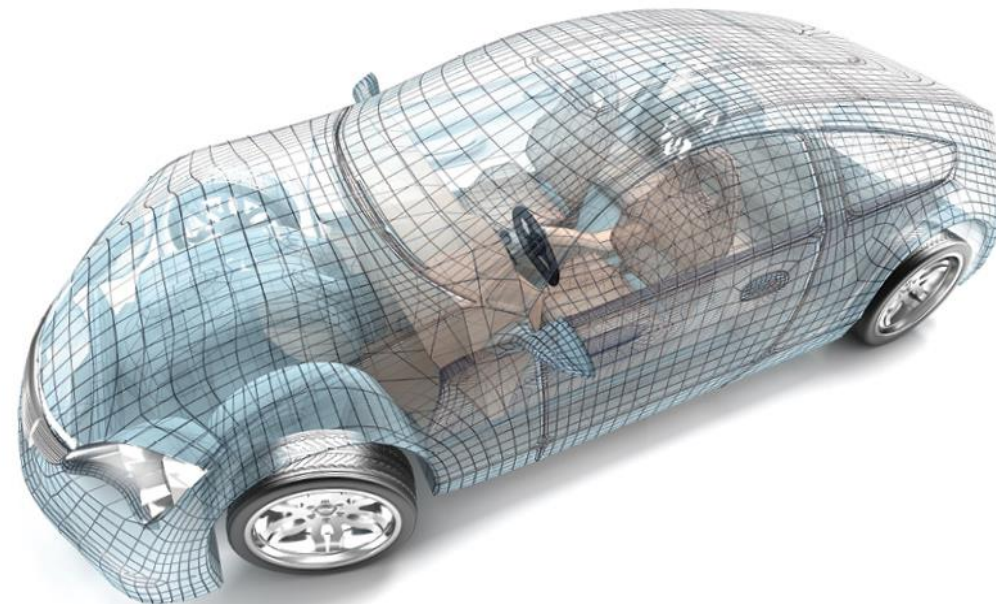




**THERMOPLASTIC
COMPOSITES CONFERENCE**

**A VIRTUAL EVENT
APRIL 29 - MAY 1, 2020**



CFRTPs and Mobility: Now and in the Future

Presented By: Paul Hassett
Manager, Strategic Market & Portfolio
Covestro LLC

PRESENTED BY

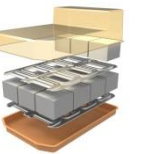
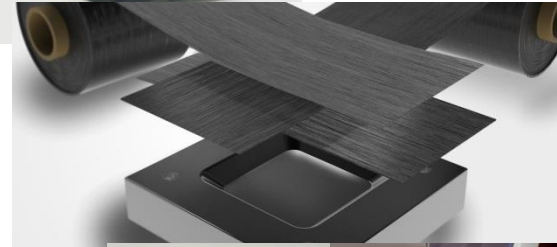


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Agenda

- Covestro/Mobility
- CFRTP/Maezio® Composites
- Maezio and Mobility
 - Automotive
 - Micro Mobility
- Sustainability of CFRTP: Life Cycle Analysis
- Q&A





Covestro...and Mobility



- A world leader in high tech polymer materials
- ~\$17B in sales ¹
- ~17k employees¹

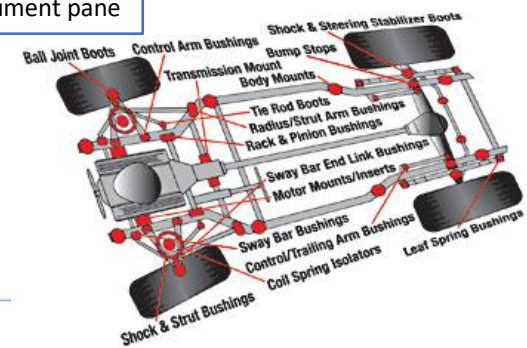
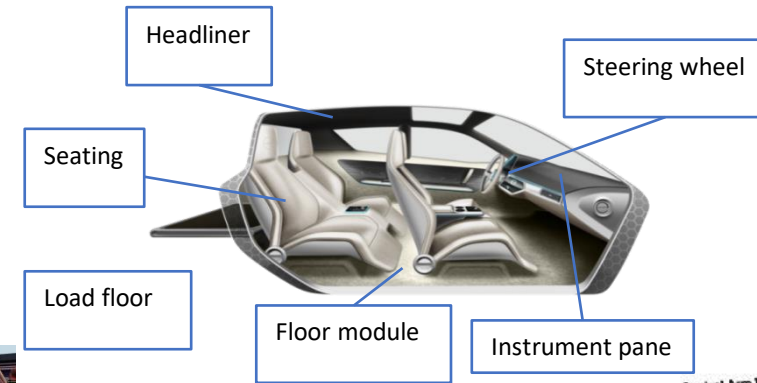
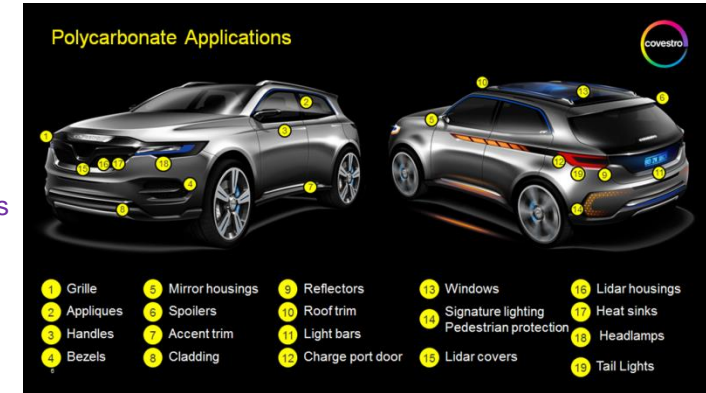
¹2018

