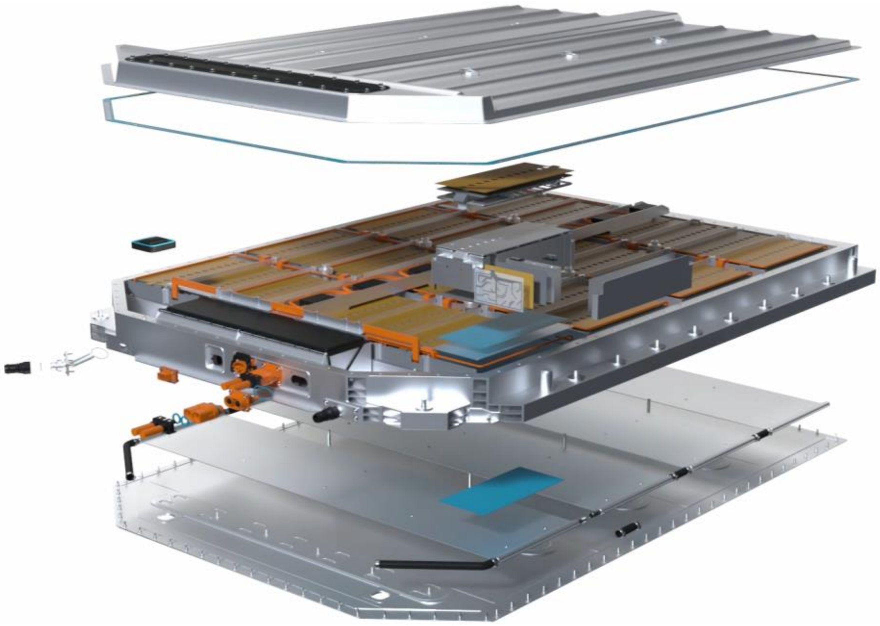

WeAutomotive Techtalk Webinar

System-Critical Elastomer Components for Battery Systems

June 5th 2024, Andreas Proksch, Dr. Ondrej Kysilka

DATWYLER

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Datwyler market focus and core competencies

Business Areas

Technology & Innovation

Sustainability & Operational Excellence

Finance & Shared Services

Group Functions

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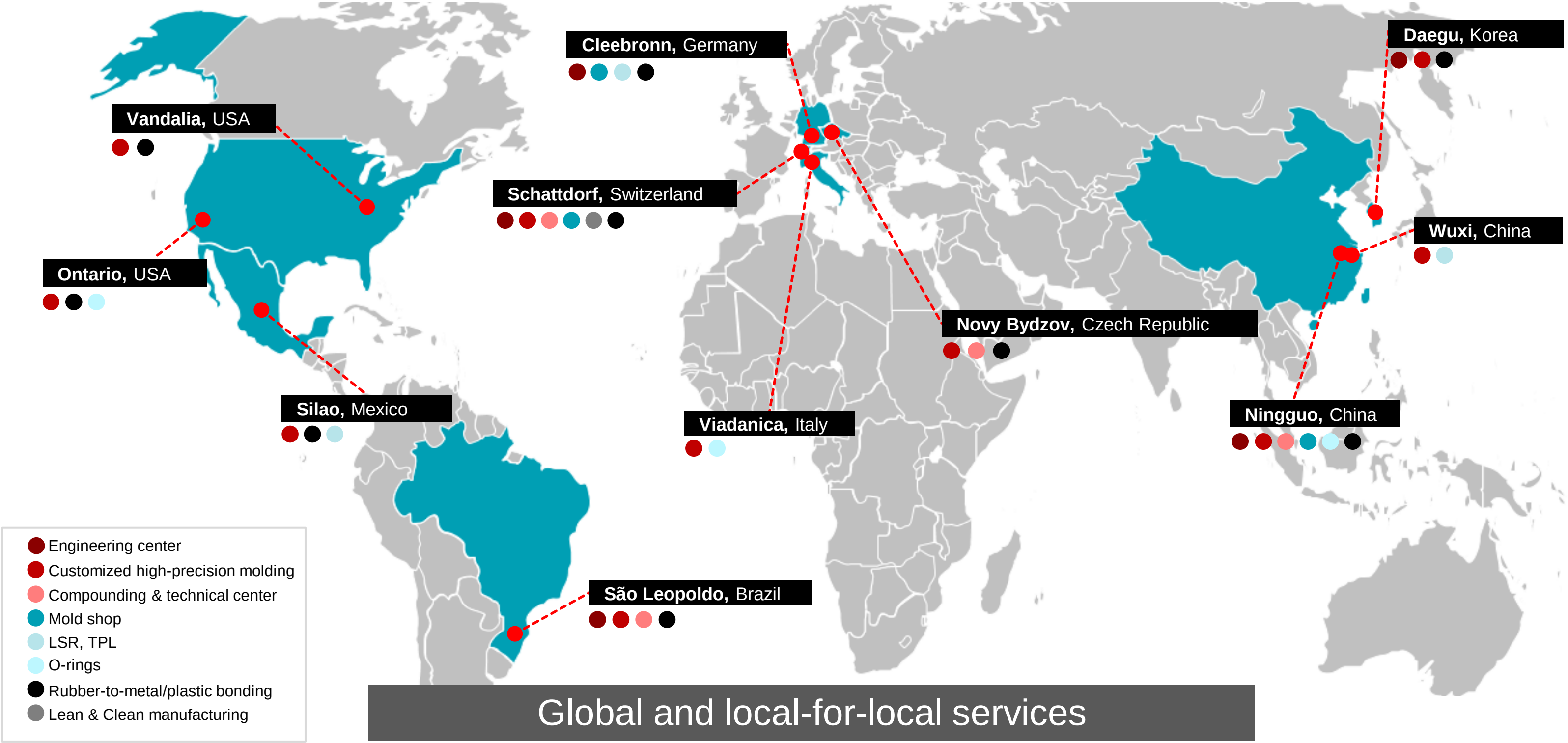
Global engineering and manufacturing mobility experts



