Preparation and thermal energy storage studies of $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$ -KCl composites salt system with enhanced phase change performance

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Abstract

The phase change performance of the $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$ -KCl composites salt system with Al_2O_3 nanoparticles and carboxyl methyl cellulose (CMC) were investigated in this paper. The $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$ - KCl composite salt system was prepared by adding KCl (at 2, 4, 6, 8, and 10 wt.%) to $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$, respectively. Al_2O_3 nanoparticles were proposed as the nucleating agent and CMC was selected as a thickening agent for the $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$ -8wt.% KCl composites salt system. The results show $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$ – 8wt.% KCl composites salt system with 1 wt.% Al_2O_3 nanoparticles and 4 wt.% CMC, in which almost no supercooling phenomenon occurs. After 50 cycles of the melting–freezing cycle test, **aluminum oxide is uniformly dispersed in SAT composites matrix**, the latent heat remained constant at about 232.29 J/g. The maximum deviations of latent heat of composites $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$ -8wt.% KCl with 1 wt.% Al_2O_3 nanoparticles and 4 wt.% CMC before and after the fifty-run-recycling test are only 3.6%.

Keywords: Phase change material (PCM); $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$ -KCl composites salt

system; Al_2O_3 nanoparticles; Nucleating agent; Supercooling

1. Introduction

Phase change materials (PCMs) offer an effective method for the efficient usage of latent thermal energy. PCMs can be widely applied in the thermal energy storage field and even for low/medium temperature or unstable energy storage fields, such as solar energy, industrial waste heat, intermittent electric heating energy and so on [1-3]. The study and development of PCMs demonstrating high performance is of great significance for the solution of energy storage, supply, and demand. In the past few decades, PCMs have attracted great attention of researchers and has directed many investigations [4-5]. Based on the phase-change state, PCMs for latent thermal energy storage fall into three categories: solid-solid, solid-liquid and solid-gas[6], among which the solid-liquid PCMs are the most suitable for thermal energy storage. The substances used can be organic such as paraffin[7], fatty acid[8] and its derivatives[9], polyethylene glyco and polyalcohols[10], or inorganic like salt hydrates ($\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$ [11], $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ [12], $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ [13], $\text{NaSO}_4 \cdot 10\text{H}_2\text{O}$ [14], $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$ [15], $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ [16], $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ [17-31] etc.) which have advantages of a higher heat storage capacity, constant phase transition temperature, and nonflammability. Thus, inorganic PCMs are more suitable and safer than organic PCMs for energy storage application.

Since sodium acetate trihydrate (SAT) is an excellent inorganic PCM, demonstrating a large latent heat (264 J/g) with a melting point of 58°C. Thus, sodium acetate trihydrate (SAT) has been selected as the PCM for use in a conventional household hot water supply system or an indoor heating system and is considered to

be a promising medium for thermal storage applications. However, almost all of salt hydrates have a natural tendency to supercool and to phase-segregate during their solidification process, which affects the application of this kind of PCM. The common solutions used to solve these problems are adding nucleating agents and thickeners.

For SAT, Huet et al. [22] proposed AlN nanoparticles as the nucleating agent and carboxyl methylcellulose (CMC) as the thickener. The results showed that AlN nanoparticles significantly prevented supercooling. For SAT with 5 wt% AlN nanoparticles and 4 mass% CMC, no supercooling was observed. Lu et al. [23] found that 5 wt% or 4 wt% Si_3N_4 , 10 wt% ZrB_2 , 2 wt% SiO_2 , BC_4 , SiB_6 has been shown to eliminate the supercooling of SAT. B.M.L. Garay Ramirez et al [24,25] reported that carboxymethylcellulose (CMC) and silver nanoparticles (AgNPs) as nucleating agent could prevent phase segregation and supercooling.

