NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

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Enhanced Processing and Hybridization of Silica Aerogel Composites

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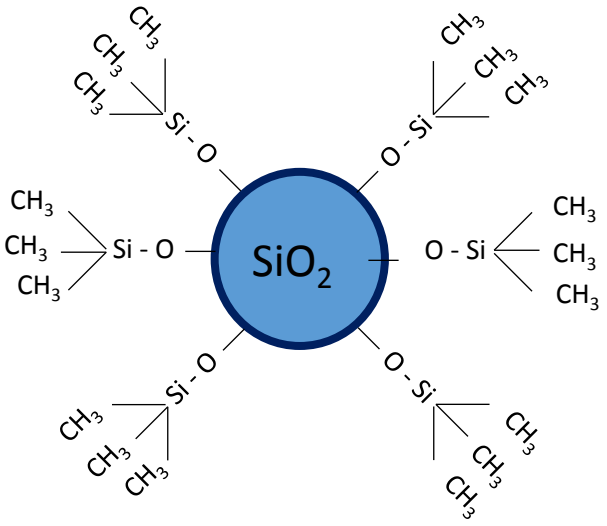
Inputs taken from WWW resources for enriching this presentation are gratefully acknowledged

Aerogel Composites

Aerogel Particles

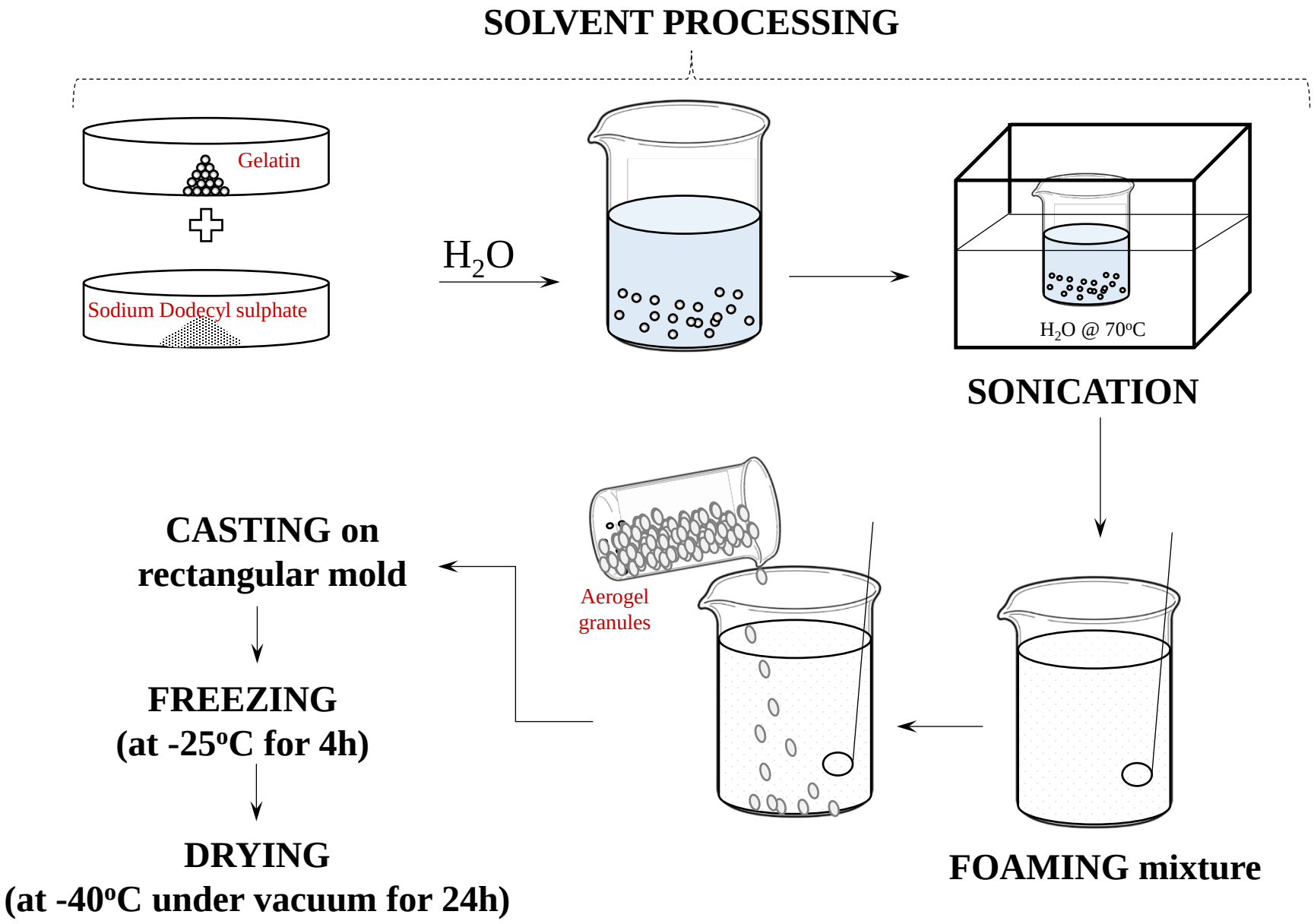
[Cabot Corp® (USA)]



