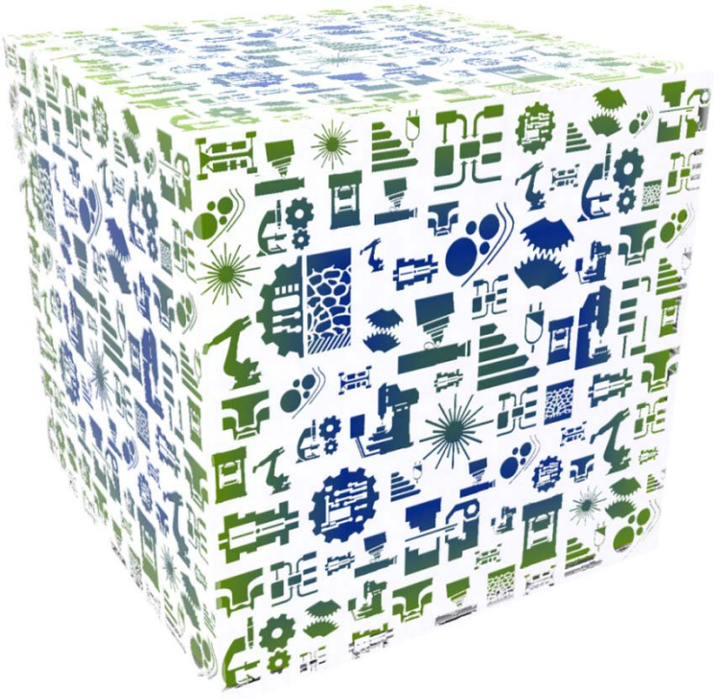
NOVEL LIGHTWEIGHT MATERIAL, DESIGN AND COOPERATION SOLUTIONS FOR ELECTRIC MOBILITY

Dipl.-Ing. Rico Schmerler, LIGHTer International Conference, Gothenburg, 20-21 Nov. 2019



Fraunhofer IWU

AGENDA

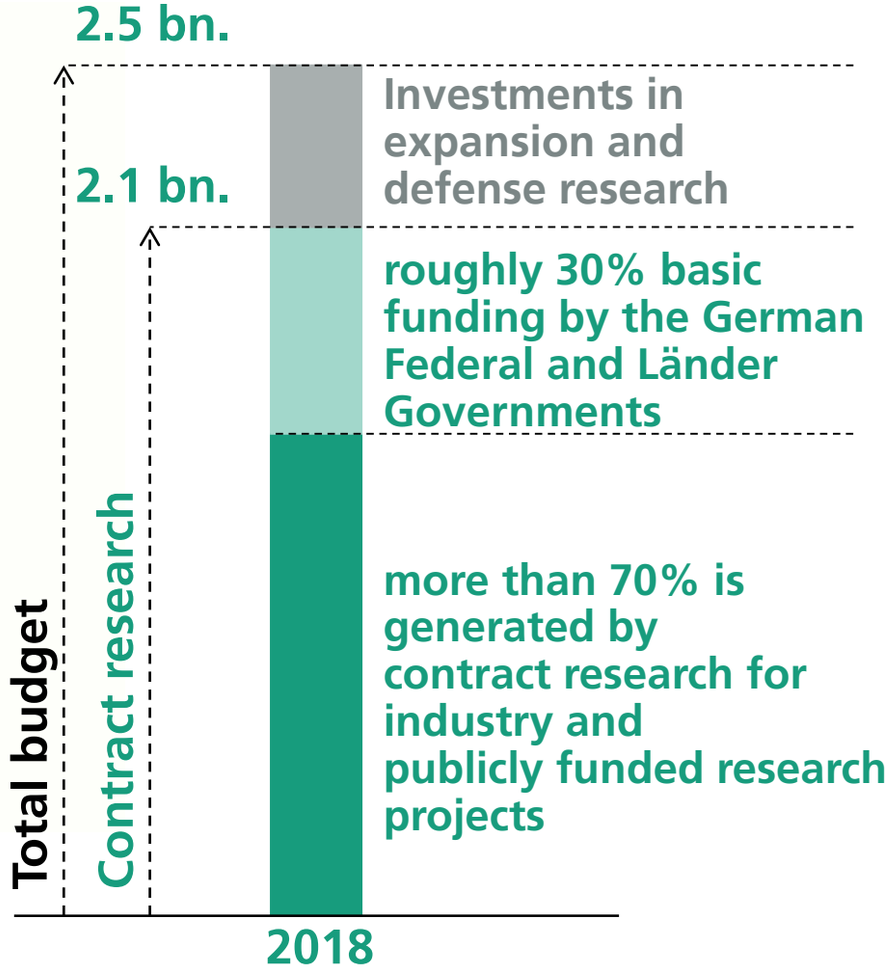
1) Introduction of Fraunhofer-Gesellschaft, Fraunhofer Project Center Wolfsburg & OHLF
2) Technologies and material solutions with project examples:
   Textile, hybrid and metal technologies
3) Battery housing solutions for Electric vehicle (EV)
   1) Mechanical
   2) Thermal
   3) Production process
4) Swedish – German cooperation approach

The Fraunhofer-Gesellschaft
At a glance

Application-oriented research for direct use in the economy and for the advantage of society

26 600 employees

72 Institutes and research units



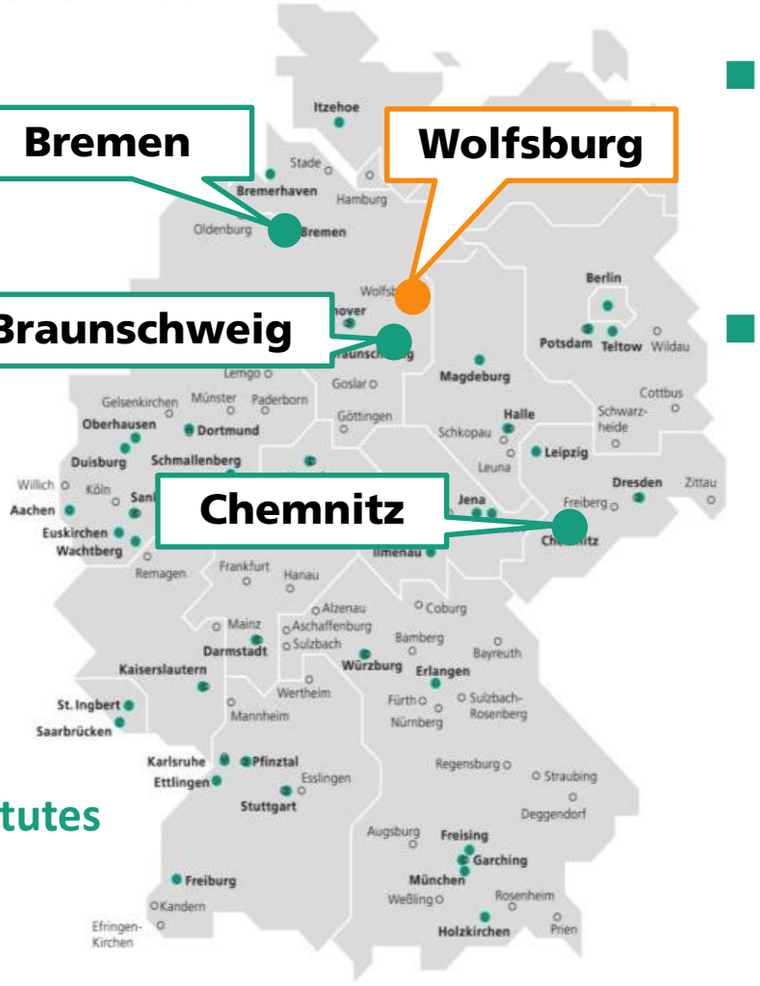
Introducing Fraunhofer Project Center Wolfsburg

→ 1st project center of Fraunhofer

23 employees

(50 planned)

