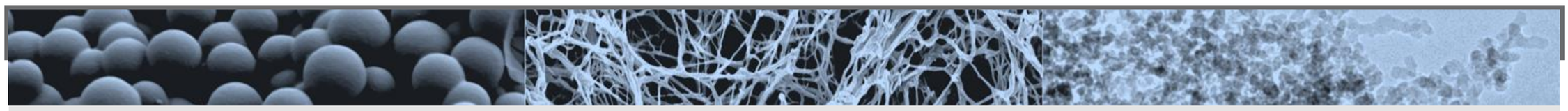
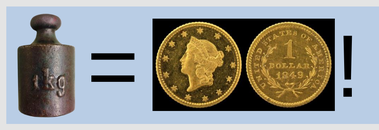
Aerogel-honeycomb sandwich composites based on resorcinol-formaldehyde and silica



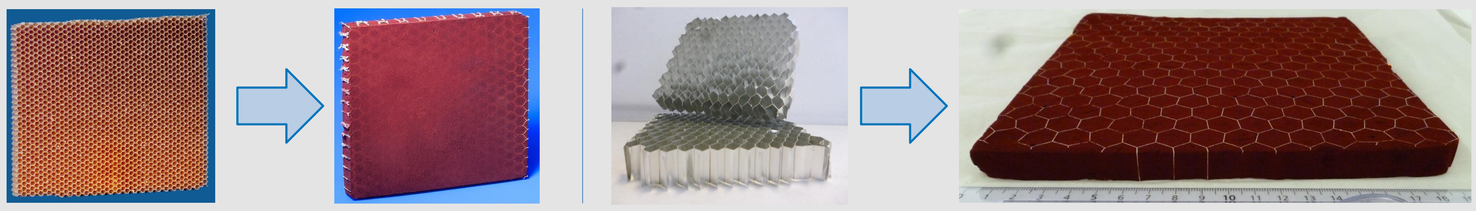
Introduction

Our Goal: Combination of lightweight materials with additional function – here: thermal insulation
→ Benefit for aerospace, aeronautics, and the transport sector

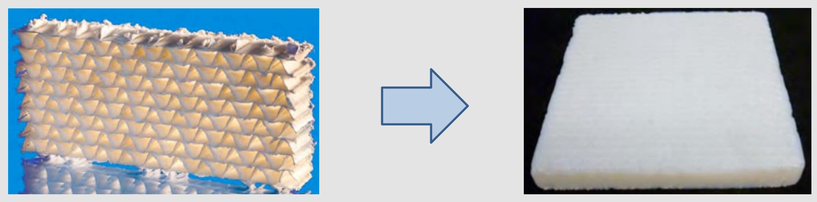


Previous results:

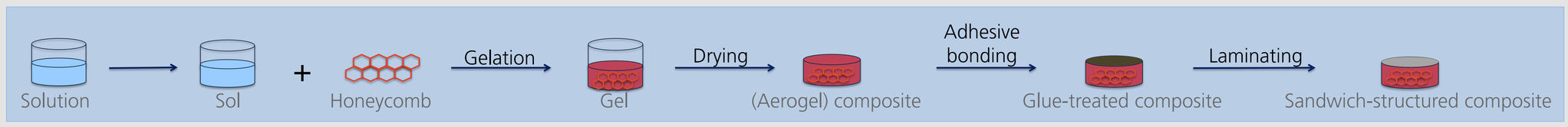
- For several years, we have been dealing with tailoring resorcinol-formaldehyde aerogels for composites based on aramid and aluminum honeycombs.[1-2]



- More recently, we prepared silica aerogels (Si) composites from tetraethyl orthosilicate and sinewave paper honeycombs.[3]



