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Fabrication and characteristics of composite phase change material based on $Ba(OH)_2{\cdot}8H_2O$ for thermal energy storage

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ABSTRACT

Latent thermal energy storage using phase change material (PCM) is an effective way to store and transport energy. In this work, expanded graphite was modified using octylphenol polyoxyethylene ether to generate modified expanded graphite (MEG), and then a novel shape-stabilized $Ba(OH)_2{\cdot}8H_2O$/MEG composite PCM was synthesized by incorporating $Ba(OH)_2{\cdot}8H_2O$ into MEG matrix. Mass fractions of $Ba(OH)_2{\cdot}8H_2O$ in composite PCM were calculated from 74% to 93%. The effects of MEG on properties of PCM were investigated using scanning electron microscopy, X-ray diffraction, differential scanning calorimetry and thermal constant analyzer. The results indicated that MEG had the desired compatibility with $Ba(OH)_2{\cdot}8H_2O$. The phase separation of $Ba(OH)_2{\cdot}8H_2O$ was effectively inhibited by the MEG matrix and the supercooling temperature decreased from 13 °C for $Ba(OH)_2{\cdot}8H_2O$ to 2.4 °C for composite PCM with a MEG matrix density of 200 g/L. At the same matrix density, the thermal conductivity of composite PCM reached 3.58 W/(m K), 1.84 times higher than that of $Ba(OH)_2{\cdot}8H_2O$. The latent heat was approximately equal to the product of the latent heat of $Ba(OH)_2{\cdot}8H_2O$ and its mass fraction. Moreover, the enthalpy loss of the composite PCM was negligible after 400 cycles, showing good thermal reliability.

1. Introduction

Latent thermal energy storage based on phase change material (PCM) has attracted great attention in the fields of energy storage and utilization because of high energy storage density and constant operating temperature [1–3]. Organic PCM has been studied for many years and researchers have also made major breakthroughs [4–7]. However, organic PCM is usually more expensive than inorganic PCM and its thermal conductivity is quite low.

Compared with organic PCM, salt hydrate has enormous advantages in latent thermal energy storage, such as higher thermal conductivity and latent heat, lower price and incombustibility [8,9]. Therefore, there is an urgent need to learn about the phase transition behaviour of hydrate salts [10]. Among the various types of hydrated salts, barium hydroxide octahydrate ($Ba(OH)_2{\cdot}8H_2O$) is considered as an attractive candidate because of its ultra-high phase change enthalpy (about 278 J/g), applicable phase change temperature (about 78 °C) and easy availability [11]. However, there are two major obstacles hampering its application: phase separation (anhydrous barium hydroxide cannot be entirely dissolved in free water from $Ba(OH)_2{\cdot}8H_2O$ at phase change temperature) and supercooling (PCM in liquid state cools down below its melting point without solidifying) [12]. Generally, effective methods to solve these problems are to add nucleating and thickening agents to hydrated salt [13]. For example, Mortazavi et al. [14] revealed that $Na_2B_4O_7{\cdot}10H_2O$ as nucleating agent can significantly decrease the supercooling temperature of $Na_2SO_4{\cdot}10H_2O$ from 25 to 1 °C. Li et al. [9] reported that adding 3 wt% $SrCl_2{\cdot}6H_2O$, 1 wt% $SrCO_3$, and 0.5 wt% hydroxyethyl cellulose into the $CaCl_2{\cdot}6H_2O$-25 wt% $MgCl_2{\cdot}6H_2O$ can reduce the supercooling degree to 2 °C. This means that $SrCl_2{\cdot}6H_2O$ and $SrCO_3$ can be effective nucleating agents for $CaCl_2{\cdot}6H_2O$-25 wt% $MgCl_2{\cdot}6H_2O$. It is easily summarized that the nucleating agents, proposed in numerous literature, are virtually always hydrated salt or anhydrous salt [9,15,16]. However, due to the strong alkalinity of $Ba(OH)_2$ and the insolubility of most barium salts, it is hard to find a suitable substance as an effective nucleating agent. As a result, there has been no systematic research about $Ba(OH)_2{\cdot}8H_2O$ used for energy storage systems.

