Integration of thermally active materials during the formation of open porous metal structures

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Introduction

- System:
  - Adsorption and desorption effects allow to "pump" heat between different temperature levels
  - E.g. water adsorption by zeolite
- Essential components are the adsorber and the evaporator:
  - Are basically heat exchangers, combined with thermally active material (zeolite)
  - Made from metal (Al, Cu, steel)
  - Crucial components, determine system efficiency and power density

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Introduction

Combining heat exchangers with thermally active material, SotA:

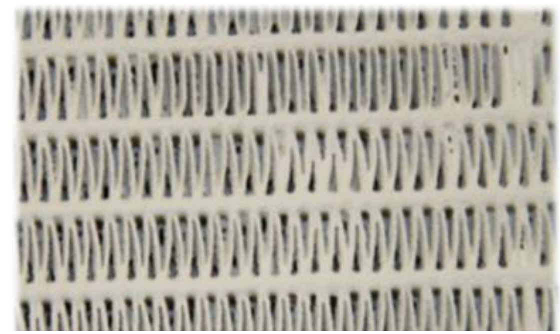
- Loose bulk of zeolite granules between the lamellae of the metal heat exchanger

  👎 Bad thermal contact zeolite/metal

- Coating of the lamellae with mixture of zeolite powder/binder

  👎 Limited specific surface

  👎 Difficult coating of fine structures



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➢ How can adorber performance be improved?

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Introduction

Requirements influencing the performance of an adsorber:

- High thermal conductivity
  - Heat transfer from active material to fluid system
- Low (thermal) mass
  - "Dead weight" will lower coefficient of performance
- Large surface
  - Thinner coating improves system kinetics
- Accessibility
  - For coating and for reactants during system operation
- Good adhesion and thermal contact of active material
- Long time stability
- Costs

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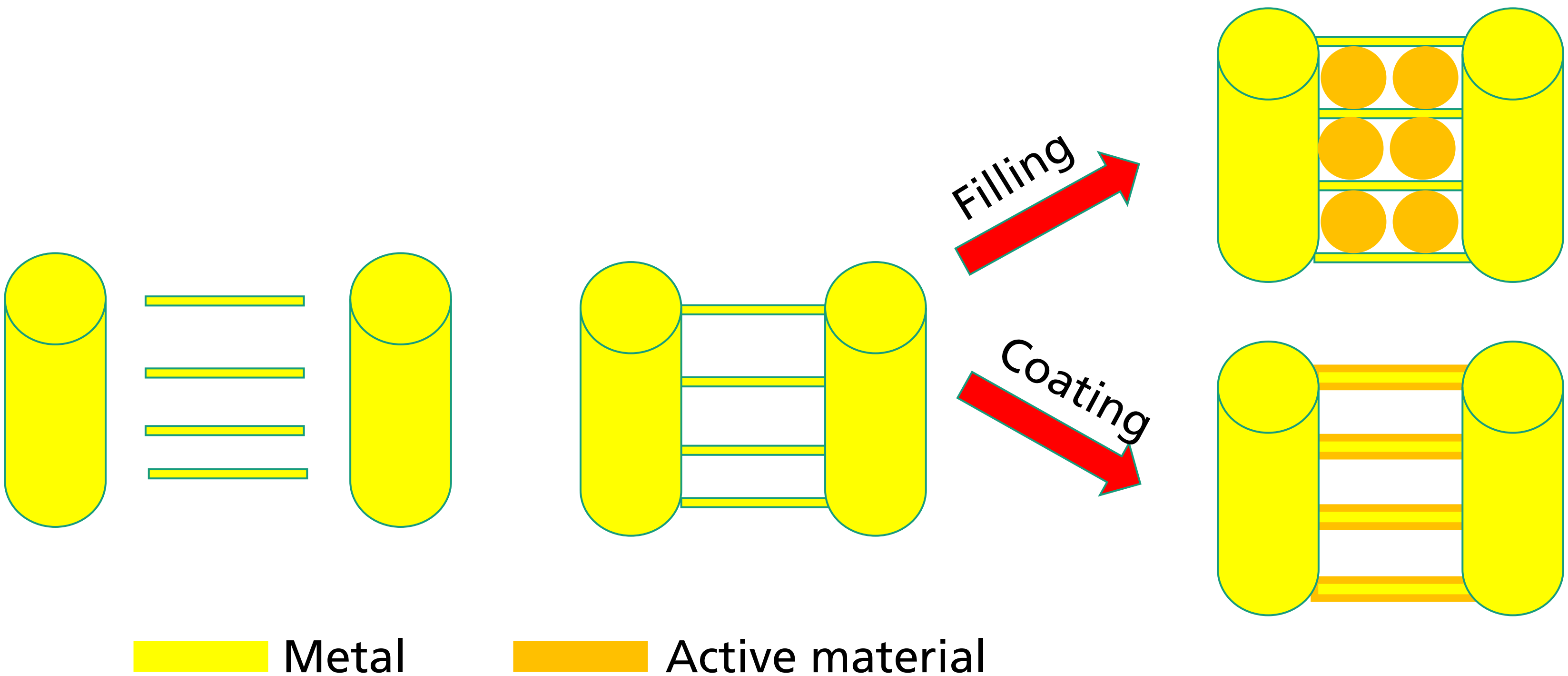
Introduction

Conventional approach (SotA)

- Production of metal semi-finished parts (lamellae, fibres, pipes,…)
- Assembly to metal adsorber structure (soldering,…)
- Combination with active material (filling, coating)