4 Fraunhofer institutes

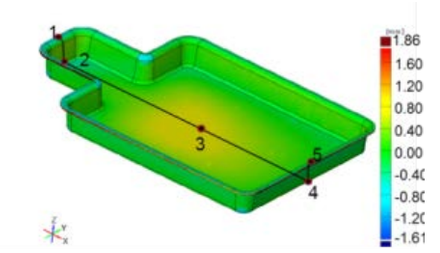


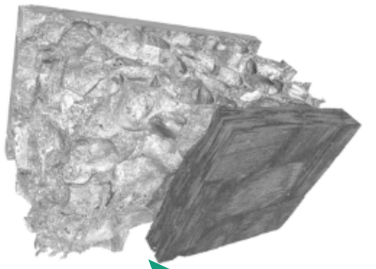
- collaboration of Fraunhofer institutes with interdisciplinary approaches in one joint project center will lead to system oriented solutions
- research topics
  - Textile manufacturing chain
  - Hybrid materials with metallic matrix
  - Components for electric vehicles

- Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM
- Fraunhofer Institute for Surface Engineering and Thin Films IST
- Fraunhofer Institute for Wood Research Wilkelm-Klauditz-Institut WKI
- Fraunhofer Institute for Machine Tools and Forming Technology IWU

Introducing Fraunhofer Project Center Wolfsburg

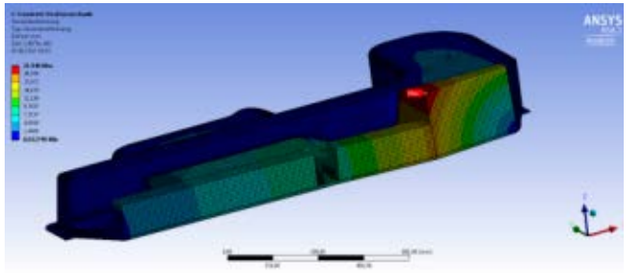
Covering the process chain from material to components





charakterization

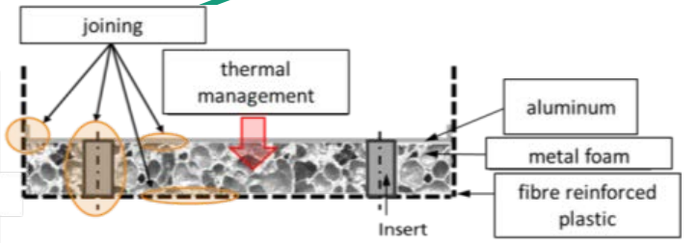
manufacturing



design

simulation

concept



idea

Fraunhofer

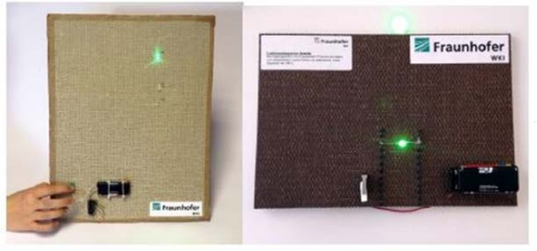
Open hybrid lab factory (OHLF) – Partner structure

Introducing Fraunhofer Project Center Wolfsburg
manufacturing technologies

Double rapier weaving machine

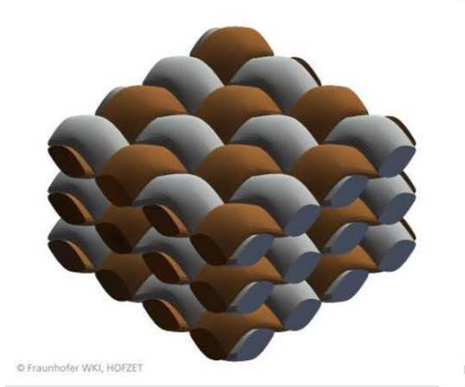
- Production of hybrid fabrics (combination of bioplastic, natural, glass, carbon and synthetic fibers), multilayer and spacer fabrics are possible

hybrid woven fabric, flax and thermoplastic matrix

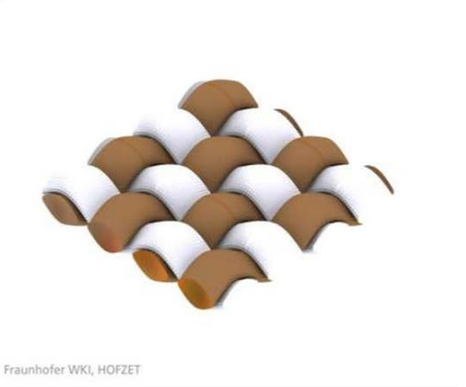


Flax multi-layer hybrid fabric with PA6 and integrated LED

double rapier weaving machine



Multi-layer hybrid fabric made from flax (brown) and glass (gray).



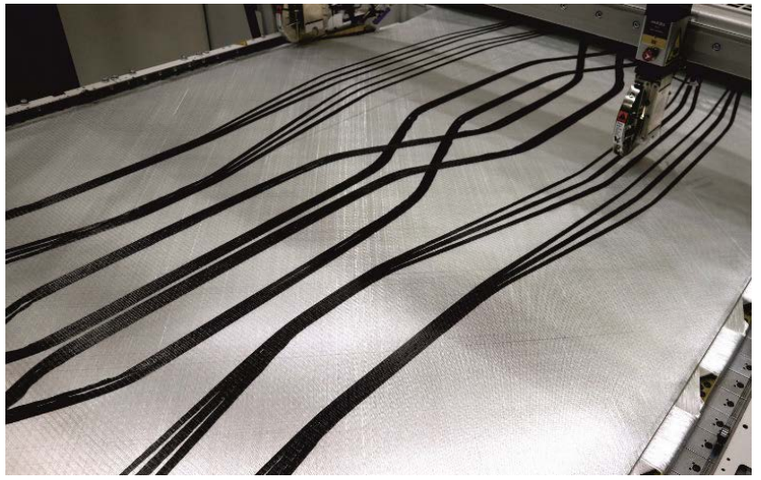
Single-layer hybrid fabric made from flax (brown) and thermoplastic matrix (white)

Introducing Fraunhofer Project Center Wolfsburg
manufacturing technologies

Multiaxial Fabric Machine

- Manufacturing of near net shape, textile semi-finished products
- Placing fibres along the load path
- Using expensive carbon fibres only where needed
- Minimizing the cut

Multiaxial Fabric Machine



Introducing Fraunhofer Project Center Wolfsburg
manufacturing technologies

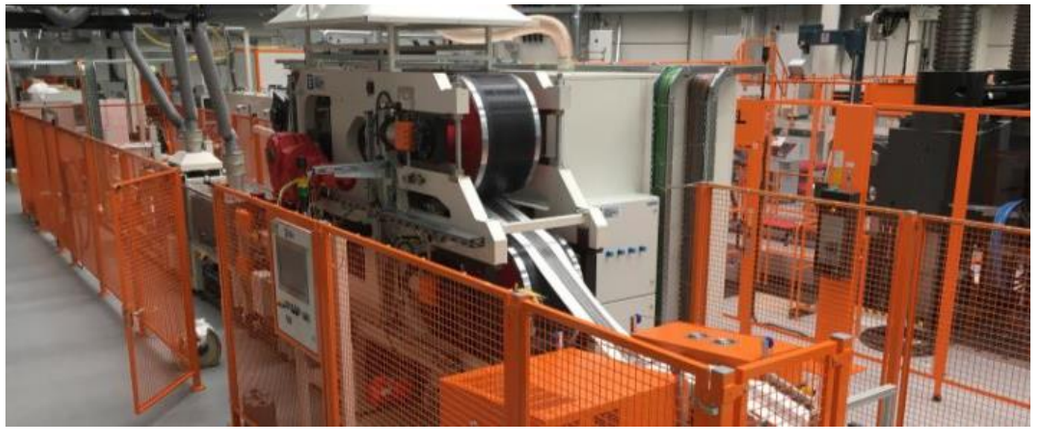
surface modification

- optimizing the interfaces of frp
- atmospheric pressure plasmatreatment of the fibres in order to receive reproducable surface properties

