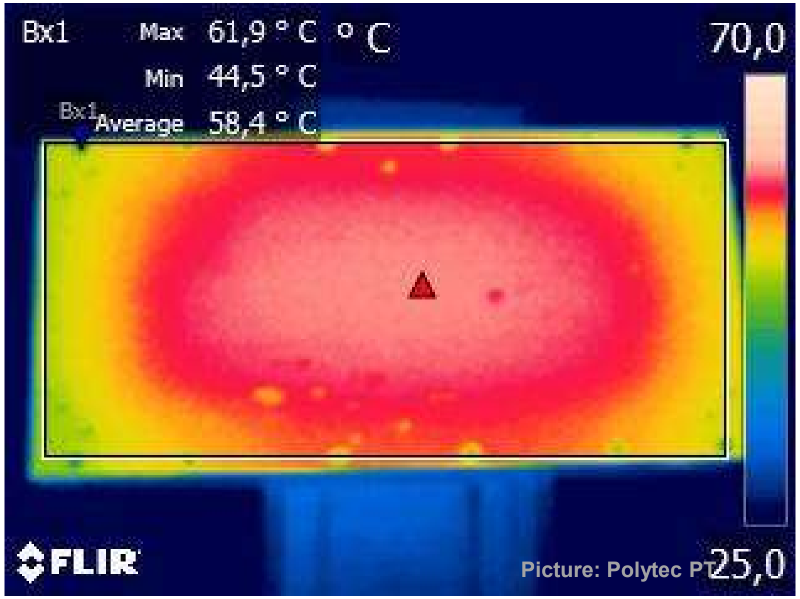
Thermal Interface Materials for batteries – challenges and solutions

A. Wiessler, Polytec PT GmbH – E-Mobility Workshop, Darmstadt, 12.11.2019

Outline

Motivation

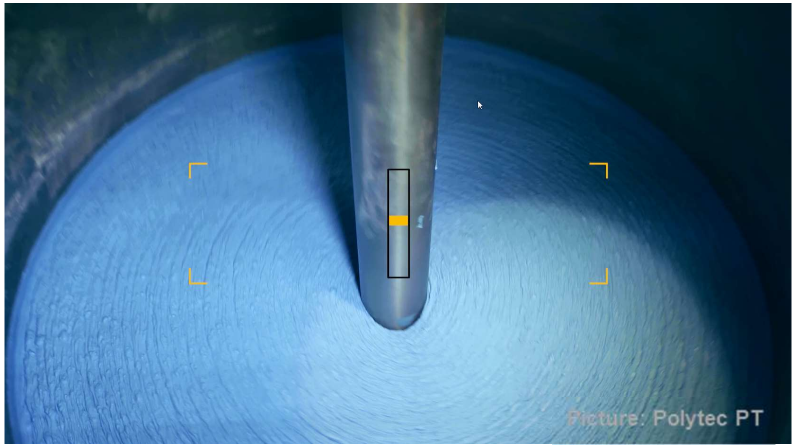
- Why Thermal Interface Materials (TIMs)?
- Selection of TIMs based on performance and process parameters
- Methods for testing and assessing TIMs
- Outlook – ongoing R&D goals