Industrial Name	**: Silica,(TMS)-oxy modified**
Raw state	: Solid Particle form
Particle size	: 0.7 – 0.4mm
Mean pore diameter	: 20nm
Bulk density	: 65 – 85kg/m^3
Melting temperature	: Above 500 °C
Operating temp	: 300 – 350°C

Source: Mahesh Sachithanadam, Sunil Chandrakant Joshi. Silica Aerogel Composites: Novel Fabrication Methods

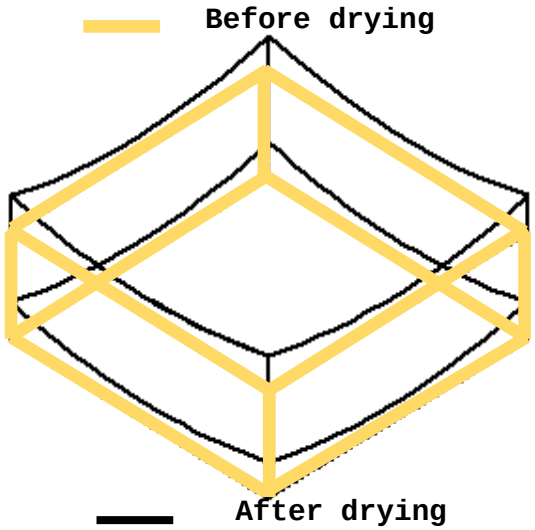
Eco-Friendly Aerogel Composites: Synthesis

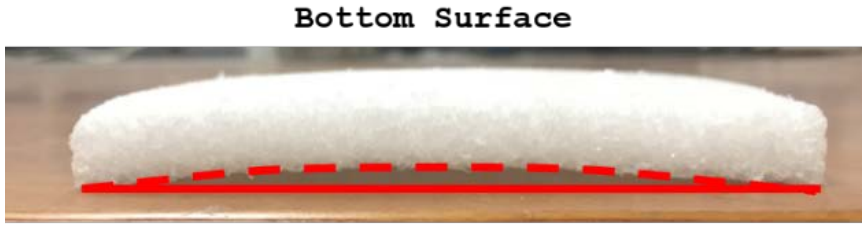


Fabrication of Flat Aerogel composite Panels

Early Technique

- After freeze drying, the panel is not flat and exhibit **Synclastic curvature**
- Cast mixture. Cover the surface using **porous transparent plastic sheet.**

