Global challenges
Environmental Regulations (Reduced CO₂-Emissions)

Global standards for CO₂ emissions

Stricter Laws require More Efficient Cars.
CO₂ Regulations Become Stricter Year by Year Globally.
Improving Fuel Economy by Reducing Weight

EU: CO₂-emissions to vehicle weight

About 10 g/km Less CO₂-Emissions per 100 Kilogram Weight Reduction
Ways of Reducing CO₂ Emission in Cars

Source: Engineered Materials (EM) Identification of external growth opportunities in the Automotive Sector, Roland Berger Strategy Consultants

*ICE=Improvements of diesel and gasoline engines
Lightweight Construction
Potential Material Selection

- Glass fiber vs. carbon fiber
- Talc filler vs. GF vs. nature fiber
- Composites/tapes reinforcement
- Short fiber vs long fiber
- Fiber content reduction
- Chemical foaming
- Polymers
  - Fiber length/content
  - Processing
- Thin Wall/High flow technology
- Microspheres*
- Physical foaming
- Metal replacement
- PC/ABS (colored parts) vs. PP LGF mold in color
- PA sGF replacement
- Metal replacement

*Currently not offered/supported by Celanese
<table>
<thead>
<tr>
<th>Solution</th>
<th>Function/place</th>
<th>Application</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hostaform® POM</td>
<td>Fuel contact, Interior, Visible</td>
<td>Fuel filler neck, Door handle, Loudspeaker grill, wiper</td>
<td>Resistable to fuels, Hard and stiff, surface</td>
</tr>
<tr>
<td></td>
<td>components</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Celanex® PBT</td>
<td>E/E, Visible components</td>
<td>Sensor housing, transmission housing, Connectors, Air inlet grill</td>
<td>stiff, good electrical properties, surface</td>
</tr>
<tr>
<td>Celstran® LFT PP</td>
<td>Interior, Exterior, Structural</td>
<td>Door modules, Frame for sun roof, Instrument panel carrier, Front end module</td>
<td>Functional integration, stiffness, high dimension stability</td>
</tr>
<tr>
<td>Celstran® LFT PA</td>
<td>components</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Celstran® CFR-TP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fortron® PPS</td>
<td>Engine compartment</td>
<td>Waterpump, Parking brake, Intake manifold, Thermostat housing</td>
<td>Temperature and chemical resistance</td>
</tr>
<tr>
<td>Vectra® LCP</td>
<td>Lighting, Sensor System</td>
<td>Lamp socket, MID -Sensors</td>
<td>Temperature resistance, Electrical properties, easyflowing</td>
</tr>
<tr>
<td>CoolPoly</td>
<td>Lighting, Sensor System</td>
<td>Heat sinks</td>
<td>Thermoconductivity</td>
</tr>
</tbody>
</table>
Lightweight Construction
Potential Material Selection

Glass fiber vs. carbon fiber
Talc filler vs. GF vs. nature fiber

PC/ABS (colored parts) vs. PP LGF mold in color
Short fiber vs long fiber

Metal replacement
Fiber content reduction

PA sGF replacement

Thin Wall/High flow technology

Chemical foaming

Application Examples

Composites/tapes reinforcement

Polymers

Fiber length/content

Processing

Microspheres*

Physical foaming

*Currently not offered/supported by Celanese
Potential Material Selection

- Composites/tapes reinforcement
- Short fiber vs long fiber
- Fiber content reduction

*Currently not offered/supported by Celanese*
Case Study
Glass content Reduction with PP-LFT (I)

Instrument Panel

Glass content change PP GF 30 (density 1.12 g/cm³) to PP GF 20 (density 1.02 g/cm³)

Concentrates offer flexibility on tailoring the let downs of the part and cost advantages

Per part 10 % material costs savings

<table>
<thead>
<tr>
<th>Tensile strength @ 23°C</th>
<th>Elongation@ break @ 23°C (%)</th>
<th>Tensile modulus @23 °C (Mpa)</th>
<th>Charpy impact Strength (23°C) kJ/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS PP-GF20*</td>
<td>80</td>
<td>2.6</td>
<td>4500</td>
</tr>
<tr>
<td>CS PP-GF30*</td>
<td>100</td>
<td>2.7</td>
<td>5500</td>
</tr>
</tbody>
</table>

*Concentrate blended down with Neat PP

Possible weight reduction via glass content 10%
Charpy notched Impact Strength PP-GF30 blended (molding T 250°C)

When reducing the glass content combining concentrates and neat PP, there is no influence of melt temp. on Impact Strengths.
Combination of Celstran® LFRT and Celstran® CFR-TP tapes

Feasibility with Under Body Cover, Fraunhofer ICT

- PP-LGF20
- oXeon TeXtreme
- FIBERFORGE
- Celstran® PP-GF40 + neat PP
- Celstran® CFR-TP PP-GF7O
- Tailored Blank Celstran® CFR-TP PP-GF7O

![Graph showing normalized impact energy at maximum force for different material combinations.]