Picture: Polytec PT

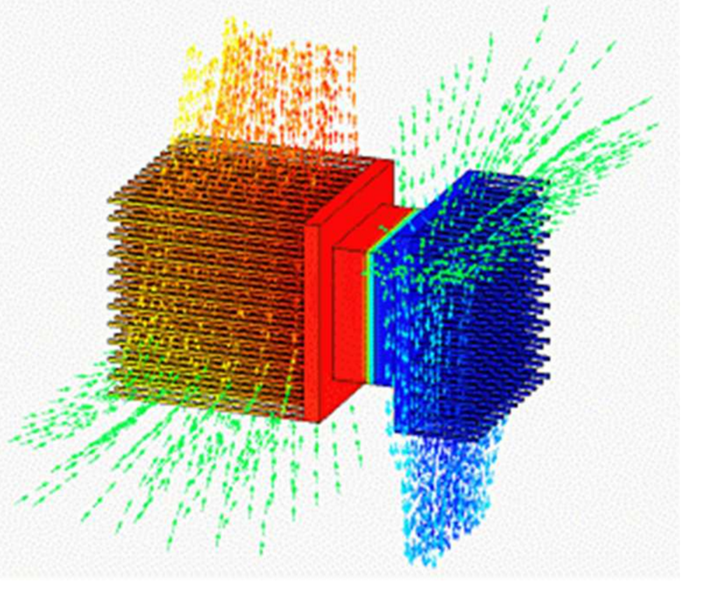
About Polytec PT

- Development & manufacturing of specialty adhesives and Thermal Interface Materials
- Customer-specific formulations
- since 2012: serial supply of a thermally conductive adhesive for hybrid batteries
- Since 2015: New development of gapfillers for numerous battery projects
- 2019: SOP of several gapfiller & adhesive projects



Why thermal management in EV-Batteries?

- Electrical performance depends on operating temperature
- Li-Ion cells degrade when exposed to too high temperatures
- Typical requirements for operating conditions:
  - Operating temperature ideally at 30-40° C
  - Cell temperature never above 80° C
  - Charging/Discharging only between 0 and 60° C

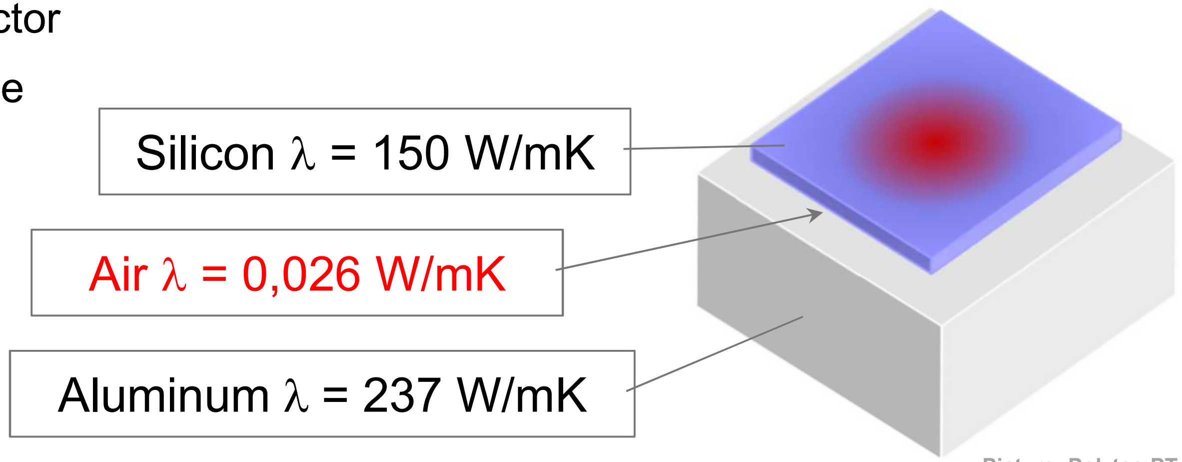


Lit.: Thomas Wetzel – Thermisches Design von Lithium-Ionen-Batteriezellen, KIT Institut für thermische Verfahrenstechnik, 2010

Picture: Wikipedia/Heatlord, CC BY-SA 3.0

Why Thermal Interface Materialis (TIMs)?

