Escola Politécnica
Universidade de São Paulo

Vidros
Aplicações Especiais

Samuel M. Toffoli

Roteiro

- História
- Formação de um Vidro
- Vidros Temperados e Laminados
- Vidros Planos – Automobilística
- Vidros Planos – Arquitetura
- Vidros Extra-Finos
- Vitrocerâmicas

História

História

O vidro é utilizado pelo homem há milhares de anos

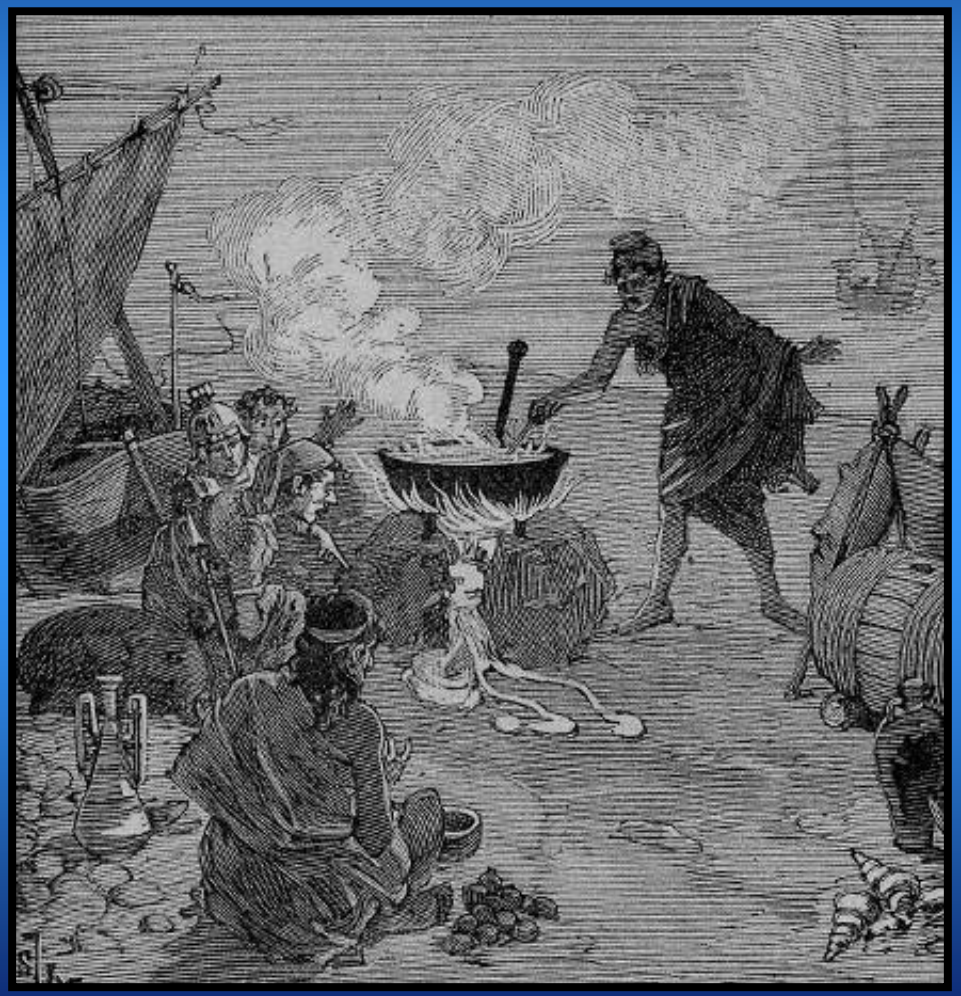
Vidro Natural: Obsidianas (produto de ação vulcânica)

História

Natureza fornece:

- **Energia**
- **Matérias-primas**
- **Tecnologia de fusão**

História



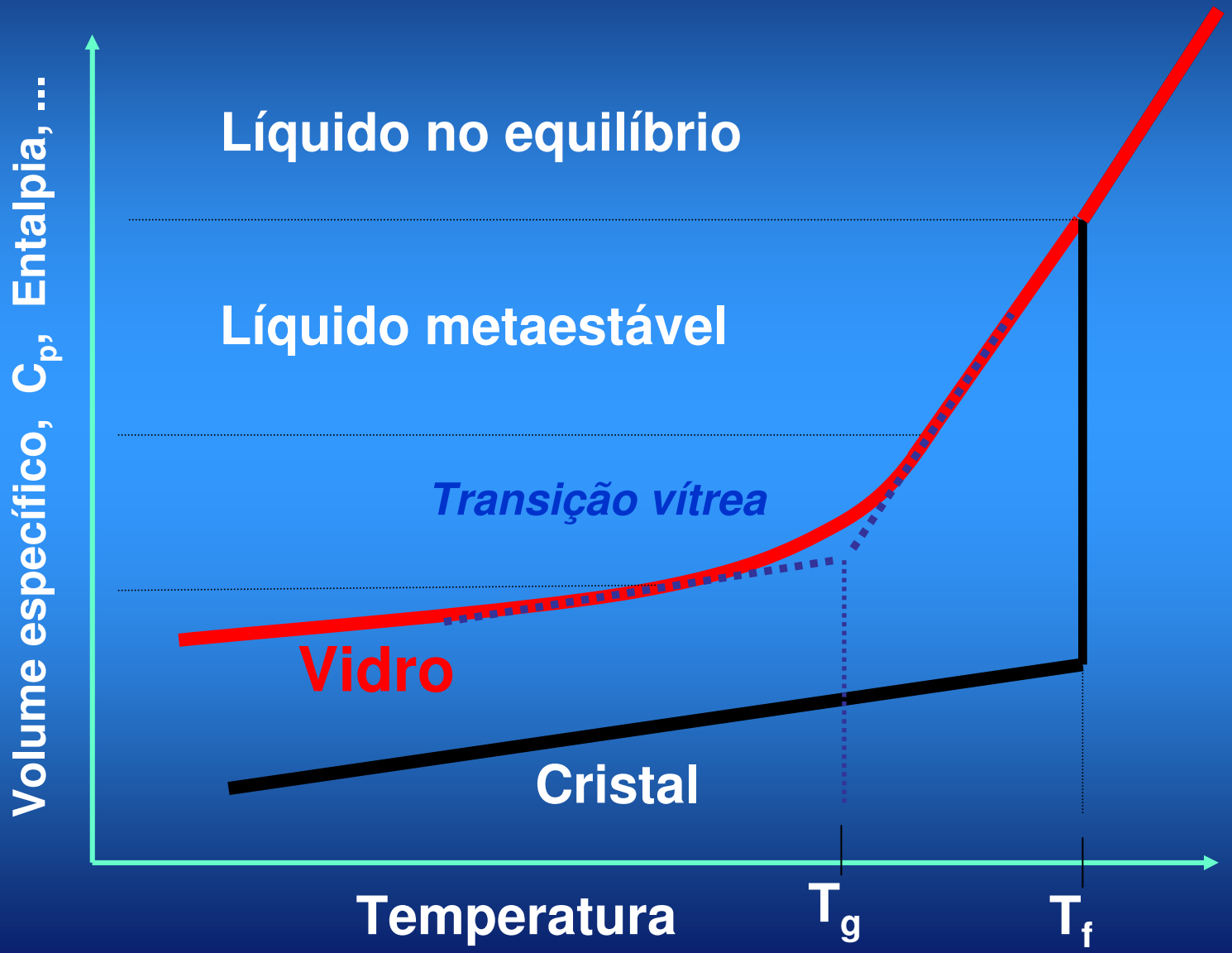
Há 4500 anos:

descoberta acidental de como fazer vidro

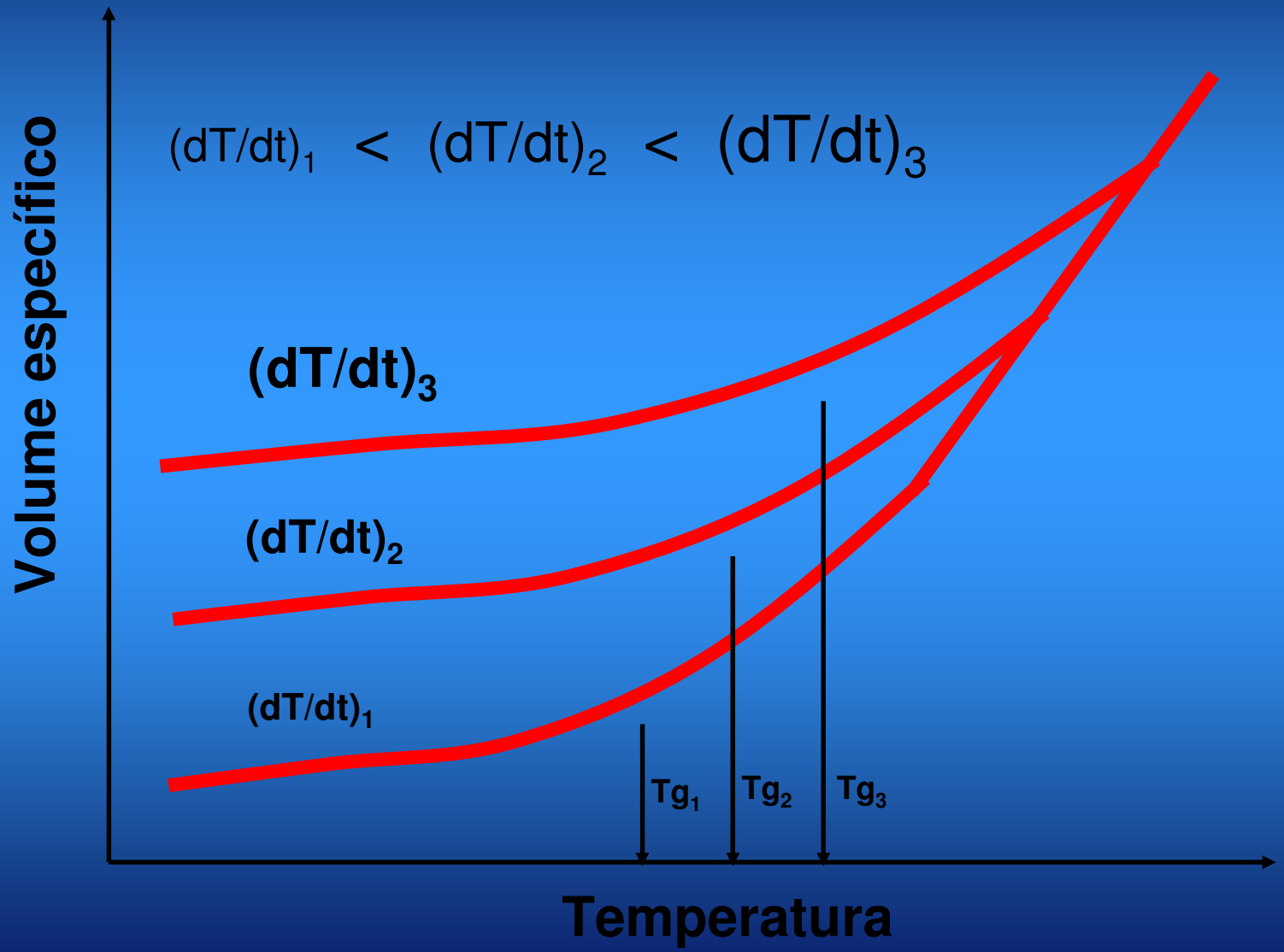
Fenícios?