Plasma source, flax fibres before (left) and after selective treatment

calendering

- Production of thermoplastic pregregs in large scale
- development of a module enabling to impregnate the fibres layed on load path (joint project with TU Braunschweig)



calendering plant @OHLF

Introducing Fraunhofer Project Center Wolfsburg
manufacturing technologies

fiber spraying

- local improvement of stiffness or strength of (hybrid) components
- reinforcement of areas with critical load
- continuous spraying of different fibres such as high strength and natural fibres or hybrid yarn

low pressure casting plant @OHLF

low pressure casting

- Use of glass fibres for casting in aluminum for an integral, load path optimized connection of CFRP and aluminum
- Advantages are light weight, optimized load path, corrosion resistancye less space required

low pressure casting plant @OHLF

Introducing Fraunhofer Project Center Wolfsburg

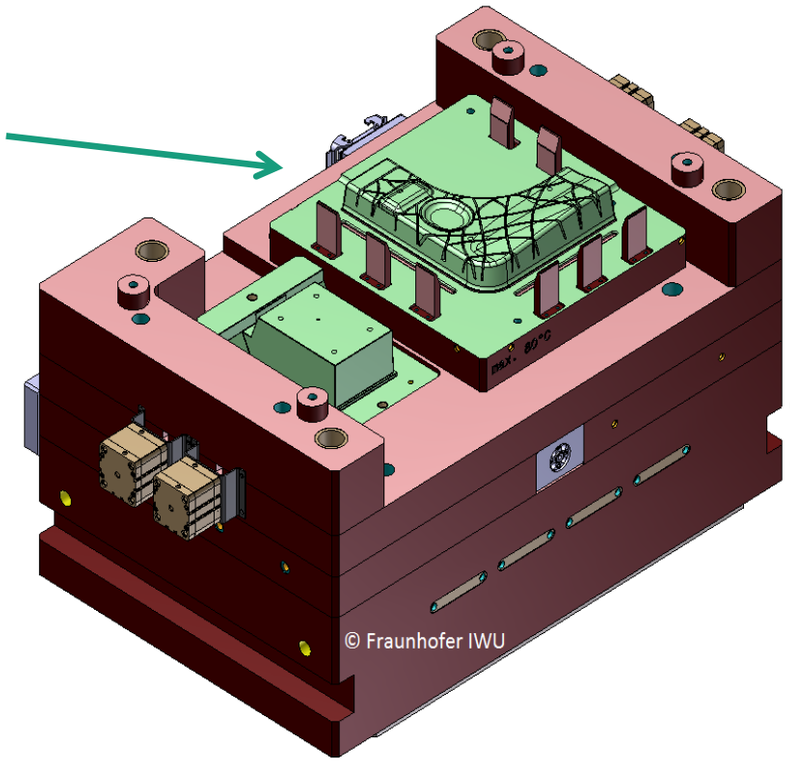
tools - forming and injection moulding

- Integral manufacturing process

1) Deep drawing of metal and FRP sheet
2) Injection molding of ribs while forming an undercut with melted polymer

→ 1 tool stroke

A-pillar / sillboard transition



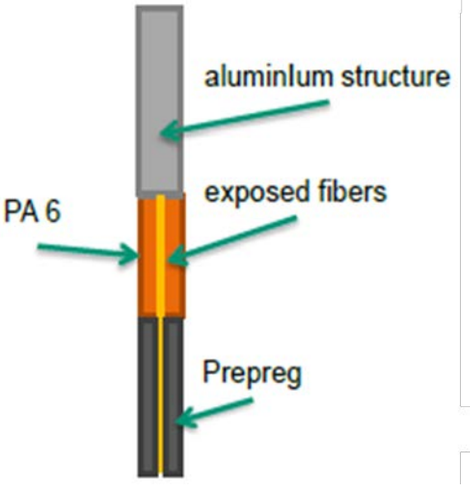
complex forming of hybrid structures component and tool

materials | textiles | fibre reinforced plastics | **tools** | components | recycling

Introducing Fraunhofer Project Center Wolfsburg

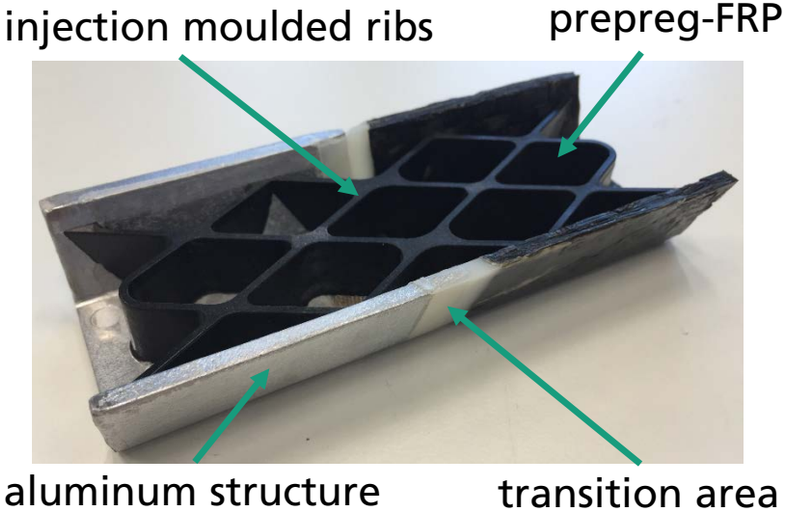
casting - transition structures

- Use of glass fibres for casting in aluminum for an integral, load path optimized connection of CFRP and aluminum



© Fraunhofer IFAM

- Advantages
  - light weight
  - Optimized load path
  - Corrosion resistant
  - Less space required



© Fraunhofer IWU@OHLF

materials | textiles | fibre reinforced plastics | tools | components | recycling

Pultrusion at Fraunhofer IWU

Current Research Objectives

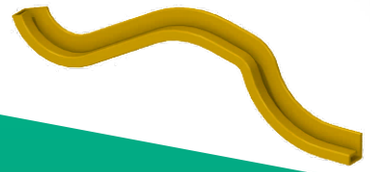
Pultrusion: a continuous process for the production of straight and low weight profiles

Fiber-/Matrix Systems

- processing and development of different fiber/matrix systems
  (glass-, carbon-, basalt fiber etc. / UP-, EP- PUR resins as well as thermoplastics etc.)

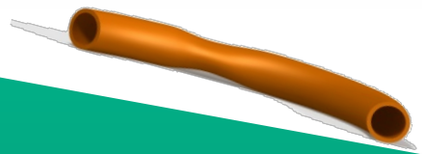
Virtual Process Chain

- simulation of fiber guidance, temperature distribution and curing within the tool, warpage etc.



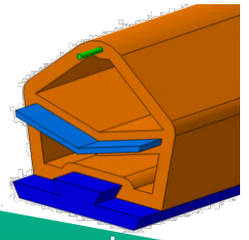
Variable curved Profiles

- realization of transitions between straight and curved sections



Changeable Cross-Section Profiles

- change of cross-section over profile length



Hybrid Profiles

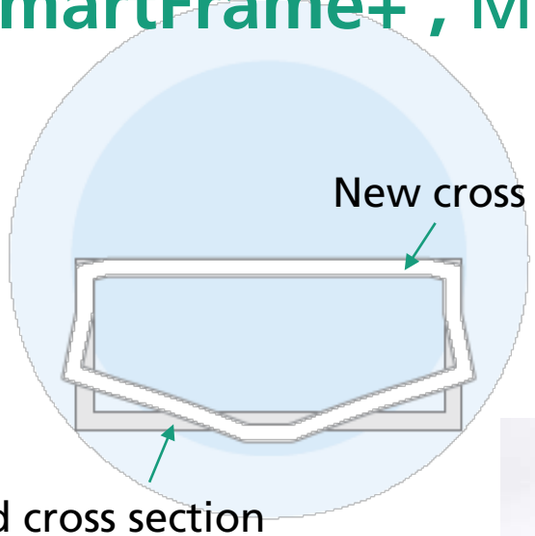
- integration of further materials (combination GFK/CFK, metals, elastomers etc.)

