Lightweight solutions for underbody protection shields of BEVs

› Glass fiber - Polypropylene (PP) organosheets and hybrid sandwich boards

Udo Steinhauer, September 6, 2023

AUTOMOTIVE COMPOSITES CONFERENCE & EXHIBITION
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Presented by SPE Automotive and Composites Divisions
WORLD'S LEADING AUTOMOTIVE COMPOSITES FORUM

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Agenda

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Around the world

Product groups & Markets

2 BEV market

Development

Challenges battery protection

3 Lightweight solutions

Composites material design

Panel design | demonstrators

Impact test design

Panel performance

Profol

Around the world

Product Groups

Markets

1

Around the world

- 200 Mio lbs | 1 billion m² film
- 220 Mio $ revenue
- 550 employees
- 26 extrusion lines
- One composites plant

Product groups

› Cast PP films

since 1980

› Composites

since 2018

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Markets

Automotive

E-mobility

Battery & Electronic

Truck

RVs

Flooring

Furniture

Packaging

Building & Construction

Stationery

BEV market

Development

Challenges of battery protection

2

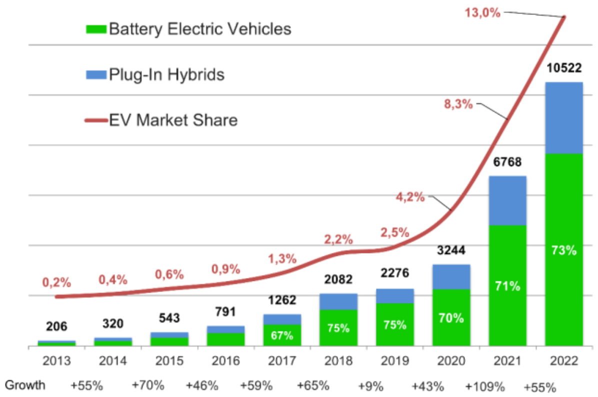
Development BEV (Battery Electric vehicle)

- Global sales: +55% 2022 to 2021
  - +48% North America
  - +15% Europe

- Market share: 13% in 2022

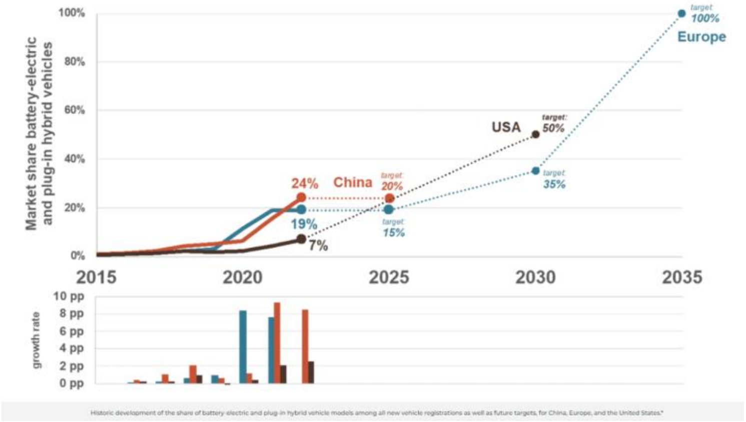
  20% in 2025 (target)

Global BEV+PHEV sales (‘000s)