Formação de um vidro

Formação de um vidro



Formação de um vidro



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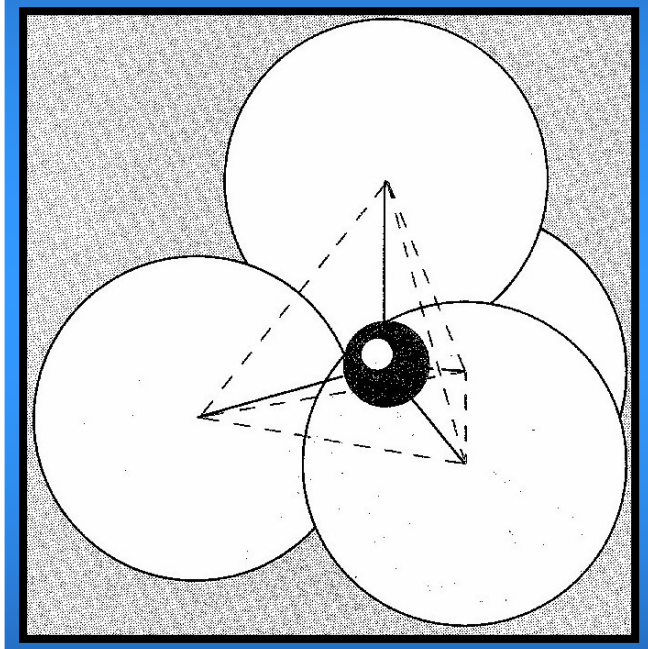
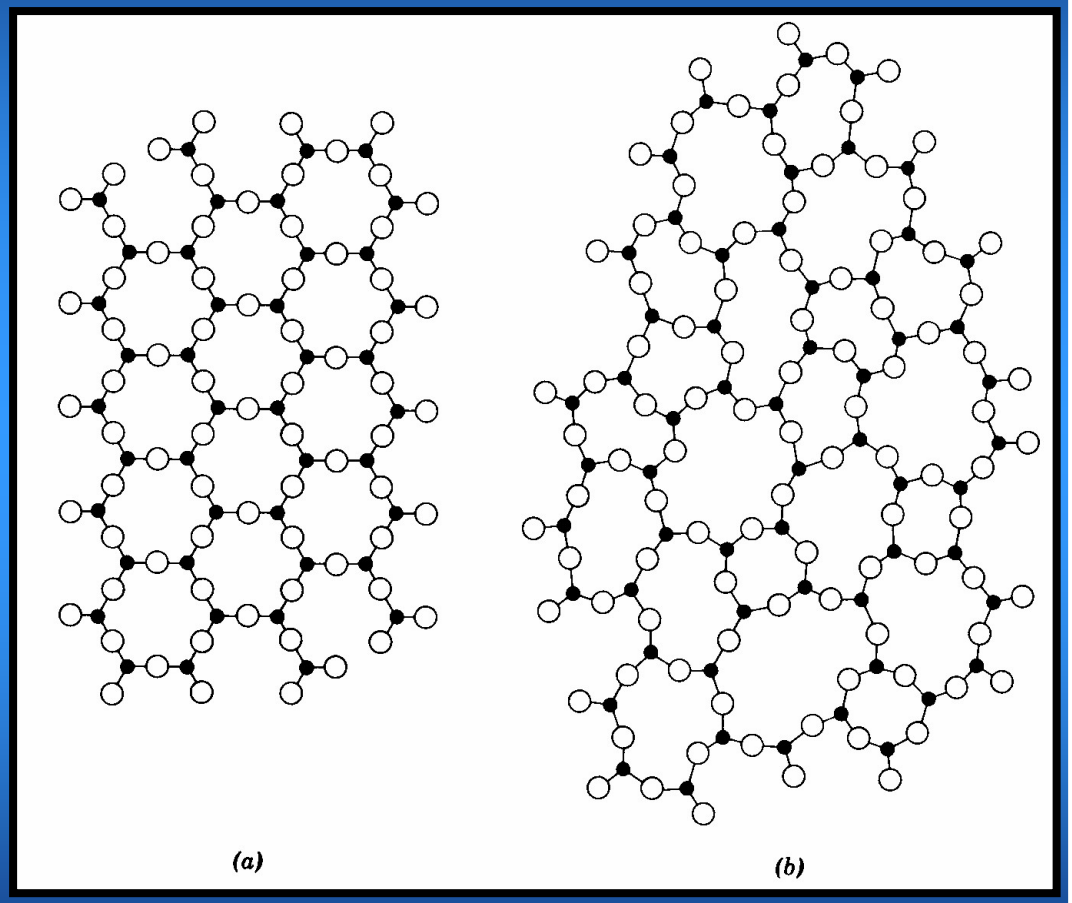
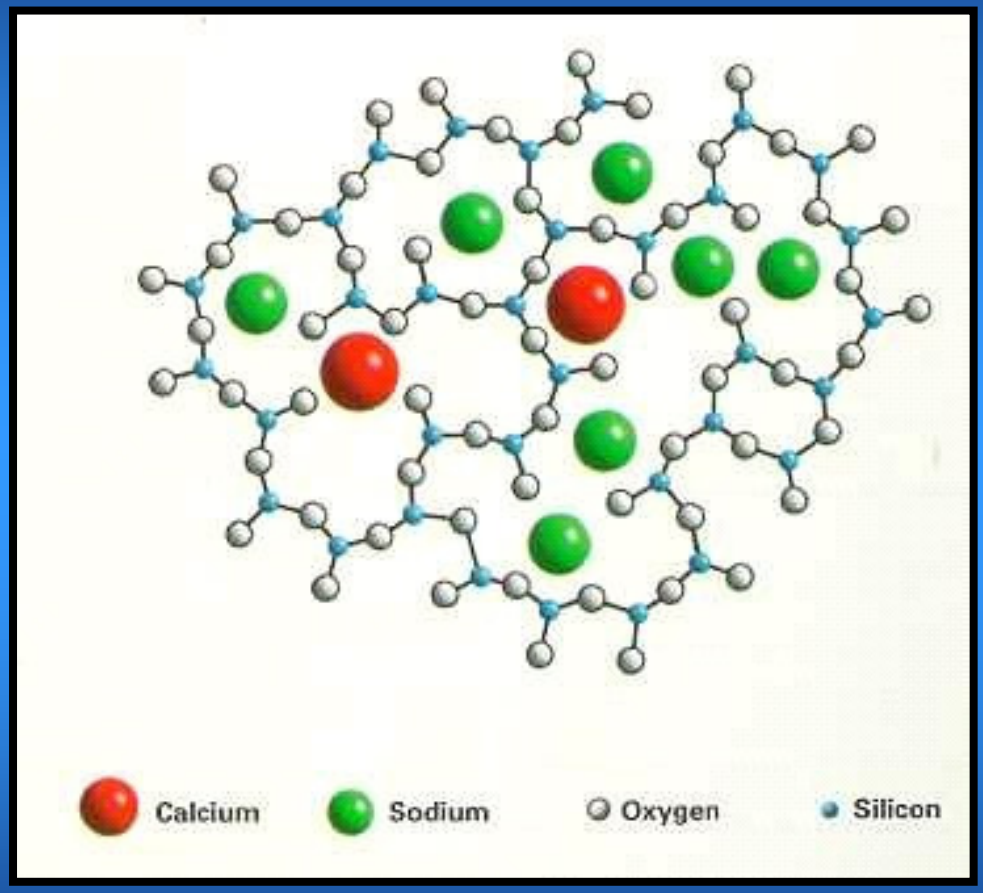




Cristalino Vítreo

(Zachariasen, 1932)

Formação de um vidro



Vidro sodo-cálcico

(janelas, garrafas, potes, vidro automotivo, box de banheiro, pratos comuns, etc.)

Vidros Temperados e Laminados

Vidros de segurança

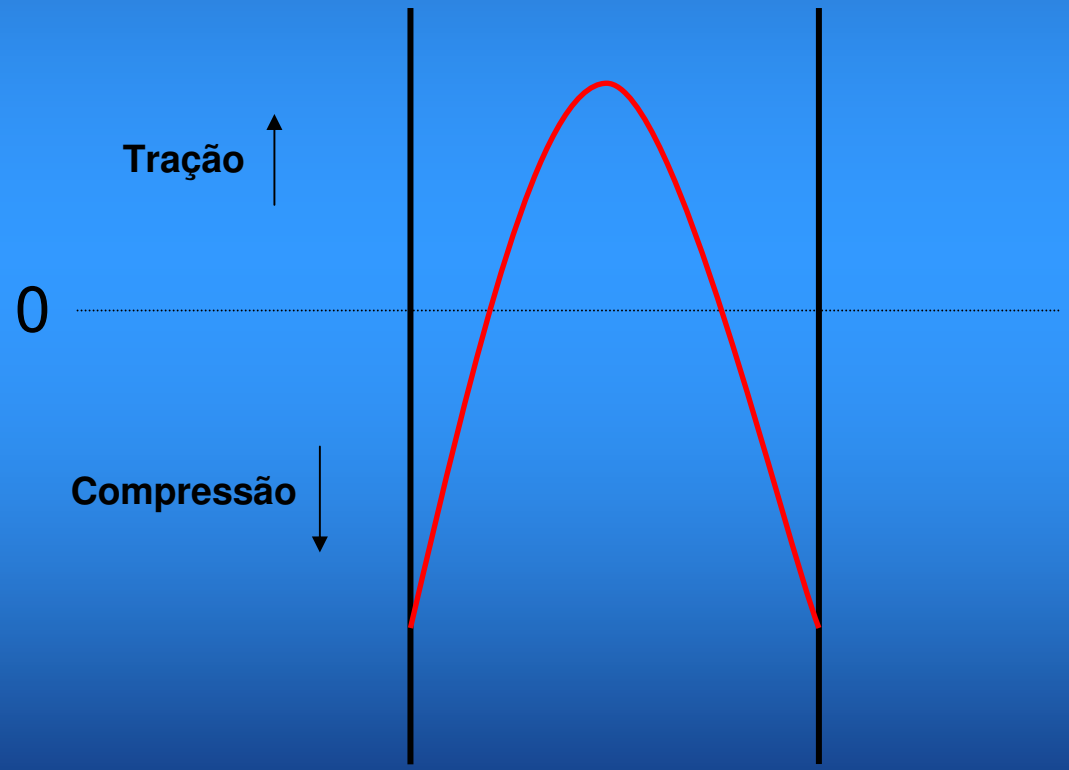
Em caso de ruptura, devem causar menos danos às pessoas do que causaria o vidro recozido

TÊMPERA

- Processo térmico: aquecimento uniforme seguido de resfriamento rápido e homogêneo
  - Resistência a impactos de 3 a 5 vezes maior
  - Cacos arredondados e menos cortantes
  - Tensões de compressão na superfície e de tração no interior