- 80+ years of discoveries & innovations
- 1000+ employees in Research and Development

- 30 sites worldwide
- Global HQ: Leverkusen Germany
- Regional HQ: Pittsburgh, Shanghai

Very large portfolio of products and solutions for many industries

- Polycarbonates and PC blends
- Polyurethanes
- Coatings, Adhesives & Specialties
- Thermoplastic Polyurethanes



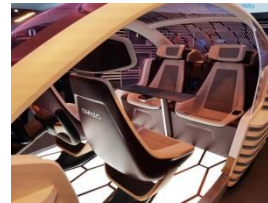
K1967 full plastic body car



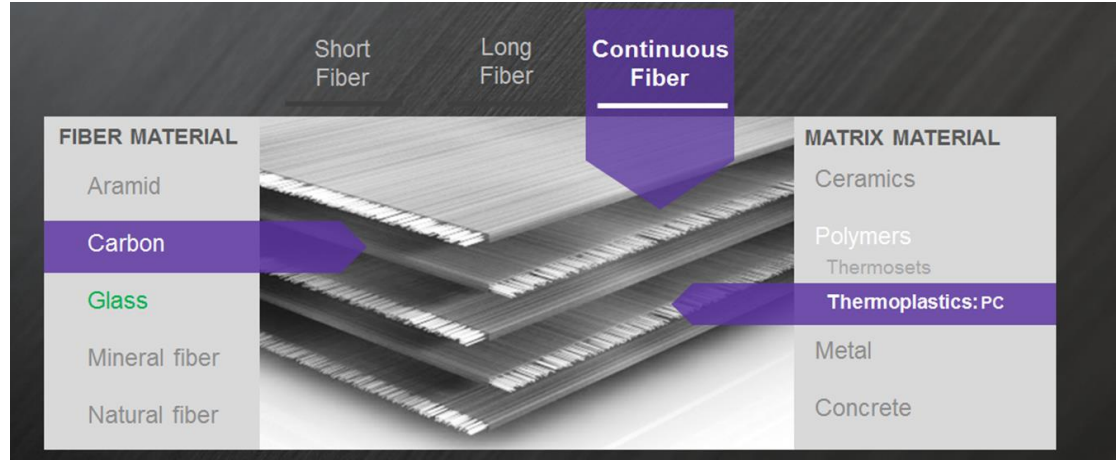
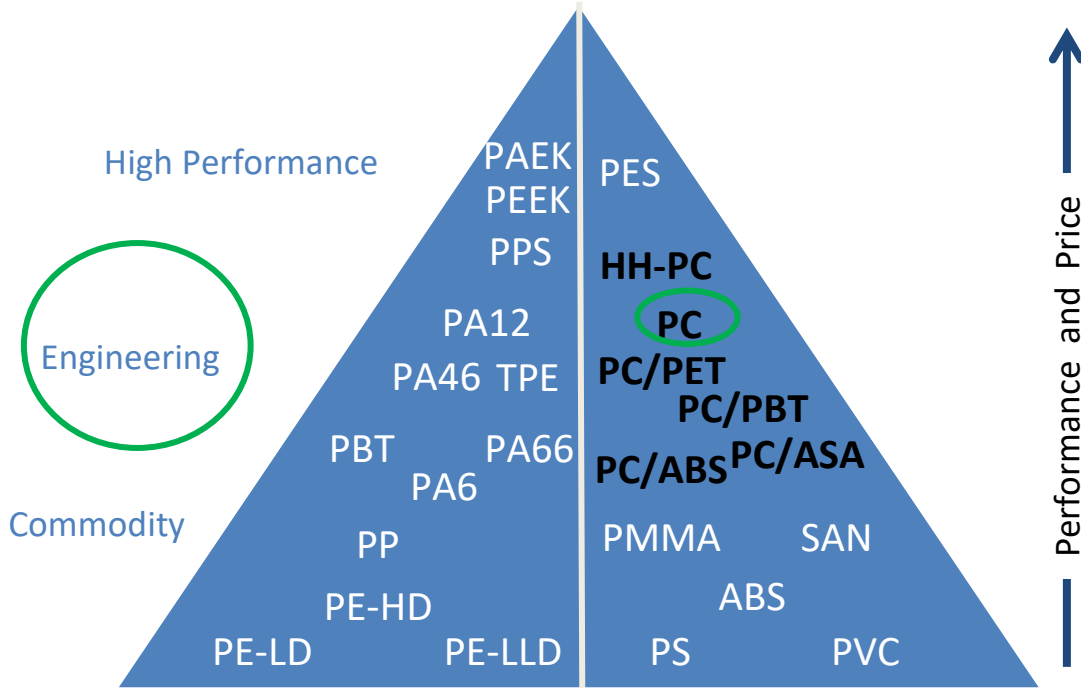
K2016 electric car concept study



World Solar Challenge 2019 Sonnenwagen by RWTH and FH Aachen

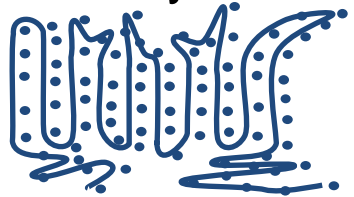


K2019 Autonomous Vehicle Concept Car



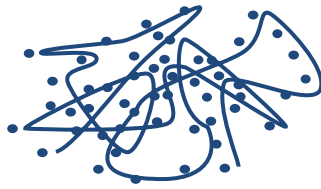
Thermoplastics

Semi-crystalline

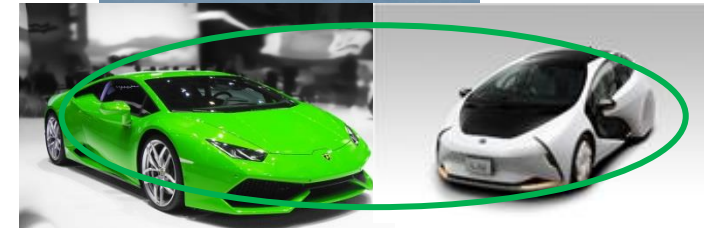


Molecules are arranged in a close, discernible order – can be re-melted.

