Combining aerogels with honeycombs – a new stiff and flexible superinsulation

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MOTIVATION

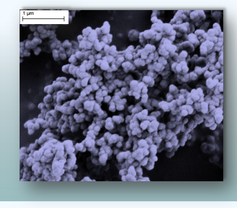
We propose to combine aramid honeycombs with organic resorcinol – formaldehyde aerogels to manufacture a new types of advanced insulation materials:

- Low thermal conductivity
- Low weight
- Adjustable mechanical properties: stiff or flexible
- Non-toxic, non-fuming.

AEROGEL

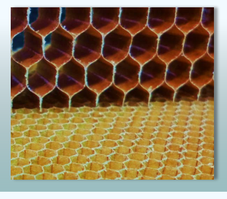
Aerogels are nanostructured highly open-porous solid materials synthesized by sol-gel process

Properties:
✓ High porosity 95 - 99%
✓ Low density 0.01-0.2 g/cm^3
✓ High specific area 500 - 2000 m^2/g
✓ Low thermal conductivity 0.002-0.03 W/mK



HONEYCOMB

Cellular solid material with different cell size and cell shape



Properties:
✓ Low density 0.02-0.04 g/cm^3
✓ Great strength to weight ratio
✓ Huge stiffness
✓ High energy absorption

COMPOSITE

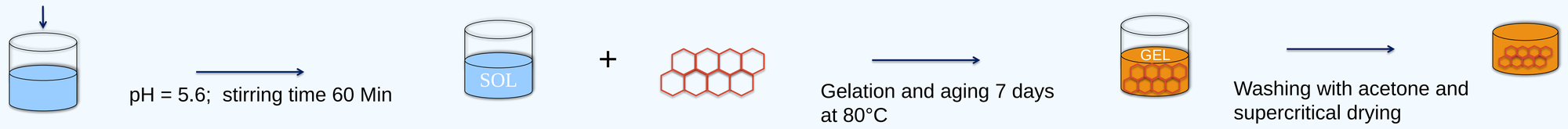
Honeycomb filled with flexible aerogel

Honeycomb filled with hard aerogel

SYNTHESIS

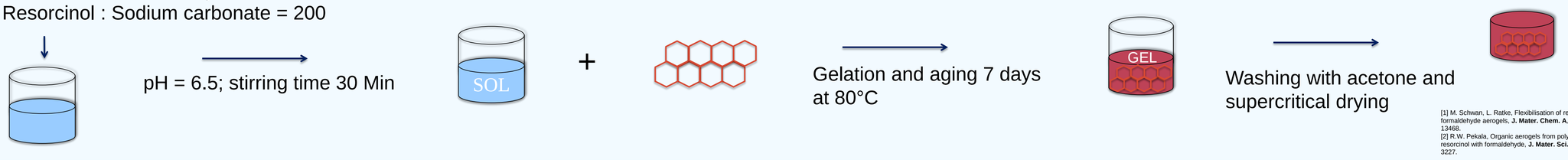
Flexible Resorcinol-Formaldehyde (RF) aerogel[1]

Resorcinol : Water = 0.008
Resorcinol : Formaldehyde 37% = 0.5
Resorcinol : Sodium carbonate = 50



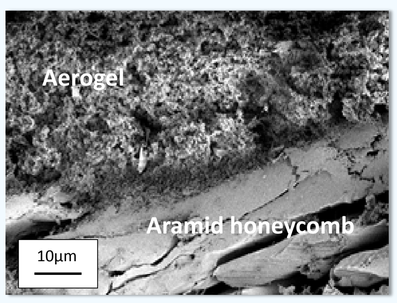
Hard Resorcinol – Formaldehyde (RF) aerogel[2]

Resorcinol : Water = 0.019
Resorcinol : Formaldehyde 24% = 0.5
Resorcinol : Sodium carbonate = 200

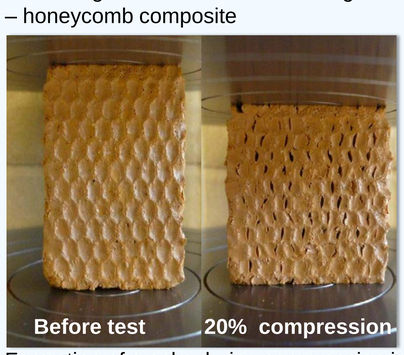


[1] M. Schwan, L. Ratke, Flexibilisation of resorcinol–formaldehyde aerogels, **J. Mater. Chem. A**, 2013, **1**, 13462-13468.
[2] R.W. Pekala, Organic aerogels from polycondensation of resorcinol with formaldehyde, **J. Mater. Sci.,** 1989, **24**, 3221-3227.

