Silicon Carbide (SiC) Foam
For Molten Salt Containment In CSP-GEN3 Systems

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INTRODUCTION & PROJECT GOALS

In the present study, a silicon carbide foam was produced using coal (carbon source) and a preceramic polymer resin (silicon source). The objective is to determine if the foam can be produced and has potential use as a porous substrate for molten salt phase change materials (PCM). The storage system was modeled after a modular design developed by Argonne National Laboratory. For the simulations, a plant capacity of 100 MWe was considered with a storage of 12 h. The key result shows that the use of silicon carbide foam, having thermal conductivity of 25 W/m·K, enhances the thermal performance of the storage system and achieves the potential of meeting the round trip and exergetic efficiencies as required by the Department of Energy's Solar Energy Technology Office.

INDUSTRY NEEDS

To achieve the high operation temperature required for the s-CO_2 turbine, a high-temperature TES system must be used.

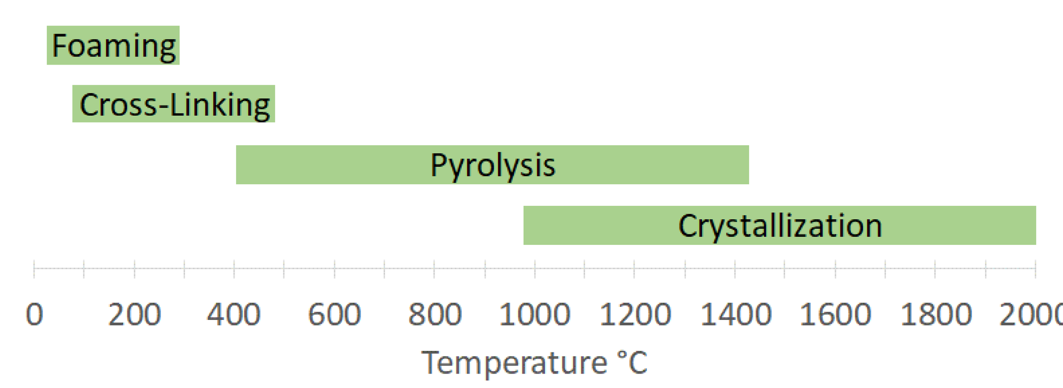
- The latent heat storage system has a much higher energy density than a sensible heat storage system.
- Compared with sensible heat storage, latent heat storage provides a smaller temperature difference between charging and discharging processes and a smaller volume requirement of materials for storing the same amount of energy.

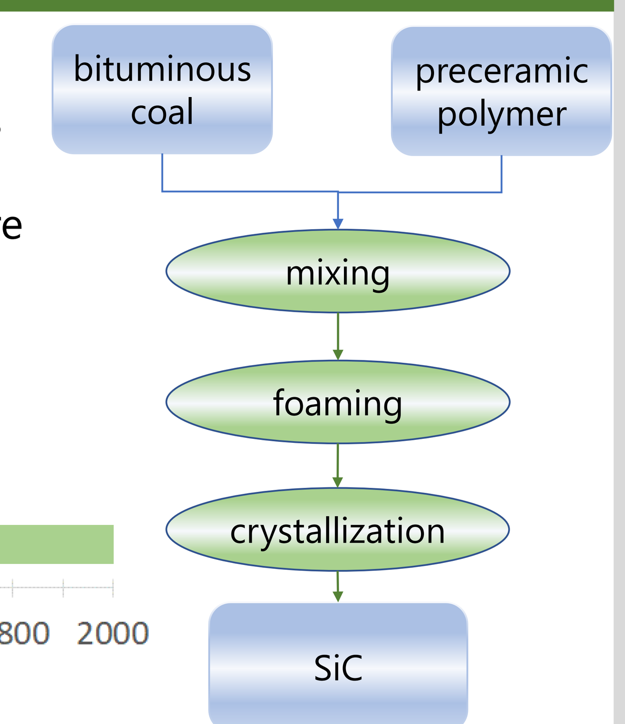
PCMs with melting point >750 °C are considered as a potential storage medium for the LHTES system to meet the temperature requirements for the s-CO_2 power cycle.

SILICON CARBIDE FOAM FROM COAL PROCESS APPROACH

SiC synthesis from Coal:

- Coal selection and blending by Rank permits foam structure optimization for PCM.
- Foaming, cross-linking and pyrolysis steps are achieved in a single furnace process run.





RESULTS

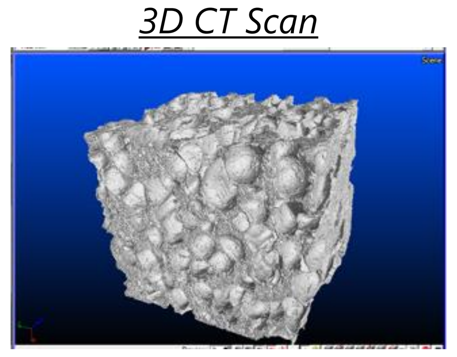
Synthesized Silicon Carbide Foam from Coal

- Density 0.6 g/cm³ – Porosity ~80%.
- Predominately yields β-SiC as determined via XRD.

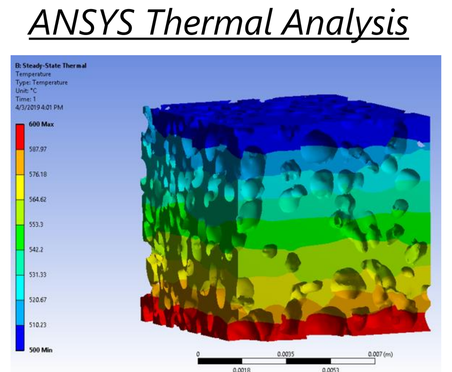
Polytype	Crystal Structure	Wt. %
3C (β-SiC)	Zinc blende (cubic)	90 (±2.1)
6H (α-SiC)	Wurtzite (hexagonal)	10 (±1.6)

- Developed foam characterization methods by (1) defining structure using 3D Computational Tomography, then (2) convert results to Solid Model Geometry, and (3) Finite Element Heat Transfer Analysis.
- SiC foam/PCM composite can potentially achieve round-trip exergy efficiency above 90-95%.

3D CT Scan



ANSYS Thermal Analysis



BENFITS AND FUTURE WORK

- Based on the investigations on the full-scale system, the SiC foam could significantly improve the heat transfer performance of the TES system. For example, the SiC foam can accelerate the melting and solidification processes for efficient thermal energy storage and release, respectively. Hence, use of SiC foam can reduce the number of required HTF tubes compared to a PCM-only system and lead to cost reduction in the CSP plant. Furthermore, the SiC foam/PCM composite could achieve the round-trip exergy efficiency to meet the storage target for the TES system thermal performance, which cannot be accomplished by using pure PCM.
- Future work will focus on optimizing the product's structure, crystallinity and purity in order to maximize heat transfer properties. Furthermore, coal and resin blending techniques will be researched to increase swell during foaming, hence lower density to reach ~90% porosity for optimal PCM loading. Corrosion resistance to chloride salts will also be investigated.

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