Kimura and Kai [26] found that mixtures of $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ with $\text{NaBr} \cdot 2\text{H}_2\text{O}$ (10 mass%) or $\text{HCOONa} \cdot 3\text{H}_2\text{O}$ were very stable during repeated phase-change cycles (over 1000) in a temperature range between 60 °C and 30 °C. In addition, a pressed mixture of anhydrous CH_3COONa , Na_2HPO_4 , and polyethylene powder was effective as a nucleating agent. Ryu et al. [27] found that supercooling of thickened $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ could be reduced from 20 °C to 2~3 °C by adding 2 mass% potassium sulfate. Cabeza et al. [28] tried to use $\text{Na}_2\text{HPO}_4 \cdot 7\text{H}_2\text{O}$ to reduce the supercooling of SAT. Li et al. [29] reported that $\text{NaCO}_3 \cdot 10\text{H}_2\text{O}$, $\text{Na}_4\text{P}_2\text{O}_7 \cdot 10\text{H}_2\text{O}$, and $\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$ could reduce the tendency of SAT to supercool. These mixtures were reported as having good thermal stability. Mao et al. [30] studied the effects of five

nucleating agents ($\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$, $\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$, $\text{Na}_2\text{SiO}_3 \cdot 9\text{H}_2\text{O}$, and $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$) and threethickeners (carboxymethyl cellulose, gelatin, and polyacrylamide) on the supercoolingdegree of SAT. Shin et al.[31] investigated the combination of CMC and expanded graphite as additives for SAT and found that composites with 2.5 wt% EG and 5 wt% CMC had a thermal conductivity of 1.85 W/mK . Nevertheless these research studies have contributed an important role for the advancement of novel PCM materials and energy storage systems, these works have disadvantages like instability and high cost of materials.

Recently, potassium chloride (KCl) and sodium chloride (NaCl) could be invoked to promote crystalline [32,33]. It is reported that ions dissolved in water may influence the viscosity and entropy of solution. Such a phenomenon is caused by the effect of ions on the hydrogen-bond network of water molecules [34]: some ions exhibit weaker interaction with water molecules than those internal ions within water molecules, while some others have stronger interaction with water molecules. That affects the degree of supercooling and leads to different crystallization. Based on the above principle, some researchers tried to accelerate crystallization of PCMs and to reduce its supercooling degree by adding salt into the matrix [35,36]. However, there is very little data regarding the research about $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ -KCl composite salt systems.

Besides, compared with traditional hydrated salt nucleating agents, Al_2O_3 is an

inorganic ceramic material with high thermal conductivity, low thermal expansion coefficient and a low cost. It has stable physical and chemical properties in large temperature range, and its nanoparticles have large specific surface area and high surface activity. Therefore, it is proposed as the nucleating agent for $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$ -KCl composite salt systems.

Herein, $\text{CH}_3\text{COO}_3\text{Na}\cdot \text{H}_2\text{O}$ -KCl composite salt system using Al_2O_3 nanoparticles and CMC were prepared and phase change performance including supercooling degree, phase change temperature, latent heat, and thermal stability were systematically studied. The objective of this work is to explore the more efficient mechanism that optimizes the thermal properties of the hydrated salts for successful commercialization in thermal energy storage systems.

2. Experimental works

2.1. Materials

SAT ($\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$, purity 99%, Tianjin Yongdachemical Co., Ltd) and potassium chloride (KCl, purity 99%, Tianjin Yongdachemical Co., Ltd) were used as purchased. CMC ($M_w < 250,000$) and nanoparticles ($\alpha\text{-Al}_2\text{O}_3$, purity higher than 99.0% and an average size of 100 nm) were purchased from Sigma Aldrich Co..