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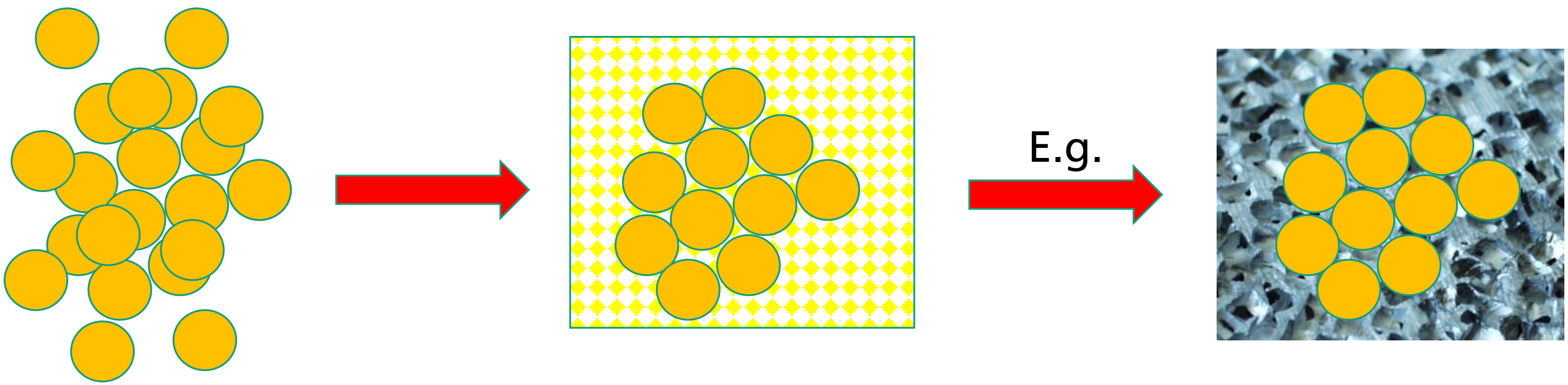
New technological approach

Alternative approach:

- Direct integration of the active material <u>during</u> the fabrication of the metal structure
- Fabrication of the porous metal structure can be done by casting or sintering



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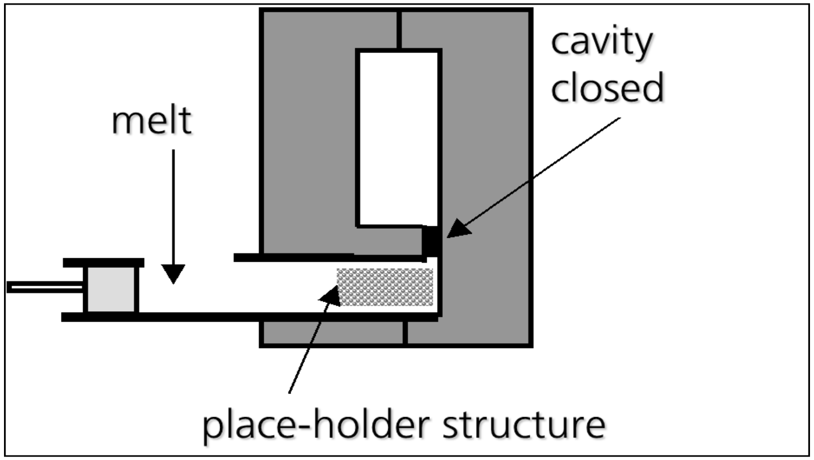
Production of composite structure - casting

- Basis: casting of metal sponges
  - Organic place-holder structure
  - Pressure assisted metal melt infiltration
  - Pyrolysis of place holder

- Adapted approach:
  - Integration of granules of the active material into the preform
  - "Granules transplantation" to solidifying metal during casting



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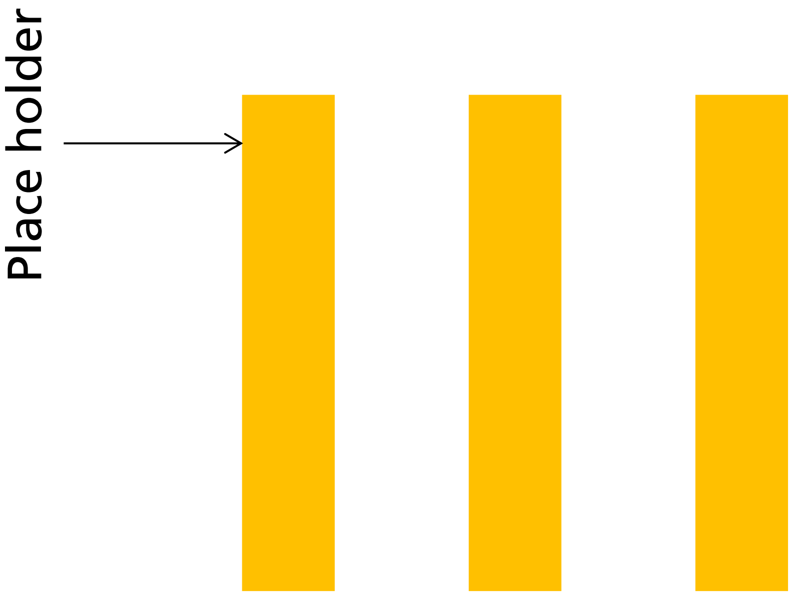
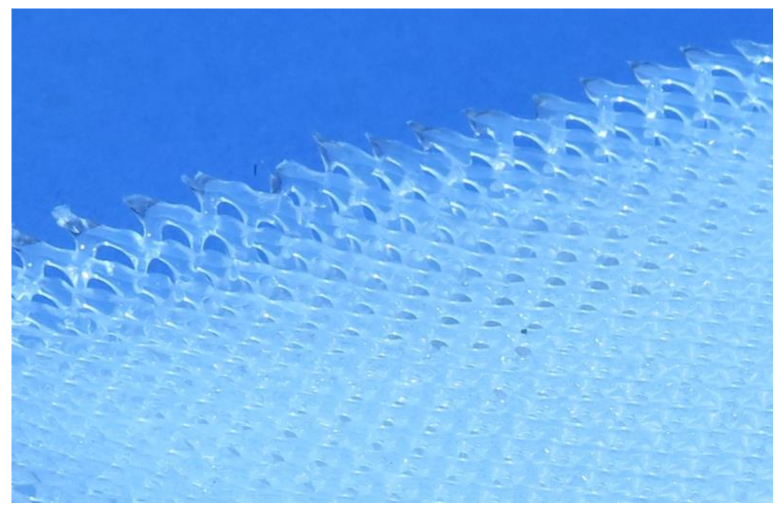
Production of composite structure - casting