Amorphous

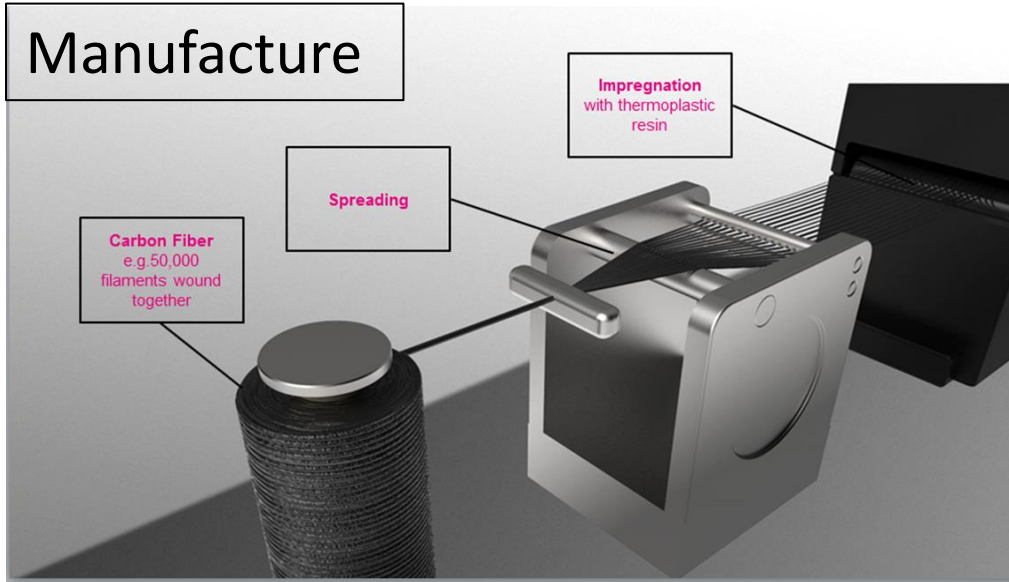


Molecules are arranged randomly and intertwined – can be re-melted.

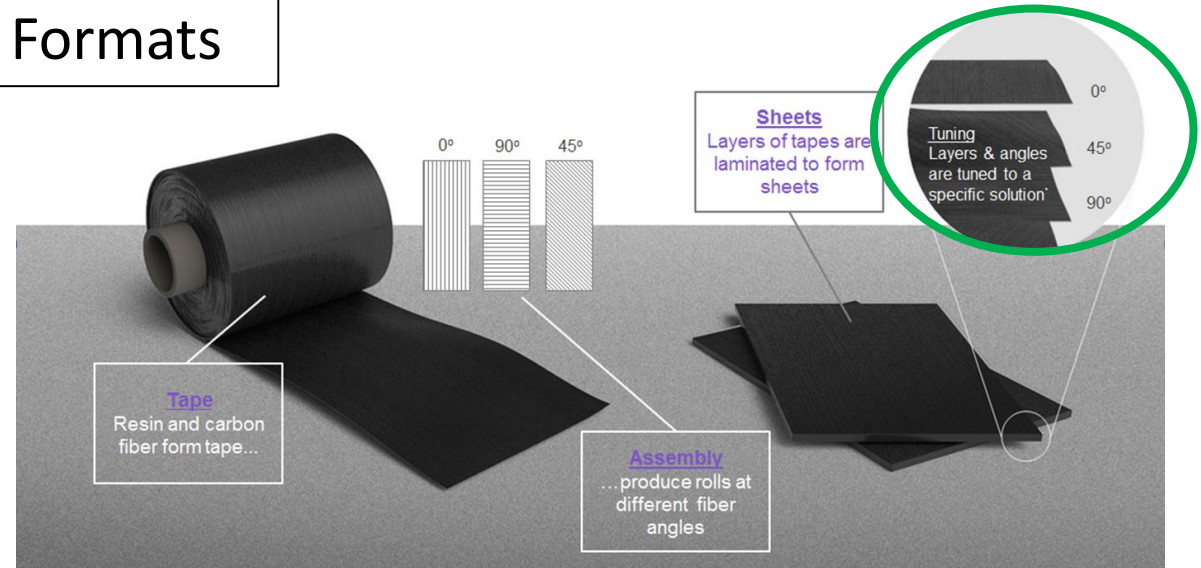




Manufacture



Formats



Typical Processing

Stamp Forming: heated sheet, matched metal tooling

Overmolding: a) stamp form, injection mold (IM)
b) forming+molding in IM tool (“hybrid”)

Automated Tape Laydown: Tape strip laydown, consolidate into sheets, form into part

ACMA
AMERICAN COMPOSITES MANUFACTURERS ASSOCIATION

Using Thermoplastic Composite Materials Across Segments: Aerospace & Automotive
April 8, 2020

ATC David Leach, Director of Business Development, Advanced Thermoplastic Composites
IACMI Uday Vaidya, Chief Technology Officer, IACMI
ACMA Dan Coughlin, VP of Market Development, ACMA

Access: ACMA’s Education Hub.