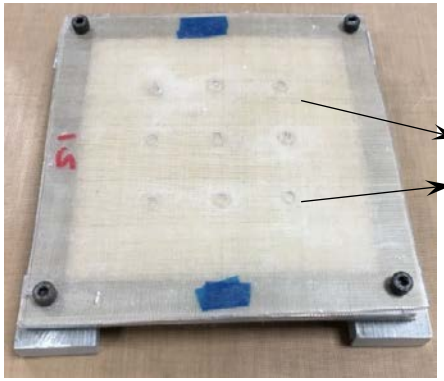


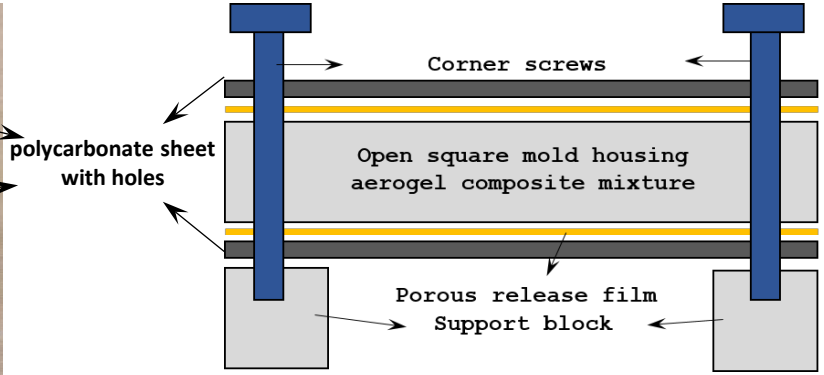


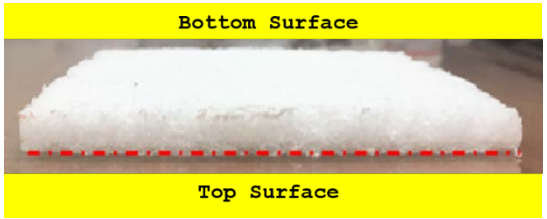
Fabrication of Flat Aerogel composite Panels

Modified Technique

- Cast mixture. Cover the open surface using **transparent perforated rigid polycarbonate sheets. Seal firmly.**
- **Perforations** on the polycarbonate sheet to facilitate vacuum circulation during freeze drying.
- Led to a perfectly flat uniform thick panel







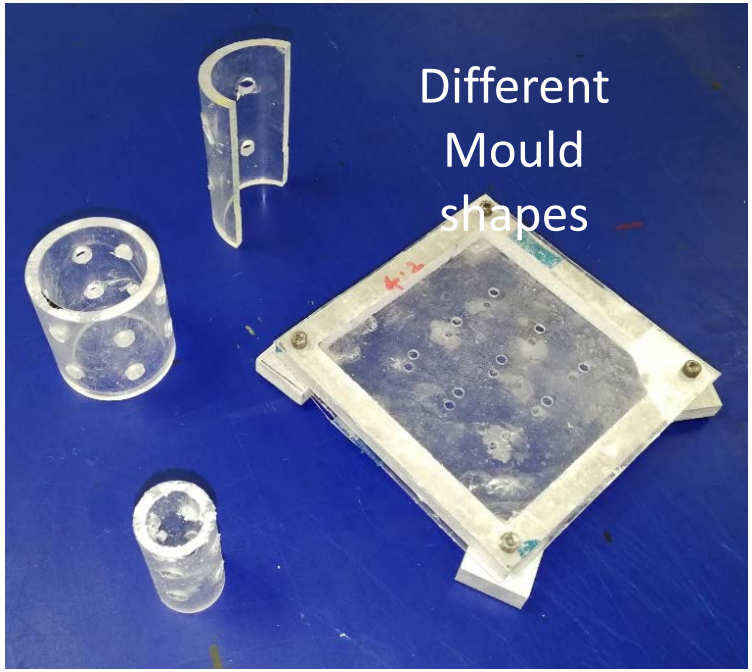
Processing Techniques for Different Morphologies

- Same technique extended to different flat and curved shape parts using appropriate moulds.
- Feasible to fabricate solid and/or hollow sections of wide range of thicknesses.
- Presence of uniform holes on moulds allow adequate vacuum.

Allows uniform sample thickness

Salient Features of developed technique

- ***Fabricate complex contours***
- ***High integrity***
- ***Complete dry***
- ***Uniform thickness***.



