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Phase change materials for thermal energy storage

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A B S T R A C T

Phase change materials (PCMs) used for the storage of thermal energy as sensible and latent heat are an important class of modern materials which substantially contribute to the efficient use and conservation of waste heat and solar energy. The storage of latent heat provides a greater density of energy storage with a smaller temperature difference between storing and releasing heat than

Abbreviations: ABS, acrylonitrile–styrene–butadiene terpolymer; AC, active carbon; AMPL, 2-amino-2-methyl-1,3-propanediol; APP, ammonium polyphosphate; AS, acrylonitrile–styrene copolymer; BDO, 1,4-butanediol; CA, capric acid; CAC, cellulose acetate; CAlg, calcium alginate; CDA, cellulose diacetate; CEL, cellulose; CET, cellulose ether; CHS, composite heat sink; CLHS, cascaded latent heat storage; CMC, carboxymethyl cellulose; CNF, carbon nanofibre; CNT, carbon nanotube; DMAC, N,N-dimethylacetamide; DMSO, dimethylsulfoxide; DSC, differential scanning calorimetry; EDA, ethylenediamine; EG, expanded graphite; EGDS, ethylene glycol distearate; EP, epoxy resin; EPDM, ethylene propylene diene monomer rubber; EVA, ethylene-vinyl acetate; FTIR, Fourier transform infrared spectroscopy; GNF, graphite nanofibre; HB-PUPCM, hyperbranched polyurethane PCM; HDPE, high-density polyethylene; HSU, heat storage unit; HTESS, hybrid thermal energy storage system; HVAC, heating, ventilation, air conditioning; IFR, intumescent flame retardant system; LA, lauric acid; LDPE, low-density polyethylene; LFTF, latent functional thermal fluid; LHS, latent heat storage; LHTES, latent heat thermal energy storage; LPG, liquefied petroleum gas; MA, myristic acid; MAPCM, molecular alloy PCM; MDI, 4,4′-diphenylmethane diisocyanate; MEPCM, microencapsulated phase change material; MF, melamine–formaldehyde resin; MMT, montmorillonite; NPG, neopentylglycol; OMT, organically-modified montmorillonite; PA, palmitic acid; PANI, polyaniline; PCL, poly(ε-caprolactone); PCM, phase change material; PD, pentadecane; PEG, poly(ethylene glycol), OH-terminated poly(ethylene oxide); PERT, pentaerythritol; PET, poly(ethylene terephthalate); PF, paraformaldehyde; PG, pentaglycerine; PMMA, poly(methyl methacrylate); PEO, poly(ethylene oxide); PPO, poly(propylene oxide); PS, polystyrene; PTHF, polytetrahydrofuran; PU, polyurethane; PV, photovoltaics; PVA, poly(vinyl alcohol); PVC, poly(vinyl chloride); RP, red phosphorus; SA, stearic acid; SAT, sodium acetate trihydrate; SEGS, solar thermal electricity generating system; SEM, scanning electron microscopy; SHS, sensible heat storage; SHTES, sensible heat thermal energy storage; SMA, styrene–maleic anhydride copolymer; SSPCM, shape-stabilized phase change material; SWCNT, single walls carbon nanotube; TD, 1-tetradecanol; TDI, toluene diisocyanate; TGA, thermogravimetric analysis; TEOS, tetraethoxysilane; TES, thermal energy storage; TESA, thermal energy storage aggregate; TESC, thermal energy storage concrete; TESM, thermal energy storage material; TPB, 1,4-polybutadiene; TRIS, tris(hydroxymethyl)aminomethane; UF, urea–formaldehyde resin; VMT, vermiculite; WAXD, wide angle X-ray diffraction.

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Applications

the sensible heat storage method. Many different groups of materials have been investigated during the technical evolution of PCMs, including inorganic systems (salt and salt hydrates), organic compounds such as paraffins or fatty acids and polymeric materials, *e.g.* poly(ethylene glycol). Historically, the relationships between the structure and the energy storage properties of a material have been studied to provide an understanding of the heat accumulation/emission mechanism governing the material's imparted energy storage characteristics.

This paper reviews the present state of the art of PCMs for thermal energy storage applications and provides an insight into recent efforts to develop new PCMs with enhanced performance and safety. Specific attention is given to the improvement of thermal conductivity, encapsulation methods and shape stabilization procedures. In addition, the flame retarding properties and performance are discussed. The wide range of PCM applications in the construction, electronic, biomedical, textile and automotive industries is presented and future research directions are indicated.

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