- Active components (battery cells, semiconductors etc.) generate heat losses
- Mechanical connection with cooling structures feature small air gaps
- Air is a very poor thermal conductor
- Consequently air gaps need to be filled with an interface material



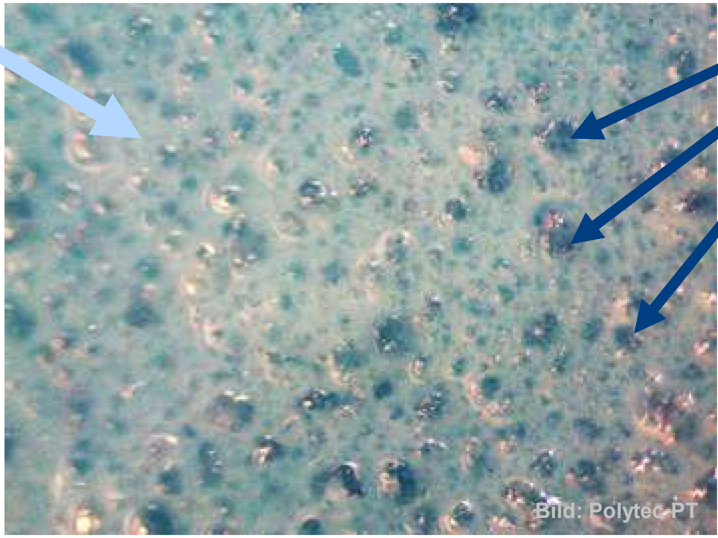
Picture: Polytec PT

What is a TIM at all?

Organic Matrix

- Oil
- Polymer
- Adhesive

0,2 - 0,3 W/mK



Thermally conductive fillers

- Ceramics
- Metals
- Graphite

30 -> 300 W/mK

for the bulk material

Modeling of thermal conductivity

Lewis-Nielsen model

$$\lambda_C = \lambda_M \cdot \frac{1 + (A-1)B\phi}{1 - \psi B\phi}$$

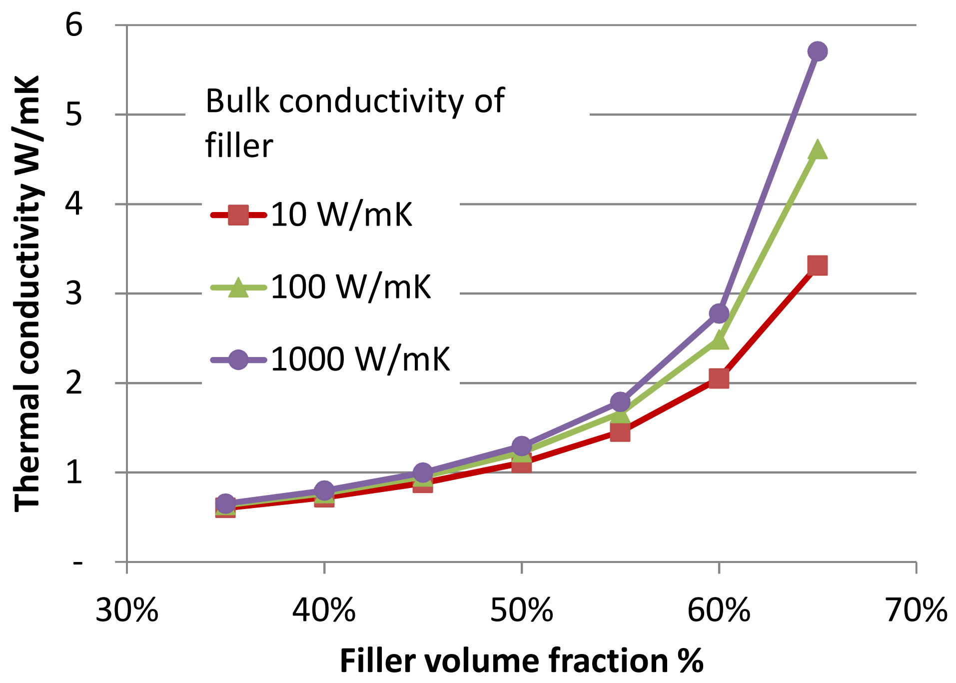
1.) Volume fraction of the filler (Φ)

2.) Conductivity of the matrix (λ_M)

3.) Maximum packing density (Ψ)

4.) Particle shape factor (A)

