High Tg Polyamide Overmolding Resins with Continuous Glass Fiber Reinforced Thermoplastic Sheet*: Composite Solutions Providing Improved Stiffness, Less Weight, and Less Design Space

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*Vizilon™ Thermoplastic Composites
Background: DuPont’s introduction of Vizilon™ Thermoplastic Composite offering

Structural materials
- PA66 to PPA
- Over-injection grades
- Continuous Glass Reinforced Sheet
- Formulated for a robust process window
- MSDS + Data sheets

Design & FEA approach
- Conceptual and quantitative design support
- Comprehensive material data
- License to validated FEA methodology
- Design Guide
- Assembly Guide

Processing support
- DuPont commercial scale moulding cell
  - Insert stamp-forming
  - Over-injection
- Customer process support – plant layout, operation
- Processing Guide

Facilitate supply chains
- OEMs/Tier 1s, processors, equipment
Vizilon™ TPC: Combining materials for processing flexibility

Structural inserts
- Textile sheet
- Random core
- PA-Random
- UD bar/tape

Preforming
- Stamping
  - shell structure
  - low pressure
- Co-compression
  - thickness variations
  - shear edge tool
  - net shape

Over-moulding
- Over-injection moulding, (2 step)
  - pre-compounded pellets
  - tuned for process
- Forming & Over-injection / Compression moulding, (1 step)
  - pre-compounded pellets
  - tuned for process

Red = sheet
Blue = over-inject
“Most automotive applications are initially dominated by Stiffness / NVH (Noise, Vibration, Harshness) requirements”

Chrysler Light Weighting Expert

Materials Trilemma® Example

- Bending Stiffness $\approx E \times I$
- Torsional Stiffness $\approx G \times J$
- Modal Analysis $\approx \sqrt{K/m_e}$

…. increase the modulus of the material, lower the density while minimizing the cost impact. Challenging!
One of the performance challenges for thermoplastic glass fiber laminate + overmolding resin composite is meeting stiffness requirements for automotive applications at elevated temperature.

Typically, 90°C testing for automotive components such as a cross car beam, lift-gates, seating, etc.

This overview will review properties of high glass transition temperature (Tg) PPA resins, and their use as an overmolding resin with stamped continuous glass fiber polyamide inserts.
What is a High Tg PPA?

• PPA’s are high performance polyamides are partially aromatic nylons. Tg (glass transition temperature) of PPA’s varies with the formulation.

• DuPont has Zytel® HTN PPA resins with Tg >100°C after moisture conditioning.

![Polyamide Diagram]

(high Tg resin’s)
Tg (glass transition temperature) effects stiffness of the polymer versus temperature
Machined Material Properties Measured

Shear testing

Testing, tension & compression

Shear samples 90°

tension/compression 0°

tension/compression 90°

shear 0°
# Machined Material Properties Measured

At 90°C, 50% GR PPA is almost twice the bending stiffness of 50% GR PA66.

![Image of machined material properties](image)

<table>
<thead>
<tr>
<th>Name</th>
<th>2-2 63% GR TPC Sheet @ 1.5mm thickness</th>
<th>2-2 75% GR TPC Sheet @ 1.5mm thickness</th>
<th>50% GR PA66 Overmolding Resin</th>
<th>50% GR PPA Overmolding Resin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>Tension</td>
<td>Tension</td>
<td>Tension</td>
<td>Tension</td>
</tr>
<tr>
<td>Temperature (Deg C)</td>
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<td>Mat Direction</td>
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<tr>
<td>Density (SG)</td>
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<td>1.98</td>
<td>1.57</td>
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<tr>
<td>Modulus (GPa)</td>
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<td>22.5</td>
<td>5.7</td>
<td>10.3</td>
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<tr>
<td>Comp. Tension Modulus (GPa)</td>
<td>20.9</td>
<td>24.8</td>
<td>5.9</td>
<td>10.6</td>
</tr>
<tr>
<td>Shear Modulus (GPa)</td>
<td>0.5</td>
<td>0.6</td>
<td>0.9</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Note: 50% GR PA66: DuPont Vizilon™ P50G1 50% GR PPA: DuPont Vizilon™ P50G4 2-2 63% GR TPC PA66 Sheet: DuPont Vizilon™ SB63G1-T1.5 2-2 75% GR TPC PA66 Sheet: DuPont Vizilon™ SB75G1-T1.5
50% GR Polyamide 66 and PPA Overmolding Resins