Advantages of additional reinforcements

- Additional reinforcements, like *Glass fibre mesh, Nylon mesh,* etc., used to facilitate casting of wet aerogel mixture.
- It not only facilitated but also eased production of complex contour shapes

- Moreover, it enhances mechanical performance of resultant Aerogel composite structures.
  - ➢ **Greater Flexibility**
  - ➢ **More Load carrying ability**

Intrinsic hybridization

Advantages

- Ultra low density (Light weight)
- Excellent thermal/sound Insulation
- High Strain recovery characteristics
- Pollution filter and etc..

Limitations

- Fragile
- Poor Mechanical performance
- Production cost

Necessitates Hybridization

Either Intrinsic or Extrinsic or both

Hybrid Aerogel composites

Intrinsic Hybridization

Additives as precursor with aerogel granules

- **FSC:** Aerogel granules + fumed Silica powder
- **CAC:** Aerogel granules + Carbon Nanotubes (CNTs)

- Negligible increase in weight
- Improved compactness

Extrinsic Hybridization

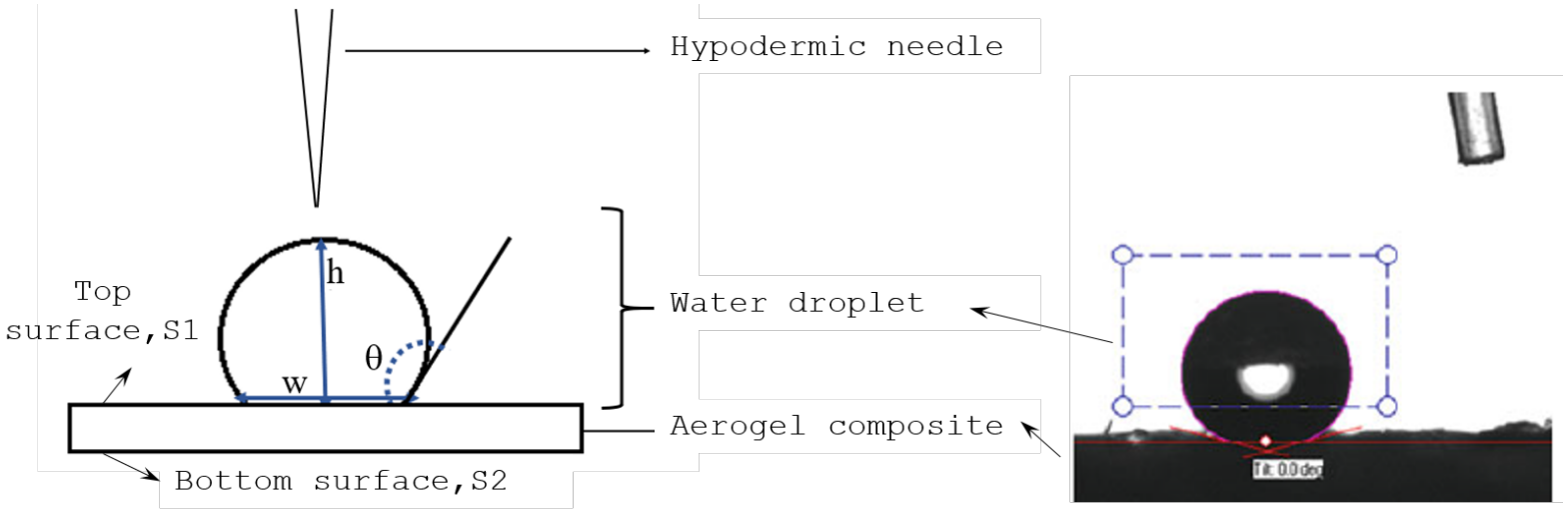
Additional macro reinforcement

- Continuous glass fabric cloth
  - Fabric cloth placed along the planar surface
- Dis-continuous short glass fibre whiskers
  - Fabric cloth placed along the planar surface

- Significant increase in weight
- Excellent mechanical performance

Characteristics of Intrinsic Hybridized Aerogel Composites

- **Hydrophobicity:** Measurement of contact angle ensures the additives doesn't alter the hydrophobic property of aerogel composites.