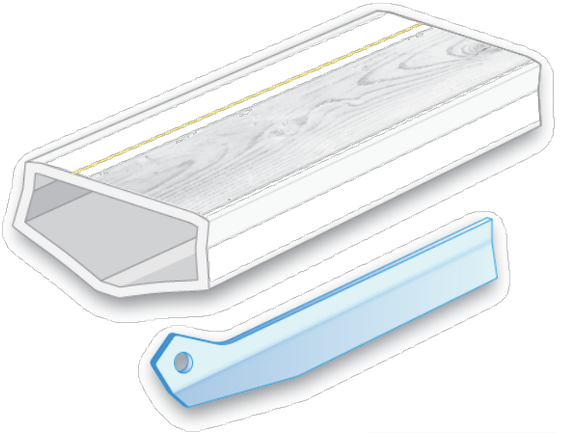
Smart Profiles

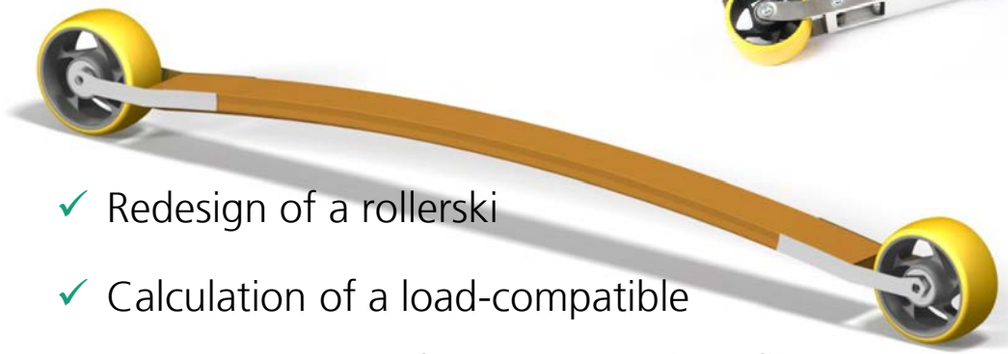
- integration of sensors and/or actuators

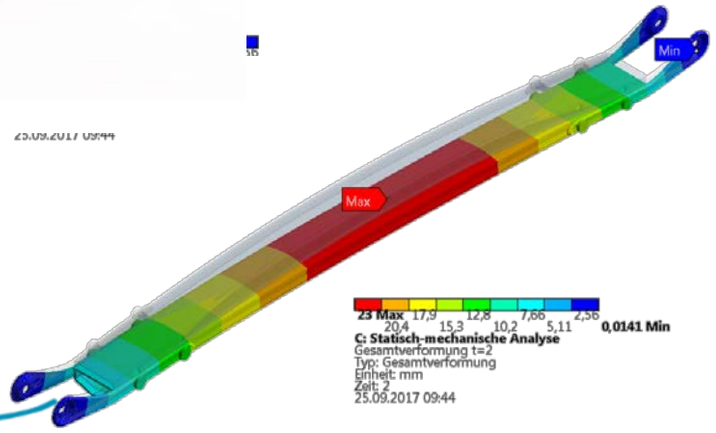
Pultrusion at Fraunhofer IWU

SmartFrame+ , Method overview









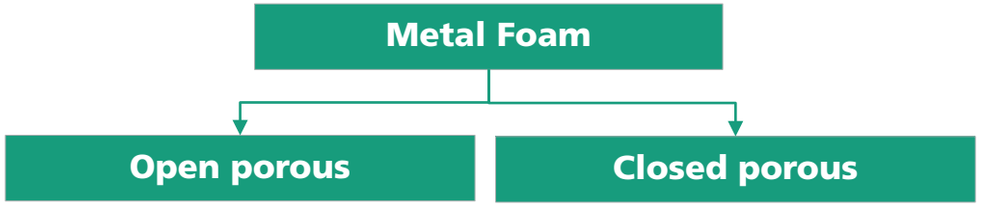
- ✓ Redesign of a rollerski
- ✓ Calculation of a load-compatible structure made of glass and carbon fiber
- ✓ Integrated Piezo-MFC-Sensors provide user feedback
- ✓ Springy effect enables a „more authentic ski feeling“

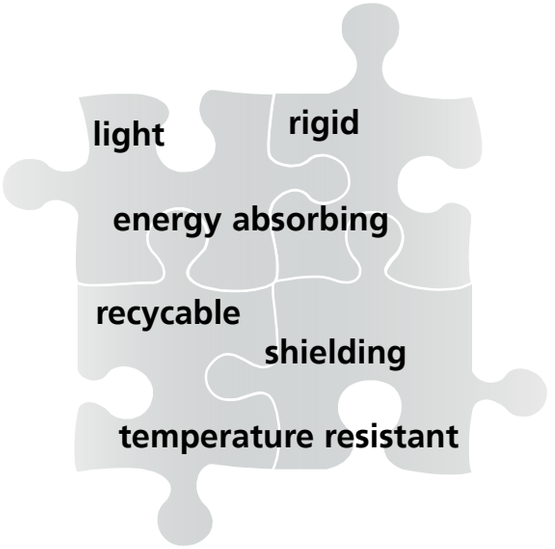
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

Fraunhofer IWU

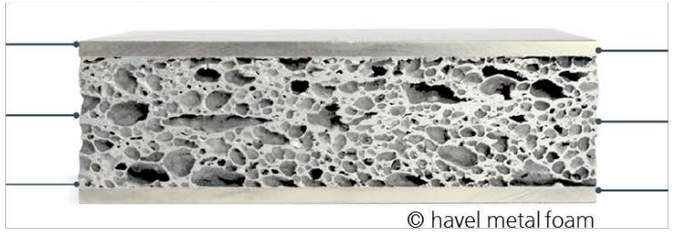
Lightweight design with metal foam at Fraunhofer IWU

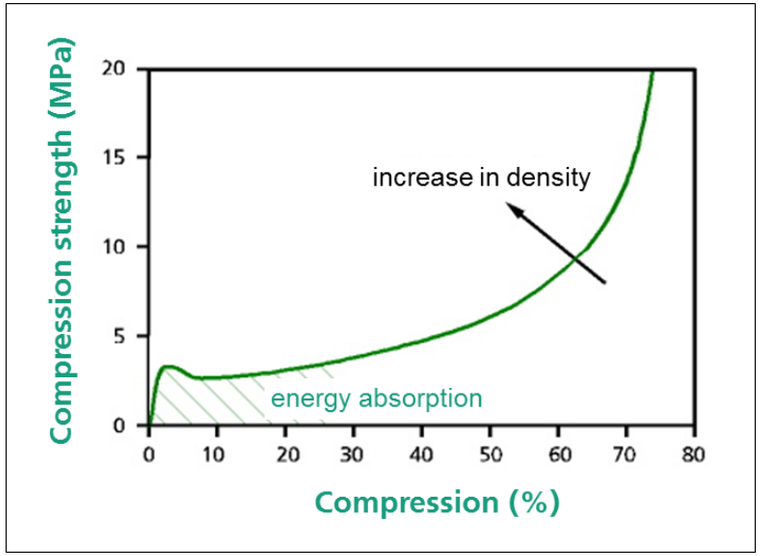
Basics





aluminum foam sandwich (AAS) → 2 aluminum cover sheets + aluminum foam core





Fraunhofer IWU

Battery housing solutions for EV

Specifications for battery housing of EV

- low weight
- low production costs
- low production time
- scaleability

- crash protection (side, front test)
- intrusion protection (stones, bollard)
- vibration performance
- battery module fixing
- interface safety (body mounting)

- thermal management
- fire safety
- thermal runway
- thermal isolation
- thermal conductivity

- production-orientated construction
- assembly orientated construction
- tolerances
- maintanence and repair

- water und gas tightness
- fire resistance
- corossion resistance
- electromagnetic compatibility

