Pilkington

First in Glass
Outline

- Coating Technology in the Glass Industry
  - On-line coating
  - Off-line coating

- Coating applications
  - Low E
  - Solar control coating
  - Self cleaning coatings
Coating Technology

• A wide variety of coating technologies are utilised by the glass industry
  – Spray Pyrolysis
  – Powder Spray
  – Chemical Vapour Deposition
  – Sputter Coating
  – Thermal Evaporation Coatings
  – Sol Gel Coatings

• These are applied
  – On Line i.e. as the glass is produced on the float line (CVD)
  – Off Line i.e. as a batch process (PVD)
Online
(CVD)
Chemical Vapour Deposition

- Pilkington Plc. has been involved with chemical vapour deposition for over 20 years
- Pilkington utilise atmospheric chemical vapour deposition to deposit coatings as the glass is produced
- On line coatings provides a variety of challenges
  - Glass is coated at >600°C
  - Glass is moving at approximately 10-15 m/min and is 3.2m wide
  - Coating must be applied continuously for a long period (upto 2 days continuously to be economic)
- On Line Coatings are
  - Hard
  - Durable
What is CVD?

- Gas Phase Reactions
- Transport to surface
- Redesorption of Film Precursor
- Surface Diffusion
- Adsorption of Film Precursor
- Nucleation and Island Growth
- Desorption of Volatile Surface Reaction Products
- Step Growth

From Chemical Vapour Deposition Principles and Applications M.L.Hitchman and K.F.Jensen
Process Involves

• Vaporisation of chemicals
• Delivery of chemicals in inert gas
• Direction of chemicals over hot glass
• Extraction of by products
• Scrubbing of waste products
Chemical Vapour Deposition (CVD) Coater Cross-section Diagram
Offline
(PVD)
Physical Vapour Deposition

• Pilkington Plc. has been involved with physical vapour deposition for over 25 years
• Pilkington utilise magnetron sputter technology to deposit coatings as the glass is produced
• On line coatings provides a variety of challenges
  – Glass is coated in vacuum at $10^{-3}$ mbar
  – Glass is moving at approximately 2-6 m/min and is 3.2m wide
  – Coating must be applied continuously for a long period (upto 10 days continuously)
• Off Line Coatings has
  – high performance
  – high flexibility
Physical Vapour Deposition

What is sputtering?

a target is bombarded and material is ejected

What is needed for sputtering?

• target (electrical conductive)
• plasma which generated particle to bombard the target
What is a plasma?

- A plasma consists of electrical negative and positive particles.
- The number of negative particles is equal to the number of positive particles, making the plasma electrically neutral.
- A plasma is electrical conductive.
- Electromagnetic wave, e.g., light.
Physical Vapour Deposition

reactive sputtering

[Diagram showing the process of reactive sputtering, including the interaction of gas molecules (Ar, O, Me) with a target to form a glass layer.]
Physical Vapour Deposition

DC magnetron cathodes

power supply

magnets

cooling system

anode

clamps for the target

plasma

magnetic field

target
AC magnetron

a) first half wave

b) second half wave
Physical Vapour Deposition

rotating cathodes

cooling tubes
magnets
targets
Pilkington Coater in Halmstad
Pilkington Coater in Gelsenkirchen
Purpose
Coating technology allows us to add functionality to glass
Coating technology is today used for a variety of products
- Low Emissivity coatings to reduce heating bills
- Solar Control coatings to reduce solar heat gain and cooling bill
- Technical products e.g. TCO’s for displays etc.
- Anti-Reflective Products
- Hydrophobic Coatings
- Self Cleaning Coatings
What coatings do - outside to inside

UV  Visible light  Infra-Red

We have to distinguish between:
• what comes from the outside to the inside - solar spectrum
• what goes from the inside to the outside - heat
What coatings do - outside to inside

Optimal curve for solar control
- no UV
- all visible light pass
- no IR

Optimal curve for low-e
- no UV
- all visible light pass
- all IR pass
Low E coatings

Insulating glass - heat transfer

Conduction + convection depends on the fill gas (air, Argon)
radiation exchange depends on the emissivity and temperature difference
Low E coatings