5.) Filler conductivity (determines B)



Lit.: T. B. Lewis, L. E. Nielsen, Journal of Applied Polymer Science, Volume 14, Issue 6, pages 1449–1471, June 1970

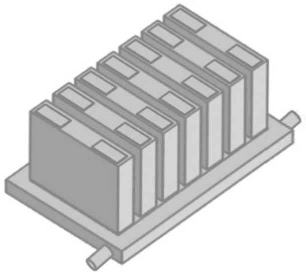
Types of Thermal Interface Materials

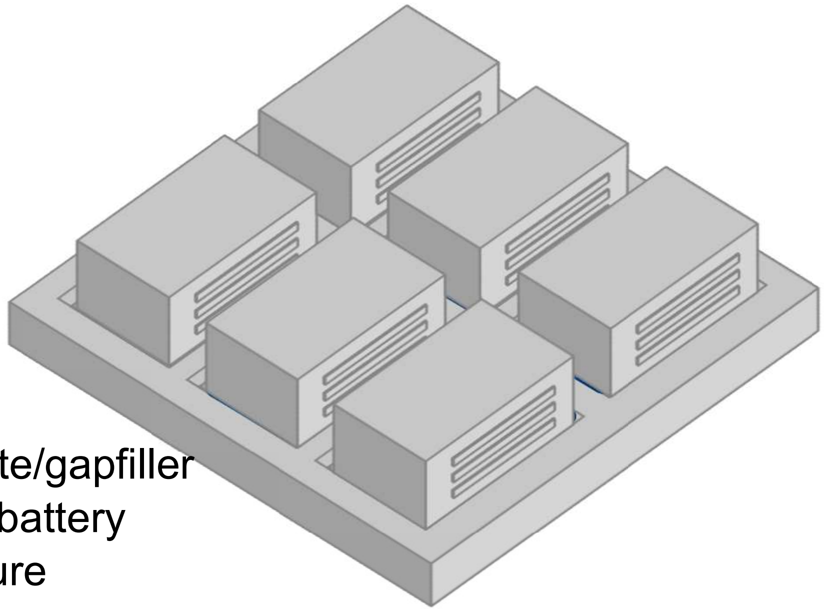
	Conductive Pads	Conductive Pastes	Conductive Adhesives	Gapfillers	Speciality: PCM*
Chemically curing	No	No	Yes	Yes	No
Reworkable	Yes	Yes	No	Yes	Yes
Advantages	Pre-fabricated „Part“-character	Ease of use	Mechanical and thermal connection	Broad range of material properties	Latent-heat storage
Short-comings	Difficult to automate Compressive force necessary	Suitability depending on installation situation Only high viscosity grades	Limited conductivity Curing time needed	Curing time needed	Mostly available as pads

*:phase change material

Examples for Thermal Interface Materials

Thermally conductive epoxies for bonding prismatic Li-Ion cells to cooler





Thermally conductive paste/gapfiller for thermal connection of battery modules to cooling structure

Fundamental properties of TIMs

- **Material properties**
  - Composition (Silicone yes/no)
  - Consistency
  - Density
  - Flame retardancy

- **Process properties**
  - Shelf life
  - Viscosity, flow properties
  - Metering / dispensing poperties
  - Abrasiveness

- **Operation properties**
  - Thermal conductivity
  - Insulation properties
  - Adhesion
  - Elasticity

- **Long-term properties**
  - Temperature resistance
  - Chemical resistance
  - Vibration resistance