Fraunhofer IWU

Battery housing solutions for EV

Research activities Fraunhofer IWU

Mechanical functional extension

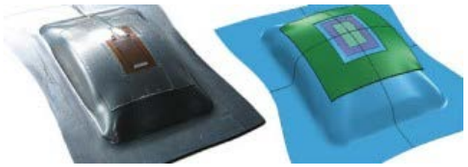
Lightweight design
•
Intrusion protection
•
Crash protection
•
Structural control

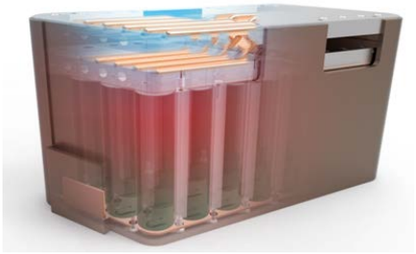
Thermal functional extension

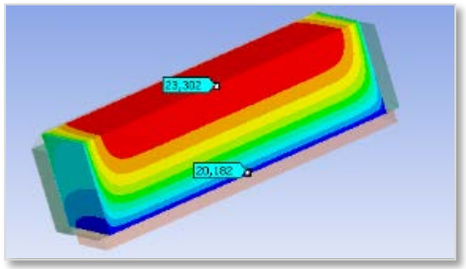
Thermal management
•
Storage and release of thermal energy
•
Increasing temperature homogenity
•
Switchable thermal conductivity
•
Fire protection

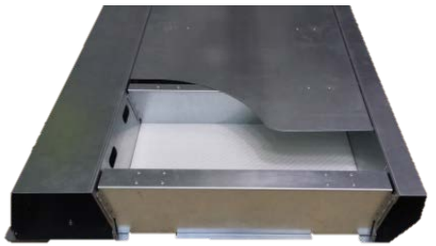
Product technology solutions

Integral manufacturing process
•
Shortening of process chain
•
Press hardening of metal components









Fraunhofer IWU

Battery housing solutions for EV

Battery housing designs/materials

aluminum
BMW i8, Daimler EQC, VW iD., Audi e-Tron, Golf GTE, Toyota Prius


© CSA Herzogenburg


© Daimler

fiber reinforced plastics (FRP)
concepts, research, prototypes, sports/racing


© SGL Carbon

steel
VW e-Up, Nissan LEAF, Daimler E18-2evo, Chevy Bolt


© Volkswagen


© Chevrolet

3D-printed
concepts, research

polymer
Samsung SDI (12V / 48V)

Battery housing solutions for EV

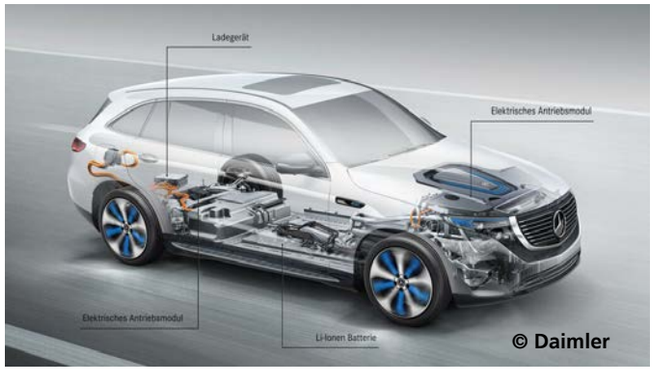
New aspects of mechanical loads for EV

- critical crash load case of EV depends on position of HV-battery
- newest and future EVs → batteries in the floor panel
- beside front and side crash scenarios the **bottom penetrations test** becomes extremely important for

→ damage protection of battery system

→ passenger safety

VW ID.