Sample	θ (degrees)		Remarks
	S1	S2	
SAC	110.1	98.2	All variants are hydrophobic.
FSC-20MG	108.0	98.0	
FSC-80MG	104.2	103.2	
CAC	117.5	114.2	

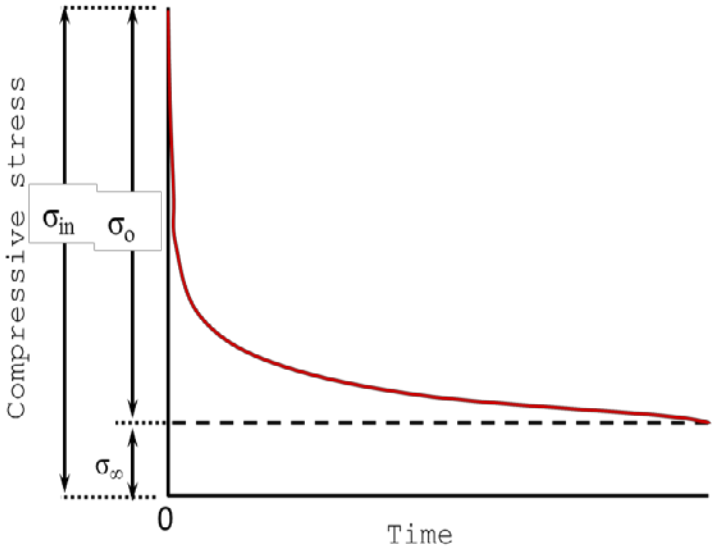
SAC: Standard Aerogel Composites; FSC: Fumed Silica aerogel Composite; CAC: Carbon nanotube Aerogel Composite

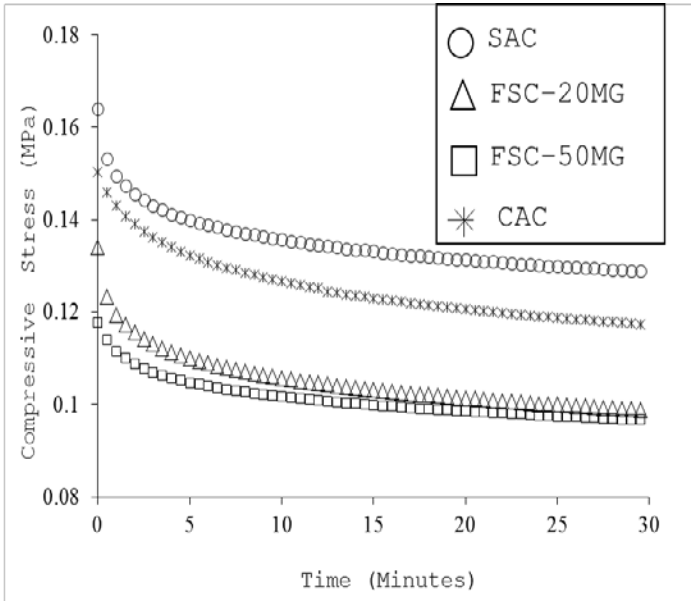
Source: Sunil Chandrakant Joshi et.al. Enhancement Studies on Manufacturing and Properties of Novel Silica Aerogel Composites. *Gels 2018*.

Characteristics of Intrinsic Hybridized Aerogel Composites

Stress relaxation behaviour

SAC: Standard Aerogel Composites; FSC: Fumed Silica aerogel Composite; CAC: Carbon nanotube Aerogel Composite