- New approach (casting):
- ➢ coating of the place holder net with zeolite granules





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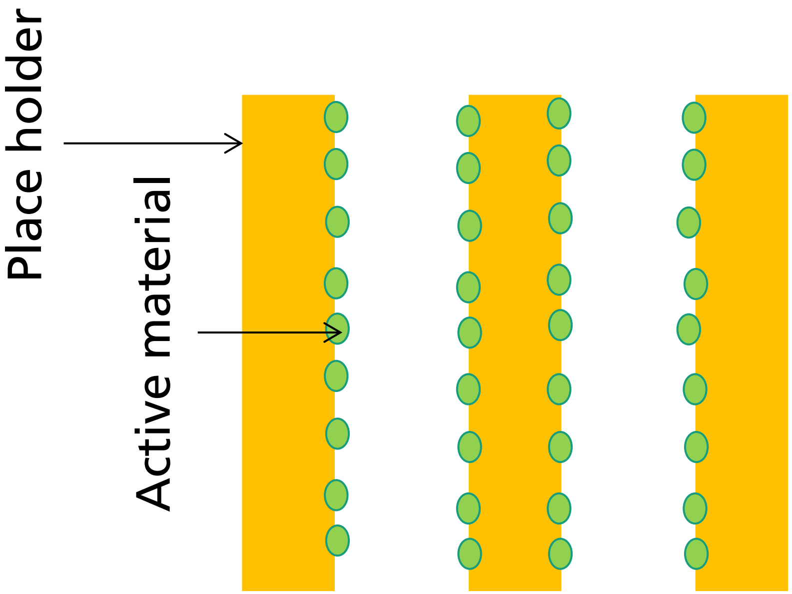

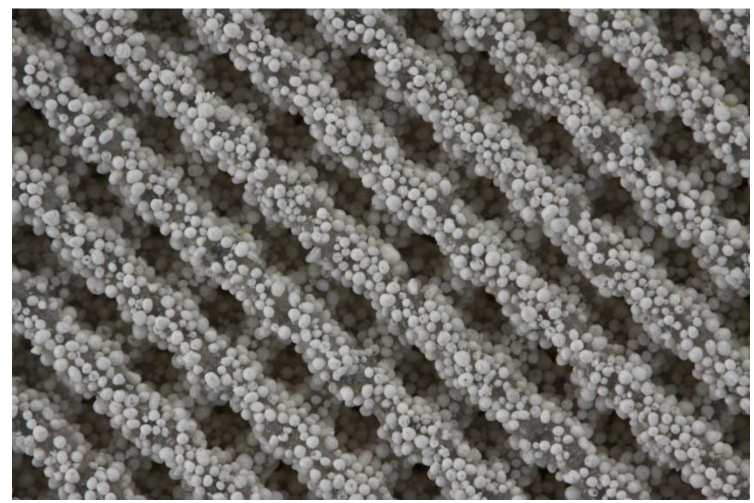

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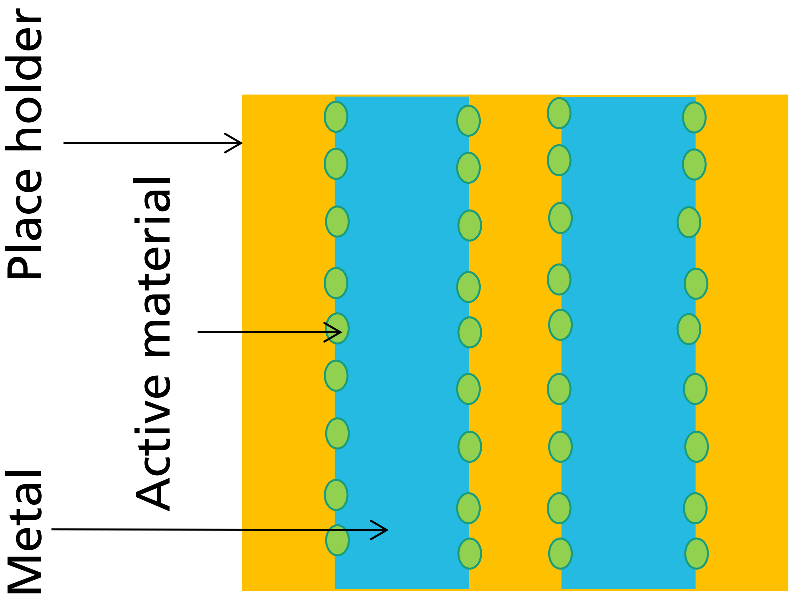
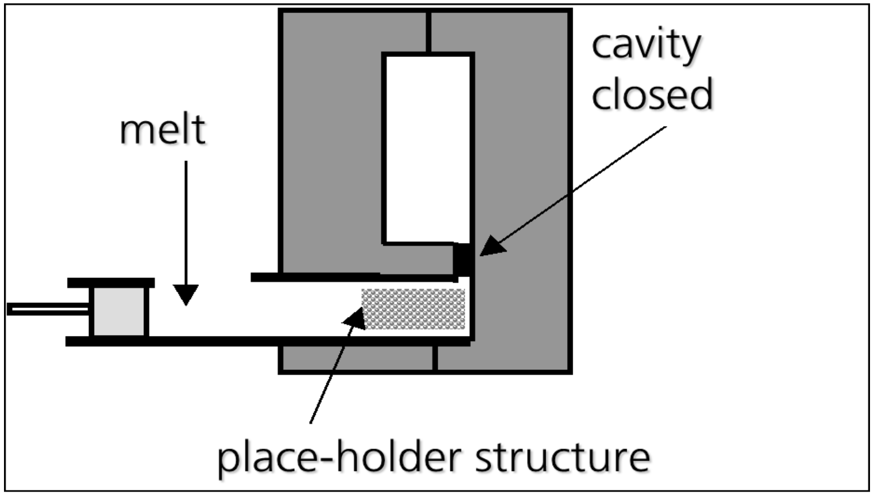
Production of composite structure - casting

