SUCROSE-DERIVED CARBON-GRAPHITE COMPOSITE FOAMS FOR THERMAL ENERGY STORAGE SYSTEMS

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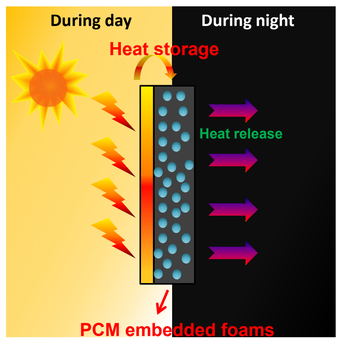
Introduction

Phase change materials (PCM) store and release thermal energy by means of phase transformations. Materials with high latent heat of fusion are being investigated for application in Thermal Energy Storage (TES) systems for conversion of solar energy and waste heat into productive, sustainable thermal energy. PCM integrated building materials can also mitigate energy requirements for heating and cooling of human dwelling spaces.

Paraffin wax, Fatty acids and Sugar alcohols are abundant and inexpensive materials of high latent enthalpy of fusion which offer economically viable benefits as PCMs. On the downside, the low thermal conductivity of these materials prove a major obstacle in widespread application.

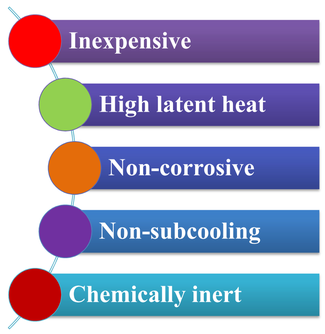
Thermal conductivity of organic PCMs ~0.21 to 0.24 W/m.K

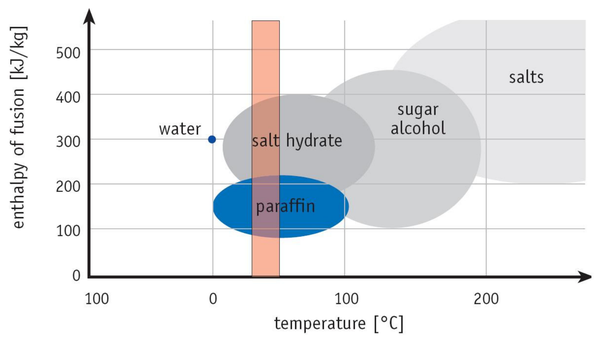


How PCM based solar TES works

Types of PCMs

Advantages of organic PCMs





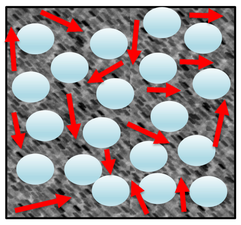
Performance enhancement of PCM

- Adaptation of extended surface or fins
- Use of binary mixture of PCMs
- Nano additives
- Encapsulation of PCM in conducting matrix
- Nano-encapsulation

Research focus

- To develop light-weight, highly porous, thermally-conducting matrix from sustainable precursor to host PCM for TES application.
- Sucrose is used as a carbon precursor forming the matrix of the foam, graphite flakes is used as the conducting filler, NaCl is used as the micro-sized pore generating template and Paraffin wax as the PCM.
- Studying the effect of compositions of the precursors on the thermal conductivity, PCM loading and enthalpy of composites.

Conducting matrix for PCM



PCM

Carbon foam matrix

Heat flow

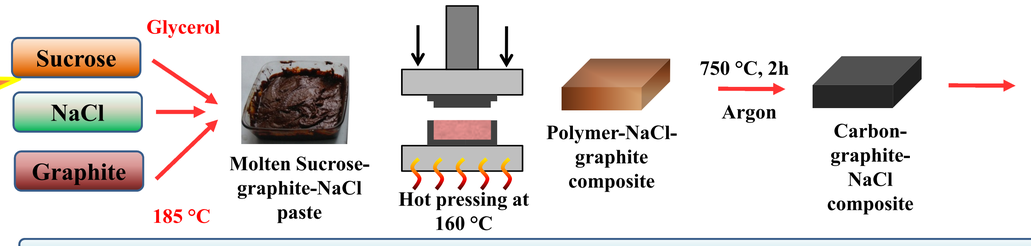
Improves heat diffusion

Composition of precursors for preparing composite carbon foams

	100 g	150 g	200 g	250 g
90 g	10 g	10 g	10 g	10 g
80 g	20 g	20 g	20 g	20 g
70 g	30 g	30 g	30 g	30 g
60 g	40 g	40 g	40 g	40 g
50 g	50 g	50 g	50 g	50 g