Stiff, Thin, Lightweight, Sustainable, Beautiful Composite Parts

Anisotropic lightweight properties

- Tensile modulus (UD, 0°): ~ 100 GPa
- Fiber volume content: up to 48 %
- Density: ~ 1.5 g/cm³

Polycarbonate (PC) resin:

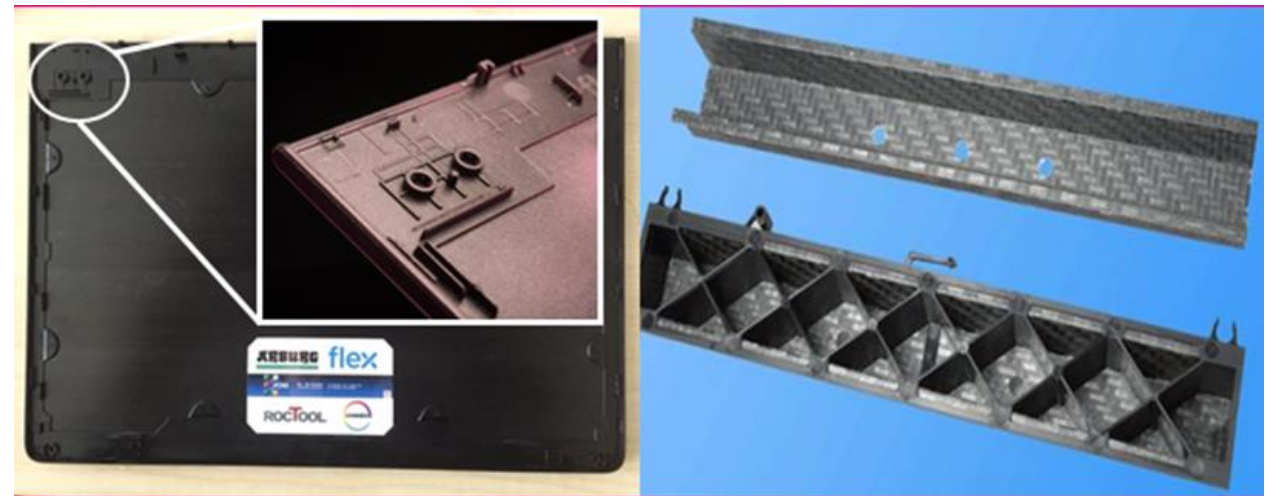
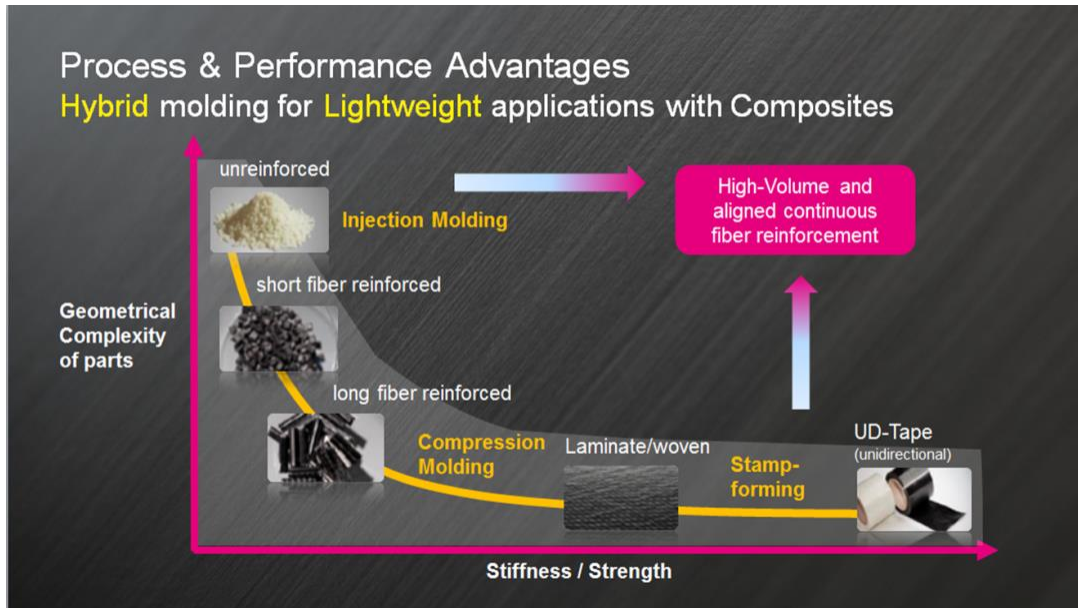
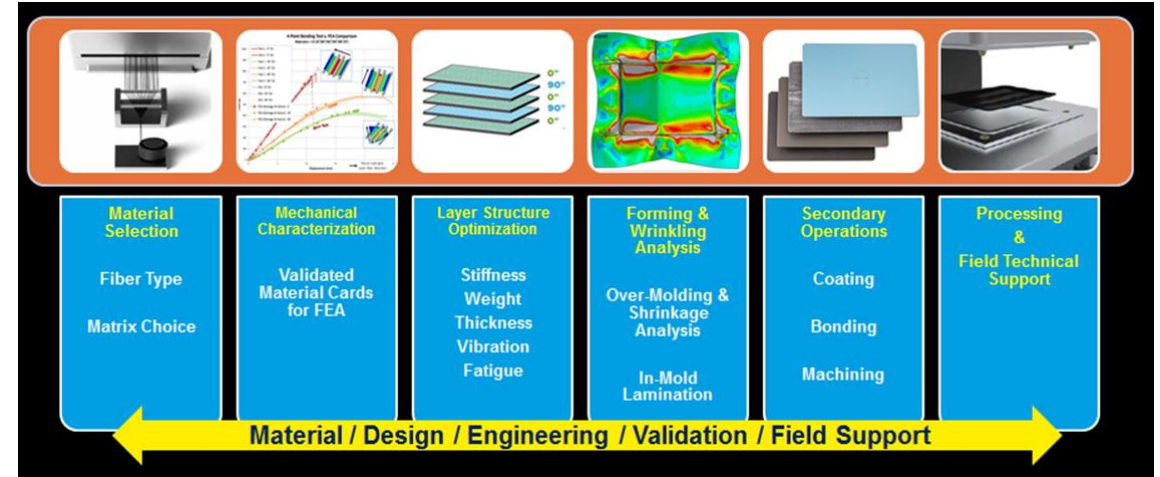
- Amorphous
- Glass transition point T_g: 145 °C
- High impact toughness