- 3.0 mm PP/GF30
- 2.5 mm PP/GF30 LFT + 0.5 mm PP/GF70 UD-Tape (0°/90°)
- 2.0 mm PP/GF30 LFT + 1.0 mm PP/GF70 UD-Tape (0°/90°)
CFR-TP can offer higher e-module than metal at proportional price
CFR-TP offers higher strength than metal at a lower price
Lightweight Construction with Engineered Materials Portfolio

Potential Material Selection

- Thin Wall/High flow technology
- Microspheres*
- Physical foaming
- Chemical foaming

* Currently not offered/ supported by Celanese
Physical Foaming
Gas injection with N2 or CO2

The same process as conventional injection molding, gas N2 or CO2 will be injected as shown on the picture.

Additional equipment for dosing and adding the gas will be needed.
Chemical Process

1-2% Chemical blowing agent Masterbatch + Celstran® LFT

- the same process as conventional injection moulding process with additional gravimetric dosing system for chemical blowing agent
- Nozzle with valve gate is necessary
- Adjustment of the process parameters

Source: Altstädt, Volker; Mantey, Axel: Thermoplastschaumspritzgießen, Carl Hanser Verlag, München (2011)
Advantages foam process vs. standard

- Distinct cycle time reduction
- Weight reduction
- Lower energy costs
- Excellent dimensional stability
- Clamping force reduction
- Better sound dampening

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-30% cycle time reduction vs. solid</td>
<td>12-30% cycle time reduction vs. solid</td>
</tr>
<tr>
<td>8-10% vs solid molded (2-2,5 mm)</td>
<td>8-10% vs solid molded (2-2,5 mm)</td>
</tr>
<tr>
<td>50 % energy costs at injection phase</td>
<td>50 % energy costs at injection phase</td>
</tr>
<tr>
<td>Reduction of shrink marks and warpage</td>
<td>Reduction of shrink marks and warpage</td>
</tr>
<tr>
<td>Reduction of Clamp Force approx. 50 %</td>
<td>Reduction of Clamp Force approx. 50 %</td>
</tr>
</tbody>
</table>

- Furthermore foam process is applicable currently for structural parts.
- Appearance parts are under development to achieve a better surface.
- Topographical design possible.
Comparison of Celstran® PP-GF20, 2,5 mm Plates

<table>
<thead>
<tr>
<th></th>
<th>Flexural modulus</th>
<th>Flexural strength</th>
<th>Charpy impact strength 23°C</th>
<th>Charpy impact strength t 23°C</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit</strong></td>
<td>MPa</td>
<td>MPa</td>
<td>kJ/m²</td>
<td>kJ/m²</td>
<td>gr</td>
</tr>
<tr>
<td>Solid</td>
<td>2915</td>
<td>69</td>
<td>58</td>
<td>46</td>
<td>275</td>
</tr>
<tr>
<td>Mucell</td>
<td>2,973</td>
<td>64</td>
<td>52</td>
<td>38</td>
<td>243</td>
</tr>
<tr>
<td>Chemical</td>
<td>2,748</td>
<td>59</td>
<td>52</td>
<td>35</td>
<td>241</td>
</tr>
</tbody>
</table>

* All plates were molded on a MuCell LFT screw

Possible weight reduction according plate samples via foaming around 10%, in parts around 8%
Investment for Mucell

► Phase 1: Application of design guidelines for conventional injection molding
► Phase 2: Application of conventional part design guidelines, but with adopted mold layout for foaming
► Phase 3: Get full use of additional design freedom

Payback Scenario for Phase 2
(Center Console Backbone)

Payback Scenario for Phase 3
(Center Console Backbone)

Source: Economic Evaluation of MuCell® Parts, Cost Calculation and Return on Invest, Trexel Presentation, held in Apr. 22nd+23rd, 2015, in Warwick (UK)
Case Study
Physical Foaming with POM

Door lock housing (others instrument panel, seat panel etc)

- Weight reduction over 10 %
- Cycle time reduced around 15 %
- Process optimization by TechService
- Low warpage & light weight achieved via MuCell

Possible weight reduction via physical foaming over 10 %
Possible weight reduction via high flow/ thin wall technology around 20%

Door Modules / Instrument Panel

Potential Example
High Flow/ Thin Wall (1,8mm) with PP-LFT

Weight reduction over 20 %
Production cost down due to significant higher run-rate

