



# Sodium acetate trihydrate-based composite phase change material with enhanced thermal performance for energy storage

Zhuang Zhang<sup>a,\*</sup>, Zhenya Duan<sup>a,\*</sup>, Dongming Chen<sup>a</sup>, Yushen Xie<sup>b</sup>, Xing Cao<sup>a,\*</sup>, Jingtao Wang<sup>c</sup>

<sup>a</sup> College of Electromechanical Engineering, Qingdao University of Science and Technology, Qingdao 266061, ^

<sup>b</sup> Qingdao Tianhuichen Technology Co., Ltd, Qingdao 266045, China

<sup>c</sup> School of Chemical Engineering and Technology, Tianjin University, Tianjin 300072, China

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## ABSTRACT

Sodium acetate trihydrate ( $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ , SAT), as the medium-low temperature phase change material (PCM), has been broadly utilized in thermal energy storage system. The specific objective of this study was to develop a new SAT-based composite PCM (CPCM) in order to restrain the supercooling and phase segregation of pure SAT. In this dissertation, SAT-CN/Nano-Cu was synthesized by adding carboxymethyl cellulose (CMC), sodium chloride (NaCl) and Nano-copper (Nano-Cu). The experimental results manifest that CMC is resultful to constrain phase separation of pure SAT. Supercooling degree of pure SAT is reduced from  $30^\circ\text{C}$  to less than  $5^\circ\text{C}$  by the addition of varying NaCl content. The Nano-Cu was furnished to further prevent the supercooling phenomenon of CPCM as well as intensify the heat transfer characteristics of pure SAT. Thermal properties containing thermal conductivity, latent heat and specific heat capacity were systematically analyzed using DSC and thermal properties analyzer. The analysis results demonstrate that a satisfactory thermal conductivity, high latent heat and inclusive of an appropriate specific heat capacity are achieved by the SAT-CN/Nano-Cu. In short, this work reported optimum CPCM consisted of SAT, 3 wt% CMC, 4 wt% NaCl and 0.8 wt% Nano-Cu that possesses superior phase change performance. Additionally, admirable thermal stability is retained by the CPCM.

## 1. Introduction

Phase change material (PCM), which is regard as the effective substance for thermal energy storage, has been extensively applied in the field of renewable energy, such as solar energy and industrial waste heat. The development and utilization of PCMs with desirable performance play a critical role in solving the disproportion between energy supply and demand [1,2]. At present, PCMs that have drawn copious attention are mainly divided into three categories: organic, inorganic and eutectic compounds [3,4]. Compared with the other two, the inorganic PCMs, especially salt hydrates show promising properties which include higher latent heat of fusion per unit volume, relatively higher thermal conductivity, and lower cost [5]. The salt hydrates which are belonged to the medium-low temperature PCMs generally undergo phase transitions at a temperature range between  $50$  and  $100^\circ\text{C}$  [6]. Extensive research has shown that the medium-low temperature PCMs have emerged as powerful options for domestic hot water usage and buildings energy conservation [7,8].

Sodium acetate trihydrate ( $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$ , SAT) is one of the

most widely used salt hydrate PCMs with a melting point of  $58.0^\circ\text{C}$  and a relatively high latent heat of fusion ( $264.0 \text{ J} \cdot \text{g}^{-1}$ ) [9]. However, the major drawbacks of SAT still remain: (1) The phase-segregate results in low thermal cycling stability; (2) It has a natural tendency to supercool during the solidification process. SAT, as an incongruent salt hydrate, suffers from severe phase separation, especially during repeated melting and freezing cycles. This will bring about the reduction of total heat storage capacity. Phase separation can be resolved by adding additional water or thickening agents into SAT. Substantial experiments performed by Furbo et al. [10] noted that undissolved salt could be completely dissolved at the melting point by adding extra water into salt hydrates, and thereby the phase segregation of salt hydrates is circumvented. However, this solution will decrease the melting temperature of salt hydrates and impair the performance of storage [11]. Under this circumstance, thickening agents are utilized to enhance the performance of salt hydrates. Ryu et al. [12] used a super absorbent polymer and carboxymethyl cellulose (CMC) as thickeners. The result indicated that the former could effectively inhibit phase separation of the high hydrate inorganic salt while CMC was effective for the low hydrate inorganic

\* Corresponding author

E-mail addresses: [qust\\_zyduan@163.com](mailto:qust_zyduan@163.com) (Z. Duan), [caoxing@qust.edu.cn](mailto:caoxing@qust.edu.cn) (X. Cao).

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