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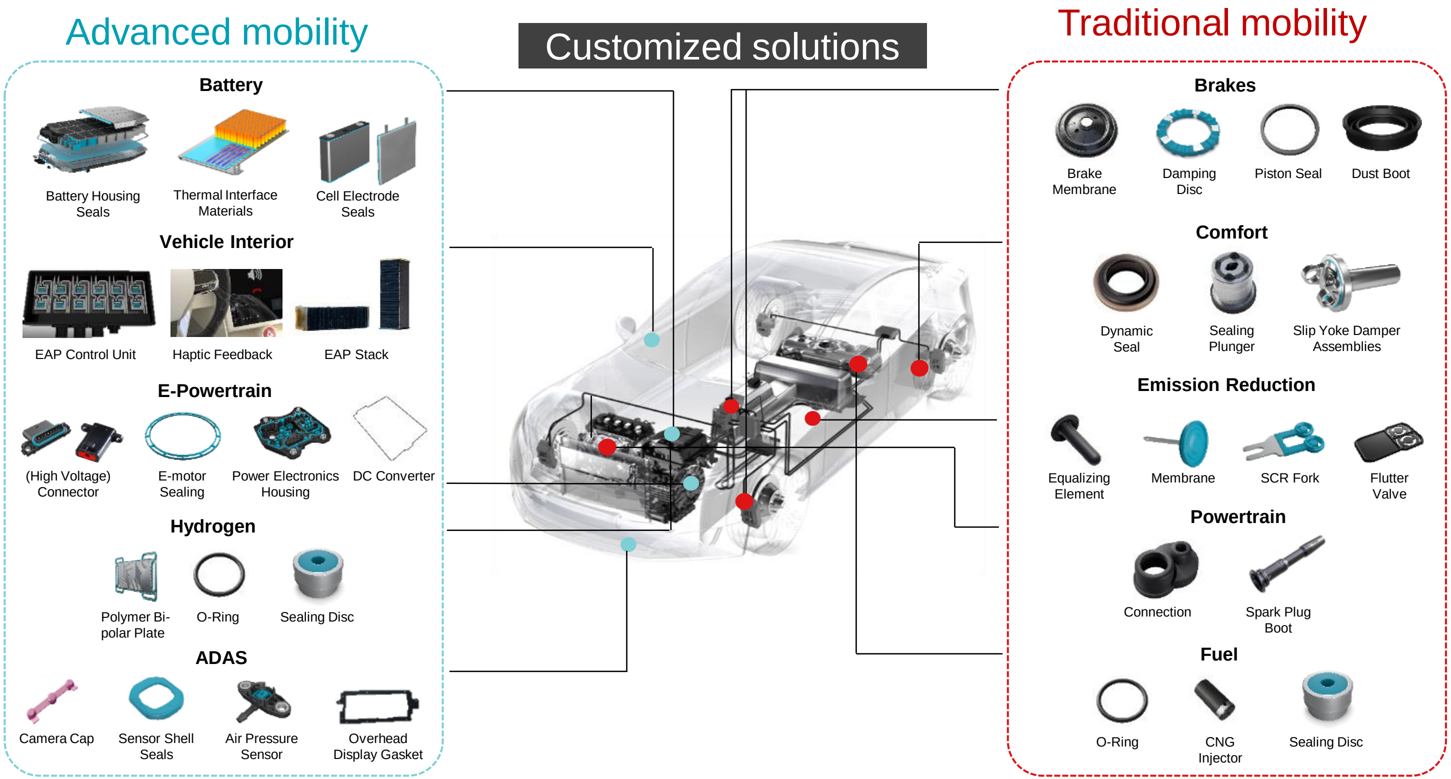
Mobility product portfolio



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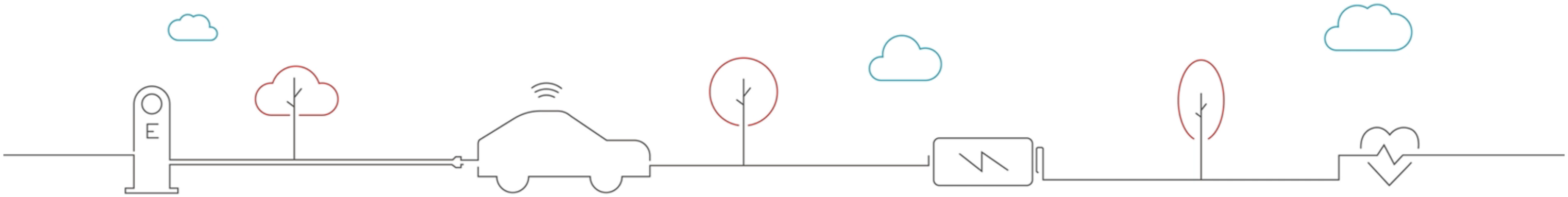
Engineering at the Heart of Mobility