Source: www.ev-volumes.com

Share BEV+PHEV and future targets



Source: icct https://theicct.org/2022-update-ev-sales-us-eu-ch-aug22/

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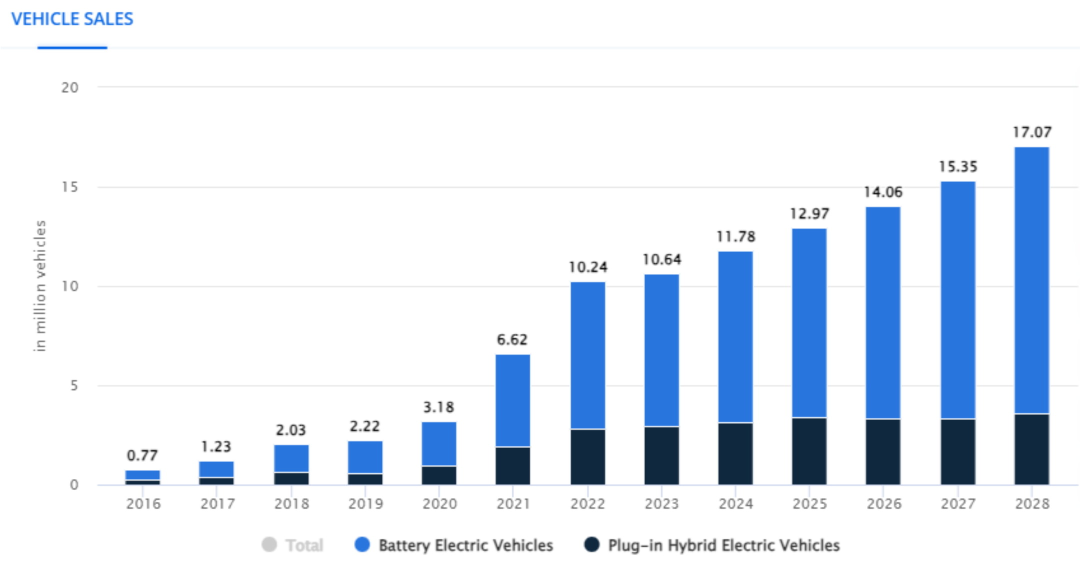
Development BEV

› Estimate global sales (unit sales): 13 million vehicles in 2025

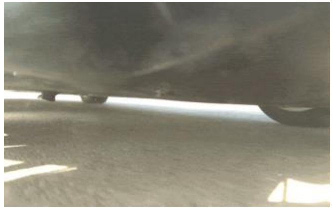


Most recent update: May 2023

Source: Statista https://www.statista.com/outlook/mmo/electric-vehicles/worldwide#unit-sales

Challenges in battery protection

› Impacts by tow hitch, blocks, alternators, etc.



Three ball tow hitch

Concrete block

Alternator

Picture: Continental

Source: Tesla
https://medium.com/@teslamotors/tesla-adds-titanium-underbody-shield-and-aluminum-deflector-plates-to-model-s-544f35965a0d

› Thermal runaway

Source: NTSB report
https://www.repairerdrivennews.com/2021/01/18/ntsb-report-highlights-safety-risks-precautions-for-electric-vehicle-towing-storage/

Pictures: Forward Engineering | UL Research Institutes

Lightweight solutions

Composites material design

Panel design | demonstrators

Impact test design

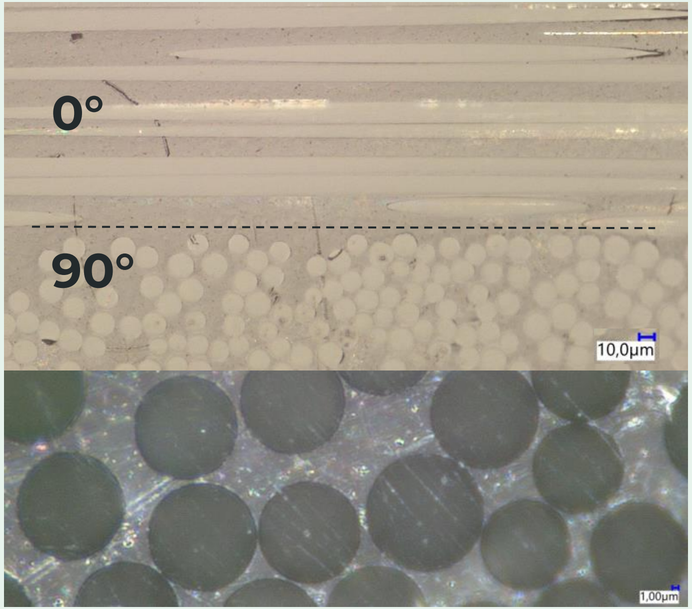
Panel performance

3

Composite material design

Glass fiber – Polypropylene (PP) unidirectional tapes (UD tapes)