- New approach (casting):
  - coating of the place holder net with zeolite granules
  - infiltration with metal melt, “transplantation” of the zeolite granules to solidifying metal during casting





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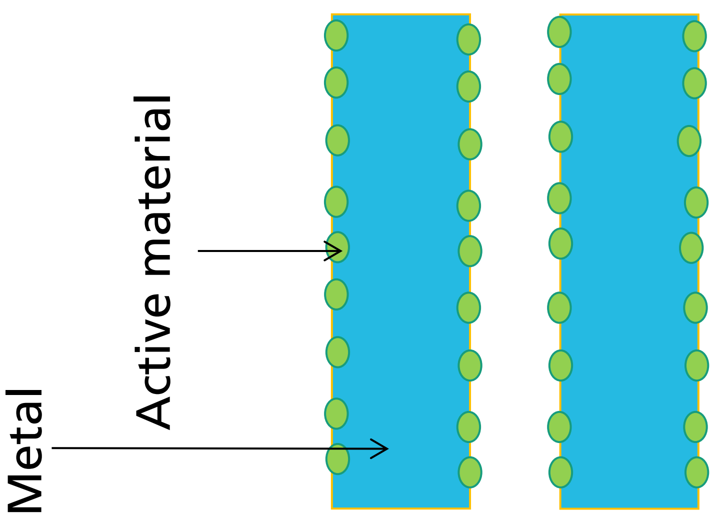
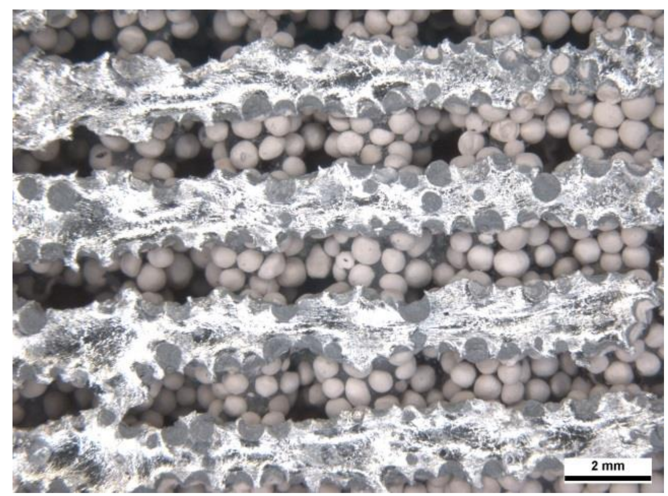
Production of composite structure - casting

- New approach (casting):
  - coating of the place holder net with zeolite granules
  - infiltration with metal melt, “transplantation” of the zeolite granules to solidifying metal during casting
  - removal of the placeholder structure (e.g. by pyrolysis)





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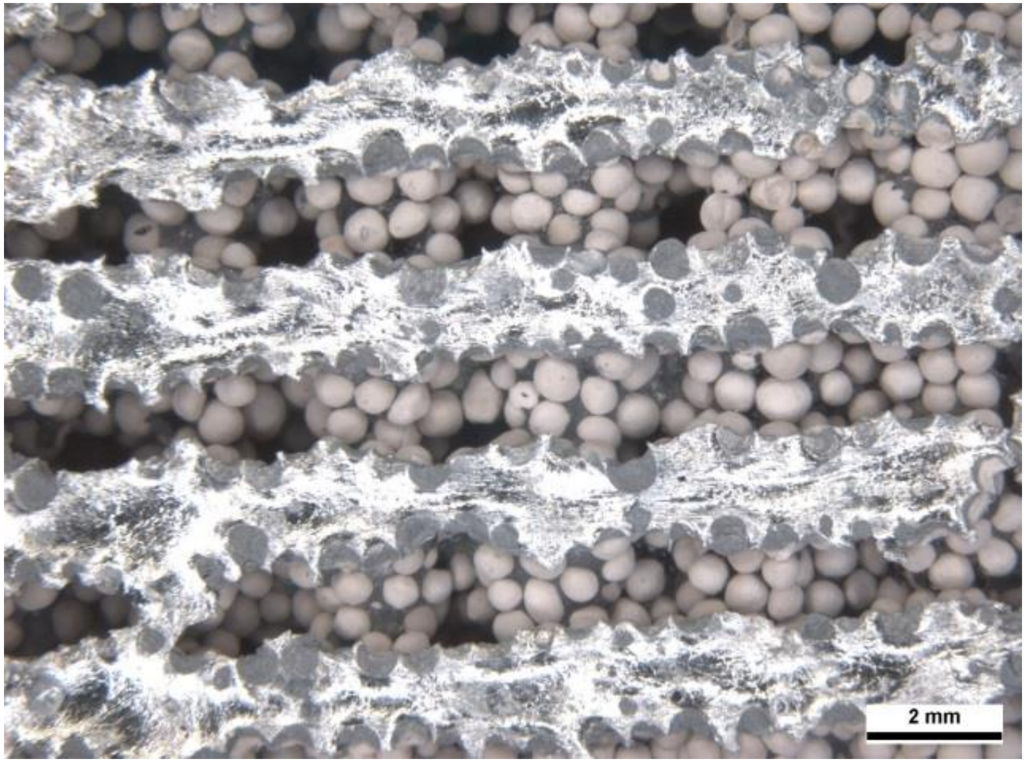
Production of composite structure - casting

- Example: open cell aluminium sponges, zeolite granules integrated into the surface of every strut



