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Enhancing the Thermal Properties of Paraffin Wax as a Latent Heat Storage Material with ZnO/Biochar Composites

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Abstract : Paraffin wax is widely recognized as an organic phase change material (PCM) with significant potential for thermal energy storage, particularly in solar energy applications. Its advantages include low cost, abundant availability, colorless appearance, stable physical and chemical properties, high latent heat of fusion, and a low melting point suitable for solar thermal systems. Additionally, paraffin wax can be stored at room temperature for extended periods without degradation, but its low thermal conductivity limits its practical applications in thermal energy storage systems. This study investigates the enhancement of the thermal properties of paraffin wax by incorporating zinc oxide nanoparticles (ZnO NPs) and nanobiochar composites. ZnO NPs were selected for their excellent thermal conductivity, while biochar, derived from waste biomass, was utilized as a sustainable and porous support material to further improve thermal performance. A series of ZnO NPs doped nanobiochar - paraffin wax composites (2.5, 5, 7.5, 10, and 12.5 wt.%) were synthesized. Also, the effect of loading ZnO NPs onto the nanobiochar surface at different mass ratios (10, 20, and 30 wt.%) on their catalytic thermal stability efficiency via using sonication rays. The as-prepared materials were investigated and characterized using various techniques such as XRD, FT-IR, Raman, DLS, SEM, TEM-EDX, BET, TGA, DSC, XPS, and their thermal properties were evaluated using a thermal performance system (TPS). By testing the as-prepared materials to know the actual increase in the thermal conductivity of paraffin wax, it was found that 20% of ZnO/biochar with the biochar to the paraffin wax molar ratio of 10% was the most efficient, as it achieved an increasing up to 1.322 W/mK with thermal conductivity enhancement of 340.66%, while the paraffin wax only and with 10 % biochar without ZnO attained to 0.300 and 0.445 W/mK, respectively. Also, this study explored the scalability of ZnO/biochar composites, including potential hurdles and future approaches for large-scale deployment. The results reveal a significant improvement in thermal conductivity and energy storage efficiency compared to pure paraffin wax. These findings suggest that ZnO/biochar composites are effective additives for improving the thermal performance of paraffin wax, making it a more efficient and sustainable option for latent heat thermal energy storage, providing a sustainable and efficient solution to critical energy and environmental challenges.

Keywords : paraffin wax, phase change material, nano biochar, solar energy applications, thermal energy storage
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