Alternative glazing

Hard coated polycarbonate for automotive applications

Automotive glazing represents a significant high volume application opportunity for thermoplastic materials. Specifically, the use of polycarbonate can provide benefits such as vehicle weight reduction, occupant containment and design flexibility. According to the author, polycarbonate has superb impact resistance, optical clarity and the processing benefits of thermoplastic, but lacks abrasion, solvent and weathering performance. However, it has been shown that solution applied silicone-based hardcoats and plasma deposited inorganic coatings can overcome some of these problems. The test data and real life performance of these applications are presented in this article, as they apply to automotive glazing requirements.

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Introduction

Hard coating polycarbonate has been used in a variety of vehicle and architectural applications for the past 20 years.\(^1,2\) These include windows for buses and trains, police and forestry vehicles, targa tops, pillar posts and head lamp lenses. Occupant safety, vehicle security, styling and weight reduction are the key drivers for the use of thermoplastic polymeric

<table>
<thead>
<tr>
<th>#</th>
<th>Test</th>
<th>Requirement</th>
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<tbody>
<tr>
<td>2</td>
<td>Transmittance</td>
<td>&gt; 70%; &lt; 5% ΔT after Test 16</td>
</tr>
<tr>
<td>10</td>
<td>Dart Impact</td>
<td>200g/6 ft.; no large fragments</td>
</tr>
<tr>
<td>13</td>
<td>Ball Impact</td>
<td>225g/6 ft.; no hole or large fragments</td>
</tr>
<tr>
<td>16</td>
<td>Weathering</td>
<td>Carbon Arc, 63°C/water spray, 1,000 hours</td>
</tr>
<tr>
<td>17</td>
<td>Abrasion Resistance</td>
<td>&lt; 15% ΔHaze @ 100 cycles</td>
</tr>
<tr>
<td>19</td>
<td>Chemical Resistance</td>
<td>Kerosene, alcohol, gasoline, washer fluid</td>
</tr>
<tr>
<td>20</td>
<td>Chemical Resistance (stressed)</td>
<td>Kerosene, alcohol, gasoline, washer fluid</td>
</tr>
<tr>
<td>21</td>
<td>Dimensional Stability</td>
<td>&lt; 0.05 warpage; 23°C/71°C; humidity</td>
</tr>
<tr>
<td>24</td>
<td>Flammability</td>
<td>&lt; 3.5”/min. burn rate; self-extinguishing</td>
</tr>
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</table>

FMVSS205/ANSI Z26. 1 Item 4 test requirements
The use of a hard coat is necessary for improving the durability of the thermoplastic materials. Thermally cured silicone hard coats have been found to perform best. Soft coatings can lead to material failure, whereas hard coats can provide an extended service life. The automotive glazing requirements for hard coated polycarbonate are covered in Table 1. The requirements, however, are the minimum set by the US government and although may be sufficient for some applications, thermoplastic glazing will need to satisfy more stringent requirements set by the OEMs and consumers. In this article, the performance of hard coated polycarbonate in areas such as impact, abrasion resistance, weathering and solar transmittance are described.

**Impact resistance**

The impact resistance of hard coated polycarbonate is well known and it is demonstrated in Figure 1 for a 0.25-inch thick specimen, using a 5 lb, 1-inch diameter steel dart.

In addition, the impact performance does not seem to change over time. Similar impact results were obtained for hard coated polycarbonate that was used as side glazing in a riot control vehicle by the Dutch police for 16 years, when compared to new material (Table 2). In all cases the failures were ductile. The impacted parts were 0.18-inch thick.

**Abrasion resistance**

The abrasion resistance of hard coated polycarbonate is compared to glass in Tables 3 and 4. In Table 3, the abrasion was tested using a Taber abrader with CS10F wheels and 500g weights, according to ASTM procedure D1044. After 1,000 cycles, the change in percent haze was approximately 1.0 for the glass and 6-10 for the hard coated polycarbonate. The hard coated polycarbonate performed better than glass during the falling sand test (ASTM D673) and similarly during a self-designed brush test. Similar abrasion performance to glass was also seen during a GM specified test. This test simulates the abrasion resistance of a substrate to car wash brushes after a number of years. As seen in Table 4, the polycarbonate performed very well in this test with a minimum increase in the percent haze after a 10 year equivalent test period.

**Current performance**

**Abrasion resistance**

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**Abrasion resistance similar to glass**

Similar abrasion performance to glass has been achieved by depositing a SiO₂ coating by plasma-enhanced chemi-
cal vapour deposition (PECVD) on top of the silicone hard coat. The SiO₂/silicone hard coat/polycarbonate system had improved weathering, water immersion and thermocycling and abrasion performance. However, due to the slow deposition rates this option is not economically attractive for automotive glazing applications at the present. Future research must be directed at processes that can uniformly deposit the SiO₂ coating at rates in excess of 1 µm/min over large surface areas.

Weathering
The weathering performance of hard coated polycarbonate can be seen in Table 5. The results, after 3 years exposure at 45 degrees facing south in Florida and Arizona show adequate performance for the polycarbonate. We do know that hard coated polycarbonate fails between 4 and 5 years in Florida by coating delamination and efforts are currently under way in increasing the life of the hard coat. Studies to establish a correlation between real world life expectancy and Florida and Arizona exposures for hard coated polycarbonate are currently under way.

Solar transmittance
The solar transmittance of hard coated polycarbonate was evaluated in the 300 to 2,500 nm range using a global air mass of 1.5. The results for two 4.0 mm thick hard coated polycarbonate samples, colour matched to two 4.0-mm-thick automotive glasses are presented in Table 6. Hard coated polycarbonate has low transmission in the UV range (<400 nm) and high transmission in the visible region (400-700 nm). Since polycarbonate absorbs most of the UV light, it will protect the interior of the vehicle from deterioration. Also, its high transmission in the visible range will benefit the driver’s visibility. Work is in progress to minimise the transmittance of hard coated polycarbonate in the IR (>700 nm) region.

Conclusion
Hard coated polycarbonate can be used in certain automotive glazing applications at present. Its impact resistance, styling flexibility, light transmittance properties and light weight are all beneficial to the OEMs. However, in order for the thermoplastic glazing to increase its presence in automotive applications, technology developments in improving the abrasion resistance and weathering of the hard coats as well as more efficient processes for applying the hard coats and producing the parts will be necessary. Total system design is important in addressing polycarbonate’s lower modulus and its higher impact resistance than glass in glazing applications.

Retrofitting vehicles with thermoplastics glazing and collecting real world data will be the best way for understanding the performance of these systems and their advantages and disadvantages compared to glass.

References

This paper was first presented at the 29th “ISATA” Conference held in Florence, Italy, from 3 - 6 June 1996.