Stress relaxation behaviour follows Kohlrausch function

$$\sigma(t) = \sigma_o e^{-t^b} + \sigma_\infty$$

$\div$ by σ_{in} on both sides

$$K_r = K_1 e^{-t^b} + K_a$$

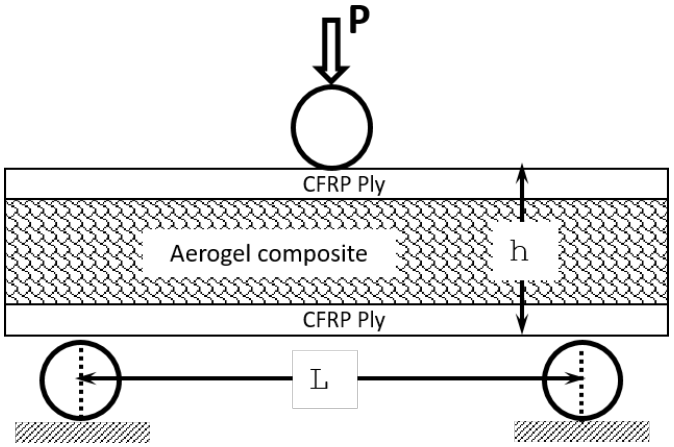
$$K_r \approx 0.23\, e^{-t^b} + 0.75$$

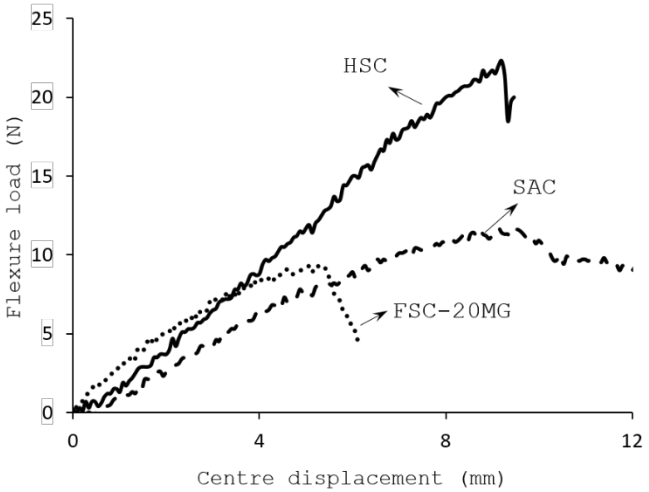
- ❑ **Nearly 23% of compressive stress released without unloading aerogel samples of hybrid kind.**
  - **Exhibit excellent stress damping property**

Source: Sunil Chandrakant Joshi et.al. Enhancement Studies on Manufacturing and Properties of Novel Silica Aerogel Composites. *Gels 2018*.

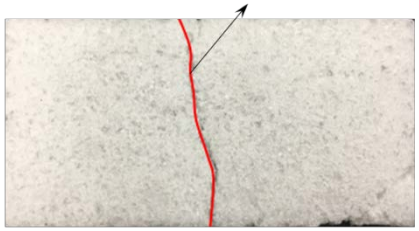
Characteristics of Intrinsic Hybridized Aerogel Composites

Flexure behaviour





Crack induced along whole width of aerogel sample due to flexure

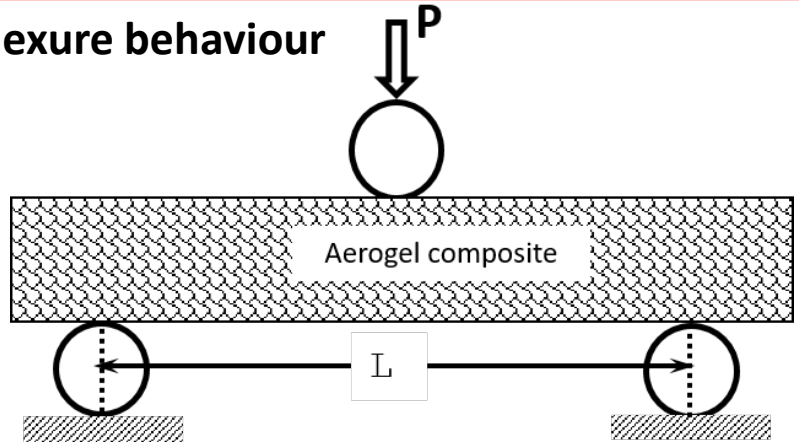


- **Benchmark sample:** Nomex honeycomb core (HSC) between single CFRP ply.
- Increasing compactness by adding fumed silica, FSC exhibit less flexural deformation compared to standard aerogel composite sample (SAC).
- **Failure displacement of both SAC and HSC samples are almost same.**
- Failure due to crack on tensile side exists only under the contact load point. The rest of the region shows perfect integrity.
  - **Confirms that aerogel composites is a suitable core material for sandwich construction.**