Vidros de segurança

TÊMPERA: Tensões



Seção transversal de uma chapa de vidro

Vidros de segurança

LAMINAMENTO

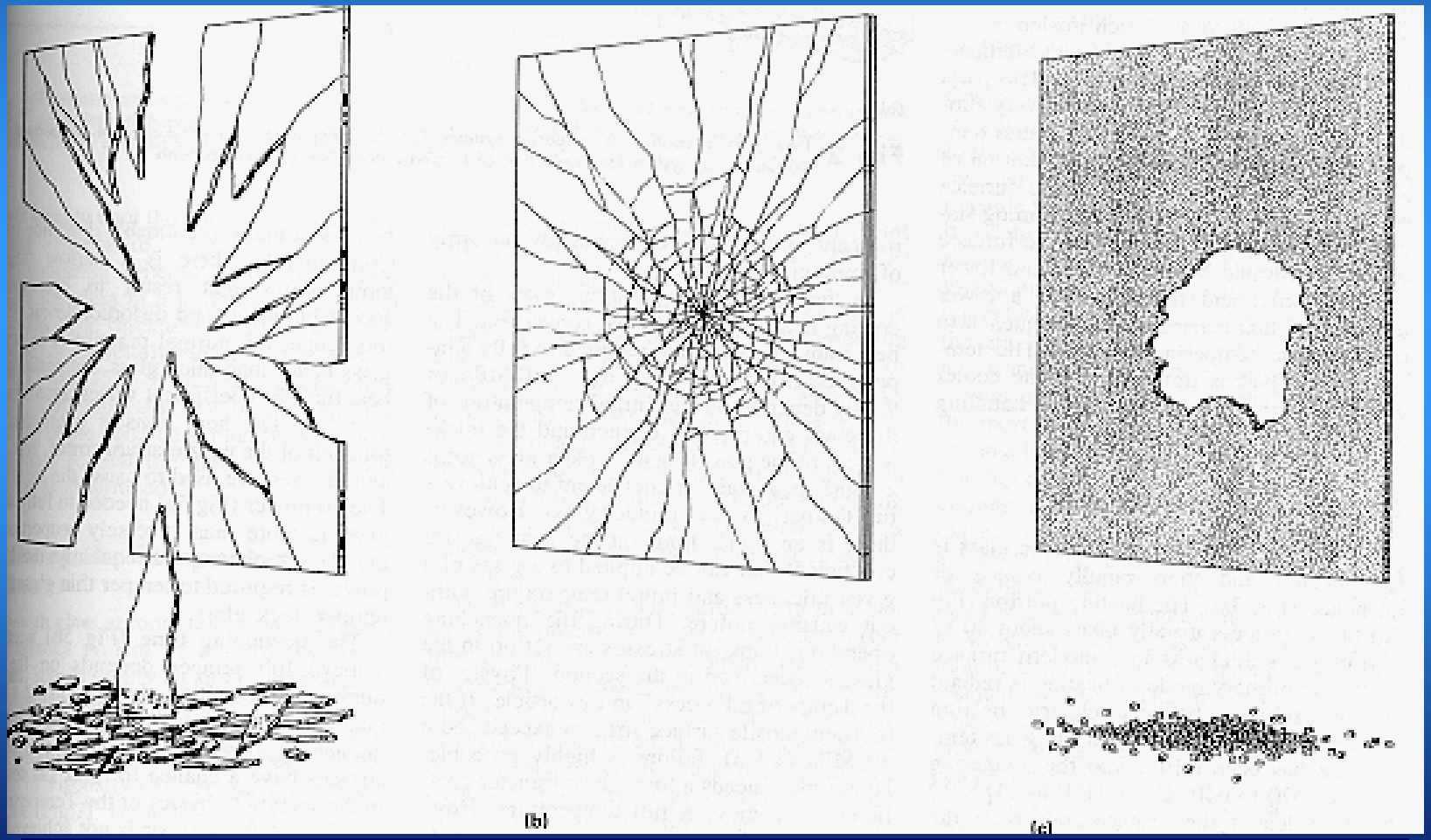
- Sanduíche: 2 folhas de vidro + 1 folha de PVB

PVB = poli(vinil butiral)

- O conjunto "cola" em auto-clave (P e T)
- O conjunto apresenta ótima capacidade de absorção de impactos ao fraturar-se

Vidros de segurança

MODOS DE FRATURA

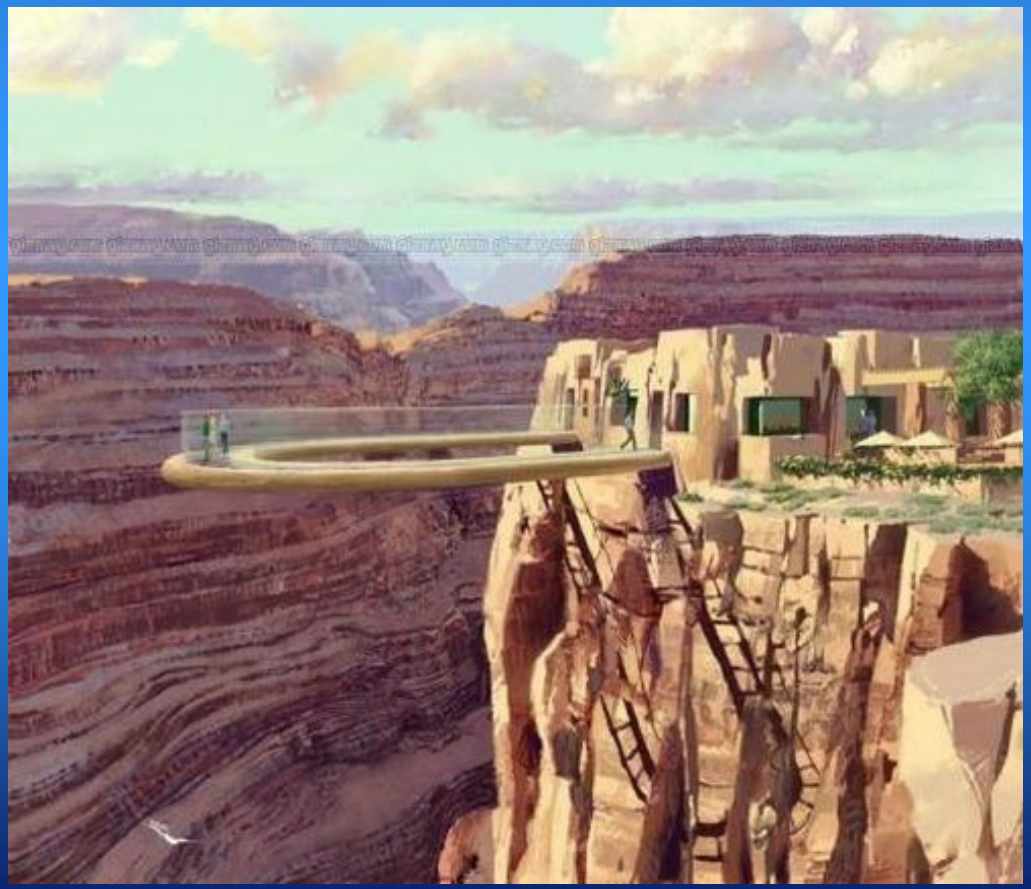


Recozido Laminado Temperado

Aplicações Especiais

Vidro Laminado

Grand Canyon Skyway



Vidro Laminado

Grand Canyon Skyway

Vidro Laminado

Grand Canyon Skyway

Vidro Laminado

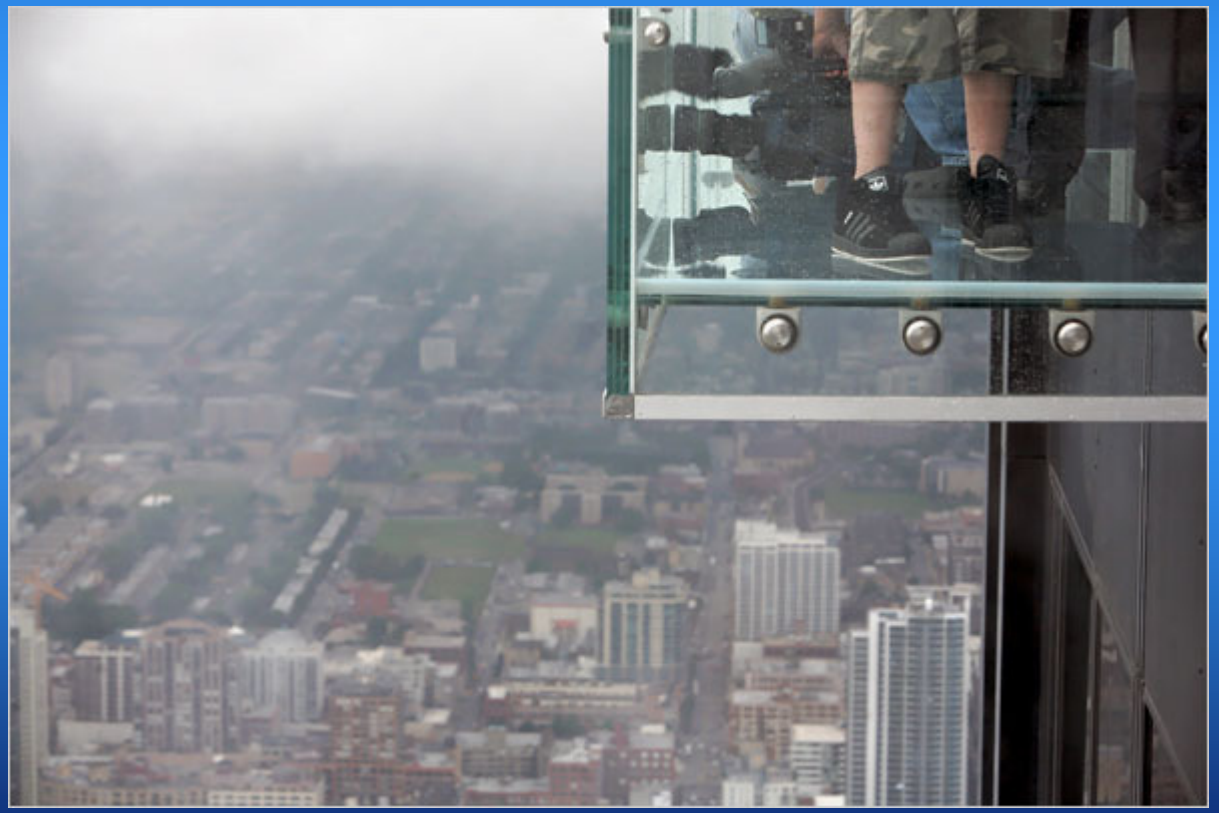
- **Sears Tower** (atual Willis Tower), Chicago, Illinois, EUA
- Inaugurado em 1973, e desde então a mais alta estrutura dos Estados Unidos.
- Skydeck: 103° andar, 412 m de altura

Vidro Laminado

- Sears Tower (atual Willis Tower), Chicago, EUA

Vidro Laminado

Willis Tower Skydeck

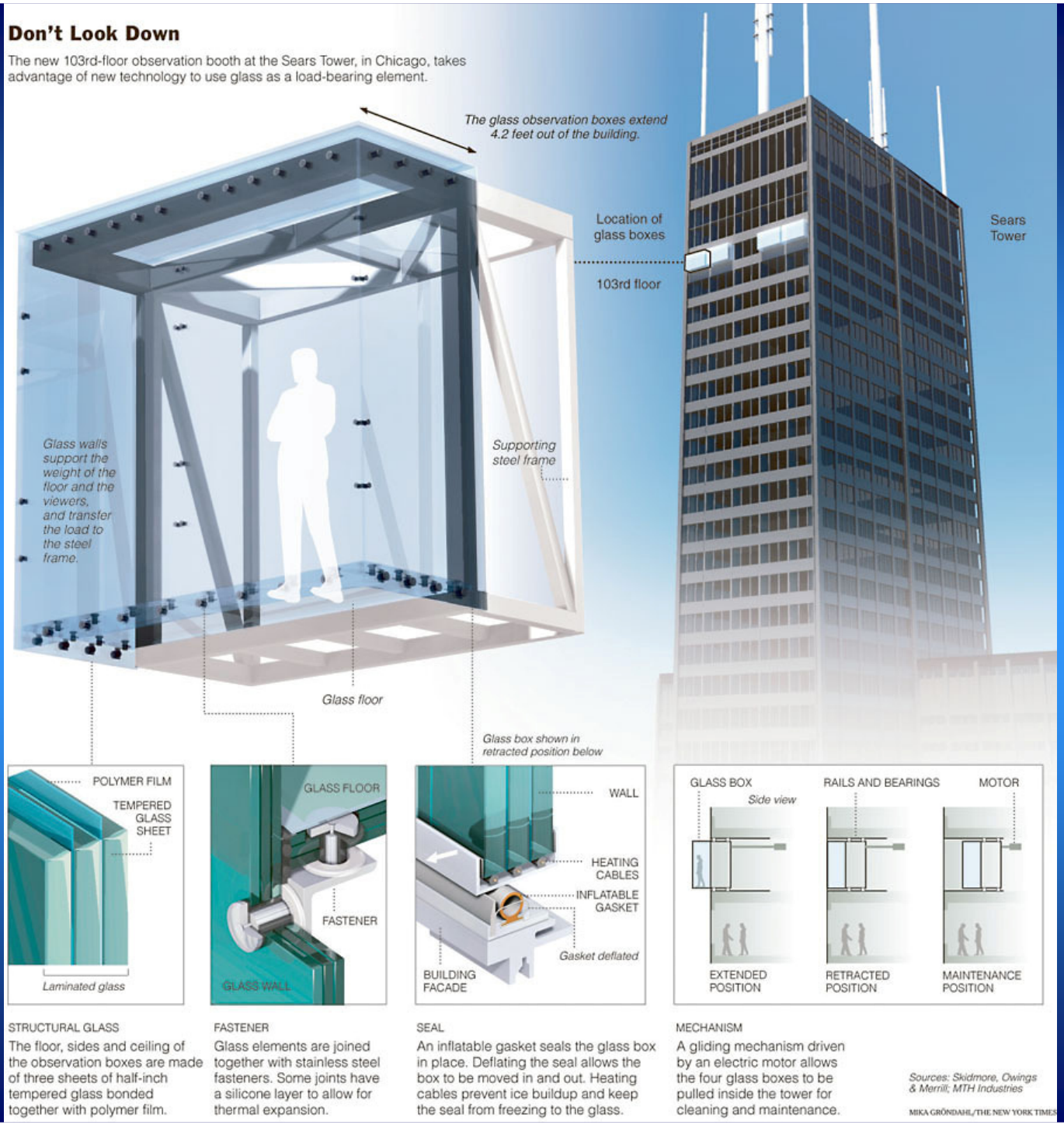


Vidro Laminado

Willis Tower Skydeck

Don't Look Down

The new 103rd-floor observation booth at the Sears Tower, in Chicago, takes advantage of new technology to use glass as a load-bearing element.



