



Preparation and characterization of three-dimensional graphene network encapsulating 1-hexadecanol composite



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HIGHLIGHTS

- Three-dimensional graphene network/1-hexadecanol composite was prepared by one-pot method.
- The composite PCMs exhibited enhanced thermal conductivity and electrical conductivity.
- The composite PCMs have desirable phase change enthalpy and excellent shape stability.

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ABSTRACT

In this paper, three-dimensional graphene network encapsulating 1-hexadecanol composite was prepared by one-pot method, which is based on Pickering emulsion template. The composite phase change materials (PCMs) showed enhanced thermal conductivity and electrical conductivity due to the interconnected graphene network in PCMs. In addition, the composite PCMs exhibited excellent shape stability, which prevented the leakage of PCMs during phase change. This novel shape-stable PCM can be used in thermal energy storage and conversion.

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1. Introduction

Phase change materials (PCMs), which can store or release latent heat during phase change, have been widely used in thermal energy management system [1–4]. However, most organic PCMs exhibit inherent low thermal conductivity and leakage during phase change, which decrease the efficiency of thermal storage and hinder their practical application.

Preparing shape-stable PCMs with high thermal conductive supporting materials have become one of the most effective ways to resolve the problems [5–8]. Recently, three-dimensional (3D) graphene aerogel (GA) has been used to prepare the composite PCMs due to its high thermal conductivity and interconnected network structure [9–12]. Usually, the composite PCMs are prepared by two steps including the preparation of GA and the introduction

of GA into PCMs via vacuum impregnation. The common methods to prepare GA are the hydrothermal method and freeze-drying. High temperature, vacuum environment and specific equipments are required in these methods.

In this paper, a one-pot method, which is based on Pickering emulsions stabilized by GO, is reported for the synthesis of three-dimensional (3D) graphene network encapsulating 1-hexadecanol composite. It is a simple and controllable way to prepare the composite PCMs. Unlike other research, the impregnation and freeze-drying step are unnecessary. The GO sheets are directly reduced by N_2H_4 (64% Sigma) at 90 °C for 2 h and accumulate at the surface of Pickering emulsions. Therefore, the composite PCMs are one-pot synthesized. The structure of the composite PCMs is controlled by the Pickering emulsion template. In addition, this method is high-yield and more applicable for production. The size of the composite PCMs can be centimeters to ten centimeters. The composite PCMs exhibit enhanced thermal conductivity and shape stability compared with pure 1-hexadecanol. This novel shape-stable composite PCM can be used in thermal energy storage.

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2. Experimental

2.1. Preparation of the composite PCMs

1-Hexadecanol was heated at 80 °C, allowing 1-hexadecanol to melt. GO (4 mg/ml) was mixed with melted 1-hexadecanol by means of IKA Vortex at 2500 rpm for 2 min at pH = 1. The stable Pickering emulsion was generated as shown in Fig. 1a and b. The FT-IR spectra (Fig. 1c) of GO illustrate the existence of oxygen-containing functional groups. GO is an amphiphile with a hydrophobic basal plane and hydrophilic edges, which can act like a Pickering emulsifier. It can be seen that there is no new absorption peaks of the GO/1-hexadecanol microspheres, indicating that there is no chemical reaction between 1-hexadecanol and GO. However, the stretching vibration of C=O (1728 cm^{-1}) of the GO/1-hexadecanol microspheres increased slightly compared to that of GO (1718 cm^{-1}). The shift is due to the physical reaction between 1-hexadecanol and GO.

Then N_2H_4 (64% Sigma) was mixed with the Pickering emulsion by stirring at 500 rpm for 2 min. The glass vial was heated at 90 °C

for 2 h without stirring. During the reduction process, the reduced GO sheets covering the 1-hexadecanol droplets became more hydrophilic and accumulated at the surface of the Pickering templates due to π - π stacking. Therefore, 3D graphene network encapsulating PCMs was one-pot synthesized (Fig. 1b).

For convenience, the composite PCMs prepared with GO mass fraction of 2%, 6%, 10% are named as PCM1, PCM2 and PCM3, respectively. The samples with a diameter of 50 mm and a thickness of 20 mm were prepared for thermal conductivity and electrical resistivity measurement by tableting a certain amount of the composite PCMs into cylindrical mold ($\phi 50 \times 20$ mm). The surface of the samples was flattened by a sand paper.