Efficient processing

- Scalability & low cycle times
- Low humidity absorption: 0.1 - 0.3 % (resin)

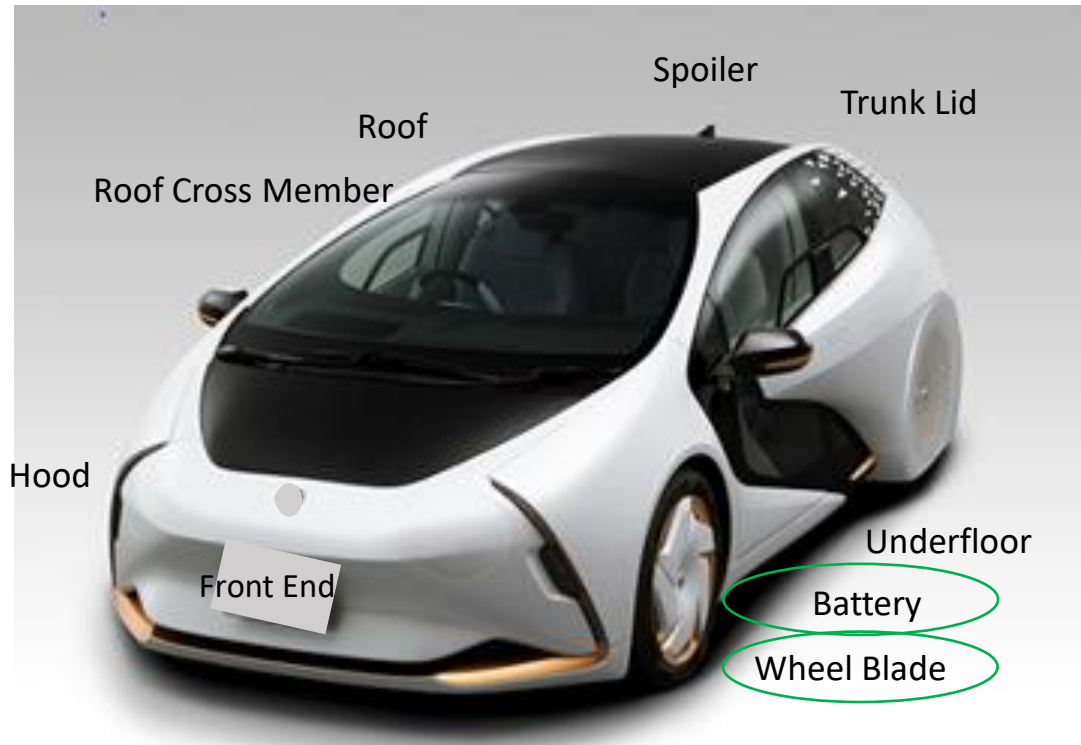
Design & surface quality

- Translucent or opaque
- Low processing shrinkage: 0.6 - 0.8 %

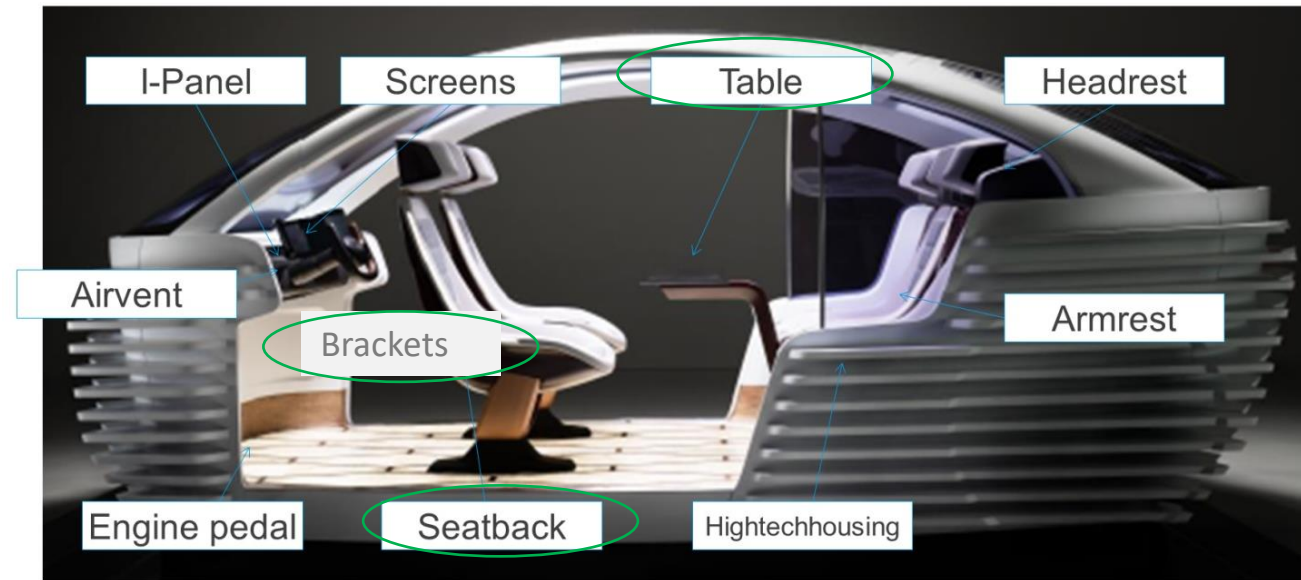




A wide variety of developing and potential applications



Exterior



Interior



Wheel Blade

- Objectives
 - Design, prototype, test, and scale new wheel blade
 - Meet the aesthetic, performance, sustainability, and cost targets of OEM (NIO) on time and within cost target
- Key Challenges
 - Short timeline
 - Incorporation of attachment method
 - Pass rigorous testing: mechanical, functional, water jetting, gravel impact, car wash, heat resistance, heat aging, chemical/fluids, environmental
- Results
 - Project completed in 24 months: concept to commercial vehicle
 - Compression mold polycarbonate screw bosses
 - Passed all required tests
- Next Steps
 - On-going commercial supply
 - Exploring other interior and exterior applications





Seat Back

- Objectives
 - Design, prototype, test for Guangzhou Auto Show, Fall 2019
 - Meet the aesthetic, performance and sustainability targets of OEM (GAC)
- 100% Recycled Maezio composite
 - Developmental product
 - Re-formed laminate from cut material
 - Natural, marble-like appearance
- Seat Attributes and benefits
 - 50% lighter than conventional seat backs
 - Recyclable
 - Stream-lined manufacturing and material use
 - Injection molded fittings and attachments
 - Integrate components, reduce materials