Sealing technologies for battery system

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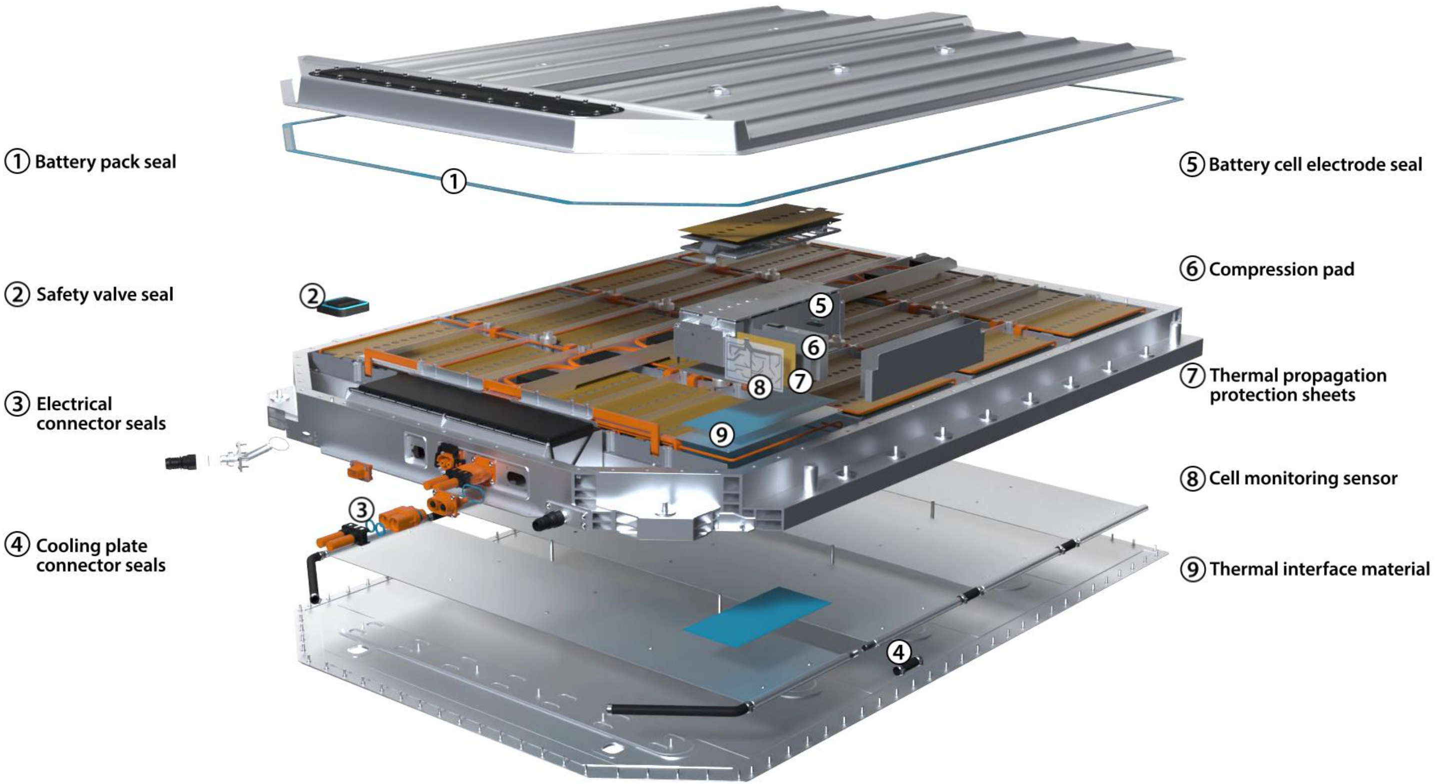
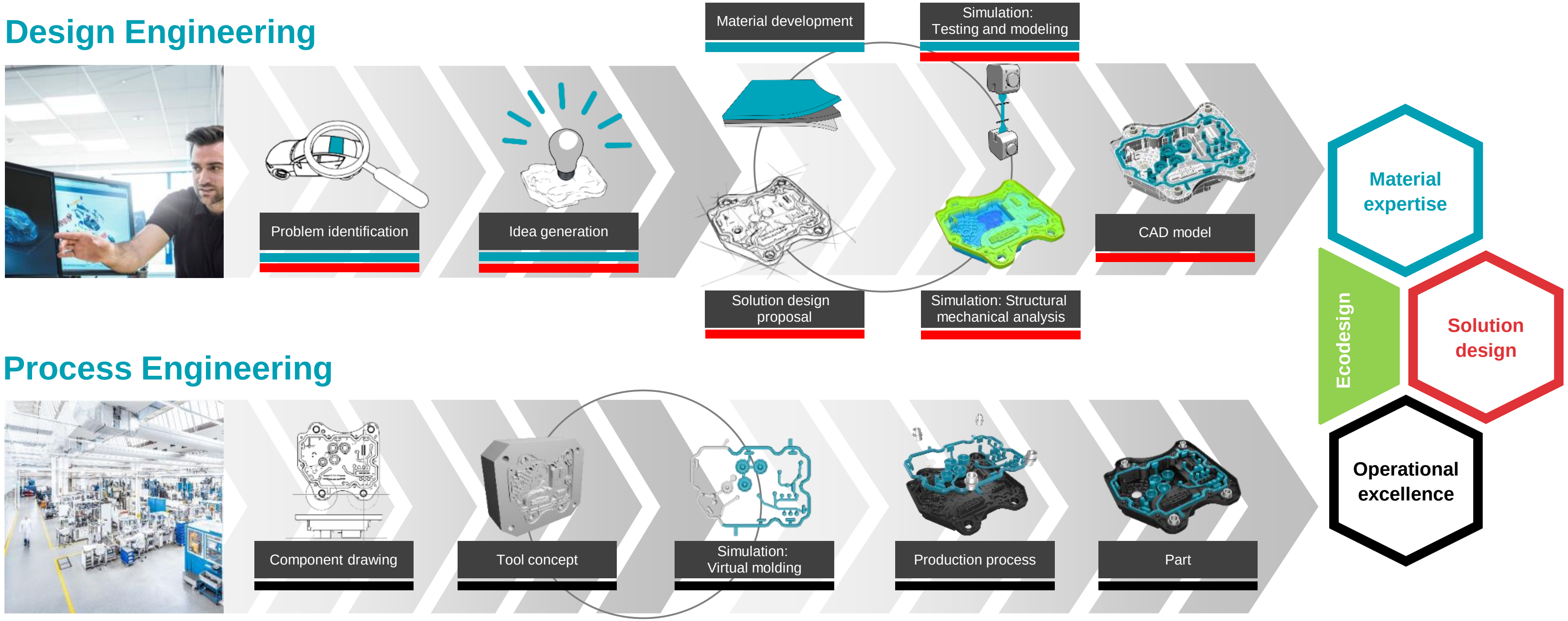
Applications in battery system



Co-engineering process

Partners for full-service and in-house solutions



Materials expertise

Developing elastomer compounds for system-critical components

All materials are customer-designed developments and are produced internally in Datwyler's mixing plants. Currently more than 800 active recipes globally

Different elastomeric materials and possible applications	
NR	Damping Elements
SBR	Brake Systems
EPDM	Brake-by-wire, Battery Systems, H_2-applications
CR	Damping Elements
NBR	Membranes
HNBR	Membranes, E-liquids, Immersion Cooling
VMQ	Battery Systems, Conducting Materials
FKM	Liquid Mgmt, H_2-applications, High Temperatures
FVMQ	Liquid Mgmt, Transmission
AEM	Transmission, E-liquids

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Mixing and testing facilities

Laboratory scale | **Industrial scale** | **Testing and analytical labs**

- Internal mixing know-how
- Various mixing equipment at lab scale
- Several industrial scale mixing sitess
- High level of automation and quality control

- Standard polymer testing methods
- Rheological and dynamic analysis
- Optical and electron microscopy
- Chemical and elemental analysis
- Focus on multicomponent parts and surface modifications

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How Datwyler's material team can support you

Raw Materials Testing & Research

Rubber Compound Formulation Expertise

Materials Science

Mixing Process

Failure Analyses & Quality Control

Surface Treatment

Chemical Compliance

Expert Network

Battery cell seals

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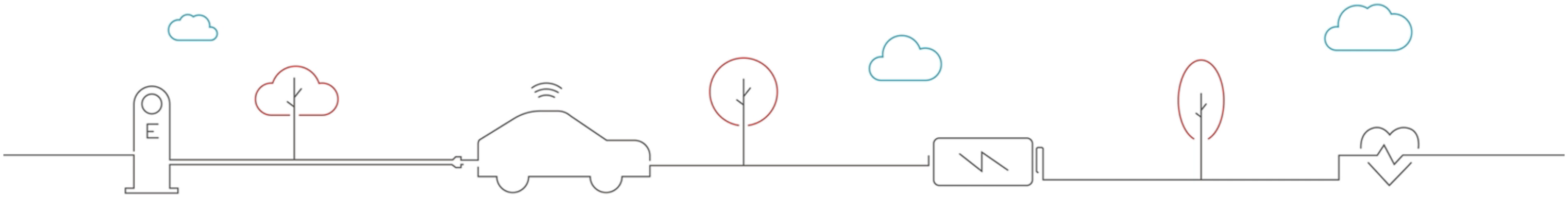
Engineering at the Heart of Mobility