2.2. Characterization

A FEI Quanta 200FEG scanning electron microscope (SEM) was used to observe the structure of the composite PCMs. The thermal properties of the samples were measured by differential scanning calorimeter (MDSC-Q100) at a ramp rate of 5 °C/min and thermogravimetric analysis (TGA, STA 449 C) in nitrogen atmosphere.

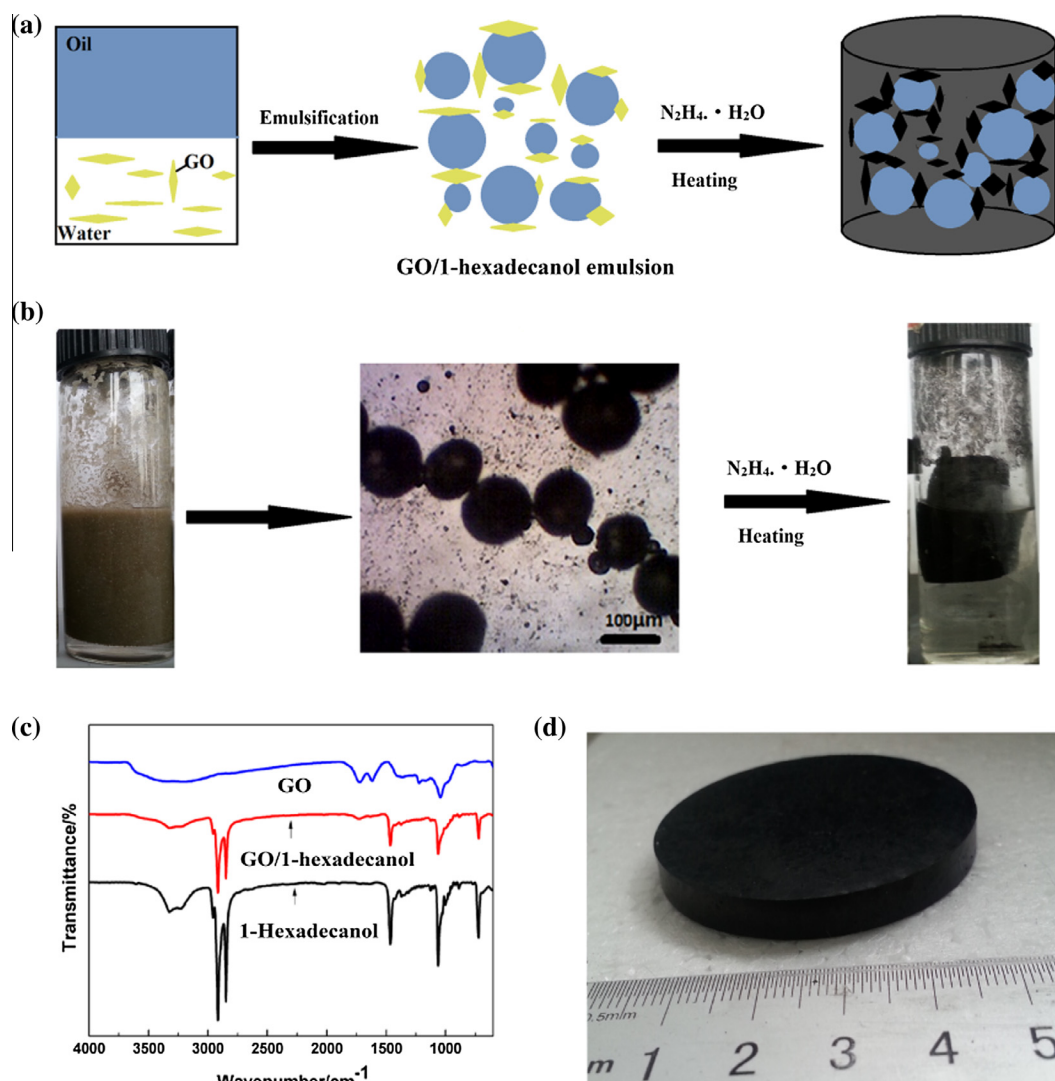


Fig. 1. Schematic illustration of the formation process of the composite PCMs (a), photographs of the formation process of the composite PCMs (b), FT-IR spectra of GO, 1-hexadecanol and GO/1-hexadecanol microspheres (c) and image of the sample for thermal conductivity measurement (d).

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