Insulating glass - heat transfer

outside uncoated glass $\varepsilon = 0.89$
inside

$0^\circ C$ $20^\circ C$

Heat exchange $5\mu m-50\mu m$

Low e glass $\varepsilon = 0.04$

$0^\circ C$ $20^\circ C$
Low E coatings

Double glazing – U-value

Air

ε=0.02

Ar

Kr
Low E coatings

Low emissivity = high reflectivity for IR-Radiation
(wavelength 5μm - 50 μm)

→ conductive layer

conductive oxide or high conductive metal
SnO$_2$:F or Ag
K glass or Optitherm SN
On-line coating or offline coating
Low E coatings

online

- offline

colour suppression

glass

conductive oxide

dielectric layer

dielectric layer

glass

silver
# Low E coatings

## advantages - disadvantages

### K glass

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online</td>
<td>Limited performance $\varepsilon &gt; 0.12$</td>
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<tr>
<td>scratch resistant</td>
<td></td>
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<tr>
<td>humidity resistant</td>
<td></td>
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<tr>
<td>possible for single glazings</td>
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### Optitherm

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>High performance $\varepsilon &lt; 0.03$</td>
<td>vaccum process</td>
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<tr>
<td>No Haze</td>
<td>limit storage time</td>
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<tr>
<td>High transmission</td>
<td>needs special processing</td>
</tr>
<tr>
<td></td>
<td>stable only in insulating glass</td>
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</table>
Low-e and solar control

Comparison uncoated glass - low E glass

- Float
- low-e
- double silver
solar radiation
300nm - 2500nm

Absorbed radiation = heat
300nm-2500nm -> 5μm-
50μm

Reflection from
first pane

Heat transfer to the
outside

Reflection from
second pane

Heat transfer to the inside

Direct transmitted
radiation

$g = T_e + q_i$

$g$ should be low - coating should be on pos. 2
Solar control coatings

Example: double silver coatings

- **Oxide 3**: 40nm
- **Silver 2**: 17nm
- **Oxide 2**: 85nm
- **Silver 1**: 8nm
- **Oxide 1**: 25nm
- **Glass**

Thickness variations for $\Delta E^* \leq 3$ have to be less than 2%.

2% of 8nm silver is 0.16nm, which is about one atomic layer.
## Solar control coatings

<table>
<thead>
<tr>
<th>Product</th>
<th>g-value</th>
<th>$T_L$</th>
<th>$R_{L\text{ out}}$</th>
<th>$R_{L\text{ inside}}$</th>
<th>$\varepsilon_n$</th>
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<tr>
<td>PILKINGTON Suncool™ Brilliant 66/33</td>
<td>0.36</td>
<td>0.66</td>
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<td>PILKINGTON Suncool™ Brilliant 30/17</td>
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</table>
Self cleaning coatings

Pilkington Activ™

- Self Cleaning performance uses two properties
  - Hydrophilic water sheet action and
  - Photo decomposition of organic material

Properties reduce dirt build up and reduce the maintenance required
Pilkington Activ™

Changes in wetting properties with UV Exposure

Before UV Exposure

15 mins UV Exposure

30 mins UV Exposure

45 mins UV Exposure
Comparisons of Titania Coated and Float Glass
Resulting Reactions

\[ \text{O}_2 + e^- \rightarrow \text{O}_2^- \]

\[ \text{H}_2\text{O} + \text{H}^+ \rightarrow \text{OH}^* \]
Pilkington Activ™

Absorbance

Wavelength/nm

- CVD TiO2 film/glass
- Normal uncoated glass
Photocatalytic Effect

UV-Absorption

- $O_2^-$
- $OH^*$

H$_2$O + CO$_2$ ---> Organic Soil

SUN

TiO$_2$ - Layer
Barrier Layer
Glass
The photoactivity of the coating can be measured by monitoring the decomposition of a standard contaminant

- A thin film of stearic acid (~200Å) is applied from a methanol solution onto the coating
  - Stearic acid used as a typical organic contaminant
  - FTIR (Fourier transform infra-red spectroscopy) used to detect C-H stretch of stearic acid
  - C-H absorption intensity measured after varying UV exposure
Stearic Acid Decomposition

C-H Absorption Zero UV exposure

C-H Absorption ~60 mins UV exposure

UV 0.77W/m² @340nm
The coating’s **photoactivity** breaks down **organic** material reducing adherence of dirt to surface.

The coating’s **hydrophilic** action then helps to wash off the dirt.
Clear Float / Pilkington Activ™ Comparison