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Graphene-enhanced Composite Phase Change Materials for Thermal Energy Storage

Abstract

Graphene is quite famous for its high specific surface area ($\geq 2600 \text{ m}^2 \text{ g}^{-1}$) and superior thermal conductivity of $5000 \text{ W}/(\text{m} \cdot \text{K})$ [1]. Thus, graphene has been used widely as a filler to fabricate highly thermal conductive composites. [2] In addition, graphene is light in weight and meanwhile possesses inherent good flexibility, high tensile modulus or Young's modulus (1100 GPa) and the ultimate strength (116 GPa) [3]. Consequently, graphene was considered as an ideal material to improve thermal conductivity and comprehensive performances of composite phase change materials (PCMs) in our present studies. Firstly, three-dimensional graphene (3D-GA) was creatively synthesized through hydrothermal methods using graphene oxide (GO) as a precursor and ethylenediamine (EDA) as a moderate reducing agent. And *n*-octadecane (OD)/3D-GA composite PCMs were successfully prepared by solution impregnation and vacuum impregnation methods. Structural characterization and morphology of the composite PCMs confirm that there was no strong chemical interaction between OD and 3D-GA, and OD was successfully filled into the porous structure of 3D-GA by physical interaction (observed from Figure 1(a)). Furthermore, the composites have a much better phase change property, and the melting enthalpy and crystallization enthalpy can reach 195.70 J g^{-1} and 196.67 J g^{-1} , respectively. Moreover, the composite PCM has excellent thermal cycling stability and the phase change enthalpy almost has no obvious change after 60 times of DSC thermal cycling (observed from Figure 1(b)). The thermal conductivity of the composite PCMs can be enhanced to $1.636 \text{ W m}^{-1} \text{ K}^{-1}$ indicating a connected thermal conductive network between OD and 3D-GA. Secondly, we used PEG as PCMs, 4,4'-diphenylmethane diisocyanate (MDI) as the cross-linking agent, and GO was selected as a supporting skeleton to design a novel polymer based solid-solid composite PCMs. Results reveal that GO nano-sheets induced a regular lamellar structure and an interconnected thermal conductive network for the composite PCMs, and PEG was homogeneously intercalated into the GO nano-sheets (observed from Figure 2). This molecular structure supplies the SSPCMs with excellent phase change behavior, good thermal cycling stability and high thermal conductivity. As a result, the SSPCMs display a fast thermal-response rate and outstanding thermal regulating performance, which can maintain their temperature in the range of $50 \text{ }^\circ\text{C} \sim 57 \text{ }^\circ\text{C}$ for about 410 s.

References

- [1] O. C. Compton, S. B. T. Nguyen, Graphene Oxide, Highly Reduced Graphene Oxide, and Graphene: Versatile Building Blocks for Carbon-Based Materials, *Small* 6 (2010) 711-723
- [2] S. Park, S. He, J. Wang, A. Stein, C. W. Macosko, Graphene-polyethylene nanocomposites: Effect of graphene functionalization, *Polymer* 104 (2016) 1-9.

Figures

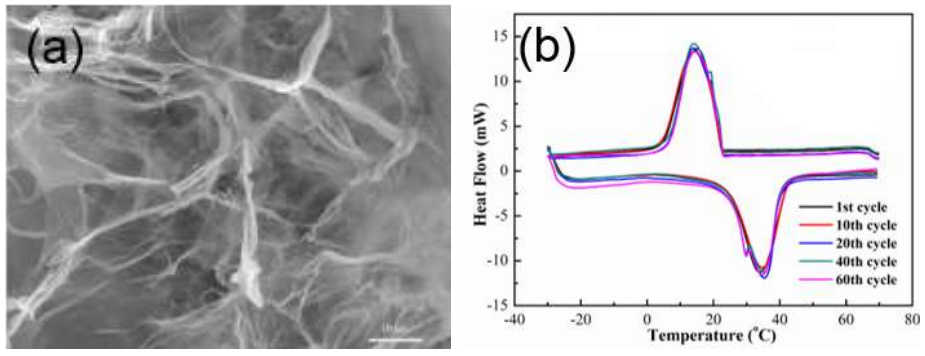


Figure 1: SEM images and thermal -regulating properties of OD/3D-GA composite PCMs

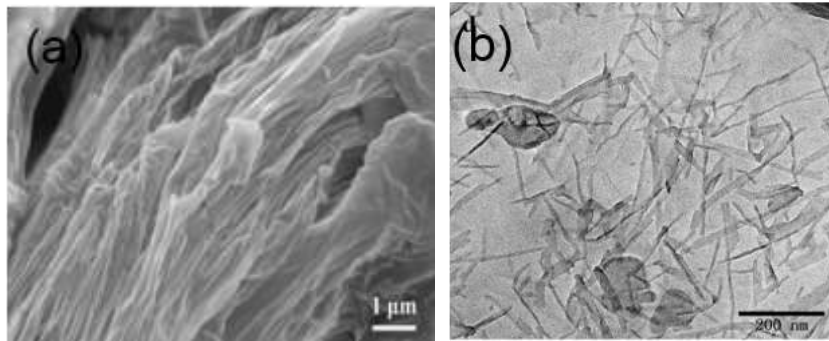


Figure 2: SEM images (a) and TEM images (b) of solid-solid composite PCMs