

RESEARCH ARTICLE

Comparative Analysis of Thermal Energy Management for Different Phase Change Materials by Polypyrrole Impregnation

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ABSTRACT

Energy storage systems have emerged as a key area of research due to growing global energy sustainability concerns. Phase change materials (PCMs) store energy in the form of latent heat and have applications at various temperatures. In the present work, Octadecane (M.P. 28°C) and Paraffin wax (M.P. 58°C) are selected as phase change materials, while Polypyrrole is chosen as a supporting material. Octadecane or Paraffin-based composites with varying weight percentages of Polypyrrole are prepared by the direct melt mixing method. Leakage tests suggest that Octadecane having 30-wt% Polypyrrole (OCT/PPY-3 composite) and Paraffin having 20-wt% of Polypyrrole (PAR/PPY-2 composite) show excellent shape stability. XRD patterns and FTIR spectra confirm the successful synthesis of OCT/PPY-3 and PAR/PPY-2 composites without any impurities or chemical reactions. DSC analysis reveals that Polypyrrole impregnation decreases the latent heat of octadecane and paraffin by 88 and 68 J g⁻¹, respectively, without any change in the melting temperature of the respective PCMs. Polypyrrole impregnation enhances the thermal stability and thermal conductivity of octadecane by 30°C and 47%, respectively; however, it does not affect paraffin. Charging and discharging times of pure PCM are shortened by polypyrrole impregnation. Therefore, the inherent properties of OCT and paraffin have been altered in distinct ways as a result of polypyrrole impregnation. In conclusion, OCT/PPY-3 can be considered a promising material for thermal management in buildings and textiles, while PAR/PPY-2 can be a promising candidate for water heaters and solar cookers.

1 | Introduction

The increasing global population, overuse of energy resources for development, and the constraints of non-renewable and renewable energy sources are widening the gap between energy demand and supply, driving researchers toward energy storage solutions [1]. Phase change materials (PCMs) are an emerging class of materials in the field of energy storage devices due to their ability to store energy in the form of thermal energy. They store and release energy during the phase transition process in

the form of latent heat. During the phase transition process, the supplied/absorbed heat does not increase/decrease the temperature of the material and is utilized in overcoming molecular interactions and rearranging the structure. At this stage, energy is stored/released in the form of latent heat at a constant temperature, offering a much higher energy density [2].

Among all three classes of PCMs—organic, inorganic, and eutectic materials, organic PCMs have advantages over the other two classes because of their high latent heat, high energy density,

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