Battery Systems

Battery Cell Seal

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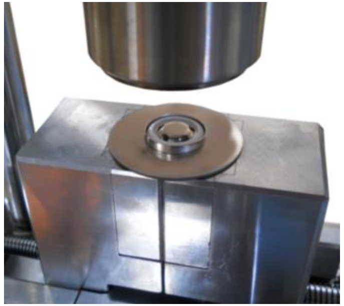
Assembly methods

Cylindrical

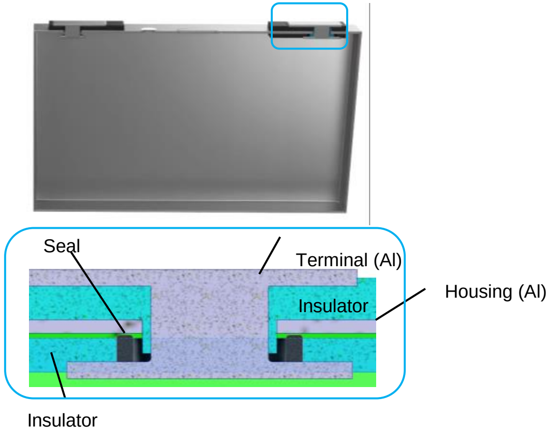
- Crimping
- Riveting (4680 lid)



Crimping, https://youtu.be/llgoP9Ob8iU

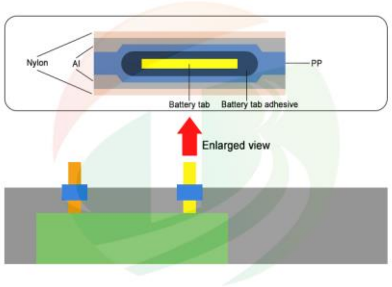
Prismatic

- Riveting
- Bolt
- Laser welding



Pouch

- Heat seal



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Electrolyte compatibility test

Initial Conditions:

- Electrolyte preparation and storage in nitrogen filled glove box
- Initial electrolyte HF and water content (< 10 ppm, respectively)

Aging conditions:

- Samples submerged in electrolyte for several hundred hours at a specific temperature

After ageing in electrolyte

Sample	Mechanical integrity	Surface appearance	Electrolyte coloration	HF formation (ppm)	Swelling (wt.%)	Mass change after drying (wt.%)
Reference	N/A	N/A	Colorless	28	N/A	N/A
FKM 1	OK	Duller and paler	Slightly yellowish	48	21	4
EPDM 1	OK	No significant change	No significant coloration	42	5.5	<-1

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Datwyler rubber seal

Conventional seals:

- Thermoplastics like polypropylene, polyamide (PA, 12), and perfluoroalkoxy (PFA) are used

Rubber seals:

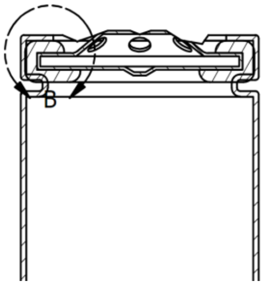
- Rubber (EPDM, and FKM) tested and approved for electrolyte compatibility: low HF formation and swelling after aging
- Customized design and simulation

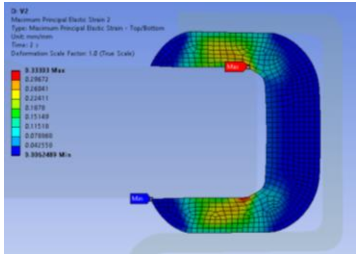
Advantageous over thermoplastic seals for:

- Long lifespan of electric vehicles (EVs)
- High-vibration environments in EVs
- Effective sealing despite geometrical changes

After ageing in electrolyte

Properties	Unit	EPDM 1	EPDM 2	EPDM 3
ΔMicrohardness	IRHD	2	2	1
ΔTensile strength	N/mm^2	-0.4	-0.2	0.4
ΔModulus at 100%	N/mm^2	0.4	0.2	0.1
ΔElongation at break	%	-20	-29	0





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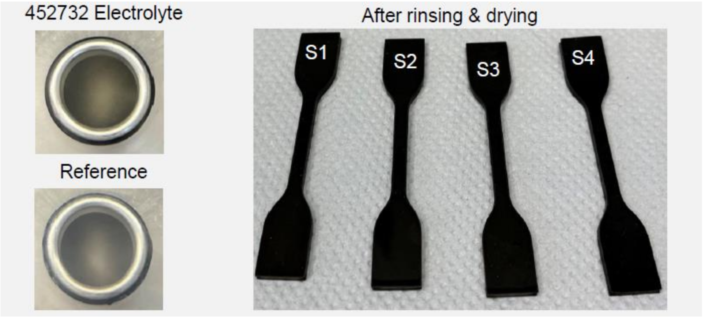
Electrolyte ageing results

- A proven material portfolio based on EPDM and FKM formulations (lab and industrial scale)

- Compounds show:
  - Moderate to excellent electrolyte resistance
  - Electrically insulating properties
  - Stability in given tested environment
  - Very good mechanical properties
  - Very good deformation properties, i.e. compression set



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Fire retardant compounds

Flame resistance in rubber compounds

Measurement methods

- Difficult to quantify
- Difficult to run
- Examples:
  - Ease of ignition (LOI)
  - Fire strength (MARHE)
  - Fire spread and speed (UL94)
  - Specialized testing

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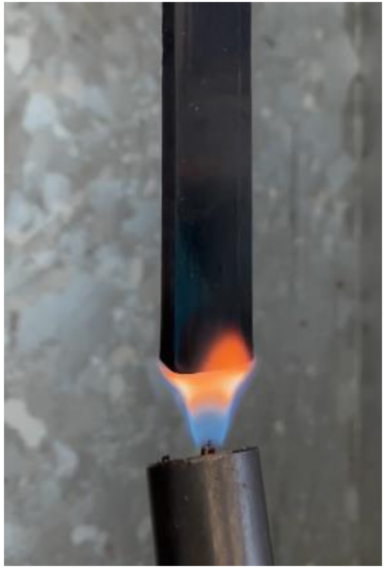
Flame resistance in rubber compounds

UL94 standardization

- Vertical burn (VB) is more difficult to meet compared to horizontal burn (HB)
- Flame applied for 10 seconds
- “After-flame time” is recorded
- Based on “after-flame time” the fire resistance classification is assigned
- The classification: **V0 > V1 > V2**

