DuPont™ SentryGlas®:
Safety, design possibilities & efficiencies. Latest innovations and developments

Kamal Niazy

DuPont Glass Laminating Solutions

NewGlassTechnology
Where progress never stops

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Advances in Design with Laminated Glass

SentryGlas® interlayer

- Interlayer requirements: What do you need?
- Strength under loading
- Calculation methods
  - Approvals – France
- Post glass breakage - Overhead Glazing
- Fire performance – London underground testing
- Special applications - Cost saving with SentryGlas® interlayer
- Compatibility study with Dow Corning sealants
Interlayer Requirements for Architectural Glazing

What do architects & specifiers need?

- Safety: Safe breakage and fragment retention
- Enhanced impact performance; greater security from range of threats; e.g. severe weather and man-made threats
- More demanding strength/deflection performance both pre & post glass breakage
- Greater durability/lifetime demands
- High temperature performance
- Cost efficiency

Greater scope for using stiffer, tough structural polymers
Structural interlayers: What is different?
Viscoelastic Properties

**Standard test method for polymers**
(e.g. ASTM D 4065)

SentryGlas® is stiffer than PVB over a wide range of temperatures
Deflection Data for Laminated Glass

Laminates with SentryGlas® develop least deflection at a specified applied load – Note thickness differences

\[ \sigma_A = 2.38 \text{ MPa/s (~ 7 s ramp)} \]

Strong Coupling Effect by the stiff SentryGlas®
SentryGlas® interlayer for laminated glass

What does it mean - Higher strength

SentryGlas® provides a strong coupling effect of the glass panes.

- Larger spans
- Use of thinner glass

Thinner glass can translate to overall **lower cost**:

- Lower cost of glass
- Reduced framing costs
- Decreased installation costs

*DuPont™ Strength of Glass Calculator available free on the web (www.sentryglas.com)*
SentryGlas® Strength Approvals

- Laminate effective thickness method – Adopted by ASTM E1300-2009
- German Dibt Approval: product approval and coupling effect (2011)
- Nearly similar approach in the European Code DRAFT EN 13474 / WG8 with $\omega$ interlayer stiffness families + numerical approach with G modulus.

Interlayer Shear Modulus, $G$ (MPa)

<table>
<thead>
<tr>
<th>$G$</th>
<th>10^{-3}</th>
<th>10^{-2}</th>
<th>10^{-1}</th>
<th>10^0</th>
<th>10^1</th>
<th>10^2</th>
<th>10^3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h_{\text{eff,w}}$ (mm)</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ionoplast (SentryGlas(R) Plus)

PVB

JGJ 102 - 2003 Limit

$5 \text{ mm} / 0.76 \text{ mm} / 5 \text{ mm}$

$$h_{\text{eff,w}} = \sqrt[3]{h_1^3 + h_2^3} + 12\Gamma I_s$$

$$\Gamma = \frac{1}{1 + 9.6 \frac{EI_s h_v}{Gh_2^2 a^2}}$$

G – measure of shear transfer (0 $\rightarrow$ 1)

Use effective thickness in engineering formulae / analytical approach.
Document Technique d’Application

Référence Avis Technique 6/12-2086

Vitrage feuilleté
Limited glass
Texte en allemand

Vitrage feuilleté

SentryGlas®

Relevant de la norme | NF EN 14449

Titulaire : Société DuPont de Nemours (France) S.A.S
23/25 rue Delariviére Lefouillon-Défense 9
FR-92800 Puteaux
SentryGlas® French DTA approval

**Approach**

- Approval for wind, live and snow loads.
- Equivalent thickness method
- Maximum temp of SentryGlas® laminates is 80 °C (PVB 63 °C)
- Nearly “fully monolithic” behavior for wind loads
- Significant glass thickness reduction!
Overhead Impact Testing Program

Comparing laminates Structure with different interlayers

- **Monolithic**: 12mm FT (50KG @ room temp)
- **SentryGlas®**: 6mmFT/0.89mm SGP/6mmFT
- **PVB**: 6mmFT/1.52mm PVB/6mmFT
- **“Stiff” PVB**: 6mmFT/1.52mm Stiff PVB/6mmFT
- **EVA**: 6mmFT/1.52mm EVA/6mmFT

Tested Conditions:
- **50Kg** for Monolithic
- **100KG** for laminates dropped from **1.2 m** height at **50°C**

**Panel size: 1500mm x 1200mm**

Laminates resist impact and supports 100Kg for **15 mins**
Overhead Impact Testing Program