2.2 Preparation of SAT composites

The $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$ -KCl composites containing Al_2O_3 nanoparticles and CMC were prepared using a simple blending method and ultrasonic dispersion. KCl and Al_2O_3 nanoparticles were added to the SAT based PCM, and this mixture was stirred homogeneously using a magnetic stirrer at 70 °C for 20 min. The CMC was then

added with the above mixture and the stirring was continued for another 10 min. Furthermore, to improve the dispersion stably and minimum aggregation of Al_2O_3 nanoparticles, the preparation processes were performed using an ultrasonic vibrator for 30min. The vibrator temperature during the preparation processes was kept at above the melting point of the SAT as it was sufficient to keep the SAT in liquid state.

2.3. Characterization

The size and crystal morphology of Al_2O_3 nanoparticles were measured by transmission electron microscopy (TEM, JEM-1200EX) and X-ray diffraction (XRD, D/max2000, Rigaku). The morphology of SAT composites matrix was observed by scanning electron microscope (FE-SEM, Su8010, Hitachi, Japan) and the aluminum oxide distribution was confirmed with energy dispersive spectroscopy (Energy Dispersive X-ray Spectrometry). Differential scanning calorimetry (DSC) was conducted at a heating rate of 1°C min^{-1} under a constant stream of argon at atmospheric pressure using a NETZSCH DSC 200 F3. The temperature precision of the DSC is 0.1°C , the calorimetric precision of the DSC is 1%. Amounts of SAT, KCl, Al_2O_3 nanoparticles and CMC were measured on an analytical balance with 0.1 mg precision (Mettler Toledo, type AB104-S, Greifensee, Switzerland).

The values of supercooling and heat storage (release) curves were tested as following procedure: fifty-gram of sample was weighted and placed in a test tube (30 mm in diameter and 100 mm in high), and the thermocouple of temperature recorder (with a maximum error of 0.1°C) was inserted into the center of the test tube, which was then put in the thermostat (with temperature stability of 0.5°C .) at a constant temperature of 70°C for solidification and when the temperature stabilized at 70°C ,

the test tubes were transferred to a 30 °C thermostatic waterbath. Finally, the values of supercooling and heat release curves were recorded by a computer-controlled data acquisition system with an interval data recordation time of 60s. To obtain the heat storage curves, the test tubes with PCMs were put into a 30°C thermostatic waterbath, and when the temperature stabilized at 30°C°, the test tubes were transferred to a 70 °C thermostatic waterbath. Table 1 shows a summary of the estimated uncertainties.

Table 1. Uncertainties of measurements estimated	
property	estimated uncertainty
mass	0.12
temperature	0.12~0.58
latent heat	0.28

3. Results and discussion

To research the concentration of potassium chloride and the phase change temperature of the $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ -KCl composite salt system, experiments were carried out with varying content (2wt.%, 4wt.%, 6wt.%, 8wt.% and 10wt.%) of potassium chloride. Fig. 1(a) displays the freezing curve of $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ with a phase change temperature at about 58°C. It is obvious that the pure $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ exhibits a significant degree of supercooling about 28.3°C. When 4-6 wt.% potassium chloride was added to the sodium acetate solution, few potassium chloride was deposited at the bottom. While 6-8 wt.% potassium chloride was added to the sodium acetate solution, a noticeable amount of potassium chloride was deposited at the bottom. Once the concentration of potassium chloride is greater than 8 wt.%, a substantial

amount of potassium chloride was deposited. Potassium chloride having limited solubility in sodium acetate solution, and with the increase of potassium chloride content, excessive amounts of potassium chloride was deposited at the bottom. This phenomenon may influence the circulation performance of the $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ -KCl composite salt system. Fig. 1(b-f) shows the cooling curves of $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$

with different potassium chloride contents (2wt.%, 4wt.%, 6wt.%, 8wt.%, and 10wt.%), It is evident that the phase change temperatures are found to be 58, 54, 53, 52, 50 and 50°C, respectively.

Fig.1 Cooling curves of $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ -KCl composite salt systems at different KCl content.

The aforementioned results indicate that the potassium chloride causes a gradual decrease in the phase change temperature of the system. The phase change temperature of $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ -KCl was gradually lowered with the increasing of

KCl content.