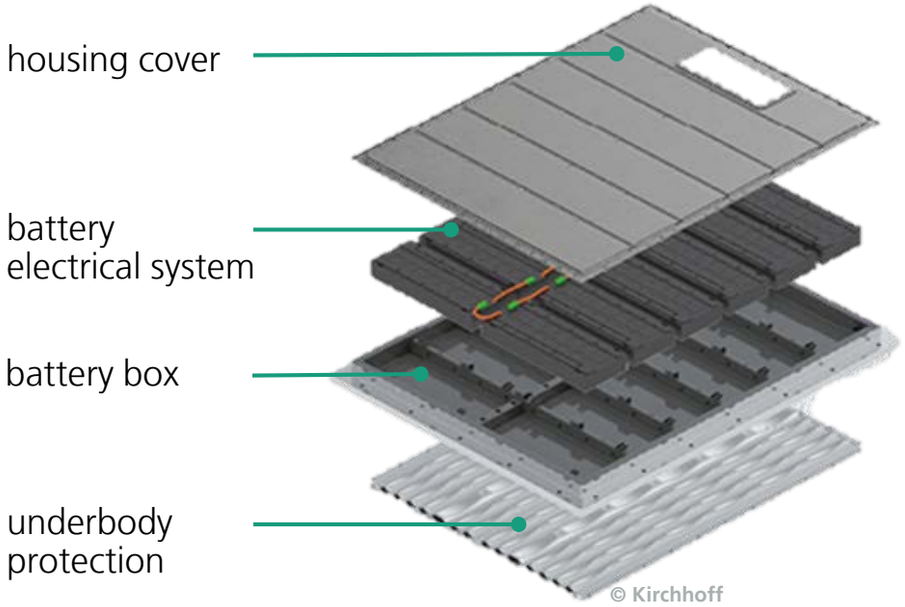
Daimler EQC

BMW i3

Battery housing solutions for EV

Motivation

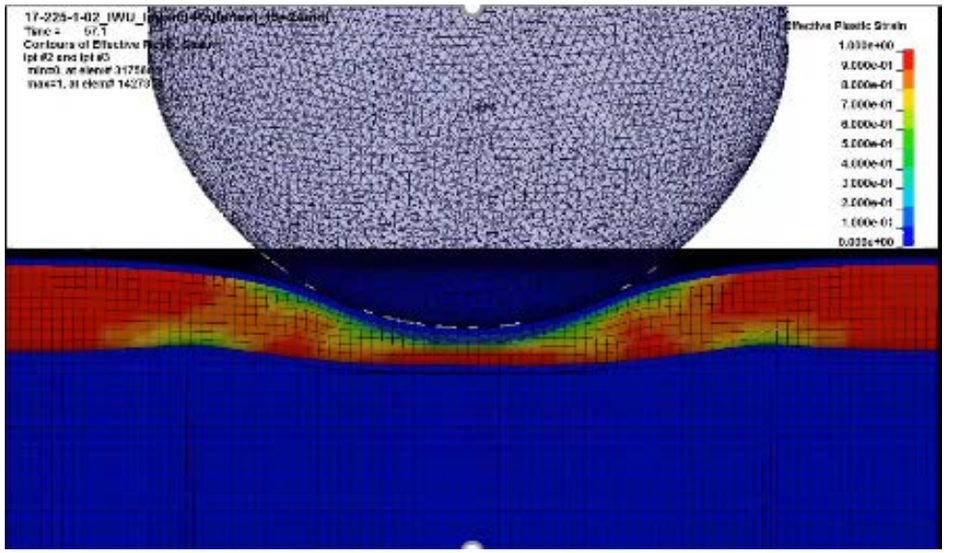
sub systems of battery housing

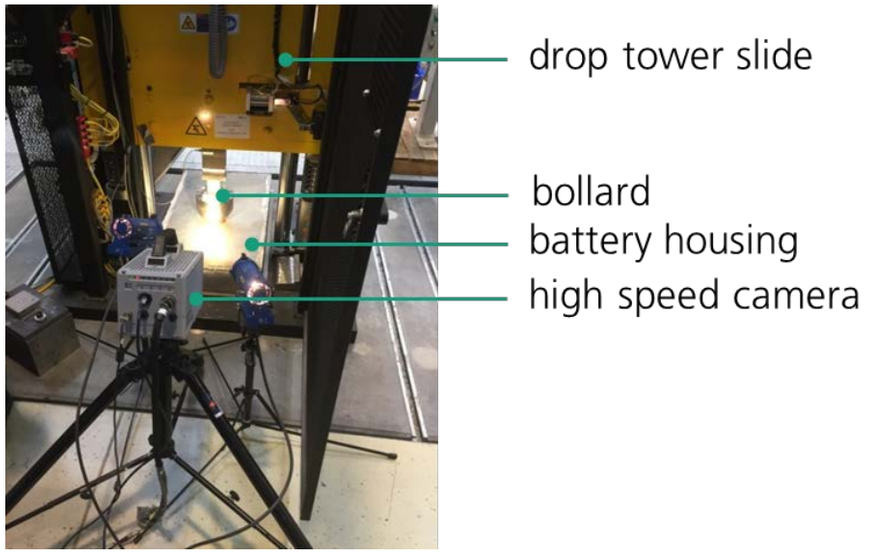


Battery housing solutions for EV – mechanical functionality

Aluminum battery housing bollard test – project example

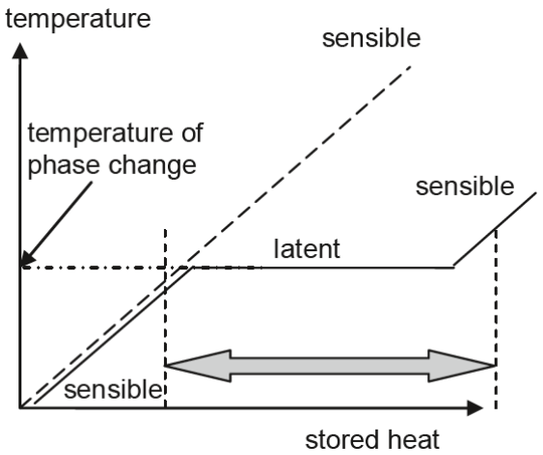
- Sandwich lightweight design
- High energy absorption through closed cell aluminum foam deformation
- Good thermal properties:
  Thermal conductivity, fire behavior
- Electromagnetic compatibility (EMC)





Passive temperature control

- phase change material (PCM) for passive temperature control
- Paraffine:
  - state of aggregation is a reversible process
  - adjustable melting range
  - physiologically harmless
  - high thermal capacity, but:
    low thermal conductivity!

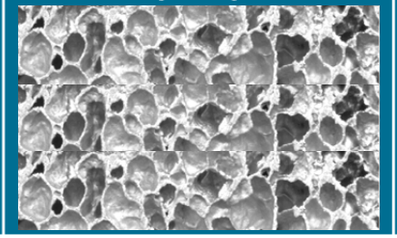


Enthalpy of PCM (solid/liquid)

$$H_{PCM} = \begin{cases} \int_{T_0}^{T} c_{p,s} \cdot dT\,, & \text{für } T < T_{su} \\ \int_{T_0}^{T_{su}} c_{p,s} \cdot dT + \int_{T_{su}}^{T_{so}} c_{p,latent} \cdot dT\,, & \text{für } T_{su} < T < T_{so} \\ \int_{T_0}^{T_{su}} c_{p,s} \cdot dT + \int_{T_{su}}^{T_{so}} c_{p,latent} \cdot dT + \int_{T_{so}}^{T} c_{p,l} \cdot dT\,, & \text{für } T > T_{so} \end{cases}$$

Infiltration of metal foam with PCM

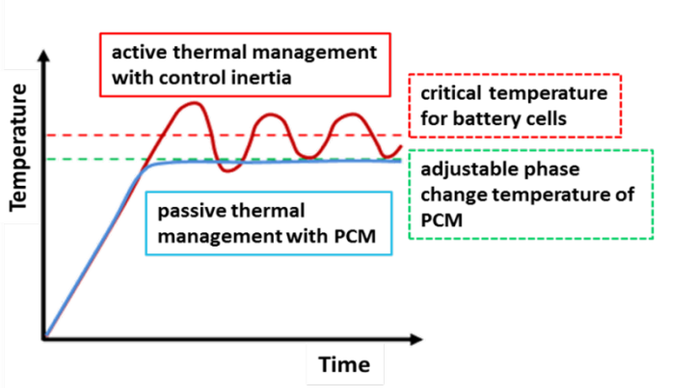
+ state of aggregation is a reversible process
+ adjustable melting range
+ physiologically harmless

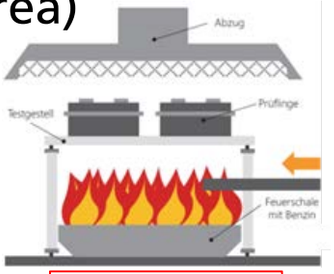
	PCM (RT44HC[4])	Metal Foam (MF)	PCM + MF (ρ_{MS} = 0,5 g/cm³)
			
Density [g/cm³]	0,8 (solid) 0,7 (liquid)	≥ 0,4	0,54
Thermal Conductivity [W/m·K]	0,2	15 **Factor 35**	7
Heat Capacity specific [J/g·K] latent [J/g] latent [W·h/kg]	 2 255 71	 0,7 - -	 0,94 256 71
Bsp.: Heat Capacity [J/g] for heating from 25 °C to 44 °C	287	13 **Factor 21**	272

Infiltration of metal foam with PCM

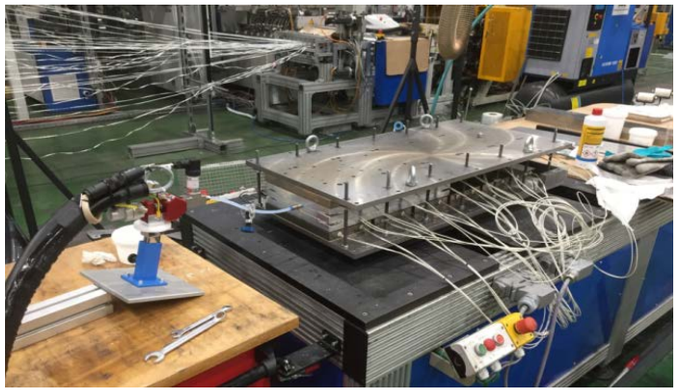
- strategies of thermal management with PCM

1) complete passive thermal management (load case depend, defined temperature area)
2) flatten thermal load peaks
3) increasing of temperature homogeneity
4) preventing / mitigation thermal runway

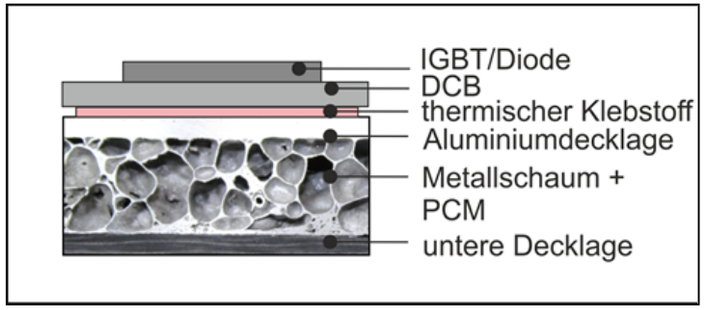




ECE R100 fire test



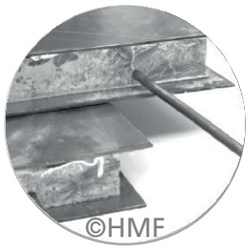
- mixing and metering unit for infiltration of parts and assemblies at Fraunhofer IWU
- infiltration with pressure and/or vacuum into a mold or direct into a part

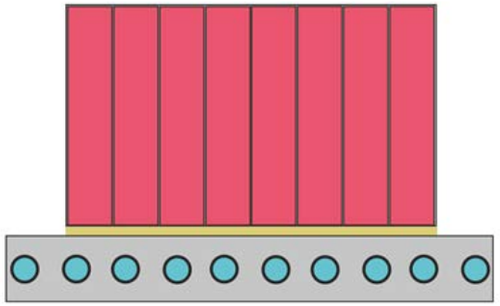


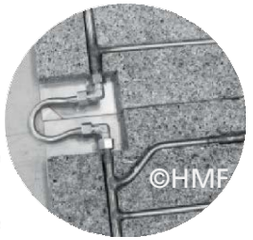
Integration of metal foam/PCM thermal management in EV-batteries