STRUCTURAL GLASS

The floor, sides and ceiling of the observation boxes are made of three sheets of half-inch tempered glass bonded together with polymer film.

FASTENER

Glass elements are joined together with stainless steel fasteners. Some joints have a silicone layer to allow for thermal expansion.

SEAL

An inflatable gasket seals the glass box in place. Deflating the seal allows the box to be moved in and out. Heating cables prevent ice buildup and keep the seal from freezing to the glass.

MECHANISM

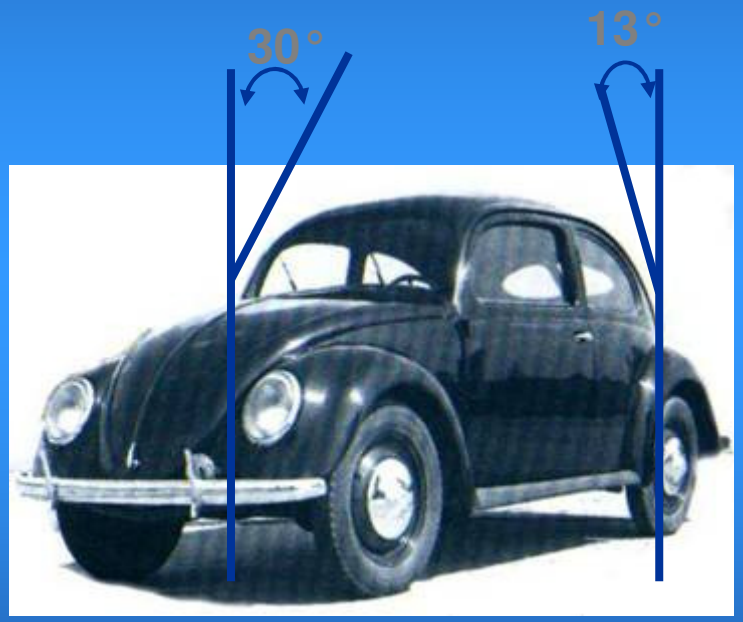
A gliding mechanism driven by an electric motor allows the four glass boxes to be pulled inside the tower for cleaning and maintenance.

Sources: Skidmore, Owings & Merrill; MTH Industries

MIKA GRÖNDAHL/THE NEW YORK TIMES

Vidro Plano – Automóveis

1960



Area envidraçado:
2,2 m²

2000

Área envidraçado:
4,32 m²

Vidro Plano – Automóveis

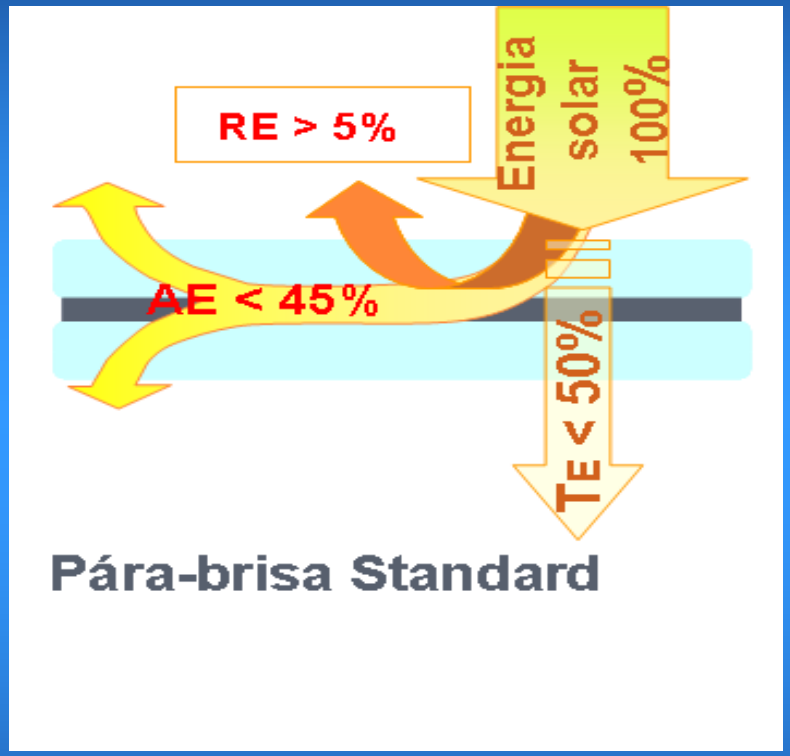
Renault Zoe (Elétrico), 2012

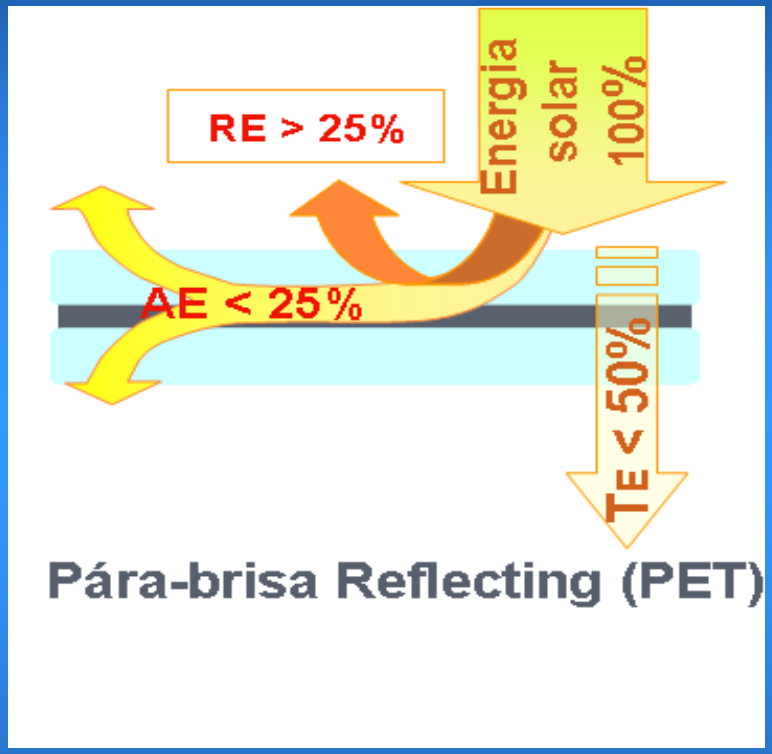
Vidro Plano – Automóveis

Conforto térmico $\Rightarrow$ controle da radiação IV

Proteção anti UV $\Rightarrow$ controle da radiação UV

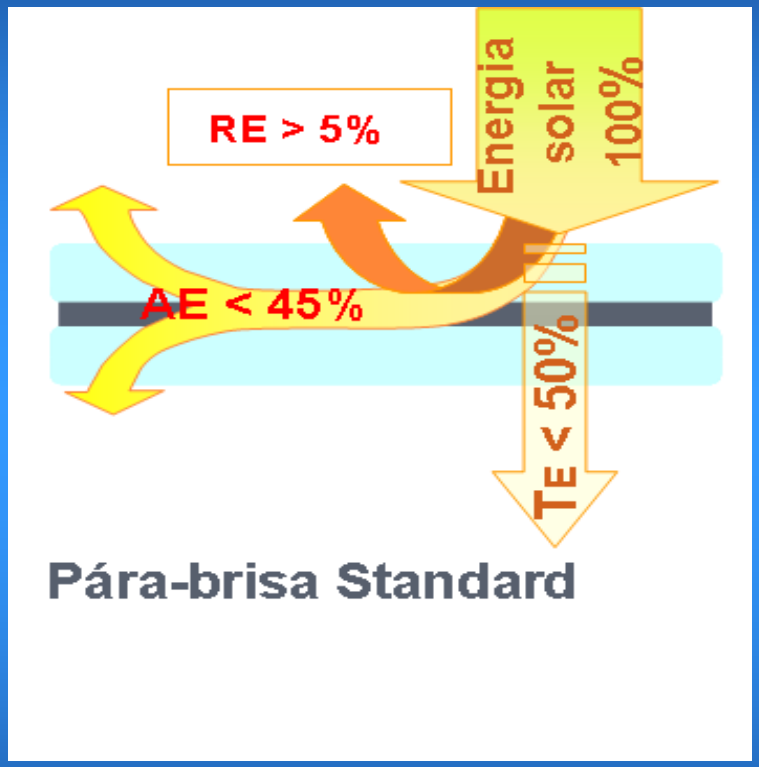
Thermocontrol® Reflecting (Saint-Gobain)

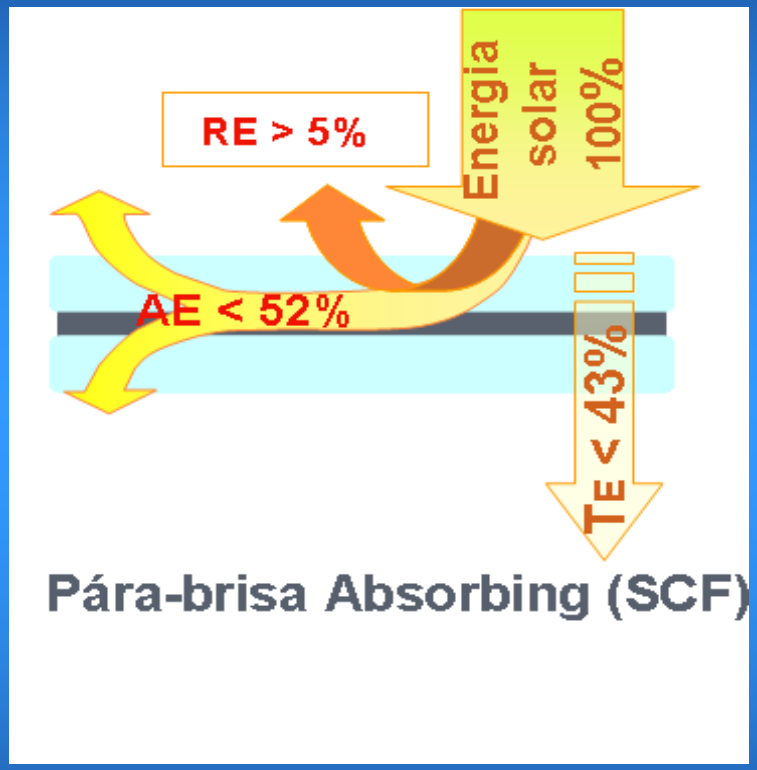




- A energia solar é refletida por um filme metálico inserido no pára-brisa
- Restrição: Vidros muito curvos e antena integrada