When the mass fraction of potassium chloride is greater than 8 wt.%, the phase change temperature of the composite salt system reaches about 50°C and remains relatively unchanged with a further increase in the potassium chloride content.

Theoretical computations provides wealthy information about the properties of the clusters, including the structural features and vibrational frequencies. So, in order to explain the effect of additive on the phase change temperature, density functional theory (DFT) calculations was carried out to investigate the change of the microstructures. Given in the high concentration of the SAT solution, the initial calculations were performed on the starting geometries for Na-Na dimers, Na-CH₃COO⁻ ion pairs. The geometries were optimized using the B3LYP/6-311++G (d, p) basis set. As shown in Figure 2(a), Na⁺ ion was hydrated with four H₂O molecules, and the hydration distance was 0.241 nm. Na-Na dimers were formed by sharing two H₂O molecules between Na⁺ ions. The distance of Na-Na in dimers was 0.354 nm, corresponding with the theoretical structure of sodium acetate hydrate. Ion pairs were formed between two CH₃COO⁻ ions and Na⁺ ions in both the ends of the dimers. The mean distance of Na-O was 0.242 nm. Hydrogen bond was formed between the H₂O molecule of ion clusters and H₂O molecule of ion pairs. The average distance of O-O was 0.278 nm, belonging to moderate intensity hydrogen bond. It is obvious that the micro species above have abundant structure type including contact ion pairs, dimers, hydrogen bond and so on, assuring the stable existence of the ion clusters. On the basis of the above calculations, the microstructure after the addition

of KCl was studied. As is shown in Figure 2(b), the ion pairs, dimers, hydrogen bond were still exist in the salt system. The distance of the Na-Na in the dimers was 0.356 nm, increasing 0.002 nm compared with the original one. The average distance of Na-O in ion pairs was 0.243 nm, corresponding with the original distance. In the salt system, K^+ and Cl^- ions interact with each other and form ion pairs with the distance of 0.288 nm. One H_2O molecule was shared by K^+ and Na^+ ions, forming sharing ion pairs with the distance of 0.477 nm. K^+ interacts with the O atom of CH_3COO^- ions, forming contact ion pairs, and the distance was 0.272 nm. According to the above analysis, it can be concluded that the addition of KCl didn't make a lot of changes on the original microstructures. The change of the phase change temperature was effected by the new structures formed between K^+ ions and the original ion clusters,

including sharing ion pairs and contact ion pairs. In addition, Cl^- ions didn't interact with other solution species, indicating the main factor influencing the phase change temperature was the K^+ positive ions of the additive. This conclusion can provide significant theoretical support and guidance for selecting efficient additives of phase change materials.

Fig 2. The possible microstructure of (a) $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ solution, (b) $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ –KCl solution.

In addition, the supercooling degree of the $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ with different potassium chloride contents (2wt.%, 4wt.%, 6wt.%, 8wt.%, and 10wt.%) are 9.2, 3.5, 3.1, 7.1 and 9.0 °C, respectively. In consideration of phase change temperatures, supercooling degree and excessive amounts of potassium chloride precipitation in the bottom, the maximum concentration of potassium chloride was 8% in $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ -KCl composite salt system.

Fig. 3 depicts the DSC melting curve of $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ –8%KCl composites. Its phase change temperature (onset temperature) is observed to be 50.41°C and the latent heat is 236.17 J/g. However, supercooling affects this material to be widely used in application. Therefore, investigation of the supercooling temperature of $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ –8%KCl composite system is valuable for the development of enhanced phase change materials.

Fig.3 DSC melting curve of $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ –8% KCl composite salt system.

