

Preparation and thermal properties of ethylene glycole distearate as a novel phase change material for energy storage

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Abstract

The latent heat thermal energy storage (LHTES) capacity of phase change materials (PCMs) increases with molecular weight and secondary interactions as their efficiency depends on the energy storage capacity per unit mass during its melting and freezing. In this study, ethylene glycole distearate (EGDS) as a novel PCM having high energy storage capacity (215.80 J/g) and suitable phase change temperature for LHTES was synthesized by esterification of stearic acid with ethylene glycol. The esterification reaction was proven by Fourier Transform Infrared (FT-IR) Spectroscopy. Thermal stability of the novel PCM was investigated by thermal cycling (1000 melting/freezing cycles). Latent heats of melting and freezing of EGDS were found 215.43 J/g–216.45 J/g by Differential Scanning Calorimetry (DSC) method, respectively after thermal cycling as melting and freezing temperatures were 65.35 and 65.83 °C, respectively. Thermal gravimetric analysis (TGA) was used to determine endurance of EGDS.

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1. Introduction

The temperature of the medium remains more or less constant during the phase transition in common PCMs. For application of a PCM, information about its latent heat of phase transition as well as densities and specific heats is necessary [1]. Because high latent heat is required to provide a higher thermal storage per unit weight as high density is desirable to allow a smaller size of storage container. In addition, higher specific heat is preferred to provide for better sensible heat storage.

Solid–liquid PCMs including water, salt hydrates, paraffins, certain hydrocarbons and metal alloys are often used for LHTES applications. Salt hydrates used for thermal storage in space heating and cooling applications have low material costs, but high packaging costs. A more economic way may be possible with medium priced, organic materials with high latent heat suitable for low cost packaging [2]. For this reason, polymer/fatty acid blends were investigated by calorimetric, spectroscopic and microscopy methods [3,4]. Sari prepared eutectic mixtures of fatty acids for decreasing fusion temperature and

increasing LHTES efficiency [5]. Alkan sulfonated paraffin samples slightly to increase the energy storage efficiency without changing thermophysical properties [6].

Some materials undergoing solid/liquid transitions have been considered as alternative PCMs. Nicolice et al. investigated new materials for solar thermal storage-solid/liquid transitions in fatty acids esters [7]. Babich et al. investigated hydrocarbons, ethers, alcohols, ketones, and halogenated species and polymers as novel energy storage materials using DSC thermal analysis [8]. Thermophysical properties of some paraffins applicable to thermal energy storage determined by Hadjieva et al. [9]. Also, latent heat characteristics of fatty acid derivatives pursuant phase change material applications were studied by Suppes et al. [10]. Feldman et al. proposed some fatty acids and their mixtures as PCMs for thermal energy storage [11]. Besides, butanediol di-stearate was prepared and characterized as novel Solid–liquid PCM by Li and Ding [12].

EGDS is a premium quality fatty acid ester, having applications in shampoos, cosmetics, creams and ointments. EGDS is used as a pearling as well as an opacifying and emulsifying agent. EGDS imparts an attractive appearance to the product in which it is used. However, it has not been considered as a PCM for LHTES applications so far. Therefore, this work

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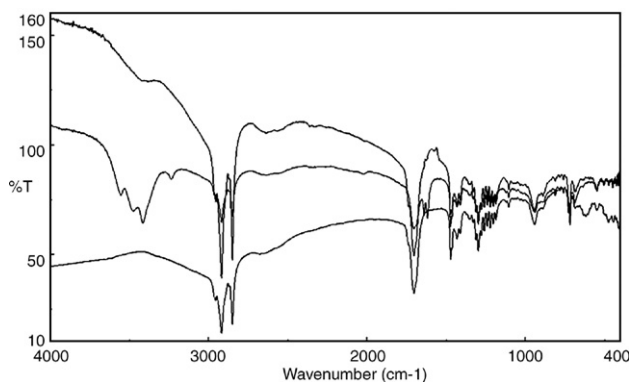


Fig. 1. FTIR spectra of stearic acid in the middle, EGDS (upper curve) before thermal cycling, and EGDS after thermal cycling (lower curve) in KBr.

focuses on preparing EGDS as a novel PCM by direct esterification of stearic acid and ethylene glycole. The esterification reaction was characterized by FT-IR spectroscopy method. Thermal properties of the EGDS as PCM were determined by using TGA analysis DSC thermal analysis technique.