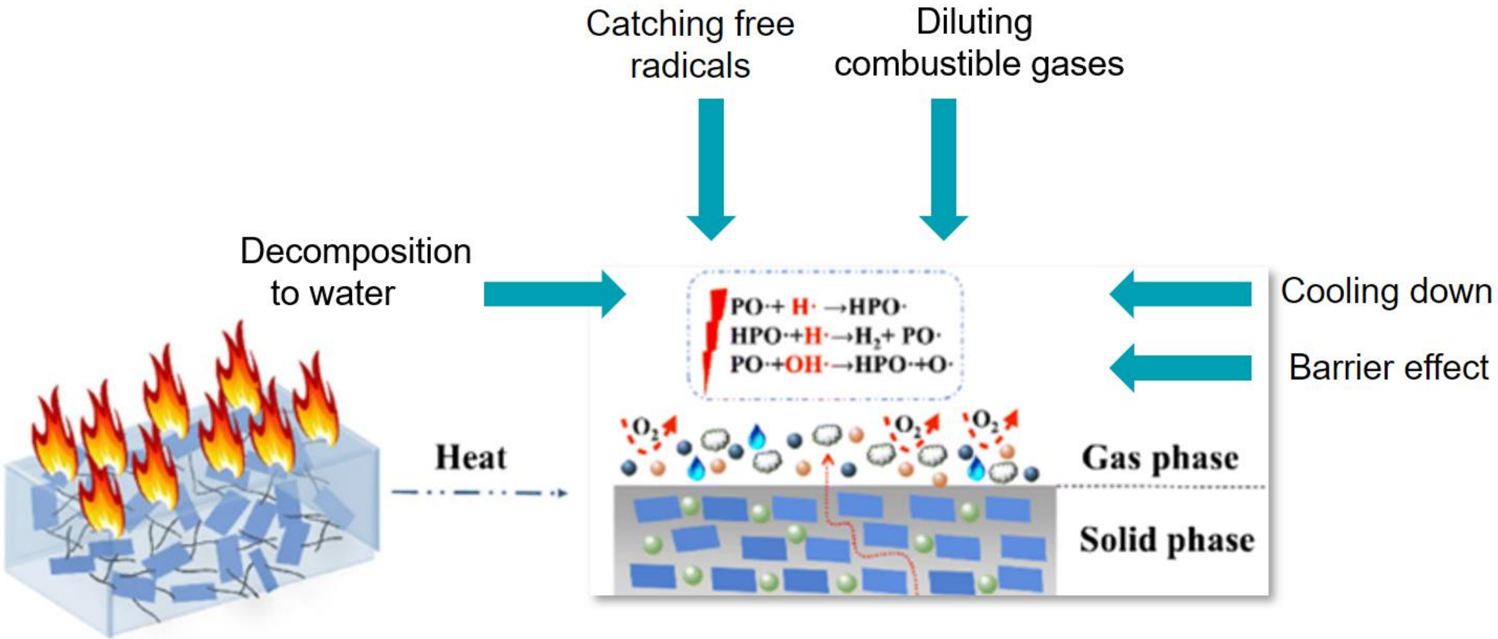
Not classified



Top classification – **V0**

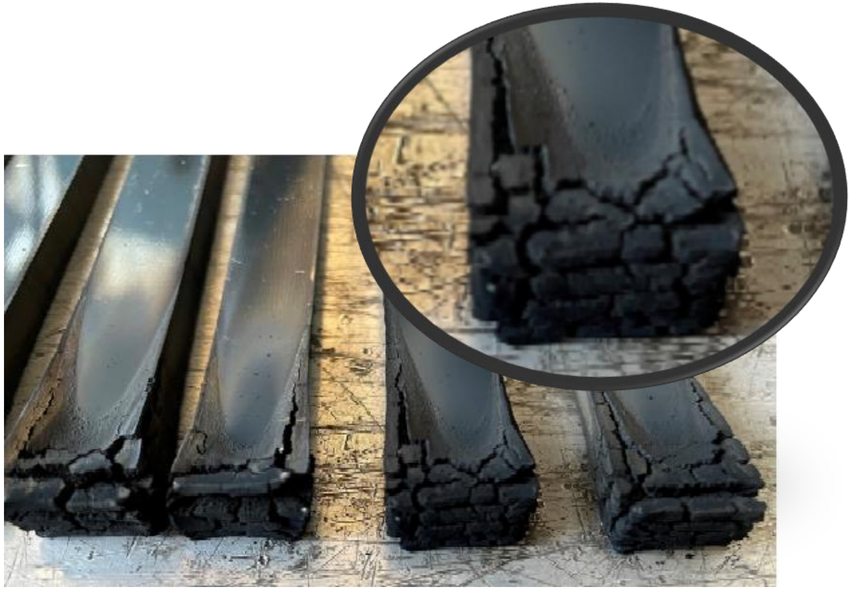
Flame resistance in rubber compounds

Mechanisms



Source: https://www.researchgate.net/figure/Schematic-illustrations-of-the-flame-retardant-mechanism-of-PLA-FGO-HQ_fig12_334618631

Standard vs. fire resistant compound



Standard compound

Fire resistant compound

Flame resistance in rubber compounds

- Fire resistant compounds exhibit self-extinguishing properties, contributing to the fire safety of EVs and is slowly becoming a new standard

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Intumescent fire retardants

intumescent filler

The EPDM-intumescent filler testpieces after testing

Material	Mode of FR	Classification
70 ShA EPDM	intumescent filler	V0
80 ShA EPDM	intumescent filler, phosphoric additives	V0

Meet the Developer: Fire resistant compounds

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Flame resistance in rubber compounds

Portfolio

Example of a V0 battery pack gasket

Material	Mode of FR	Datwyler lab	Certified external lab
50 ShA EPDM		V0	V0
60 ShA EPDM		V0	V0
70 ShA EPDM	Special fillers, halogen-free	V0	V0
80 ShA EPDM		V0	V0

Properties	Units	Results
Density	g/cm³	1.272
Hardness	ShA	72
Micro Hardness	IRHD	74
Tensile Strength	N/mm²	12.2
Elongation at Break	%	352
Modulus at 100% Elongation	N/mm²	3.6
Tear Strength A	N/mm	6.0
DVR	%	
DVR 24h/130°C, 25%	%	13
DVR 22h/140°C	%	48

Example of 70 ShA EPDM certified as UL94-V0.