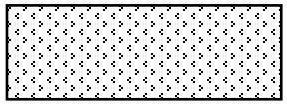
Source: Sunil Chandrakant Joshi et.al. Enhancement Studies on Manufacturing and Properties of Novel Silica Aerogel Composites. *Gels 2018*.

Characteristics of Extrinsic Hybridized Aerogel Composites

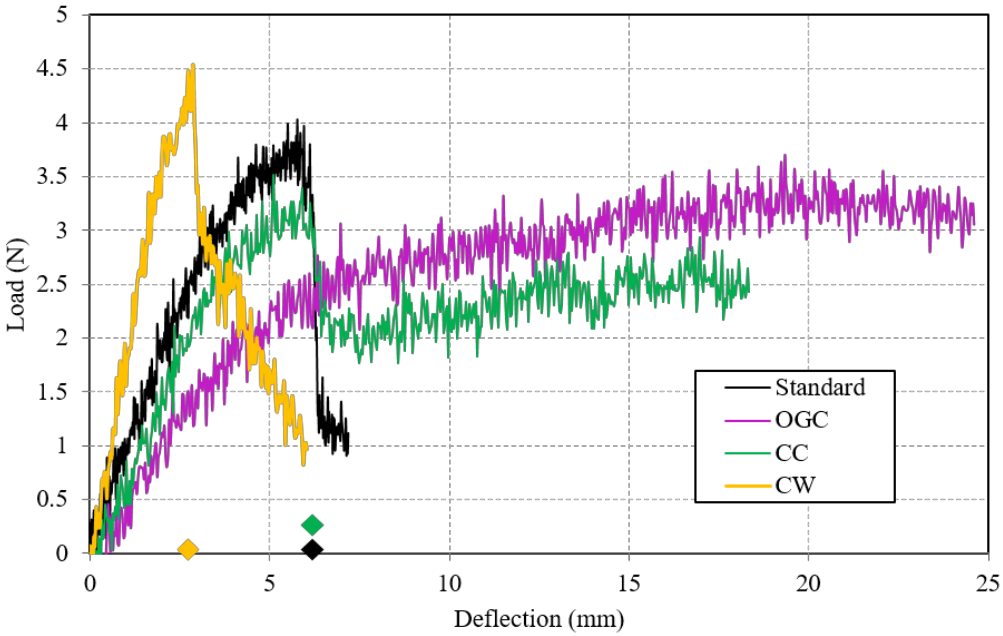
Flexure behaviour



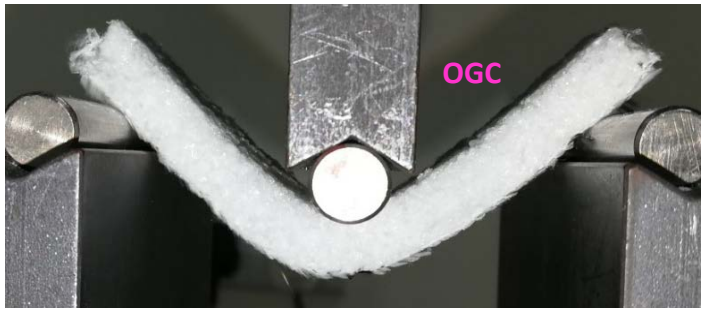
- Four different configurations tested to investigate out of plane deformation

Standard		No reinforcements
OGC		Glass fabric reinforcement along the outer tensile surface of aerogel composite
CC		Glass fabric reinforcement in the mid-plane of aerogel composite
CW		Short glass fibre reinforcement within aerogel composite