- Next Steps
 - Selection of model/program for incorporation
 - Investigate other applications

“Mobility trends such as electrification and autonomous driving are redefining the role and function of car interiors. There is a growing need for material solutions that are lightweight and sustainable while opening up ways to create new user experiences ranging from visual to tactile feedback.”

-- Zhang Fan, Vice President, GAC R&D Center

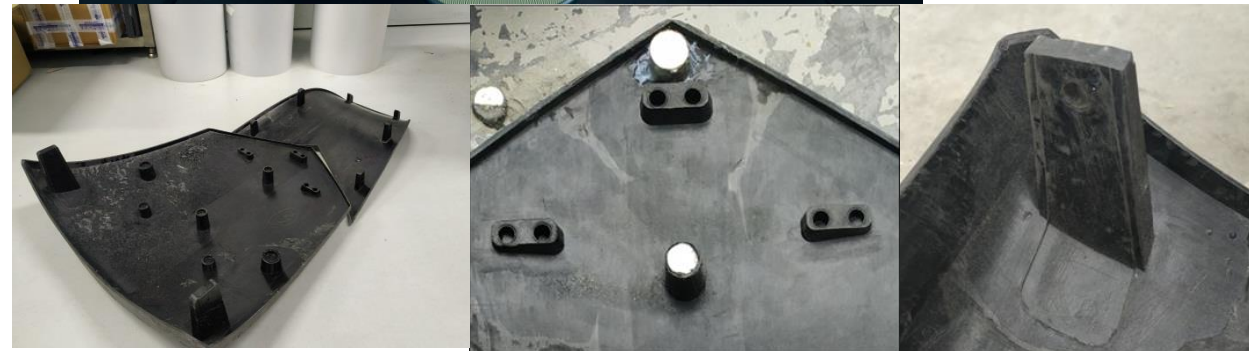




Table Top

- Objectives
 - Create space in a multi-functional interior for a concept car at the 2019 KShow by designing and prototyping an attractive, slim, strong, working surface; easily stored when not in use
 - Set the stage for a commercial part and for other applications
- Materials and Key Processing Steps
 - Maezio CF/PC sheets + Baydur® polyurethane foam
 - Thermoform sheets (Dr. Schneider tool)
 - “Sandwich” molding – inject foam between sheets (Engel IM)
 - Finish with matte and clear coatings
- Results
 - Foldable for storage in a 2cm (0.79”) wide opening
 - Nearly 60X increase in load with similar deflection
- Next Steps
 - Investigating Table Top 2.0 (e.g. cost reduction)
 - Exploring other interior /exterior auto and non-auto applications



Metal Replacement

- Electronics Brackets
- Autonomous Vehicle Concept Car
- Replace Aluminum part w/CF composite
- Key Value prop: vibration reduction
- Stamp forming
- Next Steps
 - awaiting further OEM push on project
 - apply learnings to other applications