⇒ Very good thermal contact between zeolite and heat exchanger

⇒ Ratio of zeolite/metal and porosity can be adjusted

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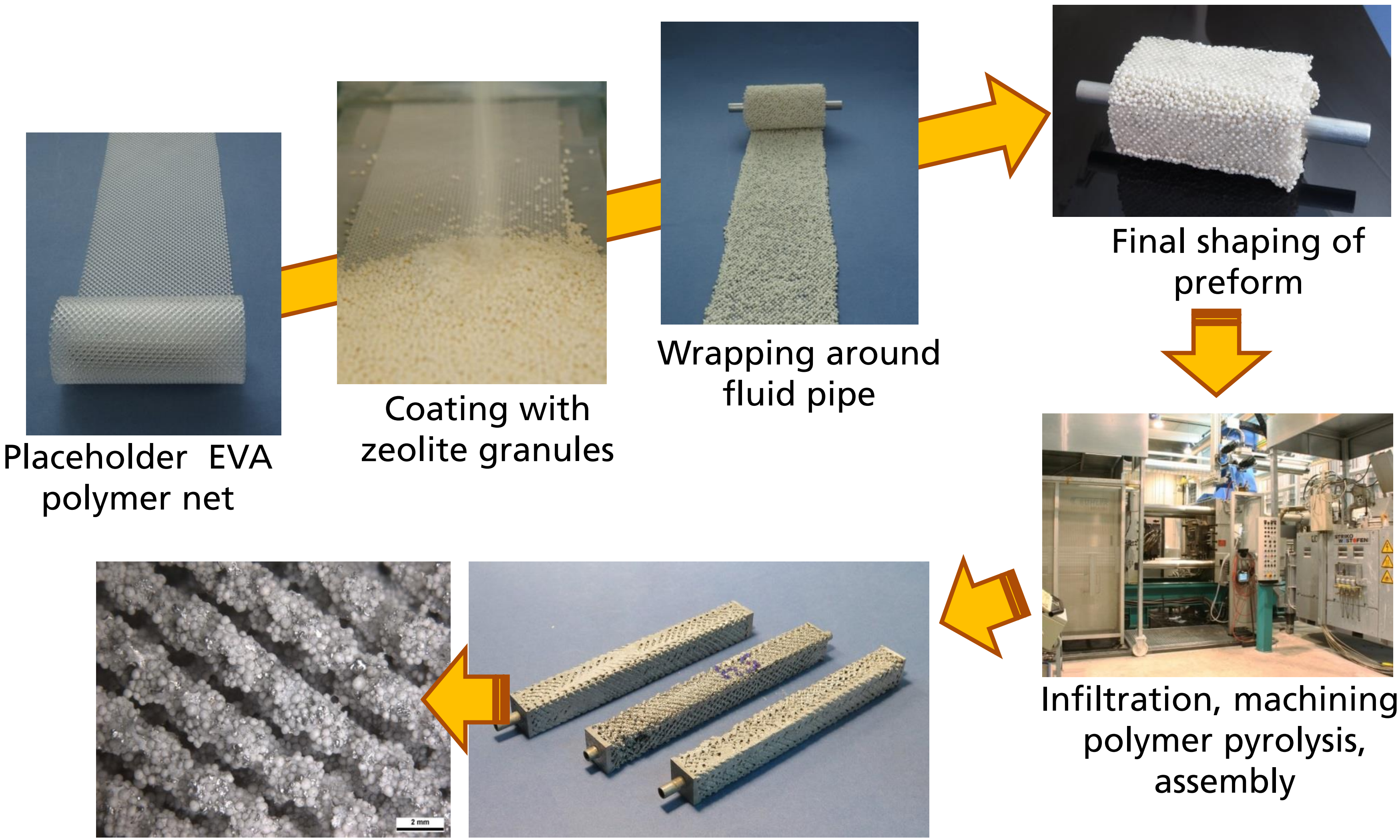
Production of composite structure - casting



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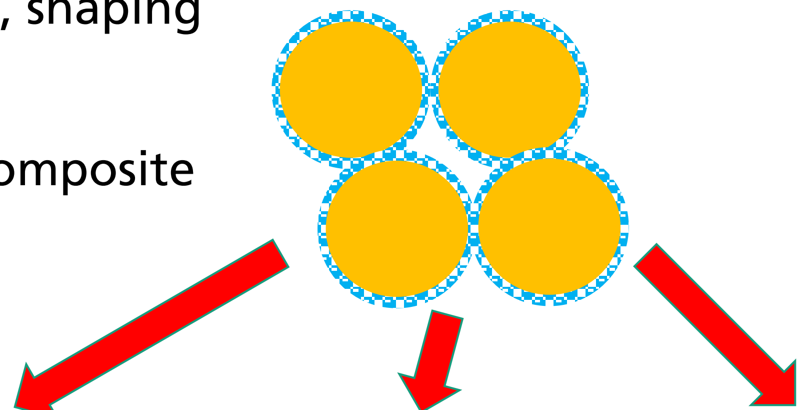
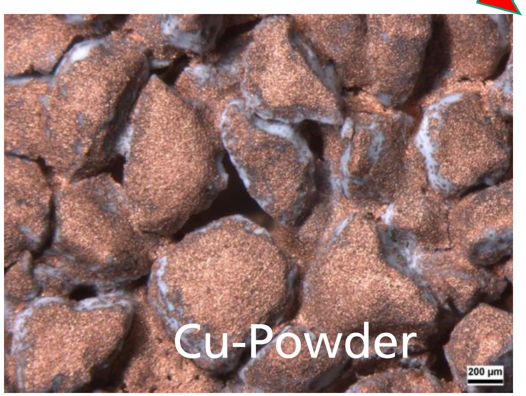
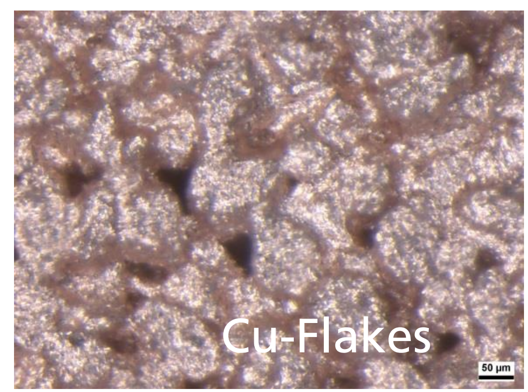
Production of composite structure - sintering