Experimental

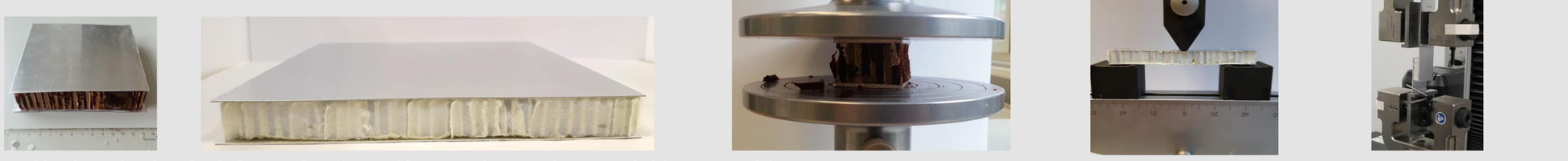


Scheme: Production of Aerogel-honeycomb sandwich-structured composites using a sol-gel process

- Aerogel composites were prepared as described in our previous publications (see Scheme above)[1,2,3]
- Several commercial glue systems were evaluated initially in terms of applicability, hardening behavior, sample penetration - and price: silicone, silane-modified, polyester, polyurethane (PU), epoxy resins

→ For RF, silicone-based glue performed best, for Si epoxy resin was selected for further studies

- Glues were applied to aerogel honeycomb composites before aluminum sheets of varying thickness were added.



Results

Table: Thermal and mechanical properties of aerogel honeycomb composites as sandwich core material

Sandwich core	Honeycomb	Adhesive	Thickness Al cover [mm]	Envelope density [kg/m³]	Thermal conductivity [mW/m*K]	Compressive modulus [MPa]	Compressive strength [MPa]	Bending modulus [MPa]	Bending strength [MPa]	Shear modulus [kPa]	Shear strength [kPa]
RF	-	-	-		19.9 (Hot Disk)	2.066					
-	Aramid					17.24	0.6415				
-	Aluminum	-	-			20.42	1.346				
RF	Aluminum	-	-	230[*]	83.3 [*] (Hot Disk)	36.33	1.852				
RF	Aramid	-	-		20,9 (HFM)	27.94	0.7732				
RF	Aluminum	Silicone	0.3	258	184 (HFM)	35.37	1.847	37.72	1.118	239.1	16.30
RF	Aluminum	Silicone	0.5	316	153 (HFM)	33.41	1.669	32.02	1.439		
RF	Aramid	Silicone	0.3	225	36.2 (HFM)	22.79	0.6908	43.89	0.9939	2061	85.50
RF	Aramid	Silicone	0.5	288	36.4 (HFM)	25.91	0.8488	38.75	1.193		
RF	Aramid	Silicone	1.0			21.88	0.8008	162.4	2.109		
RF	Aramid	Silicone	2.0			25.46	0.8111	101.9	4.789		
Si	-	-	-	96,4	20.6 (HotDisk)	5.55	-				
-	Paper	-	-			6.56	0.620				
Si	Paper	-	-	147	32-34 (HFM)	6.73	0.750				
Si	Paper	Epoxy	0.5	Not det.	47-51 (HFM)	7.90	0.730	642	5.75	11.5	0.474

[*] different recipe: (higher solid content)

Conclusions

- Screening of several commercial adhesive systems allowed identification of suitable adhesives for silica and RF aerogels, respectively
- Aerogel composites with honeycombs based on paper, aramid, and aluminum were then covered with aluminum sheets
- Mechanical properties were determined and illustrated an insignificant influence of the cover thickness on compressive modulus and compressive strength while bending behavior varied significantly.
- It was determined to what extent the thermal conductivity increased with cover thickness.

→ Studies demonstrate tailoring of lightweight materials with fine-tuned mechanical and thermal properties.
→ Empirical material data are now being collected in a database in order to support simulation studies.
→ Generic parts relevant for the transport sector are subject of ongoing studies.

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References
[1] R. Tannert, M. Schwan, B. Milow, L. Ratke, *2nd Seminar on Aerogels,* Hamburg, Germany, **2014**.
[2] R. Tannert, M. Schwan, L. Ratke, *J. Supercrit. Fluids* **2015**, *106*, 57-61.
[3] A. Berkefeld, M. Heyer, B. Milow, *J. Sol-Gel Sci. Technol.* **2017**, *84*, 486-495.

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