CARBON
48^g

ALUMINUM
92^g



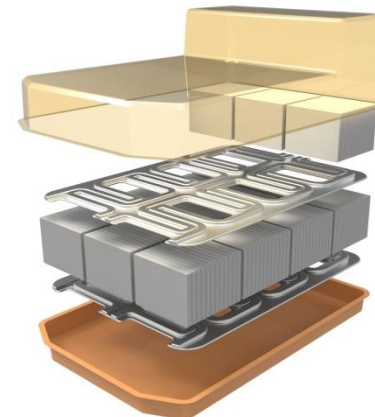
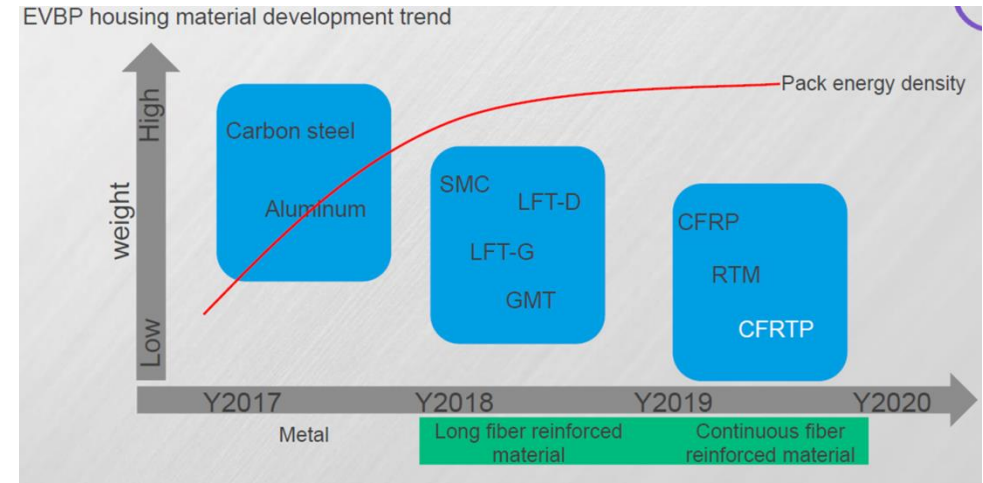
RapidTPC
Making Composites Simple





Why CFRTPs for EV Battery Packs?

- EVBP Target: Maximize Pack Energy Density
 - Pack Energy Density = $\frac{\text{Battery Pack Energy Density}}{\text{Battery Pack Weight}}$
- Material Pain Points from EVBP Industry
 - Metals are at their limits for the combination of deep draw geometry and lightweight targets
 - While long fiber reinforced plastics allow for complex part forming, it can be brittle for thin-wall designs
 - CFRP(thermoset) cycle time is long and is not as easily reusable as CFRTPs
- CFRTP value proposition
 - Thin wall design: up to 50% reduction in weight
 - Short cycle time for economic mass production
 - Recycle



Upper cover: Protecting the battery module

Module frame /side(terminal plate): Clamping the battery cells together to module

Bottom housing: Provides structural stiffness to integrate the battery pack with the chassis safely

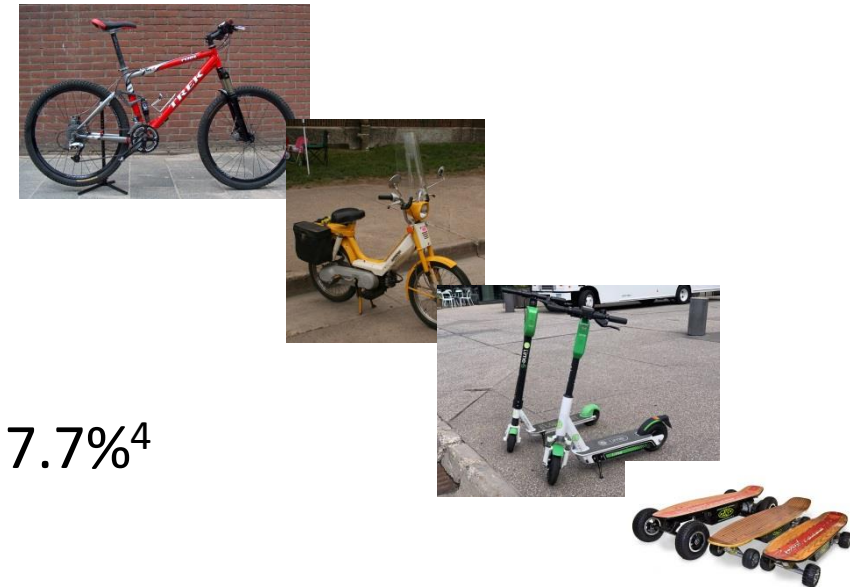


Micro-Mobility

Mega-Trends: Urbanization/Sustainability/Recreation

Increasing market dynamics, new concepts and materials

- Bicycles/e-bikes
 - Global Bicycle Market \$45B increasing to \$62B (2016 /2024)¹
 - Global Bike carbon frames: 1.1MM units 2017, steady growth²
 - Global e-Bike Sales: forecast \$20.5B (40MM units) in 2023³
- e-scooters Market Size Worth \$41.98 Billion By 2030 | CAGR: 7.7%⁴
- e-skateboards, other form factors?