6 mm FT | 1.52 mm SentryGlas(R) | 6 mm FT - 50 kg / 1.2 m (Confidential)
Second Impact after all glass fractured
Conclusions – Overhead Glazing

- Impact test method simulates potential loading from installation and/or maintenance workers in distress
- Tempered glass provides no barrier to fall-through after breakage
- Standard PVB laminates constructions tested resisted impact at room temperature but only show limited retention capability under load and higher temperature
- Standard PVB, Stiff PVB and EVA laminates provide no barrier to fall-through after breakage at 50 °C
- SentryGlas® Ionoplast laminates provide impact resistance and stay in place after glass breakage under load up to 50 °C
- Proof testing of glazing designs should take into account the impact load, load duration and in service temperature
Planar™ | SentryGlas® System

- Significant post-fracture strength
- Temperature range
  -20°C to +55°C
  [-5°F to 130°F]
  50-60 Cycles
- 4, 6 & 8 fixings
- Size range tested
  1.8m x 3.6m
  [6ft x 12ft]
Structure: 88.4 SGP
Overhead: Bowling Green Subway Station Canopy

New-York, USA

Benefits:
- Post-glass breakage integrity
- Strength
- Proven durability / Open edges

Contractor W&W
System: Planar®
Laminator: Pilkington
SentryGlas®: Fire performance testing – London Underground (LU)

- Actual LU guidance: No laminated glass
- Behavior of laminated glass in fire situation
- Monolithic tempered glass issues:
  - Post breakage performance
  - Behavior under terrorist threat (blast)
- PVB toughened laminated glass improves performance
- SentryGlas® laminated glass required for optimum post breakage and high load performance
SentryGlas®: Fire performance testing – London Underground (LU)

- Research program by LU: Test laminated tempered glass reaction to fire
  - PVB: Meets standards
  - SentryGlas®: 8mm toughened/1.52mm SentryGlas®/8mm toughened
  - BRE Garston August 2013 – Completed and successful

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Test Standard</th>
<th>Result</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>BS 6853: Annex B.1- AMD 1</td>
<td>R 0.51</td>
<td>Toxicity (Y/N)</td>
</tr>
<tr>
<td>Test 2</td>
<td>BS 6853: Annex D 8.4 AMD 1</td>
<td>Ao (on) 0.17</td>
<td>Fume Density</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ao (off) 0.22</td>
<td></td>
</tr>
<tr>
<td>Test 3</td>
<td>BS EN 13823 (SBI)</td>
<td>Euroclass B-s1, d0.</td>
<td>Fire Resistance</td>
</tr>
<tr>
<td></td>
<td>BS EN 11925-2 Single flame source test</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BS EN13501-1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Approval: SentryGlas® was issued in October 2013 and added to the LU guideline
Special Applications with SentryGlas®

- SEFAR Architecture VISION Fabric Projects
- High temperature
- High UV Transmission SentryGlas®
SEFAR Architecture VISION Fabric

- High precision fabrics produced from synthetic fibers
- Different fabrics with a mesh opening of between 25% and 70%
- Metal coatings used: Aluminum, Chromium, Titanium and Gold, Aluminum/Copper alloy
- 1 or 2 sides visual aspect
- Proved compatibility with SentryGlas® interlayer.
Project: Headquarters Belarusian Potash Company

Minsk, Belarussia

Benefits:
- Structural
- Edge durability
- Transparency
- Post-glass breakage integrity
Project: Castellano 79 Business Center

Madrid, Spain

Benefits:
- Structural
- Edge durability
- Transparency
- Post-glass breakage integrity

Checkerboard effect created by alternating panels of clear laminated and aluminum metal coated panels on exterior façade of this project in Madrid
High Temperature performance
Project: Cleveland Clinic Abu-Dhabi

Benefits:
- Structural performance – High temperature
- Edge durability
- Transparency
- Post-glass breakage integrity

Laminator: White Aluminum
High Temperature performance
Project: Maroc Telecom

Rabat - Morocco

Benefits:
- Structural performance
- High temperature
- Edge durability
- Transparency
- Post-glass breakage integrity
**High UV Transmission SentryGlas®**

- Increases UV-Radiation transmittance
- For greenhouses, botanic gardens, or other special applications
- Similar mechanical properties versus standard SentryGlas®

![UV Light Transmittance Curves](image)

**Botanical Garden, Berlin**
High UV Transmission SentryGlas® Application

Bombay Sapphire Distillery – UK
Heatherwick Studio
Arup
Laminated glass with SentryGlas®: A cost competitive solution
Cantilevered Balustrade with Handrail- 3kN Line load