Thermocontrol® Absorbing (Saint-Gobain)

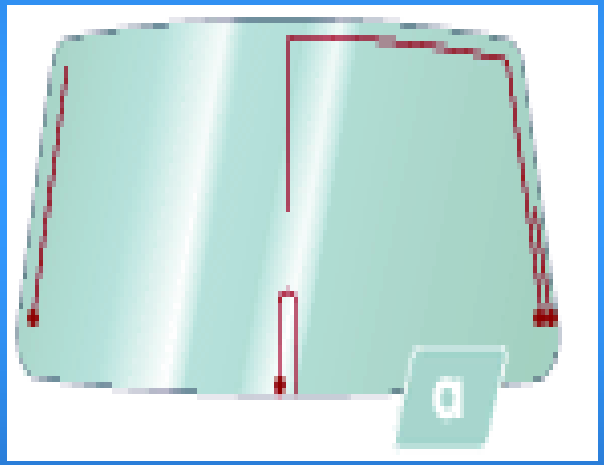




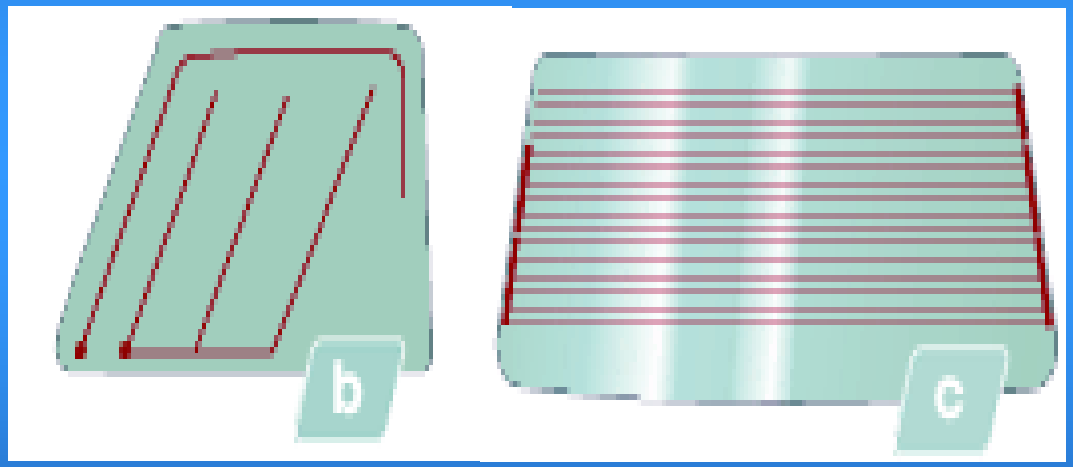
•A energia solar é absorvida por um PVB especial inserido no pára-brisa

Vidro Plano – Automóveis

Antenas e alarmes



Fio condutor em pára-brisas

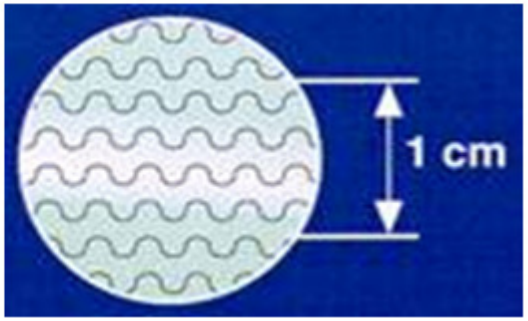


Condutores serigrafados em temperados

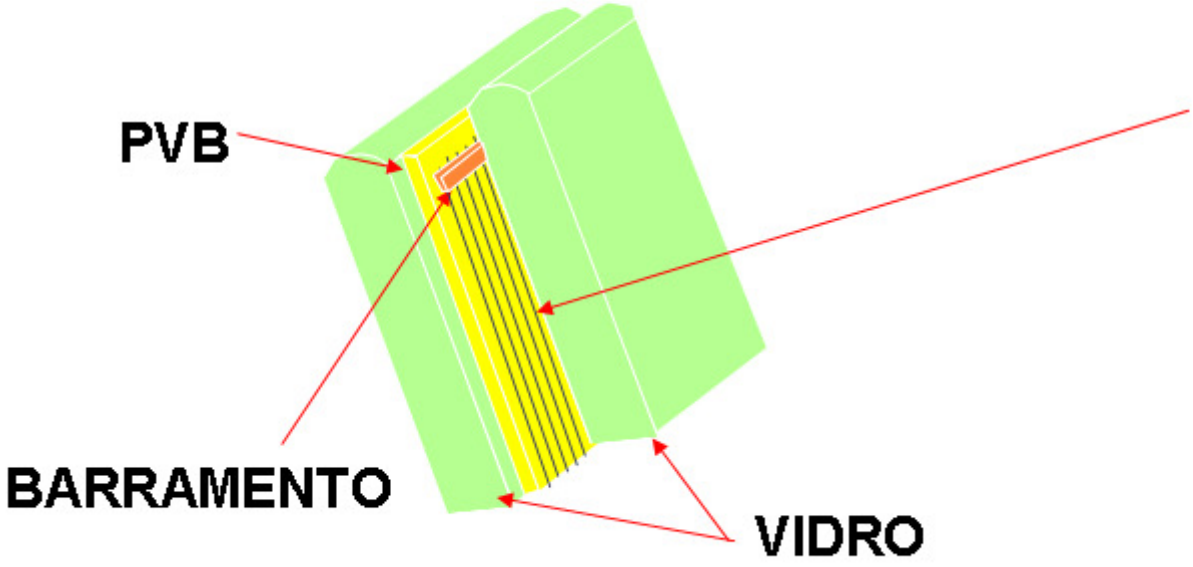
Vidro Plano – Automóveis

Anti-embaçante

– Micro filamentos de tungstênio aplicados sobre o PVB do pára-brisa.