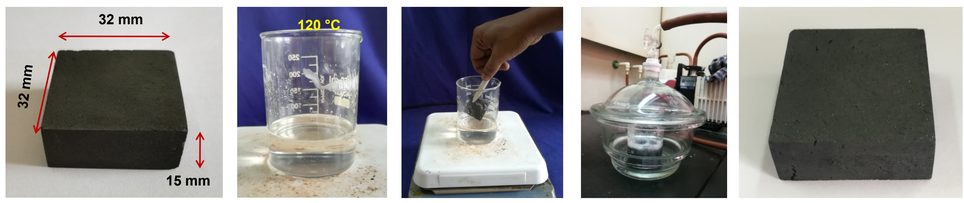
NaCl
Sucrose
Graphite

Synthesis of thermally conducting carbon foams



A green, simple, scalable process to produce carbon foams by hot-pressing molten sucrose-NaCl-graphite mixture in a stainless steel mould

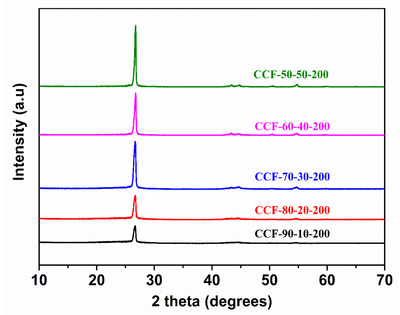
Conducting carbon foams-Paraffin wax composites

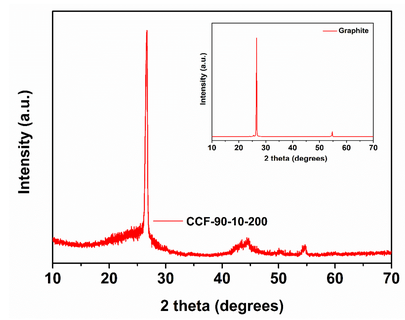


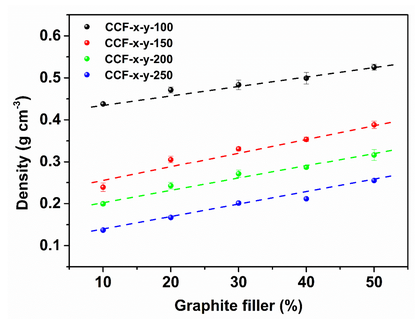
Vacuum impregnation of Paraffin wax in foam

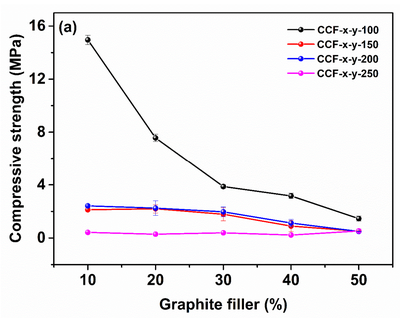
Composite carbon foam was placed in a beaker containing molten wax and heated to 120 °C for 15 min. The beaker is then degassed in a vacuum dessicator for 15 min. Foam is removed and allowed to cool to room temperature.

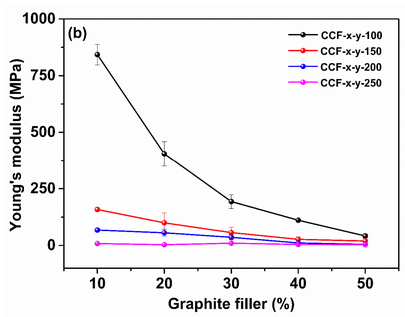
Characterisation of Conducting carbon foams

