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Enhancing Thermal Energy Storage: Investigating the Use of Graphene Nanoplatelets in Phase Change Materials for Sustainable Applications

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The adoption of phase change materials (PCMs) for thermal energy storage in low- and medium-temperature settings is witnessing a notable surge. However, the lesser thermal conductivity (TC) poses a noteworthy challenge to PCM's heat transfer and storage capabilities. One of the noteworthy solutions to augment the TC is incorporating nanoparticles in the PCM. Nevertheless, nanoparticles often clump together after several cycles due to poor compatibility and weak interfacial strength. Functionalization methods have been proposed to address this issue, offering improved performance for energy storage applications. Herein, graphene nanoplatelets (GNP) and functionalized graphene nanoplatelets (FGNP) are dispersed into A70 PCM at mass fractions ranging from 0.1 to 1.0 wt% using two-step method. Fourier transform infrared analysis confirms the successful integration of FGNP into A70 PCM without altering its chemical characteristics. Adding 1.0 wt% FGNP to A70 PCM increases its TC by 140.88%, with just a 3.02% decrease in latent heat enthalpy. However, incorporating pure GNP (1.0 wt%) improves TC by 48.83%. The engineered nano-PCMs exhibit robust thermal and chemical stability even after undergoing 1000 thermal cycles, remaining unchanged up to 414.64 °C. This exceptional stability makes the formulated nanoenhanced PCM suitable for sustainable thermal applications.

1. Introduction

Solar energy has garnered considerable attention from researchers across various disciplines due to its versatile applications. Combining solar power with thermal energy storage (TES) has many benefits.[1,2] Integrating photovoltaic (PV) and photovoltaic-thermal (PVT) systems with a TES system can significantly enhance electrical and thermal efficiency. Utilizing TES technology presents an opportunity for economical storage of significant thermal energy and electrical energy. TES has significant prospects, but solar energy is intermittent and unequal, therefore efficient TES methods are needed, especially in low-light circumstances.[3] Phase change materials (PCMs), with their large latent heat capacity, are appealing for recovering waste heat from solar modules and saving high-quality energy.[4] PCMs are ideal because of their excellent heat storage capacity and low volume expansion and contraction such as they absorb and release up to 15x more thermal energy while maintaining a stable temperature within the same volume compare to water and rock which are common sensible heat storage materials.[5]

PCMs are classified into three main categories: organic, inorganic, and eutectic PCMs. Eutectic PCMs possess the unique characteristic of undergoing melting and freezing congruently without separating into different components. They are typically composed of combinations of organic–organic, inorganic–inorganic, or inorganic–organic materials.[6] In contrast, inorganic PCMs contain salt hydrates or metallic components

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