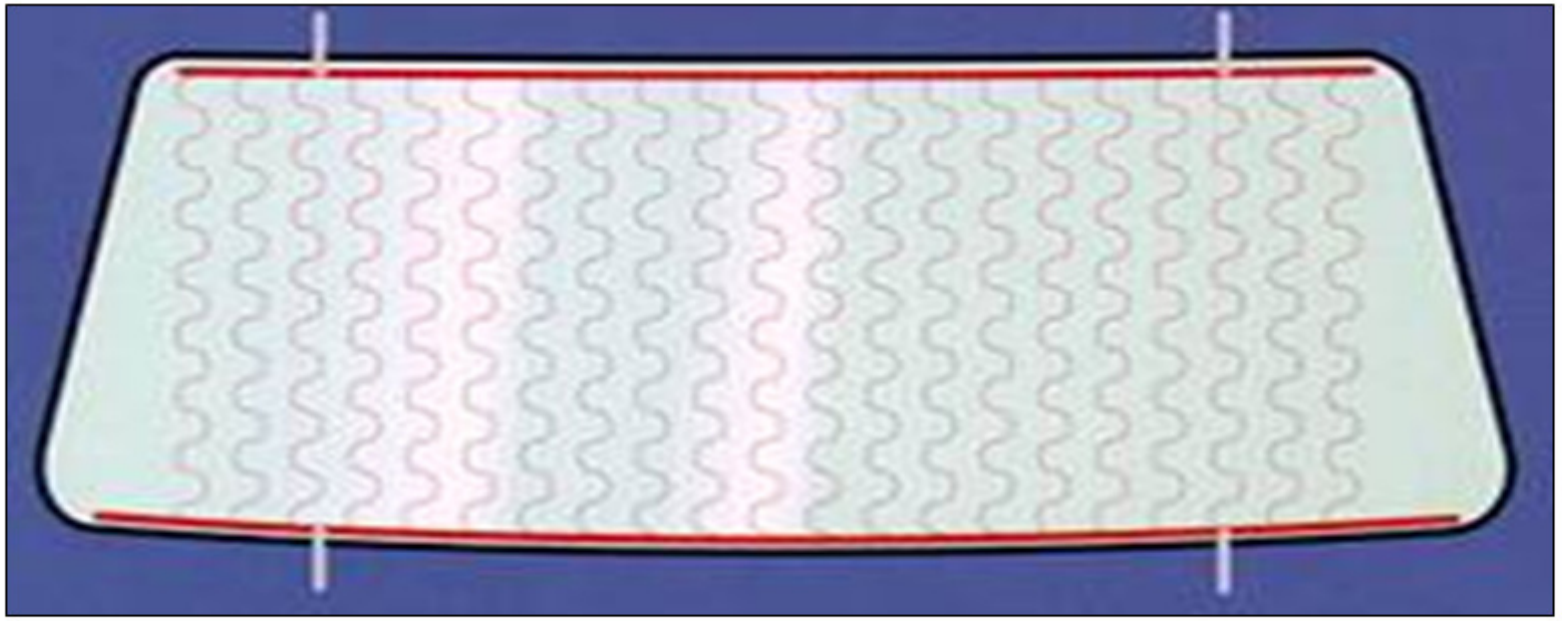


FILAMENTOS DE AQUECIMENTO



Vidro Plano – Automóveis

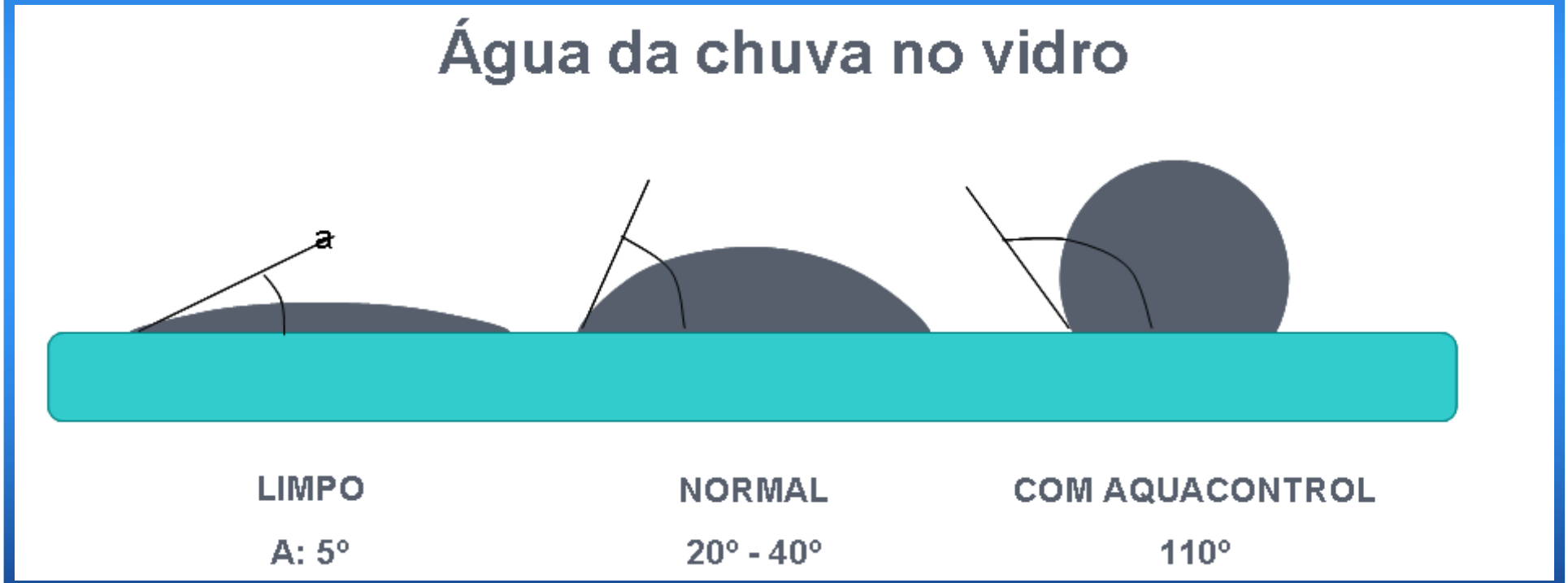
Pára-brisa anti-embaçante



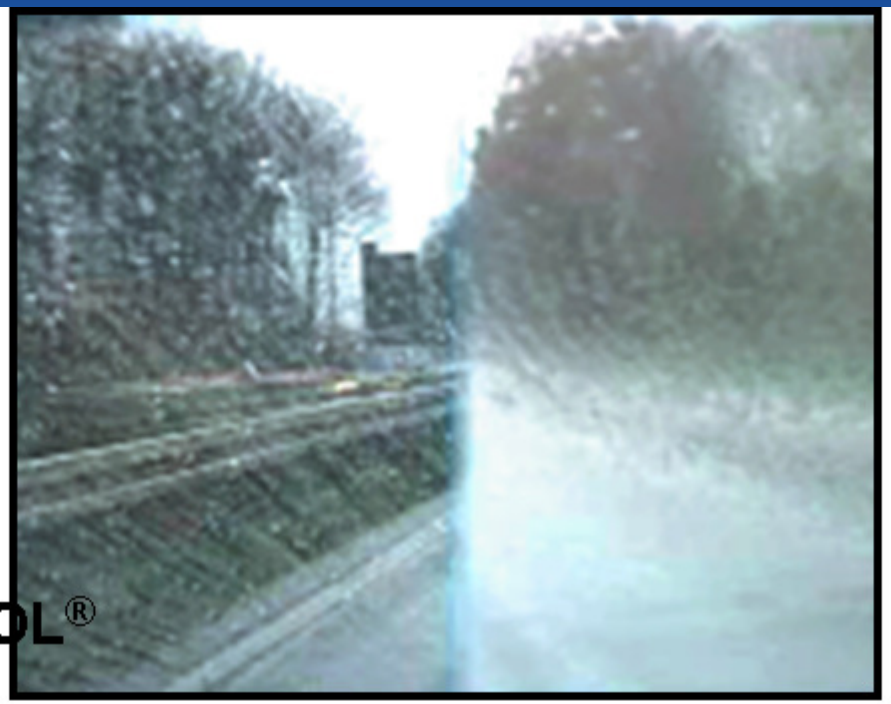
Os filamentos são aplicados em toda área visível do pára-brisa, alcançando até mesmo as áreas que a ventilação forçada não desembaça com rapidez.