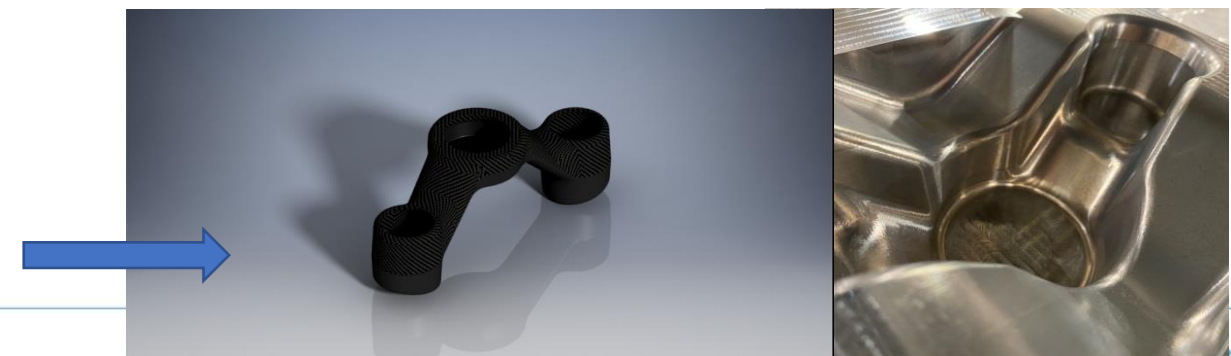


- ¹[\[https://www.bike-eu.com/sales-trends/nieuws/2016/12/global-bike-market-to-grow-by-38-up-to-2024-10128381\]](https://www.bike-eu.com/sales-trends/nieuws/2016/12/global-bike-market-to-grow-by-38-up-to-2024-10128381)
- ²[\[https://www.adroitmarketresearch.com/industry-reports/bicycle-carbon-frames-market\]](https://www.adroitmarketresearch.com/industry-reports/bicycle-carbon-frames-market)
- ³[\[https://www.bike-eu.com/sales-trends/nieuws/2020/01/deloitte-study-e-bike-sales-in-2023-at-40million-units-generating-19-billion-euro-10137172\]](https://www.bike-eu.com/sales-trends/nieuws/2020/01/deloitte-study-e-bike-sales-in-2023-at-40million-units-generating-19-billion-euro-10137172)
- ⁴[\[https://www.grandviewresearch.com/press-release/global-electric-scooters-market\]](https://www.grandviewresearch.com/press-release/global-electric-scooters-market)



Bicycle Brake Lever Case Study

- Objectives
 - Develop a lightweight, thermoplastic composite version of a brake lever for U.S. OEM
 - Compare the development and commercial scale costs and product performance to thermoset version
- Key Challenges
 - High draft-angles
 - Original design was for AL casting. DFM is very different.
 - Tight side tolerances
- Results
 - First objective accomplished
 - Significant savings compared to thermoset version: total cost to OEM (self-manufacture vs. purchase) reduced by >30%
- Status and Next Steps
 - Awaiting final results of coating and mechanical tests
 - OEM committed to purchase
 - Add features for next generation: e.g. grips
 - Apply to other bike parts e.g. crown part being developed



Bicycle Crank Lever and Wheel Rim

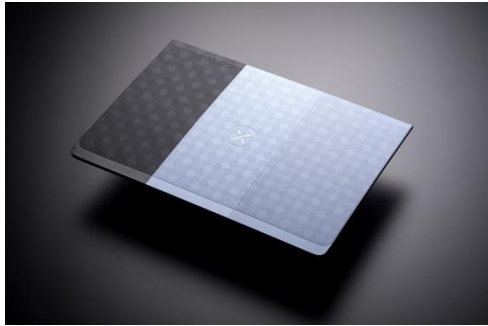


- High stiffness due to load-optimized unidirectional laminate reinforcement and sandwich structure with foam core
- Reduced processing steps: significantly faster than epoxy-based system
- PC matrix allowed new design and high surface quality
- High impact performance



Ensinger



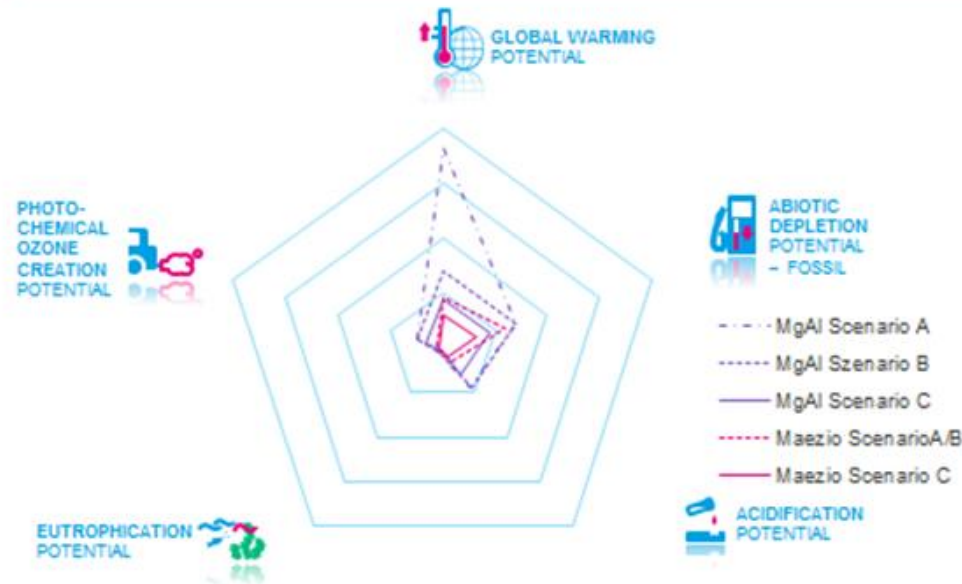


Normalized LCA Results

Significant reductions of environmental impacts could be achieved in several categories

Life Cycle of one Composite Laptop Cover

NORMALIZED LCA RESULTS*



* Normalization via CML Normalization (World) in GaBI.

RESULTS

In all considered impact categories and scenarios, the Maezio™ laptop A-cover has the potential to have a (significantly) better environmental performance compared to the laptop A-cover made from MgAl alloy.

- The highest reductions of environmental impacts could be achieved in the following categories:
 - Global Warming Potential (GWP)
 - Acidification Potential (AP)
 - Photochemical Ozone Creation Potential (POCP)
- Raw materials like carbon fibers or magnesium possess the highest contribution to the environmental impacts followed by electricity consumption.

This presentation may contain forward-looking statements based on current assumptions and forecasts made by Covestro.

Various known and unknown risks, uncertainties and other factors could lead to material differences between the actual future results, financial situation, development or performance of the company and the estimates given here. These factors include those discussed in Covestro's public reports, which are available on the Covestro website at www.covestro.com.

The company assumes no liability whatsoever to update these forward-looking statements or to adjust them to future events or developments. Maezio is a registered trademark of the Covestro group.



Questions?

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