Characteristics of Extrinsic Hybridized Aerogel Composites



- Flexural displacement of both **standard** and **CC** samples are same.
  - **No use of reinforcement placed along mid surface.**
- Whiskers fabric samples **CW** shows more resistance to flexural
  - **Higher peak load but smaller failure displacement.**
- Greater flexural displacement of **external reinforced aerogel composite OGC.**
  - **Avoid the nucleation of tensile crack**
  - **Typical behaviour of flexible thin structure.**



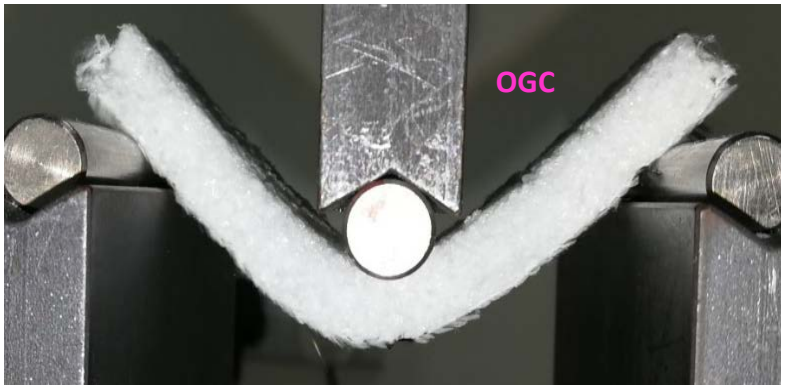
Summary

- Novel, eco-friendly, silica aerogel composites developed.
- Technique improvised to fabricate the composites of any shape (perfect flat to contoured circular sections) in either solid or hollow form.

- Influence of intrinsic additives precursors on physical and mechanical properties of the composites selectively studied.
- Preliminary results show that aerogel composites is a promising core material for sandwich structure.
- Excellent stress relaxation behaviour useful in stress dampening.

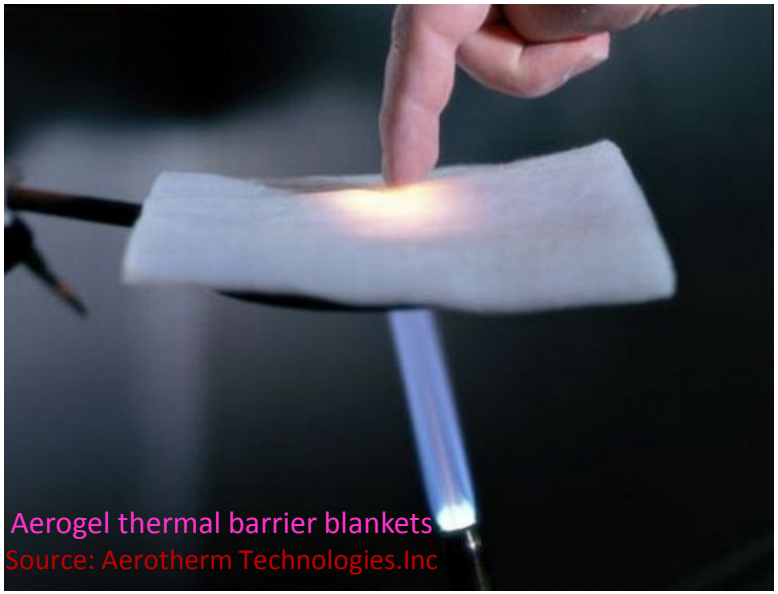
Summary

- Despite a slight increase in weight, extrinsic glass fabric reinforcement of aerogel composites shows large flexural tolerance. Useful property.

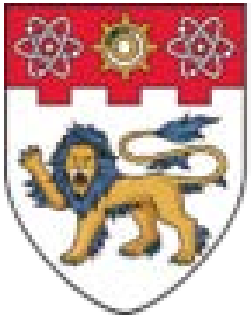


- Reinforcement also helps in forming contoured surfaces. Enhanced possibility of different applications.

e.g.: thermal barrier blankets



Aerogel thermal barrier blankets
Source: Aerotherm Technologies.Inc



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Thank you

Questions?

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