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The experimental exploration of sodium chloride solution on thermal behavior of phase change materials

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ABSTRACT

Phase change materials (PCMs) are the effective substances for thermal energy storage. Unfortunately, various problems such as high supercooling degree, low crystal growth rate and poor thermal conductivity greatly hinder the large-scale utilization of PCMs. The present study focuses on improving the crystallization and decreasing supercooling degree by adding various proportions of NaCl/NaCl solutions into the n-octadecane-based PCMs for thermal energy storage. The experimental results show that 20 wt% NaCl solutions have the greatest effect on the thermal performance of PCMs. The supercooling degree has been minimized up to 6 °C with the addition of NaCl. It can not only promote crystallization under 1 wt% addition rate, but also enhance latent heat storage performance. Such observations have been verified by the kinetics of crystallization. The researches on supercooling could advance the application of PCMs on solar energy.

1. Introduction

Solar energy, as an inexhaustible and green natural resource, has attracted researches' attention for its promising future in industry. However, the applications of such energy are limited due to time and space constraints. Accordingly, solar energy is usually stored in the form of electric power and thermal energy [1–3]. Nowadays, storing solar energy in the form of latent heat by using phase change materials (PCMs) is found to be one of the latest and the most efficient energy storage technologies [4]. Compared to other energy storage methods, one striking feature of PCMs is the high energy storage density. One of the most common phase change process is the melting of ice. When melting at 0 °C, 1 g ice absorbs 333 J heat, which is approximately equal to the total amount of energy released when cooling 1 g water from 80 °C to 0 °C (333 J). Thus, the phase change process either from ice to water or from water to ice could be employed as an energy storage approach. Besides H_2O, the materials having different phase change temperatures are selected by researchers depending on the temperature window within which the PCMs are applied.

Based on the current data, there are still many unresolved problems existing for the uptake of PCMs in solar energy applications, namely high supercooling degree [5,6], low crystal growth rates [7,8], and poor thermal conductivity [9,10]. The supercooling phenomenon of PCMs always restrains the process of storing/releasing energy. Some researchers employed hot pipes or added high thermal-conductive materials such as metal, carbon to reduced the gaps of supercooling [11,12]. Although such integrations can accelerate the thermal conduction process, the latent heat was found to be decreasing with the increase of the fillers' weight percentage.

Sodium chloride (NaCl) could be invoked as the sediment to promote nucleation [13]. 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 [14]: 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 the 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 (salting out method) [15,16].

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Table 1
Recipes for sample preparations (percent in weight).

Sample	n-Octade-cane (g)	NaCl (g)	1 wt% NaCl solution (g)	5 wt% NaCl solution (g)	20 wt% NaCl solution (g)	Addition rate (wt%)
1	10					
2	9.8813	0.1049				1
3	9.5003	0.5061				5
4	9.9082		0.1014			1
5	9.5052		0.5046			5
6	9.0034		1.0072			10
7	9.5020			0.5053		5
8	9.9118				0.1053	1
9	9.5198				0.5067	5
10	9.0018				1.0095	10

In the present research, influences of NaCl and its solution on thermal properties' enhancement of the PCMs are investigated. The relevant crystallization mechanisms of the PCMs mixed with NaCl or its solution are also studied.

2. Materials and experimental

Sodium chloride (NaCl, Tianjin Guangfu Technology Development Co., Ltd.) was dissolved in distilled water to prepare the salt solutions with specific concentrations as shown in Table 1. And a certain amount of n-octadecane (99 wt%, Alfa) was placed into the beakers. NaCl/NaCl solution was then dispersed into n-octadecane according the designed weight rates listed in Table 1 with the assistance of ultrasonic wave.

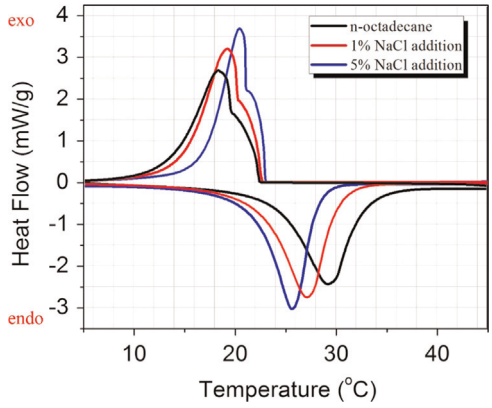

Fig. 1. DSC curves of PCMs with various addition rates of NaCl.

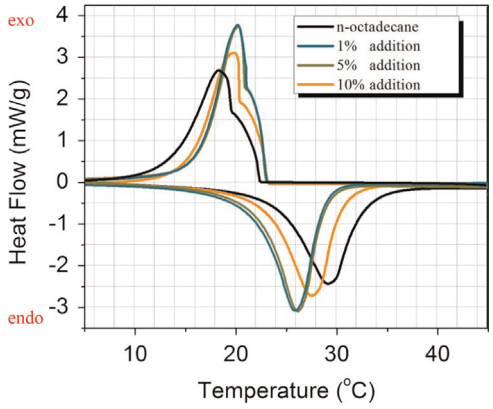

Fig.3. DSC curves of PCMs with various addition rates of 1% NaCl solution.

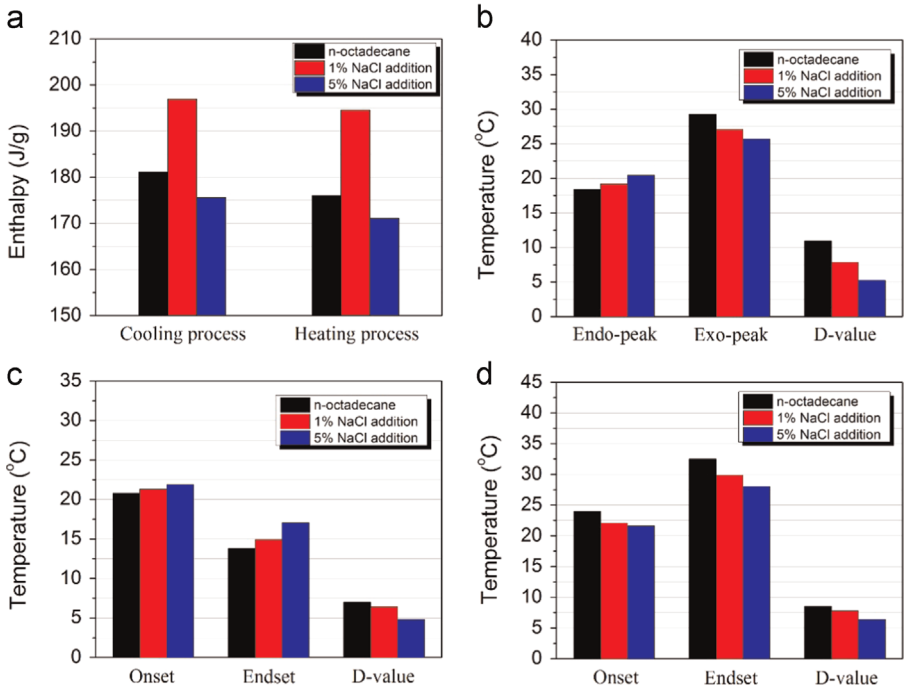

Fig. 2. DSC data analysis of PCMs without and with 1% and 5% NaCl, respectively: (a) latent heat; (b) peak temperature; (c) phase change temperature during cooling process; (d) phase change temperature during heating process.