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Crosslinking polyethylene glycol and silica microcapsules composite phase change material with wide heat storage temperature range and shape memory function

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ABSTRACT

Micro-encapsulated phase change materials (MEPCMs) have attracted considerable research interest owing to their tunable phase change enthalpy through flexible selection of core materials. Typically, they are combined with another matrix materials to expand their application scope. However, when MEPCMs are combined with conventional matrix materials, the resulting composites often exhibit significantly reduced energy storage capacity. In this work, we developed a new composite material consisting of MEPCMs and the solid-solid phase change matrix. The MEPCMs were synthesized via interfacial polymerization, with methyl stearate (MS) as the core and silica (SiO₂) as the shell, while graphene oxide (GO) was incorporated into the shell layer to enhance functional performance. The phase change enthalpy of the MEPCMs reached 152.7 J/g. The matrix material was prepared by reacting polyethylene glycol (PEG) with 3-isocyanatopropyltriethoxysilane (IPTS), followed by self-crosslinking. The composite material largely inhibits the reduction of phase change enthalpy (141.5 J/g) and exhibits a wide heat storage temperature range (38–58 °C), excellent shape stability and shape memory behavior. Additionally, it demonstrates enhanced thermal conductivity (0.43 W·m⁻¹·K⁻¹) and high photothermal conversion efficiency (86.2 %). Benefiting from highly reactive silanol groups, the composite can also be applied as phase change coatings, demonstrating superior thermal storage capacity and application potential.

1. Introduction

Technological advancement and industrial development have engendered dual effects. Firstly, the demand for energy has significantly increased, thereby precipitating an energy crisis. Secondly, the escalation in energy consumption has triggered multiple environmental issues, which in turn exert a non-negligible impact on human productivity and quality of life. In light of this, the optimization of secondary energy utilization is regarded as effective strategies to mitigate the energy crisis and alleviate environmental pollution [1–6]. Thermal energy storage is a critical component in secondary energy utilization, enabling efficient management of intermittent energy sources and recovery of waste heat, thereby enhancing overall energy system sustainability.

Phase Change Materials (PCMs) represent a class of functional materials characterized by their exceptional thermal energy storage properties. The defining feature of PCMs lies in their ability to absorb or release substantial latent heat through phase transition processes within

specific temperature ranges [7–12]. They have emerged as a research focus in the field of energy storage and conversion, garnering significant attention from both academia and industry due to their notable characteristics, including high energy storage density, recyclability and excellent chemical stability [13–17]. According to the phase change state, PCMs can be further classified into solid-solid PCMs, solid-liquid PCMs, solid-gas PCMs and liquid-gas PCMs, among which solid-liquid PCMs are currently the most widely utilized due to their high latent heat and feasibility [18].

However, solid-liquid PCMs exhibit some drawbacks, with the most significant being liquid leakage during the phase transition process [19]. Therefore, one of the primary challenges in advancing solid-liquid PCMs research lies in achieving efficient encapsulation to effectively prevent material leakage during phase transition processes [20–24]. A prevalent methodology in current research focuses on the microencapsulation of PCMs to fabricate mechanically stable core-shell configurations, thereby significantly reducing the potential leakage of PCMs components when

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