A New Material for Microencapsulation of Phase Change Materials for Thermal Energy Storage

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Abstract
Phase change materials (PCMs) serve as energy storage materials that can effectively reduce the heating and cooling load. To overcome the issue of leakage in practical applications, there has been a growing significance in conducting research on microencapsulation and composite production. In this study, humic acid, which has an organic structure, was used for the microencapsulation of PCMs. To evaluate the morphological, thermal, and chemical properties of the synthesized composite materials, Differential Scanning Calorimetry (DSC) and Fourier Transform Infrared spectroscopy (FTIR) were utilized. The thermal resistance of the composites was tested at a temperature of 70 °C. DSC analysis revealed that the paraffin composite had a melting point of 38.79 °C and a latent heat storage capacity of 52.56 J/g. Based on these comprehensive analyses, it can be concluded that the microcapsules obtained demonstrate remarkable potential as energy storage materials.

Keywords: Phase change materials, Thermal energy storage, Paraffine, Humic Acid, microcapsule

1. Introduction

Thermal energy storage can be achieved by modifying the internal energy of a material through the storage of sensible heat, latent heat, thermochemical reactions, or a combination of these mechanisms.

In sensible heat storage (SHS), thermal energy is stored by raising the temperature of a solid or liquid medium. This system utilizes the heat capacity and temperature variation of the material during the charging and discharging process. The amount of stored heat depends on the specific heat of the medium, the temperature change, and the quantity of the storage material involved (Baylin, 1979).

Latent heat storage (LHS), on the other hand, relies on the absorption or release of heat during a phase transition of the storage material, such as from solid to liquid or liquid to gas, and vice versa.

Phase change materials (PCMs) serve as latent heat storage materials. They facilitate the transfer of thermal energy during the phase transition between solid and liquid states. This unique characteristic sets them apart from conventional storage materials. Initially, solid-liquid PCMs behave similarly to traditional storage materials, where their temperature rises as heat is absorbed (Ming et al, 2016). However, unlike conventional materials, PCMs possess the remarkable property of absorbing and releasing heat at a nearly constant temperature. This quality allows them to store a significantly higher amount of heat per unit volume, ranging from 5 to 14 times more compared to materials like water, masonry, or rock (Sharma et al, 2009).

There is a wide variety of PCMs available with specific heat of fusion within desired temperature ranges. However, for PCMs to be suitable as latent heat storage materials, they must exhibit desirable thermodynamic, kinetic, and chemical properties. Additionally, factors such as economic viability and easy availability need to be considered (Tay et al, 2009).

Microencapsulation plays a critical role in industries where protection and controlled release of active ingredients are vital. By encapsulating substances, it becomes possible to shield them from external factors like light, moisture, and temperature, ensuring their stability and enhancing their performance. Both humic acid and PCMs offer numerous benefits individually, and their combination through microencapsulation opens new possibilities (Farhan et al, 2015).

In this study paraffin as used an PCM and microencapsulated with humic acid. The prepared microcapsules characterized using thermal and chemical analyses.

2.MATERIALS AND METHOD

In this study paraffin, with a melting temperature of 40 °C, was used as the core material, while humic acid served as the shell material. The process began by adding ammonium sulfate, an emulsifier, and humic acid to water, which was then heated to 70 °C. The mixture was stirred at 1000 rpm for 15 minutes. Following that, the PCM was introduced to the solution and mixed for an additional 15 minutes. HCl was added to the solution to achieve a pH of approximately 4, and then formaldehyde was added. The mixture was further stirred for 3 hours. The micro-PCM preparation involved utilizing a coacervation microencapsulation process, as illustrated in Figure 1.

After completing the process, the composites were washed with pure water and subsequently filtered to obtain the microcapsules.

3. RESULTS AND DISCUSSION

Leakage test was conducted to evaluate whether there was any leakage of the PCM subsequent to the encapsulation process. The test was performed within a temperature range of 60-70 °C. Within the first 2 minutes, leakage was observed in the PCM sample, whereas no leakage was detected in the composite sample. By the 5th minute, the PCM had completely melted, yet there was still no evidence of leakage from the composite, as shown in Figure 2. Even after 1 hour of testing, no changes and leakage were observed in the composite.