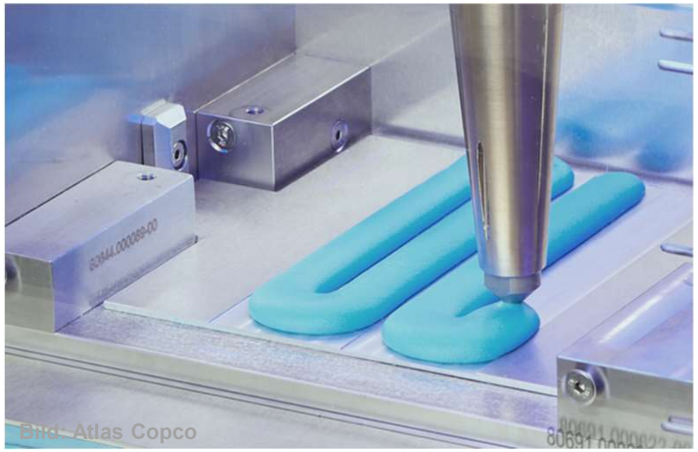
Example 1: thermally conductive adhesives

Feature	Range of values
Consistency	Self levelling… pasty
Curing conditions	24 h/23 °C … 60 min/80 °C
Therm. conductivity	0,8 …. 2 W/mK*
Density	1,5 … 2 g/cm²
Modulus	100 … 9.000 MPa
Lap sheer strength**	5 … 15 MPa
Elongation at break	up to ~20 %

* Up to 3 W/mK upon request (with compromises regarding mechanical properties)
** on untreated aluminum

Example 2: thermally conductive pastes

Feature	Range of values
Konsistenz	pasty
Viscosity at 40 °C	150 ... 250 Pa s
Gap dimensions	0,2 … 2 mm
Curing	Non-curing
Therm. conductivity	2,0 …. 2,7 W/mK
Density	~2 g/cm³



Example 3: thermally conductive gapfillers

Feature	Range of values
Consistency	Self-levelling… pasty
Viscosity at 23 °C	50 … 250 Pa s
Gap dimensions	0,2 … 5 mm
Curing	Curing at RT
Therm. conductivity	1,5 …. 3,2 W/mK
Density	2,0 …3,1 g/cm³


Picture: Polytec PT

Testing of long-term properties of TIMs

- Accelerated ageing tests – Test Methods
- Goal: Validation of vehicle life time (10-15 years)

  - Temperature- & humidity storage (THT)
  - Temperature-cycling / -schocks (TC)
  - Combined TC und THT storage, e.g. VW PV-1200
  - Vibration tests (with temperature cycling), e.g. VW 82161
  - Power cycling test (PC)
  - Flammability

