

Thermal Behavior of Form-stable Paraffin/expanded Graphite Composites [★]

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Abstract

A common phase change material (PCM) utilized for thermal energy storage is paraffin wax (PW). However, the applicability and thermal energy storage effectiveness of PW are constrained by its leakage and poor thermal conductivity. By using the melting-blending technique, composites of PW and expanded graphite (EG) were created, and investigations into the morphology and thermal behavior of PW/EG composites were conducted. In this study, it was found that PW was used as a coating to cover the EG structure and no leakage was detected. The final PW/EG composites had the latent heat of fusion around 122 J/g. Additionally, the embedded PW in EG had a higher degree of crystalline growth. We propose that PW/EG composites have significant potential in thermodynamics-related fields.

Keywords: paraffin wax; expanded graphite; phase change material; crystallization

1 Introduction

Phase change materials (PCMs) are known for their thermal energy storage characteristics [1,2], and it has been employed in numerous fields, including textiles [3-8], architecture structures [9-12], photovoltaic power collection [13-16], electrical devices [17,18], food preservation [19,20] and many

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others. Paraffin wax (PW) has been studied as one of the organic PCMs whose phase change behavior and thermal energy storage is dependent on the number of carbon atoms (n), only when n is greater than 17 can the PW be found in its solid phase [2].

PW has a melting point that ranges from 30 °C to 80 °C and rises as n increases. In addition, PW has an enthalpy that varies between 150 J/g and 280 J/g due to C-H and C-C bonds. If the PW is not altered, the solid-liquid behavior it naturally exhibits may cause leakage. Furthermore, the effectiveness of thermal energy storage is constrained by PW's poor thermal conductivity (around 0.43 W K⁻¹ m⁻¹) [21].

Expanded graphite (EG) is a substitute for storing PW since it prevents leaking and improves thermal conductivity. [22, 23]. EG is a layered carbon-based material with interlayer spacing of approximately 0.8 nm [24]. It has been established that EG's interlayer space can store PCMs. [23, 25-29]. Zhang Dong et al. [30] have prepared polyethylene glycol (PEG)/EG composites and introduced PEG/EG composites into asphalt binders for construction. M. Kenisarin et al. [31] incorporated PW into two different EGs and it was found that the optimal weight ratio of EG in the PW/EG composite was 6 wt%, and the PW/EG composite achieved a maximum thermal conductivity of 1.26 W K⁻¹ m⁻¹. However, it noticed that the best PW/EG composite is determined by the morphology of the PW/EG composite and that there may be too much PW in the prepared PW/EG composite. According to this perspective, leakage results for PW/EG composites are inconclusive, which might prevent them from being used to other fields.

In this work, the PW/EG composites were prepared by melt mixing method. Particularly, An excess of PW was added, with a PW to EG weight ratio of 10:1. The PW/EG composites were obtained after the removal of excess PW from the PW/EG mixture. The thermal behavior and leakage of the PW/EG composites were studied.

2 Experimental

2.1 Materials

PW was purchased from Sigma Aldrich and EG particles with density of 0.04 g/cm³ were provided by company Vecomas (SORBETIN®, Czech Republic) [24].

2.2 Preparation of PW/EG composites

The weights of the used PW powder and the used EG powder were recorded and marked as m_{PW} and m_{EG} before the PW/EG composite was made.

In order to create PW/EG composites, the PW powders were first placed in a glass breaker to break them down, and then they were heated to a temperature of 80 °C in an oven to melt the PW until it was uniformly molten. After that, EG particles were added to the molten PW in a weight ratio of 10:1 (PW:EG), and the PW/EG combination was kept in an oven at 80 °C for 4 hours. The PW/EG mixture was then removed and allowed to cool to room temperature in order to create solid PW/EG composites. It has been observed that there may be an excess of PW in the EG structure.

Therefore, the very absorbent paper was employed to remove too much EG, and the following