**Load Case**

Type A: Cantilevered Balustrade- With a handrail  
**Size:** 1500mm (W) x 1100mm (H)

**Support Conditions:**  
Glass uniformly bonded into rigid channel in accordance with BS6180-2011.

<table>
<thead>
<tr>
<th>Interlayer Type</th>
<th>Glass Specification- mm</th>
<th>Comparison of Glass thickness as a %</th>
<th>Peak Deflection - mm</th>
<th>Peak Stress N/mm²</th>
<th>Weight of Glass</th>
<th>Cost Comparison %</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVB</td>
<td>15 FT/1.52mm PVB/15 FT</td>
<td>125</td>
<td>13.73</td>
<td>33.44</td>
<td>130 KG</td>
<td>125%</td>
</tr>
<tr>
<td>SentryGlas®</td>
<td>12 HST/0.89 mm SGP/12 HST</td>
<td>100</td>
<td>13.38</td>
<td>32.87</td>
<td>105 Kg</td>
<td>100%</td>
</tr>
<tr>
<td>Monolithic</td>
<td>25mm</td>
<td>105</td>
<td>12.4</td>
<td>31.25</td>
<td>103 Kg</td>
<td>137%</td>
</tr>
</tbody>
</table>

3000N/m run uniform line load applied 100mm from FFL, with associated loads applied to the infill.

1500N/m² uniform load applied to the infill only.

1500N point load applied to the most onerous point anywhere on the barrier structure. The recommended size of the impactor is 25mm x 25mm.

**Maximum allowable deflection:** 20mm

Note these loads are not concurrent.
**Cantilevered Balustrade with Handrail - 1.5KN Line load; 1500N/m² uniform load, 1500N point load**

### Comparison Data

<table>
<thead>
<tr>
<th>Interlayer Type</th>
<th>Glass Specification- mm</th>
<th>Comparison of Glass thickness as a %</th>
<th>Peak Deflection - mm</th>
<th>Peak Stress N/mm²</th>
<th>Weight of Glass</th>
<th>Cost Comparison %</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVB</td>
<td>12 FT/1.52mm PVB/12 FT</td>
<td>120</td>
<td>13.07</td>
<td>25.68</td>
<td>105 KG</td>
<td>113%</td>
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<tr>
<td>SentryGlas®</td>
<td>10 HST / 0.89 mm SGP / 10 HST</td>
<td>100</td>
<td>11.74</td>
<td>23.91</td>
<td>87 KG</td>
<td>100%</td>
</tr>
<tr>
<td>Monolithic</td>
<td>19mm</td>
<td>95</td>
<td>14.7</td>
<td>27.78</td>
<td>78 Kg</td>
<td>107%</td>
</tr>
</tbody>
</table>

**Cantilevered Balustrade with Handrail - 0.74KN Line load; 1000N/m² uniform load, 500N point load**

### Comparison Data

<table>
<thead>
<tr>
<th>Interlayer Type</th>
<th>Glass Specification- mm</th>
<th>Comparison of Glass thickness as a %</th>
<th>Peak Deflection - mm</th>
<th>Peak Stress N/mm²</th>
<th>Weight of Glass</th>
<th>Cost Comparison %</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVB</td>
<td>10 FT/1.52mm PVB/10 FT</td>
<td>125</td>
<td>11.31</td>
<td>18.43</td>
<td>87 KG</td>
<td>97%</td>
</tr>
<tr>
<td>SentryGlas®</td>
<td>8 HST / 0.89 mm SGP / 8 HST</td>
<td>100</td>
<td>11.58</td>
<td>18.72</td>
<td>72 KG</td>
<td>100%</td>
</tr>
<tr>
<td>Monolithic</td>
<td>15mm</td>
<td>93</td>
<td>13.87</td>
<td>21.12</td>
<td>62 Kg</td>
<td>75%</td>
</tr>
</tbody>
</table>
Freestanding glass barrier
Tested To BS6180:2011
Ref: CRLTL0001

Components
Clamping rail: C.R.L TAPERLOC® L68S10D (surface mounted aluminium base shoe profile).
Glass: 17.5 mm laminated toughened glass comprising of 2 plies of 6 mm toughened glass laminated with a 1.52 mm DuPont SGP interlayer.
TAPERLOC® wedges
Handrail: Spaced at 230 mm centres
Continuous (as described in BS 6180:2011)
Top rail continuously seated, or through glass fixed rail with minimum two connector brackets per pane not more than 1000 mm apart.