2. Experimental

2.1. Materials

Stearic acid (SA; $C_{17}H_{35}COOH$) (Aldrich), ethylene glycole, hydrochloric acid were used without further purification.

2.2. Synthesis of EGDS

Stearic acid was esterified by ethylene glycole according to the Fischer esterification reaction in which esters could be

prepared by the reversible, acid-catalyzed, combination of a carboxylic acid with an alcohol. The acid (hydrochloric acid) used in this experiment have a strong dehydrating capability, also assisting in pulling the reaction to the right. This reaction was not limited by any steric hindrance in the carboxylic acid or the alcohol because of the linear structure of stearic acid. Based on FT-IR results the reaction was completed. Density of EGDS was determined by using a pycnometer.

2.3. DSC analysis

Thermal properties of the SA and EGDS such as melting and crystallization points, and latent heats were measured by DSC technique (SETARAM DSC 131). Indium was used as a reference for temperature calibration. The analyses were performed between the temperatures of 20 °C and 100 °C at 5 °C/min heating rate under a constant stream of argon at flow rate of 60 mL/min. The temperature accuracy was ± 0.01 °C, and heat flow repeatability was 0.2 μ W. A 5 to 10 mg of sample was sealed in an aluminum pan. The melting and crystallization points were taken as onset temperatures. The latent heat of PCM was determined by numerical integration of the area of the peak of thermal transition. All DSC measurements are repeated three times for each sample.

2.4. Thermal cycling

The EGDS samples were subjected to melting/freezing cycling process by a thermal cycler (Biorad model). The samples were heated from 20 °C to 100 °C and cooled back to 20 °C by 1000 times. The stability was checked according to structural and thermal consistency. For this reason, a Jasco 430 model FTIR spectrophotometer and SETARAM DSC 131 instrument were used.

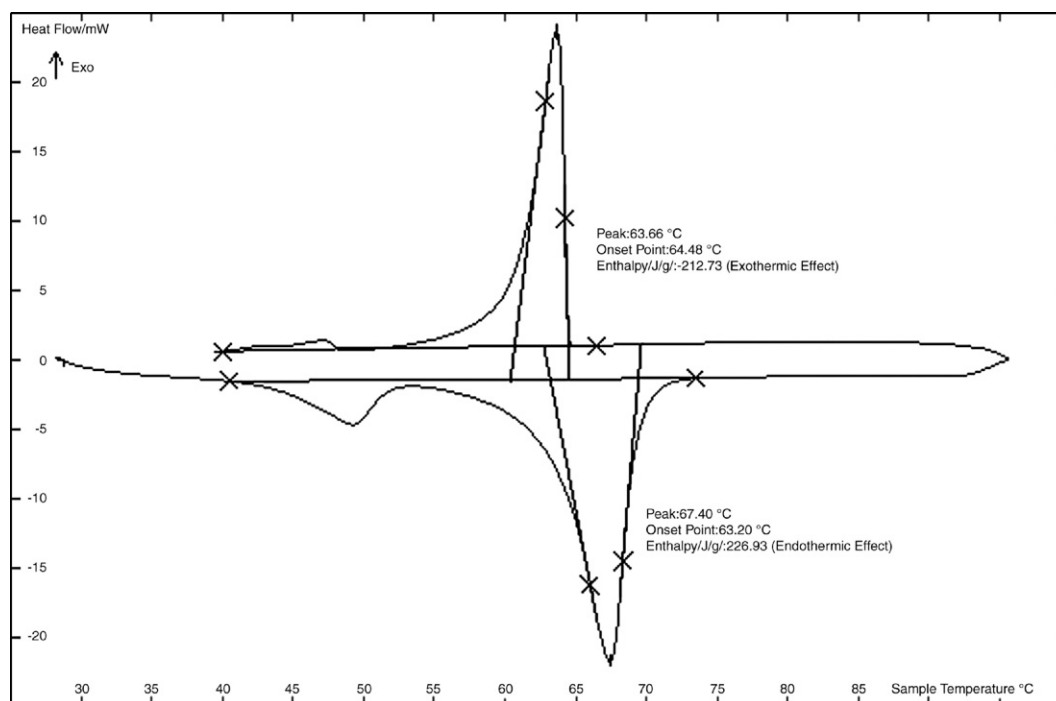


Fig. 2. DSC thermograms for EGDS before thermal cycling.

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