O_2, T, ΔT, H_2O, Vib, Δp

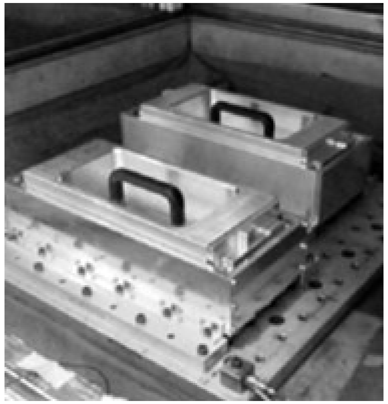
Picture: Polytec PT

Testing of long-term properties of TIMs

- Accelerated ageing tests – Test Methods

Besides material properties and test conditions sample preparation is of essence

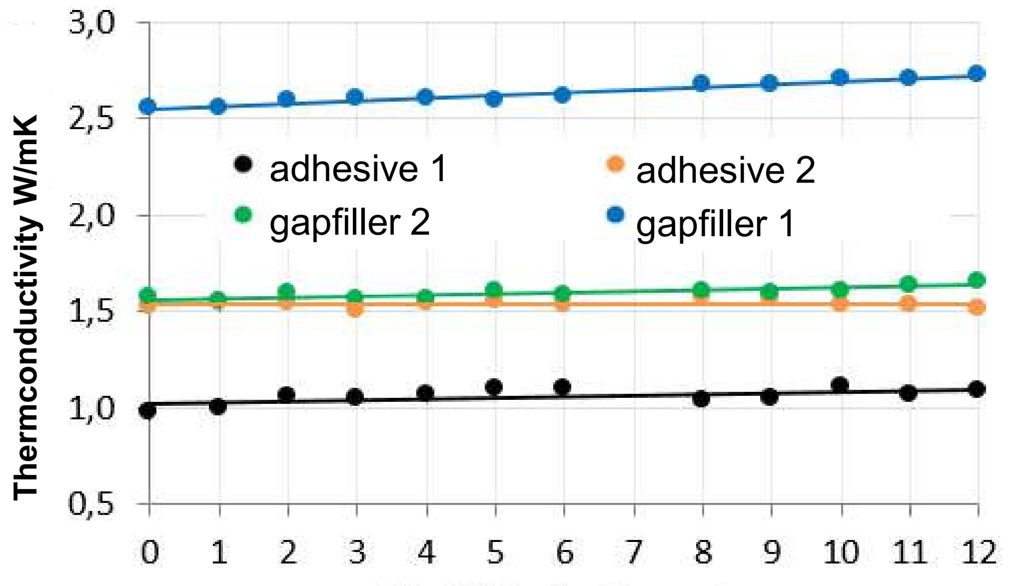
Bulk Material ≠ Lab tests ≠ Samples in module dimensions ≠ Dummy Modules ≠ Battery & vehicle testing (OEM)



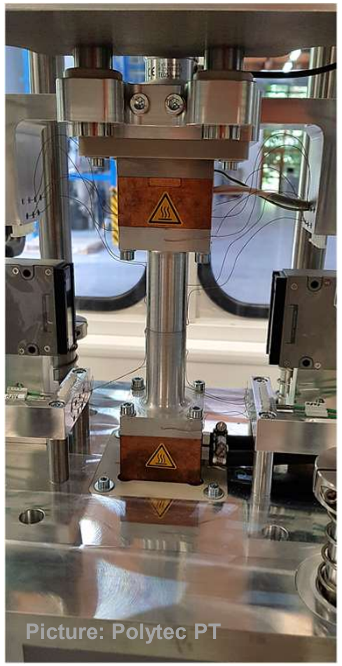
Pictures: Polytec PT

Testing of long-term properties of TIMs

Accelerated ageing tests – Test Methods



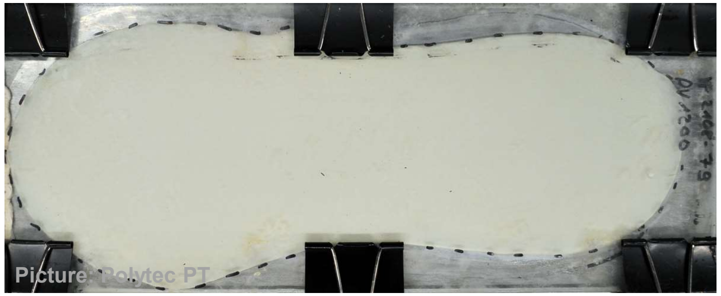
PV1200 Temperature cycling + humidity -40…+80 °C in weeks



Testing of long-term properties of TIMs

- Accelerated ageing tests – PV 1200

  - Aluminum/glass substrate
    150 x 390 mm
  - 2 mm gap
  - Horizontal storage
  - 2 cycles/day -40 … +80 °C
    appr. 30 … 80 % r.F.
  - Duration 12 weeks
    (2000 hours)
  - Optical inspection



Example:

2-part
Gapfiller

- Ok after 12 weks (2000 h)
- No crack formation oder delamination

- Dismanteling

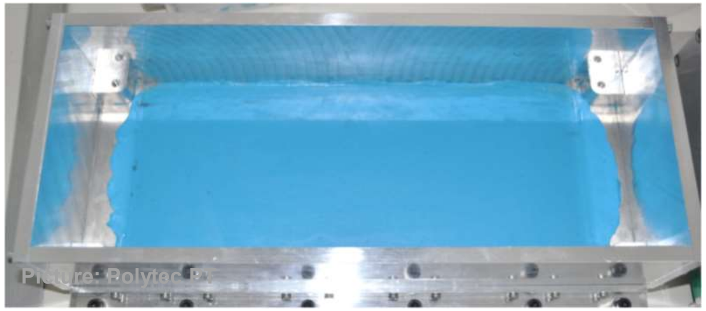
Testing of long-term properties of TIMs

- Accelerated ageing tests – Vibration

  - On the basis of VW 82161
  - Dummy-module 150 x 390 mm
  - Testing on shaker with temperature cycling
    at -20 … + 65 ° C
    5 … 200 Hz
  - Duration 120 h
    (X, Y, Z 40 h each)
  - Optical Inspection