- New approach (sintering):
  - Coating of the active material granules with binder
  - Mixing with metal powder/flakes/fibres, adherence to granules surface
  - Transfer to mould, shaping
  - Sintering
  - Finished porous composite







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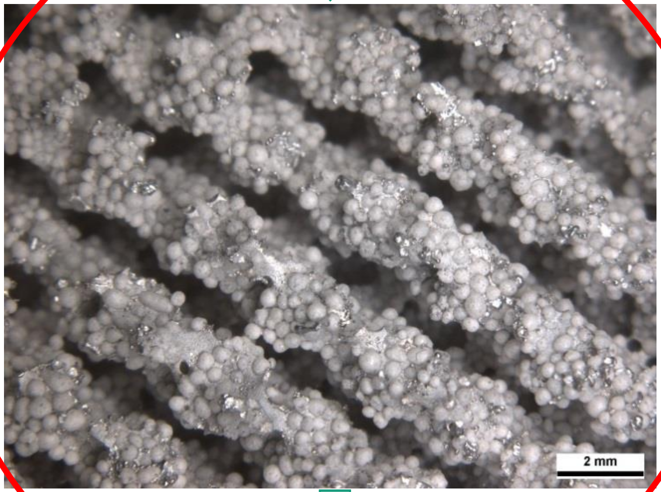
Production of composite structures

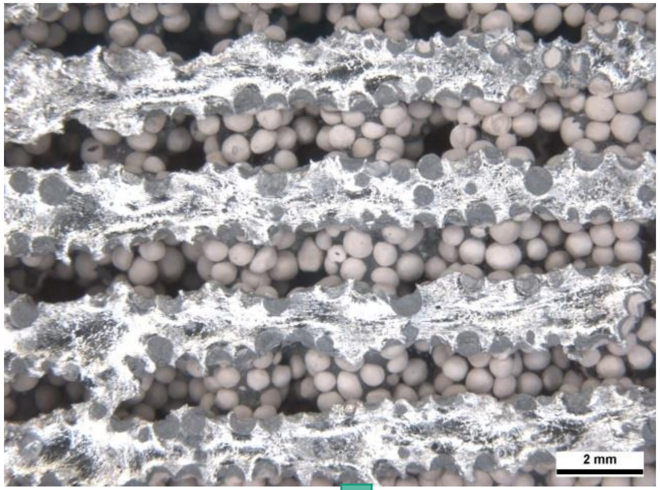
Combination of metal foam with

+ expanded glas granules (boiling stones)



evaporator

+ zeolite (adsorbens)



adsorber

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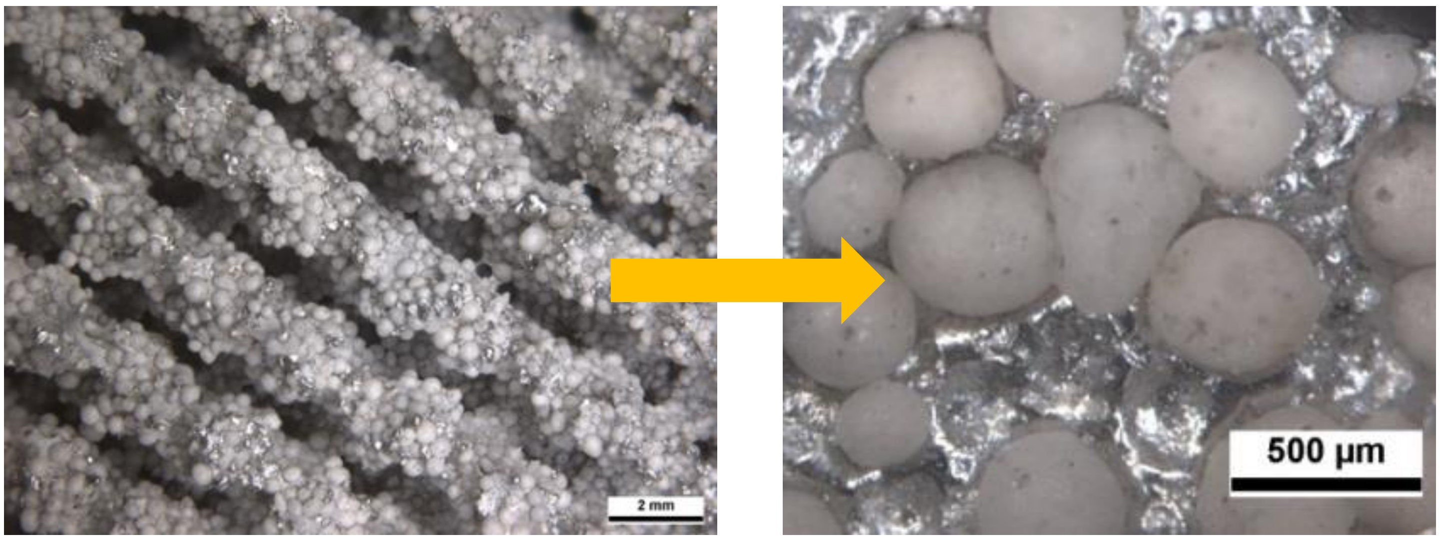
Expanded glass integration - evaporator

- New composite evaporator structure:
  - ➢ expanded glass granules act as nucleation sites (bubble formation)