Fig. 4 shows transmission electron microscopy (TEM) photographs of Al_2O_3 nanoparticles as the nucleating agent. The photographs illustrate that the nanoparticles

are irregularly shaped, aggregated, and approximately 100 nm in diameter. The crystalline phase of Al_2O_3 nanoparticles was determined using X-ray diffraction (XRD). All peaks were measured using XRD and compared with peaks from data retrieved from the joint committee on powder diffraction standards [37], as shown in Fig. 5, which correctly confirms that the material used in this study was α - Al_2O_3 .

Fig.4 TEM image of Al_2O_3 nanoparticles.

Fig.5XRD pattern of Al_2O_3 nanoparticles.

Al_2O_3 with different mass fractions (0, 0.5 %, 1.0 %, 1.5 %, 2.0 %, 2.5 % and 3.0 %) were selected as the nucleating agent while the content of CMC was fixed at 4 wt.%. The relationship between the Al_2O_3 concentration and the supercooling degree of the composite PCM is shown in Fig. 6. The measurements were repeated for three times in order to ascertain the correct values. For $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ with 1.5 wt.% Al_2O_3 the supercooling degree (average) is reduced to 8.7°C which affects the application widely. Therefore, as a nuclear agent, Al_2O_3 nanoparticles are not suitable to eliminate the supercooling of SAT. The supercooling degree (average) of the $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ –8% KCl composite system after the addition (by mass) of 0, 0.5 %, 1.0 %, 2.0 %, 2.5 % and 3.0 % of Al_2O_3 were 7.3, 3.5, 0.1, 2.3, 4.6, 5.3, and 5.9 °C, respectively. The results show $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ – 8wt.% KCl composite salt system with 1 wt.% Al_2O_3

nanoparticles and 4 wt.% CMC, in which almost no supercooling phenomenon occurs.

Therefore, Al_2O_3 nanoparticles can be an effective nucleating agent, and has a better performance to reduce supercooling of $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O} - 8\text{wt.}\% \text{ KCl}$ composites salt system.

Fig. 6 Influence of the concentration of Al_2O_3 nanoparticles on the supercooling degree of composite PCM.

The mechanism of nucleation is schematically demonstrated in Fig. 7. The surficial Al and O atoms respectively adsorb OH^- and H^+ to form M-OH during the dispersion of alumina nanoparticles in the aqueous solution. Further adsorption of H^+ leads to positively charged M-OH_2^+ on the particle surface in an acidic solution. For the case of an alkaline solution, the M-OH adsorbs OH^- resulting in negatively charged particle surfaces. The isoelectric point of alumina occurred at pH= 7-9, which is lower than sodium acetate solution (pH=10.3-10.4 at 70°C); thus, alumina surfaces are

negatively charged possessing hydroxyl groups. Said hydroxyls strongly interact with Na^+ , CH_3COO^- and H_2O molecules in the solution leading to an intensive adherence between the ions and the crystals. As a result of the weakened diffusion capacity of particles in the sodium acetate solution, the contact probability of particle nucleation effectively increases.

Fig.7 Schematic diagram of the nucleation mechanism.

The PCM composites are required to maintain thermal stability during a great number of melting and freezing cycles. Therefore, a thermal cycling test was employed to deduce thermal reliability of PCM composites from the viewpoint of the supercooling, segregation and latent heat changes of thermal cycling test. In these experiments, the test tubes containing $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ –8% KCl with 1wt.% Al_2O_3 nanoparticles and 4wt.% CMC were placed into the temperature controlled water bath. The selected heating and cooling temperatures were 70.0°C and 30°C, respectively.

Figs. 8 (a) and (b) display the cooling and heating curves of $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ –8% KCl with 1wt.% Al_2O_3 nanoparticles and 4wt.% CMC. As seen in these figures, crystallizing ratios is slowly during the cooling process and the heat release time was sustained between 40 and 50 min, while the degree of supercooling was between 0°C and 2°C, indicative of the composite PCMs releasing relatively more latent heat.