Apart from phase separation and supercooling, the leakage of solid-liquid PCM is another problem that restricts its application [17]. To solve this problem, increasing attention has been paid to form-stable

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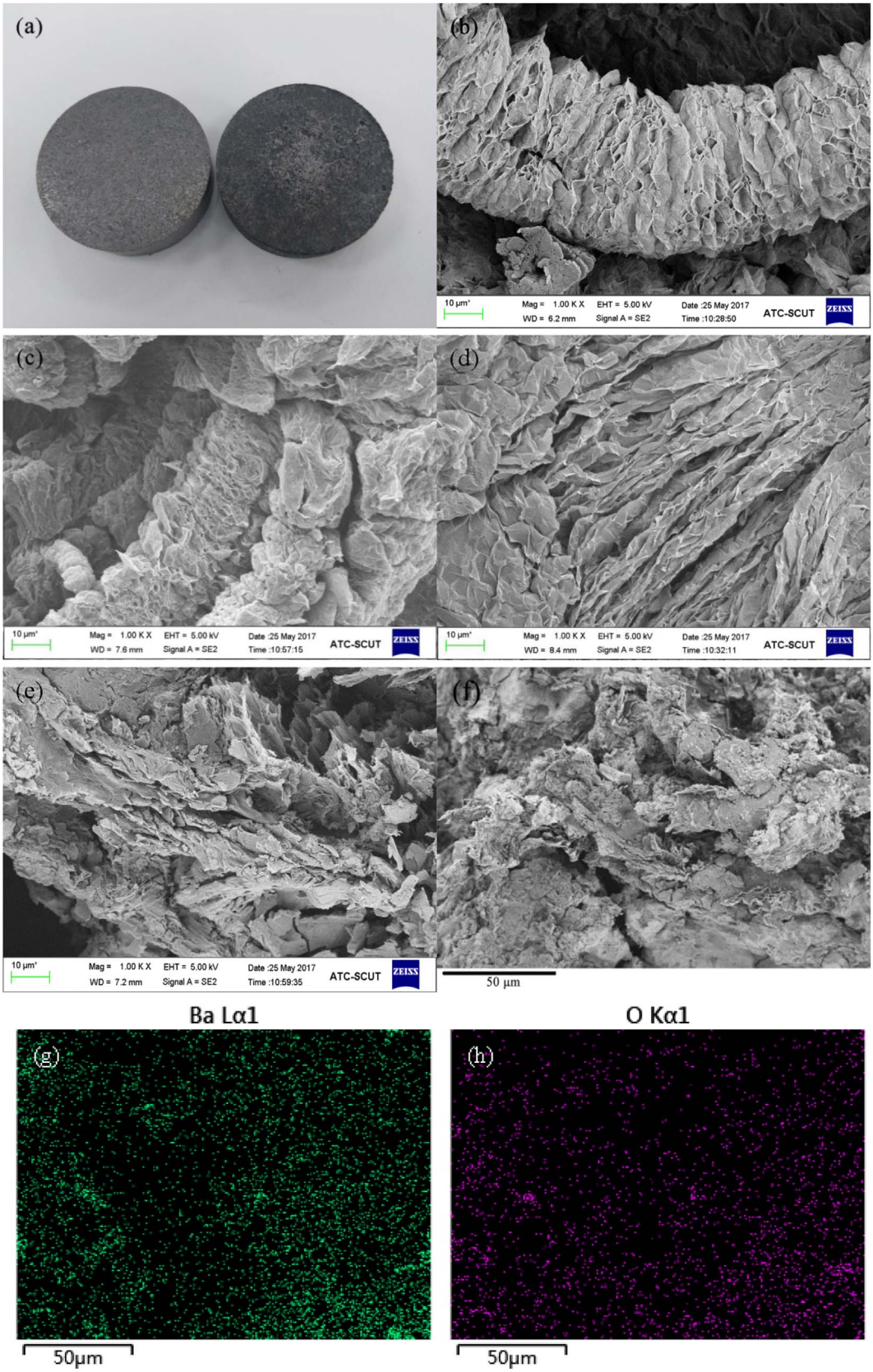

Fig. 1. (a) Optical images of MEG matrix (left) and composite PCM (right); SEM images: (b) EG; (c) MEG; (d) MEG matrix; (e, f) Composite PCM; Element mapping images: (g) Ba; (h) O.