We offer UL94-V0 solutions based on various polymers – EPDM, HNBR and AEM of various hardness

Flame resistance in rubber compounds

Normal compound

FR compound

Intumescent compound

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Thermal interface materials

Indirect cooling

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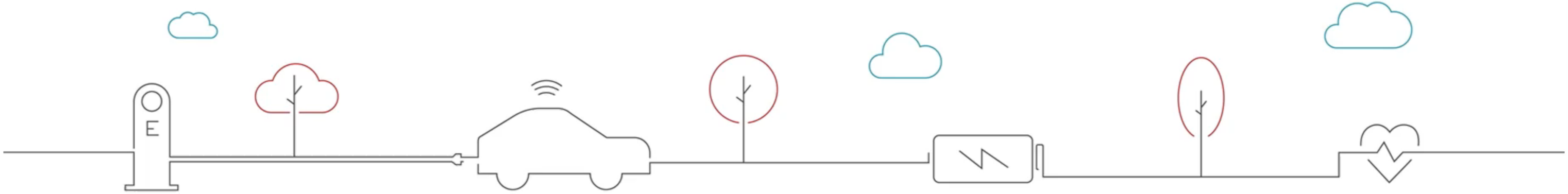
Engineering at the Heart of Mobility



Battery Systems

Thermal interface material (TIM)

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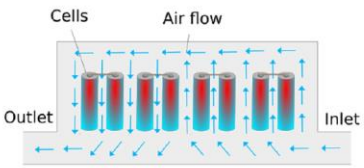
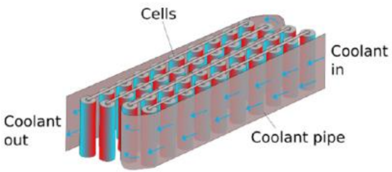
Thermal management of battery electric vehicles

Air cooling



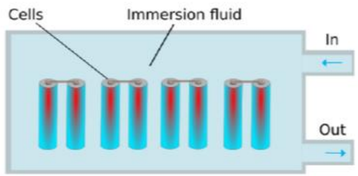
- Simple in design
- Low cost
- No issues with leakage
- Low heat capacity and thermal conductivity compared to liquids

Indirect liquid cooling



- Most frequently used in battery thermal management
- Cooling fluid flowing through channels transfers the heat
- Usually, a coolant made of a mixture of water and ethylene glycol

Immersion (direct liquid) cooling



- Emerging technology
- Reducing complexity of the system and component design resulting in reduced weight
- Positive impact on temperature stability, uniformity and efficiency

Roe Ch. et al. Immersion coling for lithium-ion batteries – A review. Elsevier. 2022.

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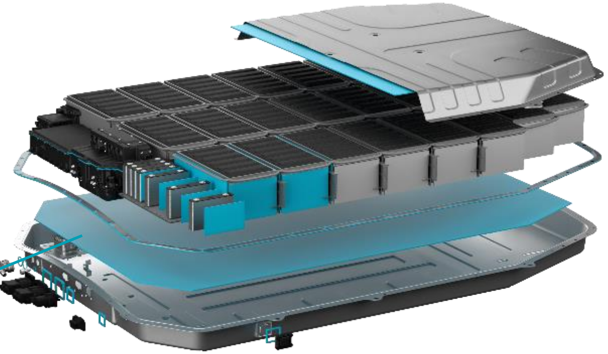
Thermal interface materials (TIMs)

Various Thermal interface material solutions

- *Thermal rubber pads*
- Thermal gap fillers
- Thermal pastes
- Adhesives

Thermal Interface Material



Source: https://www.youtube.com/watch?v=ssU2mjiNi_Q

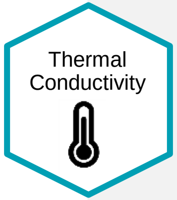
These materials can be processed

- Cure-in-place
- Molded or calandered thermally conductive pad

Thermal interface materials (TIMs) are designed to provide adequate thermal conductivity to evacuate heat → thus enhance **performance, longevity and safety**

Thermally conductive elastomers

Overview

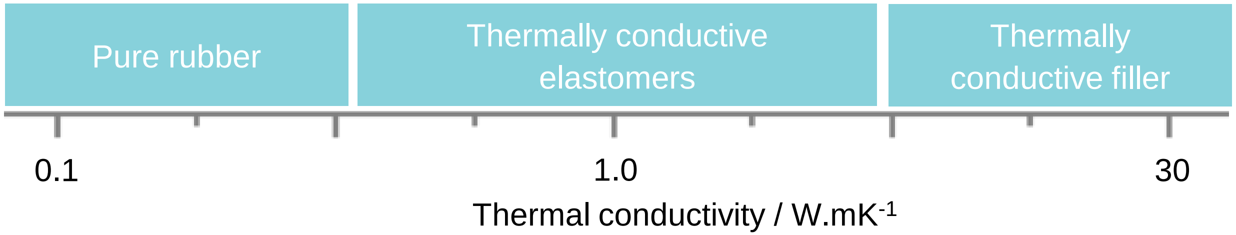


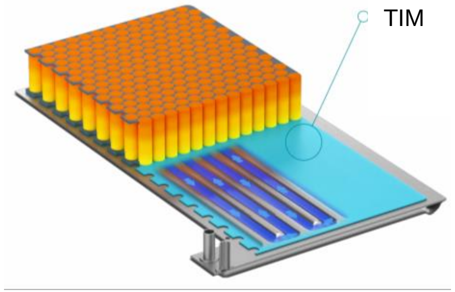
Thermally conductive materials are capable of thermal transfer

Thermal management of EVs is using the principle in so-called **thermal interface materials** that support the heat transfer from battery cell/module to the cooling system

Thermal interface materials keep the optimal operating temperature of battery and prevent thermal runaway event

Thermal conductivity is measured in Watts per meter-Kelvin [W.mK^{-1}]