Tensile Modulus (GPa)  
23°C vs 90°C

- **50% GR PA66 @23C**: 8.2 GPa
- **50% GR PA66 @90C**: 5.7 GPa
- **50% GR PPA @23C**: 12.1 GPa
- **50% GR PPA @90C**: 10.3 GPa

*Moisture Conditioning*
Accelerated conditioned (70°C, 62%RH) with a 21 day lab soak. Samples are accelerated conditioned and left to rest in a lab with conditions set to 50%RH/23°C for 21 days before testing.
PA66 Continuous Glass Fiber Sheet (63% and 75% by weight)

*Moisture Conditioning
Accelerated conditioned (70°C, 62%RH) with a 21 day lab soak. Samples are accelerated conditioned and left to rest in a lab with conditions set to 50%RH/23°C for 21 days before testing.

Continuous glass reinforced sheet is more consistent in stiffness versus temperature
PPA’s have very low moisture growth (< .001 mm/mm) that make these resins suitable for large structural applications such as an inner panel for a lift-gate.
Cross-member analysis example

Gray - Base material
(75% GR TPC sheet)

Red – Over molding
(50% GR PA66 or 50% GR PPA)

TPC sheet thickness = 1.5mm
Overmolding resin thickness of 1.5 mm
Boundary Conditions

1st and 2nd Natural Frequencies

Moment Applied

Fixed

Vertical Force

Free – Free conditions

All Tests done at 90°C

All Tests done at 90°C

Torsional Stiffness

Bending Stiffness

Fixed

Fixed

DuPont
Results (Bending and Torsional Stiffness)

Use of a high Tg 50% GR PPA overmolding resin improves bending stiffness by 16% and torsional stiffness by 49% as compared to a 50% GR PA66.
Overmolded Beam Testing

- Two combinations of materials were evaluated by using the 3 Point-Bending Test:

  - 2-2, 63% GR TPC PA66 sheet over-moulded with 50% GR PA66*
    (PA sheet over-moulded with PA66 resin)
  - 2-2, 63% GR TPC PA66 sheet over-moulded with 50% GR PPA*
    (PA sheet over-moulded with PPA resin)

- 2-2, 63% GR TPC PA66 is a heat stabilized, 2-2 Twill Weave Glass Fabric reinforced polyamide based thermoplastic composite sheet.

These tests were performed to see if a difference in terms of performance could be observed between 50% GR PA66 and 50% GR PPA over-molding resins.
DuPont Testing on Vizilon™ over-molded TPC “beam” part

- Test: 3-Point-Bending
- Part: “DuPont” beam (stamped and over-moulded)

- Beam state: conditioned for 2-3 weeks (70°C/62%RH) + 1 week (23°C/50%RH)
- Boundary conditions: Free-Free Mode (unconstrained) to emphasize OM resin effect
- Test temperature: 23°C / 90°C  Test speed: 0.2 inch/min | 3 repeats

* dimensions in mm
50% GRPA66 and 50% GR PPA as overmolding resin

Average curves - Free-Free boundary condition
Test temperatures: 23°C - 90°C

2-2 63% GR TPC PA66 Sheet overmolded with 50% GR PPA @ 23°C

2-2 63% GR TPC PA66 Sheet overmolded with 50% GR PA66 @ 23°C

2-2 63% GR TPC PA66 Sheet overmolded with 50% GR PPA @ 90°C

50% GR PA66: DuPont Vizilon™ P50G1
50% GR PPA: DuPont Vizilon™ P50G4
2-2 63% GR TPC PA66 Sheet: DuPont Vizilon™ SB63G1-T1.5
2-2 75% GR TPC PA66 Sheet: DuPont Vizilon™ SB75G1-T1.5
50% GR PA66 and 50% GR PPA as overmolding resin

Average curves - Free-Free boundary condition
Test temperatures: 90°C

= 28% stiffness improvement
Observation/Summary

- Beams over-moulded with high Tg PPA are stiffer than PA66 over-moulded beams @ 23°C

- At 90°C, behaviour of high Tg PPA over-moulded beams is almost equivalent to those over-moulded with PA66 at 23°C

- At 90°C, 28% stiffness improvement with high Tg PPA overmolding

- At 90°C, PPA over-moulded beams absorbed around 30% more energy than PA6.6 over-moulded beams.

- Higher stiffness solution will allow use of less design space or a design with less weight
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