Microencapsulation of \(n\)-heptadecane phase change material with starch shell

Fateme Irani\(^a\), Zahra Ranjbar\(^{a,b,*}\), Siamak Moradian\(^b\), Ali Jannesari\(^a\)

\(^a\) Department of surface coatings and corrosion, Institute for Color Science and Technology, 16765-654, Tehran, Iran
\(^b\) Center of Excellence for Color Science and Technology, 16765-654, Tehran, Iran

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**ABSTRACT**

In this study, \(n\)-heptadecane as a phase change material was microencapsulated with a starch wall for thermal energy storage applications. The effect of encapsulation parameters including mixing rate, reaction time, starch to \(n\)-heptadecane mass ratio and starch to water mass ratio were investigated on the microcapsule properties. The chemical compositions of the prepared microcapsules were characterized by Fourier transform infrared spectroscopy. The optical microscopy and scanning electron microscopy observations showed that the spherical microcapsules with a rough and intact shell were formed. The particle size analysis and thermogravimetric analysis were utilized to study the microcapsule structural properties and to explain the microencapsulation mechanism. The mechanism of the microencapsulation involved a multi-stage adsorption of starch components started with the migration of the amylose-lipid complexes onto the \(n\)-heptadecane droplets. The microencapsulated \(n\)-heptadecane with the starch wall had high melting and solidifying enthalpies and a proper thermal reliability, according to the results of differential scanning calorimetry. The prepared microcapsules can be used in different matrices, such as surface coatings, sheets, and liquid media.

1. Introduction

Phase change materials (PCMs) have attracted increasing interests for thermal energy storage due to their high heat storage density, reliability, practicability, and a moderate variation of their volumes and temperatures. They can absorb and release a large amount of latent heat when undergoing the phase change, mainly solid to liquid or liquid to solid. Based on this mechanism, PCMs are capable of regulating the surrounding temperature at close to their melting temperatures [1]. The PCM properties, applications, and characterizations have been extensively investigated by numerous researchers [2–6]. The straight chain alkanes (\(n\)-alkanes) known as paraffin are one of the organic PCMs (OPCMs). Safety, chemical inactivity, non-corrosiveness and good thermal properties are of their advantages as the OPCMs [7]. However, the OPCMs are restricted to direct use for energy storage because of their gradual leakage during the melting state, low thermal conductivity, and flammability. Microencapsulation of the PCMs are developed to increase heat transfer area, control their volume changes as phase change occurs, and limit the environmental impacts on their performance [8,9]. Microencapsulation is a process to coat the micron-sized (1 \(\mu\)m–1 mm) particles with a proper shell. Some of most often used microencapsulation methods are categorized as chemical processes, physico-chemical processes and physico-mechanical processes [10]. The comprehensive studies of the PCM microencapsulation are summarized in several reviews [11–13]. Su et al. [14] fabricated the microencapsulated paraffin by an in-situ polymerization method using methanol-modified melamine-formaldehyde prepolymer to decrease the residual formaldehyde and improve the shell mechanical properties. The impact of wall materials on the microencapsulated caprylic acid was studied by Konuklu et al. [15]. Caprylic acid as an OPCM was microencapsulated with different wall materials, including urea-formaldehyde, melamine-formaldehyde and urea + melamine-formaldehyde using the simple coacervation method. Malekipirbazari et al. [16] produced paraffin wax microcapsules with gelatin/gum Arabic wall through the complex coacervation method. Microcapsules of \(n\)-octadecane with silica wall were prepared by He et al. [17]. The encapsulation mechanism was based on the sol-gel process by sodium silicate as a silica precursor. Giro-Paloma et al. [18] investigated the properties of microcapsules containing paraffin or palmitic acid as the PCMs. The microencapsulation was carried out using an emulsion polymerization technique with poly(styrene-co-ethylacrylate) for wall material. Zhang et al. [19] synthesized the microencapsulated \(n\)-eicosane with zirconia shell by the sol-gel process to achieve the thermal energy storage and photoluminescence properties. Zirconia precursor...