Iranian Polymer Journal (2018) 27:495–505
https://doi.org/10.1007/s13726-018-0626-5

ORIGINAL RESEARCH

Shape-stable phenolic/polyethylene glycol phase change material: kinetics study and improvements in thermal properties of nanocomposites

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Received: 5 January 2018 / Accepted: 23 April 2018 / Published online: 6 June 2018

Abstract

Storage, transformation, and absorption of energy play effective roles in application and performance of heat and thermal energy beneficiary. Phase change materials (PCMs) are substances with high heat of fusion which can be utilized to design thermal protective and thermal energy storage systems. However, PCM leakage in phase changing process is a well-known disadvantage of the PCM containing systems. One of the approaches to avoid PCM leakage is to prepare shape-stabilized PCM in polymeric composites. In this study, polyethylene glycol (PEG), as a PCM, was shape-stabilized with low leakage in the novolac colloidal structure with no solvent and through a sol–gel in situ polymerization process. Supercooling is a negative associate phenomenon in these systems, which may occur due to the low rate of nucleation and nucleation growth. Nanoclay was used to avoid supercooling of PEG. PEG supercooling significantly decreased when 2.5 wt% of nanoclay was incorporated. This is due to the role of nanoclay particles as the crystal nuclei. The sol–gel polymerization kinetics of novolac resin in the presence of nanoclay and molten PEG was also studied using the Kamal–Sourour model. Results showed that 85 wt% of PEG was preserved with leakage less than 3.5 wt% by shape stabilization encapsulated with colloidal structure of the phenolic resin. Nanoclay improved the thermal properties of the system and reduced the supercooling about 20%. Moreover, based on Kamal–Sourour model, polymerization kinetics could suggest a lower novolac curing rate in the presence of molten PEG and nanoclay.

Keywords Thermal insulator · Phase change material · Nanocomposites · Thermal properties · Reaction kinetics

Introduction

Nowadays, latent heat for thermal energy storage is one of the most important technologies that plays an effective role in the use of energy [1, 2]. A phase change material (PCM) absorbs or releases a large amount of energy during the phase change process [3, 4]. PCMs are used for thermal applications, due to their capability for high latent heat storage per unit volume, via phase change at desired operating temperature range [5–7]. However, PCMs are not easy to use, because of their melt flow, weak thermal stability, flammability, and low thermal conductivity [7]. To solve this problem, PCMs can be encapsulated in a proper material. Encapsulation is a process to encompass the PCM with suitable material [8]. This process was first invented by Barrett K Green in the 1940s [9]. This additional requirement not only increases cost, but also reduces the thermal performance of the system, due to increased thermal resistance of system [4] and holding the PCM isolated from the surrounding [9]. Beside, encapsulation prevents the leakage of PCM from the system [10], while its shape is stabilized during phase change.

Recently, impregnating the solid–liquid PCMs into porous carriers is becoming a promising encapsulation technique in the field of shape-stabilized PCM [8, 11]. These porous carriers can be easily divided into numerous standalone energy storage units, which can improve the heat transfer efficiency of PCMs during the phase change process [8].

In addition to the leakage, PCMs have shortcomings of supercooling [12, 13]. When some molten PCMs are cooled, they solidify at a temperature below their melting points,

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