Example:

1-part conductive paste



Testing of long-term properties of TIMs

- Accelerated ageing tests – Power cycling

  - Aluminum cylinder Ø 30 mm
  - Upper cylidger periodically heated to 90 or 110 ° C
  - Low cylinder cooled
  - Periodical measurement of thermal resistance Rth in situ according to ASTM D5470

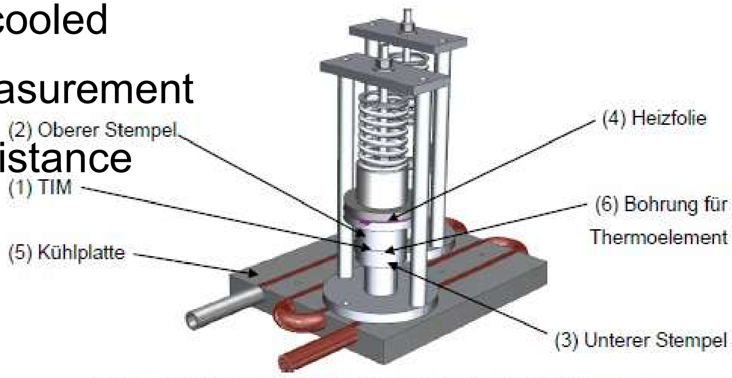
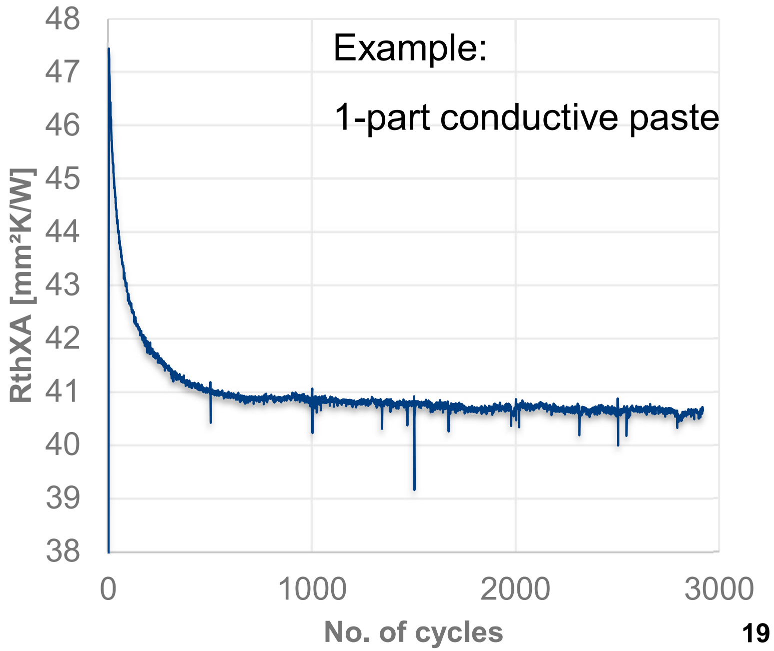


Abbildung 1: Prinzipieller Aufbau des TIM-Probenhalters der DHBW Stuttgart



Outlook – R&D goals

- High thermal conductivities
- Suitability for respective processes (Flowability/Compressability)
- Low manufacturing cost
- Customized mechanical properties
- Reworkability
- Customer specific requirements

Thank you very much

for your attention