Vidro Plano – Automóveis

Coating que repele água

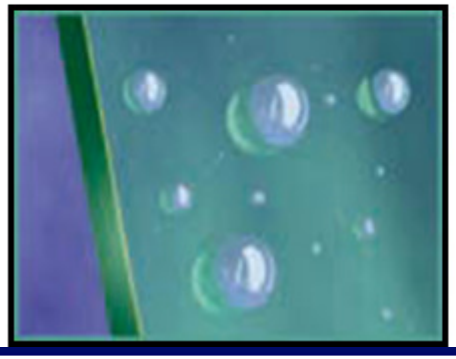


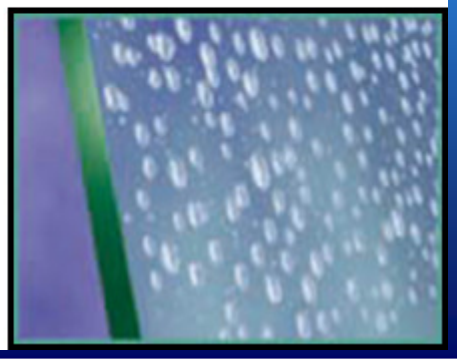
Vidro Plano – Automóveis



SGS **AQUACONTROL®**

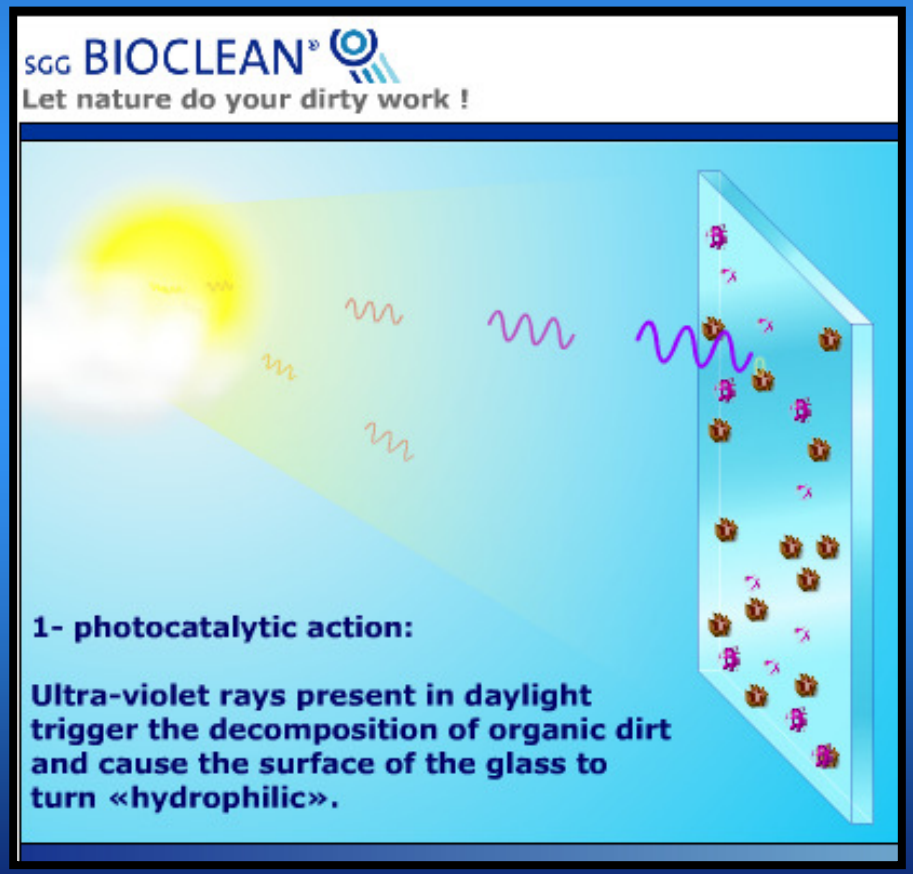
Sem aplicacao

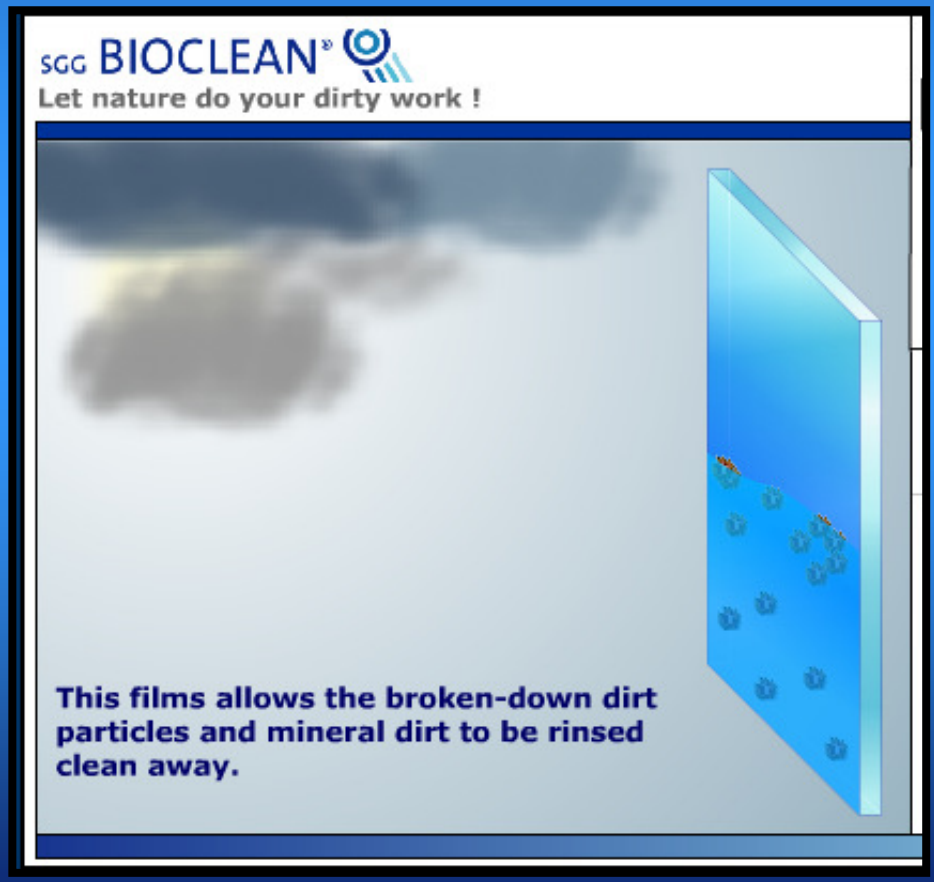




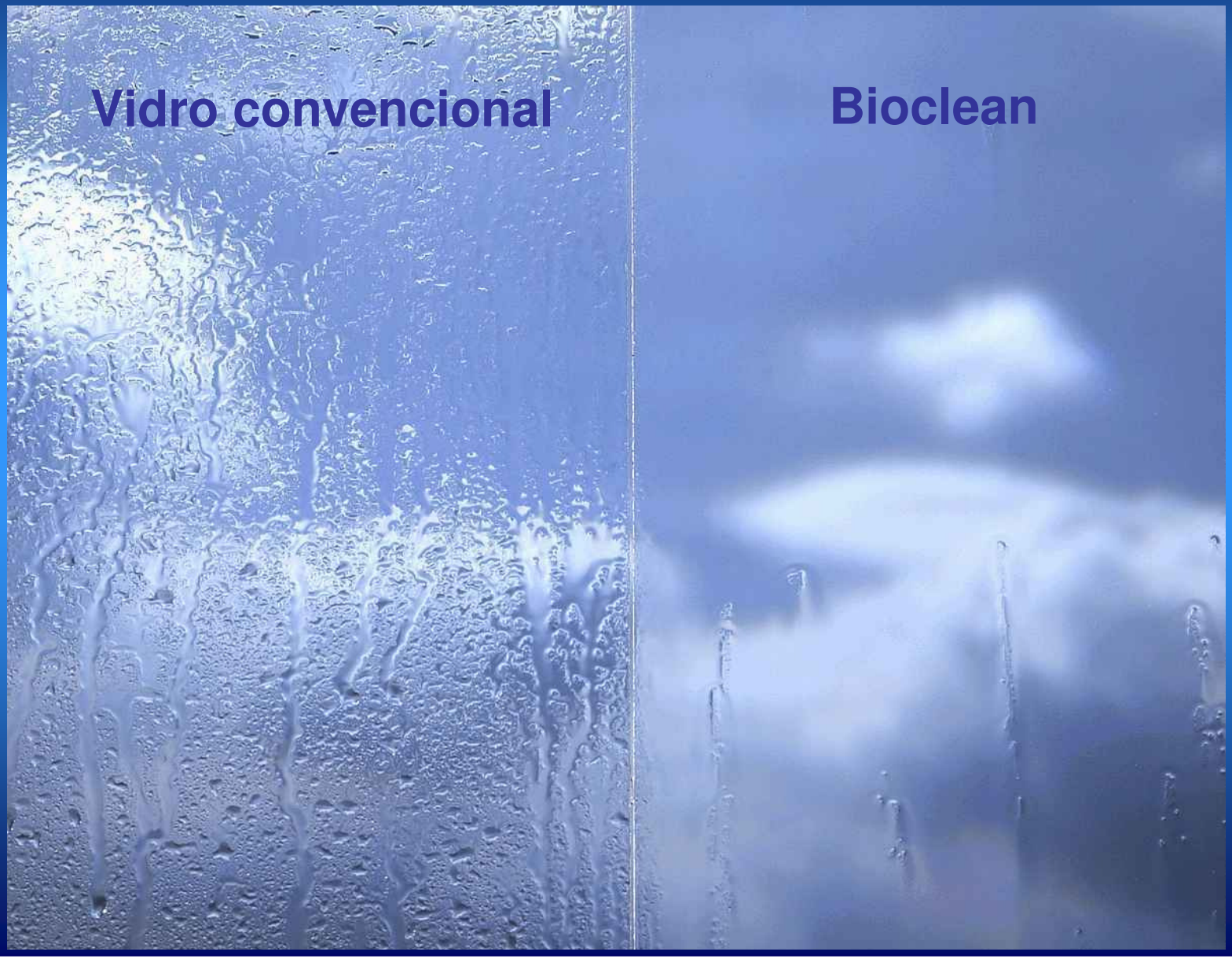
Vidro Plano – Arquitetura

Vidro auto-limpante





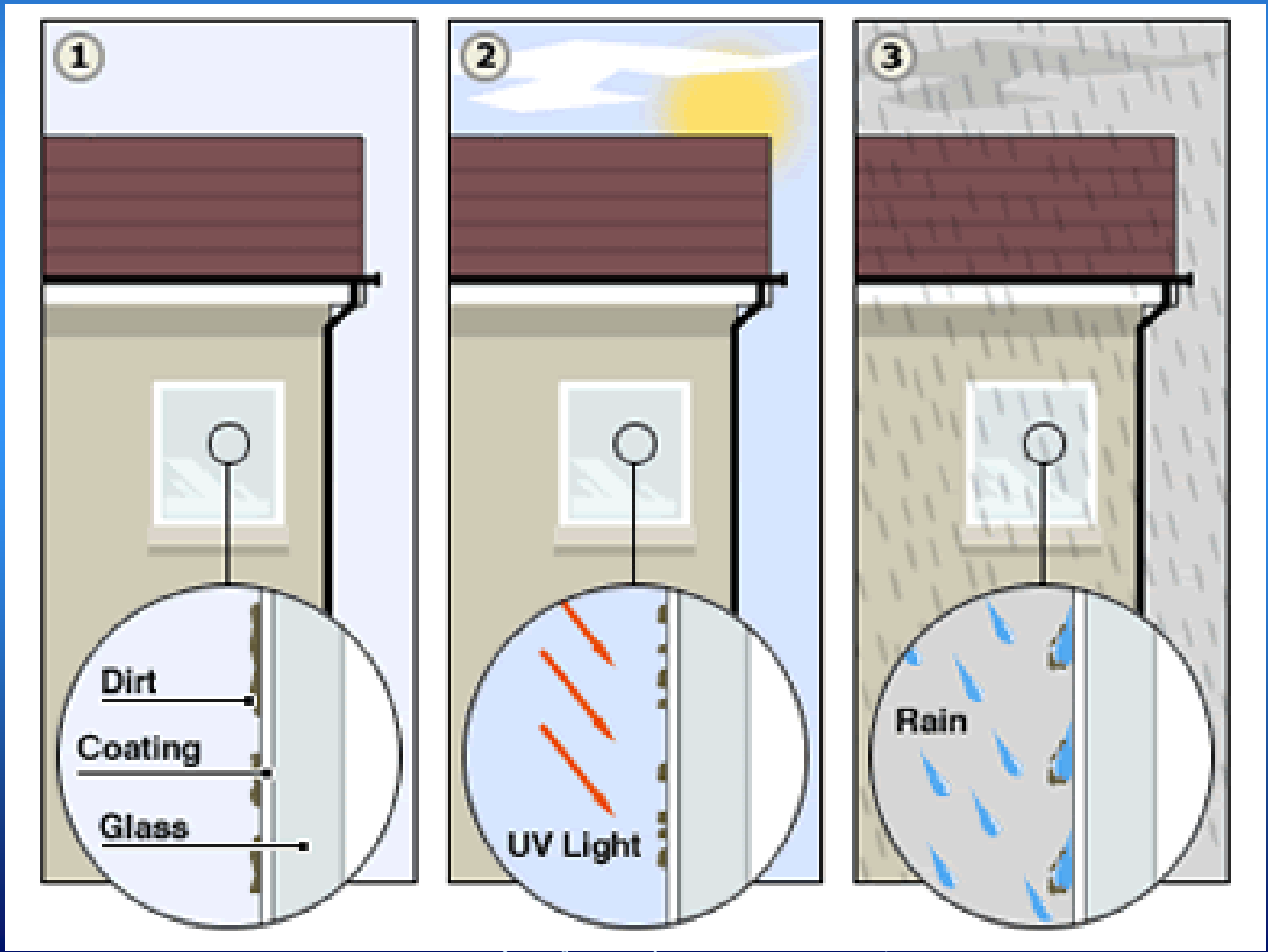
Vidro Plano – Arquitetura



Vidro Plano – Arquitetura

Vidro Plano – Arquitetura

Vidro auto-limpante



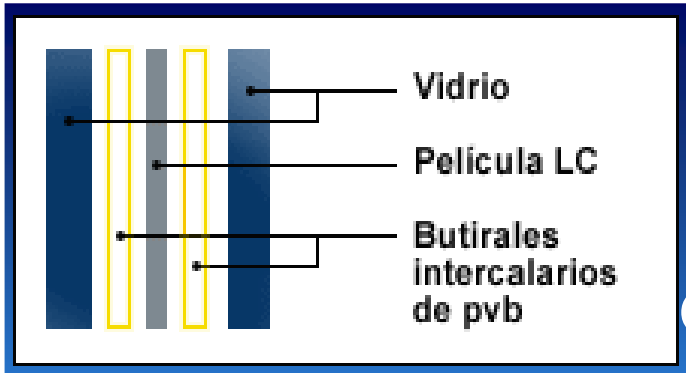
Activ®
(Pilkington)