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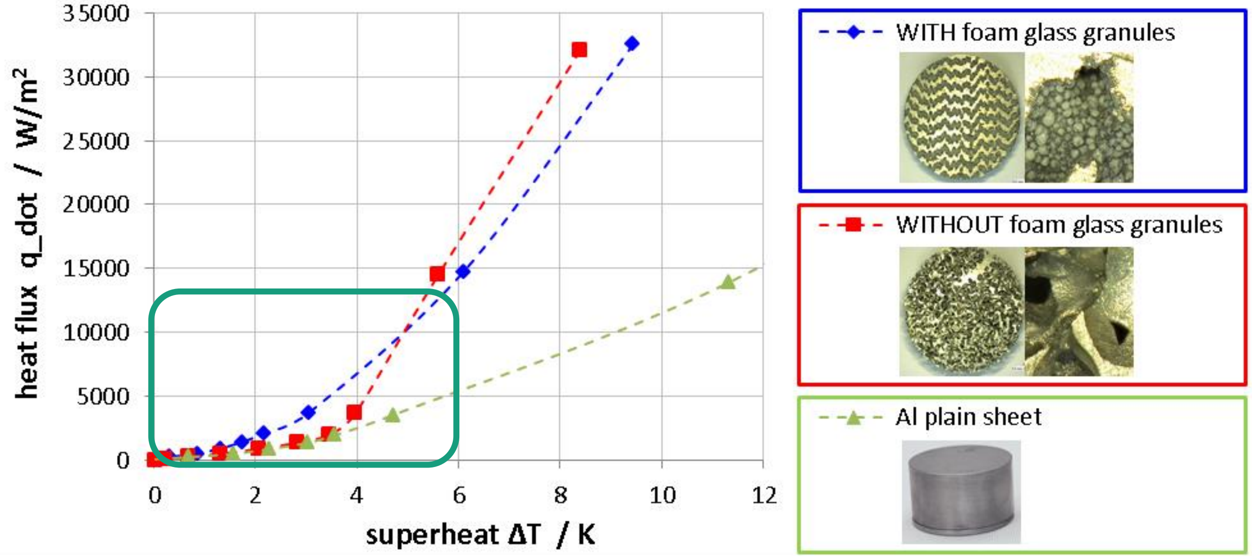
Expanded glass integration - evaporator

- Impact of expanded glass granules



➢ High wall superheat: Sponge sample without granules performs better

➢ Low wall superheat: Sponge sample with granules performs better
→ relevant for adsorption heat pump application!

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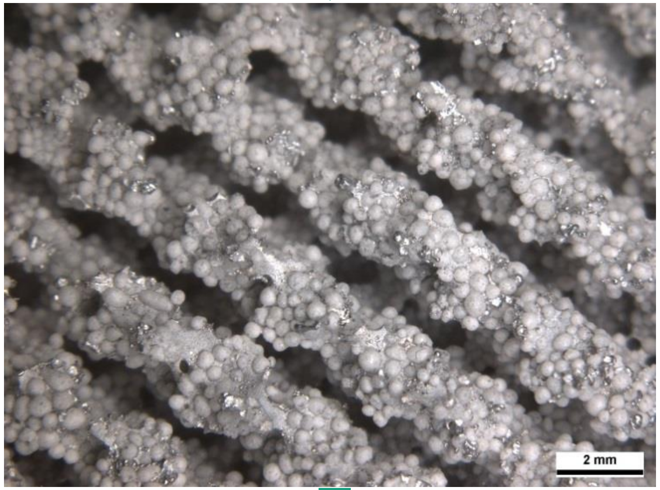
Production of composite structures

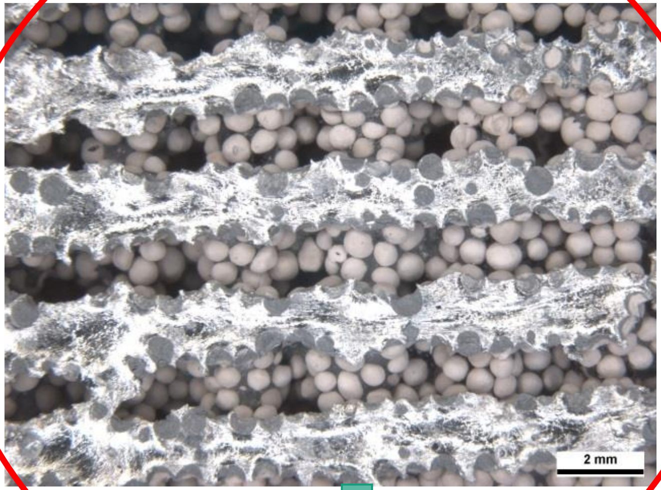
combination metal foam +

+ expanded glas granules(boiling stones)



evaporator

+ zeolite (adsorbens)



adsorber

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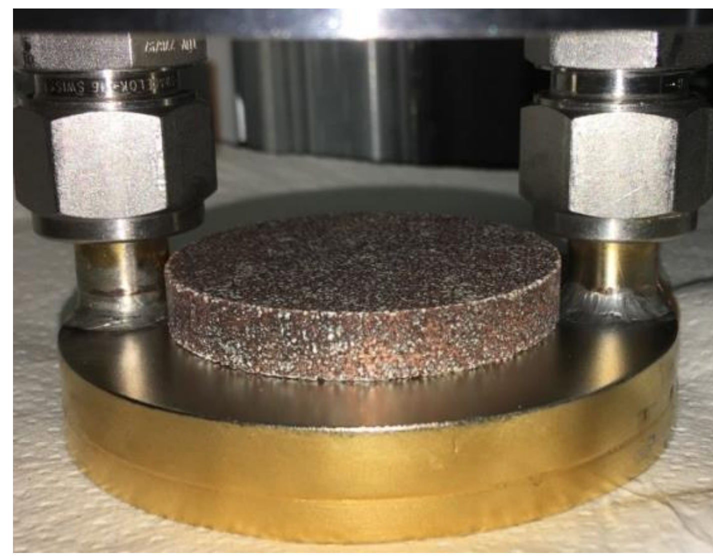
Zeolite integration - adsorber