Starting material for lightweight composites



Important parameters

- Fully impregnated glass fiber in polypropylene matrix form uniquely mechanical properties of UD-tape, resulting in high mechanical strength
- Gapless and bubble-free enclosure of individual glass fiber filaments

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Lightweight Panel Design | demonstrators

Three different panel design made of glass fiber – PP UD tapes vs a 2,5mm thick aluminum plate (length 500mm x width 360mm)

- Organosheet: 20 layers of UD tapes in 0° and 90°
- Sandwich: 2x 5 layers UD tape with PP-GF30 core
- Sandwich: 2x 5 layers UD tape with PP foam core

Panel	Panel Description	Material	Thickness [mm]	Mass relative to baseline
1.0	Aluminum baseline	EN AW 5754-H22 aluminum	**2.5**	-
2.1	Monolithic proUD 8*0|2*90	20 proUD	**3.9**	**-7%**
3.0	Sandwich-proUD 8*0|2*90 skins + PP_GF30	[5 proUD |PP_GF30 | 5 proUD]	**5.12**	**+3%**
3.1	Sandwich-proUD 8*0|2*90 skins + PP_foam	[5 proUD |PP_foam | 5 proUD]	**7.2**	**-35%**

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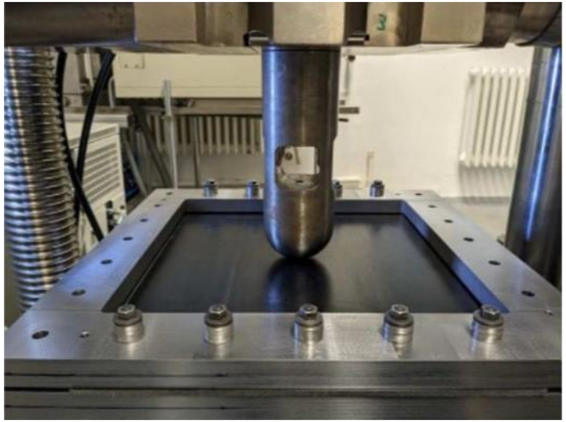
Impact test design

Impact / load by a 90mm diameter hemispherical intender

Drop tower test



Bollard test

- Drop Tower test

  Dynamic test: resistance to damage up to 400J

- Bollard test

  Quasi-static test: failure mechanism, how damages propagate as panel is loaded to rupture

Panel performance

Drop Tower test (dynamic)

- Aluminum panel suffers plasticity and permanent deformation though yielding at energy levels as low as 50J and increases at higher energy levels
- **Less damage to composites panels**
  - **2.1 Organosheet 20 layers**: no permanent deformation even at 400J; cracking starting at 250J
  - **3.0 Sandwich with PP-GF30 core**: minor deformation starting from 50J; cracking at 325J
  - **3.1 Sandwich with PP-foam core**: minor deformation starting at 250J; no cracking even at 400J