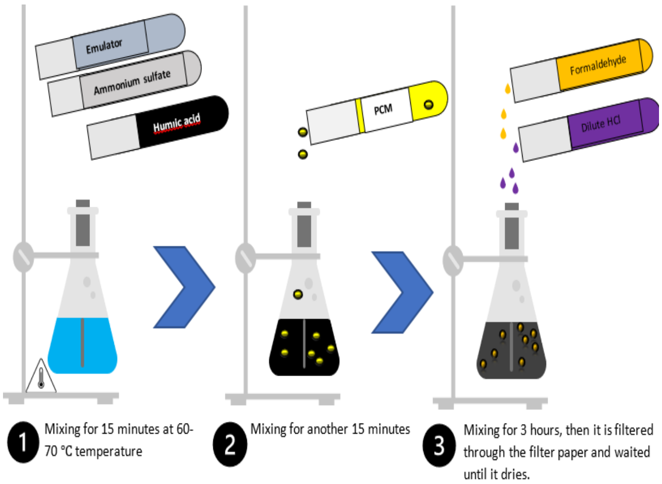

Figure 1. scheme of the microcapsulation process

Time	0 min	5 min	30 min	60 min
Paraffin				
HT1				

Figure 2. Leakage test

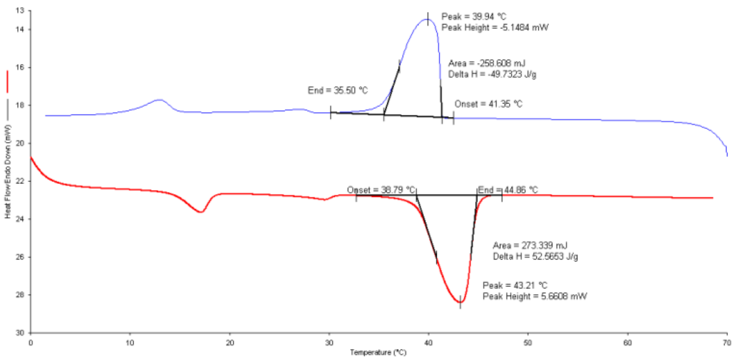

Figure 3. DSCanalyses of the microcapsules

Differential scanning calorimetry (DSC) is widely recognized as the primary thermal technique utilized in analytical studies. It offers a rapid and user-friendly approach to obtain comprehensive information about a wide range of materials, regardless of their intended application. DSC has found extensive application in diverse fields, including polymers, plastics, foods, pharmaceuticals, glasses, ceramics, proteins, and life science materials. Essentially, DSC can be employed to measure the fundamental properties of almost any material, providing valuable insights to analysts.

Figure 3 illustrates both the melting and cooling phases of the material. The melting phase initiated at a temperature of 38.79°C, with an enthalpy value of 52.56 J/g. In the cooling phase, the temperature began at 41.35°C, and the corresponding enthalpy was -49.35 J/g.

The FTIR spectra of the core material, shell material, and microPCMs are depicted in Figure 4,5 and Figure 6. Notably, each characteristic peak associated with the core material remains preserved even after microencapsulation. These findings provide confirmation that the preparation of paraffin within HA has been successfully

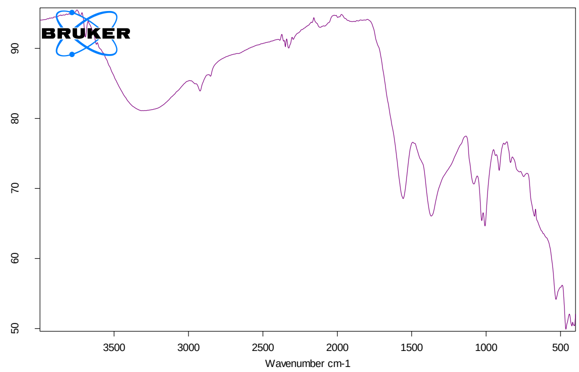

Figure 4. FTIR of the humic acid

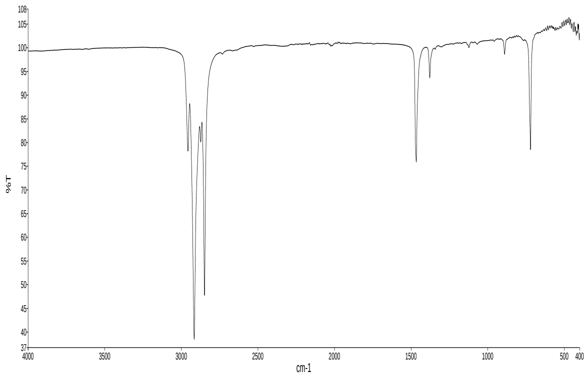

Figure 5. FTIR of the PCM

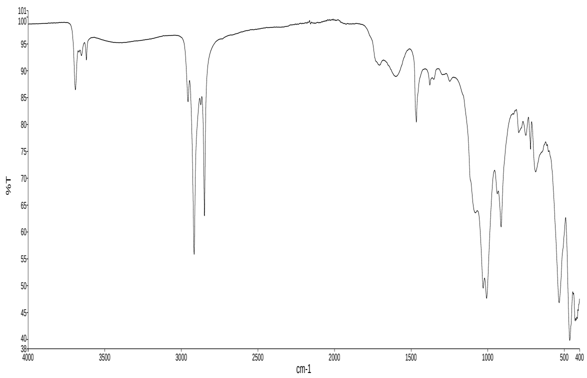

Figure 6. FTIR of the microcapsules

4. CONCLUSIONS

The main objective of this study was to develop leakage-free and thermally stable microPCMs for efficient thermal energy storage applications. Paraffin was selected as the core material and microencapsulated with humic acid using the coacervation technique. The FTIR analysis confirmed the preservation of the core material's chemical structure even after encapsulation with humic acid shells.

Moreover, the paraffin microcapsules with humic acid exhibited a commendable thermal energy storage capacity, and the resulting microcapsules demonstrated robustness in preventing core material leakage. To further enhance the strength of the composite, the study suggests the utilization of paraffin microencapsulated with humic acid and formaldehyde.

This research highlights the successful development of reliable microPCMs with improved thermal properties, paving the way for their potential implementation in various thermal energy storage applications.

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