Intended load resistance:
0.74 kN/m line load, 0.5 kN/m concentrated load, 1.0 kN/m2 uniform load.

Test sample
Pane size 1100 mm wide x 1195 mm high.
Clamping rail position Bottom edge of profile installed at finished floor level.
Load application 1100 mm above finished floor level.

Test results

<table>
<thead>
<tr>
<th>Load</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.74 kN/m line load applied across whole width of pane</td>
<td>Deflection 14.1 mm</td>
</tr>
<tr>
<td>0.5 kN concentrated load applied at centre of width of pane</td>
<td>Deflection 9.1 mm</td>
</tr>
<tr>
<td>1.11 kN/m line load applied across whole width of pane</td>
<td>No failure, no permanent distortion</td>
</tr>
<tr>
<td>0.75 kN concentrated load applied at centre of width of pane</td>
<td>No failure, no permanent distortion</td>
</tr>
</tbody>
</table>

Range of applicability
Suitable for any pane width greater than 450 mm, provided there is a continuous handrail.
Suitable for pane heights up to 1500 mm above finished floor level, subject to a wind load resistance check if used externally.

Usage constraints
Not appropriate if mounted with the top edge of the clamping rail more than 60 mm below finished floor level.
LT190X TAPERLOC® wedges installed at 230 mm are required to meet the BS6180:2011 loadings.

Signed

John Bernard Colvin M.A. (Cantab.)
Glass Consultant
Dow Corning® Sealants
SentryGlas® Interlayer

Compatibility tests

Completed september 2013
1. Dow Corning Lab’s Standard Compatibility Test
   1.1 Description
   1.2 Process
   1.3 Results with SentryGlas® – Dupont
   1.4 Comment

2. Compatibility Test Following IFT Guideline
   2.1 Process Reference
   2.2 Process 4.1 – Time line and Progress
   2.3 Process 4.2 – Time line and Progress
   2.4 Testing Method

3. Results

4. Conclusion
1. Dow Corning® Lab’s Standard Compatibility Test

1.1 Description: qualitative test of chemical compatibility

- Special coating and all other material: Setting Blocks, Tape, Gasket, Backer Rod, Comp. Sealant

- Ageing: 21 days under UV exposure (direct and indirect) following ETAG

- Check of the adherence on glass, with extra material, change of color, apparition of bleeding

> Approval to use the interlayer in contact with our Sealant

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1.2 Process: Modified ASTM C1087 or ETAG 002 Paragraph 5.1.4.2.5.

3 days curing

21 days in UV Exposure
  UVA and UVB
  Max 50°C

Application Ageing Start Testing

(1) According to Modified ASTM C1087 or ETAG 002 Paragraph 5.1.4.2.5. – Dow Corning COOL project number 12-6710 sample number 28346 - 2013
### 1.3 Results with SentryGlas® - Dupont:

<table>
<thead>
<tr>
<th>Sealant</th>
<th>Yellowing (Y/N)</th>
<th>Bubbles (Y/N)</th>
<th>Adhesion on interlayer (Y/N)</th>
<th>Adhesion on edge of glass (% CF/% AF)</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dow Corning® 993</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>70% Cohesive / 30% Adhesive Failure</td>
<td>Good Compatibility</td>
</tr>
<tr>
<td>Dow Corning® 994</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>70% Cohesive / 30% Adhesive Failure</td>
<td>Good Compatibility</td>
</tr>
<tr>
<td>Dow Corning® 895</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>70% Cohesive / 30% Adhesive Failure</td>
<td>Good Compatibility</td>
</tr>
<tr>
<td>Dow Corning® 995</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>70% Cohesive / 30% Adhesive Failure</td>
<td>Good Compatibility</td>
</tr>
<tr>
<td>Dow Corning® 3362</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>70% Cohesive / 30% Adhesive Failure</td>
<td>Good Compatibility</td>
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<tr>
<td>Dow Corning® 3362-HD</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>70% Cohesive / 30% Adhesive Failure</td>
<td>Good Compatibility</td>
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<tr>
<td>Dow Corning® 791</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>50% Cohesive / 50% Adhesive Failure</td>
<td>Good Compatibility</td>
</tr>
<tr>
<td>Dow Corning® 791-T</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>100% Cohesive Failure</td>
<td>Good Compatibility</td>
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<tr>
<td>Dow Corning® 757</td>
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<td>100% Adhesive Failure</td>
<td>Good Compatibility</td>
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<tr>
<td>Dow Corning® 756-SMS</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>100% Cohesive Failure</td>
<td>Good Compatibility</td>
</tr>
</tbody>
</table>

### 1.4 Comment:

Loss of adhesion on the edge of the glass is due to the nature of the glass and not due to the chemistry of interlayer.