Panel performance

Drop Tower test – Panel images after 400 J impact

1.0 Aluminum panel

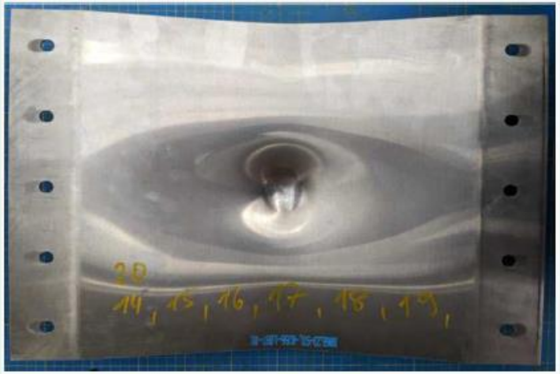


Fig 3: Alu panel- top side

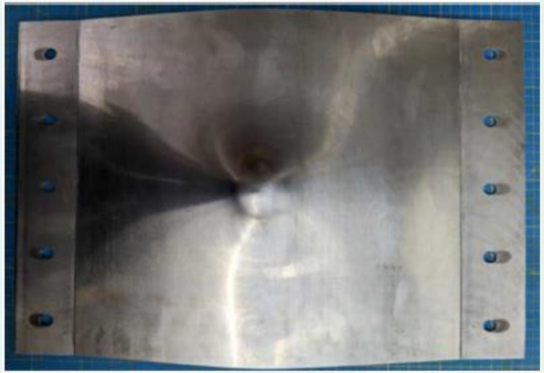


Fig 4: Alu panel- bottom side

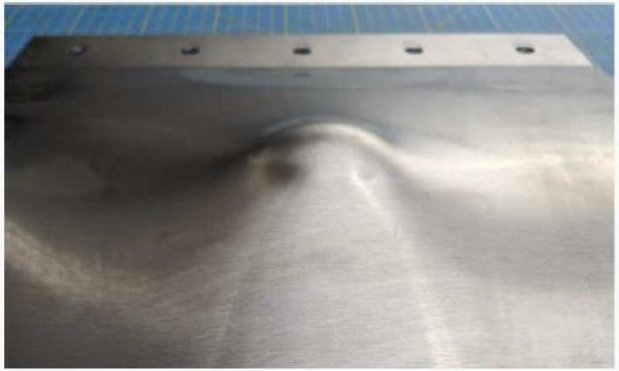


Fig 5: Alu panel- in region of indenter

Panel performance

Drop Tower test – Panel images after 400J impact

2.1 Organosheet 20 layers

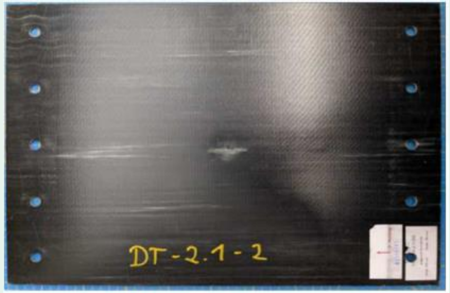


Fig 6: Monolithic 2.1 panel- top side

Fig 7: Monolithic 2.1 panel- bottom side

3.0 Sandwich with PP-GF30 core

Fig 8: Sandwich 3.0 panel- top side

Fig 9: Sandwich 3.0 panel- bottom side

3.1 Sandwich with PP-foam core

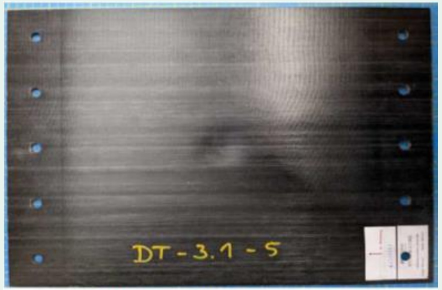
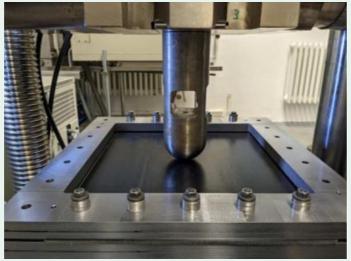


Fig 10: Sandwich 3.1 panel- top side

Fig 11: Sandwich 3.1 panel- bottom side

Panel performance

Bollard test (quasi static)



- All panels achieve peak forces and energy absorptions at rupture fulfilling requirements for medium size EV
- Organosheet 20 layers: **43% higher energy absorption than aluminum plate**
- Sandwich with PP-foam core: **withstand significant deformation without failure** of the skins or core-to-skin interface
  - → "ductile" response to impacts
  - → lightweight damage tolerant underbody shield