The heating process of composite PCMs can be categorized into three states: (1) not-melted, (2) partially melted, and (3) fully-melted. When the heating temperatures were under 54.0°C, no further changes were observed during the heating

process, which signifies that the SAT is in the not-melted state. When the heating temperatures were at 54.0°C and 57.0°C, composite PCMs dissociated itself into the solid phase and the liquid phase, which indicate the composite PCMs are in the partially-melted state and the melting ratios were minimal. When the heating temperatures were above 57.0°C, the composite PCMs are in the fully-melted and the heating ratios were fast.

Fig.8 The cooling and heating curves of $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ -8%KCl + 1wt.% Al_2O_3 nanoparticles and 4wt.% CMC with different cycle number.

Fig. 9(a) and (c) display the SEM image of the cross section of the $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ -8%KCl composites containing Al_2O_3 nanoparticles and CMC after coating with gold. Fig. 9(b) and (d) display the corresponding EDS maps of aluminum in SAT composites matrix. The EDS aluminum map shows that aluminum oxide is uniformly dispersed in SAT composites matrix after the fifth thermal cycle and there is

no remarkable segregation and agglomeration of aluminum in the mapping area, which is conducive to thermal performance.

Fig.9 SEM image and the corresponding EDS maps of aluminum SAT composite matrix; (a,b), first melting-freezing; (c,d), after 50 melting-freezing cycles

Figs. 10 (a) and (b) display the latent heat changes of the $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ –8% KCl with 1wt.% Al_2O_3 nanoparticles and 4wt.% CMC during the thermal cycling test that involves the repeated heating and cooling processes associated with DSC. After the fifth thermal cycle, the latent heat remains constant at about 232.29 J/g. The maximum deviation of latent heat for $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ –8% KCl with 1wt.% Al_2O_3 nanoparticles and 4wt.% CMC

before and after the fifty-run-recycling test was just 3.6%.

Fig.10(a) DSC melting curves of $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ –8% KCl with 1wt.% Al_2O_3 nanoparticles and 4wt.% CMC (first melting-freezing) and (b) of $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ –8% KCl with 1wt.% Al_2O_3 nanoparticles and 4wt.% CMC (after 50 melting-freezing cycles).

4. Conclusions

Herein, The $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ -KCl composites containing Al_2O_3 nanoparticles and CMC were prepared using a simple blending method and ultrasonic dispersion. The phase change performance including supercooling degree, phase change

temperature, latent heat, and thermal stability were systematically studied. The tentative conclusions can be summarized as follows:

- a). The results verify that the phase change temperature of $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$ -KCl was gradually lowered with the increasing of KCl content. The temperature range was between 50°C and 58°C . According to phase change temperatures, supercooling degree and excessive amounts of potassium chloride precipitation in the bottom, 8% was the maximum concentration of potassium chloride in $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$ -KCl composite salt system.
- b). For composite $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$ -8% KCl with 1 wt.% Al_2O_3 nanoparticles and 4 wt.% CMC, could efficiently solve the problems of supercooling degree and phase segregation; meanwhile, they had small influence on calorific value.
- c). After 50 melting-freezing cycles, aluminum oxide is uniformly dispersed in SAT composite matrix, and the latent heat was calculated to be 232.29 J/g. The maximum deviation of latent heat of the composite $\text{CH}_3\text{COONa}\cdot 3\text{H}_2\text{O}$ -8% KCl with 1 wt. % Al_2O_3 nanoparticles and 4 wt. % CMC before and after the fifty-run-recycling test was only 3.6%. Characterization results indicate that this material possesses excellent and stable thermal storage performance suitable for its application for thermal storage systems.

Acknowledgments

Financial support from the National Science Foundation for Qaidam Saline Lake Chemical Engineering Science of China (No. U1407105) and Natural Science

Foundation of Qinghai province of China (No.2015-ZJ-930Q)are gratefully acknowledged.We also acknowledge computing resources and time on the Supercomputing Center of Cold and Arid Region Environmentand Engineering Research Institute of CAS.

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