Vidro Plano – Arquitetura

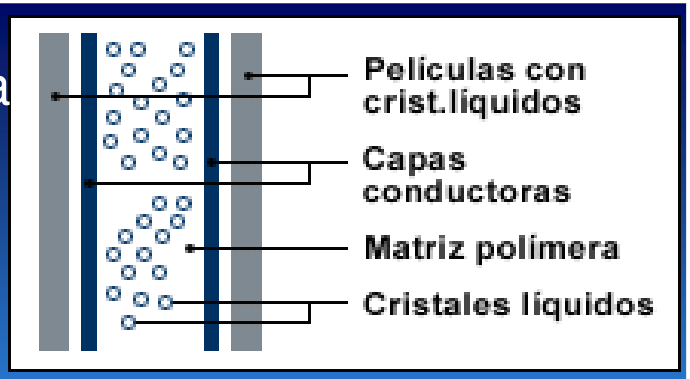
Vidro anti-reflexo

Vidro Plano – Arquitetura

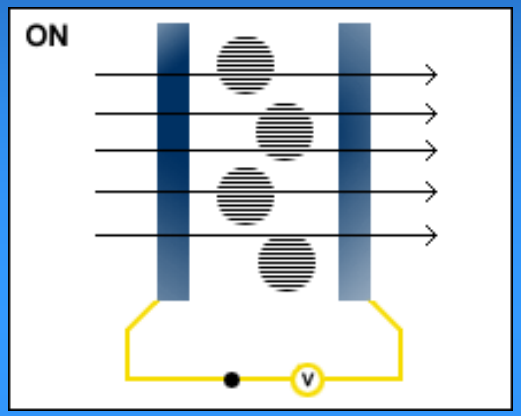
Vidro opticamente ativo

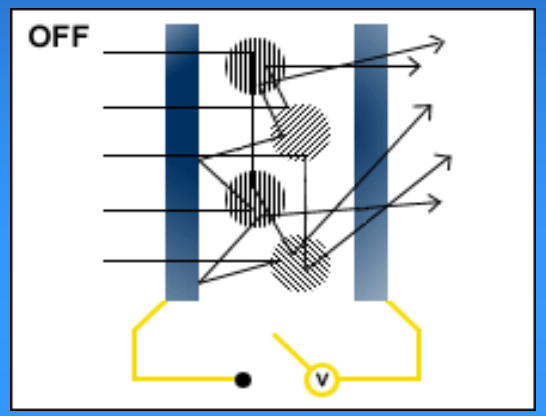


Corte da película



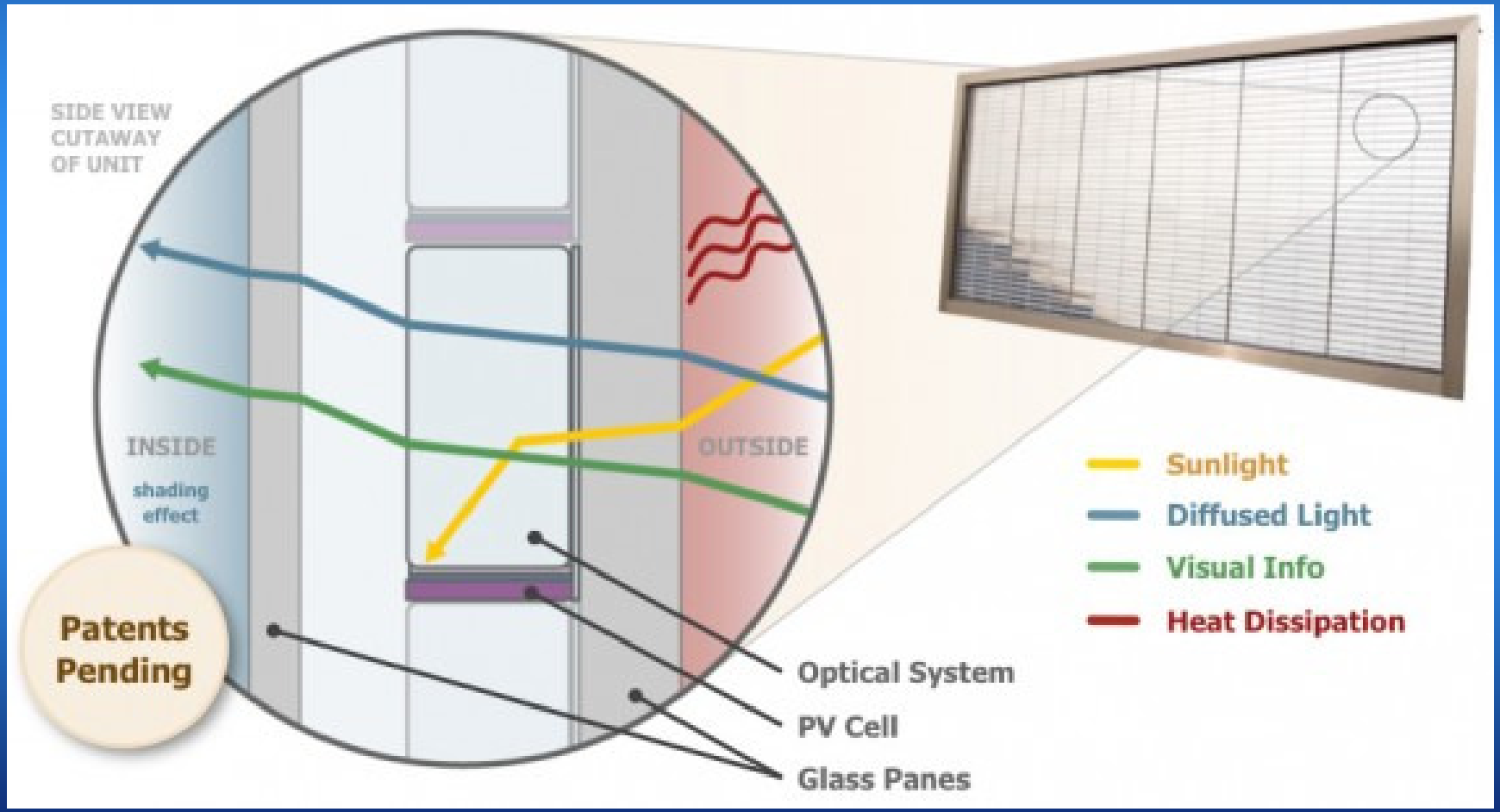
Corte transversal





Vidro Plano – Arquitetura

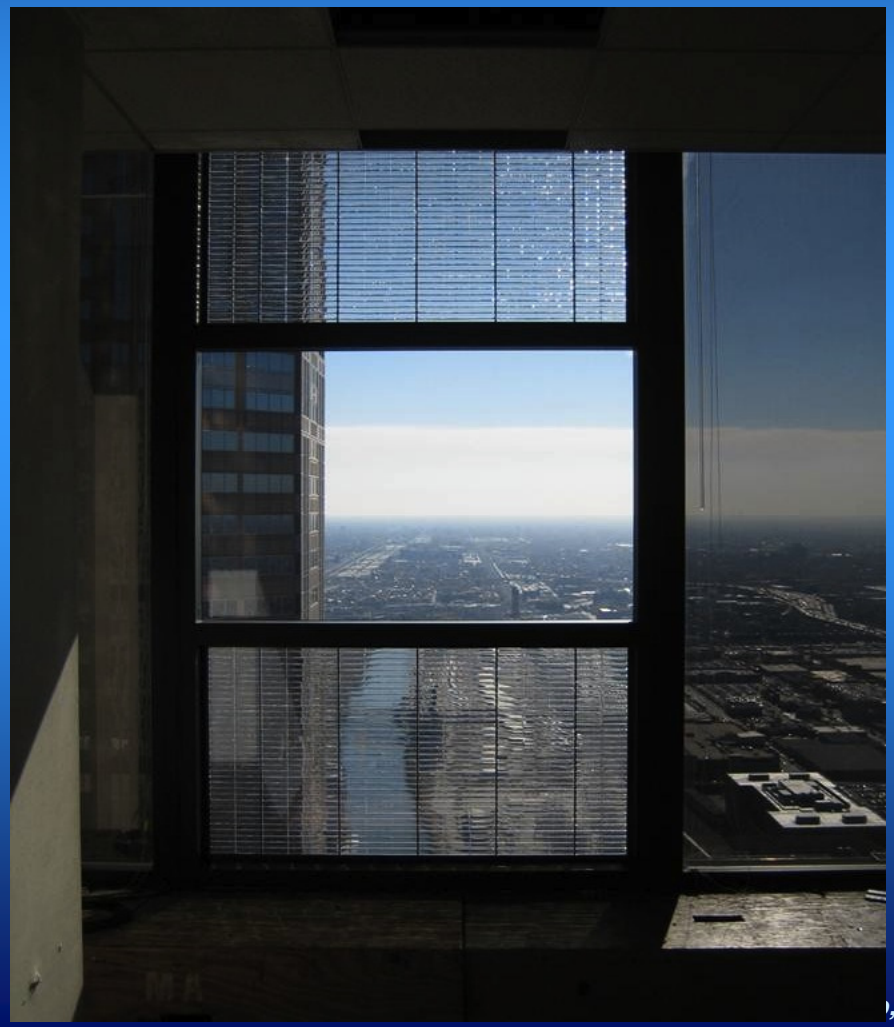
Pythagoras – PVGU (Photo-Voltaic Glass Unit)

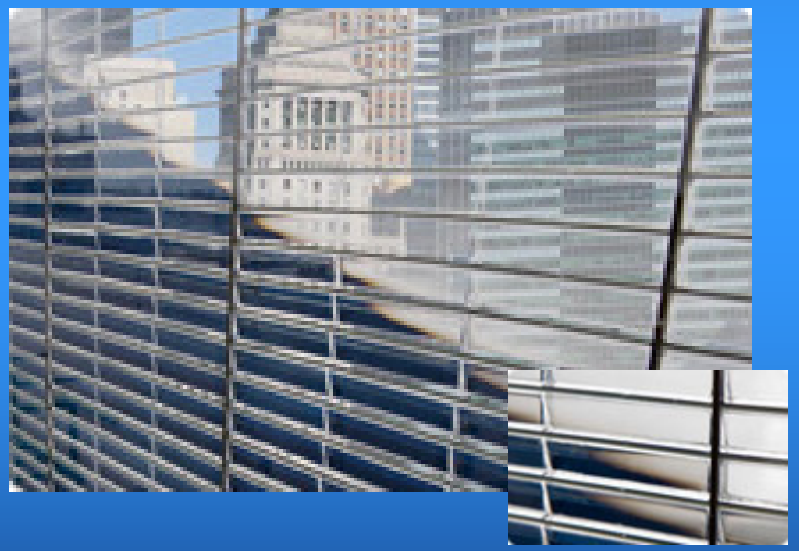


Vidro Plano – Arquitetura

Pythagoras – PVGU (Photo-Voltaic Glass Unit)

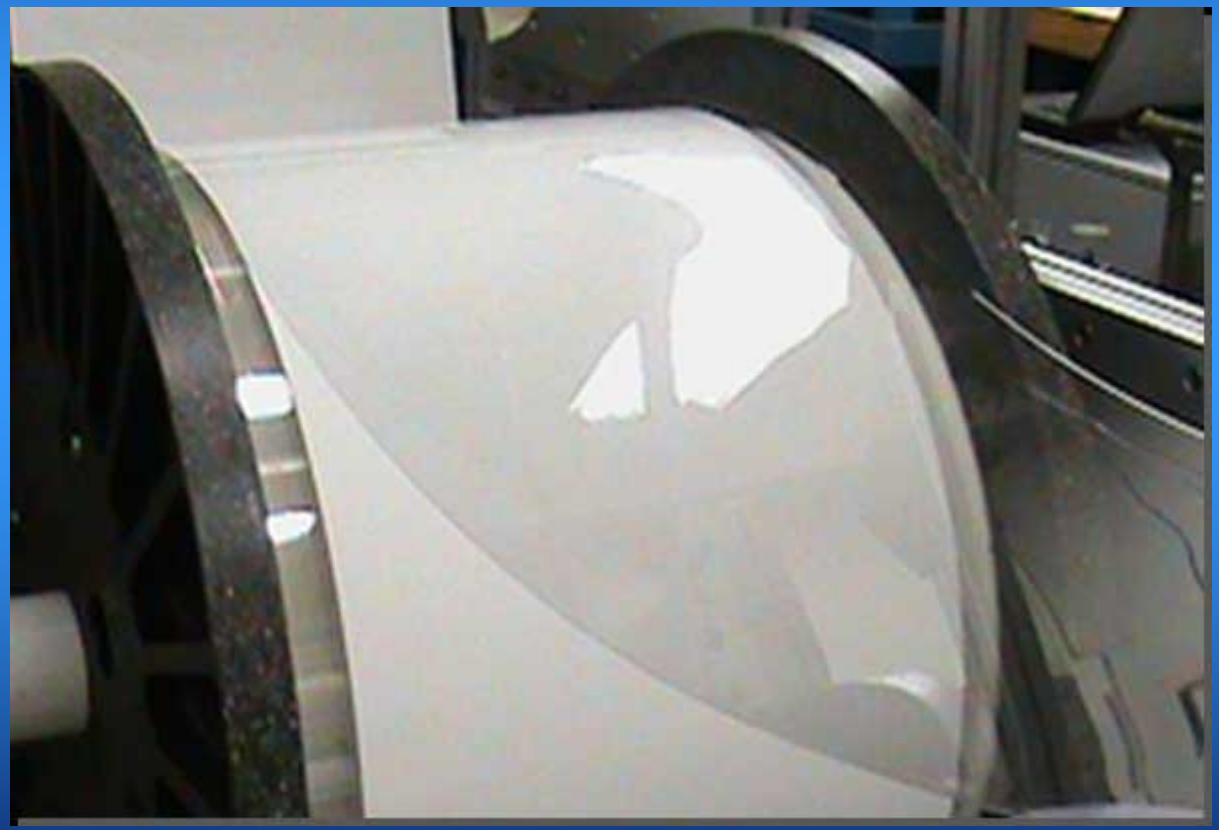
Pythagoras Solar (Israel, EUA e Taiwan)





Vidro Plano Extra-Fino

Folhas com até 50 μm de espessura ⇒ flexíveis



Vidro Plano Extra-Fino

Têmpera Química

Tempered for Strength

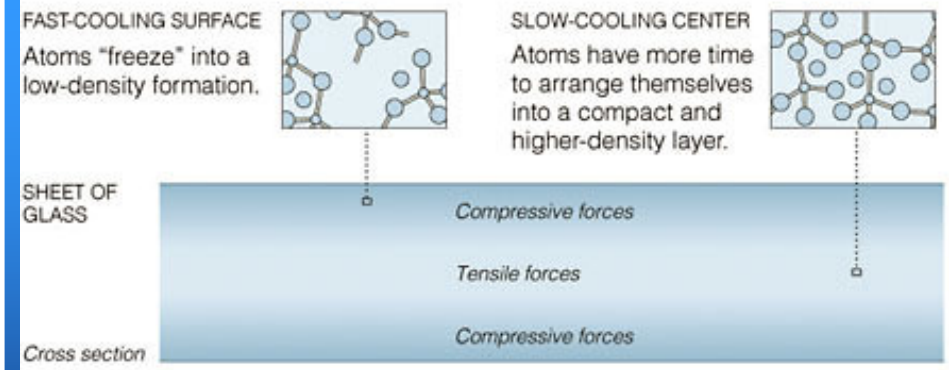
The process of tempering makes glass stronger by putting the surface into compression, so that more force is needed for cracks to spread and grow.

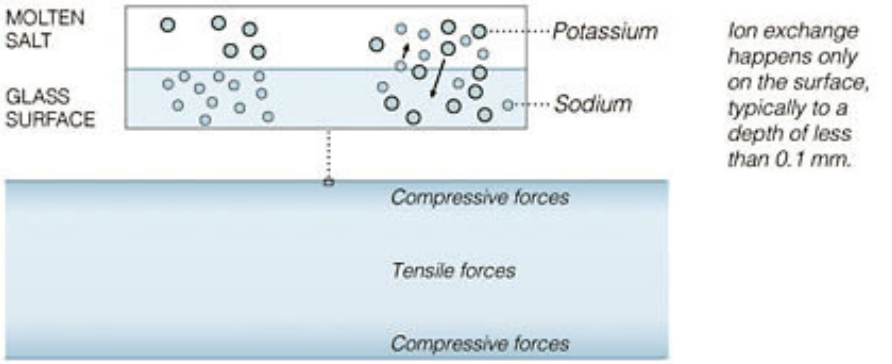
Thermal tempering

A sheet of glass is heated and then cooled with air. The surface cools more rapidly than the interior. As the interior cools gradually, it becomes more dense and shrinks, pulling the less dense surface into compression. Thermal tempering works well for flat sheets, although it can cause optical distortions to the glass because the sheet sits on rollers while being heated.

Chemical tempering

Glass is put into a hot bath of molten salt. A chemical reaction causes some sodium atoms on the surface to be replaced with larger potassium atoms from the salt bath. The larger atoms overcrowd and compress a thin surface layer of the glass. Chemical tempering works best for curved or irregular glass, and for glass where optical qualities are important.





Source: David J. Green, The Pennsylvania State University

MIKA GRÖNDAHL/THE NEW YORK TIMES

Vidro Plano Extra-Fino

Gorilla Glass (Corning)

Vitrocerâmicas

Vidros tratados termicamente para obter cristalização controlada em seu interior

$\alpha \sim 0\ ^{\circ}C^{-1}$

Escola Politécnica
Universidade de São Paulo

Vidros
Aplicações Especiais

Samuel M. Toffoli