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Panel performance

Bollard test – Load vs Deflection curve

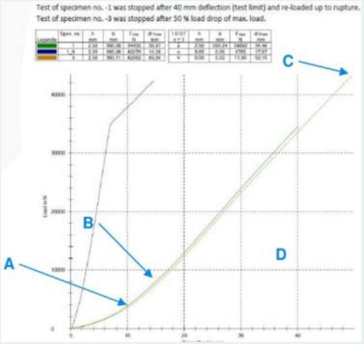
1.0 Aluminum panel

A. Nonpermanent deformation

B: Plastic deformation starts and spreads rapidly through panel

C: Test stopped when panel crack develops

D: Panel absorbs energy via irreversible plastic deformation



2.1 Organosheet 20 layers

A: Nonpermanent deformation

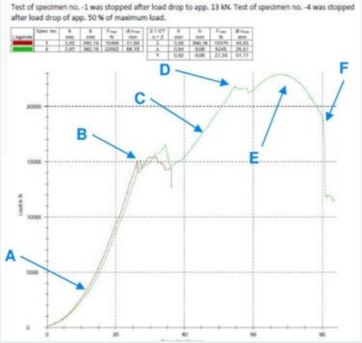
B: Fiber failure on first skin

C: Change in panel stiffness

D: Fiber failure on other side of panel

E: Panel continues to absorb a large amount of energy

F: Final panel rupture



3.0 Sandwich PP-GF30 core

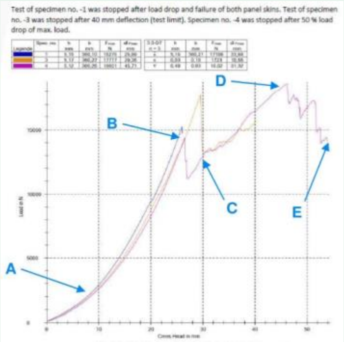
A: Nonpermanent deformation

B: Fiber failure on first skin

C: Core crushing but panel continues to absorb a large amount of energy

D: Fiber failure on another layer; peak force

E: Final panel rupture

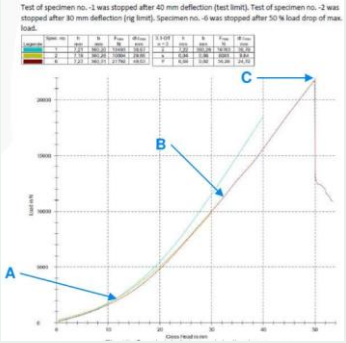


3.1 Sandwich PP-foam core

A: Nonpermanent deformation

B: Panel exhibits a “ductile” response; no fiber failure of the skin or at core-to-skin interface

C: Fiber failure on panel skin; rupture



Panel performance

Bollard test – Panel images after rupture (top and bottom)