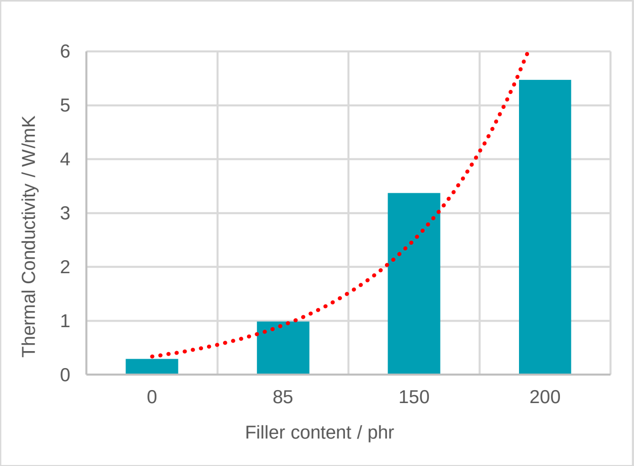


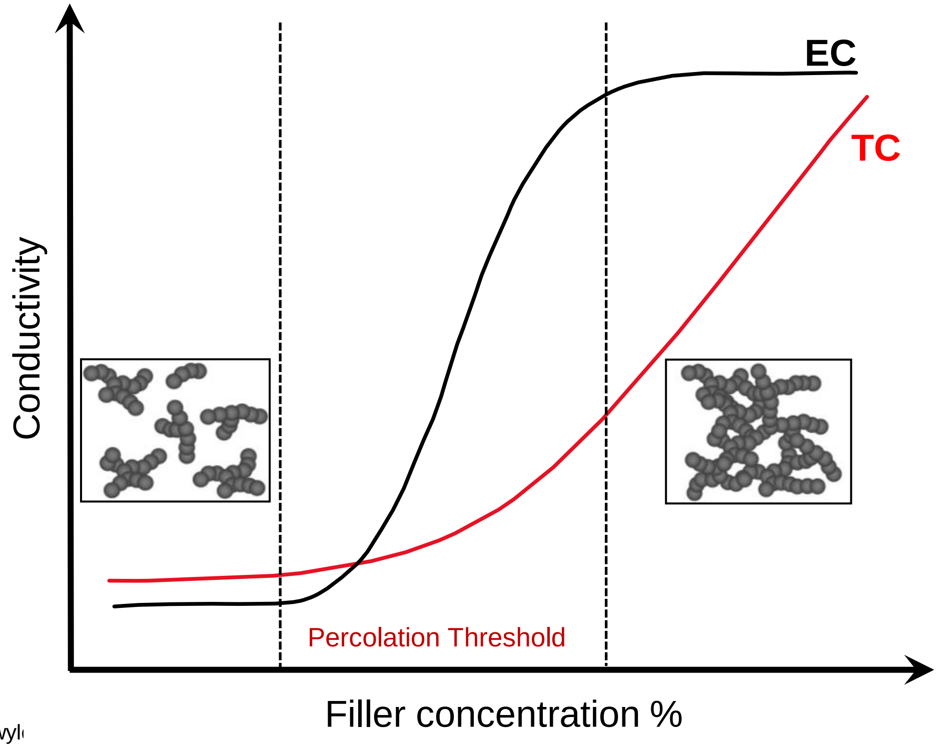
Thermally conductive elastomer

Overview

Percolation threshold

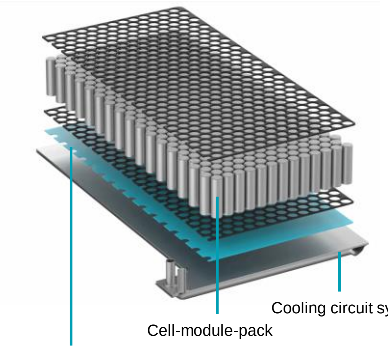
- Thermal transfer is governed by phonon-phonon coupling
- Filler-filler interaction
- Conductive path
- Percolation threshold
- Filler content

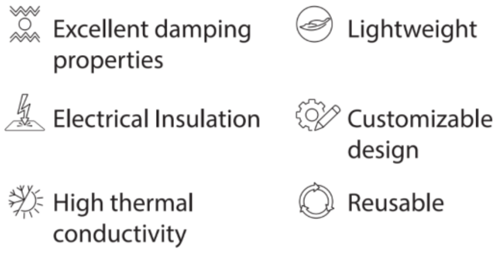




Thermal management and safety

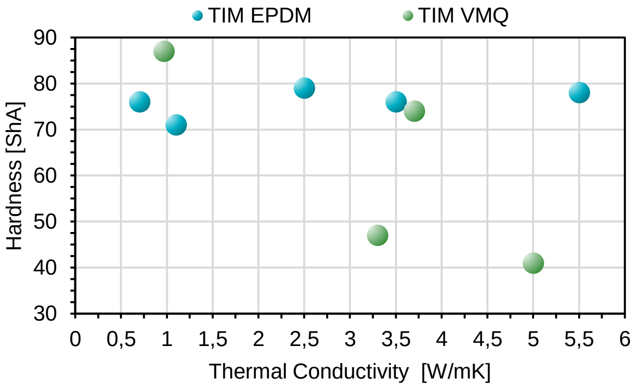
Indirect cooling of batteries (thermal rubber pad)

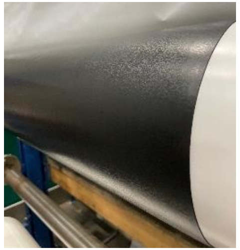




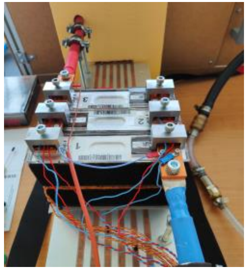
Datwyler's project ETEMI® thermal rubber pads (lab scale development)

Characteristics	TIM EPDM 1	TIM EPDM 2	TIM VMQ 1	TIM VMQ 2
Hardness ShA	75	79	41	47
Density / g/cm^3	1.35	1.48	1.46	1.69
Thermal conductivity / W/mK	4.2	2.5	5.0	3.9
Flammability test (UL94)	V0	V0	V0	V0





Calendering



Performance test in battery systems

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Immersion cooling

Pros and cons of immersion cooling

+

- Temperature stability and uniformity
- Dielectric fluids are **non-conductive and normally "non-flammable"**
- The design complexity of the system could be, contributing to reduced weight
- High cooling efficiency enables fast charging

−

- The weight of some of the fluids is a concern (e.g. hydrofluoroethers)
- More space between the cells for fluid flow: reduced pack volumetric energy density
- Lower specific heat capacity compared to water-glycol
- Different chemical compatibility puts greater demand on seals and hoses
- Leakage and corrosion risk

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Different chemical families used for immersion cooling

- Aqueous solutions (incl. water-glycol, indirect)
- Hydrocarbon-based liquids (mineral oil)
- Ester-based liquids
- Fluorocarbon-based fluids
- Hydrofluoroether (HFE)-based fluids
- Silicone oils

AMG Battery Pack https://youtu.be/Rpf5uGCs-hI

Selection of sealing material depends on various factors such as the specific **application requirements**, **compatibility with cooling liquid**, **safety considerations**, **environmental impact**, and **cost**

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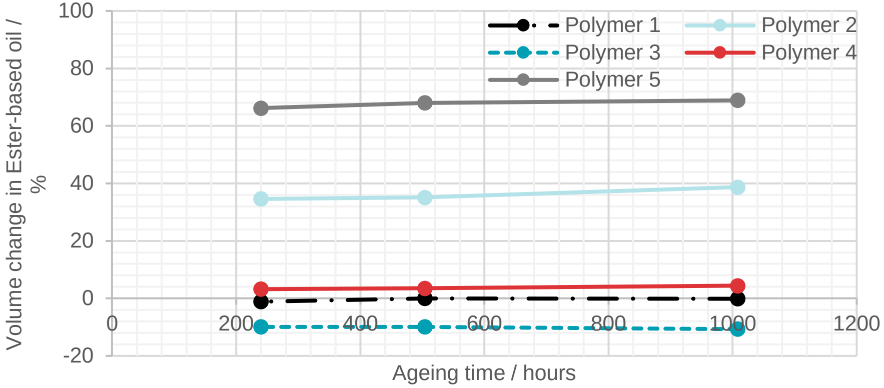
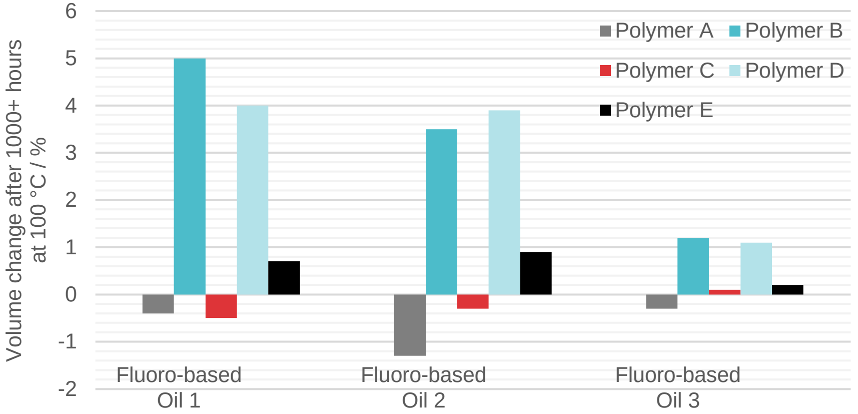
Chemical compatibility tests (examples)



