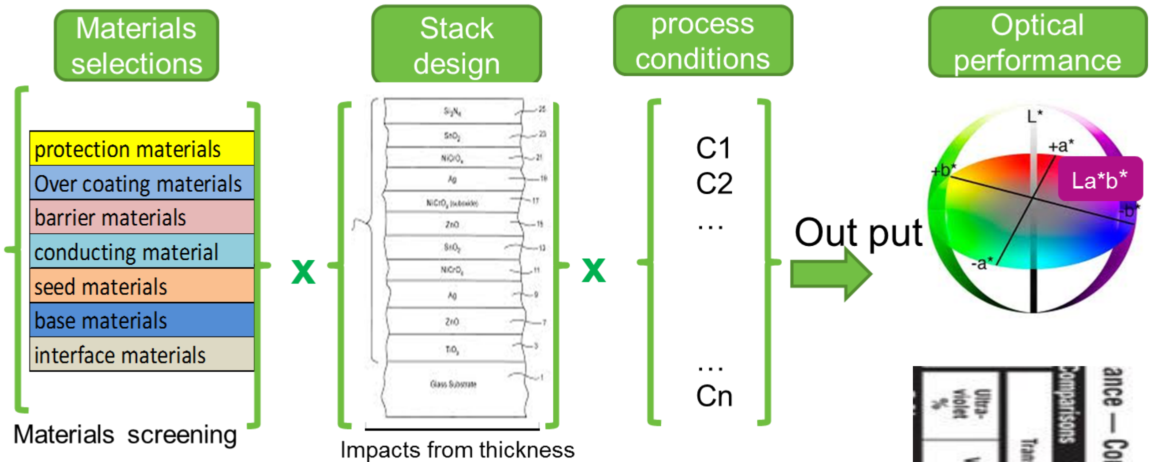
- Each stack materials showed unique contributions to the low-E performance

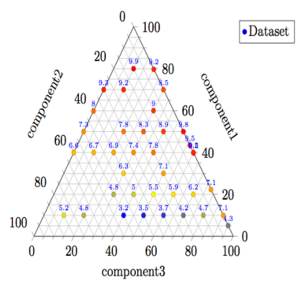


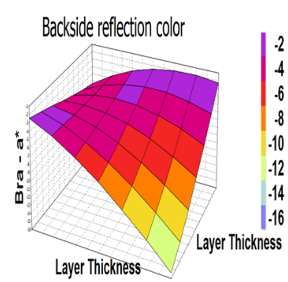
** "large area glass coating", Hans Joachim Gläser, Von Ardenne Anlagen Technik, 2000*

Low-E Stack Optimization is challenging, and new technology can help accelerate the developments

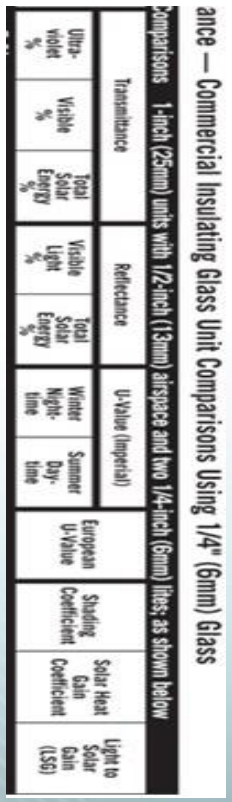
- Multiple generations of Low-E prototype products that surpass the current market products performance through HPC™
  - Materials screening and optimization
  - Modeling design
  - Solving the interface challenges
  - Challenging optical limit, thermal data limit
  - Challenging heat, durability, stability for a wide range of conditions.
  - Reduce manufacture cost



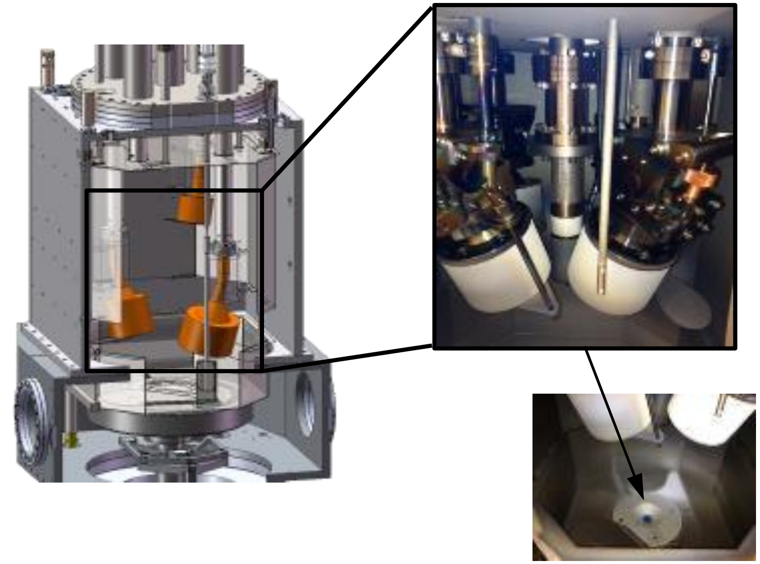


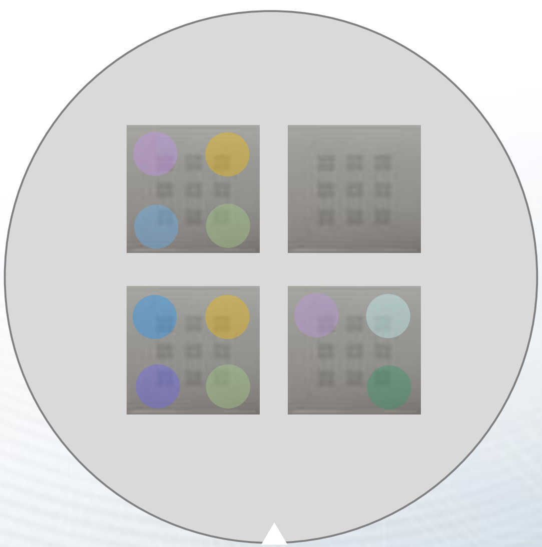


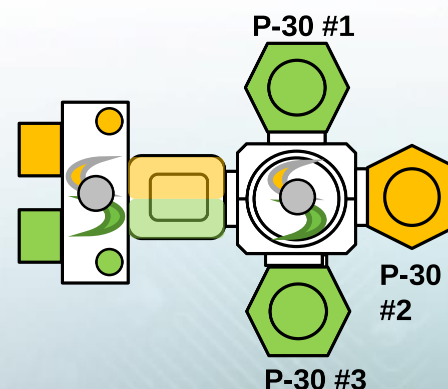
Environmental mechanical durability test



More than 60 Inventions were Quickly Identified with IMI's HPC™ technology







Summary and Future trends in low-E

- Energy savings in buildings are standardized in all developed countries, and their functioning spec is based essentially on low-E coating.

- Low-E technology combines materials science, optical design, vacuum deposition that provide an unique solution for building saving energy for different climates, and are required for the most of commercial building and are used for more and more residential building, worldwide.

- Low-E industry is continually growing and becoming one of the most important sector in glass industry.
  - Glass industry future trends: gradual shift in demand from low quality flat and sheet glass toward high quality float glass.
  - Low E is one of the fastest growing sectors in the glass industry due to environmental factors being more and more important.

Thank you

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