RESULTS AND CONCLUSION



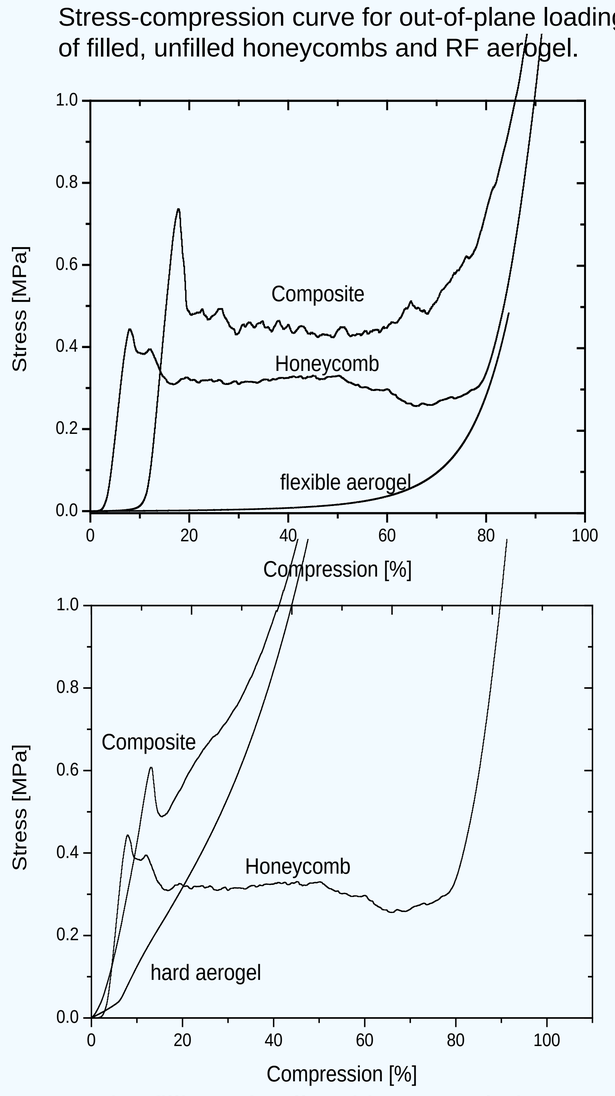
SEM image of cross section of aerogel-– honeycomb composite



Formation of cracks during compression in the middle of cells approves a sufficient contact between both materials

Material	Thermal conductivity, W/mK	Young's Modulus, MPa	Density, g/cm^3
Aramid honeycomb	0.060	0.03 In – plane 10.7 Out - of – plane	0.03
Hard RF aerogel	0.009	0.65	0.22
Flexible RF aerogel	0.037	0.01	0.05
Composite with hard RF aerogel	0.030	1.36 In – plane 5.11 Out - of - plane	0.17
Composite with flexible RF aerogel	0.041	0.10 In – plane 13.6 Out - of – plane	0.08

Stress-compression curve for out-of-plane loading of filled, unfilled honeycombs and RF aerogel.



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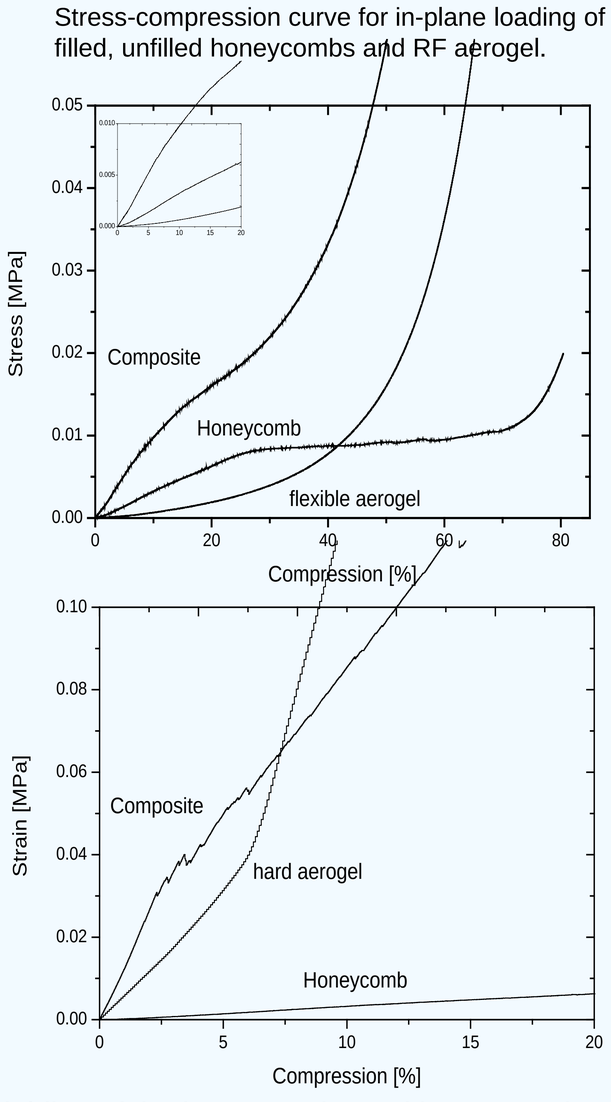

The filling of cells with aerogel changes the yielding of the honeycombs and increases the Young's modulus.

SUMMARY

✓ Reduced thermal conductivity
✓ Improved mechanical properties
✓ Sufficient, continuous contact between aerogel and honeycomb
✓ Non-toxic, non-fuming, light insulating material