- strategies of thermal management with metal foam and PCM for EV-batteries

metal foam sandwich with integrated flow channels





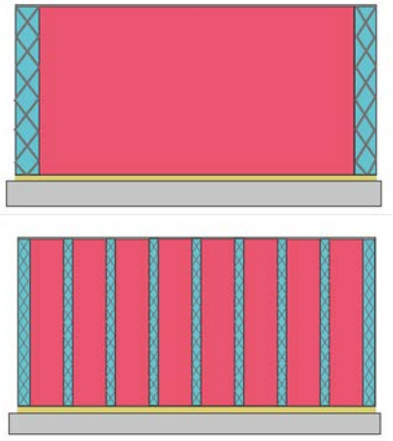


Aluminum foam **s**andwich with integrated steel tubing

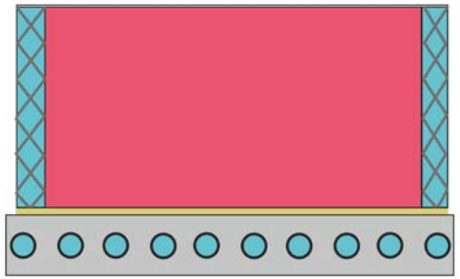
directly integrated during foaming process

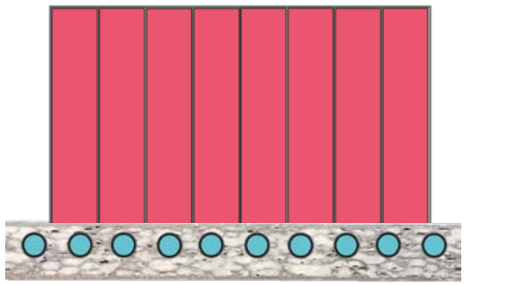
aluminum foam panel (milled) with integrated tubing

passive cooling with phase change material (PCM)



combinations of active and passive strategies

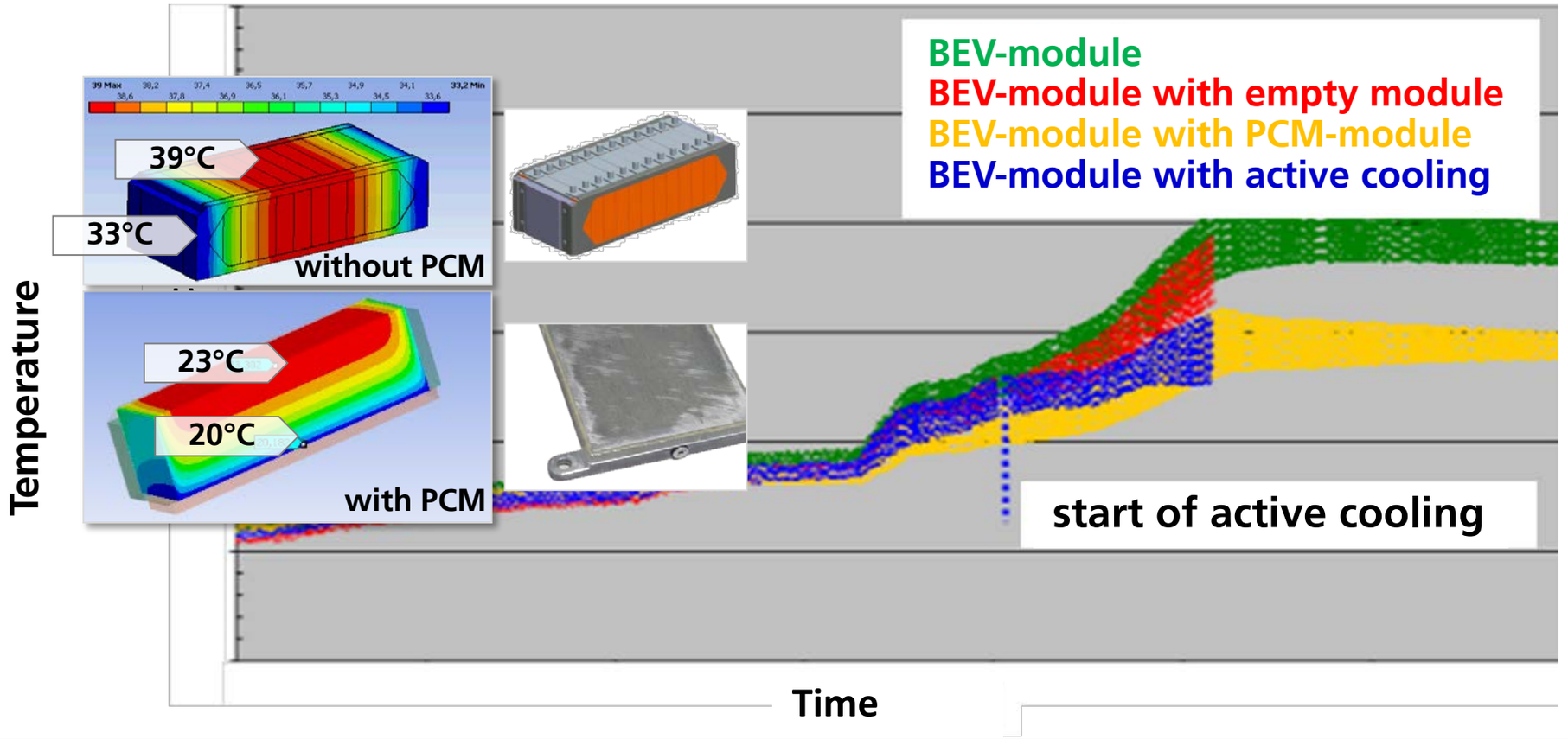




Fraunhofer IWU

Metal foam with PCM for thermal management of EV

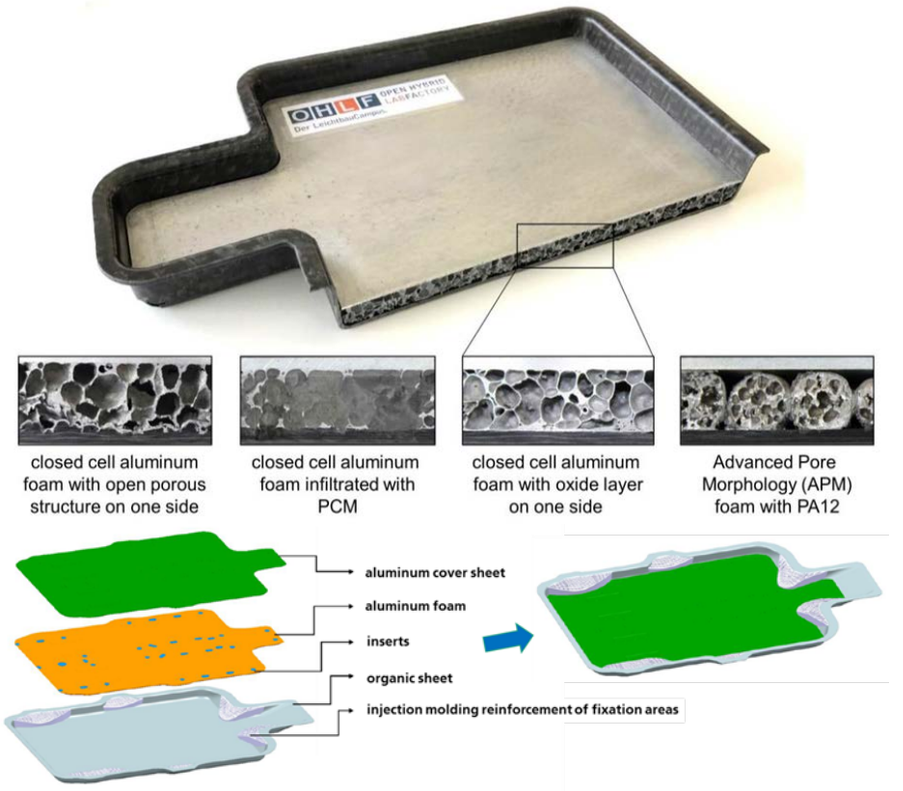
- passive thermal management with PCM-module for BEV-module was successfully realized for defined load case, without exceeding the thermal critical value
- simulation and experimental investigation: test for 1.5 h load case successfully for BEV and PHEV
- temperature gradient $\Delta T < 5$ K



