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Flower-like hollow porous silica sphere for high-temperature thermal storage

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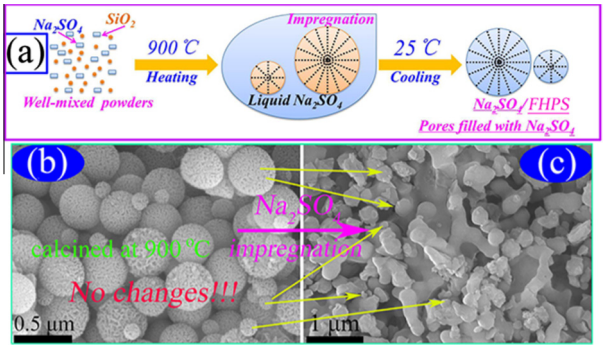
HIGHLIGHTS

- FHPS was tailor-made through a facile self-assembly process.
- High-temperature Na_2SO_4/FHPS shape-stabilized composite PCM was prepared firstly.
- Formation mechanisms of FHPS and Na_2SO_4/FHPS are systematically discussed.
- 200-cycle test was applied to exam the thermal properties.

GRAPHICAL ABSTRACT

Low- and middle-temperature PCMs are always the objects of prime investigations, however, the field of PCMs' applications is not limited to low and middle temperatures only. In the present study, sodium sulfate was employed as high-temperature storage medium. Flower-like hollow porous silica (FHPS) supporting material was first tailor-made by a self-assembly process using TEOS as SiO_2 precursor and CTAB as template. A novel shape-stabilized phase change material (ss-PCM) was tailor-made by blending FHPS and the Na_2SO_4 PCM via a facile mixing and sintering method. Various techniques were employed to characterize its structural and thermal properties.



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ABSTRACT

Flower-like hollow porous silica (FHPS) for high temperature thermal storage was first tailor-made by a self-assembly process using TEOS as SiO_2 precursor and CTAB as template. A novel high-temperature Na_2SO_4/FHPS composite shape-stabilized PCM (ss-PCM) with a maximum absorption ratio of 80% Na_2SO_4 was designed. Na_2SO_4 was well dispersed in FHPS pores. The ss-PCM melted at 890.35 °C with the latent heat of 128.7 J/g and solidified at 874.29 °C with the latent heat of 130.5 J/g. The ss-PCM was thermally stable even after a 200-cycle of melting and freezing. The latent heat values of the ss-PCM make it suitable PCM for latent heat storage purposes at high temperature.

1. Introduction

Thermal energy storage in general, and phase change materials (PCMs) in particular, have been a hotspot in research ever since the