Edge of the glass is sandblasted. No good adhesion on that surface.
2. Compatibility Test Following IFT Guideline (2)

2.1 Process Reference: ift-GUIDELINE DI-02engl/1 (May 2009) § 4.1 and 4.2

4.1: Test Methods applying contact material to glazing rebate without UV radiation

- 3 samples by sealant + 1 without application, 21 weeks ageing in oven at 60°C, testing every 7 weeks

4.2: Test method for contact material applied to weather sealing fully exposed to weathering

- 3 samples by sealant + 1 without application, 7 weeks ageing in climatic chamber 58°C – 95% Humidity and 14 weeks ageing in UV exposure, testing every 7 weeks

Blank test common to both method: 1 sample by sealant + 1 without application, no ageing

2.2 Process 4.1 - Timeline and Progress

- Ageing Start 05/04
- Evaluation & Restart 24/05
- Evaluation & Restart 12/07
- Last Evaluation 30/08
2. Compatibility Test Following IFT Guideline

2.3 Process 4.2 - Timeline and Progress

<table>
<thead>
<tr>
<th>Ageing Start 03/04</th>
<th>7 Weeks 58°C / 95% h°</th>
<th>Evaluation &amp; Restart 22/05</th>
<th>7 Weeks UV Exposure UVA and UVB - Max 50°C</th>
<th>Evaluation &amp; Restart 10/07</th>
<th>7 Weeks UV Exposure UVA and UVB - Max 50°C</th>
<th>Last Evaluation 28/08</th>
</tr>
</thead>
</table>

2.4 Testing Method

Visual assessment subsequent to all test methods described. The percentage of the damaged edge (GK) is expressed by the following equation in % of the total length of the respective edge.

For autoclaved edge (long): \[ GK = \frac{x_1 + x_2 + \ldots + x_n}{L} \times 100\% \]

For cut edge (short): \[ GK = \frac{x_1 + x_2 + \ldots + x_n}{K} \times 100\% \]

X is the diameter of the bubbles.
L is the length of autoclaved edge (long)
K is the length of cut edge (short)
2.4 Testing Method

Fig. 4 Sketch to assess laminate changes

© IFT Rosenheim
### 2.4 Testing Method

<table>
<thead>
<tr>
<th>Time in h</th>
<th>Edge K</th>
<th>Edge L</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$e_{\text{max}}$ in mm</td>
<td>$e_m$ in mm</td>
<td>$x_{\text{max}}$ in mm</td>
</tr>
</tbody>
</table>

Following all exposures, a maximum penetration depth between approximately 1cm is permitted, if test and inspection show a stagnation of changes/migrations between the 1st, 2nd and 3rd assessment.

This include all changes such as bubble formation, clouding, discoloration. Complete delaminations over the entire surface are excluded.
### 3. Results

#### Oven 60°C

<table>
<thead>
<tr>
<th>Sealant</th>
<th>Sample</th>
<th>After 7 weeks</th>
<th>After 14 Weeks</th>
<th>After 21 Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank</td>
<td>1</td>
<td>Nothing to report</td>
<td>Nothing to report</td>
<td>Nothing to report</td>
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<tr>
<td>Dow Corning® 993</td>
<td>2</td>
<td>Nothing to report</td>
<td>Nothing to report</td>
<td>Nothing to report</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Nothing to report</td>
<td>Nothing to report</td>
<td>Nothing to report</td>
</tr>
<tr>
<td>Dow Corning® 994</td>
<td>1</td>
<td>Nothing to report</td>
<td>Nothing to report</td>
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<tr>
<td></td>
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<tr>
<td>Dow Corning® 995</td>
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</tr>
<tr>
<td></td>
<td>3</td>
<td>Nothing to report</td>
<td>Nothing to report</td>
<td>Nothing to report</td>
</tr>
<tr>
<td>Dow Corning® 3362</td>
<td>1</td>
<td>Nothing to report</td>
<td>Nothing to report</td>
<td>Nothing to report</td>
</tr>
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</tr>
<tr>
<td></td>
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#### 58°C / 95% h° UV Exposure

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After following IFT guideline test for lamination foil and Dow Corning compatibility test, no negative effect of the SentryGlas® interlayer and on the silicone sealant has been observed. Additionally, no delamination of the SentryGlas interlayer has been observed.
Thank you!

The miracles of science™