1.0 Aluminum panel

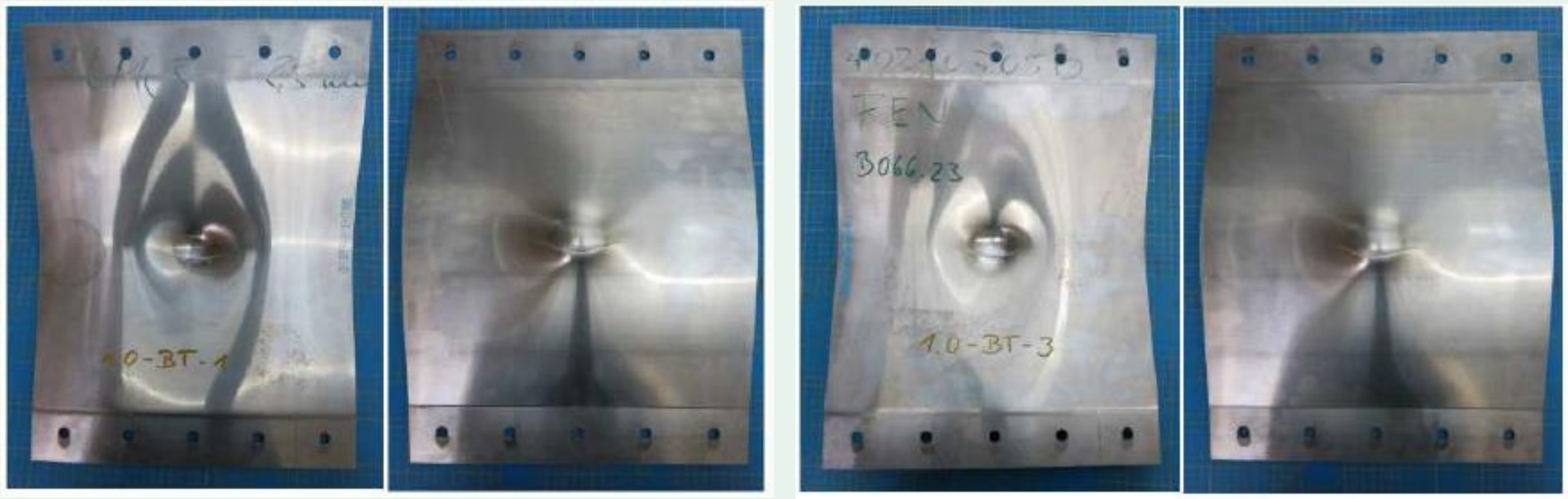


Fig 16: Alu baseline panel- after bollard testing

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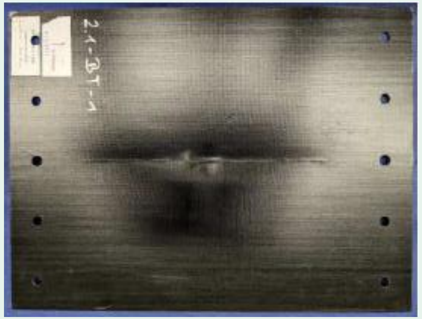
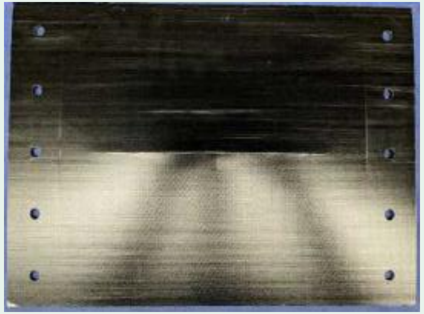
Panel performance

Bollard test – Panel images after rupture (top and bottom)

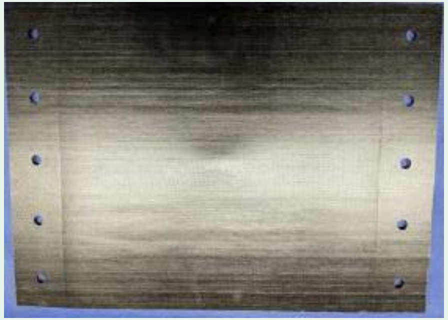
2.1 Organosheet 20 layers





3.0 Sandwich with PP-GF30 core

3.1 Sandwich with PP-foam core



Conclusion

Glass fiber - PP lightweight boards made from UD-tapes are the solution to meet all critical requirements of underbody protection shields:

- High strength-to-weight ratio: **absorbing up to 43% more energy** and being **up to 35% lighter** than high strength aluminum
- Impact resistant: composite shields are much more resistant to damage than aluminum and **withstand significantly larger impacts** without permanent deformation
- Composites shields retain significant strength even in the damage state
- Corrosion resistant (glass fiber + PP)
- Easy to mold and shape (thermoplastic properties)
- Cost effective
- [Remark: UL 2596 test pending (Test Method for Thermal and Mechanical Performance of Battery Enclosure Materials)]

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THANK YOU!

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