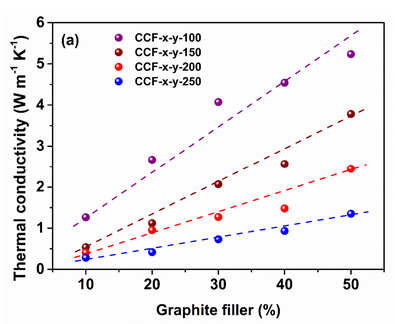


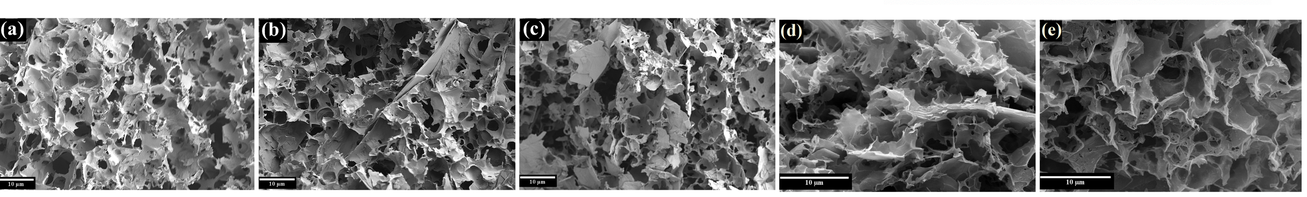




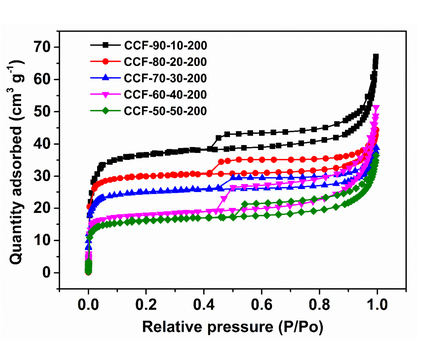




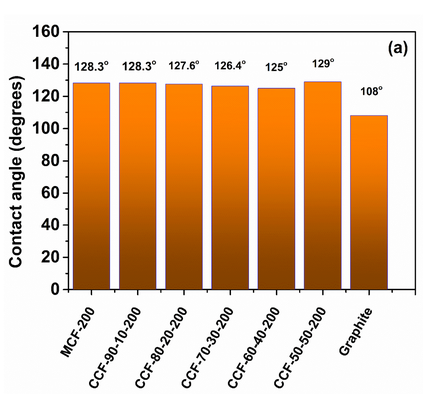


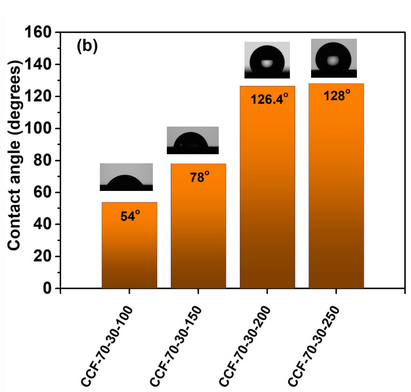


Composite carbon foams (a) CCF-90-10-200 (b) CCF-80-20-200 (c) CCF-70-30-200 (d) CCF-60-40-200 (e) CCF-50-50-200

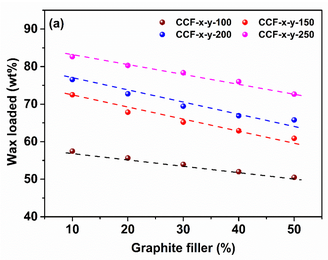


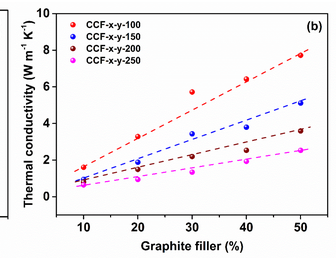
BET Surface area: 50 to 113 $m^2 g^{-1}$

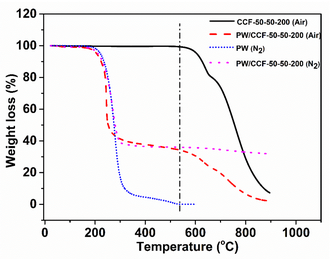


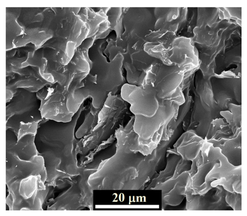


Properties of carbon foams-Paraffin wax composite

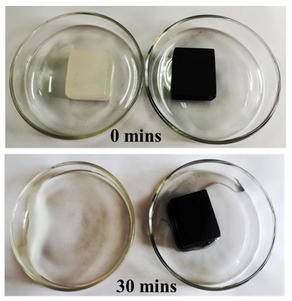




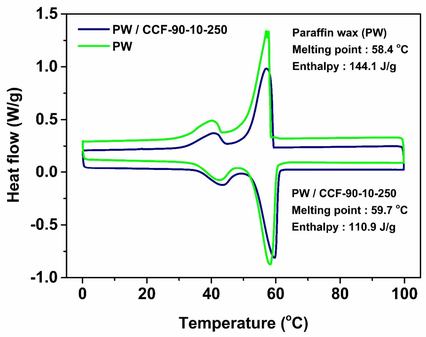




SEM image of Foam-wax composite



Form stability of paraffin wax-foam composite



Highlights

- Low cost, environmentally benign precursors
- The porosity of the foams can be controlled by the NaCl loading.
- Graphite filler loading can be optimized to tune the thermal conducting of the foams.
- Conducting carbon foams produced using this method possess microcells of dimension <20 µm. The small pore dimensions enhances the capillary forces thus aiding impregnation and mitigating leakage during melting.
- The inherent hydrophobicity of the foams assists wax impregnation.

Conclusions

- Conducting carbon foams with high thermal conductivity were prepared using a simple hot-pressing method
- Sucrose as carbon precursor, graphite as conducting filler and NaCl particles as sacrificial template were used
- By varying NaCl concentration and graphite filler loading the porosities (76.1 to 93.4%) and thermal conductivity (0.282 to 5.23$Wm^{-1}K^{-1}$) were optimised
- The microcellular foams were impregnated with Paraffn wax using vacuum impregnation technique to create composites
- The PW/CCF composites exhibited good enthalpy of fusion (77% of wax) at high mass loading of wax, and showed excellent stability during reheating.

Acknowledgement

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LPSC, Thiruvananthapuram

References

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