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Green synthesized 3D coconut shell biochar/polyethylene glycol composite as thermal energy storage material

B Kalidasan [a], A.K. Pandey [a,b,*], R. Saidur [a,c], Belqasem Aljafari [d], Aman Yadav [e], M Samykano [e]

[a] Research Centre for Nano-Materials and Energy Technology (RCNMET), School of Engineering and Technology, Sunway University, No. 5, Jalan Universiti, Bandar Sunway, Petaling Jaya, Selangor Darul Ehsan 47500, Malaysia

[b] Center for Global Health Research , Saveetha Medical College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, India

[c] Lancaster University, Lancaster LA1 4YW, United Kingdom

[d] Electrical Engineering Department, College of Engineering, Najran University, Najran 11001, Saudi Arabia

[e] Faculty of Mechanical & Automotive Engineering Technology, University Malaysia Pahang Al-Sultan Abdullah, Pekan, Pahang 26600, Malaysia

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ABSTRACT

Developing stable, economic, safer and carbon-based nanoparticles from agro solid waste facilitates a new dimension of advancement for eco-friendly nanomaterials in competition to existing nanoparticles. Herewith, a three dimensional highly porous honeycomb structured carbon-based coconut shell (CS) nanoparticle is prepared through green synthesis technique using tube furnace to energies organic phase change material (PCM). CS nanoparticle synthesis using a green approach is incorporated with polyethylene glycol (PEG) using a two-step technique to develop PEG/CS nanocomposite PCM. Thermophysical features of the nanocomposites are characterized using transient hot bridge (ThB), differential scanning calorimeter (DSC) and thermogravimetric analysis (TGA), whereas optical property and chemical stability is evaluated using UV–Vis and FTIR spectrometers. Resulting nanocomposite demonstrates higher thermal conductivity by 114.5 % (improved from 0.24 W/m·K to 0.515 W/m·K). Energy storage enthalpy increased from 141.2 J/g to 150.1 J/g with 1.0 % weight fraction of CS nanoparticles. Optical absorbance of the nanocomposite is improved by 2.14 times compared to base PCM. The developed nanocomposite samples exhibit extreme thermal stability up to 215 °C. The 3D porous structure of CS nanoparticles shows better contact area with PEG, causing low interfacial thermal resistance for improved thermal network channels and pathways for extra heat transfer and phonon propagation.

Introduction

Application of phase change materials (PCMs) as an energy storage technology can improve the efficiency of energy utilisation through the phase transition process, which is a cost effective passive technology [1]. Generally, PCM are of three types a) Organic (fatty acid, sugar alcohol, paraffin); b) Inorganic (salt hydrate); c) Eutectic (blend of organic & inorganic) [2]. Organic PCMs are predominantly preferred as thermal energy storage materials over inorganic PCM owing to their ability to store energy at wide range of temperature, high heat storage density [3], better chemical & thermal stability [4], isothermal behaviour, no issue of supercooling [5], non-corrosive in nature [6], eco-friendly and economical. Despite numerous advantages of PCM, most of the organic PCM lack thermal conductivity, poor optical absorbance and leakage issue; which limits their applications for many thermal regulation solutions. Nonetheless, to improve the thermal characteristics of organic PCM, different dimensional nanoparticles like carbon nanotubes [7], graphene [8], expanded graphite, hybrid conducting polymers [9] and tetrapods [10] has been explored. In majority of the case the optical absorbance of organic PCM matrix are enhanced by the nanomaterials dispersed with PCM to enhance the thermo-physical characteristics. Likewise, to overcome leakage issue core PCM are encapsulated using silica gel [11]; as well shape stabilized via wood powder/high density polyethylene [12]. However, all the aforementioned nanomaterials continue to confront challenges with high manufacturing costs and difficulty in mass production, resulting in the development of most nanomaterials remaining at the laboratory stage, making large-scale manufacture and use challenging. In addition, these nanoparticles are

* Corresponding author at: Research Centre for Nano-Materials and Energy Technology (RCNMET), School of Engineering and Technology, Sunway University, No. 5, Jalan Universiti, Bandar Sunway, Petaling Jaya, Selangor Darul Ehsan 47500, Malaysia.

E-mail address: adarshp@sunway.edu.my (A.K. Pandey).

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