Functionally integrated lightweight battery housing

Covering the process chain from material to components

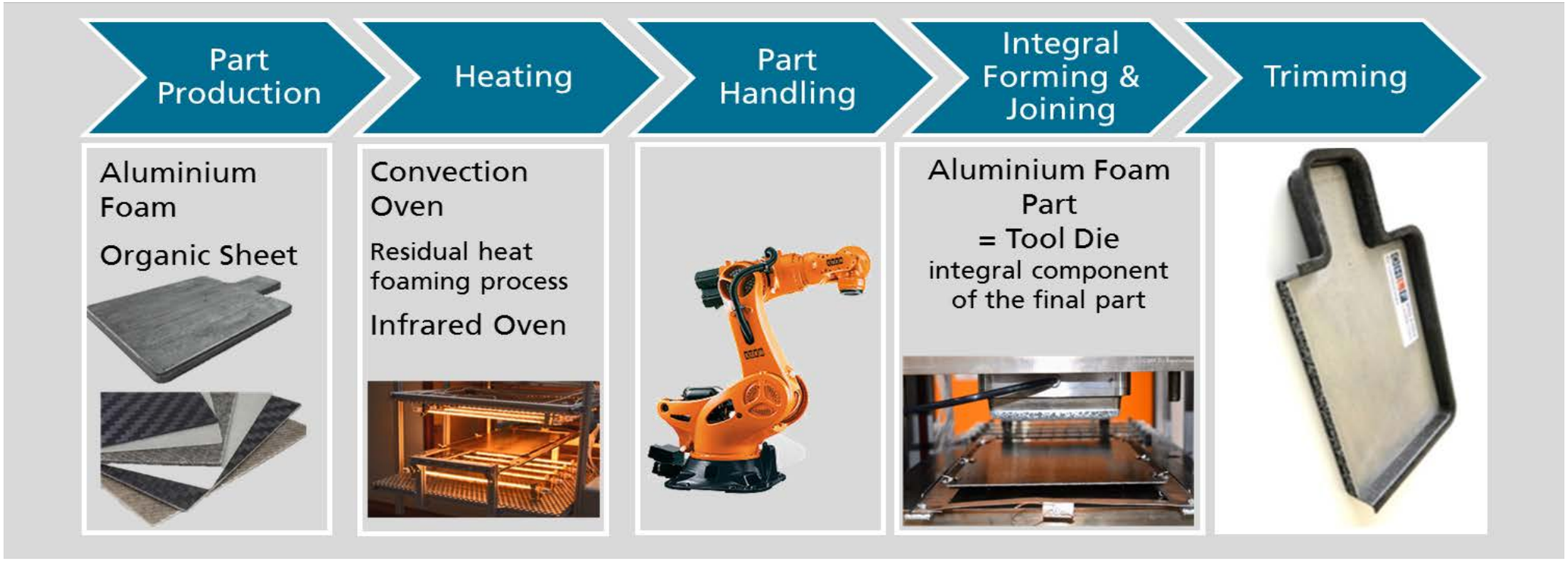
- Motivation: insufficient range of EV, thermal and mechanical functions separated, battery heating during charge and discharge → performance loss and safety issues
- Goals: development of a new concept for a battery housing, combining mechanical and thermal functions in a multi-material-mix, mass reduction, process step reduction
- Approach: sandwich setup with aluminum top sheet, aluminum foam core & FRP outer shell, optional integration of PCM into foam
- Results:
  - **mass reduction of 29 %** without thermal management (38,2 kg → 27,1 kg)
  - **mass reduction of 12 %** including PCM
  - **reduction of process steps** through integral forming and joining process



Functionally integrated lightweight battery housing

Manufacturing process

- hybrid components: complex process chain
- developed process: reduction of process steps
- integral forming and joining

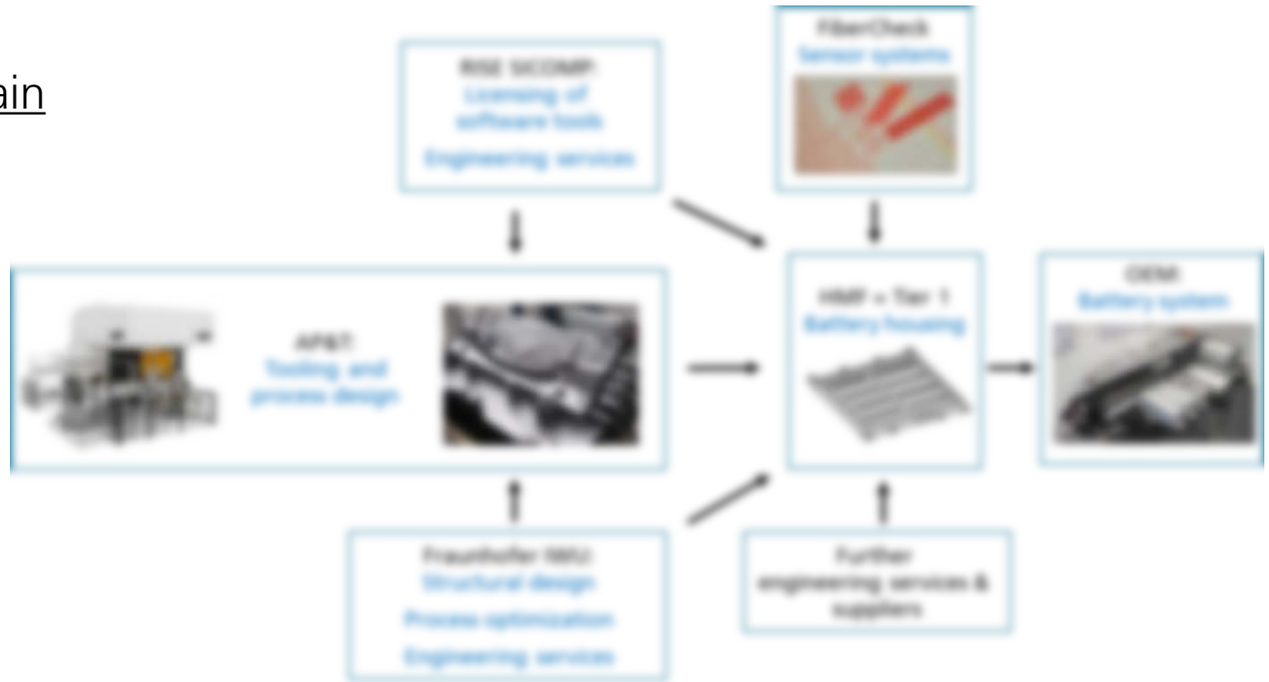


Swedish – German cooperation approach

SafEBat: Secure Applications for Electric Battery Housing

- Development and process design of a battery housing with integrated sensors and thermal management in true scale
- Research partners: RISE SICOMP and Fraunhofer IWU

Possible value chain



Thank you for your attention !

Fraunhofer Institute for Machine Tools and
Forming Technology IWU

Dipl.-Ing. Rico Schmerler
Phone: +49 (172) 5618108
Mail: Rico.Schmerler@iwu.fraunhofer.de
Address: Fraunhofer Project Center Wolfsburg
Hermann-Münch-Straße 2
38440 Wolfsburg
Germany

Acknowledgements:

Niedersächsisches Ministerium für Wissenschaft und Kultur

Bundesministerium für Bildung und Forschung