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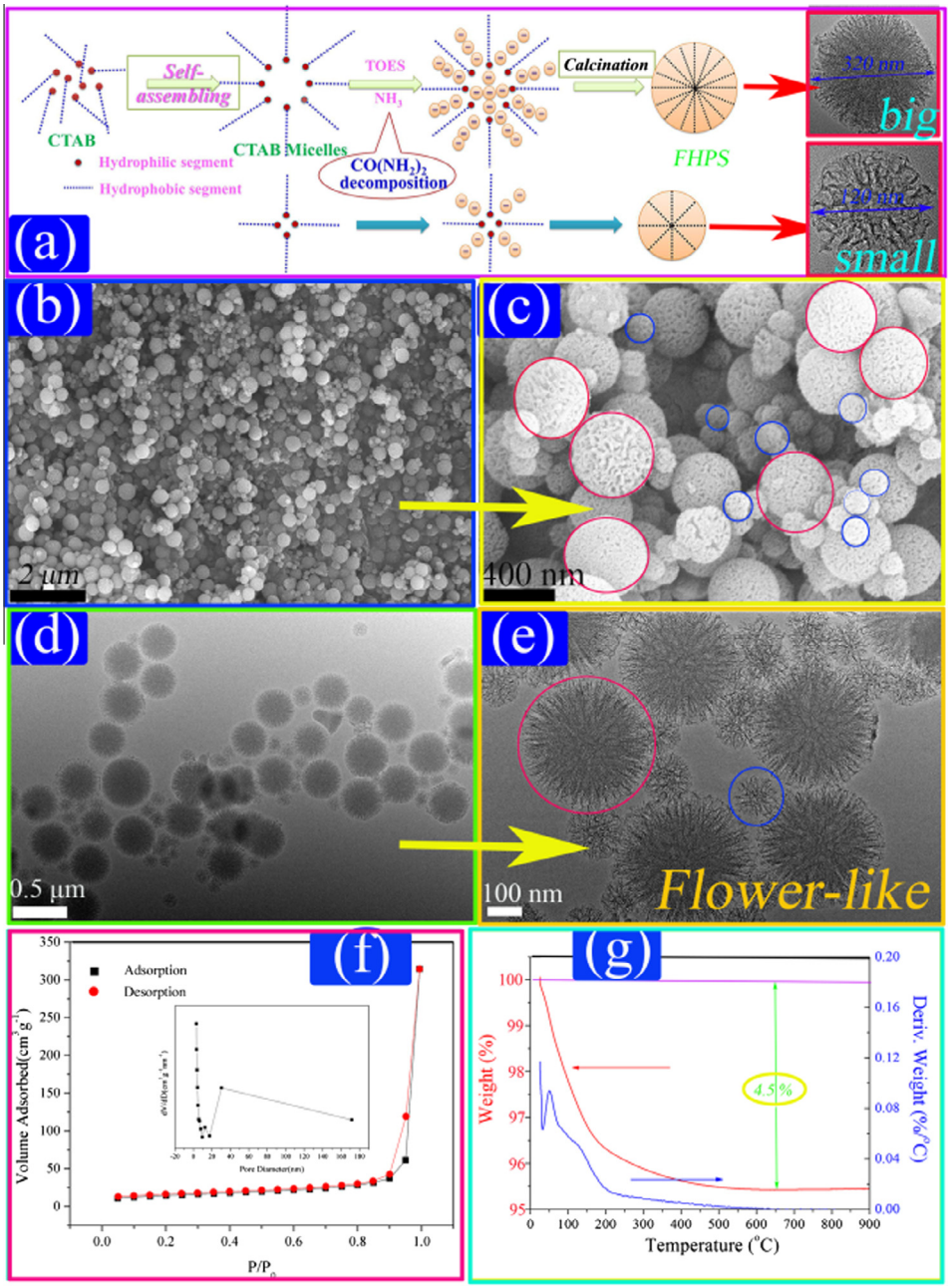

Fig. 1. FHPS: (a) Schematic formation processes; (b and c) SEM photographs; (d and e) TEM images. (f) N_2 adsorption-desorption isotherms and pore size distribution; (g) TGA curve and DTG thermogram.

energy crisis in the 1970s. PCM is a sort of functional materials allowing the cycle of heat storage and release from its melting to solidification within a slight temperature change [1]. PCMs have attracted more and more attention in the field of solar thermal energy application, building energy conservation, thermal management system, etc. [2]. As known, latent heat storage accomplished through a solid–liquid phase transition is a particularly valuable technique [3]. However, the drawback for direct use of this kind PCMs relies in the leakage of the liquid phase above their melting point. The common approach to overcome this issue is to store the PCMs in supporting materials for preparing shape-stabilized PCMs (ss-PCMs) [4,5]. Among various ss-PCMs, low-temperature and middle-temperature PCMs are always the objects of prime investigations [6]. Though the study starts from 1990s, using inorganic materials as supporters are still insufficient, especially for high-temperature PCMs. However, the field of PCMs' applications is not limited to low and middle temperatures only. Thus, the further study on the high-temperature ss-PCMs is necessary.

Sodium sulfate is regarded as an excellent high-temperature PCM due to its high phase change temperature (around 880 °C), environmental friendliness, easy availability and low costs [7]. Selecting an appropriate porous material for ss-PCMs is a promising idea to enhance the thermal performance [8]. It is worth mentioning that the fibrous structured hollow porous silica nanospheres, because of their radial-like direct channels and large pore size, help target PCM molecules reach the adsorption sites more easily than other porous materials [9]. However, this kind material used as supporting material has never been reported. Herein, Na_2SO_4/SiO_2 ss-PCM based on the flower-like hollow porous silica (FHPS) was prepared and studied. FHPS was first synthesized via a facile self-assembly process. The resulting Na_2SO_4/SiO_2 ss-PCM will be useful for the high-temperature thermal energy storage.