- Long-term stability (1000hrs/100 °C) of selected polymers in ester-based cooling liquids



- Swelling behavior of selected polymers in fluoro-based cooling liquids
- Set of data available for all mentioned families

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Thermal barrier materials

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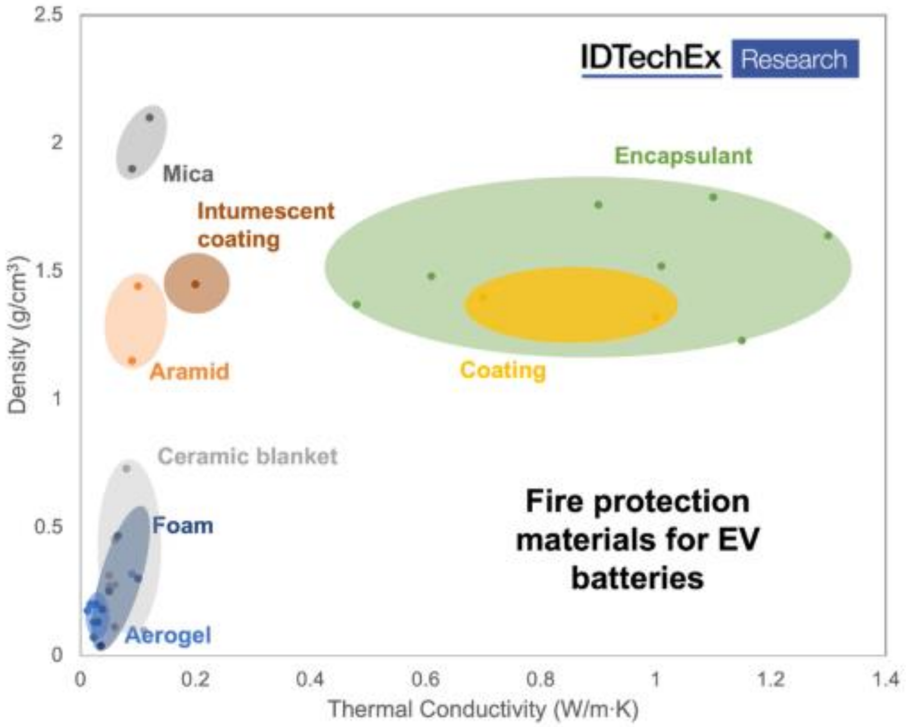
Battery performance and safety

Thermal barrier material



Filler research done and first potential filler types in test phase

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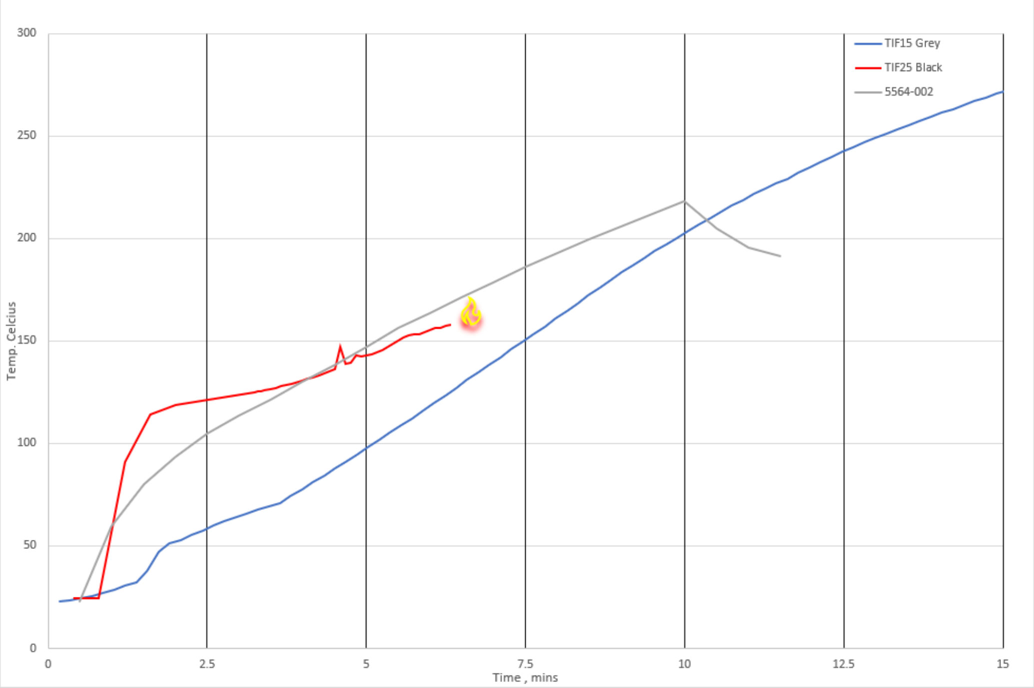
Battery performance and safety

Thermal barrier material

Heat propagation (hot plate) test in house



Preliminary tests show our material (grey line) keeping T below 200 °C after 5 minutes (=meeting existing safety requirement)

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Please feel free to contact us in case of any questions!

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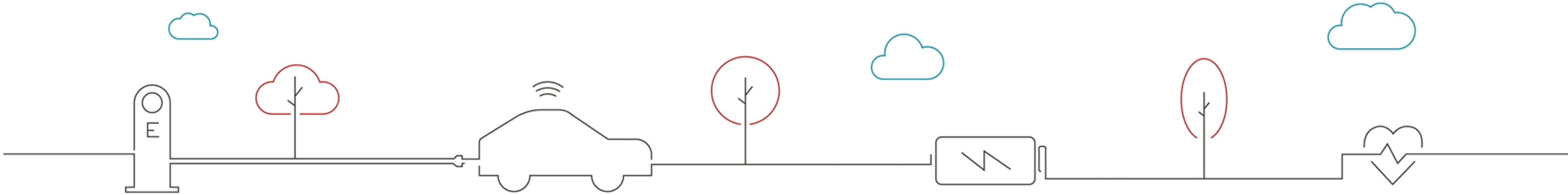

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