- Variable compositions possible
- Typical: 50vol% zeolite, 10vol% binder, 15vol% metal, open porosity for vapour transport 20vol%
- Size of zeolite granules: >60µm
- Thermal conductivity (Cu, Al): 2-5 W/m/K

- Active materials like zeolites are often not stable at high temperatures.
- Casting/sintering: >600°C
- Investigation of zeolite degradation



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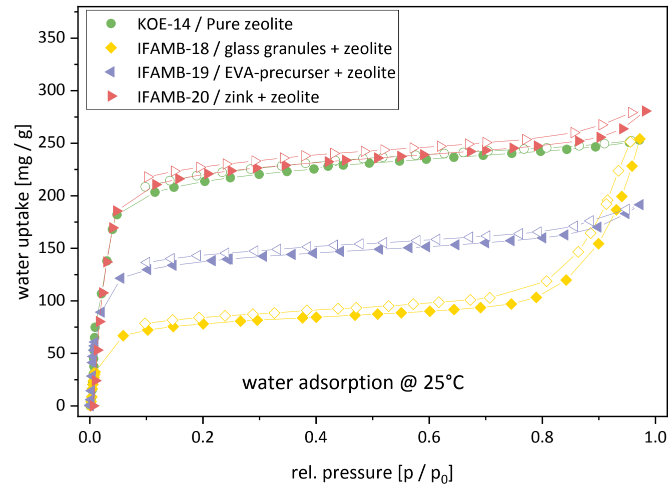
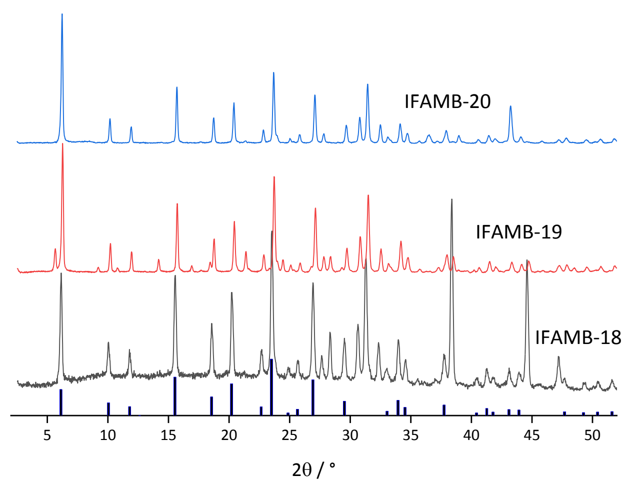
Zeolite integration – adsorber zeolite – stability

- Water adsorption behaviour of zeolite is retained
- Structure is affected by chosen process → slight degradation of sample IFAMB-18
- XRD investigation shows a slight shift of peaks and some amorphous background only on sample IFAMB-18
- No signs of degradation for IFAMB-19 and IFAMB-20





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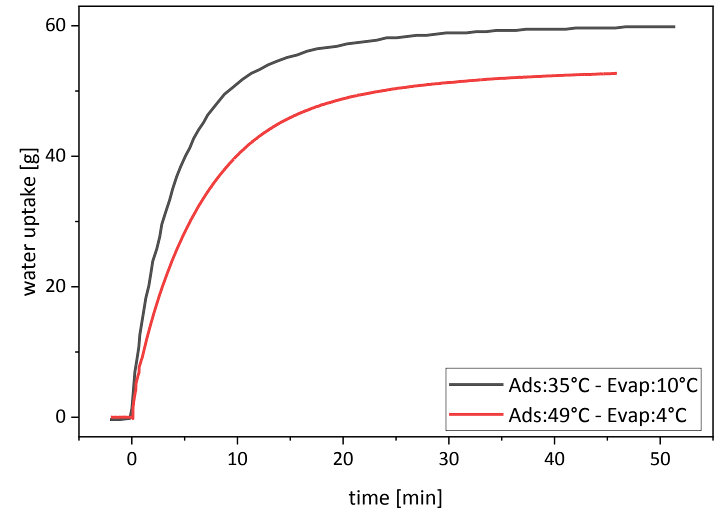
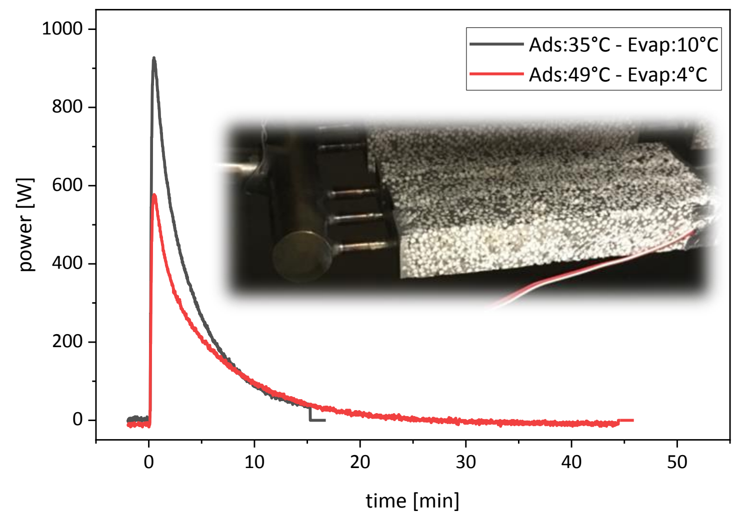
Zeolite integration – adsorber zeolite – potential

- Successful manufacturing of an adsorber module made of zeolite-Al-composite
- Directly integrated fluid pipes
- Successful measurements on manufactured adsorber give promising results





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Summary and conclusion

- New approach for production of porous metal structures combined with active materials
- Integration of the active material in-situ during the formation of the metal porous structure
- Simple process
- Ratio of active material/metal and porosity can be adjusted
- Application: evaporator and adsorber for adsorption heat pumps / chillers
- Evaporator: significantly improved boiling behaviour
- Adsorber: using suitable processing parameters the degradation of zeolite can be avoided

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