< 1,8 mm wall thickness
Potential Example
High Flow/ Thin Wall (1,8mm) with PP-LFT

<table>
<thead>
<tr>
<th>Material</th>
<th>Tensile strength</th>
<th>E-Modulus</th>
<th>Elongation @ break</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP-GF30</td>
<td>120</td>
<td>7100</td>
<td>2.5</td>
</tr>
<tr>
<td>PP-GF30 High flow</td>
<td>109</td>
<td>6911</td>
<td>2.37</td>
</tr>
<tr>
<td>PP-GF30 high flow HF003 blended</td>
<td>111</td>
<td>6927</td>
<td>2.34</td>
</tr>
</tbody>
</table>

Spiral Flow (mm), wall thickness 2 mm

Possible weight reduction via high flow/ thin wall technology around 20%
Lightweight Construction
Potential Material Selection

- Glass fiber vs. carbon fiber
- Talc filler vs. GF vs. nature fiber
- PC/ABS (colored parts) vs. PP LGF mold in color
- Metal replacement
- PA sGF replacement

Potential Material Selection

* Currently not offered/ supported by Celanese
Case Study
Metal replacement with PPS

Charge air pipe for turbo charger

Fortron® PPS replaces aluminium

More than 40 % weight and 25 % cost reduction by replacing aluminium and optimizing production process: extrusion blow molding and assembly injection molding
Case Study
Metal replacement with Celstran® LFRT

Door module
Steel

Celstran® PP

Weight reduction via metal substitution and integration: about 8 kg
Possible weight reduction via PA-sGF with PP-LFT around 20%
Case Study
PC/ABS Replacement with PP-LFT (I)

Overhead Console

Celstran® is about 20% lighter as PC-ABS

Density PP-GF20 1.02
Weight reduction around 20 %
Better impact behaviour to PC/ABS
**Case study**
PC ABS replacement with PP-LFT(II)

**Celstran® PP-GF30 versus PC-ABS GF10**

Penetration test ISO 6603-2

<table>
<thead>
<tr>
<th>Fracture energy [J]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

Impact behaviour at -40°C, RT, +85°C and 120°C Each tested at three different wall thicknesses

Celstran® is tougher vs PC ABS even at colder temperatures
Case Study  
PC/ABS Replacement with PP-LFT (III)  

<table>
<thead>
<tr>
<th>Material</th>
<th>Density</th>
<th>Flexural Modulus (23°C)</th>
<th>Flexural Stress</th>
<th>Charpy Notched Impact Strength 23°C</th>
<th>Tensile Strain (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC-ABS – sGF10</td>
<td>1,23</td>
<td>4000</td>
<td>115</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>PP-GF 20</td>
<td>1,02</td>
<td>5150</td>
<td>160</td>
<td>22,5</td>
<td>2,8</td>
</tr>
<tr>
<td>PP-GF 30</td>
<td>1,12</td>
<td>7000</td>
<td>180</td>
<td>24</td>
<td>2,2</td>
</tr>
</tbody>
</table>

Celstran® vs PC ABS shows better performance and it is a lighter material
Case Study
Material and Design with POM

Bumper brackets

Possible weight reduction with material and design over 14 %

- Material substitution to POM
- Weight reduction around 14 %
- Switch from screw to snap fit fixation
- Zero gap lines
- Reduction of design and construction space

Zero gap between bumper and body
Lightweight Construction
Potential Material Selection

- Glass fiber vs. carbon fiber
- Talc filler vs. GF vs. nature fiber
- PC/ABS (colored parts) vs. PP LGF mold in color
- Metal replacement
- PA sGF replacement
- Thin Wall/High flow technology
- Microspheres*
- Physical foaming
- Chemical foaming
- Composites/tapes reinforcement
- Short fiber vs. long fiber
- Fiber content reduction
- Polymers
- Processing

*Currently not offered/ supported by Celanese
**Case Study**
Combination of Potential Lightweight Construction

**Example Part: IP and Air Duct Panel**

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight Reduction</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP-EPDM TV 20</td>
<td>-5%</td>
<td></td>
</tr>
<tr>
<td>PP-LGF20</td>
<td>-30%</td>
<td></td>
</tr>
<tr>
<td>3.5 mm Talc filler vs. GF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5 mm Thin Wall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5 mm Foaming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PP-LGF20</td>
<td></td>
<td>Recyclate for cost optimization</td>
</tr>
<tr>
<td>PP-LGF20</td>
<td></td>
<td>5-8%/MuCell process*</td>
</tr>
</tbody>
</table>

Possible Weight savings ~40% combining 3 weight reduction methods

*optional / future also better quality process

1In dependence on the part requirements
Thank you for your attention!

QUESTIONS
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